Formalization of the Resolution Calculus for First-Order Logic
I present a formalization in Isabelle/HOL of the resolution calculus for first-order logic with formal soundness and completeness proofs. To prove the calculus sound, I use the substitution lemma, and to prove it complete, I use Herbrand interpretations and semantic trees. The correspondence between unsatisfiable sets of clauses and finite semantic trees is formalized in Herbrand’s theorem. I discuss the difficulties that I had formalizing proofs of the lifting lemma found in the literature, and I formalize a correct proof. The completeness proof is by induction on the size of a finite semantic tree. Throughout the paper I emphasize details that are often glossed over in paper proofs. I give a thorough overview of formalizations of first-order logic found in the literature. The formalization of resolution is part of the IsaFoL project, which is an effort to formalize logics in Isabelle/HOL.
A Dynamic Logic for Learning Theory

Building on previous work that bridged Formal Learning Theory and Dynamic Epistemic Logic in a topological setting, we introduce a Dynamic Logic for Learning Theory (DLLT), extending Subset Space Logics with dynamic observation modalities, as well as with a learning operator, which encodes the learner's conjecture after observing a finite sequence of data. We completely axiomatise DLLT, study its expressivity and use it to characterise various notions of knowledge, belief, and learning.

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Agent Programming Languages and Logics in Agent-Based Simulation
Research in multi-agent systems has resulted in agent programming languages and logics that are used as a foundation for engineering multi-agent systems. Research includes reusable agent programming platforms for engineering agent systems with environments, agent behavior, communication protocols and social behavior, and work on verification. Agent-based simulation is an approach for simulation that also uses the notion of agents. Although agent programming languages and logics are much less used in agent-based simulation, there are successful examples with agents designed according to the BDI paradigm, and work that combines agent-based simulation platforms with agent programming platforms. This paper analyzes and evaluates benefits of using agent programming languages and logics for agent-based simulation. In particular, the paper considers the use of agent programming languages and logics in a case study of simulating emergency care units.

A hamiltonian cycle in the square of a 2-connected graph in linear time
Fleischner's theorem says that the square of every 2-connected graph contains a Hamiltonian cycle. We present a proof resulting in an \( O(|E|) \) algorithm for producing a Hamiltonian cycle in the square \( G^2 \) of a 2-connected graph \( G \). The previous best was \( O(|V|^2) \) by Lau in 1980. More generally, we get an \( O(|E|) \) algorithm for producing a Hamiltonian path between any two prescribed vertices, and we get an \( O(|V|^2) \) algorithm for producing cycles \( C_k \) of lengths 3, 4, \ldots, \(|V|\), respectively.
**At the roots of dictionary compression: String attractors**

A well-known fact in the field of lossless text compression is that high-order entropy is a weak model when the input contains long repetitions. Motivated by this fact, decades of research have generated myriads of so-called dictionary compressors: algorithms able to reduce the text's size by exploiting its repetitiveness. Lempel-Ziv 77 is one of the most successful and well-known tools of this kind, followed by straight-line programs, run-length Burrows-Wheeler transform, macro schemes, collage systems, and the compact directed acyclic word graph. In this paper, we show that these techniques are different solutions to the same, elegant, combinatorial problem: to find a small set of positions capturing all distinct text's substrings. We call such a set a string attractor. We first show reductions between dictionary compressors and string attractors. This gives the approximation ratios of dictionary compressors with respect to the smallest string attractor and allows us to uncover new asymptotic relations between the output sizes of different dictionary compressors. We then show that the k-attractor problem —deciding whether a text has a size-t set of positions capturing all substrings of length at most k — is NP-complete for k ≥ 3. This, in particular, includes the full string attractor problem. We provide several approximation techniques for the smallest k-attractor, show that the problem is APX-complete for constant k, and give strong inapproximability results. To conclude, we provide matching lower and upper bounds for the random access problem on string attractors. The upper bound is proved by showing a data structure supporting queries in optimal time. Our data structure is universal: by our reductions to string attractors, it supports random access on any dictionary-compression scheme. In particular, it matches the lower bound also on LZ77, straight-line programs, collage systems, and macro schemes, and therefore essentially closes (at once) the random access problem for all these compressors.

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**Compressed and Practical Data Structures for Strings**

In this dissertation, I will cover a number of different topics related to strings in compressed and practical settings. I will first present some fundamental techniques from the area, and then cover 6 different topics within the area. A short introduction to each of these topics is given in the following. Finger Search in Grammar-Compressed Strings. Grammar-based compression, where one replaces a long string by a small context-free grammar that generates the string, is a simple and powerful paradigm that captures many popular compression schemes. Given a grammar, the random access problem is to compactly represent the grammar while supporting random access, that is, given a position in the original uncompressed string report the character at that position. We study the random access problem with the finger search property, that is, the time for a random access query should depend on the distance between a specified index f, called the finger, and the query index i. We consider both a static variant, where we first place a finger and subsequently access indices near the finger efficiently, and a dynamic variant where also moving the finger such that the time depends on the distance moved is supported. Let n be the size of the grammar, and let N be the size of the string. For the static variant we give a linear space representation that supports placing the finger in O(logN) time and subsequently accessing and moving the finger in O(logD) time, where D is the distance between the finger and the accessed index. For the dynamic variant we give a linear space representation that supports placing the finger in O(logN) time and subsequently accessing and moving the finger in O(logD + loglogN) time. Compared to the best linear space solution to random access, we improve a O(logN) query bound to O(logD) for the static variant and to O(logD + loglogN) for the dynamic variant, while maintaining linear space. As an application of our results we obtain an improved solution to the longest common extension problem in grammar compressed strings. To obtain our results, we introduce several new techniques of independent interest, including a novel van Emde Boas style decomposition of grammars. Compressed Indexing with Signature Grammars. The compressed indexing problem is to preprocess a string S of length n into a compressed representation that supports pattern matching queries. That is, given a string P of length m report all occurrences of P in S. We present a data structure that supports pattern matching queries...
in $O(m + \text{occ}(\log n + \log z))$ time using $O(z \log(n/z))$ space where $z$ is the size of the LZ77 parse of $S$ and $> 0$, when the alphabet is small or the compression ratio is at least polynomial. We also present two data structures for the general case; one where the space is increased by $O(z \log g z)$, and one where the query time changes from worst-case to expected. In all cases, the results improve the previously best known solutions. Notably, this is the first data structure that decides if $P$ occurs in $S$ in $O(m)$ time using $O(z \log(n/z))$ space. Our results are mainly obtained by a novel combination of a randomized grammar construction algorithm with well known techniques relating pattern matching to 2D-range reporting. Dynamic Relative Compression, Dynamic Partial Sums, and Substring Concatenation. Given a static reference string $R$ and a source string $S$, a relative compression of $S$ with respect to $R$ is an encoding of $S$ as a sequence of references to substrings of $R$. Relative compression schemes are a classic model of compression and have recently proved very successful for compressing highly-repetitive massive data sets such as genomes and web-data. We initiate the study of relative compression in a dynamic setting where the compressed source string $S$ is subject to edit operations. The goal is to maintain the compressed representation compactly, while supporting edits and allowing efficient random access to the (uncompressed) source string. We present new data structures that achieve optimal time for updates and queries while using space linear in the size of the optimal relative compression, for nearly all combinations of parameters. We also present solutions for restricted and extended sets of updates. To achieve these results, we revisit the dynamic sums problem and the substring concatenation problem. We present new optimal or near optimal bounds for these problems. Plugging in our new results we also immediately obtain new bounds for the string indexing for patterns with wildcards problem and the dynamic text and static pattern matching problem. Succinct Partial Sums and Fenwick Trees. We consider the well-studied partial sums problem in succinct space where one is to maintain an array of $n$ k-bit integers subject to updates such that partial sums queries can be efficiently answered. We present two succinct versions of the Fenwick Tree—which is known for its simplicity and practicality. Our results hold in the encoding model where one is allowed to reuse the space from the input data. Our main result is the first that only requires $nk + o(n)$ bits of space while still supporting sum/update in $O(b \log b n)$ time where $2 < b < \log O(1) n$. The second result shows how optimal time for sum/update can be achieved while only slightly increasing the space usage to $nk + o(nk)$ bits. Beyond Fenwick Trees, the results are primarily based on bit-packing and sampling—making them very practical—and they also allow for simple optimal parallelization. Fast Dynamic Arrays. We present a highly optimized implementation of tiered vectors, a data structure for maintaining a sequence of $n$ elements supporting access in time $O(1)$ and insertion and deletion in time $O(n)$ for $> 0$ while using $o(n)$ extra space. We consider several different implementation optimizations in C++ and compare their performance to that of vector and multiset from the standard library on sequences with up to 100 elements. Our fastest implementation uses much less space than multiset while providing speedups of 40× for access operations compared to multiset and speedups of 10,000× compared to vector for insertion and deletion operations while being competitive with both data structures for all other operations. Parallel Lookups in String Indexes. Here we consider the indexing problem on in the parallel random access machine model. Recently, the first PRAM algorithms were presented for looking up a pattern in a suffix tree. We improve the bounds, achieving optimal results for all parameters but the preprocessing. Given a text $T$ of length $n$ we create a data structure of size $O(n)$ that answers pattern matching queries for a pattern $P$ of length $m$ in $O(\log m)$ time and $O(m)$ work.

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Density of Real Zeros of the Tutte Polynomial
The Tutte polynomial of a graph is a two-variable polynomial whose zeros and evaluations encode many interesting properties of the graph. In this article we investigate the real zeros of the Tutte polynomials of graphs, and show that they form a dense subset of certain regions of the plane. This is the first density result for the real zeros of the Tutte polynomial in a region of positive volume. Our result almost confirms a conjecture of Jackson and Sokal except for one region which is related to an open problem on flow polynomials.
Domino convergence: Why one should hill-climb on linear functions
In the theory community of evolutionary computation, linear pseudo-boolean functions are often regarded as easy problems since all of them can be optimized in expected time $O(n \log n)$ by simple unbiased algorithms. However, results from genetic algorithms and estimation-of-distribution algorithms indicate that these algorithms treat different linear functions differently. More precisely, an effect called “domino convergence” is described in the literature, which means that bits of large weight in the linear function are optimized earlier than bits of low weight. Hence, different linear functions may lead to rather different expected optimization times. The present paper conducts a study of domino convergence. By rigorous runtime analyses, it is shown that domino convergence is mostly a consequence of the crossover underlying genetic algorithms and EDAs. Here a performance gap of order $\Omega(n/\log n)$ between different linear functions is proved. In simple mutation-only EAs the effect of domino convergence is much less pronounced, with the typical performance gap being logarithmic in the population size. The effect disappears when population size 1 is used and the algorithm is reduced to hillclimbing. Different selection mechanisms, including cut and tournament selection are investigated and their impact on domino convergence is analyzed.

Drawing Trees
We formally prove in Isabelle/HOL two properties of an algorithm for laying out trees visually. The first property states that removing layout annotations recovers the original tree. The second property states that nodes are placed at least a unit of distance apart. We have yet to formalize three additional properties: That parents are centered above their children, that drawings are symmetrical with respect to reflection and that identical subtrees are rendered identically.

Dynamic bridge-finding in $\tilde{O}(\log^2 n)$ amortized time
We present a deterministic fully-dynamic data structure for maintaining information about the bridges in a graph. We support updates in $\tilde{O}(\log <i>n</i>)$ amortized time, and can find a bridge in the component of any given vertex, or a bridge separating any two given vertices, in $O(\log <i>n</i>/\log \log <i>n</i>)$ worst case time. Our bounds match the current best for bounds for deterministic fully-dynamic connectivity up to $\log \log <i>n</i>$ factors. The previous best dynamic bridge finding was an $\tilde{O}(\log <i>n</i>/\log \log <i>n</i>)$ amortized time algorithm by Thorup.
[STOC2000], which was a bittrick-based improvement on the $O((\log n)^4)$ amortized time algorithm by Holm et al.[STOC98, JACM2001]. Our approach is based on a different and purely combinatorial improvement of the algorithm of Holm et al., which by itself gives a new combinatorial $\tilde{O}((\log n)^3)$ amortized time algorithm. Combining it with Thorup's bittrick, we get down to the claimed $\tilde{O}((\log n)^2)$ amortized time.

Essentially the same new trick can be applied to the biconnectivity data structure from [STOC98, JACM2001], improving the amortized update time to $\tilde{O}((\log n)^3)$. We also offer improvements in space. We describe a general trick which applies to both of our new algorithms, and to the old ones, to get down to linear space, where the previous best use $O(n \log \log n)$. Our result yields an improved running time for deciding whether a unique perfect matching exists in a static graph.

**Engineering a Multi-Agent System in Jason and CArtAgO**

This paper presents the overall strategy utilized by Jason-DTU to achieve a shared second place in the annual Multi-Agent Programming Contest. It provides an overview of the implementation details considering perception, task handling, agent logic and more. The paper analyzes the team’s results in each match, and is summarized by evaluating strengths and weaknesses of the proposed multi-agent system.

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Fast fencing

We consider very natural "fence enclosure" problems studied by Capoyleas, Rote, and Woeginger and Arkin, Khuller, and Mitchell in the early 90s. Given a set $S$ of $n$ points in the plane, we aim at finding a set of closed curves such that (1) each point is enclosed by a curve and (2) the total length of the curves is minimized. We consider two main variants. In the first variant, we pay a unit cost per curve in addition to the total length of the curves. An equivalent formulation of this version is that we have to enclose $n$ unit disks, paying only the total length of the enclosing curves. In the other variant, we are allowed to use at most $k$ closed curves and pay no cost per curve. For the variant with at most $k$ closed curves, we present an algorithm that is polynomial in both $n$ and $k$. For the variant with unit cost per curve, or unit disks, we present a near-linear time algorithm. Capoyleas, Rote, and Woeginger solved the problem with at most $k$ curves in $O(nk)$ time. Arkin, Khuller, and Mitchell used this to solve the unit cost per curve version in exponential time. At the time, they conjectured that the problem with $k$ curves is NP-hard for general $k$. Our polynomial time algorithm refutes this unless P equals NP.
Formalization of Bachmair and Ganzinger’s Ordered Resolution Prover
This Isabelle/HOL formalization covers Sections 2 to 4 of Bachmair and Ganzinger’s “Resolution Theorem Proving” chapter in the Handbook of Automated Reasoning. This includes soundness and completeness of unordered and ordered variants of ground resolution with and without literal selection, the standard redundancy criterion, a general framework for refutational theorem proving, and soundness and completeness of an abstract first-order prover.

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Formalizing Bachmair and Ganzinger’s Ordered Resolution Prover
We present a formalization of the first half of Bachmair and Ganzinger’s chapter on resolution theorem proving in Isabelle/HOL, culminating with a refutationally complete first-order prover based on ordered resolution with literal selection. We develop general infrastructure and methodology that can form the basis of completeness proofs for related calculi, including superposition. Our work clarifies several of the fine points in the chapter’s text, emphasizing the value of formal proofs in the field of automated reasoning.

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In-place sparse suffix sorting

Suffix arrays encode the lexicographical order of all suffixes of a text and are often combined with the Longest Common Prefix array (LCP) to simulate navigational queries on the suffix tree in reduced space. In space-critical applications such as sparse and compressed text indexing, only information regarding the lexicographical order of a size-$b$ subset of all $n$ text suffixes is often needed. Such information can be stored space-efficiently (in $b$ words) in the sparse suffix array (SSA). The SSA and its relative sparse LCP array (SLCP) can be used as a space-efficient substitute of the sparse suffix tree. Very recently, Gawrychowski and Kociumaka [11] showed that the sparse suffix tree (and therefore SSA and SLCP) can be built in asymptotically optimal $O(b)$ space with a Monte Carlo algorithm running in $O(n)$ time. The main reason for using the SSA and SLCP arrays in place of the sparse suffix tree is, however, their reduced space of $b$ words each. This leads naturally to the quest for in-place algorithms building these arrays. Franceschini and Muthukrishnan [8] showed that the full suffix array can be built in-place and in optimal running time. On the other hand, finding sub-quadratic in-place algorithms for building the SSA and SLCP for general subsets of suffixes has been an elusive task for decades. In this paper, we give the first solution to this problem. We provide the first in-place algorithm building the full LCP array in $O(n \log n)$ expected time and the first Monte Carlo in-place algorithms building the SSA and SLCP in $O(n + b \log^2 n)$ expected time. We moreover describe the first in-place solution for the suffix selection problem: to compute the $i$-th smallest text suffix. In order to achieve these results, we show that we can quickly overwrite the text with a reversible and implicit data structure supporting Longest Common Extension queries in polylogarithmic time and text extraction in optimal time: this structure is strictly more powerful than a plain text representation and is of independent interest.

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Leading the Teacher Team - Balancing Between Formal and Informal Power in Program Leadership

This continuous research within Nordic engineering institutions targets the contexts and possibilities for leadership among engineering education program directors. The IFP-model, developed based on analysis of interviews with program leaders in these institutions, visualizes the program director's informal and formal power. The model is presented as a tool for starting a shared discussion on the complexities of the leadership of engineering program development. The authors liken program development to hunting in teams. Each individual expert in the program is needed, and all experts will need to work and collaborate for the same target. This calls for strategic and long-term thinking of engineering education development. Institutions should support the development of both formal structures as well as informal leadership skills among their program directors, but never fall for the temptation to see the program director as the only actor on the stage.

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Many-valued hybrid logic
In this article we define a family of many-valued semantics for hybrid logic, where each semantics is based on a finite Heyting algebra of truth-values. We provide sound and complete tableau systems for these semantics. Moreover, we show how the tableau systems can be made terminating and thereby give rise to decision procedures for the logics in question. Our many-valued hybrid logics turn out to be 'intermediate' logics between intuitionistic hybrid logic and classical hybrid logic in a specific sense explained in the article. Our results show that many-valued hybrid logic is indeed a natural enterprise.
Medium step sizes are harmful for the compact genetic algorithm

We study the intricate dynamics of the Compact Genetic Algorithm (cGA) on OneMax, and how its performance depends on the step size $1/K$, that determines how quickly decisions about promising bit values are fixed in the probabilistic model. It is known that cGA and UMDA, a related algorithm, run in expected time $O(n \log n)$ when the step size is just small enough ($K = \Theta(n \log n)$) to avoid wrong decisions being fixed. UMDA also shows the same performance in a very different regime (equivalent to $K = \Theta(\log n)$ in the cGA) with much larger steps sizes, but for very different reasons: many wrong decisions are fixed initially, but then reverted efficiently. We show that step sizes in between these two optimal regimes are harmful as they yield larger runtimes: we prove a lower bound of $\Omega(K^{1/3}n + n \log n)$ for the cGA on OneMax for $K = O(n \log n)$. For $K = \Omega(\log 3 n)$ the runtime increases with growing $K$ before dropping again to $O(Kn + n \log n)$ for $K = \Omega(n \log n)$. This suggests that the expected runtime for cGA is a bimodal function in $K$ with two very different optimal regions.
and worse performance in between.

Multi-Agent Programming Contest 2016 – The Python-DTU Team
We provide a detailed description of the Python-DTU system, including the overall system design and the tools used in the agent contest.
Natural Deduction and the Isabelle Proof Assistant

We describe our Natural Deduction Assistant (NaDeA) and the interfaces between the Isabelle proof assistant and NaDeA. In particular, we explain how NaDeA, using a generated prover that has been verified in Isabelle, provides feedback to the student, and also how NaDeA, for each formula proved by the student, provides a generated theorem that can be verified in Isabelle.

Online bipartite matching with amortized $O(\log^2 n)$ replacements

In the online bipartite matching problem with replacements, all the vertices on one side of the bipartition are given, and the vertices on the other side arrive one by one with all their incident edges. The goal is to maintain a maximum matching while minimizing the number of changes (replacements) to the matching. We show that the greedy algorithm that always takes the shortest augmenting path from the newly inserted vertex (denoted the SAP protocol) uses at most amortized $O(\log^2 n)$ replacements per insertion, where $O(n)$ is the total number of vertices inserted. This is the first analysis to achieve a polylogarithmic number of replacements for any replacement strategy, almost matching the $\Omega(\log n)$ lower bound. The previous best strategy known achieved amortized $O(n \log \log n)$ replacements [Bosek, Leniowski, Sankowski, Zych, FOCS 2014]. For the SAP protocol in particular, nothing better than then trivial $O(n \log \log n)$ bound was known except in special cases. Our analysis immediately implies the same upper bound of $O(n \log \log n)$ reassignments for the capacitated assignment problem, where each vertex on the static side of the bipartition is initialized with the capacity to serve a number of vertices. We also analyze the problem of minimizing the maximum server load. We show that if the final graph has maximum server load $\leq L$, then the SAP protocol makes amortized $O(\min\{\log \log n, L\})$ reassignments. We also show that this is close to tight because $\Omega(\min\{\log \log n, L\})$ reassignments can be necessary.
On the Approximation Ratio of Lempel-Ziv Parsing

Shannon's entropy is a clear lower bound for statistical compression. The situation is not so well understood for dictionary-based compression. A plausible lower bound is $b$, the least number of phrases of a general bidirectional parse of a text, where phrases can be copied from anywhere else in the text. Since computing $b$ is NP-complete, a popular gold standard is $z$, the number of phrases in the Lempel-Ziv parse of the text, where phrases can be copied only from the left. While $z$ can be computed in linear time, almost nothing has been known for decades about its approximation ratio with respect to $b$. In this paper we prove that $z = O \left( b \log \left( \frac{n}{b} \right) \right)$, where $n$ is the text length. We also show that the bound is tight as a function of $n$, by exhibiting a string family where $z = \Omega \left( b \log n \right)$. Our upper bound is obtained by building a run-length context-free grammar based on a locally consistent parsing of the text. Our lower bound is obtained by relating $b$ with $r$, the number of equal-letter runs in the Burrows-Wheeler transform of the text. On our way, we prove other relevant bounds between compressibility measures.

Optimal Mutation Rates for the $(1+\lambda)$ EA on OneMax Through Asymptotically Tight Drift Analysis

We study the $(1+\lambda)$ EA, a classical population-based evolutionary algorithm, with mutation probability $c/n$, where $c > 0$ and $\lambda$ are constant, on the benchmark function OneMax, which counts the number of 1-bits in a bitstring. We improve a well-established result that allows to determine the first hitting time from the expected progress (drift) of a stochastic process,
known as the variable drift theorem. Using our improved result, we show that upper and lower bounds on the expected runtime of the \((1+\lambda)\) EA obtained from variable drift theorems are at most apart by a small lower order term if the exact drift is known. This reduces the analysis of expected optimization time to finding an exact expression for the drift. We then give an exact closed-form expression for the drift and develop a method to approximate it very efficiently, enabling us to determine approximate optimal mutation rates for the \((1+\lambda)\) EA for various parameter settings of \(c\) and \(\lambda\) and also for moderate sizes of \(n\). This makes the need for potentially lengthy and costly experiments in order to optimize \(c\) for fixed \(n\) and \(\lambda\) for the optimization of OneMax unnecessary. Interestingly, even for moderate \(n\) and not too small \(\lambda\) it turns out that mutation rates up to 10% larger than the asymptotically optimal rate \(1/n\) minimize the expected runtime. However, in absolute terms the expected runtime does not change by much when replacing \(1/n\) with the optimal mutation rate.

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- Web of Science (2015): Indexed yes  
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- Web of Science (2014): Indexed yes  
- BFI (2013): BFI-level 2  
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- ISI indexed (2013): ISI indexed yes  
- BFI (2012): BFI-level 2  
- Scopus rating (2012): SJR 0.836 SNIP 1.204 CiteScore 0.99  
- ISI indexed (2012): ISI indexed yes  
- Web of Science (2012): Indexed yes  
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- Scopus rating (2011): SJR 0.848 SNIP 1.184 CiteScore 0.91  
- ISI indexed (2011): ISI indexed yes  
- Web of Science (2011): Indexed yes  
- BFI (2010): BFI-level 2  
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- BFI (2009): BFI-level 2  
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- BFI (2008): BFI-level 1  
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- Scopus rating (2007): SJR 0.99 SNIP 1.43  
- Scopus rating (2006): SJR 1.13 SNIP 1.757  
- Scopus rating (2005): SJR 0.781 SNIP 1.387
Optimal-time text indexing in BWT-runs bounded space

Indexing highly repetitive texts, such as genomic databases, software repositories, and versioned text collections, has become an important problem since the turn of the millennium. A relevant compressibility measure for repetitive texts is r, the number of runs in their Burrows-Wheeler Transform (BWT). One of the earliest indexes for repetitive collections, the Run-Length FMindex, used O(r) space and was able to efficiently count the number of occurrences of a pattern of length m in the text (in loglogarithmic time per pattern symbol, with current techniques). However, it was unable to locate the positions of those occurrences efficiently within a space bounded in terms of r. Since then, a number of other indexes with space bounded by other measures of repetitiveness, the number of phrases in the Lempel-Ziv parse, the size of the smallest grammar generating the text, the size of the smallest automaton recognizing the text factors, have been proposed for efficiently locating, but not directly counting, the occurrences of a pattern. In this paper, we close this long-standing problem, showing how to extend the Run-Length FMindex so that it can locate the occurrences efficiently within O(r) space (in loglogarithmic time each), and reaching optimal time O(m + occ) within O(r log(n/r)) space, on a RAM machine with words of w = (log n) bits. Raising the space to O(rw logσ(n/r)), we support locate in O(m log(σ)/w + occ) time, which is optimal in the packed setting and had not been obtained before in compressed space. We also describe a structure using O(r log(n/r)) space that replaces the text and efficiently extracts any text substring, with an O(log(n/r)) additive time penalty over the optimum. Preliminary experiments show that our new structure outperforms the alternatives by orders of magnitude in the space/time tradeoff map.

Programming and Verifying a Declarative First-Order Prover in Isabelle/HOL

We certify in the proof assistant Isabelle/HOL the soundness of a declarative first-order prover with equality. The LCF-style prover is a translation we have made, to Standard ML, of a prover in John Harrison’s Handbook of Practical Logic and Automated Reasoning. We certify it by replacing its kernel with a certified version that we program, certify and generate code from; all in Isabelle/HOL. In a declarative proof each step of the proof is declared, similar to the sentences in a thorough paper proof. The prover allows proofs to mix the declarative style with automatic theorem proving by using a tableau prover. Our motivation is teaching how automated and declarative provers work and how they are used. The prover allows studying concrete code and a formal verification of correctness. We show examples of proofs and how they are made in the prover. The entire development runs in Isabelle’s ML environment as an interactive application or can be
used standalone in OCaml or Standard ML (or in other functional programming languages like Haskell and Scala with some additional work).

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BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.9
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.56
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**Querying Social Practices in Hospital Context**
Understanding the social contexts in which actions and interactions take place is of utmost importance for planning one’s goals and activities. People use social practices as means to make sense of their environment, assessing how that context relates to past, common experiences, culture and capabilities. Social practices can therefore simplify deliberation and planning in complex contexts. In the context of patient-centered planning, hospitals seek means to ensure that patients and their families are at the center of decisions and planning of the healthcare processes. This requires on one hand that patients are aware of the practices being in place at the hospital and on the other hand that hospitals have the means to evaluate and adapt current practices to the needs of the patients. In this paper we apply a framework for formalizing social practices of an organization to an emergency department that carries out patient-centered planning. We indicate how such a formalization can be used to answer operational queries about the expected outcome of operational actions.

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Runtime analysis for self-adaptive mutation rates

We propose and analyze a self-adaptive version of the (1,) evolutionary algorithm in which the current mutation rate is part of the individual and thus also subject to mutation. A rigorous runtime analysis on the OneMax benchmark function reveals that a simple local mutation scheme for the rate leads to an expected optimization time (number of fitness evaluations) of $O(n \log n + n \log n)$. This time is asymptotically smaller than the optimization time of the classic (1,) EA and (1 +) EA for all static mutation rates and best possible among all -parallel mutation-based unbiased black-box algorithms. Our result shows that self-adaptation in evolutionary computation can find complex optimal parameter settings on the fly. At the same time, it proves that a relatively complicated self-adjusting scheme for the mutation rate proposed by Doerr et al. (GECCO 2017) can be replaced by our simple endogenous scheme. Moreover, the paper contributes new tools for the analysis of the two-dimensional drift processes arising in self-adaptive EAs, including bounds on occupation probabilities in processes with non-constant drift.
Teaching First-Order Logic with the Natural Deduction Assistant (NaDeA)

The natural deduction proof system is a popular way of teaching logic. It is also important in the philosophy of logic and the foundations of mathematics, in particular for systems of intuitionistic logic and constructive type theory, and it is used in many proof assistants along with automatic proof methods like the tableaux procedure and the resolution calculus. The natural deduction assistant (NaDeA) has been used for teaching first-order logic to hundreds of computer science bachelor students since 2015 [1, 2]. NaDeA runs in a standard browser and is open source software. Upon completion of a natural deduction proof the student obtains a formal proof in the interactive proof assistant Isabelle/HOL [3] of not only the correctness of the student’s natural deduction proof but also of the validity of the formula with respect to the classical semantics of formulas in first-order logic. Our formalization of the syntax, semantics and the inductive definition of the natural deduction proof system extends work by Stefan Berghofer [4] and Melvin Fitting [5] but with a much more detailed soundness proof that can be examined and tested by the students. The corresponding completeness proof is also available but it is of course quite demanding. We describe the main advantages and disadvantages of using an advanced e-learning tools like NaDeA for teaching logic. Furthermore we briefly survey related and future work. NaDeA can be used with or without installing Isabelle and is available online. URL Address: https://nadea.compute.dtu.dk/.

The bane of low-dimensionality clustering

In this paper, we give a conditional lower bound of \(n^{\omega(k)}\) on running time for the classic \(k\)-median and \(k\)-means clustering objectives (where \(n\) is the size of the input), even in low-dimensional Euclidean space of dimension four, assuming the Exponential Time Hypothesis (ETH). We also consider \(k\)-median (and \(k\)-means) with penalties where each point need not be assigned to a center, in which case it must pay a penalty, and extend our lower bound to at least three-dimensional Euclidean space. This stands in stark contrast to many other geometric problems such as the traveling salesman problem, or computing an independent set of unit spheres. While these problems benefit from the so-called (limited) blessing of dimensionality, as they can be solved in time \(n^{O(d)}\) or \(2^{n^{1-1/d}}\) in \(d\) dimensions, our work shows that widely-used clustering objectives have a lower bound of \(n^{\omega(k)}\) in \(d\) dimensions, even in dimension four. We complete the picture by considering the two-dimensional case: we show that there is no algorithm that solves the penalized version in time less than \(n^{\omega(k)}\), and provide a matching upper bound of \(n^{\omega(k)}\). The main tool we use to establish these lower bounds is the placement of points on the moment curve, which takes its inspiration from constructions of point sets yielding Delaunay complexes of high complexity.
The flow index and strongly connected orientations

We prove that, for any natural number $p$, the flow index $\varphi(G) < 2 + \frac{1}{p}$ if and only if $G$ has a strongly connected modulo $(2p + 1)$-orientation. For the case $p = 1$ we prove that the flow index of every 8-edge-connected graph is strictly less than 3.
The Impact of Parametrization on Randomized Search Heuristics

In this work we present runtime analyses of randomized search heuristics (RSH) in various settings that are determined by parameters of the problems, the algorithms and also exogenous parameters like noise. In the process we provide new techniques for the theoretical analysis of RSH as well as new optimization algorithms. We consider the following topics. Escaping local optima using local search. We analyze memetic algorithms, i.e. evolutionary algorithms equipped with a local search after mutation. To this end we consider the (1+1) EA equipped with Standard Local Search (SLS) and Variable-Depth Search (VDS) on an artificial test function. We determine features of the fitness landscape that lead to the (1+1) EA using SLS outperforming the (1+1) EA using VDS with an exponential performance gap. Moreover, we present a new local search operator, Opportunistic Local Search (OLS), that can deal with such features in the landscape and show that the (1+1) EA with OLS can efficiently optimize a discretized Rastrigin function. Stochastic fitness functions. We analyze the role of populations in stochastic optimization. We assume that the objective function is subject to noise, introducing stochastic errors in its evaluation. On classical test functions, such noise makes optimization by the simple (1+1) EA hillclimber infeasible even in exponential time. Interestingly, the use of parent and offspring populations of only logarithmic size turns the algorithm into an efficient one. The results are obtained by drift analysis. An asymptotic expansion of the expected runtime of the (1+λ) EA on ONEMAX. We consider the (1+λ) EA with mutation probability c/n, where c > 0 is a constant on ONEMAX. We give an asymptotic expansion for the expected runtime depending on both c and λ. Our results show that c = 1 is the optimal mutation rate for λ = o(logloglogn/logloglogn) and that c only has an impact on the lower-order terms of the expected runtime, i.e. c = 1 is no longer the only optimal mutation rate. Our methods are strongly based on variable drift theorems for upper and lower bounds and a precise analysis of order statistics of the binomial distribution. To the best of our knowledge this is the first tight runtime analysis of a population-based EA, up to lower-order terms. Furthermore, we develop helpful stochastic tools for runtime analyses. Optimal mutation rates for the (1+λ) EA on ONEMAX. We consider the (1+λ) EA with mutation probability c/n on ONEMAX, where c > 0 and λ are constant. We present an improved variable drift theorem that weakens the requirement that no large steps towards the optimum may occur in the process to a stochastic one, reducing the analysis of the expected optimization time to finding an exact expression for the drift. We formalize an exact closed-form expression for the drift and provide small error approximations that are very efficient to compute. Self-adjusting mutation rates for the (1+λ) EA on ONEMAX. We propose a new mechanism to self-adjust the mutation rate in population-based evolutionary algorithms. It consists of creating half the offspring with a higher and the rest with a lower mutation rate. The mutation rate is then adjusted, based on the success of the subpopulations. We show that the (1+λ) EA optimizes ONEMAX in an expected optimization time of O(nλ/logλ + n logn) which has been shown to be best-possible among all λ-parallel mutation-based unbiased black-box algorithms.

General information

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Three Categories of Context-Aware Systems

With regard to context-aware systems: some optimize system-internal processes, based on the context state at hand; others maximize the user-perceived effectiveness of delivered services, by providing different service variants depending on the situation of the user; still others are about offering value-sensitivity when the society demands so. Even though those three perspectives cover a broad range of currently relevant applications there are no widely accepted and commonly used corresponding concepts and terms. This is an obstacle to broadly understand, effectively integrate, and adequately assess such systems. We address this problem, by considering a (component-based) methodological derivation of technical (software) specifications based on underlying enterprise models. That is because context states are about the enterprise environment of a (software) system while the delivery of context-aware services is about technical (software) functionalities; hence, we need a perspective on both. We consider the SDBC (Software Derived from Business Components) approach that brings together enterprise modeling and software specification. On that basis: (a) We deliver a base context-awareness conceptualization; (b) We partially align it to agent technology because adapting behaviors to environments assumes some kind of pro-activity that is only fully covered by agent systems, in our view. We partially illustrate our proposed conceptualization and particularly - the agent technology implications, by means of a case example featuring land border security.

Dynamic Relative Compression, Dynamic Partial Sums, and Substring Concatenation

Given a static reference string $R$ and a source string $S$, a relative compression of $S$ with respect to $R$ is an encoding of $S$ as a sequence of references to substrings of $R$. Relative compression schemes are a classic model of compression and have recently proved very successful for compressing highly-repetitive massive data sets such as genomes and web-data. We initiate the study of relative compression in a dynamic setting where the compressed source string $S$ is subject to edit operations. The goal is to maintain the compressed representation compactly, while supporting edits and allowing efficient random access to the (uncompressed) source string. We present new data structures that achieve optimal time for updates and queries while using space linear in the size of the optimal relative compression, for nearly all combinations of parameters. We also present solutions for restricted and extended sets of updates. To achieve these results, we revisit the dynamic partial sums problem and the substring concatenation problem. We present new optimal or near optimal bounds for these problems. Plugging in our new results we also immediately obtain new bounds for the string indexing for patterns.
with wildcards problem and the dynamic text and static pattern matching problem.

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BFI (2013): BFI-level 2
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BFI (2010): BFI-level 2
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Scopus rating (2007): SJR 0.99 SNIP 1.43
Scopus rating (2006): SJR 1.13 SNIP 1.757
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Scopus rating (2002): SJR 0.876 SNIP 1.428
Scopus rating (2001): SJR 1.15 SNIP 1.093
Scopus rating (2000): SJR 0.408 SNIP 1.055
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Contracting a planar graph efficiently
We present a data structure that can maintain a simple planar graph under edge contractions in linear total time. The data structure supports adjacency queries and provides access to neighbor lists in O(1) time. Moreover, it can report all the arising self-loops and parallel edges. By applying the data structure, we can achieve optimal running times for decremental bridge detection, 2-edge connectivity, maximal 3-edge connected components, and the problem of finding a unique perfect matching for a static planar graph. Furthermore, we improve the running times of algorithms for several planar graph problems, including decremental 2-vertex and 3-edge connectivity, and we show that using our data structure in a black-box manner, one obtains conceptually simple optimal algorithms for computing MST and 5-coloring in planar graphs.

Best laid plans of lions and men
We answer the following question dating back to J. E. Littlewood (1885-1977): Can two lions catch a man in a bounded area with rectifiable lakes? The lions and the man are all assumed to be points moving with at most unit speed. That the lakes are rectifiable means that their boundaries are finitely long. This requirement is to avoid pathological examples where the man survives forever because any path to the lions is infinitely long. We show that the answer to the question is not always "yes" by giving an example of a region R in the plane where the man has a strategy to survive forever. R is a polygonal region with holes and the exterior and interior boundaries are pairwise disjoint, simple polygons. Our construction is the first truly two-dimensional example where the man can survive. Next, we consider the following game played on the entire plane instead of a bounded area: There is any finite number of unit speed lions and one fast man who can run with speed 1 + for some value > 0. Can the man always survive? We answer the question in the affirmative for any constant > 0.
In this paper we show how to construct a data structure for a string S of size N compressed into a context-free grammar of size n that supports efficient Karp–Rabin fingerprint queries to any substring of S. That is, given indices i and j, the answer to a query is the fingerprint of the substring S[i,j]. We present the first O(n) space data structures that answer fingerprint queries without decompressing any characters. For Straight Line Programs (SLP) we get O(logN) query time, and for Linear SLPs (an SLP derivative that captures LZ78 compression and its variations) we get O(loglogN) query time. We extend the result to solve the longest common extension problem in query time O((logN)^\epsilon) and O(logloglogN) for SLPs and Linear SLPs, respectively. Here, \epsilon denotes the length of the LCE.
Subsequence automata with default transitions

Let S be a string of length n with characters from an alphabet of size σ. The subsequence automaton of S (often called the directed acyclic subsequence graph) is the minimal deterministic finite automaton accepting all subsequences of S. A straightforward construction shows that the size (number of states and transitions) of the subsequence automaton is $O(n\sigma)$ and that this bound is asymptotically optimal. In this paper, we consider subsequence automata with default transitions, that is, special transitions to be taken only if none of the regular transitions match the current character, and which do not consume the current character. We show that with default transitions, much smaller subsequence automata are possible, and provide a full trade-off between the size of the automaton and the delay, i.e., the maximum number of consecutive default transitions followed before consuming a character. Specifically, given any integer parameter $k$, $1 < k \leq \sigma$, we present a subsequence automaton with default transitions of size $O(nk\log_k \sigma)$ and delay $O(\log_k \sigma)$. Hence, with $k=2$ we obtain an automaton of size $O(n\log \sigma)$ and delay $O(\log \sigma)$. At the other extreme, with $k=\sigma$, we obtain an automaton of size $O(n\sigma)$ and delay $O(1)$, thus matching the bound for the standard subsequence automaton construction. Finally, we generalize the result to multiple strings. The key component of our result is a novel hierarchical automata construction of independent interest.

General information

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Scopus rating (2010): SJR 0.593 SNIP 1.026
Scopus rating (2009): SJR 0.732 SNIP 1.171
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Scopus rating (2008): SJR 0.823 SNIP 1.306
Scopus rating (2007): SJR 0.688 SNIP 1.514
A Cycle of Maximum Order in a Graph of High Minimum Degree has a Chord

A well-known conjecture of Thomassen states that every cycle of maximum order in a 3-connected graph contains a chord. While many partial results towards this conjecture have been obtained, the conjecture itself remains unsolved. In this paper, we prove a stronger result without a connectivity assumption for graphs of high minimum degree, which shows Thomassen's conjecture holds in that case. This result is within a constant factor of best possible. In the process of proving this, we prove a more general result showing that large minimum degree forces a large difference between the order of the largest cycle and the order of the largest chordless cycle.

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BFI (2015): BFI-level 1
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BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 0.61 SNIP 1.037 SJR 0.852
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Scopus rating (2012): CiteScore 0.53 SNIP 1.067 SJR 0.661
ISI indexed (2012): ISI indexed yes
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A Framework for Organization-Aware Agents

Open systems are characterized by the presence of a diversity of heterogeneous and autonomous agents that act according to private goals. Organizations, such as those used in real-life to structure human activities such as task allocation, coordination and supervision, can regulate the agents' behavior space and describe the expected behavior of the agents. Assuming an open environment, where agents are developed independently of the Organizational structures, agents need to be able to reason about the structure, so that they can deliberate about their actions and act within the expected boundaries and work towards the objectives of the organization. In this paper, we present the AORTA reasoning framework and show how it can be integrated into typical BDI-agents. We provide operational semantics that enables agents to make organizational decisions in order to coordinate and cooperate without explicit coordination mechanisms within the agents. The organizational model is independent of that of the agents, and the approach is not tied to a specific organizational model, but uses an organizational metamodel. We show how AORTA helps agents work together in a system with an organization for choosing the best tender for a building project.
A framework of DYNAMIC data structures for string processing

In this paper we present DYNAMIC, an open-source C++ library implementing dynamic compressed data structures for string manipulation. Our framework includes useful tools such as searchable partial sums, succinct/gap-encoded bitvectors, and entropy/run-length compressed strings and FM indexes. We prove close-to-optimal theoretical bounds for the resources used by our structures, and show that our theoretical predictions are empirically tightly verified in practice. To conclude, we turn our attention to applications. We compare the performance of five recently-published compression algorithms implemented using DYNAMIC with those of state-of-the-art tools performing the same task. Our experiments show that algorithms making use of dynamic compressed data structures can be up to three orders of magnitude more space-efficient (albeit slower) than classical ones performing the same tasks.

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A gentle introduction to epistemic planning: The DEL approach

Epistemic planning can be used for decision making in multi-agent situations with distributed knowledge and capabilities. Dynamic Epistemic Logic (DEL) has been shown to provide a very natural and expressive framework for epistemic planning. In this paper, we aim to give an accessible introduction to DEL-based epistemic planning. The paper starts with the most classical framework for planning, STRIPS, and then moves towards epistemic planning in a number of smaller steps, where each step is motivated by the need to be able to model more complex planning scenarios.

Amalgams and $\chi$-boundedness

A class of graphs is hereditary if it is closed under isomorphism and induced subgraphs. A class $G$ of graphs is $\chi$-bounded if there exists a function $f: \mathbb{N} \to \mathbb{N}$ such that for all graphs $G \in G$, and all induced subgraphs $H$ of $G$, we have that $\chi(H) \leq f$
We prove that proper homogeneous sets, clique-cutsets, and amalgams together preserve $\chi$-boundedness. More precisely, we show that if $G$ and $G^*$ are hereditary classes of graphs such that $G$ is $\chi$-bounded, and such that every graph in $G^*$ either belongs to $G$ or admits a proper homogeneous set, a clique-cutset, or an amalgam, then the class $G^*$ is $\chi$-bounded. This generalizes a result of [J Combin Theory Ser B 103(5) (2013), 567–586], which states that proper homogeneous sets and clique-cutsets together preserve $\chi$-boundedness, as well as a result of [European J Combin 33(4) (2012), 679–683], which states that 1-joins preserve $\chi$-boundedness. The house is the complement of the four-edge path. As an application of our result and of the decomposition theorem for “cap-free” graphs from [J Graph Theory 30(4) (1999), 289–308], we obtain that if $G$ is a graph that does not contain any subdivision of the house as an induced subgraph, then $\chi(G) \leq 3\omega(G)-1$.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Penev, I. (Intern)
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- BFI (2017): BFI-level 2
- Scopus rating (2017): SNIP 1.45 SJR 1.104 CiteScore 0.82
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 0.71 SJR 1.105 SNIP 1.362
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 1.469 SNIP 1.598 CiteScore 0.85
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 1.281 SNIP 1.136 CiteScore 0.73
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 1.477 SNIP 1.698 CiteScore 0.9
- ISI indexed (2013): ISI indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 1.37 SNIP 1.446 CiteScore 0.79
- ISI indexed (2012): ISI indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 1.139 SNIP 1.235 CiteScore 0.76
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 1.273 SNIP 1.205
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 1.748 SNIP 1.512
- BFI (2008): BFI-level 1
- Scopus rating (2008): SJR 1.615 SNIP 1.884
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 1.49 SNIP 1.496
- Scopus rating (2006): SJR 1.24 SNIP 1.16
- Web of Science (2006): Indexed yes
- Scopus rating (2005): SJR 0.625 SNIP 0.786
- Scopus rating (2004): SJR 1.057 SNIP 1.625
- Web of Science (2004): Indexed yes
- Scopus rating (2003): SJR 1.598 SNIP 1.157
An Approach for Hospital Planning with Multi-Agent Organizations

The background for this paper is a development that the Danish hospitals are undertaking which requires the establishment of a common emergency department. It is uncertain exactly what and how many resources the department needs and so resources are assigned dynamically as seen necessary by the staff. Such dynamic adjustments pose a challenge in predicting what consequences these adjustments may lead to. We propose an approach to deal with this challenge that applies simulation with intelligent agents and logics for organizational reasoning. We present some of the expected obstacles with this approach and potential ways to overcome them.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Larsen, J. B. (Intern), Villadsen, J. (Intern)
Pages: 454-465
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Volume: 10314
Publisher: Springer
ISBN (Print): 978-3-319-60839-6
Series: Lecture Notes in Computer Science
Volume: 10314
ISSN: 0302-9743
Main Research Area: Technical/natural sciences
Conference: International Joint Conference on Rough Sets, Olsztyn, Poland, 03/07/2017 - 03/07/2017
Computer Science, Artificial Intelligence (incl. Robotics), Database Management, Information Systems Applications (incl. Internet), Information Storage and Retrieval, Multi-agent organizations, Logic, Simulation, Soft computing, Process mining
Electronic versions:
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DOIs:
10.1007/978-3-319-60840-2_33
Source: FindIt
Source-ID: 2372495948
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017
A Natural Logic for Natural-language Knowledge Bases
We describe a natural logic for computational reasoning with a regimented fragment of natural language. The natural logic comes with intuitive inference rules enabling deductions and with an internal graph representation facilitating conceptual path finding between pairs of terms as an approach to semantic querying. Our core natural logic proposal covers formal ontologies and generative extensions thereof. It further provides means of expressing general relationships between classes in an application. We discuss extensions of the core natural logic with various conservative as well as non-conservative constructs in order to approach scientific use of natural language. Finally, we outline a prototype system addressing life science for the natural logic knowledge base setup being under continuous development.

A proof of the Barát-Thomassen conjecture
The Barát-Thomassen conjecture asserts that for every tree $T$ on $m$ edges, there exists a constant $k_T$ such that every $k_T$-edge-connected graph with size divisible by $m$ can be edge-decomposed into copies of $T$. So far this conjecture has only been verified when $T$ is a path or when $T$ has diameter at most 4. Here we prove the full statement of the conjecture.
A Runtime Analysis of Parallel Evolutionary Algorithms in Dynamic Optimization

A simple island model with (Formula presented.) islands and migration occurring after every (Formula presented.) iterations is studied on the dynamic fitness function Maze. This model is equivalent to a (Formula presented.) EA if (Formula presented.), i. e., migration occurs during every iteration. It is proved that even for an increased offspring population size up to (Formula presented.), the (Formula presented.) EA is still not able to track the optimum of Maze. If the migration interval is chosen carefully, the algorithm is able to track the optimum even for logarithmic (Formula presented.). The relationship of (Formula presented.), and the ability of the island model to track the optimum is then
investigated more closely. Finally, experiments are performed to supplement the asymptotic results, and investigate the impact of the migration topology.

**General information**

State: Published

Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Sheffield

Authors: Lissovoi, A. (Ekstern), Witt, C. (Intern)

Pages: 641–659

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Main Research Area: Technical/natural sciences

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BFI (2017): BFI-level 2

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Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2

Scopus rating (2016): CiteScore 1.11 SJR 0.648 SNIP 1.184

Web of Science (2016): Indexed yes

BFI (2015): BFI-level 2

Scopus rating (2015): SJR 0.739 SNIP 1.16 CiteScore 1.15

Web of Science (2015): Indexed yes

BFI (2014): BFI-level 2

Scopus rating (2014): SJR 0.854 SNIP 1.197 CiteScore 1.2

Web of Science (2014): Indexed yes

BFI (2013): BFI-level 2

Scopus rating (2013): SJR 0.952 SNIP 1.395 CiteScore 1.26

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): SJR 0.836 SNIP 1.204 CiteScore 0.99

ISI indexed (2012): ISI indexed yes

Web of Science (2012): Indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): SJR 0.848 SNIP 1.184 CiteScore 0.91

ISI indexed (2011): ISI indexed yes

Web of Science (2011): Indexed yes

BFI (2010): BFI-level 2

Scopus rating (2010): SJR 0.904 SNIP 1.317

BFI (2009): BFI-level 2

Scopus rating (2009): SJR 0.95 SNIP 1.351

BFI (2008): BFI-level 1

Scopus rating (2008): SJR 1.129 SNIP 1.218

Scopus rating (2007): SJR 0.99 SNIP 1.43

Scopus rating (2006): SJR 1.13 SNIP 1.757

Scopus rating (2005): SJR 0.781 SNIP 1.387

Scopus rating (2004): SJR 1.001 SNIP 1.472

Scopus rating (2003): SJR 0.888 SNIP 1.279

Scopus rating (2002): SJR 0.876 SNIP 1.428

Scopus rating (2001): SJR 1.15 SNIP 1.093

Scopus rating (2000): SJR 0.408 SNIP 1.055
Certified Soundness of Simplest Known Formulation of First-Order Logic

In 1965, Donald Monk published a paper about an axiomatic system for first-order predicate logic that he described as "the simplest known formulation of ordinary logic". In this paper we show work in progress on certifying soundness of this system in the interactive proof assistant Isabelle. Through this work we demonstrate the usefulness of using proof assistants for validating mathematical results. This work also establishes an outline for future work such as a certified completeness proof of the axiomatic system in Isabelle.

Characterizing width two for variants of treewidth

In this paper, we consider the notion of special treewidth, recently introduced by Courcelle (2012). In a special tree decomposition, for each vertex \( v \) in a given graph, the bags containing \( v \) form a rooted path. We show that the class of graphs of special treewidth at most two is closed under taking minors, and give the complete list of the six minor obstructions. As an intermediate result, we prove that every connected graph of special treewidth at most two can be constructed by arranging blocks of special treewidth at most two in a specific tree-like fashion. Inspired by the notion of special treewidth, we introduce three natural variants of treewidth, namely spaghetti treewidth, strongly chordal treewidth and directed spaghetti treewidth. All these parameters lie between pathwidth and treewidth, and we provide common structural properties on these parameters. For each parameter, we prove that the class of graphs having the parameter at most two is minor closed, and we characterize those classes in terms of a tree of cycles with additional conditions. Finally, we show that for each \( k \geq 3 \), the class of graphs with special treewidth, spaghetti treewidth, directed spaghetti treewidth, or strongly chordal treewidth, respectively at most \( k \), is not closed under taking minors.
Chords in longest cycles
If a graph $G$ is 3-connected and has minimum degree at least 4, then some longest cycle in $G$ has a chord. If $G$ is 2-connected and cubic, then every longest cycle in $G$ has a chord.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Thomassen, C. (Intern)
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Main Research Area: Technical/natural sciences

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Journal: Journal of Combinatorial Theory. Series B
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.13 SJR 1.942 SNIP 1.973
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.095 SNIP 2.049 CiteScore 1.29
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.021 SNIP 2.028 CiteScore 1.1
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.936 SNIP 1.918 CiteScore 1.19
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.181 SNIP 2.093 CiteScore 1.2
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.176 SNIP 1.759 CiteScore 1.11
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.104 SNIP 1.599
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.457 SNIP 1.993
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.49 SNIP 2.598
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.393 SNIP 1.989
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.068 SNIP 1.973
Scopus rating (2005): SJR 1.365 SNIP 1.464
Chromatic number via Turán number

For a graph $G$ and a family of graphs $F$, the general Kneser graph $KG(G, F)$ is a graph with the vertex set consisting of all subgraphs of $G$ isomorphic to some member of $F$ and two vertices are adjacent if their corresponding subgraphs are edge disjoint. In this paper, we introduce some generalizations of Turán number of graphs. In view of these generalizations, we give some lower and upper bounds for the chromatic number of general Kneser graphs $KG(G, F)$. Using these bounds, we determine the chromatic number of some family of general Kneser graphs $KG(G, F)$ in terms of generalized Turán number of graphs. In particular, we determine the chromatic number of every Kneser multigraph $KG(G, F)$ where $G$ is a multigraph each of whose edges has the multiplicity at least 2 and $F$ is an arbitrary family of simple graphs. Moreover, the chromatic number of general Kneser graph $KG(G, F)$ is exactly determined where $G$ is a dense graph and $F = \{K1, 2\}$. 

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Shahrood University of Technology
Authors: Alishahi, M. (Ekstern), Hajiabolhassan, H. (Intern)
Pages: 2366-2377
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.72 SJR 0.877 SNIP 1.034
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.877 SNIP 1.133 CiteScore 0.64
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Compressed Subsequence Matching and Packed Tree Coloring

We present a new algorithm for subsequence matching in grammar compressed strings. Given a grammar of size \( n \) compressing a string of size \( N \) and a pattern string of size \( m \) over an alphabet of size \( \sigma \), our algorithm uses \( O(n + \frac{n\sigma}{w}) \) space and \( O(n + \frac{n\sigma}{w} \log N \cdot \log w \cdot \text{occ}) \) or \( O(n + \frac{n\sigma}{w} \log w \cdot \log N \cdot \text{occ}) \) time. Here \( w \) is the word size and \( \text{occ} \) is the number of minimal occurrences of the pattern. Our algorithm uses less space than previous algorithms and is also faster for \( \text{occ} = o\left(\frac{n}{\log N}\right) \) occurrences. The algorithm uses a new data structure that allows us to efficiently find the next occurrence of a given character after a given position in a compressed string. This data structure in turn is based on a new data structure for the tree color problem, where the node colors are packed in bit strings.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Cooperative epistemic multi-agent planning for implicit coordination

Epistemic planning can be used for decision making in multi-agent situations with distributed knowledge and capabilities. Recently, Dynamic Epistemic Logic (DEL) has been shown to provide a very natural and expressive framework for epistemic planning. We extend the DEL-based epistemic planning framework to include perspective shifts, allowing us to define new notions of sequential and conditional planning with implicit coordination. With these, it is possible to solve planning tasks with joint goals in a decentralized manner without the agents having to negotiate about and commit to a joint policy at plan time. First we define the central planning notions and sketch the implementation of a planning system built on those notions. Afterwards we provide some case studies in order to evaluate the planner empirically and to show that the concept is useful for multi-agent systems in practice.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Albert Ludwigs Universität Freiburg
Authors: Engesser, T. (Ekstern), Bolander, T. (Intern), Mattmüller, R. (Ekstern), Nebel, B. (Ekstern)
Pages: 75-90
Publication date: 2017
Conference: 9th Workshop on Methods for Modalities, Kanpur, India, 08/01/2017 - 08/01/2017
BFI conference series: International Workshop on Methods for Modalities (5010598)
Main Research Area: Technical/natural sciences

Cycles through all finite vertex sets in infinite graphs

A closed curve in the Freudenthal compactification $|G|$ of an infinite locally finite graph $G$ is called a Hamiltonian curve if it meets every vertex of $G$ exactly once (and hence it meets every end at least once). We prove that $|G|$ has a Hamiltonian curve if and only if every finite vertex set of $G$ is contained in a cycle of $G$. We apply this to extend a number of results and conjectures on finite graphs to Hamiltonian curves in infinite locally finite graphs. For example, Barnette’s conjecture (that every finite planar cubic 3-connected bipartite graph is Hamiltonian) is equivalent to the statement that every one-ended planar cubic 3-connected bipartite graph has a Hamiltonian curve. It is also equivalent to the statement that every planar cubic 3-connected bipartite graph with a nowhere-zero 3-flow (with no restriction on the number of ends) has a Hamiltonian curve. However, there are 7-ended planar cubic 3-connected bipartite graphs that do not have a Hamiltonian curve.

General information

State: Published
Organisations: Algorithms and Logic, Department of Applied Mathematics and Computer Science, Northwestern Polytechnical University
Authors: Kundgen, A. (Intern), Li, B. (Ekstern), Thomassen, C. (Intern)
Pages: 259–275
Publication date: 2017
Main Research Area: Technical/natural sciences
Density of Real Zeros of the Tutte Polynomial

The Tutte polynomial of a graph is a two-variable polynomial whose zeros and evaluations encode many interesting properties of the graph. In this article we investigate the real zeros of the Tutte polynomials of graphs, and show that they form a dense subset of certain regions of the plane. This is the first density result for the real zeros of the Tutte polynomial in a region of positive volume. Our result almost confirms a conjecture of Jackson and Sokal except for one region which is related to an open problem on flow polynomials.

General information
State: Published
Organisations: Algorithms and Logic, Department of Applied Mathematics and Computer Science, Korea Advanced Institute of Science & Technology
Authors: Ok, S. (Ekstern), Perrett, T. (Intern)
Deterministic indexing for packed strings

Given a string $S$ of length $n$, the classic string indexing problem is to preprocess $S$ into a compact data structure that supports efficient subsequent pattern queries. In the deterministic variant the goal is to solve the string indexing problem without any randomization (at preprocessing time or query time). In the packed variant the strings are stored with several character in a single word, giving us the opportunity to read multiple characters simultaneously. Our main result is a new string index in the deterministic and packed setting. Given a packed string $S$ of length $n$ over an alphabet $\sigma$, we show how to preprocess $S$ in $O(n)$ (deterministic) time and space $O(n)$ such that given a packed pattern string of length $m$ we can
support queries in (deterministic) time \( O\left(\frac{m}{\alpha} + \log m + \log \log \sigma\right) \), where \( \alpha = \frac{w}{\log \sigma} \) is the number of characters packed in a word of size \( w = \Theta(\log n) \). Our query time is always at least as good as the previous best known bounds and whenever several characters are packed in a word, i.e., \( \log \sigma \)

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Bille, P. (Intern), Gertz, I. L. (Intern), Skjoldjensen, F. R. (Intern)
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Electronic versions:
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Source: FindIt
Source-ID: 2373292598
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

**Epistemic Planning: (Dagstuhl Seminar 17231)**
The seminar Epistemic Planning brought together the research communities of Dynamic Epistemic Logic, Knowledge Representation and Reasoning, and Automated Planning to address fundamental problems on the topic of epistemic planning. In the context of this seminar, dynamic epistemic logic investigates the formal semantics of communication and communicative actions, knowledge representation and reasoning focuses on theories of action and change, and automated planning investigates computational techniques and tools to generate plans. The original goals of the seminar were to develop benchmarks for epistemic planning, to explore the relationship between knowledge and belief in multi-agent epistemic planning, to develop models of agency and capability in epistemic planning and to explore action types and their representations (these originally separate goals were merged during the seminar), and finally to identify practical tools and resources. An additional goal explored during the workshop was the correspondence between planning problems and games.

**General information**
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Arizona State University, Université de Lorraine, University of Toronto
Authors: Baral, C. (Ekstern), Bolander, T. (Intern), van Ditmarsch, H. (Ekstern), McIraith, S. (Ekstern)
Number of pages: 47
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Volume: 7
Number: 06
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Main Research Area: Technical/natural sciences
Electronic versions:
baral2017epistemic.pdf
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Evidence logics with relational evidence

We introduce a family of logics for reasoning about relational evidence: evidence that involves an ordering of states in terms of their relative plausibility. We provide sound and complete axiomatizations for the logics. We also present several evidential actions and prove soundness and completeness for the associated dynamic logics.
Fast Dynamic Arrays

We present a highly optimized implementation of tiered vectors, a data structure for maintaining a sequence of n elements supporting access in time O(1) and insertion and deletion in time O(n) for > 0 while using o(n) extra space. We consider several different implementation optimizations in C++ and compare their performance to that of vector and set from the standard library on sequences with up to 108 elements. Our fastest implementation uses much less space than set while providing speedups of 40× for access operations compared to set and speedups of 10,000× compared to vector for insertion and deletion operations while being competitive with both data structures for all other operations.

First-Order Logic According to Harrison

We present a certified declarative first-order prover with equality based on John Harrison’s Handbook of Practical Logic and Automated Reasoning, Cambridge University Press, 2009. ML code reflection is used such that the entire prover can be executed within Isabelle as a very simple interactive proof assistant. As examples we consider Pelletier’s problems 1-46.
Flexible indexing of repetitive collections

Highly repetitive strings are increasingly being amassed by genome sequencing experiments, and by versioned archives of source code and webpages. We describe practical data structures that support counting and locating all the exact occurrences of a pattern in a repetitive text, by combining the run-length encoded Burrows-Wheeler transform (RLBWT) with the boundaries of Lempel-Ziv 77 factors. One such variant uses an amount of space comparable to LZ77 indexes, but it answers count queries between two and four orders of magnitude faster than all LZ77 and hybrid index implementations, at the cost of slower locate queries. Combining the RLBWT with the compact directed acyclic word graph answers locate queries for short patterns between four and ten times faster than a version of the run-length compressed suffix array (RLCSA) that uses comparable memory, and with very short patterns our index achieves speedups even greater than ten with respect to RLCSA.

Formalization of Many-Valued Logics

Partiality is a key challenge for computational approaches to artificial intelligence in general and natural language in particular. Various extensions of classical two-valued logic to many-valued logics have been investigated in order to meet this challenge. We use the proof assistant Isabelle to formalize the syntax and semantics of many-valued logics with determinate as well as indeterminate truth values. The formalization allows for a concise presentation and makes
Formalizing a Paraconsistent Logic in the Isabelle Proof Assistant

We present a formalization of a so-called paraconsistent logic that avoids the catastrophic explosiveness of inconsistency in classical logic. The paraconsistent logic has a countably infinite number of non-classical truth values. We show how to use the proof assistant Isabelle to formally prove theorems in the logic as well as meta-theorems about the logic. In particular, we formalize a meta-theorem that allows us to reduce the infinite number of truth values to a finite number of truth values, for a given formula, and we use this result in a formalization of a small case study.

From LZ77 to the run-length encoded burrows-wheeler transform, and back

The Lempel-Ziv factorization (LZ77) and the Run-Length encoded Burrows-Wheeler Transform (RLBWT) are two important tools in text compression and indexing, being their sizes $z$ and $r$ closely related to the amount of text self-repetitiveness. In this paper we consider the problem of converting the two representations into each other within a working space proportional to the input and the output. Let $n$ be the text length. We show that RLBWT can be converted to LZ77 in $O(n \log r)$ time and $O(r)$ words of working space. Conversely, we provide an algorithm to convert LZ77 to RLBWT in $O(n(\log r + \log z))$ time and $O(r + z)$ words of working space. Note that $r$ and $z$ can be constant if the text is highly...
repetitive, and our algorithms can operate with (up to) exponentially less space than naive solutions based on full decompression.

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Burrows-Wheeler transform, Compressed computation, Lempel-Ziv, Repetitive text collections

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**Graphs with No Induced Five-Vertex Path or Anti-path**
We prove that a graph G contains no induced five-vertex path and no induced complement of a five-vertex path if and only if G is obtained from 5-cycles and split graphs by repeatedly applying the following operations: substitution, split unification, and split unification in the complement, where split unification is a new class-preserving operation introduced here.

**General information**
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Princeton University, University of Grenoble, Wesleyan University
Authors: Chudnovsky, M. (Ekstern), Esperet, L. (Ekstern), Lemoine, L. (Ekstern), Maceli, P. (Ekstern), Maffray, F. (Ekstern), Penev, I. (Intern)
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Main Research Area: Technical/natural sciences

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Scopus rating (2017): SNIP 1.45 SJR 1.104 CiteScore 0.82
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 0.71 SJR 1.105 SNIP 1.362
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.469 SNIP 1.598 CiteScore 0.85
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.281 SNIP 1.136 CiteScore 0.73
Immersive Algorithms: Better Visualization with Less Information

Visualizing algorithms, such as drawings, slideshow presentations, animations, videos, and software tools, is a key concept to enhance and support student learning. A typical visualization of an algorithm show the data and then perform computation on the data. For instance, a standard visualization of a standard binary search on an array shows an array of sorted numbers and then illustrate the action of the algorithm in a step-by-step fashion. However, this approach does not fully capture the computational environment from the perspective of the algorithm. Specifically, the algorithm does not "see" the full sorted array, but only the single position that it accesses during each step of the computation. To fix this discrepancy we introduce the immersive principle that states that at any point in time, the displayed information should closely match the information accessed by the algorithm.

We give several examples of immersive visualizations of basic algorithms and data structures, discuss methods for implementing it, and briefly evaluate it.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Bille, P. (Intern), Gørtz, I. L. (Intern)
Learning to Act: Qualitative Learning of Deterministic Action Models

In this article we study learnability of fully observable, universally applicable action models of dynamic epistemic logic. We introduce a framework for actions seen as sets of transitions between propositional states and we relate them to their dynamic epistemic logic representations as action models. We introduce and discuss a wide range of properties of actions and action models and relate them via correspondence results. We check two basic learnability criteria for action models: finite identifiability (conclusively inferring the appropriate action model in finite time) and identifiability in the limit (inconclusive convergence to the right action model). We show that deterministic actions are finitely identifiable, while arbitrary (non-deterministic) actions require more learning power—they are identifiable in the limit. We then move on to a particular learning method, i.e. learning via update, which proceeds via restriction of a space of events within a learning-specific action model. We show how this method can be adapted to learn conditional and unconditional deterministic action models. We propose update learning mechanisms for the afore mentioned classes of actions and analyse their computational complexity. Finally, we study a parametrized learning method which makes use of the upper bound on the number of propositions relevant for a given learning scenario. We conclude with describing related work and numerous directions of further work.
We present new algorithms for the sliding window Lempel-Ziv (LZ77) problem and the approximate rightmost LZ77 parsing problem. Our main result is a new and surprisingly simple algorithm that computes the sliding window LZ77 parse in $O(w)$ space and either $O(n)$ expected time or $O(n \log \log w + z \log \log \sigma)$ deterministic time. Here, $w$ is the window size, $n$ is the size of the input string, $z$ is the number of phrases in the parse, and $\sigma$ is the size of the alphabet. This matches the space and time bounds of previous results while removing constant size restrictions on the alphabet size. To achieve our result, we combine a simple modification and augmentation of the suffix tree with periodicity properties of sliding windows. We also apply this new technique to obtain an algorithm for the approximate rightmost LZ77 problem that uses $O(n(\log z + \log n))$ time and $O(n)$ space and produces a $(1 + \varepsilon)$-approximation of the rightmost parsing (any constant $\varepsilon > 0$). While this does not improve the best known time-space trade-offs for exact rightmost parsing, our algorithm is significantly simpler and exposes a direct connection between sliding window parsing and the approximate rightmost matching problem.
Logical Entity Level Sentiment Analysis

We present a formal logical approach using a combinatory categorial grammar for entity level sentiment analysis that utilizes machine learning techniques for efficient syntactical tagging and performs a deep structural analysis of the syntactical properties of texts in order to yield precise results. The method should be seen as an alternative to pure machine learning methods for sentiment analysis, which are argued to have high difficulties in capturing long distance dependencies, and can be dependent on significant amount of domain specific training data. The results show that the method yields high correctness, but further investment is needed in order to improve its robustness.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Department of Management Engineering, Transport Modelling, Algorithms and Logic, Technical University of Denmark
Authors: Petersen, N. C. (Intern), Villadsen, J. (Intern)
Pages: 54-71
Publication date: 2017

Lower bounds on the run time of the univariate marginal distribution algorithm on OneMax

The Univariate Marginal Distribution Algorithm (UMDA), a popular estimation of distribution algorithm, is studied from a run time perspective. On the classical OneMax benchmark function, a lower bound of $\Omega(\mu \sqrt{n} + n \log n)$, where $\mu$ is the population size, on its expected run time is proved. This is the first direct lower bound on the run time of the UMDA. It is stronger than the bounds that follow from general black-box complexity theory and is matched by the run time of many evolutionary algorithms. The results are obtained through advanced analyses of the stochastic change of the frequencies of bit values maintained by the algorithm, including carefully designed potential functions. These techniques may prove useful in advancing the field of run time analysis for estimation of distribution algorithms in general.

General information
State: Published
Matching and Compression of Strings with Automata and Word Packing

Dynamic Relative Compression, Dynamic Partial Sums, and Substring Concatenation Given a static reference string R and a source string S, a relative compression of S with respect to R is an encoding of S as a sequence of references to substrings of R. Relative compression schemes are a classic model of compression and have recently proved very successful for compressing highly-repetitive massive data sets such as genomes and web-data. We initiate the study of relative compression in a dynamic setting where the compressed source string S is subject to edit operations. The goal is to maintain the compressed representation compactly, while supporting edits and allowing efficient random access to the (uncompressed) source string. We present new data structures that achieve optimal time for updates and queries while using space linear in the size of the optimal relative compression, for nearly all combinations of parameters. We also present solutions for restricted and extended sets of updates. To achieve these results, we revisit the dynamic partial sums problem and the substring concatenation problem. We present new optimal or near optimal bounds for these problems. Plugging in our new results we also immediately obtain new bounds for the string indexing for patterns with wildcards problem and the dynamic text and static pattern matching problem. Subsequence Automata with Default Transitions Let S be a string of length n with characters from an alphabet of size \( \sigma \). The subsequence automaton of S (often called the directed acyclic subsequence graph) is the minimal deterministic finite automaton accepting all subsequences of S. A straightforward construction shows that the size (number of states and transitions) of the subsequence automaton is \( O(n) \) and that this bound is asymptotically optimal. In this paper, we consider subsequence automata with default transitions, that is, special transitions to be taken only if none of the regular transitions match the current character, and which do not consume the current character. We show that with default transitions, much smaller subsequence automata are possible, and provide a full trade-off between the size of the automaton and the delay, i.e., the maximum number of consecutive default transitions followed before consuming a character. Specifically, given any integer parameter \( k \), \( 1 < k \), we present a subsequence automaton with default transitions of size \( O(nk \log k) \) and delay \( O(\log k) \). Hence, with \( k = 2 \) we obtain an automaton of size \( O(n \log n) \) and delay \( O(\log n) \). At the other extreme, with \( k = \), we obtain an automaton of size \( O(n) \) and delay \( O(1) \), thus matching the bound for the standard subsequence automaton construction. Finally, we generalize the result to multiple strings. The key component of our result is a novel hierarchical automata construction of independent interest. Deterministic Indexing for Packed Strings Given a string S of length n, the classic string indexing problem is to preprocess S into a compact data structure that supports efficient subsequent pattern queries. In the deterministic variant the goal is to solve the string indexing problem without any randomization (at preprocessing time or query time). In the packed variant the strings are stored with several character in a single word, giving us the opportunity to read multiple characters simultaneously. Our main result is a new string index in the deterministic and packed setting. Given a packed string S of length n over an alphabet \( \sigma \), we show how to preprocess S in \( O(n) \) (deterministic) time and space \( O(n) \) such that given a packed pattern string of length m we can support queries in (deterministic) time \( O(m + \log m + \log \log n) \); where \( \log n = \log \) is the number of characters packed in a word of size \( w = \log n \). Our query time is always at least as good as the previous best known bounds and whenever several characters are packed in a word, i.e., \( \log w \), the query times are faster. Dynamic Partial Sums in Constant Time and Succinct Space with the Ultra Wide Word-RAM Model The dynamic partial sums problem is to dynamically maintain an array of n integers while supporting efficient access, update and partial sums queries. This classic problem, and its variations, are very well studied in many different computational models [Fre82,FS89,Fen94, HSS11, HR03, HRS96,RRR01, PD04]. We solve the partial sums problem in the ultra wide word-RAM model, recently introduced by Farzan et al. [FLONS15], where we, in constant time, are allowed to manipulate words of size \( w_2 \) and access \( w \) memory locations. Farzan et al. [FLONS15] additionally gave a solution to the dynamic partial sums problem by simulating the RAMBO model to obtain a result by Brodnik et al. [BKMN06]. In this
In this paper, we present an improved solution to the dynamic partial sums problem in the ultra wide word-RAM model that supports all operations in either constant or $O(\log \log n)$ time, depending on whether we allow multiplication, and succinct space. We pose as an open problem whether it is possible in the ultra wide word-RAM model to additionally support the classic select operation in constant time.

**General information**
- **State:** Published
- **Organisations:** Department of Applied Mathematics and Computer Science, Algorithms and Logic
- **Authors:** Skjoldjensen, F. R. (Intern), Bille, P. (Intern), Gørtz, I. L. (Intern), Thomassen, C. (Intern)
- **Number of pages:** 80
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- **Electronic versions:** phd446_Skjoldjensen_FR.pdf

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- **Projects:**
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**Motif trie: An efficient text index for pattern discovery with don't cares**

We introduce the motif trie data structure, which has applications in pattern matching and discovery in genomic analysis, plagiarism detection, data mining, intrusion detection, spam fighting and time series analysis, to name a few. Here the extraction of recurring patterns in sequential and textual data is one of the main computational bottlenecks. For this, we address the problem of extracting maximal patterns with at most $k$ don’t care symbols and at least $q$ occurrences, according to a maximality notion we define. We apply the motif trie to this problem, also showing how to build it efficiently. As a result, we give the first algorithm that attains a stronger notion of output-sensitivity, where the cost for an input sequence of $n$ symbols is proportional to the actual number of occurrences of each pattern, which is at most $n$ (much smaller in practice). This avoids the best-known cost of $O(nc)$ per pattern, for constant $c>1$, which is otherwise impractical for massive sequences with large $n$.

**General information**
- **State:** Published
- **Organisations:** Department of Applied Mathematics and Computer Science, Algorithms and Logic, Università di Pisa
- **Authors:** Grossi, R. (Ekstern), Menconi, G. (Ekstern), Pisanti, N. (Ekstern), Trani, R. (Ekstern), Vind, S. J. (Intern)
- **Pages:** 74-87
- **Publication date:** 2017
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- **Volume:** 710
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  - BFI (2017): BFI-level 2
  - Scopus rating (2017): SJR 0.488 SNIP 0.996 CiteScore 1.08
  - Web of Science (2017): Indexed Yes
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  - Scopus rating (2016): CiteScore 0.97 SJR 0.547 SNIP 0.996
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 2
  - Scopus rating (2015): SJR 0.592 SNIP 1.123 CiteScore 1
NaDeA: A Natural Deduction Assistant with a Formalization in Isabelle

We present a new software tool for teaching logic based on natural deduction. Its proof system is formalized in the proof assistant Isabelle such that its definition is very precise. Soundness of the formalization has been proved in Isabelle. The tool is open source software developed in TypeScript / JavaScript and can thus be used directly in a browser without any further installation. Although developed for computer science bachelor students who are used to study and program concrete computer code in a programming language we consider the approach relevant for a broader audience and for other proof systems as well.
Nash Equilibria in Symmetric Graph Games with Partial Observation

We investigate a model for representing large multiplayer games, which satisfy strong symmetry properties. This model is made of multiple copies of an arena; each player plays in his own arena, and can partially observe what the other players do. Therefore, this game has partial information and symmetry constraints, which make the computation of Nash equilibria difficult. We show several undecidability results, and for bounded-memory strategies, we precisely characterize the complexity of computing pure Nash equilibria for qualitative objectives in this game model.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Centre National de la Recherche Scientifique
Authors: Bouyer, P. (Ekstern), Markey, N. (Ekstern), Vester, S. (Intern)
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Scopus rating (2016): CiteScore 1.22 SJR 0.724 SNIP 1.228
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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.619 SNIP 1.032 CiteScore 1.12
Web of Science (2015): Indexed yes
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Scopus rating (2014): SJR 0.775 SNIP 1.479 CiteScore 1.39
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.764 SNIP 1.306 CiteScore 1.21
On a combination of the 1-2-3 conjecture and the antimagic labelling conjecture

This paper is dedicated to studying the following question: Is it always possible to injectively assign the weights 1, ..., |E(G)| to the edges of any given graph G (with no component isomorphic to K2) so that every two adjacent vertices of G get distinguished by their sums of incident weights? One may see this question as a combination of the well-known 1-2-3 Conjecture and the Antimagic Labelling Conjecture. Throughout this paper, we exhibit evidence that this question might be true. Benefiting from the investigations on the Antimagic Labelling Conjecture, we first point out that several classes of graphs, such as regular graphs, indeed admit such assignments. We then show that trees also do, answering a recent conjecture of Arumugam, Premalatha, Bača and Semaničová-Feňovčíková. Towards a general answer to the question above, we then prove that claimed assignments can be constructed for any graph, provided we are allowed to use some number of additional edge weights. For some classes of sparse graphs, namely 2-degenerate graphs and graphs with maximum average degree 3, we show that only a small (constant) number of such additional weights suffices.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, INRIA Institut National de Recherche en Informatique et en Automatique, CNRS Centre National de la Recherche Scientifique
Authors: Bensmail, J. (Ekstern), Senhaji, M. (Ekstern), Lyngsie, K. S. (Intern)
Number of pages: 18
Publication date: 2017
Main Research Area: Technical/natural sciences

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Journal: Discrete Mathematics and Theoretical Computer Science
Volume: 19
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Article number: 21
ISSN (Print): 1462-7264
On a directed variation of the 1-2-3 and 1-2 Conjectures

In this paper, we consider the following question, which stands as a directed analogue of the well-known 1-2-3 Conjecture: Given any digraph $D$ with no arc $uv$ verifying $d^+(u) = d^-(v) = 1$, is it possible to weight the arcs of $D$ with weights among 1; 2; 3 so that, for every arc $uv$ of $D$, the sum of incident weights out-going from $u$ is different from the sum of incident weights in-coming to $v$? We answer positively to this question, and investigate digraphs for which even the weights among 1; 2 are sufficient. In relation with the so-called 1-2 Conjecture, we also consider a total version of the problem, which we prove to be false. Our investigations turn to have interesting relations with open questions related to the 1-2-3 Conjecture.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Ecole Normale Superieure de Lyon, AGH University of Science and Technology
Authors: Barme, E. (Ekstern), Bensmail, J. (Intern), Przybyło, J. (Ekstern), Wozniak, M. (Ekstern)
On q-power cycles in cubic graphs
In the context of a conjecture of Erdos and Gyárfás, we consider, for any q ≥ 2, the existence of q-power cycles (i.e. with length a power of q) in cubic graphs. We exhibit constructions showing that, for every q ≥ 3, there exist arbitrarily large cubic graphs with no q-power cycles. Concerning the remaining case q = 2 (which corresponds to the conjecture of Erdos and Gyárfás), we show that there exist arbitrarily large cubic graphs whose only 2-power cycles have length 4 only, or 8 only.

General information
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Organisations: Department of Applied Mathematics and Computer Science , Algorithms and Logic
Authors: Bensmail, J. (Intern)
Pages: 211–220
Publication date: 2017
Main Research Area: Technical/natural sciences

On the Minimum Number of Spanning Trees in k-Edge-Connected Graphs
We show that a k-edge-connected graph on n vertices has at least \( n(k/2)^{k-1} \) spanning trees. This bound is tight if k is even and the extremal graph is the n-cycle with edge multiplicities k/2. For k odd, however, there is a lower bound \( c_k n^{k-1} \), where \( c_3 > 1.77 \) and \( c_5 > 2.75 \). Not surprisingly, \( c_3 \) is smaller than the corresponding number for 4-edge-connected graphs. Examples show that \( c_3 \leq 2+\sqrt{3} \approx 1.93 \). However, we have no examples of 5-edge-connected graphs with fewer spanning trees than the n-cycle with all edge multiplicities (except one) equal to 3, which is almost 6-regular. We have no examples of 5-regular 5-edge-connected graphs with fewer than \( 3.09 n^{5-1} \) spanning trees, which is more than the corresponding number for 6-regular 6-edge-connected graphs. The analogous surprising phenomenon occurs for each higher odd edge connectivity and regularity.

General information
Pathway computation in models derived from bio-science text sources
This paper outlines a system, OntoScape, serving to accomplish complex inference tasks on knowledge bases and bio-models derived from life-science text corpora. The system applies so-called natural logic, a form of logic which is readable for humans. This logic affords ontological representations of complex terms appearing in the text sources. Along with logical propositions, the system applies a semantic graph representation facilitating calculation of bio-pathways. More generally, the system affords means of query answering appealing to general and domain specific inference rules.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Roskilde University, Copenhagen Business School
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Bio-models using natural logic and semantic graphs, Querying and pathway computation, Semantic text processing in bio-informatics
DOIs: 10.1007/978-3-319-60438-1_42
Links: http://www.scopus.com/inward/record.url?scp=85021920748&partnerID=8YFLogxK (Link to publication in Scopus)
Source: Scopus
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Querying Natural Logic Knowledge Bases
This paper describes the principles of a system applying natural logic as a knowledge base language. Natural logics are regimented fragments of natural language employing high level inference rules. We advocate the use of natural logic for knowledge bases dealing with querying of classes in ontologies and class-relationships such as are common in life-science descriptions. The paper adopts a version of natural logic with recursive restrictive clauses such as relative clauses and adnominal prepositional phrases. It includes passive as well as active voice sentences. We outline a prototype for partial translation of natural language into natural logic, featuring further querying and conceptual path finding in natural logic knowledge bases.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Roskilde University, Copenhagen Business School
Number of pages: 8
Pages: 294-301
Publication date: 2017

Host publication information
Roots of the Chromatic Polynomial

The chromatic polynomial of a graph $G$ is a univariate polynomial whose evaluation at any positive integer $q$ enumerates the proper $q$-colourings of $G$. It was introduced in connection with the famous four colour theorem but has recently found other applications in the field of statistical physics. In this thesis we study the real roots of the chromatic polynomial, termed chromatic roots, and focus on how certain properties of a graph affect the location of its chromatic roots.

Firstly, we investigate how the presence of a certain spanning tree in a graph affects its chromatic roots. In particular we prove a tight lower bound on the smallest non-trivial chromatic root of a graph admitting a spanning tree with at most three leaves. Here, non-trivial means different from 0 or 1. This extends a theorem of Thomassen on graphs with Hamiltonian paths. We also prove similar lower bounds on the chromatic roots of certain minor-closed families of graphs.

Later, we study the Tutte polynomial of a graph, which contains the chromatic polynomial as a specialisation. We discuss a technique of Thomassen using which it is possible to deduce that the roots of the chromatic polynomial are dense in certain intervals. We extend Thomassen’s technique to the Tutte polynomial and as a consequence, deduce a density result for roots of the Tutte polynomial. This partially answers a conjecture of Jackson and Sokal.

Finally, we refocus our attention on the chromatic polynomial and investigate the density of chromatic roots of several graph families. In particular, we show that the chromatic roots of planar graphs are dense in the interval $(3; 4)$, except for a small interval around $\phi + 2$, where $\phi$ denotes the golden ratio. We also investigate the chromatic roots of related minor-closed classes of graphs and bipartite graphs.
Spanning quadrangulations of triangulated surfaces

In this paper we study alternating cycles in graphs embedded in a surface. We observe that 4-vertex-colorability of a triangulation on a surface can be expressed in terms of spanning quadrangulations, and we establish connections between spanning quadrangulations and cycles in the dual graph which are noncontractible and alternating with respect to a perfect matching. We show that the dual graph of an Eulerian triangulation of an orientable surface other than the sphere has a perfect matching M and an M-alternating noncontractible cycle. As a consequence, every Eulerian triangulation of the torus has a nonbipartite spanning quadrangulation. For an Eulerian triangulation G of the projective plane the situation is different: If the dual graph G+ is nonbipartite, then G+ has no noncontractible alternating cycle, and all spanning quadrangulations of G are bipartite. If the dual graph G+ is bipartite, then it has a noncontractible, M-alternating cycle for some (and hence any) perfect matching, G has a bipartite spanning quadrangulation and also a nonbipartite spanning quadrangulation.
A connected graph $G$ is said to be arbitrarily partitionable (AP for short) if for every partition $(n_1, \ldots, n_p)$ of $|V(G)|$ there exists a partition $(V_1, \ldots, V_p)$ of $V(G)$ such that each $V_i$ induces a connected subgraph of $G$ on $n_i$ vertices. Some stronger versions of this property were introduced, namely the ones of being online arbitrarily partitionable and recursively arbitrarily partitionable (OL-AP and R-AP for short, respectively), in which the subgraphs induced by a partition of $G$ must not only be connected but also fulfill additional conditions. In this paper, we point out some structural properties of OL-AP and R-AP graphs with connectivity 2. In particular, we show that deleting a cut pair of these graphs results in a graph with a bounded number of components, some of whom have a small number of vertices. We obtain these results by studying a simple class of 2-connected graphs called balloons.
Succinct partial sums and fenwick trees

We consider the well-studied partial sums problem in succinct space where one is to maintain an array of $n$ $k$-bit integers subject to updates such that partial sums queries can be efficiently answered. We present two succinct versions of the Fenwick Tree—an is known for its simplicity and practicality. Our results hold in the encoding model where one is allowed to reuse the space from the input data. Our main result is the first that only requires $nk + o(n)$ bits of space while still supporting sum/update in $O(\log bn)/O(\log bn)$ time where $2 \leq b \leq \log O(1)n$. The second result shows how optimal time for sum/update can be achieved while only slightly increasing the space usage to $nk + o(nk)$ bits. Beyond Fenwick Trees, the results are primarily based on bit-packing and sampling—making them very practical—and they also allow for simple optimal parallelization.

General information

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
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Fenwick tree, Parallel, Partial sums, Succinct

The (1+λ) evolutionary algorithm with self-adjusting mutation rate

We propose a new way to self-adjust the mutation rate in population-based evolutionary algorithms. Roughly speaking, it consists of creating half the offspring with a mutation rate that is twice the current mutation rate and the other half with half...
the current rate. The mutation rate is then updated to the rate used in that subpopulation which contains the best offspring. We analyze how the (1 + A) evolutionary algorithm with this self-adjusting mutation rate optimizes the OneMax test function. We prove that this dynamic version of the (1 + A) EA finds the optimum in an expected optimization time (number of fitness evaluations) of O(nA/log A + n log n). This time is asymptotically smaller than the optimization time of the classic (1 + A) EA. Previous work shows that this performance is best-possible among all A-parallel mutation-based unbiased black-box algorithms. This result shows that the new way of adjusting the mutation rate can find optimal dynamic parameter values on the fly. Since our adjustment mechanism is simpler than the ones previously used for adjusting the mutation rate and does not have parameters itself, we are optimistic that it will find other applications.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Ecole Polytechnique
Authors: Doerr, B. (Ekstern), Witt, C. (Intern), Gießen, C. (Intern), Yang, J. (Ekstern)
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Dynamic parameter control, Mutation, Runtime analysis, Optimization Techniques, Optimization, Adjustment mechanisms, Black box algorithms, Current mutations, Expected optimization time, Fitness evaluations, Run-time analysis, Evolutionary algorithms
Electronic versions: 1704.02191.pdf
DOIs:
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The Impact of a Sparse Migration Topology on the Runtime of Island Models in Dynamic Optimization
Island models denote a distributed system of evolutionary algorithms which operate independently, but occasionally share their solutions with each other along the so-called migration topology. We investigate the impact of the migration topology by introducing a simplified island model with behavior similar to (Formula presented.) islands optimizing the so-called Maze fitness function (Kötzing and Molter in Proceedings of parallel problem solving from nature (PPSN XII), Springer, Berlin, pp 113â€“122, 2012). Previous work has shown that when a complete migration topology is used, migration must not occur too frequently, nor too soon before the optimum changes, to track the optimum of the Maze function. We show that using a sparse migration topology alleviates these restrictions. More specifically, we prove that there exist choices of model parameters for which using a unidirectional ring of logarithmic diameter as the migration topology allows the model to track the oscillating optimum through nMaze-like phases with high probability, while using any graph of diameter less than (Formula presented.) for some sufficiently small constant (Formula presented.) results in the island model losing track of the optimum with overwhelming probability. Experimentally, we show that very frequent migration on a ring topology is not an effective diversity mechanism, while a lower migration rate allows the ring topology to track the optimum for a wider range of oscillation patterns. When migration occurs only rarely, we prove that dense migration topologies of small diameter may be advantageous. Combined, our results show that the sparse migration topology is able to track the optimum through a wider range of oscillation patterns, and cope with a wider range of migration frequencies.

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BFI (2018): BFI-level 2
The Interplay of Population Size and Mutation Probability in the (1+λ) EA on OneMax

The ((Formula presented.)) EA with mutation probability c / n, where (Formula presented.) is an arbitrary constant, is studied for the classical OneMax function. Its expected optimization time is analyzed exactly (up to lower order terms) as a function of c and (Formula presented.). It turns out that 1 / n is the only optimal mutation probability if (Formula presented.), which is the cut-off point for linear speed-up. However, if (Formula presented.) is above this cut-off point then the standard mutation probability 1 / n is no longer the only optimal choice. Instead, the expected number of generations is (up to lower order terms) independent of c, irrespectively of it being less than 1 or greater. The theoretical results are obtained by a careful study of order statistics of the binomial distribution and variable drift theorems for upper and lower
bounds. Experimental supplements shed light on the optimal mutation probability for small problem sizes.
The number of colorings of planar graphs with no separating triangles

A classical result of Birkhoff and Lewis implies that every planar graph with \( n \) vertices has at least \( 152n - 1 \) distinct 5-vertex-colorings. Equality holds for planar triangulations with \( n - 4 \) separating triangles. We show that, if a planar graph has no separating triangle, then it has at least \( (2 + 10^{-12})n \) distinct 5-vertex-colorings. A similar result holds for \( k \)-colorings for each fixed \( k \geq 5 \). Infinitely many planar graphs without separating triangles have less than \( 2.252n \) distinct 5-vertex-colorings. As an auxiliary result we provide a complete description of the infinite 6-regular planar triangulations.
The square of a planar cubic graph is 7-colorable
We prove the conjecture made by G. Wegner in 1977 that the square of every planar, cubic graph is 7-colorable. Here, 7 cannot be replaced by 6.
Tight bounds for top tree compression

We consider compressing labeled, ordered and rooted trees using DAG compression and top tree compression. We show that there exists a family of trees such that the size of the DAG compression is always a logarithmic factor smaller than the size of the top tree compression (even for an alphabet of size 1). The result settles an open problem from Bille et al. (Inform. and Comput., 2015).

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Algorithms and Logic , Technical University of Denmark
Time-space trade-offs for lempel-ziv compressed indexing

Given a string S, the compressed indexing problem is to preprocess S into a compressed representation that supports fast substring queries. The goal is to use little space relative to the compressed size of S while supporting fast queries. We present a compressed index based on the Lempel-Ziv 1977 compression scheme. Let $n$, and $z$ denote the size of the input string, and the compressed LZ77 string, respectively. We obtain the following time-space trade-offs. Given a pattern string $P$ of length $m$, we can solve the problem in (i) $O(m + \text{occ} \lg \lg n)$ time using $O(z \lg (n/z) \lg \lg z)$ space, or (ii) $(m(1 + \lg z/\lg(n/z) + \text{occ}(\lg n + \lg z))$ time using $O(z \lg (n/z))$ space, for any $0 < \epsilon < 1$. In particular, (i) improves the leading term in the query time of the previous best solution from $O(m \lg m)$ to $O(m)$ at the cost of increasing the space by a factor $\lg \lg z$. Alternatively, (ii) matches the previous best space bound, but has a leading term in the query time of $O(m(1 + \lg z/\lg(n/z)))$. However, for any polynomial compression ratio, i.e., $z = O(n^{1-\delta})$, for constant $\delta > 0$, this becomes $O(m)$. Our index also supports extraction of any substring of length $\ell$ in $O(\ell + \lg(n/z))$ time. Technically, our results are obtained by novel extensions and combinations of existing data structures of independent interest, including a new batched variant of weak prefix search.
The expected runtime is obtained. This bound crucially assumes that all marginal probabilities of the algorithm are confined to the interval $[1/n, 1 - 1/n]$. If $\mu \geq c'\sqrt{n \log n}$ for a constant $c' > 0$ and $\lambda = (1 + O(1))\mu$, the behavior of the algorithm changes and the bound on the expected runtime becomes $O(\mu \sqrt{n})$, which typically even holds if the borders on the marginal probabilities are omitted. The results supplement the recently derived lower bound $\Omega(\mu \sqrt{n + n \log n})$ by Krejca and Witt (FOGA 2017) and turn out as tight for the two very different values $\mu = c \log n$ and $p = c'\sqrt{n \log n}$. They also improve the previously best known upper bound $O(n \log n \log \log n)$ by Dang and Lehre (GECCO 2015).

Graph reconstruction with a betweenness oracle

Graph reconstruction algorithms seek to learn a hidden graph by repeatedly querying a blackbox oracle for information about the graph structure. Perhaps the most well studied and applied version of the problem uses a distance oracle, which can report the shortest path distance between any pair of nodes. We introduce and study the betweenness oracle, where $\text{bet}(a, m, z)$ is true iff $m$ lies on a shortest path between $a$ and $z$. This oracle is strictly weaker than a distance oracle, in the sense that a betweenness query can be simulated by a constant number of distance queries, but not vice versa. Despite this, we are able to develop betweenness reconstruction algorithms that match the current state of the art for distance reconstruction, and even improve it for certain types of graphs. We obtain the following algorithms: 1. Reconstruction of general graphs in $O(n^2)$ queries 2. Reconstruction of degree-bounded graphs in $\tilde{O}(n^{3/2})$ queries 3. Reconstruction of geodetic degree-bounded graphs in $\tilde{O}(n)$ queries. In addition to being a fundamental graph theoretic problem with some natural applications, our new results shed light on some avenues for progress in the distance reconstruction problem.

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A Framework for Organization-Aware Agents: JAAMAS Extended Abstract

This short paper introduces and summarizes the AORTA reasoning framework that can be integrated into BDI-agents to enable organizational decision-making. This work has recently been published in the Journal of Autonomous Agents and Multi-Agent Systems (JAAMAS), as [3].

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Delft University of Technology
Authors: Jensen, A. S. (Intern), Dignum, V. (Ekstern), Villadsen, J. (Intern)
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Analysis of Ant Colony Optimization and Population-Based Evolutionary Algorithms on Dynamic Problems

This thesis presents new running time analyses of nature-inspired algorithms on various dynamic problems. It aims to identify and analyse the features of algorithms and problem classes which allow efficient optimization to occur in the presence of dynamic behaviour. We consider the following settings:

λ-MMAS on Dynamic Shortest Path Problems. We investigate how increasing the number of ants simulated per iteration may help an ACO algorithm to track optimum in a dynamic problem. It is shown that while a constant number of ants per-vertex is sufficient to track some oscillations, there also exist more complex oscillations that cannot be tracked with a polynomial-size colony.

MMAS and (μ+1) EA on Maze We analyse the behaviour of a (μ + 1) EA with genotype diversity on a dynamic fitness function Maze, extended to a finite-alphabet search space. We prove that the (μ + 1) EA is able to track the dynamic optimum for finite alphabets up to size μ, while MMAS is able to do so for any finite alphabet size.

Parallel Evolutionary Algorithms on Maze. We prove that while a (1 + λ) EA is unable to track the optimum of the dynamic fitness function Maze for offspring population size up to λ = O(n1−ε), a simple island model with Ω(log n) islands is able to do so if the migration interval is chosen appropriately.

Migration Topology in Island Models. We investigate the impact of the migration topology on the performance of an island model optimizing a Maze-like dynamic function, demonstrating that in some cases, a less-dense migration topology is preferable to a complete migration topology.

(1+1) EA on Generalized Dynamic OneMax. We analyze the (1 + 1) EA on dynamically changing OneMax, re-proving known results on first hitting times using modern drift analysis, and providing a new anytime analysis showing how closely the EA can track the dynamically moving optimum over time. These results are also extended to a finite-alphabet search space.
Announcements to Attentive Agents
In public announcement logic it is assumed that all agents pay attention to the announcement. Weaker observational conditions can be modelled in action model logic. In this work, we propose a version of public announcement logic wherein it is encoded in the states of the epistemic model which agents pay attention to the announcement. This logic is called attention-based announcement logic. We give an axiomatization of the logic and prove that complexity of satisfiability is the same as that of public announcement logic, and therefore lower than that of action model logic. An attention-based announcement can also be described as an action model. We extend our logic by integrating attention change. Finally, we add the notion of common belief to the language, we exploit this to formalize the concept of joint attention, that has been widely discussed in the philosophical and cognitive science literature, and we provide a corresponding axiomatization. This axiomatization also employs the auxiliary notion of attention-based relativized common belief.
Aspects of the Tutte polynomial

This thesis studies various aspects of the Tutte polynomial, especially focusing on the Merino-Welsh conjecture.

We write $T(G;x,y)$ for the Tutte polynomial of a graph $G$ with variables $x$ and $y$. In 1999, Merino and Welsh conjectured that if $G$ is a loopless 2-connected graph, then

$$T(G;1,1) \leq \max\{T(G;2,0), T(G;0,2)\}.$$  

The three numbers, $T(G;1,1)$, $T(G;2,0)$ and $T(G;0,2)$ are respectively the numbers of spanning trees, acyclic orientations and totally cyclic orientations of $G$.

First, I extend Negami's splitting formula to the multivariate Tutte polynomial. Using the splitting formula, Thomassen and I found a lower bound for the number of spanning trees in a $k$-edge-connected graph. Our bound is tight for $k$ even, but for $k$ odd we give a slightly better lower bound which we believe is not tight. We prove that the minimum number of spanning trees in a 3-edge-connected graph with $n$ vertices is, not surprisingly, significantly smaller than the minimum number of spanning trees in a 4-edge-connected graph. However, we conjecture that the minimum number of spanning trees of a 5-edge-connected graph is actually obtained by a 6-edge-connected graph asymptotically.

Thomassen proved the following partial result for the Merino-Welsh conjecture. Assume the graph $G$ is loopless, bridgeless and has $n$ vertices and $m$ edges.

If $m \leq 1.066n$ then $T(G;1,1) \leq T(G;2,0)$.
If $m \geq 4(n-1)$ then $T(G;1,1) \leq T(G;0,2)$.

I improve in this thesis Thomassen's result as follows:

If $m \leq 1.29(n-1)$ then $T(G;1,1) \leq T(G;2,0)$.
If $m \geq 3.58(n-1)$ and $G$ is 3-edge-connected then $T(G;1,1) \leq T(G;0,2)$.

Strengthening Thomassen's idea that acyclic orientations dominate spanning trees in sparse graphs, I conjecture that the ratio $T(G;2,0)/T(G;1,1)$ increases as $G$ gets sparser. To support this conjecture, I prove a variant of the conjecture for
series-parallel graphs.

The Merino-Welsh conjecture has a stronger version claiming that the Tutte polynomial is convex on the line segment between (2,0) and (0,2) for loopless 2-connected graphs. Chavez-Lomeli et al. proved that this holds for coloopless paving matroids, and I provide a shorter proof of their theorem. I also prove it for minimally 2-edge-connected graphs. As a general statement for the convexity of the Tutte polynomials, I show that the Tutte polynomial of a sparse paving matroid is almost surely convex in the first quadrant. In contrast, I conjecture that the Tutte polynomial of a sparse paving matroid with fixed rank is almost never convex in the first quadrant.

The following multiplicative version of the Merino-Welsh conjecture was considered by Noble and Royle:

\[ T(G;1,1) \leq T(G;2,0) T(G;0,2). \]

Noble and Royle proved that this multiplicative version holds for series-parallel graphs, using a computer algorithm that they designed. Using a property of the splitting formula which I found, I improve their algorithm so that it is applicable to the class of graphs with bounded treewidth (or pathwidth). As an application, I verify that the multiplicative version holds for graphs with pathwidth at most 3.

A zero-free interval for chromatic polynomials of graphs with 3-leaf spanning trees

It is proved that if \( G \) is a graph containing a spanning tree with at most three leaves, then the chromatic polynomial of \( G \) has no roots in the interval \( (1,t_1] \), where \( t_1 \approx 1.2904 \) is the smallest real root of the polynomial \((t-2)^6+4(t-1)^2(t-2)^2(t-1)^4\). We also construct a family of graphs containing such spanning trees with chromatic roots converging to \( t_1 \) from above. We employ the Whitney 2-switch operation to manage the analysis of an infinite class of chromatic polynomials.
Better Eager Than Lazy? How Agent Types Impact the Successfulness of Implicit Coordination

Epistemic planning can be used for decision making in multiagent situations with distributed knowledge and capabilities. In recent work, we proposed a new notion of strong policies with implicit coordination. With this it is possible to solve planning tasks with joint goals from a single-agent perspective without the agents having to negotiate about and commit to a joint policy at plan time. We study how and under which circumstances the decentralized application of those policies leads to the desired outcome.

General information
Bisimulation and expressivity for conditional belief, degrees of belief, and safe belief

Plausibility models are Kripke models that agents use to reason about knowledge and belief, both of themselves and of each other. Such models are used to interpret the notions of conditional belief, degrees of belief, and safe belief. The logic of conditional belief contains that modality and also the knowledge modality, and similarly for the logic of degrees of belief and the logic of safe belief. With respect to these logics, plausibility models may contain too much information. A proper notion of bisimulation is required that characterises them. We define that notion of bisimulation and prove the required characterisations: on the class of image-finite and preimage-finite models (with respect to the plausibility relation), two pointed Kripke models are modally equivalent in either of the three logics, if and only if they are bisimilar. As a result, the information content of such a model can be similarly expressed in the logic of conditional belief, or the logic of degrees of belief, or that of safe belief. This, we found a surprising result. Still, that does not mean that the logics are equally expressive: the logics of conditional and degrees of belief are incomparable, the logics of degrees of belief and safe belief are incomparable, while the logic of safe belief is more expressive than the logic of conditional belief. In view of the result on bisimulation characterisation, this is an equally surprising result. We hope our insights may contribute to the growing community of formal epistemology and on the relation between qualitative and quantitative modelling.

General information
State: Published
Organisations: Algorithms and Logic, Department of Applied Mathematics and Computer Science, Université de Lorraine
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Pages: 2447-2487
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 0.72 SJR 0.927 SNIP 1.29
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.902 SNIP 1.004 CiteScore 0.69
We consider the problem of storing a grammar of size $n$ compressing a string of size $N$, and a set of positions $\{i_1, \ldots, i_k\}$ (bookmarks) such that any substring of length $l$ crossing one of the positions can be decompressed in $O(l)$ time. Our solution uses space $O((n+b) \max\{1, \log^* n - \log^* (n/b + b/n)\})$. Existing solutions for the bookmarking problem either require more space or a super-constant “kick-off” time to start the decompression.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Haifa
Authors: Cording, P. H. (Intern), Gawrychowski, P. (Ekstern), Weimann, O. (Ekstern)
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ISBN (Print): 978-3-319-46048-2
ISBN (Electronic): 978-3-319-46049-9

Series: Lecture Notes in Computer Science
Boxed Permutation Pattern Matching.

Given permutations T and P of length n and m, respectively, the Permutation Pattern Matching problem asks to find all m-length subsequences of T that are order-isomorphic to P. This problem has a wide range of applications but is known to be NP-hard. In this paper, we study the special case, where the goal is to only find the boxed subsequences of T that are order-isomorphic to P. This problem was introduced by Bruner and Lackner who showed that it can be solved in O(n^3) time. Cho et al. [CPM 2015] gave an O(n^2 m) time algorithm and improved it to O(n^2 log m). In this paper we present a solution that uses only O(n^2) time. In general, there are instances where the output size is Ω(n^2) and hence our bound is optimal. To achieve our results, we introduce several new ideas including a novel reduction to 2D offline dominance counting. Our algorithm is surprisingly simple and straightforward to implement.

Capacitated Vehicle Routing with Nonuniform Speeds

The capacitated vehicle routing problem (CVRP) involves distributing identical items from a depot to a set of demand locations using a single capacitated vehicle. We introduce the heterogeneous capacitated vehicle routing problem, a generalization of CVRP to the setting of multiple vehicles having nonuniform speeds, and present for it a constant-factor approximation algorithm. Our main contribution is an approximation algorithm for the heterogeneous traveling salesman problem, which is the special case of heterogeneous CVRP with uncapacitated vehicles. Given a metric denoting distances between vertices, a depot r containing k vehicles having respective speeds {\lambda(i)}_{i=1}^k, the objective in heterogeneous TSP is to find a tour for each vehicle (starting and ending at r) so that every vertex is covered in some tour and the maximum completion time is minimized; the completion time of a vehicle is the distance traveled divided by its speed. Our algorithm relies on a new approximate minimum spanning tree construction called Level-Prim, which is related to but different from Light Approximate Shortest-path Trees. We also extend the widely used tour-splitting technique to nonuniform speeds, using ideas from the 2-approximation algorithm for scheduling in unrelated machines.
Capacitated Vehicle Routing with Non-Uniform Speeds

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General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Algorithms and Logic , Carnegie Mellon University, IBM Thomas J. Watson Research Center
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Main Research Area: Technical/natural sciences

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Scopus rating (2017): SNIP 1.374 SJR 1.267 CiteScore 1.35
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BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.81 SJR 1.637 SNIP 1.69
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.596 SNIP 1.666 CiteScore 1.63
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.512 SNIP 1.898 CiteScore 1.85
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.173 SNIP 1.678 CiteScore 1.71
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.54 SNIP 1.586 CiteScore 1.49
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.324 SNIP 1.547 CiteScore 1.45
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.437 SNIP 1.507
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.786 SNIP 1.576
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.06 SNIP 1.64
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.575 SNIP 1.92
Chromatic roots and minor-closed families of graphs

Given a minor-closed class of graphs $G$, what is the minimum of the non-trivial roots of the chromatic polynomial of $G \in G$? When $G$ is the class of all graphs, the answer is known to be $32/27$. We answer this question exactly for three minor-closed classes of graphs. Furthermore, we conjecture precisely when the value is larger than $32/27$.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Perrett, T. (Intern)
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
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Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 1.042 SNIP 1.316 CiteScore 0.98
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.068 SNIP 1.339 CiteScore 0.91
BFI (2013): BFI-level 1
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.959 SNIP 1.313 CiteScore 0.95
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.211 SNIP 1.298 CiteScore 0.98
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.011 SNIP 1.044
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.115 SNIP 1.37
BFI (2008): BFI-level 1
Code Generation for a Simple First-Order Prover

We present Standard ML code generation in Isabelle/HOL of a sound and complete prover for first-order logic, taking formalizations by Tom Ridge and others as the starting point. We also define a set of so-called unfolding rules and show how to use these as a simple prover, with the aim of using the approach for teaching logic and verification to computer science students at the bachelor level.

Decomposing graphs into a constant number of locally irregular subgraphs

A graph is locally irregular if no two adjacent vertices have the same degree. The irregular chromatic index χirr′(G) of a graph G is the smallest number of locally irregular subgraphs needed to edge-decompose G. Not all graphs have such a decomposition, but Baudon, Bensmail, Przybyło, and Woźniak conjectured that if G can be decomposed into locally irregular subgraphs, then χirr′(G)≤3. In support of this conjecture, Przybyło showed that χirr′(G)≤3 holds whenever G has minimum degree at least 1010.

Here we prove that every bipartite graph G which is not an odd length path satisfies χirr′(G)≤10. This is the first general constant upper bound on the irregular chromatic index of bipartite graphs. Combining this result with Przybyło’s result, we show that χirr′(G)≤328 for every graph G which admits a decomposition into locally irregular subgraphs. Finally, we show that χirr′(G)≤2 for every 16-edge-connected bipartite graph G.
Decomposing highly edge-connected graphs into homomorphic copies of a fixed tree

The Tree Decomposition Conjecture by Barát and Thomassen states that for every tree T there exists a natural number k(T) such that the following holds: If G is a k(T)-edge-connected simple graph with size divisible by the size of T, then G can be edge-decomposed into subgraphs isomorphic to T. So far this conjecture has only been verified for paths, stars, and a family of bistars. We prove a weaker version of the Tree Decomposition Conjecture, where we require the subgraphs in the decomposition to be isomorphic to graphs that can be obtained from T by vertex-identifications. We call
such a subgraph a homomorphic copy of T. This implies the Tree Decomposition Conjecture under the additional constraint that the girth of G is greater than the diameter of T. As an application, we verify the Tree Decomposition Conjecture for all trees of diameter at most 4.

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BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.13 SJR 1.942 SNIP 1.973
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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.095 SNIP 2.049 CiteScore 1.29
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.021 SNIP 2.028 CiteScore 1.1
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.936 SNIP 1.918 CiteScore 1.19
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.181 SNIP 2.093 CiteScore 1.2
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.176 SNIP 1.759 CiteScore 1.11
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.104 SNIP 1.599
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Scopus rating (2009): SJR 2.457 SNIP 1.993
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.49 SNIP 2.598
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.393 SNIP 1.989
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.068 SNIP 1.973
Scopus rating (2005): SJR 1.365 SNIP 1.464
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.808 SNIP 2.02
Decomposing Oriented Graphs into Six Locally Irregular Oriented Graphs

An undirected graph G is locally irregular if every two of its adjacent vertices have distinct degrees. We say that G is decomposable into k locally irregular graphs if there exists a partition $E_1\cup E_2\cup\cdots\cup E_k$ of the edge set $E(G)$ such that each $E_i$ induces a locally irregular graph. It was recently conjectured by Baudon et al. that every undirected graph admits a decomposition into at most three locally irregular graphs, except for a well-characterized set of indecomposable graphs. We herein consider an oriented version of this conjecture. Namely, can every oriented graph be decomposed into at most three locally irregular oriented graphs, i.e. whose adjacent vertices have distinct outdegrees? We start by supporting this conjecture by verifying it for several classes of oriented graphs. We then prove a weaker version of this conjecture. Namely, we prove that every oriented graph can be decomposed into at most six locally irregular oriented graphs. We finally prove that even if our conjecture were true, it would remain NP-complete to decide whether an oriented graph is decomposable into at most two locally irregular oriented graphs.
Detecting structural breaks in time series via genetic algorithms

Detecting structural breaks is an essential task for the statistical analysis of time series, for example, for fitting parametric models to it. In short, structural breaks are points in time at which the behaviour of the time series substantially changes. Typically, no solid background knowledge of the time series under consideration is available. Therefore, a black-box optimization approach is our method of choice for detecting structural breaks. We describe a genetic algorithm framework which easily adapts to a large number of statistical settings. To evaluate the usefulness of different crossover and mutation operations for this problem, we conduct extensive experiments to determine good choices for the parameters and operators of the genetic algorithm. One surprising observation is that use of uniform and one-point crossover together gave significantly better results than using either crossover operator alone. Moreover, we present a specific fitness function which exploits the sparse structure of the break points and which can be evaluated particularly efficiently. The experiments on artificial and real-world time series show that the resulting algorithm detects break points with high precision and is computationally very efficient. A reference implementation with the data used in this paper is available as an applet at the following address: http://www.imm.dtu.dk/~pafi/TSX/. It has also been implemented as package SBRect for the statistics language R.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Ecole Polytechnique, Linnaeus University
Authors: Doerr, B. (Ekstern), Fischer, P. (Intern), Hilbert, A. (Ekstern), Witt, C. (Intern)
Pages: 4707–4720
Publication date: 2016
Main Research Area: Technical/natural sciences
Distance labeling schemes for trees

We consider distance labeling schemes for trees: given a tree with n nodes, label the nodes with binary strings such that, given the labels of any two nodes, one can determine, by looking only at the labels, the distance in the tree between the two nodes. A lower bound by Gavoille et al. [Gavoille et al., J. Alg., 2004] and an upper bound by Peleg [Peleg, J. Graph Theory, 2000] establish that labels must use Θ(log²(n)) bits. Gavoille et al. [Gavoille et al., ESA, 2001] show that for very small approximate stretch, labels use Θ(log(n) log(log(n))) bits. Several other papers investigate various variants such as, for example, small distances in trees [Alstrup et al., SODA, 2003]. We improve the known upper and lower bounds of exact distance labeling by showing that 1/4 log₂(n) bits are needed and that 1/2 log₂(n) bits are sufficient. We also give (1 + ε)-stretch labeling schemes using Theta(log(n)) bits for constant ε > 0. (1 + ε)-stretch labeling schemes with polylogarithmic label size have previously been established for doubling dimension graphs by Talwar [Talwar, STOC,
In addition, we present matching upper and lower bounds for distance labeling for caterpillars, showing that labels must have size \(2\log n - \Theta(\log \log n)\). For simple paths with \(k\) nodes and edge weights in \([1,n]\), we show that labels must have size \((k - 1)/k \log n + \Theta(\log k)\).

**General information**
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen, Bar-Ilan University
Authors: Alstrup, S. (Ekstern), Gørtz, I. L. (Intern), Bistrup Halvorsen, E. (Ekstern), Porat, E. (Ekstern)
Pages: 1-16
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**Distributed synthesis in continuous time**
We introduce a formalism modelling communication of distributed agents strictly in continuous-time. Within this framework, we study the problem of synthesising local strategies for individual agents such that a specified set of goal states is reached, or reached with at least a given probability. The flow of time is modelled explicitly based on continuous-time randomness, with two natural implications: First, the non-determinism stemming from interleaving disappears. Second, when we restrict to a subclass of non-urgent models, the quantitative value problem for two players can be solved in EXPTIME. Indeed, the explicit continuous time enables players to communicate their states by delaying synchronisation (which is unrestricted for non-urgent models). In general, the problems are undecidable already for two players in the quantitative case and three players in the qualitative case. The qualitative undecidability is shown by a reduction to decentralized POMDPs for which we provide the strongest (and rather surprising) undecidability result so far.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Saarland University
Authors: Hermanns, H. (Ekstern), Krčál, J. (Ekstern), Vester, S. (Intern)
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Dynamic and approximate pattern matching in 2D

We consider dynamic and online variants of 2D pattern matching between an mXm pattern and an nXn text. All the algorithms we give are randomised and give correct outputs with at least constant probability.

- For dynamic 2D exact matching where updates change individual symbols in the text, we show updates can be performed in $O(\log^2 n)$ time and queries in $O(\log^2 m)$ time.
- We then consider a model where an update is a new 2D pattern and a query is a location in the text. For this setting we show that Hamming distance queries can be answered in $O(\log m + H)$ time, where $H$ is the relevant Hamming distance.
- Extending this work to allow approximation, we give an efficient algorithm which returns a $(1+\epsilon)$ approximation of the Hamming distance at a given location in $O(\epsilon^{-2} \log^2 m \log \log n)$ time.

Finally, we consider a different setting inspired by previous work on locality sensitive hashing (LSH). Given a threshold $k$ and after building the 2D text index and receiving a 2D query pattern, we must output a location where the Hamming distance is at most $(1+\epsilon)k$ as long as there exists a location where the Hamming distance is at most $k$.

- For our LSH inspired 2D indexing problem, the text can be preprocessed in $O(n^2(4/3+1/(1+\epsilon)) \log^3 n)$ time into a data structure of size $O(n^2(1+1/(1+\epsilon)))$ with query time $O(n^2(1/(1+\epsilon))m^2)$.

Dynamic Relative Compression, Dynamic Partial Sums, and Substring Concatenation

Given a static reference string $R$ and a source string $S$, a relative compression of $S$ with respect to $R$ is an encoding of $S$ as a sequence of references to substrings of $R$. Relative compression schemes are a classic model of compression and have recently proved very successful for compressing highly-repetitive massive data sets such as genomes and web-data. We initiate the study of relative compression in a dynamic setting where the compressed source string $S$ is subject to edit operations. The goal is to maintain the compressed representation compactly, while supporting edits and allowing efficient random access to the (uncompressed) source string. We present new data structures that achieve optimal time for updates and queries while using space linear in the size of the optimal relative compression, for nearly all combinations of parameters. We also present solutions for restricted and extended sets of updates. To achieve these results, we revisit the dynamic partial sums problem and the substring concatenation problem. We present new optimal or near optimal bounds for these problems. Plugging in our new results we also immediately obtain new bounds for the string indexing for patterns with wildcards problem and the dynamic text and static pattern matching problem.
Edge-partitioning graphs into regular and locally irregular components

A graph is locally irregular if every two adjacent vertices have distinct degrees. Recently, Baudon et al. introduced the notion of decomposition into locally irregular subgraphs. They conjectured that for almost every graph $G$, there exists a minimum integer $\chi'_{irr}(G)$ such that $G$ admits an edge-partition into $\chi'_{irr}(G)$ classes, each of which induces a locally irregular graph. In particular, they conjectured that $\chi'_{irr}(G) \leq 3$ for every $G$, unless $G$ belongs to a well-characterized family of non-decomposable graphs. This conjecture is far from being settled, as notably (1) no constant upper bound on $\chi'_{irr}(G)$ is known for $G$ bipartite, and (2) no satisfactory general upper bound on $\chi'_{irr}(G)$ is known. We herein investigate the consequences on this question of allowing a decomposition to include regular components as well. As a main result, we prove that every bipartite graph admits such a decomposition into at most 6 subgraphs. This result implies that every graph $G$ admits a decomposition into at most $6(\lceil \log \chi(G) \rceil + 1)$ subgraphs whose components are regular or locally irregular.
Grammar-based compression, where one replaces a long string by a small context-free grammar that generates the string, is a simple and powerful paradigm that captures many popular compression schemes. Given a grammar, the random access problem is to compactly represent the grammar while supporting random access, that is, given a position in the original uncompressed string report the character at that position. In this paper we study the random access problem with the finger search property, that is, the time for a random access query should depend on the distance between a specified index \( f \) called the finger, and the query index \( i \). We consider both a static variant, where we first place a finger and subsequently access indices near the finger efficiently, and a dynamic variant where also moving the finger such that the time depends on the distance moved is supported.

Let \( n \) be the size the grammar, and let \( N \) be the size of the string. For the static variant we give a linear space representation that supports placing the finger in \( O(\log(N)) \) time and subsequently accessing in \( O(\log(D)) \) time, where \( D \) is the distance between the finger and the accessed index. For the dynamic variant we give a linear space representation that supports placing the finger in \( O(\log(N)) \) time and accessing and moving the finger in \( O(\log(D) + \log(\log(N))) \) time. Compared to the best linear space solution to random access, we improve a \( O(\log(D)) \) query bound to \( O(\log(D)) \) for the static variant and to \( O(\log(D) + \log(\log(N))) \) for the dynamic variant, while maintaining linear space. As an application of our results we obtain an improved solution to the longest common extension problem in grammar compressed strings. To obtain our results, we introduce several new techniques of independent interest, including a novel van Emde Boas style decomposition of grammars.
Formalization of the Resolution Calculus for First-Order Logic

A formalization in Isabelle/HOL of the resolution calculus for first-order logic is presented. Its soundness and completeness are formally proven using the substitution lemma, semantic trees, Herbrand’s theorem, and the lifting lemma. In contrast to previous formalizations of resolution, it considers first-order logic with full first-order terms, instead of the propositional case.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Schlichtkrull, A. (Intern)
Pages: 341-357
Publication date: 2016

Game-based verification and synthesis

Infinite-duration games provide a convenient way to model distributed, reactive and open systems in which several entities and an uncontrollable environment interact. Here, each entity as well as the uncontrollable environment are modelled as players.
A strategy for an entity player in the model corresponds directly to a program for the corresponding entity of the system. A strategy for a player which ensures that the player wins no matter how the other players behave then corresponds to a program ensuring that the specification of the entity is satisfied no matter how the other entities and the environment behaves. Synthesis of strategies in games can thus be used for automatic generation of correct-by-construction programs from specifications.

We consider verification and synthesis problems for several well-known game-based models. This includes both model-checking problems and satisfiability problems for logics capable of expressing strategic abilities of players in games with both qualitative and quantitative objectives.

A number of computational complexity results for model-checking and satisfiability problems in this domain are obtained. We also show how the technique of symmetry reduction can be extended to solve finitely-branching turn-based games more efficiently. Further, the novel concept of winning cores in parity games is introduced. We use this to develop a new polynomial-time under-approximation algorithm for solving parity games. Experimental results show that this algorithm performs better than the state-of-the-art algorithms in most benchmark games.

Two new game-based modelling formalisms for distributed systems are presented. The first makes it possible to reason about systems where several identical entities interact. The second provides a game-based modelling formalism for distributed systems with continuous time and probability distributions over the duration of delays. For these new models we provide decidability and undecidability results for problems concerning computation of symmetric Nash equilibria and for deciding existence of strategies that ensure reaching a target with a high probability.

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Authors: Vester, S. (Intern), Hansen, M. R. (Intern)
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Electronic versions: phd414_Vester_S.pdf

Relations
Projects:
Game-based verification and synthesis
Publication: Research › Ph.D. thesis – Annual report year: 2016

Graph Decompositions
The topic of this PhD thesis is graph decompositions. While there exist various kinds of decompositions, this thesis focuses on three problems concerning edgedecompositions. Given a family of graphs H we ask the following question: When can the edge-set of a graph be partitioned so that each part induces a subgraph isomorphic to a member of H? Such a decomposition is called an H-decomposition. Apart from the existence of an H-decomposition, we are also interested in the number of parts needed in an H-decomposition.

Firstly, we show that for every tree T there exists a constant k(T) such that every k(T)-edge-connected graph whose size is divisible by the size of T admits a T-decomposition. This proves a conjecture by Barát and Thomassen from 2006.

Moreover, we introduce a new arboricity notion where we restrict the diameter of the trees in a decomposition into forests. We conjecture that for every natural number k there exists a natural number d(k) such that the following holds: If G can be decomposed into k forests, then G can be decomposed into k + 1 forests in which each tree has diameter at most d(k). We verify this conjecture for k ≤ 3. As an application we show that every 6-edge-connected planar graph contains two edge-disjoint 18/19-thin spanning trees.

Finally, we make progress on a conjecture by Baudon, Bensmail, Przybyło, and Wozniak stating that if a graph can be
decomposed into locally irregular graphs, then there exists such a decomposition with at most 3 parts. We show that this conjecture is true if the number 3 is replaced by 328, establishing the first constant upper bound for this problem.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Merker, M. (Intern), Thomassen, C. (Intern)
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**Relations**

Projects:

- Graph Decompositions

**Group-colouring, group-connectivity, claw-decompositions, and orientations in 5-edge-connected planar graphs**

Let \( G \) be a graph, let \( \Gamma \) be an Abelian group with identity \( 0_{\Gamma} \), and, for each vertex \( v \) of \( G \), let \( p(v) \) be a prescription such that

\[
\sum_{v \in V(G)} p(v) = 0_{\Gamma}.
\]

A \((\Gamma, p)\)-flow consists of an orientation \( D \) of \( G \) and, for each edge \( e \) of \( G \), a label \( f(e) \) in \( \Gamma \setminus \{0_{\Gamma}\} \) such that, for each vertex \( v \) of \( G \),

\[
\sum_{e \text{ points in to } v} f(e) - \sum_{e \text{ points out from } v} f(e) = p(v)
\]

If such an orientation \( D \) and labelling \( f \) exists for all such \( p \), then \( G \) is \( \Gamma \)-connected.

Our main result is that if \( G \) is a 5-edge-connected planar graph and \( |\Gamma| \geq 3 \), then \( G \) is \( \Gamma \)-connected. This is equivalent to a dual colourability statement proved by Lai and Li (2007): planar graphs with girth at least 5 are “\( \Gamma \)-colourable”. Our proof is considerably shorter than theirs. Moreover, the \( \Gamma \)-colourability result of Lai and Li is already a consequence of Thomassen’s (2003) 3-list-colour proof for planar graphs of girth at least 5.

Our theorem (as well as the girth 5 colourability result) easily implies that every 5-edge-connected planar graph for which \(|E(G)|\) is a multiple of 3 has a claw decomposition, resolving a question of Barát and Thomassen. It also easily implies the dual of Grötzsch’s Theorem, that every planar graph without 1- or 3-cut has a 3-flow; this is equivalent to Grötzsch’s Theorem.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Waterloo
Authors: Richter, R. B. (Ekstern), Thomassen, C. (Intern), Younger, D. H. (Ekstern)
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Ecole Polytechnique
Authors: Doerr, B. (Ekstern), Witt, C. (Intern)
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Main Research Area: Technical/natural sciences

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Volume: 75
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ISSN (Print): 0178-4617
Ratings:
BFI (2018): BFI-level 2
One of the most famous conjectures in graph theory is Hedetniemi's conjecture stating that the chromatic number of the categorical product of graphs is the minimum of their chromatic numbers. Using a suitable extension of the definition of the categorical product, Zhu proposed in 1992 a similar conjecture for hypergraphs. We prove that Zhu's conjecture is true for the usual Kneser hypergraphs of same rank. It provides to the best of our knowledge the first non-trivial and explicit family of hypergraphs with rank larger than two satisfying this conjecture (the rank two case being Hedetniemi's conjecture). We actually prove a more general result providing a lower bound on the chromatic number of the categorical product of any Kneser hypergraphs as soon as they all have same rank. We derive from it new families of graphs satisfying Hedetniemi's conjecture. The proof of the lower bound relies on the Zp-Tucker lemma.
Categorical product, Kneser graphs and hypergraphs, Hedetniemi's conjecture, Zp-Tucker lemma
How I convinced Isabelle that resolution is complete

Isabelle is a proof assistant, i.e., a computer program that can help its user conduct proofs and check their correctness. In this talk I motivate the use of proof assistants, and I explain how I used Isabelle to prove a logical system, the resolution calculus, sound and complete.

Infinitely connected subgraphs in graphs of uncountable chromatic number

Erdős and Hajnal conjectured in 1966 that every graph of uncountable chromatic number contains a subgraph of infinite connectivity. We prove that every graph of uncountable chromatic number has a subgraph which has uncountable chromatic number and infinite edge-connectivity. We also prove that, if each orientation of a graph G has a vertex of infinite outdegree, then G contains an uncountable subgraph of infinite edge-connectivity.
We prove that any graph $G$ of minimum degree greater than $2k - 1$ has a $(k + 1)$-connected induced subgraph $H$ such that the number of vertices of $H$ that have neighbors outside of $H$ is at most $2k - 1$. This generalizes a classical result of Mader, which states that a high minimum degree implies the existence of a highly connected subgraph. We give several variants of our result, and for each of these variants, we give asymptotics for the bounds. We also compute optimal values for the case when $k = 2$. Alon, Kleitman, Saks, Seymour, and Thomassen proved that in a graph of high chromatic number, there exists an induced subgraph of high connectivity and high chromatic number. We give a new proof of this theorem with a better bound.

**Isolating highly connected induced subgraphs**

We prove that any graph $G$ of minimum degree greater than $2k - 1$ has a $(k + 1)$-connected induced subgraph $H$ such that the number of vertices of $H$ that have neighbors outside of $H$ is at most $2k - 1$. This generalizes a classical result of Mader, which states that a high minimum degree implies the existence of a highly connected subgraph. We give several variants of our result, and for each of these variants, we give asymptotics for the bounds. We also compute optimal values for the case when $k = 2$. Alon, Kleitman, Saks, Seymour, and Thomassen proved that in a graph of high chromatic number, there exists an induced subgraph of high connectivity and high chromatic number. We give a new proof of this theorem with a better bound.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Lyon
Authors: Penev, I. (Intern), Thomasse, S. (Ekstern), Trotignon, N. (Ekstern)
Number of pages: 28
Pages: 592-619
Liftings in Finite Graphs and Linkages in Infinite Graphs with Prescribed Edge-Connectivity

Let G be a graph and let s be a vertex of G. We consider the structure of the set of all lifts of two edges incident with s that preserve edge-connectivity. Mader proved that two mild hypotheses imply there is at least one pair that lifts, while Frank showed (with the same hypotheses) that there are at least \((\deg(s) - 1)/2\) disjoint pairs that lift. We consider the lifting...
graph: its vertices are the edges incident with s, two being adjacent if they form a liftable pair. We have three main results, the first two with the same hypotheses as for Mader’s Theorem.

(i) Let F be a subset of the edges incident with s. We show that F is independent in the lifting graph of G if and only if there is a single edge-cut C in G of size at most r + 1 containing all the edges in F, where r is the maximum number of edge-disjoint paths from a vertex (not s) in one component of G - C to a vertex (not s) in another component of G - C.

(ii) In the k-lifting graph, two edges incident with s are adjacent if their lifting leaves the resulting graph with the property that any two vertices different from s are joined by k pairwise edge-disjoint paths. If both deg(s) and k are even, then the k-lifting graph is a connected complete multipartite graph. In all other cases, there are at most two components. If there are exactly two components, then each component is a complete multipartite graph. If deg(s) is odd and there are two components, then one component is a single vertex.

(iii) Huck proved that if k is odd and G is (k+1)-edge-connected, then G is weakly k-linked (that is, for any k pairs \(x_i, y_i\), there are k edge-disjoint paths \(P_i\) with \(P_i\) joining \(x_i\) and \(y_i\)). We use our results to extend a slight weakening of Huck’s theorem to some infinite graphs: if k is odd, every (k + 2)-edge-connected, locally finite, 1-ended, infinite graph is weakly k-linked.

General information
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Authors: Ok, S. (Intern), Richter, R. B. (Ekstern), Thomassen, C. (Intern)
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Scopus rating (2012): SJR 0.528 SNIP 0.999 CiteScore 0.57
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.665 SNIP 0.645 CiteScore 0.49
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.729 SNIP 0.743
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.102 SNIP 1.27
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.874 SNIP 1.313
Scopus rating (2007): SJR 0.784 SNIP 0.996
Scopus rating (2006): SJR 0.469 SNIP 0.966
Web of Science (2006): Indexed yes
Locating Depots for Capacitated Vehicle Routing

We study a location-routing problem in the context of capacitated vehicle routing. The input to the k-location capacitated vehicle routing problem (k-LocVRP) consists of a set of demand locations in a metric space and a fleet of k identical vehicles, each of capacity Q. The objective is to locate k depots, one for each vehicle, and compute routes for the vehicles so that all demands are satisfied and the total cost is minimized. Our main result is a constant-factor approximation algorithm for k-LocVRP. In obtaining this result, we introduce a common generalization of the k-median and minimum spanning tree problems (called k median forest), which might be of independent interest. We give a local-search based (3+ε)-approximation algorithm for k median forest, which leads to a (12+ε)-approximation algorithm for k-LocVRP, for any constant ε > 0.
The longest common extension (LCE) of two indices in a string is the length of the longest identical substrings starting at these two indices. The LCE problem asks to preprocess a string into a compact data structure that supports fast LCE queries.

In this paper we generalize the LCE problem to trees and suggest a few applications of LCE in trees to tries and XML databases. Given a labeled and rooted tree $T$ of size $n$, the goal is to preprocess $T$ into a compact data structure that supports the following LCE queries between subpaths and subtrees in $T$. Let $v_1$, $v_2$, $w_1$, and $w_2$ be nodes of $T$ such that $w_1$ and $w_2$ are descendants of $v_1$ and $v_2$ respectively.

- **LCEPP**($v_1$, $w_1$, $v_2$, $w_2$): (path-path LCE) return the longest common prefix of the paths $v_1 \rightarrow w_1$ and $v_2 \rightarrow w_2$.

- **LCEPT**($v_1$, $w_1$, $v_2$): (path-tree LCE) return maximal path-path LCE of the path $v_1 \rightarrow w_1$ and any path from $v_2$ to a descendant leaf.

- **LCETT**($v_1$, $v_2$): (tree-tree LCE) return a maximal path-path LCE of any pair of paths from $v_1$ and $v_2$ to descendant leaves.

We present the first non-trivial bounds for supporting these queries. For LCEPP queries, we present a linear-space solution with $O(\log^* n)$ query time. For LCEPT queries, we present a linear-space solution with $O((\log \log n)^2)$ query time, and complement this with a lower bound showing that any path-tree LCE structure of size $O(n \polylog(n))$ must necessarily use $O(\log \log n)$ time to answer queries. For LCETT queries, we present a time-space trade-off, that given any parameter $\tau$, $1 \leq \tau \leq n$, leads to an $O(n^\tau)$ space and $O(n/\tau)$ query-time solution. This is complemented with a reduction to the set intersection problem implying that a fast linear space solution is not likely to exist.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Warsaw, University of Haifa
Authors: Bille, P. (Intern), Gawrychowski, P. (Ekstern), Gertz, I. L. (Intern), Landau, G. M. (Ekstern), Weimann, O. (Ekstern)
Pages: 98-107
Maximal unbordered factors of random strings

A border of a string is a non-empty prefix of the string that is also a suffix of the string, and a string is unbordered if it has no border. Loptev, Kucherov, and Starikovskaya [CPM 2015] conjectured the following: If we pick a string of length $n$ from a fixed alphabet uniformly at random, then the expected length of the maximal unbordered factor is $n - O(1)$. We prove that this conjecture is true by proving that the expected value is in fact $n - \Theta(\sigma^{-1})$, where $\sigma$ is the size of the alphabet. We discuss some of the consequences of this theorem.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen
Authors: Cording, P. H. (Intern), Knudsen, M. B. T. (Ekstern)
Pages: 93-96
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Nash-Williams' cycle-decomposition theorem
We give an elementary proof of the theorem of Nash-Williams that a graph has an edge-decomposition into cycles if and only if it does not contain an odd cut. We also prove that every bridgeless graph has a collection of cycles covering each edge at least once and at most 7 times. The two results are equivalent in the sense that each can be derived from the other.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Thomassen, C. (Intern)
Number of pages: 11
Publication date: 2016
Main Research Area: Technical/natural sciences
On the Relationship between a Computational Natural Logic and Natural Language

This paper makes a case for adopting appropriate forms of natural logic as target language for computational reasoning with descriptive natural language. Natural logics are stylized fragments of natural language where reasoning can be conducted directly by natural reasoning rules reflecting intuitive reasoning in natural language. The approach taken in this paper is to extend natural logic stepwise with a view to covering successively larger parts of natural language. We envisage applications for computational querying and reasoning, in particular within the life-sciences.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Roskilde University, Copenhagen Business School
Pages: 335-342
Publication date: 2016

Optimal mutation rates for the (1+\lambda) EA on OneMax

We study the (1 + \lambda) EA with mutation probability \( c/n \), where \( c > 0 \) is a constant, on the ONEMAX problem. Using an improved variable drift theorem, we show that upper and lower bounds on the expected runtime of the (1+\lambda) EA obtained from variable drift theorems are at most apart by a small lower order term if the exact drift is known. This reduces the analysis of expected optimization time to finding an exact expression for the drift.

We then give an exact closed-form expression for the drift and develop a method to approximate it very efficiently, enabling us to determine approximate optimal mutation rates for the (1+\lambda) EA for various parameter settings of \( c \) and \( \lambda \) and also for moderate sizes of \( n \). This makes the need for potentially lengthy and costly experiments in order to optimize the parameters unnecessary.

Interestingly, even for moderate \( n \) and not too small \( \lambda \) it turns out that mutation rates up to 10% larger than the asymptotically optimal rate \( 1/n \) minimize the expected runtime. However, in absolute terms the expected runtime does not change by much when replacing \( 1/n \) with the optimal mutation rate.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Gießen, C. (Intern), Witt, C. (Intern)
Pages: 1147-1154
Publication date: 2016
Orientations of infinite graphs with prescribed edge-connectivity

We prove a decomposition result for locally finite graphs which can be used to extend results on edge-connectivity from finite to infinite graphs. It implies that every 4k-edge-connected graph G contains an immersion of some finite 2k-edge-connected Eulerian graph containing any prescribed vertex set (while planar graphs show that G need not contain a subdivision of a simple finite graph of large edge-connectivity). Also, every 8k-edge connected infinite graph has a k-arc-connected orientation, as conjectured in 1989.
Paraconsistency

Paraconsistency is about handling inconsistency in a coherent way. In classical and intuitionistic logic everything follows from an inconsistent theory. A paraconsistent logic avoids the explosion. Quite a few applications in computer science and engineering are discussed in the Intelligent Systems Reference Library Volume 110: Towards Paraconsistent Engineering (Springer 2016). We formalize a paraconsistent many-valued logic that we motivated and described in a special issue on logical approaches to paraconsistency (Journal of Applied Non-Classical Logics 2005). We limit ourselves to the propositional fragment of the higher-order logic. The logic is based on so-called key equalities and has a countably infinite number of truth values. We prove theorems in the logic using the definition of validity. We verify truth tables and also counterexamples for non-theorems. We prove meta-theorems about the logic and finally we investigate a case study.

Parallel Lookups in String Indexes

Recently, the first PRAM algorithms were presented for looking up a pattern in a suffix tree. We improve the bounds, achieving optimal results.

General information
Today we have software in many artefacts, from medical devices to cars and airplanes, and the software must not only be efficient and intelligent but also reliable and secure. Tests can show the presence of bugs but cannot guarantee their absence. A machine-checked proof using mathematical logic provides strong evidence for software correctness but it is requires advanced knowledge and skills. We have developed a tool which helps the student to practice their skills and also allows a better conceptual understanding of state-of-the-art proof assistants. Previously the proofs has been carried out using pen and paper because no adequate tool was available. The learning problem is how to make abstract concepts of logic as concrete as possible.

ProofJudge is a computer system and teaching approach for teaching mathematical logic and automated reasoning which augments the e-learning tool NaDeA (Natural Deduction Assistant). We believe that automatic feedback on student assignments would allow the students to enhance their skill in natural deduction proofs which are fundamental in formal verification and artificial intelligence applications. The teachers will benefit too and can put more emphasis on the semantics. Natural deduction is taught at most if not all universities but few tools exist. Initially we plan to have former students on the course to evaluate ProofJudge and later it will be employed in the course.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Algorithms and Logic
Authors: Christiansen, A. R. (Intern), Farach-Colton, M. (Ekstern)
Pages: 61-67
Publication date: 2016
Robustness of Populations in Stochastic Environments

We consider stochastic versions of OneMax and LeadingOnes and analyze the performance of evolutionary algorithms with and without populations on these problems. It is known that the (1+1) EA on OneMax performs well in the presence of very small noise, but poorly for higher noise levels. We extend these results to LeadingOnes and to many different noise models, showing how the application of drift theory can significantly simplify and generalize previous analyses. Most surprisingly, even small populations (of size $O(\log n)$) can make evolutionary algorithms perform well for high noise levels, well outside the abilities of the (1+1) EA. Larger population sizes are even more beneficial; we consider both parent and offspring populations. In this sense, populations are robust in these stochastic settings.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Friedrich-Schiller-Universität Jena
Authors: Gießen, C. (Intern), Kötzing, T. (Ekstern)
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Web of Science (2018): Indexed yes
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.11 SJR 0.648 SNIP 1.184
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.739 SNIP 1.16 CiteScore 1.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.854 SNIP 1.197 CiteScore 1.2
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.952 SNIP 1.395 CiteScore 1.26
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.836 SNIP 1.204 CiteScore 0.99
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.848 SNIP 1.184 CiteScore 0.91
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.904 SNIP 1.317
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.95 SNIP 1.351
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.129 SNIP 1.218
Running a Prover in a Prover - Isabelle as a Meta-Logic
Isabelle provides a foundation of mathematics and I show how you can run your own verified prover directly in the Isabelle prover or as a stand-alone program. I describe the formalization of syntax and semantics and discuss the proof of soundness and completeness for a simple prover for first-order logic.

Sparse Text Indexing in Small Space
In this work, we present efficient algorithms for constructing sparse suffix trees, sparse suffix arrays, and sparse position heaps for b arbitrary positions of a text T of length n while using only O(b) words of space during the construction. Attempts at breaking the naïve bound of Ω(nb) time for constructing sparse suffix trees in O(b) space can be traced back to the origins of string indexing in 1968. First results were not obtained until 1996, but only for the case in which the b suffixes were evenly spaced in T. In this article, there is no constraint on the locations of the suffixes. Our main contribution is to show that the sparse suffix tree (and array) can be constructed in O(nlog 2b) time. To achieve this, we develop a technique that allows one to efficiently answer b longest common prefix queries on suffixes of T, using only O(b)
space. We expect that this technique will prove useful in many other applications in which space usage is a concern. Our first solution is Monte Carlo, and outputs the correct tree with high probability. We then give a Las Vegas algorithm, which also uses $O(b)$ space and runs in the same time bounds with high probability when $b = O(\sqrt{n})$. Additional trade-offs between space usage and construction time for the Monte Carlo algorithm are given. Finally, we show that, at the expense of slower pattern queries, it is possible to construct sparse position heaps in $O(n + \log b)$ time and $O(b)$ space.

**General information**

State: Published

Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technische Universität Dortmund, Weizmann Institute of Science, University of Bristol

Authors: Bille, P. (Intern), Fischer, J. (Ekstern), Gørtz, I. L. (Intern), Kopelowitz, T. (Ekstern), Sach, B. (Ekstern), Vildhøj, H. W. (Intern)

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Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2

Scopus rating (2016): SJR 1.32 SNIP 1.951 CiteScore 2.1

Web of Science (2016): Indexed yes

BFI (2015): BFI-level 2

Scopus rating (2015): SJR 1.443 SNIP 1.77 CiteScore 1.94

Web of Science (2015): Indexed yes

BFI (2014): BFI-level 2

Scopus rating (2014): SJR 1.325 SNIP 1.471 CiteScore 1.61

Web of Science (2014): Indexed yes

BFI (2013): BFI-level 2

Scopus rating (2013): SJR 1.148 SNIP 1.334 CiteScore 1.4

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): SJR 1.072 SNIP 1.296 CiteScore 1.21

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): SJR 1.015 SNIP 1.164 CiteScore 1.11

ISI indexed (2011): ISI indexed no

BFI (2010): BFI-level 2

Scopus rating (2010): SJR 1.224 SNIP 1.771

BFI (2009): BFI-level 2

Scopus rating (2009): SJR 1.443 SNIP 1.752

Web of Science (2009): Indexed yes

BFI (2008): BFI-level 1

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Scopus rating (2007): SJR 0.721 SNIP 1.549

Scopus rating (2006): SNIP 1.159 SJR 0.496

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paper_5.pdf
Subsequence Automata with Default Transitions

Let $S$ be a string of length $n$ with characters from an alphabet of size $\sigma$. The subsequence automaton of $S$ (often called the directed acyclic subsequence graph) is the minimal deterministic finite automaton accepting all subsequences of $S$. A straightforward construction shows that the size (number of states and transitions) of the subsequence automaton is $O(n\sigma)$ and that this bound is asymptotically optimal. In this paper, we consider subsequence automata with default transitions, that is, special transitions to be taken only if none of the regular transitions match the current character, and which do not consume the current character. We show that with default transitions, much smaller subsequence automata are possible, and provide a full trade-off between the size of the automaton and the delay, i.e., the maximum number of consecutive default transitions followed before consuming a character. Specifically, given any integer parameter $k$, $1 < k \leq \sigma$, we present a subsequence automaton with default transitions of size $O(nk\log_k \sigma)$ and delay $O(\log_k \sigma)$. Hence, with $k = 2$ we obtain an automaton of size $O(n\log \sigma)$ and delay $O(\log \sigma)$. On the other extreme, with $k = \sigma$, we obtain an automaton of size $O(n\sigma)$ and delay $O(1)$, thus matching the bound for the standard subsequence automaton construction. The key component of our result is a novel hierarchical automata construction of independent interest.

Synthetic Completeness Proofs for Seligman-style Tableau Systems

Hybrid logic is a form of modal logic which allows reference to worlds. We can think of it as ‘modal logic with labelling built into the object language’ and various forms of labelled deduction have played a central role in its proof theory. Jerry Seligman’s work [11,12] in which ‘rules involving labels’ are rejected in favour of ‘rules for all’ is an interesting exception to this. Seligman’s approach was originally for natural deduction; the authors of the present paper recently extended it to tableau inference [1,2]. Our earlier work was syntactic: we showed completeness by translating between Seligman-style and labelled tableaus, but our results only covered the minimal hybrid logic; in the present paper we provide completeness results for a wider range of hybrid logics and languages. We do so by adapting the synthetic approach to tableau completeness (due to Smullyan, and widely applied in modal logic by Fitting) so that we can directly build maximal...
consistent sets of tableau blocks.

The 3-flow conjecture, factors modulo k, and the 1-2-3-conjecture

Let k be an odd natural number ≥5, and let G be a (6k−7)-edge-connected graph of bipartite index at least k−1. Then, for each mapping f:V(G)→N, G has a subgraph H such that each vertex v has H-degree f(v) modulo k. We apply this to prove that, if c:V(G)→Zk is a proper vertex-coloring of a graph G of chromatic number k≥5 or k−1≥6, then each edge of G can be assigned a weight 1 or 2 such that each weighted vertex-degree of G is congruent to c modulo k. Consequently, each nonbipartite (6k−7)-edge-connected graph of chromatic number at most k (where k is any odd natural number ≥3) has an edge-weighting with weights 1,2 such that neighboring vertices have distinct weighted degrees (even after reducing these weighted degrees modulo k). We characterize completely the bipartite graph having an edge-weighting with weights 1,2 such that neighboring vertices have distinct weighted degrees. In particular, that problem belongs to P while it is NP-complete for nonbipartite graphs. The characterization also implies that every 3-edge-connected bipartite graph with at least 3 vertices has such an edge-labeling, and so does every simple bipartite graph of minimum degree at least 3.
The complexity of deciding whether a graph admits an orientation with fixed weak diameter

An oriented graph $G$ is said weak (resp. strong) if, for every pair $\{u,v\}$ of vertices of $G$, there are directed paths joining $u$ and $v$ in either direction (resp. both directions). In case, for every pair of vertices, some of these directed paths have length at most $k$, we call $G$ $k$-weak (resp. $k$-strong). We consider several problems asking whether an undirected graph $G$ admits orientations satisfying some connectivity and distance properties. As a main result, we show that deciding whether $G$ admits a $k$-weak orientation is NP-complete for every $k \geq 2$. This notably implies the NP-completeness of several problems asking whether $G$ is an extremal graph (in terms of needed colours) for some vertex-colouring problems.
The impact of migration topology on the runtime of island models in dynamic optimization

We introduce a simplified island model with behavior similar to the $\lambda (1+1)$ islands optimizing the Maze fitness function, and investigate the effects of the migration topology on the ability of the simplified island model to track the optimum of a dynamic fitness function. More specifically, we prove that there exist choices of model parameters for which using a unidirectional ring as the migration topology allows the model to track the oscillating optimum through $n$ Mazelike phases with high probability, while using a complete graph as the migration topology results in the island model losing track of the optimum with overwhelming probability. Additionally, we prove that if migration occurs only rarely, denser migration topologies may be advantageous. This serves to illustrate that while a less-dense migration topology may be useful when optimizing dynamic functions with oscillating behavior, and requires less problem-specific knowledge to determine when migration may be allowed to occur, care must be taken to ensure that a sufficient amount of migration occurs during the optimization process.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Sheffield
Authors: Lissovoi, A. (Ekstern), Witt, C. (Intern)
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The power of two choices with simple tabulation

The power of two choices is a classic paradigm for load balancing when assigning $m$ balls to $n$ bins. When placing a ball, we pick two bins according to two hash functions $h_0$ and $h_1$, and place the ball in the least loaded bin. Assuming fully random hash functions, when $m = O(n)$, Azar et al. [STOC'94] proved that the maximum load is $\lceil \log n \rceil + O(1)$ with high probability. No such bound was known with a hash function implementable in constant time. In this paper, we investigate the power of two choices when the hash functions $h_0$ and $h_1$ are implemented with simple tabulation, which is a very efficient hash function evaluated in constant time. Following their analysis of Cuckoo hashing [J.ACM'12], Pǎtraşcu and Thorup claimed that the expected maximum load with simple tabulation is $O(\log n)$. This did not include any high probability guarantee, so the load balancing was not yet to be trusted. Here, we show that with simple tabulation, the maximum load is $O(\log n)$ with high probability, giving the first constant time hash function with this guarantee. We also give a concrete example where, unlike with fully random hashing, the maximum load is not bounded by $\lceil \log n \rceil + O(1)$, or even $(1 + o(1)) \lceil \log n \rceil$ with high probability. Finally, we show that the expected maximum load is $\lceil \log n \rceil + O(1)$, just like with fully random hashing.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen
Authors: Dahlgaard, S. (Ekstern), Knudsen, M. B. T. (Ekstern), Rotenberg, E. (Intern), Thorup, M. (Ekstern)
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Main Research Area: Technical/natural sciences
The Resolution Calculus for First-Order Logic
This theory is a formalization of the resolution calculus for first-order logic. It is proven sound and complete. The soundness proof uses the substitution lemma, which shows a correspondence between substitutions and updates to an environment. The completeness proof uses semantic trees, i.e., trees whose paths are partial Herbrand interpretations. It employs Herbrand’s theorem in a formulation which states that an unsatisfiable set of clauses has a finite closed semantic tree. It also uses the lifting lemma which lifts resolution derivation steps from the ground world up to the first-order world. The theory is presented in a paper at the International Conference on Interactive Theorem Proving [7] and an earlier version in an MSc thesis [6]. It mostly follows textbooks by Ben-Ari [1], Chang and Lee [3], and Leitsch [4]. The theory is part of the IsaFoL project [2].

Update Strength in EDAs and ACO: How to Avoid Genetic Drift
We provide a rigorous runtime analysis concerning the update strength, a vital parameter in probabilistic model-building GAs such as the step size 1/K in the compact Genetic Algorithm (cGA) and the evaporation factor ρ in ACO. While a large update strength is desirable for exploitation, there is a general trade-off: too strong updates can lead to genetic drift and poor performance. We demonstrate this trade-off for the cGA and a simple MMAS ACO algorithm on the OneMax function. More precisely, we obtain lower bounds on the expected runtime of Ω(K√n + n log n) and Ω(√n/ρ + n log n), respectively, showing that the update strength should be limited to 1/K, ρ = O(1/√n log n). In fact, choosing 1/K, ρ ∼ 1/(√n log n) both algorithms efficiently optimize OneMax in expected time O(n log n). Our analyses provide new insights into the stochastic behavior of probabilistic model-building GAs and propose new guidelines for setting the update strength in global optimization.
Verification of an LCF-Style First-Order Prover with Equality

We formalize in Isabelle/HOL the kernel of an LCF-style prover for first-order logic with equality from John Harrison’s Handbook of Practical Logic and Automated Reasoning. We prove the kernel sound and generate Standard ML code from the formalization. The generated code can then serve as a verified kernel. By doing this we also obtain verified components such as derived rules, a tableau prover, tactics, and a small declarative interactive theorem prover. We test that the kernel and the components give the same results as Harrison’s original on all the examples from his book. The formalization is 600 lines and is available online.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Jensen, A. B. (Intern), Schlichtkrull, A. (Intern), Villadsen, J. (Intern)
Number of pages: 15
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Isabelle/HOL, Verification, First-order logic, Equality, Soundness, LCF-style prover, OCaml, Code generation, Standard ML (SML), Isabelle/ML
Electronic versions:
Isabelle2016_10.pdf
Links:
http://www21.in.tum.de/~nipkow/Isabelle2016/
Source: PublicationPreSubmission
Source-ID: 127746966
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Winning Cores in Parity Games

We introduce the novel notion of winning cores in parity games and develop a deterministic polynomial-time under-approximation algorithm for solving parity games based on winning core approximation. Underlying this algorithm are a number properties about winning cores which are interesting in their own right. In particular, we show that the winning core and the winning region for a player in a parity game are equivalently empty. Moreover, the winning core contains all fatal attractors but is not necessarily a dominion itself. Experimental results are very positive both with respect to quality of approximation and running time. It outperforms existing state-of-the-art algorithms significantly on most benchmarks.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Vester, S. (Intern)
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Parity Games, Winning Cores, Algorithms, Computational Complexity
DOIs:
10.1145/2933575.2933589
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016
**Hashing for Statistics over K-Partitions**

In this paper we analyze a hash function for k-partitioning a set into bins, obtaining strong concentration bounds for standard algorithms combining statistics from each bin. This generic method was originally introduced by Flajolet and Martin [FOCS'83] in order to save a factor $\Omega(k)$ of time per element over k independent samples when estimating the number of distinct elements in a data stream. It was also used in the widely used Hyper Log Log algorithm of Flajolet et al. [AOFAC'97] and in large-scale machine learning by Li et al. [NIPS'12] for minwise estimation of set similarity. The main issue of k-partition, is that the contents of different bins may be highly correlated when using popular hash functions. This means that methods of analyzing the marginal distribution for a single bin do not apply. Here we show that a tabulation based hash function, mixed tabulation, does yield strong concentration bounds on the most popular applications of k-partitioning similar to those we would get using a truly random hash function. The analysis is very involved and implies several new results of independent interest for both simple and double tabulation, e.g. A simple and efficient construction for invertible bloom filters and uniform hashing on a given set.

**General information**

State: Published  
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen  
Authors: Dahlgaard, S. (Ekstern), Knudsen, M. B. T. (Ekstern), Rotenberg, E. (Intern), Thorup, M. (Ekstern)  
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**Planar Reachability in Linear Space and Constant Time**

We show how to represent a planar digraph in linear space so that reach ability queries can be answered in constant time. The data structure can be constructed in linear time. This representation of reach ability is thus optimal in both time and space, and has optimal construction time. The previous best solution used $O(n \log n)$ space for constant query time [Thorup FOCS'01].

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen  
Authors: Holm, J. (Ekstern), Rotenberg, E. (Intern), Thorup, M. (Ekstern)  
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Main Research Area: Technical/natural sciences
Dynamic planar embeddings of dynamic graphs

We present an algorithm to support the dynamic embedding in the plane of a dynamic graph. An edge can be inserted across a face between two vertices on the boundary (we call such a vertex pair linkable), and edges can be deleted. The planar embedding can also be changed locally by flipping components that are connected to the rest of the graph by at most two vertices. Given vertices u, v, linkable(u, v) decides whether u and v are linkable, and if so, returns a list of suggestions for the placement of (u, v) in the embedding. For non-linkable vertices u, v, we define a new query, one-flip-linkable(u, v) providing a suggestion for a flip that will make them linkable if one exists. We will support all updates and queries in O(log^2 n) time. Our time bounds match those of Italiano et al. for a static (flipless) embedding of a dynamic graph. Our new algorithm is simpler, exploiting that the complement of a spanning tree of a connected plane graph is a spanning tree of the dual graph. The primal and dual trees are interpreted as having the same Euler tour, and a main idea of the new algorithm is an elegant interaction between top trees over the two trees via their common Euler tour.

(1+1) EA on Generalized Dynamic OneMax

Evolutionary algorithms (EAs) perform well in settings involving uncertainty, including settings with stochastic or dynamic fitness functions. In this paper, we analyze the (1+1) EA on dynamically changing OneMax, as introduced by Droste (2003). We re-prove the known results on first hitting times using the modern tool of drift analysis. We extend these results to search spaces which allow for more than two values per dimension.

Furthermore, we make an anytime analysis as suggested by Jansen and Zarges (2014), analyzing how closely the (1+1) EA can track the dynamically moving optimum over time. We get tight bounds both for the case of bit strings, as well as for the case of more than two values per position. Surprisingly, in the latter setting, the expected quality of the search point maintained by the (1+1) EA does not depend on the number of values per dimension.
Access, Rank, and Select in Grammar-compressed Strings

Given a string S of length N on a fixed alphabet of σ symbols, a grammar compressor produces a context-free grammar G of size n that generates S and only S. In this paper we describe data structures to support the following operations on a grammar-compressed string: access(S,i,j) (return substring S[i,j]), rank c (S,i) (return the number of occurrences of symbol c before position i in S), and select c (S,i) (return the position of the ith occurrence of c in S). Our main result for access is a method that requires $\mathcal{O}(n\log N)$ bits of space and $\mathcal{O}(\log N + m/\log\sigma N)$ time to extract $m = j-i+1$ consecutive symbols from S. Alternatively, we can achieve $\mathcal{O}(\log N + m/\log\sigma N)$ query time using $\mathcal{O}(nr\log(N/n)\log N)$ bits of space, matching a lower bound stated by Verbin and Yu for strings where N is polynomially related to n when $\tau = \log \epsilon N$. For rank and select we describe data structures of size $\mathcal{O}(n\tau\log N)$ bits that support the two operations in $\mathcal{O}(\log N)$ time. We also extend our other structure to support both operations in $\mathcal{O}(\log N)$ time using $\mathcal{O}(mnr\log(N/n)\log N)$ bits of space. When $\tau = \log \epsilon N$ the query time is $O(\log N/\log\log N)$ and we provide a hardness result showing that significantly improving this would imply a major breakthrough on a hard graph-theoretical problem.
Our results can be divided into two categories. In the first category we study problems related to pattern matching. In particular, we present new algorithms for counting and comparing substrings, and a new algorithm for finding all occurrences of a pattern in which we may insert gaps. In the other category we deal with accessing and decompressing parts of the compressed string. We show how to quickly access a single character of the compressed string, and present a data structure that supports fast decompression of substrings from prespecified positions.

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Algorithms and Data Structures for Strings, Points and Integers: or, Points about Strings and Strings about Points
This dissertation presents our research in the broad area of algorithms and data structures. More specifically, we show solutions for the following problems related to strings, points and integers. Results hold on the Word RAM and we measure space in w-bit words.

Compressed Fingerprints. The Karp-Rabin fingerprint of a string is a useful type of hash value that has multiple applications due to its strong properties. Given a string $S$ of length $N$ compressed into a straight line program (SLP) of size $n$, we show a $O(n)$ space data structure that supports fingerprint queries, retrieving the fingerprint of any substring of $S$. Queries are answered in $O(lg N)$ time. If the compression is a Linear SLP (capturing LZ78 compression and variations), we get $O(lg lg N)$ query time.

Our structure matches the best known query time bound for random access in SLPs, and is the first for general (unbalanced) SLPs that answers fingerprint queries without decompressing any text. We also support longest common extension queries, returning the length $\ell$ that the substrings from two given positions in $S$ are equal. Answers are correct w.h.p. and take time $O(lg N lg \ell)$ and $O(lg lg N + lg \ell lg lg \ell)$ for SLPs and Linear SLPs, respectively.

Dynamic Compression. In the dynamic relative compression scheme, we compress a string $S$ of length $N$ into $n$ substrings of a given reference string of length $r$. We give data structures that maintain an asymptotically optimal compression in the scheme and support access, replace, insert and delete operations on $S$. Our solutions support each operation in $O(lg n/ lg lg n + lg lg r)$ time and $O(n)$ space; or $O(lg n/ lg lg n)$ time and $O(n lg r)$ space. They can be naturally generalized to compress multiple strings.

Our solutions obtain almost-optimal bounds, and are the first to dynamically maintain a string under a compression scheme that can achieve better than entropy compression. We also give improved results for the substring concatenation problem, and an extension of our structure can be used as a black box to get an improved solution to the previously studied dynamic text static pattern problem.

Compressed Pattern Matching. In the streaming model, input data flows past a client one item at a time, but is far too large for the client to store. The annotated streaming model extends the model by introducing a powerful but untrusted annotator (representing “the cloud”) that can annotate input elements with additional information, sent as one-way communication to the client. We generalize the annotated streaming model to be able to solve problems on strings and present a data structure that allows us to trade off client space and annotation size. This lets us exploit the power of the annotator.

In compressed pattern matching we must report occurrences of a pattern of length $m$ in a text compressed into $n$ phrases (capturing LZ78 compression and variations). In the streaming model, any solution to the problem requires $\Omega(n)$ space. We show that the problem can be solved in $O(lg n)$ client space in the annotated streaming model, using $O(lg n)$ time and $O(lg n)$ words of annotation per phrase. Our solution shows that the annotator let us solve previously impossible problems, and it is the first solution to a classic problem from combinatorial pattern matching in the annotated streaming model.

Pattern Extraction. The problem of extracting important patterns from text has many diverse applications such as data mining, intrusion detection and genomic analysis. Consequently, there are many variations of the pattern extraction problem with different notions of patterns and importance measures. We study a natural variation where patterns must 1)
contain at most k don’t cares that each match a single character, and 2) have at least q occurrences. Both k and q are input parameters.
We show how to extract such patterns and their occurrences from a text of length n in $O(nk + k^3 occ)$ time and space, where occ is the total number of pattern occurrences. Our bound is the first output-sensitive solution for any approximate variation of the pattern extraction problem, with all previous solutions requiring $\Omega(n^2)$ time per reported pattern. Our algorithm is relatively simple, but requires a novel analysis technique that amortizes the cost of creating the index over the number of pattern occurrences.

Compressed Point Sets. Orthogonal range searching on a set of points is a classic geometric data structure problem. Given a query range, solutions must either count or report the points inside the range. Variants of this problem has numerous classic solutions, typically storing the points in a tree.
We show that almost any such classic data structure can be compressed without asymptotically increasing the time spent answering queries. This allows us to reduce the required space use if the point set contains geometric repetitions (copies of equal point set that are translated relative to each other). Our result captures most classic data structures, such as Range Trees, KD-trees, R-trees and Quad Trees. We also show a hierarchical clustering algorithm for ensuring that geometric repetitions are compressed.

Points with Colors. Colored orthogonal range searching is a natural generalization of orthogonal range searching which allows us to perform statistic analysis of a point set. We must store n points that each have a color (sometimes called a category) and support queries that either count or report the distinct colors of the points inside a query range.
We show data structures that support both types of queries in sublinear time, storing two-dimensional points in linear space and high-dimensional points in almost-linear space. These are the first (almost) linear space solutions with sublinear query time. We also give the first dynamic solution with sublinear query time for any dimensionality. Previous solutions answer queries faster, but require much more space.

Points with Weights in Practice. If points are each assigned a weight, it is natural to consider the threshold range counting problem. A data structure must store the points and be able to count the number of points within a query range with a weight exceeding some threshold. This query appears naturally in a software system built by Milestone Systems, and allows detecting motion in video from surveillance cameras. We implement a prototype of an index for 3-dimensional points that use little space and answers threshold queries efficiently. In experiments on realistic data sets, our prototype shows a speedup of at least a factor 30 at the expense of 10% additional space use compared to the previous approach. An optimized version of our proposed index is implemented in the latest version of the Milestone Systems software system.

Finger Predecessor. The predecessor problem is to store a set of n integers from a universe of size N to support predecessor queries, returning the largest integer in the set smaller than a given integer q. We study a variation where the query additionally receives a finger to an integer i in the set from which to start the search. We show a linear space data structure that answers such finger predecessor queries in $O(lg lg |\ell - q|)$ time. This generalizes and improves the $O(lg lg N)$ time solutions for the standard predecessor problem. Our data structure is the first with a query time that only depends on the numerical distance between the finger and the query integer.

Dynamic Partial Sums. The well-studied partial sums problem is to store a sequence of n integers with support for sum and search queries. The sequence is static in the sense that its length cannot change, but the update operation can be used to change the value of an integer in the sequence by a given value. There are matching lower and upper bounds showing that the problem can be solved on the w-bit Word RAM in linear space and $_(lg n = lg(w/\delta _n))$ time per operation, where $\delta _n$ is the maximum number of bits allowed in updates. As a natural generalization, we consider dynamic partial sums, allowing insertions and deletions in the sequence. Our solution requires linear space and supports all operations in optimal worst-case time $\Theta(lg n/ lg(w/\delta _n))$, matching lower bounds for all supported operations. Our data structure is the first dynamic partial sums solution that matches the lower bounds, and the first to support storing integers of more than lg w bits.
A suffix tree or not a suffix tree?
In this paper we study the structure of suffix trees. Given an unlabeled tree \( \tau \) on \( n \) nodes and suffix links of its internal nodes, we ask the question “Is \( \tau \) a suffix tree?”, i.e., is there a string \( S \) whose suffix tree has the same topological structure as \( \tau \)? We place no restrictions on \( S \), in particular we do not require that \( S \) ends with a unique symbol. This corresponds to considering the more general definition of implicit or extended suffix trees. Such general suffix trees have many applications and are for example needed to allow efficient updates when suffix trees are built online. Deciding if \( \tau \) is a suffix tree is not an easy task, because, with no restrictions on the final symbol, we cannot guess the length of a string that realizes \( \tau \) from the number of leaves. And without an upper bound on the length of such a string, it is not even clear how to solve the problem by an exhaustive search. In this paper, we prove that \( \tau \) is a suffix tree if and only if it is realized by a string \( S \) of length \( n - 1 \), and we give a linear-time algorithm for inferring \( S \) when the first letter on each edge is known. This generalizes the work of I et al. (2014) [15]. [All rights reserved Elsevier].
A Suffix Tree Or Not a Suffix Tree?
In this paper we study the structure of suffix trees. Given an unlabeled tree $r$ on $n$ nodes and suffix links of its internal nodes, we ask the question “Is $r$ a suffix tree?”, i.e., is there a string $S$ whose suffix tree has the same topological structure as $r$? We place no restrictions on $S$, in particular we do not require that $S$ ends with a unique symbol. This corresponds to considering the more general definition of implicit or extended suffix trees. Such general suffix trees have many applications and are for example needed to allow efficient updates when suffix trees are built online. We prove that $r$ is a suffix tree if and only if it is realized by a string $S$ of length $n - 1$, and we give a linear-time algorithm for inferring $S$ when the first letter on each edge is known. This generalizes the work of I et al.

A System for Conceptual Pathway Finding and Deductive Querying
We describe principles and design of a system for knowledge bases applying a natural logic. Natural logics are forms of logic which appear as stylized fragments of natural language sentences. Accordingly, such knowledge base sentences can be read and understood directly by a domain expert. The system applies a graph form computed from the input natural logic sentences. The graph form generalizes the usual partial-order ontological sub-class structures by accommodation of affirmative sentences comprising recursive phrase structures. In this paper we focus on the logical inference rules for extending the concept graph form enabling deductive querying as well as computation of pathways between the concepts mentioned in the sentences.
Completeness and Termination for a Seligman-style Tableau System

Proof systems for hybrid logic typically use @-operators to access information hidden behind modalities; this labelling approach lies at the heart of the best known hybrid resolution, natural deduction, and tableau systems. But there is another approach, which we have come to believe is conceptually clearer. We call this Seligman-style inference, as it was first introduced and explored by Jerry Seligman in natural deduction [22] and sequent calculus [23] in the 1990s. The purpose of this paper is to introduce a Seligman-style tableau system, to prove its completeness, and to show how it can be made to terminate. The most obvious feature of Seligman-style systems is that they work with arbitrary formulas, not just statements prefixed by @-operators. They do so by introducing machinery for switching to other proof contexts. We capture this idea in the setting of tableaux by introducing a rule called GoTo which allows us to "jump to a named world" on a tableau branch. We first develop a Seligman-style tableau system for basic hybrid logic and prove its completeness. We then prove termination of a restricted version of the system without resorting to loop checking, and show that the restrictions do not effect completeness. Both completeness and termination results are proved constructively: we give translations which transform tableaus in a standard labelled system into tableaus in our Seligman-system and vice-versa.

General information
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.844 SNIP 1.788 CiteScore 1.23
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Complexity Results in Epistemic Planning

Epistemic planning is a very expressive framework that extends automated planning by the incorporation of dynamic epistemic logic (DEL). We provide complexity results on the plan existence problem for multi-agent planning tasks, focusing on purely epistemic actions with propositional preconditions. We show that moving from epistemic preconditions to propositional preconditions makes it decidable, more precisely in EXPSPACE. The plan existence problem is PSPACE-complete when the underlying graphs are trees and NP-complete when they are chains (including singletons). We also show PSPACE-hardness of the plan verification problem, which strengthens previous results on the complexity of DEL model checking.

General information
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Organisations: Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic, ENS Rennes
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Compressed Data Structures for Range Searching

We study the orthogonal range searching problem on points that have a significant number of geometric repetitions, that is, subsets of points that are identical under translation. Such repetitions occur in scenarios such as image compression, GIS applications and in compactly representing sparse matrices and web graphs. Our contribution is twofold. First, we show how to compress geometric repetitions that may appear in standard range searching data structures (such as K-D trees, Quad trees, Range trees, R-trees, Priority R-trees, and K-D-B trees), and how to implement subsequent range queries on the compressed representation with only a constant factor overhead. Secondly, we present a compression scheme that efficiently identifies geometric repetitions in point sets, and produces a hierarchical clustering of the point sets, which combined with the first result leads to a compressed representation that supports range searching.

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Computing Pathways in Bio-Models Derived from Bio-Science Text Sources

This paper outlines a system, OntoScape, serving to accomplish complex inference tasks on knowledge bases and bio-models derived from life-science text corpora. The system applies so-called natural logic, a form of logic which is readable for humans. This logic affords ontological representations of complex terms appearing in the text sources. Along with logical propositions, the system applies a semantic graph representation facilitating calculation of bio-pathways. More generally, the system aords means of query answering appealing to general and domain specic inference rules.

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Cooperative Epistemic Multi-Agent Planning With Implicit Coordination

Epistemic Planning has been used to achieve ontic and epistemic control in multi-agent situations. We extend the formalism to include perspective shifts, allowing us to define a class of cooperative problems in which both action planning and execution is done in a purely distributed fashion, meaning coordination is only allowed implicitly by means of the available epistemic actions. While this approach can be fruitfully applied to model reasoning in some simple social situations, we also provide some benchmark applications to show that the concept is useful for multi-agent systems in practice.

Decomposing series-parallel graphs into paths of length 3 and triangles

An old conjecture by Jünger, Reinelt and Pulleyblank states that every 2-edge-connected planar graph can be decomposed into paths of length 3 and triangles, provided its size is divisible by 3. We prove the conjecture for a class of planar graphs including all 2-edge-connected series-parallel graphs. We also present a 2-edge-connected non-planar graph that can be embedded on the torus and admits no decomposition into paths of length 3 and triangles.
In 1978, C. Thomassen proved that in any graph one can destroy all the longest cycles by deleting at most one third of the vertices. We show that for graphs with circumference \( k \leq 8 \) it suffices to remove at most \( 1/k \) of the vertices. The Petersen graph demonstrates that this result cannot be extended to include \( k = 9 \) but we show that in every graph with circumference nine we can destroy all 9-cycles by removing 1/5 of the vertices. We consider the analogous problem for digraphs and show that for digraphs with circumference \( k = 2, 3 \), it suffices to remove 1/k of the vertices. However this does not hold for \( k \geq 4 \).

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Don't Plan for the Unexpected: Planning Based on Plausibility Models

We present a framework for automated planning based on plausibility models, as well as algorithms for computing plans in this framework. Our plausibility models include postconditions, as ontic effects are essential for most planning purposes. The framework presented extends a previously developed framework based on dynamic epistemic logic (DEL), without plausibilities/beliefs. In the pure epistemic framework, one can distinguish between strong and weak epistemic plans for achieving some, possibly epistemic, goal. By taking all possible outcomes of actions into account, a strong plan...
guarantees that the agent achieves this goal. Conversely, a weak plan promises only the possibility of leading to the goal. In real-life planning scenarios where the planning agent is faced with a high degree of uncertainty and an almost endless number of possible exogenous events, strong epistemic planning is not computationally feasible. Weak epistemic planning is not satisfactory either, as there is no way to qualify which of two weak plans is more likely to lead to the goal. This seriously limits the practical uses of weak planning, as the planning agent might for instance always choose a plan that relies on serendipity. In the present paper we introduce a planning framework with the potential of overcoming the problems of both weak and strong epistemic planning. This framework is based on plausibility models, allowing us to define different types of plausibility planning. The simplest type of plausibility plan is one in which the goal will be achieved when all actions in the plan turn out to have the outcomes found most plausible by the agent. This covers many cases of everyday planning by human agents, where we - to limit our computational efforts - only plan for the most plausible outcomes of our actions.

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Extending a perfect matching to a Hamiltonian cycle

In 1993 Ruskey and Savage conjectured that in the d-dimensional hypercube, every matching $M$ can be extended to a Hamiltonian cycle. Fink verified this for every perfect matching $M$, remarkably even if $M$ contains external edges. We prove that this property also holds for sparse spanning regular subgraphs of the cubes: for every $d \geq 7$ and every $k$, where $7 \geq k \geq d$, the $d$-dimensional hypercube contains a $k$-regular spanning subgraph such that every perfect matching (possibly with external edges) can be extended to a Hamiltonian cycle. We do not know if this result can be extended to $k = 4, 5, 6$. It cannot be extended to $k = 3$. Indeed, there are only three 3-regular graphs such that every perfect matching (possibly with external edges) can be extended to a Hamiltonian cycle, namely the complete graph on 4 vertices, the complete bipartite 3-regular graph on 6 vertices and the 3-cube on 8 vertices. Also, we do not know if there are graphs of girth at least 5 with this matching-extendability property.
Faster Fully-Dynamic minimum spanning forest

We give a new data structure for the fully-dynamic minimum spanning forest problem in simple graphs. Edge updates are supported in $O(\log^4 n / \log \log n)$ expected amortized time per operation, improving the $O(\log^4 n)$ amortized bound of Holm et al. (STOC'98, JACM'01). We also provide a deterministic data structure with amortized update time $O(\log^4 n \log \log \log n / \log \log n)$. We assume the Word-RAM model with standard instructions.
Hvornår skal vi blive bange?
Trussel. Siden slutningen af 1950erne har man forsøgt at skabe kunstigt intelligente maskiner. Udviklingen er gået langsommere, end man forventede, men nu er både forskere og lægfolk begyndt at spørge: Hvornår skal vi blive bange?

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Improved time complexity analysis of the Simple Genetic Algorithm
A runtime analysis of the Simple Genetic Algorithm (SGA) for the OneMax problem has recently been presented proving that the algorithm with population size $\mu \leq n^{1/8-\epsilon}$ requires exponential time with overwhelming probability. This paper presents an improved analysis which overcomes some limitations of the previous one. Firstly, the new result holds for population sizes up to $\mu \leq n^{1/4-\epsilon}$ which is an improvement up to a power of 2 larger. Secondly, we present a technique to bound the diversity of the population that does not require a bound on its bandwidth. Apart from allowing a stronger result, we believe this is a major improvement towards the reusability of the techniques in future systematic analyses of GAs. Finally, we consider the more natural SGA using selection with replacement rather than without replacement although the results hold for both algorithmic versions. Experiments are presented to explore the limits of the new and previous mathematical techniques.

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Authors: Oliveto, P. S. (Ekstern), Witt, C. (Intern)
In Pursuit of Natural Logics for Ontology-Structured Knowledge Bases

We argue for adopting a form of natural logic for ontology-structured knowledge bases with complex sentences. This serves to ease reading of knowledge base for domain experts and to make reasoning and querying and path-finding more comprehensible. We explain natural logic as a development from traditional logic, pointing to essential differences to description logic. We conclude with a knowledge base set-up with an embedding into clausal logic, offering also a graph view of the sentences.

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Interfacing Agents to Real-Time Strategy Games

In real-time strategy games players make decisions and control their units simultaneously. Players are required to make decisions under time pressure and should be able to control multiple units at once in order to be successful. We present the design and implementation of a multi-agent interface for the real-time strategy game STARCAST: BROOD WAR. This makes it possible to build agents that control each of the units in a game. We make use of the Environment Interface Standard, thus enabling different agent programming languages to use our interface, and we show how agents can control the units in the game in the Jason and GOAL agent programming languages.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
Authors: Jensen, A. S. (Intern), Kaysø-Rørdam, C. (Intern), Villadsen, J. (Intern)
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Learning Actions Models: Qualitative Approach

In dynamic epistemic logic, actions are described using action models. In this paper we introduce a framework for studying learnability of action models from observations. We present first results concerning propositional action models. First we check two basic learnability criteria: finite identifiability (conclusively inferring the appropriate action model in finite time) and identifiability in the limit (inconclusive convergence to the right action model). We show that deterministic actions are finitely identifiable, while non-deterministic actions require more learning power—they are identifiable in the limit. We then move on to a particular learning method, which proceeds via restriction of a space of events within a learning-specific action model. This way of learning closely resembles the well-known update method from dynamic epistemic logic. We introduce several different learning methods suited for finite identifiability of particular types of deterministic actions.
Load Scheduling in a Cloud Based Massive Video-Storage Environment

We propose an architecture for a storage system of surveillance videos. Such systems have to handle massive amounts of incoming video streams and relatively few requests for replay. In such a system load (i.e., Write requests) scheduling is essential to guarantee performance. Large-scale data-storage system (LSDSS) is an emerging hosting facility for video-storage, which has a very high number of writes while most of the videos are never or rarely watched. We discuss the design and implementation of LSDSS and load scheduling in autonomous storage environments called datacenters in LSDSS. A datacenter (DC) is the basic concept in our LSDSS, which has the self-management system to store data efficiently. A LSDSS consists of many DCs organized in a hierarchy fashion, thereby decentralizing load scheduling tasks. Because DC has a simple design, load scheduling is particularly suited for implementation on a real-time video surveillance and allows to make scheduling decisions. We also discuss experimental results that clearly show the advantage of load scheduling over the widely known base load scheduling.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Bayyapu, K. R. (Intern), Fischer, P. (Intern)
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Source-ID: 105709247
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Longest Common Extensions in Sublinear Space

The longest common extension problem (LCE problem) is to construct a data structure for an input string T of length n that supports LCE(i,j) queries. Such a query returns the length of the longest common prefix of the suffixes starting at positions i and j in T. This classic problem has a well-known solution that uses O(n) space and O(1) query time. In this paper we show that for any trade-off parameter 1≤τ≤n, the problem can be solved in O(n/τ) space and O(τ) query time. This significantly improves the previously best known time-space product lower bound.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen, Bar-Ilan University
Authors: Bille, P. (Intern), Gertz, I. L. (Intern), Knudsen, M. B. T. (Ekstern), Lewenstein, M. (Ekstern), Vildhøj, H. W. (Intern)
Pages: 65-76
Publication date: 2015

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Publisher: Springer
ISBN (Print): 978-3-319-19928-3
ISBN (Electronic): 978-3-319-19929-0
Longest Common Extensions in Trees

The longest common extension (LCE) of two indices in a string is the length of the longest identical substrings starting at these two indices. The LCE problem asks to preprocess a string into a compact data structure that supports fast LCE queries.

In this paper we generalize the LCE problem to trees and suggest a few applications of LCE in trees to tries and XML databases. Given a labeled and rooted tree T of size n, the goal is to preprocess T into a compact data structure that support the following LCE queries between subpaths and subtrees in T. Let v1, v2, w1, and w2 be nodes of T such that w1 and w2 are descendants of v1 and v2 respectively.

- LCEPP(v1, w1, v2, w2): (path-path LCE) return the longest common prefix of the paths v1 ~→ w1 and v2 ~→ w2.
- LCEPT(v1, w1, v2): (path-tree LCE) return maximal path-path LCE of the path v1 ~→ w1 and any path from v2 to a descendant leaf.
- LCETT(v1, v2): (tree-tree LCE) return a maximal path-path LCE of any pair of paths from v1 and v2 to descendant leaves.

We present the first non-trivial bounds for supporting these queries. For LCEPP queries, we present a linear-space solution with O(log* n) query time. For LCEPT queries, we present a linear-space solution with O((log log n)^2) query time, and complement this with a lower bound showing that any path-tree LCE structure of size O(n polylog(n)) must necessarily use Ω(log log n) time to answer queries. For LCETT queries, we present a time-space trade-off, that given any parameter τ, 1 ≤ τ ≤ n, leads to an O(nτ) space and O(n/τ) query-time solution. This is complemented with a reduction to the set intersection problem implying that a fast linear space solution is not likely to exist.
Meta-Logical Reasoning in Higher-Order Logic
The semantics of first-order logic (FOL) can be described in the meta-language of higher-order logic (HOL). Using HOL one can prove key properties of FOL such as soundness and completeness. Furthermore, one can prove sentences in FOL valid using the formalized FOL semantics. To aid in the construction of the proof an interactive proof assistant like Isabelle can be used. The proof assistant can even automate simple proofs using the formalized FOL semantics.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Language-Based Technology
Authors: Villadsen, J. (Intern), Schlichtkrull, A. (Intern), Hess, A. V. (Intern)
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences
Electronic versions: logica_poster.pdf
Source: PublicationPreSubmission
Source-ID: 118753618
Publication: Research - peer-review › Poster – Annual report year: 2015

Minimum Makespan Multi-Vehicle Dial-a-Ride
Dial-a-Ride problems consist of a set V of n vertices in a metric space (denoting travel time between vertices) and a set of m objects represented as source-destination pairs \{(s(i), t(i))\}_{i=1}^{m}, where each object requires to be moved from its source to destination vertex. In the multi-vehicle Dial-a-Ride problem, there are q vehicles, each having capacity k and where each vehicle j epsilon [q] has its own depot-vertex r(j) epsilon V. A feasible schedule consists of a capacitated route for each vehicle (where vehicle j originates and ends at its depot r(j)) that together move all objects from their sources to destinations. The objective is to find a feasible schedule that minimizes the maximum completion time (i.e., makespan) of vehicles, where the completion time of vehicle j is the time when it returns to its depot r(j) at the end of its route. We study the preemptive version of multi-vehicle Dial-a-Ride, in which an object may be left at intermediate vertices and transported by more than one vehicle, while being moved from source to destination. Our main results are an O(log(3) n)-approximation algorithm for preemptive multi-vehicle Dial-a-Ride, and an improved O(log t)-approximation for its special case when there is no capacity constraint (here t...
MMAS Versus Population-Based EA on a Family of Dynamic Fitness Functions

We study the behavior of a population-based EA and the Max–Min Ant System (MMAS) on a family of deterministically-changing fitness functions, where, in order to find the global optimum, the algorithms have to find specific local optima within each of a series of phases. In particular, we prove that a (2+1) EA with genotype diversity is able to find the global optimum of the Maze function, previously considered by Kötzing and Molter [9], in polynomial time. This is then generalized to a hierarchy result stating that for every $\mu$, a ($\mu + 1$) EA with genotype diversity is able to track a Maze function extended over a finite alphabet of $\mu$ symbols, whereas population size $\mu - 1$ is not sufficient. Furthermore, we show that MMAS does not require additional modifications to track the optimum of the finite-alphabet Maze functions, and, using a novel drift statement to simplify the analysis, reduce the required phase length of the Maze function.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Lissovoi, A. (Intern), Witt, C. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2018): Indexed yes
NaDeA: A Natural Deduction Assistant with a Formalization in Isabelle

We present a new software tool for teaching logic based on natural deduction. Its proof system is formalized in the proof assistant Isabelle such that its definition is very precise. Soundness of the formalization has been proved in Isabelle. The tool is open source software developed in TypeScript / JavaScript and can thus be used directly in a browser without any further installation. Although developed for undergraduate computer science students who are used to study and program concrete computer code in a programming language we consider the approach relevant for a broader audience and for other proof systems as well.
Nature-Inspired and Energy Efficient Route Planning

Cars are responsible for substantial CO2 emission worldwide. Computers can help solve this problem by computing shortest routes on maps. A good example of this is the popular Google Maps service. However, such services often require the order of the stops on the route to be fixed. By not enforcing an order on the stops, the route can be made shorter. When, for instance, a furniture dealer has to deliver goods, the order of visiting the customers will often be unimportant. We present a prototype app that can make shorter and more energy efficient routes by allowing it to change the order of the stops. The app is aimed at private persons and small businesses. The app works by using a nature-inspired algorithm called Ant Colony Optimization.

On Regular Expression Matching and Deterministic Finite Automata

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Bille, P. (Intern)
Pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences
On the chromatic number of general Kneser hypergraphs

In a break-through paper, Lovász [20] determined the chromatic number of Kneser graphs. This was improved by Schrijver [27], by introducing the Schrijver subgraphs of Kneser graphs and showing that their chromatic number is the same as that of Kneser graphs. Alon, Frankl, and Lovász [2] extended Lovász's result to the usual Kneser hypergraphs and one of our main results is to extend this to a new family of general Kneser hypergraphs. Moreover, as a special case, we settle a question from Naserasr and Tardif [26]. In 2011, Meunier introduced almost 2-stable Kneser hypergraphs and determined their chromatic number as an approach to a supposition of Ziegler [35] and a conjecture of Alon, Drewnowski, and Łuczak [3]. In this work, our second main result is to improve this by computing the chromatic number of a large family of Schrijver hypergraphs. Our last main result is to prove the existence of a completely multicolored complete bipartite graph in every coloring of a graph which extends a result of Simonyi and Tardos [29]. The first two results are proved using a new improvement of the Dol'nikov-Kříž [7, 18] bound on the chromatic number of general Kneser hypergraphs.
On the Complexity of Model-Checking Branching and Alternating-Time Temporal Logics in One-Counter Systems

We study the complexity of the model-checking problem for the branching-time logic CTL∗ and the alternating-time temporal logics ATL/ATL∗ in one-counter processes and one-counter games respectively. The complexity is determined for all three logics when integer weights are input in unary (non-succinct) and binary (succinct) as well as when the input formula is fixed and is a parameter. Further, we show that deciding the winner in one-counter games with LTL objectives is 2ExpSpacecomplete for both succinct and non-succinct games. We show that all the problems considered stay in the same complexity classes when we add quantitative constraints that can compare the current value of the counter with a constant.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Vester, S. (Intern)
Pages: 361-377
Publication date: 2015
On the Runtime of Randomized Local Search and Simple Evolutionary Algorithms for Dynamic Makespan Scheduling
Evolutionary algorithms have been frequently used for dynamic optimization problems. With this paper, we contribute to the theoretical understanding of this research area. We present the first computational complexity analysis of evolutionary algorithms for a dynamic variant of a classical combinatorial optimization problem, namely makespan scheduling. We study the model of a strong adversary which is allowed to change one job at regular intervals. Furthermore, we investigate the setting of random changes. Our results show that randomized local search and a simple evolutionary algorithm are very effective in dynamically tracking changes made to the problem instance.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Adelaide
Authors: Neumann, F. (Ekstern), Witt, C. (Intern)
Pages: 3742-3748
Publication date: 2015

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ISBN (Electronic): 978-3-319-24953-7
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Main Research Area: Technical/natural sciences
Conference: 13th International Symposium on Automated Technology for Verification and Analysis (ATVA 2015), Shanghai, China, 12/10/2015 - 12/10/2015
Electronic versions:
main.pdf
DOIs:
10.1007/978-3-319-24953-7_27
Source: PublicationPreSubmission
Source-ID: 117990493
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

On the Utility of Island Models in Dynamic Optimization
A simple island model with $\lambda$ islands and migration occurring after every $\tau$ iterations is studied on the dynamic fitness function Maze. This model is equivalent to a (1+$\lambda$) EA if $\tau=1$, i.e., migration occurs during every iteration. It is proved that even for an increased offspring population size up to $\lambda=O(n^{1-\epsilon})$, the (1+$\lambda$) EA is still not able to track the optimum of Maze. If the migration interval is increased, the algorithm is able to track the optimum even for logarithmic $\lambda$. Finally, the relationship of $\tau$, $\lambda$, and the ability of the island model to track the optimum is investigated more closely.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Lissovoi, A. (Intern), Witt, C. (Intern)
Part E: Evolutionary Computation

Part E, Evolutionary Computation, edited by Professors Frank Neumann, Carsten Witt, Peter Merz, Carlos A. Coello Coello, Oliver Schütze, Thomas Bartz-Beielstein, Jörn Mehnen, and Günther Raidl, concerns the third fundamental element of what is traditionally being considered to be the core of Computational Intelligence.

First, comprehensive surveys of genetic algorithms, genetic programming, evolution strategies, parallel evolutionary algorithms are presented, which are readable and constructive so that a large audience might find them useful and – to some extent – ready to use. Some more general topics like the estimation of distribution algorithms, indicator-based selection, etc., are also discussed.

An important problem, from a theoretical and practical point of view, of learning classifier systems is presented in depth.

Multiobjective evolutionary algorithms, which constitute one of the most important group, both from the theoretical and applied points of view, are discussed in detail, followed by an account of parallel multiobjective evolutionary algorithms, and then a more general analysis of many multiobjective problems.

Considerable attention has also been paid to a presentation of hybrid evolutionary algorithms, such as memetic algorithms, which have emerged as a very promising tool for solving many real-world problems in a multitude of areas of science and technology. Moreover, parallel evolutionary combinatorial optimization has been presented.

Search operators, which are crucial in all kinds of evolutionary algorithms, have been prudently analyzed. This analysis was followed by a thorough analysis of various issues involved in stochastic local search algorithms.

An interesting survey of various technological and industrial applications in mechanical engineering and design has been provided. Then, an account of the use of evolutionary combinatorial optimization in bioinformatics is given.

An analysis of a synergistic integration of metaheuristics, notably evolutionary computation, and constraint satisfaction, constraint programming, graph coloring, tree decomposition, and similar relevant problems completes the part.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Adelaide, University of Applied Sciences and Arts Hildesheim, CINVESTAV-IPN, Cologne University of Applied Sciences, Cranfield University, Vienna University of Technology
Pages: 823-1288
Publication date: 2015
Plan-Belief Revision in Jason
When information is shared between agents of unknown reliability, it is possible that their belief bases become inconsistent. In such cases, the belief base must be revised to restore consistency, so that the agent is able to reason. In some cases the inconsistent information may be due to use of incorrect plans. We extend work by Alechina et al. to revise belief bases in which plans can be dynamically added and removed. We present an implementation of the algorithm in the AgentSpeak implementation Jason.

Population Size vs. Mutation Strength for the (1+λ) EA on OneMax
The (1+1) EA with mutation probability c/n, where c>0 is an arbitrary constant, is studied for the classical OneMax function. Its expected optimization time is analyzed exactly (up to lower order terms) as a function of c and λ. It turns out that 1/n is the only optimal mutation probability if λ=O(ln n ln ln n/ln ln ln n), which is the cut-off point for linear speed-up. However, if λ is above this cut-off point then the standard mutation probability 1/n is no longer the only optimal choice. Instead, the expected number of generations is (up to lower order terms) independent of c, irrespectively of it being less than 1 or greater. The results are obtained by a careful study of order statistics of the binomial distribution and variable drift theorems for upper and lower bounds.
ProofJudge: Automated Proof Judging Tool for Learning Mathematical Logic

Today we have software in many artefacts, from medical devices to cars and airplanes, and the software must not only be efficient and intelligent but also reliable and secure. Tests can show the presence of bugs but cannot guarantee their absence. A machine-checked proof using mathematical logic provides strong evidence for software correctness but it requires advanced knowledge and skills. We have developed a tool which helps the student to practice their skills and also allows a better conceptual understanding of state-of-the-art proof assistants. Previously the proofs have been carried out using pen and paper because no adequate tool was available. The learning problem is how to make abstract concepts of logic as concrete as possible.

ProofJudge is a computer system and teaching approach for teaching mathematical logic and automated reasoning which augments the e-learning tool NaDeA (Natural Deduction Assistant). We believe that automatic feedback on student assignments would allow the students to enhance their skill in natural deduction proofs which are fundamental in formal verification and artificial intelligence applications. The teachers will benefit too and can put more emphasis on the semantics. Natural deduction is taught at most if not all universities but few tools exist. Initially we plan to have former students on the course to evaluate ProofJudge and later it will be employed in the course.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Villadsen, J. (Intern)
Pages: 141-148
Publication date: 2015

Random Access to Grammar-Compressed Strings and Trees

Grammar-based compression, where one replaces a long string by a small context-free grammar that generates the string, is a simple and powerful paradigm that captures (sometimes with slight reduction in efficiency) many of the popular compression schemes, including the Lempel-Ziv family, run-length encoding, byte-pair encoding, Sequitur, and Re-Pair. In this paper, we present a novel grammar representation that allows efficient random access to any character or substring without decompressing the string. Let S be a string of length N compressed into a context-free grammar S of size n. We present two representations of S achieving O(log N) random access time, and either O(n · αk(n)) construction time and space on the pointer machine model, or O(n) construction time and space on the RAM. Here, αk(n) is the inverse of the kth row of Ackermann's function. Our representations also efficiently support decompression of any substring in S: we can decompress any substring of length m in the same complexity as a single random access query and additional O(m) time. Combining these results with fast algorithms for uncompressed approximate string matching leads to several efficient algorithms for approximate string matching on grammar-compressed strings without decompression. For instance, we can find all approximate occurrences of a pattern P with at most k errors in time O(n(min{|P|k,k4 + |P|}) + log N) + occ), where occ is the number of occurrences of P in S. Finally, we generalize our results to navigation and other operations on grammar-compressed ordered trees. All of the above bounds significantly improve the currently best known results. To achieve these bounds, we introduce several new techniques and data structures of independent interest, including a predecessor data structure, two "biased" weighted ancestor data structures, and a compact representation of heavy paths in grammars.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Haifa, University of Leicester, National Institute of Informatics, Seoul National University
Authors: Bille, P. (Intern), Landau, G. M. (Ekstern), Raman, R. (Ekstern), Sadakane, K. (Ekstern), Satti, S. R. (Ekstern), Weimann, O. (Ekstern)
Pages: 513-539
Publication date: 2015
Runtime analysis of ant colony optimization on dynamic shortest path problems

A simple ACO algorithm called lambda-MMAS for dynamic variants of the single-destination shortest paths problem is studied by rigorous runtime analyses. Building upon previous results for the special case of 1-MMAS, it is studied to what extent an enlarged colony using lambda ants per vertex helps in tracking an oscillating optimum. It is shown that easy cases of oscillations can be tracked by a constant number of ants. However, the paper also identifies more involved
oscillations that with overwhelming probability cannot be tracked with any polynomial-size colony. Finally, parameters of dynamic shortest-path problems which make the optimum difficult to track are discussed. Experiments illustrate theoretical findings and conjectures.

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Authors: Lissovoi, A. (Intern), Witt, C. (Intern)
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Main Research Area: Technical/natural sciences

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BFI (2017): BFI-level 2
Scopus rating (2017): SJR 0.488 SNIP 0.996 CiteScore 1.08
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 0.97 SJR 0.547 SNIP 0.996
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.592 SNIP 1.123 CiteScore 1
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.669 SNIP 1.148 CiteScore 1.08
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.717 SNIP 1.297 CiteScore 1.17
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.78 SNIP 1.21 CiteScore 1.16
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.747 SNIP 1.246 CiteScore 1.17
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.839 SNIP 1.278
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.876 SNIP 1.434
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.098 SNIP 1.587
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.931 SNIP 1.576
Scopus rating (2006): SJR 0.834 SNIP 1.457
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.747 SNIP 1.438
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.717 SNIP 1.324
The AORTA Reasoning Framework - Adding Organizational Reasoning to Agents

Intelligent agents are entities defined by, among other things, autonomy. In systems of many agents, the agents’ individual autonomy can lead to uncertainty since their behavior cannot always be predicted. Usually, this kind of uncertainty is accommodated by imposing an organization upon the system; an organization that defines expected behavior of the agents and attempts to restrict the agents’ behavior to let it match the expectations. Restrictions can lead to a decrease in autonomy, contradicting one of the pillars of intelligent agents.

This thesis presents the AORTA reasoning framework, which is a practical component (founded in logic) that enriches intelligent agents with organizational reasoning capabilities. We take the agent’s perspective by devising a component that integrates with the agent’s usual reasoning capabilities in a non-intrusive way. This results in agents that are both organization-aware and autonomous. The reasoning component makes them organization-aware, and their autonomy is intact because the component does not change the existing reasoning mechanisms. As such, it allows the agents to decide whether to adhere to the system’s expectations.

The ability to reason about organizations has previously been successfully integrated into agent programming languages. However, the operationalization of an organization is usually tailored to a specific language. This makes it hard to apply the same approach to other languages and platforms. The AORTA reasoning framework distinguishes itself by being a generic framework that allows different kinds of agents to reason about different kinds of organizations.

We present our results in three main parts. In the first part, we present the theoretical foundations for the AORTA framework, which consists of semantics of norms, an organizational metamodel, and the AORTA reasoning component. The reasoning component is characterized by being completely decoupled from the cognitive agent, by its automated reasoning about norms and organizational options, and by the reasoning rules specified by the designer to act upon norms and options. We specify the reasoning component using structural operational semantics providing us with a formal, rigid description of the behavior of the component during execution. This enables us to precisely specify each reasoning phases (using transition rules), and it makes the implementation of the system quite straightforward.

The second part moves from theory to practice: we present an implementation of the framework and integrate it into various agent platforms. We show that the same configuration of the component can be used for different agent platforms, providing evidence for its use as a general tool for organization-awareness. Furthermore, we use practical verification to show various properties of an implementation of agents and of the system in general.

In the last part, we discuss a potential issue with our framework. The possibility to commit to organizational objectives can affect the agent’s autonomy, which contradicts our main goal. We propose a model that solves this problem by adding a filter to the agent’s decision procedure that takes consequences of fulfilling a goal into account before deciding to commit to it. By considering both the agent’s preferences and the expected outcome of fulfilling the goal, we show that it was possible for the agents to make qualified context-dependent decisions.

We claim that by using the AORTA reasoning framework, agents become organization-aware. The reasoning component provides capabilities to reason about organizations and our decision procedure ensures that the autonomy of the agents is still intact.

General information
State: Published
Organizations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Jensen, A. S. (Intern), Villadsen, J. (Intern)
Number of pages: 197
Publication date: 2015

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Publisher: Danmarks Tekniske Universitet (DTU)
The minimum number of minimal codewords in an \([n,k]\)-code and in graphic codes

We survey some lower bounds on the function in the title based on matroid theory and address the following problem by Dosa et al. (2004): Determine the smallest number of circuits in a loopless matroid with no parallel elements and with a given size and rank. In the graphic 3-connected case we provide a lower bound which is a product of a linear function of the number of vertices and an exponential function of the average degree. We also prove that, for \(p \geq 38\), every 3-connected graph with \(p\) vertices has at least as many cycles as the wheel with \(p\) vertices.
This dissertation studies problems in the general theme of combinatorial pattern matching. More specifically, we study the following topics:

Longest Common Extensions. We revisit the longest common extension (LCE) problem, that is, preprocess a string $T$ into a compact data structure that supports fast LCE queries. An LCE query takes a pair $(i, j)$ of indices in $T$ and returns the length of the longest common prefix of the suffixes of $T$ starting at positions $i$ and $j$. Such queries are also commonly known as longest common prefix (LCP) queries. We study the time-space trade-offs for the problem, that is, the space used for the data structure vs. the worst-case time for answering an LCE query. Let $n$ be the length of $T$. Given a parameter $\tau$, $1 \leq \tau \leq n$, we show how to achieve either $O(n/\sqrt{\tau})$ space and $O(\tau)$ query time, or $O(n/\tau)$ space and $O(\tau \log (|LCE(i, j)|/\tau))$ query time, where $|LCE(i, j)|$ denotes the length of the LCE returned by the query. These bounds provide the first smooth trade-offs for the LCE problem and almost match the previously known bounds at the extremes when $\tau = 1$ or $\tau = n$. We apply the result to obtain improved bounds for several applications where the LCE problem is the computational bottleneck, including approximate string matching and computing palindromes. We also present an efficient technique to reduce LCE queries on two strings to one string. Finally, we give a lower bound on the time-space product for LCE data structures in the non-uniform cell probe model showing that our second trade-off is nearly optimal.

Fingerprints in Compressed Strings. The Karp-Rabin fingerprint of a string is a type of hash value that due to its strong properties has been used in many string algorithms. We show how to construct a data structure for a string $S$ of size $N$ compressed by a context-free grammar of size $n$ that supports fingerprint queries. That is, given indices $i$ and $j$, the answer to a query is the fingerprint of the substring $S[i, j]$. We present the first $O(n)$ space data structures that answer fingerprint queries without decompressing any characters. For Straight Line Programs (SLP) we get $O(\log N)$ query time, and for Linear SLPs (an SLP derivative that captures LZ78 compression and its variations) we get $O(\log \log N)$ query time. Hence, our data structures has the same time and space complexity as for random access in SLPs. We utilize the fingerprint data structures to solve the longest common extension problem in query time $O(\log N \log e)$. Hence, our data structures has the same time and space complexity as for random access in SLPs. We utilize the fingerprint data structures to solve the longest common extension problem in query time $O(\log N \log e)$. Hence, our data structures has the same time and space complexity as for random access in SLPs. We utilize the fingerprint data structures to solve the longest common extension problem in query time $O(\log N \log e)$ for SLPs and Linear SLPs, respectively. Here, $e = |LCE(i, j)|$ denotes the length of the LCE.

Sparse Text Indexing. We present efficient algorithms for constructing sparse suffix trees, sparse suffix arrays and sparse positions heaps for b arbitrary positions of a text $T$ of length $n$ while using only $O(b)$ words of space during the construction. Our main contribution is to show that the sparse suffix tree (and array) can be constructed in $O(n \log^2 b)$ time. To achieve this we develop a technique, that allows to efficiently answer $b$ longest common prefix queries on suffixes of $T$, using only $O(b)$ space. Our first solution is Monte-Carlo and outputs the correct tree with high probability. We then give a Las-Vegas algorithm which also uses $O(b)$ space and runs in the same time bounds with high probability when $b =$
O(√n). Furthermore, additional tradeoffs between the space usage and the construction time for the Monte-Carlo algorithm are given. Finally, we show that at the expense of slower pattern queries, it is possible to construct sparse position heaps in O(n + b log b) time and O(b) space.

The Longest Common Substring Problem. Given m documents of total length n, we consider the problem of finding a longest string common to at least d ≥ 2 of the documents. This problem is known as the longest common substring (LCS) problem and has a classic O(n) space and O(n) time solution (Weiner [FOCS’73], Hui [CPM’92]). However, the use of linear space is impractical in many applications. We show several time-space trade-offs for this problem. Our main result is that for any trade-off parameter 1 ≤ τ ≤ n, the LCS problem can be solved in O(τ) space and O(n²/τ) time, thus providing the first smooth deterministic time-space trade-off from constant to linear space. The result uses a new and very simple algorithm, which computes a τ-additive approximation to the LCS in O(n²/τ) time and O(1) space. We also show a time-space trade-off lower bound for deterministic branching programs, which implies that any deterministic RAM algorithm solving the LCS problem on documents from a sufficiently large alphabet in O(τ) space must use Ω (n² log(n/τ log n))/ log log(n/(τ log n)) time.

Structural Properties of Suffix Trees. We study structural and combinatorial properties of suffix trees. Given an unlabeled tree T on n nodes and suffix links of its internal nodes, we ask the question “Is T a suffix tree?”, i.e., is there a string S whose suffix tree has the same topological structure as T ? We place no restrictions on S, in particular we do not require that S ends with a unique symbol. This corresponds to considering the more general definition of implicit or extended suffix trees. Such general suffix trees have many applications and are for example needed to allow efficient updates when suffix trees are built online. We prove that T is a suffix tree if and only if it is realized by a string S of length n – 1, and we give a linear-time algorithm for inferring S when the first letter on each edge is known.

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Towards Theory-of-Mind agents using Automated Planning and Dynamic Epistemic Logic
This thesis is part of a growing body of work in what we call epistemic planning. Epistemic planning is situated at the intersection of automated planning and what can broadly be called dynamic logics. Both are part of the much larger field of Artificial Intelligence.

Automated Planning has been around since at least the 1970s. It is a diverse collection of methods, models, algorithms and specification languages for giving autonomous agents the ability to come up with plans for proactively achieving goals. Autonomous agents can be understood as independent actors, given a purpose by their designer. Whether they are in a software system, connected to the real world with sensors and actuators, or used as a tool for modelling people, for instance in economics, they need to be able to imagine (or predict) outcomes of actions in order to form plans.

The feature that most distinguishes planning from other decision making methods, is that the planner does not know the full system from the beginning. Most of the time it would simply be too big to store in memory! Instead of being given the entire “game”, they use a specification of actions and the initial state to generate only a fraction of the full search space. This means that what an agent can plan for depends crucially on what domains we can describe. This is where logic comes into the picture.

For most of its more than 2500 year long history, logic has been mostly interested in the study of valid reasoning. In later years (in the scheme of things), more attention has been given to studying when reasoning fails in humans. Like using differential equations to analyse and simulate both when a bridge holds and when it collapses, we can use logic to analyse and simulate reasoning both when it is sound and when it isn’t.

The subbranch of logic applied in this work is Dynamic Epistemic Logic. The epistemic part concerns the formalisation of
knowledge and belief (mainly) in multi-agent settings. We can describe situations in which many agents are present and have different knowledge and beliefs about the world and each others’ knowledge and belief. Adding the dynamic part of Dynamic Epistemic Logic to our arsenal, we can describe how situations change when, broadly speaking, things happen. In the application to Automated Planning, we let these things be actions of the agents in the system. In doing so we derive new planning formalisms that allow agents to plan under consideration of how what they do changes both the world and knowledge and belief about the world.

In this thesis we give new planning formalisms for single-agent planning and new results for the model theory of multi-agent models. The first of the two fully developed planning formalisms is conditional (single-agent) epistemic planning, allowing an agent to plan with what it knows now and what it knows it will come to know. Though this is nothing new in Automated Planning, it sets the stage for later work.

The second planning formalism extends conditional epistemic planning with beliefs, letting the agent have expectations, without probabilities, of how things will turn out. Our radically different notions of bisimulation for the multi-agent versions of these models are particularly interesting for logicians, as are surprising expressivity results for well known logics on such models.

The final part of the thesis describes ideas on extending the second formalism to a multi-agent setting. With a view towards the practical implementation of agents, we shall also see how an agent can discard the parts of its model that it does not believe to be the case. While this is not necessary for analysing reasoning agents, it does seem a requirement for practical implementations. There are simply too many possibilities for a resource-bounded agent to keep track of. If the agent does discard unlikely possibilities, it must be able to do belief revision if it later turns out to be wrong. Such a procedure is also described.

The long term potential of multi-agent aware planning algorithms is that agents that can predict and understand others in order to plan cooperation, communication, and/or competition. It is the slow edging towards a general framework for multi-agent planning that is the underlying motivation, and some of the main results, of this thesis. While regrettably we haven’t gotten there yet, we’re considerably closer than when we started.
UNI C - A True Internet Pioneer, the Danish Computing Centre for Research and Education

In 1985 it was decided to merge the 3 regional computing centers NEUCC, RECKU and RECAU located respectively at the Technical University of Denmark, the University of Copenhagen and the University of Aarhus. The background for the merger was the rapid development of computing equipment which meant that small computers could now be purchased for local use by the university departments whereas the need for high performance computing could only be satisfied by a joint national purchase and advanced network access to this central computer facility. The new center was named UNI-C and succeeded in helping Danish frontline research to use innovative computing techniques and have major breakthroughs using the first massively parallel computer architectures, but the greatest impact of UNI-C on Danish society was the successful early roll out of the Internet to universities with a follow-up of establishing the first Danish Internet service to ordinary PC users. This very first Internet service became a great success and helped to put Denmark on the international map as one of the very early Internet adopters. It also meant that UNI-C was tasked by the Ministry of Education with delivering a number of different groundbreaking services to Danish schools like e.g. the Education Portal EMU, the school intranet SkoleIntra and the single sign on service, Uni-login. The growth of the service portfolio to schools meant that UNI-C stayed with the Ministry of Education when the universities were moved to a separate new ministry, and today UNI-C only delivers services to schools, whereas the service portfolio for universities is now taken care of by the DeIC, the Danish e-Infrastructure Collaboration.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Olesen, D. (Intern)
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Designing garbage-free reversible implementations of the integer cosine transform

Discrete linear transformations are important tools in information processing. Many such transforms are injective and therefore prime candidates for a physically reversible implementation into hardware. We present here reversible integer cosine transformations on n input integers. The resulting reversible circuit is able to perform both the forward transform and the inverse transform. The detailed structure of such a reversible design strongly depends on the odd prime factors of the determinant of the transform: whether those are of the form $2^k \pm 1$ or of the form $2^k \pm 2^l \pm 1$ or neither of these forms.

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Organisations: National Space Institute, Department of Applied Mathematics and Computer Science, Algorithms and Logic, Ghent University, University of Copenhagen, University of Bremen, Nanzan University
Authors: De Vos, A. (Ekstern), Burignat, S. (Ekstern), Gluck, R. (Ekstern), Mogensen, T. A. (Ekstern), Axelsen, H. B. (Ekstern), Thomsen, M. K. (Intern), Rotenberg, E. (Intern), Yokoyama, T. (Ekstern)
Publication date: 1 Oct 2014
Main Research Area: Technical/natural sciences
A Case for Embedded Natural Logic for Ontological Knowledge Bases

We argue in favour of adopting a form of natural logic for ontology-structured knowledge bases as an alternative to description logic and rule based languages. Natural logic is a form of logic resembling natural language assertions, unlike description logic. This is essential e.g. in life sciences, where the large and evolving knowledge specifications should be directly accessible to domain experts. Moreover, natural logic comes with intuitive inference rules. The considered version of natural logic leans toward the closed world assumption (CWA) unlike the open world assumption with classical negation in description logic. We embed the natural logic in DATALOG clauses which is to take care of the computational inference in connection with querying.

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AORTA: Adding Organizational Reasoning to Agents: Extended abstract

Open systems are characterized by a diversity of heterogeneous and autonomous agents that act according to private goals, and with a behavior that is hard to predict. They can be regulated through organizations similar to human organizations, which regulate the agents' behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization.

This extended abstract introduces AORTA, a component that can be integrated into agents' reasoning mechanism, allowing them to reason about (and act upon) regulations specified by an organizational model using simple reasoning rules. The added value is that the organizational model is independent of that of the agents, and that the approach is not tied to a specific organizational model.
A System for Computing Conceptual Pathways in Bio-medical Text Models

This paper describes the key principles in a system for querying and conceptual path finding in a logic-based knowledge base. The knowledge base is extracted from textual descriptions in bio-, pharma- and medical areas. The knowledge base applies natural logic, that is, a variable-free term-algebraic form of predicate logic. Natural logics are distinguished by coming close to natural language so that propositions are readable by domain experts. The natural logic knowledge base is accompanied by an internal graph representation, where the nodes represent simple concept terms as well as compound concepts stemming from entire phrases. Path finding between concepts is facilitated by a labelled graph form that represents the knowledge base as well as the ontological information.

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Bioinspired computation in combinatorial optimization - Algorithms and their computational complexity

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Colored Range Searching in Linear Space

In colored range searching, we are given a set of n colored points in d ≥ 2 dimensions to store, and want to support orthogonal range queries taking colors into account. In the colored range counting problem, a query must report the number of distinct colors found in the query range, while an answer to the colored range reporting problem must report the distinct colors in the query range. We give the first linear space data structure for both problems in two dimensions (d = 2) with o(n) worst case query time. We also give the first data structure obtaining almost-linear space usage and o(n) worst
case query time for points in $d>2$ dimensions. Finally, we present the first dynamic solution to both counting and reporting with $o(n)$ query time for $d\geq 2$ and $d\geq 3$ dimensions, respectively.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Università di Pisa
Authors: Grossi, R. (Ekstern), Vind, S. J. (Intern)
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Combining Formal Logic and Machine Learning for Sentiment Analysis
This paper presents a formal logical method for deep structural analysis of the syntactical properties of texts using machine learning techniques for efficient syntactical tagging. To evaluate the method it is used for entity level sentiment analysis as an alternative to pure machine learning methods for sentiment analysis, which often work on sentence or word level, and are argued to have difficulties in capturing long distance dependencies.

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Authors: Petersen, N. C. (Ekstern), Villadsen, J. (Intern)
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Compact q-gram profiling of compressed strings
We consider the problem of computing the q-gram profile of a string $T$ of size $N$ compressed by a context-free grammar with $n$ production rules. We present an algorithm that runs in $O(N-\alpha)$ expected time and uses $O(n+q+T_{\alpha})$ space, where $N-\alpha\leq N$ is the exact number of characters decompressed by the algorithm and $k_{T,\alpha}\leq N-\alpha$ is the number of distinct
q-grams in $T$. This simultaneously matches the current best known time bound and improves the best known space bound. Our space bound is asymptotically optimal in the sense that any algorithm storing the grammar and the q-gram profile must use $\Omega(n+q+KT,q)$ space. To achieve this we introduce the q-gram graph that space-efficiently captures the structure of a string with respect to its q-grams, and show how to construct it from a grammar.

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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.592 SNIP 1.123 CiteScore 1
Web of Science (2015): Indexed yes
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Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.717 SNIP 1.297 CiteScore 1.17
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.78 SNIP 1.21 CiteScore 1.16
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.747 SNIP 1.246 CiteScore 1.17
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Scopus rating (2010): SJR 0.839 SNIP 1.278
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.876 SNIP 1.434
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Scopus rating (2008): SJR 1.098 SNIP 1.587
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Scopus rating (2007): SJR 0.931 SNIP 1.576
Scopus rating (2006): SJR 0.834 SNIP 1.457
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.747 SNIP 1.438
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Compressed Subsequence Matching and Packed Tree Coloring

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Concentrated Hitting Times of Randomized Search Heuristics with Variable Drift

Drift analysis is one of the state-of-the-art techniques for the runtime analysis of randomized search heuristics (RSHs) such as evolutionary algorithms (EAs), simulated annealing etc. The vast majority of existing drift theorems yield bounds on the expected value of the hitting time for a target state, e.g., the set of optimal solutions, without making additional statements on the distribution of this time. We address this lack by providing a general drift theorem that includes bounds on the upper and lower tail of the hitting time distribution. The new tail bounds are applied to prove very precise sharp-concentration results on the running time of a simple EA on standard benchmark problems, including the class of general linear functions. The usefulness of the theorem outside the theory of RSHs is demonstrated by deriving tail bounds on the number of cycles in random permutations. All these results handle a position-dependent (variable) drift that was not covered by previous drift theorems with tail bounds. Moreover, our theorem can be specialized into virtually all existing drift theorems with drift towards the target from the literature. Finally, user-friendly specializations of the general drift theorem are given.

General information
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Epistemic and Doxastic Planning

This thesis is concerned with planning and logic, which are both core areas of Artificial Intelligence (AI). A wide range of research disciplines deal with AI, including philosophy, economy, psychology, neuroscience, mathematics and computer science. The approach of this thesis is based on mathematics and computer science. Planning is the mental capacity that
allow us to predict the outcome of our actions, thereby enabling us to exhibit goal-directed behaviour. We often make use of planning when facing new situations, where we cannot rely on entrenched habits, and the capacity to plan is therefore closely related to the reflective system of humans. Logic is the study of reasoning. From certain fixed principles logic enables us to make sound and rational inferences, and as such the discipline is virtually impossible to get around when working with AI.

The basis of automated planning, the term for planning in computer science, is essentially that of propositional logic, one of the most basic logical systems used in formal logic. Our approach is to expand this basis so that it is based on richer and more expressive logical systems. To this end we work with logics for describing knowledge, beliefs and dynamics, that is, systems that allow us to formally reason about these aspects. By letting these elements be used in a planning context, we obtain a system that extends the degree to which goaldirected behaviour can, at present, be captured by automated planning.

In this thesis we concretely apply dynamic epistemic logic to capture knowledge, and dynamic doxastic logic for capturing belief. We highlight two results of this thesis. The first pertains to how dynamic epistemic logic can be used to describe the (lack of) knowledge of an agent in the midst of planning. This perspective is already incorporated in automated planning, and seen in isolation this result appears mainly as an alternative to existing theory. Our second result underscores the strengths of the first. Here we show how the kinship between the aforementioned logics enable us to extend automated planning with doxastic elements. An upshot of expanding the basis of automated planning is therefore that it allows for a modularity, which facilitates the introduction of new aspects into automated planning. We round things off by describe what we consider to be the absolutely most fascinating perspective of this work, namely situations involving multiple agents. Reasoning about the knowledge and beliefs of others are essentially to acting rationally. It enables cooperation, and additionally forms the basis for engaging in a social context. Both logics mentioned above are formalized to deal with multiple agents, and the first steps have been taken towards extending automated planning with this aspect. Unfortunately, the first results in this line of research have shown that planning with multiple agents is computationally intractable, and additional work is therefore necessary in order to identify meaningful and tractable fragments.
Finite groups in which all nonabelian subgroups are TI-subgroups

In this paper, we show that G is a finite group in which every nonabelian subgroup is a TI-subgroup if and only if every nonabelian subgroup of G is normal in G.

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Scopus rating (2017): SNIP 0.906 SJR 0.69 CiteScore 0.5
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Finite Groups with Given Quantitative Non-Nilpotent Subgroups II

As an extension of Shi and Zhang's 2011 article [4], we prove that any finite group having at most 23 non-normal non-nilpotent proper subgroups is solvable except for $G \cong A_5$ or $\text{SL}(2, 5)$, and any finite group having at most three conjugacy classes of non-normal non-nilpotent proper subgroups is solvable except for $G \cong A_5$ or $\text{SL}(2, 5)$.

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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.632 SNIP 0.904 CiteScore 0.39
Fitness levels with tail bounds for the analysis of randomized search heuristics

The fitness-level method, also called the method of f-based partitions, is an intuitive and widely used technique for the running time analysis of randomized search heuristics. It was originally defined to prove upper and lower bounds on the expected running time. Recently, upper tail bounds were added to the technique; however, these tail bounds only apply to running times that are at least twice as large as the expectation. We remove this restriction and supplement the fitness-level method with sharp tail bounds, including lower tails. As an exemplary application, we prove that the running time of randomized local search on OneMax is sharply concentrated around $n\ln n - 0.1159...n$.

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Graph factors modulo $k$

We prove a general result on graph factors modulo $k$. A special case says that, for each natural number $k$, every $(12k-7)$-edge-connected graph with an even number of vertices contains a spanning subgraph in which each vertex has degree congruent to $k$ modulo $2k$.
Graph factors modulo k

If $F$ is a (possibly infinite) subset of an abelian group $\Gamma$, then we define $f(F,\Gamma)$ as the smallest natural number such that every $f(F,\Gamma)$-edge-connected (finite) graph $G$ has a flow where all flow values are elements in $F$. We prove that $f(F,\Gamma)$ exists if and only if some odd sum of elements in $F$ equals some even sum. We discuss various instances of this problem. We prove that every 14-edge-connected graph has a flow whose flow values are the five roots of unity in the complex plane. Any such flow is balanced modulo 5. So, if the edge-connectivity 14 can be reduced to 9, then the 5-flow conjecture follows, as observed by F. Jaeger. We use vector flow to prove that, for each odd natural number $k \geq 3$, every $(3k-1)$-edge-connected graph has a collection of $k$ even subgraphs such that every edge is in precisely $k-1$ of them. Finally, the flow result gives a considerable freedom to prescribe the flow values in the $(2+)$-flow conjecture by L. Goddyn and P. Seymour. For example, if $k$ is a natural number and $G$ is a 6$k$-edge-connected graph, then $G$ has a flow with flow values $1, 1+1/k$. It also has, for any irrational number $\alpha$, a flow with flow values $1, 1^+, 1^{++}1/k$.

**Group flow, complex flow, unit vector flow, and the (2+)-flow conjecture**

If $F$ is a (possibly infinite) subset of an abelian group $\Gamma$, then we define $f(F,\Gamma)$ as the smallest natural number such that every $f(F,\Gamma)$-edge-connected (finite) graph $G$ has a flow where all flow values are elements in $F$. We prove that $f(F,\Gamma)$ exists if and only if some odd sum of elements in $F$ equals some even sum. We discuss various instances of this problem. We prove that every 14-edge-connected graph has a flow whose flow values are the five roots of unity in the complex plane. Any such flow is balanced modulo 5. So, if the edge-connectivity 14 can be reduced to 9, then the 5-flow conjecture follows, as observed by F. Jaeger. We use vector flow to prove that, for each odd natural number $k \geq 3$, every $(3k-1)$-edge-connected graph has a collection of $k$ even subgraphs such that every edge is in precisely $k-1$ of them. Finally, the flow result gives a considerable freedom to prescribe the flow values in the $(2+)$-flow conjecture by L. Goddyn and P. Seymour. For example, if $k$ is a natural number and $G$ is a 6$k$-edge-connected graph, then $G$ has a flow with flow values $1, 1+1/k$. It also has, for any irrational number $\alpha$, a flow with flow values $1, 1^+, 1^{++}1/k$. 

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Scopus rating (2013): SJR 1.936 SNIP 1.918 CiteScore 1.19
We show how to compactly index video data to support fast motion detection queries. A query specifies a time interval $T$, an area $A$ in the video and two thresholds $v$ and $p$. The answer to a query is a list of timestamps in $T$ where $\geq p\%$ of $A$ has changed by $\geq v$ values. Our results show that by building a small index, we can support queries with a speedup of two to three orders of magnitude compared to motion detection without an index. For high resolution video, the index size is about 20% of the compressed video size.
**IS-A diversified**

We reconsider the nature and formal properties of the class inclusion relation, IS-A, from the point of view of information modeling and engineering of formal ontologies. In particular we review approaches to the elusive notion of intensionality. We then conduct an analysis adopting a metalogic setup where classes and properties are reified. This approach affords choices along the extensionality/intensionality spectrum. Our analysis concludes that the distinction between epistemic modes for distinguishing definitions, norms, hypotheses, and observational evidence is more important than the extensionality/intensionality dichotomy in ontological engineering.

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**MMAS vs. Population-based EA on a family of dynamic fitness functions**

We study the behavior of a population-based EA and the Max-Min Ant System (MMAS) on a family of deterministically-changing fitness functions, where, in order to find the global optimum, the algorithms have to find specific local optima within each of a series of phases. In particular, we prove that a (2+1) EA with genotype diversity is able to find the global optimum of the Maze function, previously considered by Kötzing and Molter (PPSN 2012, 113--122), in polynomial time. This is then generalized to a hierarchy result stating that for every μ, a (μ+1) EA with genotype diversity is able to track a Maze function extended over a finite alphabet of μ symbols, whereas population size μ-1 is not sufficient. Furthermore, we show that MMAS does not require additional modifications to track the optimum of the finite-alphabet Maze functions, and, using a novel drift statement to simplify the analysis, reduce the required phase length of the Maze function.

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Authors: Lissovoi, A. (Intern), Witt, C. (Intern)
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Multi-dimensional Type Theory: Rules, Categories and Combinators for Syntax and Semantics

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Authors: Villadsen, J. (Intern)
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Nash Equilibria in Symmetric Games with Partial Observation
We investigate a model for representing large multiplayer games, which satisfy strong symmetry properties. This model is made of multiple copies of an arena; each player plays in his own arena, and can partially observe what the other players do. Therefore, this game has partial information and symmetry constraints, which make the computation of Nash equilibria difficult. We show several undecidability results, and for bounded-memory strategies, we precisely characterize the complexity of computing pure Nash equilibria (for qualitative objectives) in this game model.

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Optimal decision procedures for satisfiability in fragments of alternating-time temporal logics
We consider several natural fragments of the alternating-time temporal logics ATL* and ATL with restrictions on the nesting between temporal operators and strategic quantifiers. We develop optimal decision procedures for satisfiability in these fragments, showing that they have much lower complexities than the full languages. In particular, we prove that the satisfiability problem for stateformulae in the full 'strategically at' fragment of ATL* is PSPACE-complete, whereas the satisfiability problems in the at fragments of ATL and ATL+ are \( \sum^P_3 \) complete. We note that the nesting hierarchies for fragments of ATL* collapse in terms of expressiveness above nesting depth 1, hence our results cover all such fragments with lower complexities.
Optimal Tableaux-Based Decision Procedure for Testing Satisfiability in the Alternating-Time Temporal Logic ATL+

We develop a sound, complete and practically implementable tableaux-based decision method for constructive satisfiability testing and model synthesis in the fragment ATL+ of the full Alternating time temporal logic ATL*. The method extends in an essential way a previously developed tableaux-based decision method for ATL and works in 2EXPTIME, which is the optimal worst case complexity of the satisfiability problem for ATL+. We also discuss how suitable parameterizations and syntactic restrictions on the class of input ATL+ formulae can reduce the complexity of the satisfiability problem.

Output-Sensitive Pattern Extraction in Sequences

Genomic Analysis, Plagiarism Detection, Data Mining, Intrusion Detection, Spam Fighting and Time Series Analysis are just some examples of applications where extraction of recurring patterns in sequences of objects is one of the main computational challenges. Several notions of patterns exist, and many share the common idea of strictly specifying some
parts of the pattern and to don’t care about the remaining parts. Since the number of patterns can be exponential in the length of the sequences, pattern extraction focuses on statistically relevant patterns, where any attempt to further refine or extend them causes a loss of significant information (where the number of occurrences changes). Output-sensitive algorithms have been proposed to enumerate and list these patterns, taking polynomial time $O(n^c)$ per pattern for constant $c > 1$, which is impractical for massive sequences of very large length $n$. We address the problem of extracting maximal patterns with at most $k$ don’t care symbols and at least $q$ occurrences. Our contribution is to give the first algorithm that attains a stronger notion of output-sensitivity, borrowed from the analysis of data structures: the cost is proportional to the actual number of occurrences of each pattern, which is at most $n$ and practically much smaller than $n$ in real applications, thus avoiding the aforementioned cost of $O(n^c)$ per pattern.

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Regaining the Square of Opposition in Formal Ontology Development
Use of formal ontologies is becoming widespread in information systems. Forerunners of formal ontologies are scientific classification systems such as the Linnaean biological ones. Unlike biological classifications modern formal ontologies are often non-hierarchical. A formal ontology in its basic form simply specifies all direct inclusion relationships between a finite repertoire of classes. Individuals may be conceived of as singleton classes. An assertion "P sub Q" states that class P is an immediate subclass of Q. These given relationships are often rendered as directed graphs. The subclass relationship induces a partial order relation corresponding to the relationship "all P are Q" in the square of opposition. Accordingly, so far, formal ontologies provide only assertions of the form "all P are Q". However, it is our contention that the three other assertion forms in the square of opposition come about implicitly by appropriate, often tacitly assumed default conventions as to be explained. Assume existential import so that all classes are considered non-empty, implying that there is no empty null class. Defaults: 1) Overlapping (i.e. non-disjoint) classes, viz. "some P are Q", has at least one common subclass. 2) Dually, classes are disjoint ("no P is Q") if they do not have a common subclass. 3) The assertion form "some P are not Q" is -- analogously to class overlap -- achieved by requiring that there be a subclass of P which is disjoint with Q. More radically this assertion may be held simply in the case that "all P are Q" does not hold. These default rules are routinely adopted in ontology development without mentioning. Appealing to these conventions, the 4 sentence forms in the square are effectively made at disposal. We discuss a first order metalogical formalization of the 4 sentence forms with classes reified as individual constants elucidating the logical relationships between the sentence forms. Our formalization appeals to non-provability. Non-provability incurs non-monotonicity, implying that extension of an ontology with additional subclass relationships may call for 86 retraction of derived square of opposition relationships. This reflects the crucial distinction between the closed world assumption (CWA) and the open world assumption (OWA).
Revised analysis of the (1+1) EA for the minimum spanning tree problem

We revisit the classical analysis of the (1+1) EA for the minimum spanning tree problem in the case that nothing is known about the weights of the underlying graph. Here the original upper bound on the expected running time by Neumann and Wegener [Theor. Comput. Sci. 378(1), 32-40, 2007], which depends on the largest weight of the graph, is of no use. The best upper bound available before in this case is due to Reichel and Skutella [FOGA 2009, 21-28] and is of order $O(m^3 \log n)$, where $m$ is the number of edges and $n$ the number of vertices. Using an adaptive drift analysis, we show the improved bound $O(m^2 (\sqrt{c(G)} + \log n))$, where $c(G)$ is the circumference (length of the longest cycle) of the graph. This is only by an asymptotic factor of at most $\frac{\sqrt{n}}{\log n}$ away from the classical lower bound. Furthermore, an alternative fitness function leading to the bound $O(m^2 \log n)$ is proposed, and limitations of the adaptive drift analysis are pointed out.

Robustness of Populations in Stochastic Environments

We consider stochastic versions of OneMax and Leading-Ones and analyze the performance of evolutionary algorithms with and without populations on these problems. It is known that the (1+1) EA on OneMax performs well in the presence of very small noise, but poorly for higher noise levels. We extend those results to LeadingOnes and to many different noise models, showing how the application of drift theory can significantly simplify and generalize previous analyses. Most surprisingly, even small populations (of size $(\log n)$) can make evolutionary algorithms perform well for high noise levels, well outside the abilities of the (1+1) EA! Larger population sizes are even more beneficial; we consider both parent and offspring populations. In this sense, populations are robust in these stochastic settings.
Seeing is Believing: Formalising False-Belief Tasks in Dynamic Epistemic Logic

In this paper we show how to formalise false-belief tasks like the Sally-Anne task and the second-order chocolate task in Dynamic Epistemic Logic (DEL). False-belief tasks are used to test the strength of the Theory of Mind (ToM) of humans, that is, a human's ability to attribute mental states to other agents. Having a ToM is known to be essential to human social intelligence, and hence likely to be essential to social intelligence of artificial agents as well. It is therefore important to find ways of implementing a ToM in artificial agents, and to show that such agents can then solve false-belief tasks. In this paper, the approach is to use DEL as a formal framework for representing ToM, and use reasoning in DEL to solve false-belief tasks. In addition to formalising several false-belief tasks in DEL, the paper introduces some extensions of DEL itself: edge-conditioned event models and observability propositions. These extensions are introduced to provide better formalisations of the false-belief tasks, but expected to have independent future interest.

String Indexing for Patterns with Wildcards

We consider the problem of indexing a string t of length n to report the occurrences of a query pattern p containing m characters and j wildcards. Let occ be the number of occurrences of p in t, and σ the size of the alphabet. We obtain the following results. A linear space index with query time O(m+σjloglog n+occ). This significantly improves the previously best known linear space index by Lam et al. (in Proc. 18th ISAAC, pp. 846-857, [2007]), which requires query time O(jn) in the worst case. An index with query time O(m+j+occ) using space (Mathematical expression), where k is the maximum number of wildcards allowed in the pattern. This is the first non-trivial bound with this query time. A time-space trade-off, generalizing the index by Cole et al. (in Proc. 36th STOC, pp. 91-100, [2004]). We also show that these indexes can be generalized to allow variable length gaps in the pattern. Our results are obtained using a novel combination of well-known and new techniques, which could be of independent interest.
Strongly 2-connected orientations of graphs
We prove that a graph admits a strongly 2-connected orientation if and only if it is 4-edge-connected, and every vertex-deleted subgraph is 2-edge-connected. In particular, every 4-connected graph has such an orientation while no cubic 3-connected graph has such an orientation.
Sublinear Space Algorithms for the Longest Common Substring Problem

Given $m$ documents of total length $n$, we consider the problem of finding a longest string common to at least $d \geq 2$ of the documents. This problem is known as the longest common substring (LCS) problem and has a classic $O(n)$ space and $O(n)$ time solution (Weiner [FOCS’73], Hui [CPM’92]). However, the use of linear space is impractical in many applications. In this paper we show that for any trade-off parameter $1 \leq \tau \leq n$, the LCS problem can be solved in $O(\tau)$ space and $O(n^2/\tau)$ time, thus providing the first smooth deterministic time-space trade-off from constant to linear space. The result uses a new and very simple algorithm, which computes a $\tau$-additive approximation to the LCS in $O(n^2/\tau)$ time and $O(1)$ space. We also show a time-space trade-off lower bound for deterministic branching programs, which implies that any deterministic RAM algorithm solving the LCS problem on documents from a sufficiently large alphabet in $O(\tau)$ space must use $\Omega(n\sqrt{\log(n/\tau \log n)})/\log \log(n/\tau \log n)$ time.

Substring Range Reporting

We revisit various string indexing problems with range reporting features, namely, position-restricted substring searching, indexing substrings with gaps, and indexing substrings with intervals. We obtain the following main results.
We give efficient reductions for each of the above problems to a new problem, which we call substring range reporting. Hence, we unify the previous work by showing that we may restrict our attention to a single problem rather than studying each of the above problems individually.

We show how to solve substring range reporting with optimal query time and little space. Combined with our reductions this leads to significantly improved time-space trade-offs for the above problems. In particular, for each problem we obtain the first solutions with optimal time query and \(O(\log O(1) n)\) space, where \(n\) is the length of the indexed string.

We show that our techniques for substring range reporting generalize to substring range counting and substring range emptiness variants. We also obtain non-trivial time-space trade-offs for these problems.

Our bounds for substring range reporting are based on a novel combination of suffix trees and range reporting data structures. The reductions are simple and general and may apply to other combinations of string indexing with range reporting.
Symmetry Reduction in Infinite Games with Finite Branching

Symmetry reduction has been applied extensively for verification of finite state concurrent systems and hardware designs using model-checking of the temporal logics LTL, CTL and CTL, as well as real-time and probabilistic system model-checking. In this paper we extend the technique to handle infinite-state games on graphs with finite branching where the objectives of the players can be very general. As particular applications, it is shown that the technique can be applied to reduce the state space in parity games as well as when doing model-checking of the Alternating-time temporal logic ATL.

Tetravalent one-regular graphs of order $4p^2$

A graph is one-regular if its automorphism group acts regularly on the set of its arcs. In this paper tetravalent one-regular graphs of order $4p^2$, where $p$ is a prime, are classified.
The AORTA Architecture: Integrating Organizational Reasoning in Jason

Open systems are characterized by a diversity of heterogeneous and autonomous agents that act according to private goals, and with a behavior that is hard to predict. They can be regulated through organizations similar to human organizations, which regulate the agents' behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization. In this paper, we propose the AORTA architecture for making agents organization-aware. It is designed such that it provides organizational reasoning capabilities to agents implemented in existing agent programming languages without being tied to a specific organizational model. We show how it can be integrated in the Jason agent programming language, and discuss how the agents can coordinate their organizational tasks using AORTA.

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The AORTA Architecture: Integrating Organizational Reasoning in Jason

Open systems are characterized by a diversity of heterogeneous and autonomous agents that act according to private goals, and with a behavior that is hard to predict. They can be regulated through organizations similar to human organizations, which regulate the agents' behavior space and describe the expected behavior of the agents. Agents need to be able to reason about the regulations, so that they can act within the expected boundaries and work towards the objectives of the organization. In this paper, we describe the AORTA (Adding Organizational Reasoning to Agents) architecture for making agents organization-aware. It is designed such that it provides organizational reasoning capabilities to agents implemented in existing agent programming languages without being tied to a specific organizational model. We show how it can be integrated in the Jason agent programming language, and discuss how the agents can coordinate their organizational tasks using AORTA.

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The dark side of interval temporal logic: marking the undecidability border

Unlike the Moon, the dark side of interval temporal logics is the one we usually see: their ubiquitous undecidability. Identifying minimal undecidable interval logics is thus a natural and important issue in that research area. In this paper, we identify several new minimal undecidable logics amongst the fragments of Halpern and Shoham's logic HS, including the logic of the overlaps relation, over the classes of all finite linear orders and all linear orders, as well as the logic of the meets and subinterval relations, over the classes of all and dense linear orders. Together with previous undecidability results, this work contributes to bringing the identification of the dark side of interval temporal logics very close to the definitive picture.

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Time–space trade-offs for longest common extensions

We revisit the longest common extension (LCE) problem, that is, preprocess a string $T$ into a compact data structure that supports fast LCE queries. An LCE query takes a pair $(i, j)$ of indices in $T$ and returns the length of the longest common prefix of the suffixes of $T$ starting at positions $i$ and $j$. We study the time–space trade-offs for the problem, that is, the space used for the data structure vs. the worst-case time for answering an LCE query. Let $n$ be the length of $T$. Given a parameter $\tau$, $1 \leq \tau \leq n$, we show how to achieve either $O(n/\tau)$ space and $O(\tau)$ query time, or $O(n/\tau)$ space and $O(\tau \log(|LCE(i, j)|/\tau))$ query time, where $|LCE(i, j)|$ denotes the length of the LCE returned by the query. These bounds provide the first smooth trade-offs for the LCE problem and almost match the previously known bounds at the extremes when $\tau = 1$ or $\tau = n$. We apply the result to obtain improved bounds for several applications where the LCE problem is the computational bottleneck, including approximate string matching and computing palindromes. We also present an efficient technique to reduce LCE queries on two strings to one string. Finally, we give a lower bound on the time–space product
for LCE data structures in the non-uniform cell probe model showing that our second trade-off is nearly optimal.

Towards optimal packed string matching

In the packed string matching problem, it is assumed that each machine word can accommodate up to $\alpha$ characters, thus an $n$-character string occupies $n/\alpha$ memory words. (a) We extend the Crochemore–Perrin constant-space $O(n)$-time string-matching algorithm to run in optimal $O(n/\alpha)$ time and even in real-time, achieving a factor $\alpha$ speedup over traditional algorithms that examine each character individually. Our macro-level algorithm only uses the standard AC0 instructions of the word-RAM model (i.e., no integer multiplication) plus two specialized micro-level AC0 word-size packed-string instructions. The main word-size string-matching instruction wssm is available in contemporary commodity processors. The other word-size maximum-suffix instruction wslm is only required during the pattern pre-processing. Benchmarks show that our solution can be efficiently implemented, unlike some prior theoretical packed string matching work. (b) We also consider the complexity of the packed string matching problem in the classical word-RAM model in the absence of the...
specialized micro-level instructions wssm and wslm. We propose micro-level algorithms for the theoretically efficient emulation using parallel algorithms techniques to emulate wssm and using the Four-Russians technique to emulate wslm. Surprisingly, our bit-parallel emulation of wssm also leads to a new simplified parallel random access machine string-matching algorithm. As a byproduct to facilitate our results we develop a new algorithm for finding the leftmost (most significant) 1 bits in consecutive non-overlapping blocks of uniform size inside a word. This latter problem is not known to be reducible to finding the rightmost 1, which can be easily solved, since we do not know how to reverse the bits of a word in O(1) time.

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ISI indexed (2012): ISI indexed yes
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BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.747 SNIP 1.246 CiteScore 1.17
ISI indexed (2011): ISI indexed yes
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Web of Science (2010): Indexed yes
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Scopus rating (2006): SJR 0.834 SNIP 1.457
Union-Find with Constant Time Deletions

A union-find data structure maintains a collection of disjoint sets under the operations makeset, union, and find. Kaplan, Shafir, and Tarjan [SODA 2002] designed data structures for an extension of the union-find problem in which items of the sets maintained may be deleted. The cost of a delete operation in their implementations is essentially the same as the cost of a find operation; namely, $O(\log n)$ worst-case and $O(\alpha_{M/N}(n))$ amortized, where $n$ is the number of items in the set returned by the find operation, $N$ is the total number of makeset operations performed, $M$ is the total number of find operations performed, and $\alpha_{M/N}(n)$ is a functional inverse of Ackermann's function. They left open the question whether delete operations can be implemented more efficiently than find operations, for example, in $o(\log n)$ worst-case time. We resolve this open problem by presenting a relatively simple modification of the classical union-find data structure that supports delete, as well as makeset and union operations, in constant worst-case time, while still supporting find operations in $O(\log n)$ worst-case time and $O(\alpha_{M/N}(n))$ amortized time. Our analysis supplies, in particular, a very concise potential-based amortized analysis of the standard union-find data structure that yields an $O(\alpha_{M/N}(n))$ amortized bound on the cost of find operations. All previous potential-based analyses yielded the weaker amortized bound of $O(\alpha_{M/N}(N))$. Furthermore, our tighter analysis extends to one-path variants of the path compression technique such as path splitting.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, University of Copenhagen, Octoshape ApS, Tel Aviv University
Authors: Alstrup, S. (Ekstern), Thorup, M. (Ekstern), Gørtz, I. L. (Intern), Rauhe, T. (Ekstern), Zwick, U. (Ekstern)
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BFI (2017): BFI-level 2
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.32 SNIP 1.951 CiteScore 2.1
Web of Science (2016): Indexed yes
A Comparison of Organization-Centered and Agent-Centered Multi-Agent Systems

Whereas most classical multi-agent systems have the agent in center, there has recently been a development towards focusing more on the organization of the system, thereby allowing the designer to focus on what the system goals are, without considering how the goals should be fulfilled.

We have developed and evaluated two teams of agents for a variant of the well-known Bomberman computer game. One team is based on the basic Jason system, which is an implementation in Java of an extension of the logic-based agent-oriented programming language AgentSpeak. The other team is based on the organizational model Moise+, which is combined with Jason in the middleware called J-Moise+.

We have investigated whether taking the organization-oriented approach had any clear advantages to the classical way of implementing multi-agent systems. Although not decisive the investigation did indicate that the agent-oriented approach has a number of advantages when it comes to game-like scenarios with just a few different character types.

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Organisations: Department of Applied Mathematics and Computer Science , Algorithms and Logic
Authors: Jensen, A. S. (Intern), Villadsen, J. (Intern)
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Main Research Area: Technical/natural sciences

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ISSN (Print): 1927-6974
Alternating-time temporal logic with finite-memory strategies

Model-checking the alternating-time temporal logics ATL and ATL* with incomplete information is undecidable for perfect recall semantics. However, when restricting to memoryless strategies the model-checking problem becomes decidable. In this paper we consider two other types of semantics based on finite-memory strategies. One where the memory size allowed is bounded and one where the memory size is unbounded (but must be finite). This is motivated by the high complexity of model-checking with perfect recall semantics and the severe limitations of memoryless strategies. We show that both types of semantics introduced are different from perfect recall and memoryless semantics and next focus on the decidability and complexity of model-checking in both complete and incomplete information games for ATL/ATL*. In particular, we show that the complexity of model-checking with bounded-memory semantics is Delta_2p-complete for ATL and PSPACE-complete for ATL* in incomplete information games just as in the memoryless case. We also present a proof that ATL and ATL* model-checking is undecidable for n >= 3 players with finite-memory semantics in incomplete information games.

A method to derive fixed budget results from expected optimisation times

At last year's GECCO a novel perspective for theoretical performance analysis of evolutionary algorithms and other randomised search heuristics was introduced that concentrates on the expected function value after a pre-defined number of steps, called budget. This is significantly different from the common perspective where the expected optimisation time is analysed. While there is a huge body of work and a large collection of tools for the analysis of the expected optimisation time the new fixed budget perspective introduces new analytical challenges. Here it is shown how results on the expected optimisation time that are strengthened by deviation bounds can be systematically turned into fixed budget results. We demonstrate our approach by considering the (1+1) EA on LeadingOnes and significantly improving previous results. We
prove that deviating from the expected time by an additive term of $\omega(n^{3/2})$ happens only with probability $o(1)$. This is turned into tight bounds on the function value using the inverse function. We use three, increasingly strong or general approaches to proving the deviation bounds, namely via Chebyshev’s inequality, via Chernoff bounds for geometric random variables, and via variable drift analysis.

**General information**

State: Published

Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Max Planck Institute, Aberystwyth University, University of Birmingham

Authors: Doerr, B. (Ekstern), Jansen, T. (Ekstern), Witt, C. (Intern), Zarges, C. (Ekstern)

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Main Research Area: Technical/natural sciences

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An Offer You Cannot Refuse: Obtaining Efficiency and Fairness in Preplay Negotiation Games with Conditional Offers

We study a recently introduced extension of normal form games with a phase before the actual play of the game, where each player can make binding offers for payments of utility to the other players after the play of the game, contingent on the recipient playing the strategy indicated in the offer. Such offers transform the payoff matrix of the original game and allow for some degree of cooperation between rational players while preserving the non-cooperative nature of the game. We focus on 2-player negotiations games arising in the preplay phase when offers for payments are made conditional on a suggested matching offer of the same kind being made in return by the receiver. We study and analyze such bargaining games, obtain results describing their possible solutions and discuss the degrees of efficiency and fairness that can be achieved in such negotiation process depending on whether time is valuable or not.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Imperial College London

Authors: Goranko, V. (Intern), Turrini, P. (Ekstern)

Pages: 110-123

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A Seligman-Style Tableau System

Proof systems for hybrid logic typically use @-operators to access information hidden behind modalities; this labeling approach lies at the heart of most resolution, natural deduction, and tableau systems for hybrid logic. But there is another,
less well-known approach, which we have come to believe is conceptually clearer. We call this Seligman-style inference, as it was first introduced and explored by Jerry Seligman in the setting of natural deduction and sequent calculus in the late 1990s. The purpose of this paper is to introduce a Seligman-style tableau system.

The most obvious feature of Seligman-style systems is that they work with arbitrary formulas, not just formulas prefixed by @-operators. To achieve this in a tableau system, we introduce a rule called GoTo which allows us to “jump to a named world” on a tableau branch, thereby creating a local proof context (which we call a block) on that branch. To the surprise of some of the authors (who have worked extensively on developing the labeling approach) Seligman-style inference is often clearer: not only is the approach more modular, individual proofs can be more direct. We briefly discuss termination and extensions to richer logics, and relate our system to Seligman’s original sequent calculus.

Belief Revision in the GOAL Agent Programming Language
Agents in a multiagent system may in many cases find themselves in situations where inconsistencies arise. In order to properly deal with these, a good belief revision procedure is required. This paper illustrates the usefulness of such a procedure: a certain belief revision algorithm is considered in order to deal with inconsistencies and, particularly, the issue of inconsistencies, and belief revision is examined in relation to the GOAL agent programming language.
Bioinspired computation in combinatorial optimization - Algorithms and their computational complexity

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Authors: Neumann, F. (Ekstern), Witt, C. (Intern)
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Bisimulation for Single-Agent Plausibility Models
Epistemic plausibility models are Kripke models agents use to reason about the knowledge and beliefs of themselves and each other. Restricting ourselves to the single-agent case, we determine when such models are indistinguishable in the logical language containing conditional belief, i.e., we define a proper notion of bisimulation, and prove that bisimulation corresponds to logical equivalence on image-finite models. We relate our results to other epistemic notions, such as safe belief and degrees of belief. Our results imply that there are only finitely many non-bisimilar single-agent epistemic plausibility models on a finite set of propositions. This gives decidability for single-agent epistemic plausibility planning.

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State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Universite de Lorraine
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BFI conference series: Australasian Joint Conference on Artificial Intelligence (5000495)
Main Research Area: Technical/natural sciences
Compact q-gram Profiling of Compressed Strings

We consider the problem of computing the q-gram profile of a string T of size N compressed by a context-free grammar with n production rules. We present an algorithm that runs in \( O(N - \alpha) \) expected time and uses \( O(n + k_T \cdot q) \) space, where \( N - \alpha = qn \) is the exact number of characters decompressed by the algorithm and \( k_T \cdot q \leq N - \alpha \) is the number of distinct q-grams in T. This simultaneously matches the current best known time bound and improves the best known space bound.

Our space bound is asymptotically optimal in the sense that any algorithm storing the grammar and the q-gram profile must use \( \Omega(n + k_T \cdot q) \) space. To achieve this we introduce the q-gram graph that space-efficiently captures the structure of a string with respect to its q-grams, and show how to construct it from a grammar.

Conceptual Pathway Querying of Natural Logic Knowledge Bases from Text Bases

We describe a framework affording computation of conceptual pathways between a pair of terms presented as a query to a text database. In this framework, information is extracted from text sentences and becomes represented in natural logic, which is a form of logic coming much closer to natural language than predicate logic. Natural logic accommodates a variety of scientific parlance, ontologies and domain models. It also supports a semantic net or graph view of the knowledge base. This admits computation of relationships between concepts simultaneously through pathfinding in the knowledge base graph and deductive inference with the stored assertions. We envisage use of the developed pathway functionality, e.g., within bio-, pharma-, and medical sciences for calculating bio-pathways and causal chains.
Deciding between Conflicting Influences

This paper investigates an approach of decision making internally in an agent where a decision is based on preference and expectation. The approach uses a logic for qualitative decision theory proposed by Boutilier to express such notions. To make readily use of this we describe a simple method for generating preference and expectation models that respect certain rules provided by the agents, and we briefly discuss how to integrate the approach into an existing agent programming language.
Decomposing a graph into bistars

Bárat and the present author conjectured that, for each tree $T$, there exists a natural number $k_T$ such that the following holds: If $G$ is a $k_T$-edge-connected graph such that $|E(T)|$ divides $|E(G)|$, then $G$ has a $T$-decomposition, that is, a decomposition of the edge set into trees each of which is isomorphic to $T$. The conjecture has been verified for infinitely many paths and for each star. In this paper we verify the conjecture for an infinite family of trees that are neither paths nor stars, namely all the bistars $S(k,k+1)$.
Decomposing graphs into paths of fixed length

Barát and Thomassen have conjectured that, for any fixed tree $T$, there exists a natural number $k_T$ such that the following holds: If $G$ is a $k_T$-edge-connected graph such that $|E(T)|$ divides $|E(G)|$, then $G$ has a $T$-decomposition. The conjecture is trivial when $T$ has one or two edges. Before submission of this paper, the conjecture had been verified only for two other trees: the paths of length 3 and 4, respectively. In this paper we verify the conjecture for each path whose length is a power of 2.
Diagrammatic Reasoning with Classes and Relationships

We present and discuss a diagrammatic visualization and reasoning language coming about by augmenting Euler diagrams with higraphs. The diagrams serve (hierarchical as well as trans-hierarchical) classification and specification of various logical relationships between classes. The diagrams rely on a well-defined underlying class-relationship logic, called CRL, being a fragment of predicate logic. The inference rules at the level of diagrams take form of simple diagrammatic ipso facto rules. The diagrams are intended for computerization by offering navigation and zooming facilities as known from road maps. As such they may facilitate ontological engineering, which often involves larger amounts of data. The underlying inference process is expressible in function-free definite clauses, datalog. We also discuss the relationship to similar diagram and logic proposals.
Dimensions of Organizational Coordination

It is hard, if not impossible, to assume anything about agents' behavior in a society with heterogeneous agents from different sources. Organizations are used to restrict and guide the agents' actions such that the global objectives of the society are achieved. We discuss how agents can be supported to include organizational objectives and constraints into their reasoning processes by considering two alternatives: agent reasoning and middleware regulation. We show how agents can use an organizational specification to achieve organizational objectives by delegating and coordinating their activities with other agents in the society, using the GOAL agent programming language and the OperA organizational model.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Delft University of Technology
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Engineering a Multi-Agent System in GOAL

We provide a brief description of the GOAL-DTU system, including the overall design, the tools and the algorithms that we used in the Multi-Agent Programming Contest 2013. We focus on a description of the strategies and on an analysis of the matches. We also evaluate our experiences with the GOAL agent programming language. Our strategies worked well in general and we earned a second place in the contest only losing to the winning team. Finally we provide some suggestions for future contests.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
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Pages: 329-338
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Evolutionary Algorithms for the Detection of Structural Breaks in Time Series

Detecting structural breaks is an essential task for the statistical analysis of time series, for example, for fitting parametric models to it. In short, structural breaks are points in time at which the behavior of the time series changes. Typically, no solid background knowledge of the time series under consideration is available. Therefore, a black-box optimization approach is our method of choice for detecting structural breaks. We describe a evolutionary algorithm framework which easily adapts to a large number of statistical settings. The experiments on artificial and real-world time series show that the algorithm detects break points with high precision and is computationally very efficient.

A reference implementation is available at the following address: http://www2.imm.dtu.dk/~pafi/SBX/launch.html

Fingerprints in Compressed Strings

The Karp-Rabin fingerprint of a string is a type of hash value that due to its strong properties has been used in many string algorithms. In this paper we show how to construct a data structure for a string S of size N compressed by a context-free grammar of size n that answers fingerprint queries. That is, given indices i and j, the answer to a query is the fingerprint of the substring S[i,j]. We present the first O(n) space data structures that answer fingerprint queries without decompressing any characters. For Straight Line Programs (SLP) we get O(logN) query time, and for Linear SLPs (an SLP derivative that captures LZ78 compression and its variations) we get O(loglogN) query time. Hence, our data structures has the same time and space complexity as for random access in SLPs. We utilize the fingerprint data structures to solve the longest common extension problem in query time O(logNlogℓ) and O(logℓloglogℓ + loglogN) for SLPs and Linear SLPs, respectively. Here, ℓ denotes the length of the LCE.
Finite groups in which some particular subgroups are TI-subgroups

We prove that G is a group in which all noncyclic subgroups are TI-subgroups if and only if all noncyclic subgroups of G are normal in G. Moreover, we classify groups in which all subgroups of even order are TI-subgroups.
Formalizing Theatrical Performances Using Multi-Agent Organizations
Theatrical performances usually follow strict scripts and actors are not allowed to deviate. A Danish theatrical group, Theater 770° Celsius, has invented a new method called In Real Life, in which only certain events in the storyline are specified and the actors are supposed to improvise to reach these events. The method bears a resemblance to multi-agent systems and we show how it can be formalized using the multi-agent organizational model OperA.

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Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
Authors: Jensen, A. S. (Intern), Spurkeland, J. S. (Ekstern), Villadsen, J. (Intern)
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How to Be Both Rich and Happy: Combining Quantitative and Qualitative Strategic Reasoning about Multi-Player Games
We propose a logical framework combining a game-theoretic study of abilities of agents to achieve quantitative objectives in multi-player games by optimizing payoffs or preferences on outcomes with a logical analysis of the abilities of players for achieving qualitative objectives of players, i.e., reaching or maintaining game states with desired properties. We enrich concurrent game models with payoffs for the normal form games associated with the states of the model and propose a quantitative extension of the logic ATL* enabling the combination of quantitative and qualitative reasoning.

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Authors: Bulling, N. (Ekstern), Goranko, V. (Intern)
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Hybridizing Evolutionary Algorithms with Opportunistic Local Search

There is empirical evidence that memetic algorithms (MAs) can outperform plain evolutionary algorithms (EAs). Recently the first runtime analyses have been presented proving the aforementioned conjecture rigorously by investigating Variable-Depth Search, VDS for short (Sudholt, 2008). Sudholt raised the question if there are problems where VDS performs badly. We answer this question in the affirmative in the following way. We analyze MAs with VDS, which is also known as Kernighan-Lin for the TSP, on an artificial problem and show that MAs with a simple first-improvement local search outperform VDS. Moreover, we show that the performance gap is exponential. We analyze the features leading to a failure of VDS and derive a new local search operator, coined Opportunistic Local Search, that can easily overcome regions of the search space where local optima are clustered. The power of this new operator is demonstrated on the Rastrigin function encoded for binary hypercubes. Our results provide further insight into the problem of how to prevent local search algorithms to get stuck in local optima from a theoretical perspective. The methods stem from discrete probability theory and combinatorics.

Improved Runtime Analysis of the Simple Genetic Algorithm

A runtime analysis of the Simple Genetic Algorithm (SGA) for the OneMax problem has recently been presented proving that the algorithm requires exponential time with overwhelming probability. This paper presents an improved analysis which overcomes some limitations of our previous one. Firstly, the new result holds for population sizes up to \( \mu = n^{1/4} \) which is an improvement up to a power of 2 larger. Secondly, we present a technique to bound the diversity of the population that does not require a bound on its bandwidth. Apart from allowing a stronger result, we believe this is a major improvement towards the reusability of the techniques in future systematic analyses of GAs. Finally, we consider the more natural SGA using selection with replacement rather than without replacement although the results hold for both algorithmic versions. Experiments are presented to explore the limits of the new and previous mathematical techniques.
Java to C: A Primer

This book is designed to be used as a quick introduction to C for programmers already familiar with Java. It is not a replacement for a reference book on C but is instead a supplement.

For the programmer already familiar with Java, the typical book on C requires the reader to wade through many details of already-familiar material. In this book, we quickly present the main concepts needed to begin writing serious programs in C, highlighting the differences between C and Java.

Metric propositional neighborhood logics on natural numbers

Interval logics formalize temporal reasoning on interval structures over linearly (or partially) ordered domains, where time intervals are the primitive ontological entities and truth of formulae is defined relative to time intervals, rather than time points. In this paper, we introduce and study Metric Propositional Neighborhood Logic (MPNL) over natural numbers. MPNL features two modalities referring, respectively, to an interval that is “met by” the current one and to an interval that “meets” the current one, plus an infinite set of length constraints, regarded as atomic propositions, to constrain the length of intervals. We argue that MPNL can be successfully used in different areas of computer science to combine qualitative and quantitative interval temporal reasoning, thus providing a viable alternative to well-established logical frameworks such as Duration Calculus. We show that MPNL is decidable in double exponential time and expressively complete with respect to a well-defined sub-fragment of the two-variable fragment $\text{FO2}[N,=,<,s]$ of first-order logic for linear orders with successor function, interpreted over natural numbers. Moreover, we show that MPNL can be extended in a natural way to cover full $\text{FO2}[N,=,<,s]$ , but, unexpectedly, the latter (and hence the former) turns out to be undecidable.
Multi-Agent Programming Contest 2013: The Teams and the Design of Their Systems

Five teams participated in the Multi-Agent Programming Contest in 2013: All of them gained experience in 2012 already. In order to better understand which paradigms they used, which techniques they considered important and how much work they invested, the organisers of the contest compiled together a detailed list of questions (circa 50). This paper collects all answers to these questions as given by the teams.
The main theorem of this paper provides partial results on some major open problems in graph theory, such as Tutte’s 3-flow conjecture (from the 1970s) that every 4-edge connected graph admits a nowhere-zero 3-flow, the conjecture of Jaeger, Linial, Payan and Tarsi (1992) that every 5-edge-connected graph is $\mathbb{Z}_3$-connected, Jaeger’s circular flow conjecture (1984) that for every odd natural number $k \geq 3$, every $(2k-2)$-edge-connected graph has a modulo $k$-orientation, etc. It was proved recently by Thomassen that, for every odd number $k \geq 3$, every $(2k^2+k)$-edge-connected graph $G$ has a modulo $k$-orientation; and every 8-edge-connected graph $G$ is $\mathbb{Z}_3$-connected and admits therefore a nowhere-zero 3-flow.

In the present paper, Thomassen’s method is refined to prove the following: For every odd number $k \geq 3$, every $(3k-3)$-edge-connected graph has a modulo $k$-orientation. As a special case of the main result, every 6-edge-connected graph is $\mathbb{Z}_3$-connected and admits therefore a nowhere-zero 3-flow. Note that it was proved by Kochol (2001) that it suffices to prove the 3-flow conjecture for 5-edge-connected graphs.
On Programming Organization-Aware Agents

Since it is difficult (or even impossible) to assume anything about the agents' behavior and goals in an open multi-agent system, it is often suggested that an organization is imposed upon the agents, which, by abstracting away from the...
agents, specifies boundaries and objectives that the agents, by enacting roles, are expected to adhere to. In practice, this is usually done by creating a middleware, which acts as a bridge between an organizational specification and the agents, often taking away too much of the agents’ autonomy. This project investigates how to make agents organization-aware, thus removing the middleware and letting the agents directly reason about the organization. In this paper, we discuss the results so far, and describe the future goals and research direction for the project.

On the Set of the Numbers of Conjugates of Noncyclic Proper Subgroups of Finite Groups
Let G be a finite group and (G) the set of the numbers of conjugates of noncyclic proper subgroups of G. We prove that (1) if |G| ≤ 2, then G is solvable, and (2) G is a nonsolvable group with |G| = 3 if and only if G≅PSL(2,5) or PSL(2,13) or SL(2,5) or SL(2,13).
Planning using dynamic epistemic logic: Correspondence and complexity

A growing community investigates planning using dynamic epistemic logic. Another framework based on similar ideas is knowledge-based programs as plans. Here we show how actions correspond in the two frameworks. We finally discuss fragments of DEL planning obtained by the restriction of event models. Fragments are separated by virtue of their computational complexity.

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Program Leadership from a Nordic Perspective - Program Leaders' Power to Influence Their Program

In this paper a continuation research at five technical universities in Nordic countries (N5T network) in 2012 is presented, where the aim was to find out how the program leaders conceived their function, role and mandate, and the work situations between the universities were compared. The previous research demonstrated that program leaders have quite different positions, strategies and methods when it comes to monitoring and developing their programs. In this paper, a deeper investigation is carried out of the (im-) possibilities to make real influence on the study courses that constitutes the respective Engineering study programs. Eight program leaders from the five N5T universities have been interviewed, and the analysis of these studies, has culminated in a model for the analysis of program leadership for Engineering education development.

Reimplementing a Multi-Agent System in Python

We provide a brief description of our Python-DTU system, including the overall design, the tools and the algorithms that we used in the Multi-Agent Programming Contest 2012, where the scenario was called Agents on Mars like in 2011. Our solution is an improvement of our Python-DTU system from last year. Our team ended in second place after winning at least one match against every opponent and we only lost to the winner of the tournament. We briefly describe our experiments with the Moise organizational model. Finally we propose a few areas of improvement, both with regards to our system and to the contest.
Reimplementing a Multi-Agent System in Python

We provide a brief description of our Python-DTU system, including the overall design, the tools and the algorithms that we used in the Multi-Agent Programming Contest 2012, where the scenario was called Agents on Mars like in 2011. Our solution is an improvement of our Python-DTU system from last year. Our team ended in second place after winning at least one match against every opponent and we only lost to the winner of the tournament. We briefly describe our experiments with the Moise organizational model. Finally we propose a few areas of improvement, both with regards to our system and to the contest.

Runtime analysis of ant colony optimization on dynamic shortest path problems

A simple ACO algorithm called λ-MMAS for dynamic variants of the single-destination shortest paths problem is studied by rigorous runtime analyses. Building upon previous results for the special case of 1-MMAS, it is studied to what extent an enlarged colony using $\lambda$ ants per vertex helps in tracking an oscillating optimum. It is shown that easy cases of oscillations can be tracked by a constant number of ants. However, the paper also identifies more involved oscillations that with overwhelming probability cannot be tracked with any polynomial-size colony. Finally, parameters of dynamic shortest-path problems which make the optimum difficult to track are discussed. Experiments illustrate theoretical findings and conjectures.
Sparse suffix tree construction in small space

We consider the problem of constructing a sparse suffix tree (or suffix array) for \(b\) suffixes of a given text \(T\) of length \(n\), using only \(O(b)\) words of space during construction. Attempts at breaking the naive bound of \(O(nb)\) time for this problem can be traced back to the origins of string indexing in 1968. First results were only obtained in 1996, but only for the case where the suffixes were evenly spaced in \(T\). In this paper there is no constraint on the locations of the suffixes. We show that the sparse suffix tree can be constructed in \(O(n \log_2 b)\) time. To achieve this we develop a technique, which may be of independent interest, that allows to efficiently answer \(b\) longest common prefix queries on suffixes of \(T\), using only \(O(b)\) space. We expect that this technique will prove useful in many other applications in which space usage is a concern. Our first solution is Monte-Carlo and outputs the correct tree with high probability. We then give a Las-Vegas algorithm which also uses \(O(b)\) space and runs in the same time bounds with high probability when \(b = O(\sqrt{n})\). Furthermore, additional tradeoffs between the space usage and the construction time for the Monte-Carlo algorithm are given.

Strategic games and truly playable effectivity functions

A well-known result in the logical analysis of cooperative games states that the so-called playable effectivity functions exactly correspond to strategic games. More precisely, this result states that for every playable effectivity function \(E\) there exists a strategic game that assigns to coalitions of players exactly the same power as \(E\), and every strategic game generates a playable effectivity function. While the latter direction of the correspondence is correct, we show that the former does not hold for a number of infinite state games. We point out where the original proof of correspondence goes wrong, and we present examples of playable effectivity functions for which no equivalent strategic game exists. Then, we characterize the class of truly playable effectivity functions, that do correspond to strategic games. Moreover, we discuss a construction that transforms any playable effectivity function into a truly playable one while preserving the power of most (but not all) coalitions. We also show that Coalition Logic (CL), a formalism used to reason about effectivity functions, is not expressive enough to distinguish between playable and truly playable effectivity functions, and we extend it to a logic that can make that distinction while still enjoying the good meta-logical properties of CL, such as finite axiomatization and
decidability via finite model property.
Strength of the reversible, garbage-free $2^k \pm 1$ multiplier

Recently, a reversible garbage-free $2^k \pm 1$ constant-multiplier circuit was presented by Axelsen and Thomsen. This was the first construction of a garbage-free, reversible circuit for multiplication with non-trivial constants. At the time, the strength, that is, the range of constants obtainable by cascading these circuits, was unknown. In this paper, we show that there exist infinitely many constants we cannot multiply by using cascades of $2^k \pm 1$-multipliers; in fact, there exist infinitely many primes we cannot multiply by. Using these results, we further provide an algorithm for determining whether one can multiply by a given constant using a cascade of $2^k \pm 1$-multipliers, and for generating the minimal cascade of $2^k \pm 1$-multipliers for an obtainable constant, giving a complete characterization of the problem. A table of minimal cascades for multiplying by small constants is provided for convenience.
Tableaux-Based Decision Method for Single-Agent Linear Time Synchronous Temporal Epistemic Logics with Interacting Time and Knowledge

Temporal epistemic logics are known, from results of Halpern and Vardi, to have a wide range of complexities of the satisfiability problem: from PSPACE, through non-elementary, to highly undecidable. These complexities depend on the choice of some key parameters specifying, inter alia, possible interactions between time and knowledge, such as synchrony and agents' abilities for learning and recall. In this work we develop practically implementable tableau-based decision procedures for deciding satisfiability in single-agent synchronous temporal-epistemic logics with interactions between time and knowledge. We discuss some complications that occur, even in the single-agent case, when interactions between time and knowledge are assumed and show how the method of incremental tableaux can be adapted to work in EXPSPACE, respectively 2EXPTIME, for these logics, thereby also matching the upper bounds obtained for them by Halpern and Vardi.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Roskilde University
Authors: Ajspur, M. (Forskerdatabase), Goranko, V. (Intern)
The hardness of the functional orientation 2-color problem

We consider the Functional Orientation 2-Color problem, which was introduced by Valiant in his seminal paper on holographic algorithms [SIAM J. Comput. 37(5) (2008), 1565-1594]. For this decision problem, Valiant gave a polynomial time holographic algorithm for planar graphs of maximum degree 3, and showed that the problem is NP-complete for planar graphs of maximum degree 10. A recent result on defective graph coloring by Corrêa et al. [Australas. J. Combin. 43 (2009), 219-230] implies that the problem is already hard for planar graphs of maximum degree 8. Together, these results leave open the hardness question for graphs of maximum degree between 4 and 7. We close this gap by showing that the answer is always yes for arbitrary graphs of maximum degree 5, and that the problem is NP-complete for planar graphs of maximum degree 6. Moreover, for graphs of maximum degree 5, we note that a linear time algorithm for finding a solution exists.
The maximum number of minimal codewords in an \([n, k]\)-code

We survey some upper and lower bounds on the function in the title, and make them explicit for \(n \leq 15\) and \(1 \leq k \leq 15\). Exact values are given for cycle codes of graphs for \(3 \leq n \leq 15\) and \(1 \leq k \leq 13\).
The analysis of randomized search heuristics on classes of functions is fundamental to the understanding of the underlying stochastic process and the development of suitable proof techniques. Recently, remarkable progress has been made in bounding the expected optimization time of a simple evolutionary algorithm, called (1+1) EA, on the class of linear functions. We improve the previously best known bound in this setting from \((1.39+o(1))en \ln n\) to \(en \ln n + O(n)\) in expectation and with high probability, which is tight up to lower-order terms. Moreover, upper and lower bounds for arbitrary mutation probabilities \(p\) are derived, which imply expected polynomial optimization time as long as \(p = O((\ln n)/n)\) and \(p = \Omega(n^{-C})\) for a constant \(C > 0\), and which are tight if \(p = c/n\) for a constant \(c > 0\). As a consequence, the standard mutation probability \(p = 1/n\) is optimal for all linear functions, and the (1+1) EA is found to be an optimal mutation-based algorithm. Furthermore, the algorithm turns out to be surprisingly robust since the large neighbourhood explored by the mutation operator does not disrupt the search.
Time-Space Trade-Offs for the Longest Common Substring Problem

The Longest Common Substring problem is to compute the longest substring which occurs in at least $d \geq 2$ of $m$ strings of total length $n$. In this paper we ask the question whether this problem allows a deterministic time-space trade-off using $O(n^{1+\varepsilon})$ time and $O(n^{1-\varepsilon})$ space for $0 \leq \varepsilon \leq 1$. We give a positive answer in the case of two strings ($d = m = 2$) and $0 < \varepsilon \leq 1/3$. In the general case where $2 \leq d \leq m$, we show that the problem can be solved in $O(n^{1-\varepsilon})$ space and $O(n^{1+\varepsilon} \log 2n (d \log 2n + d^2))$ time for any $0 \leq \varepsilon < 1/3$. 
Tree compression with top trees

We introduce a new compression scheme for labeled trees based on top trees [3]. Our compression scheme is the first to simultaneously take advantage of internal repeats in the tree (as opposed to the classical DAG compression that only exploits rooted subtree repeats) while also supporting fast navigational queries directly on the compressed representation.

We show that the new compression scheme achieves close to optimal worst-case compression, can compress exponentially better than DAG compression, is never much worse than DAG compression, and supports navigational queries in logarithmic time.
Undecidability in Epistemic Planning
Dynamic epistemic logic (DEL) provides a very expressive framework for multi-agent planning that can deal with nondeterminism, partial observability, sensing actions, and arbitrary nesting of beliefs about other agents' beliefs. However, as we show in this paper, this expressiveness comes at a price. The planning framework is undecidable, even if we allow only purely epistemic actions (actions that change only beliefs, not ontic facts). Undecidability holds already in the S5 setting with at least 2 agents, and even with 1 agent in S4. It shows that multi-agent planning is robustly undecidable if we assume that agents can reason with an arbitrary nesting of beliefs about beliefs. We also prove a corollary showing undecidability of the DEL model checking problem with the star operator on actions (iteration).

When do evolutionary algorithms optimize separable functions in parallel?
Separable functions are composed of subfunctions that depend on mutually disjoint sets of bits. These subfunctions can be optimized independently, however in black-box optimization this direct approach is infeasible as the composition of subfunctions may be unknown. Common belief is that evolutionary algorithms make progress on all subfunctions in parallel, so that optimizing a separable function does not take not much longer than optimizing the hardest subfunction—subfunctions are optimized "in parallel." We show that this is only partially true, already for the simple (1+1) evolutionary algorithm (1+1) EA. For separable functions composed of k Boolean functions indeed the optimization time is the maximum optimization time of these functions times a small $O(\log k)$ overhead. More generally, for sums of weighted subfunctions that each attain non-negative integer values less than $r = o(\log^{1/2} n)$, we get an overhead of $O(r \log n)$. However, the hoped for parallel optimization behavior does not always come true. We present a separable function with $k \leq \sqrt{n}$ subfunctions such that the (1+1) EA is likely to optimize many subfunctions sequentially. The reason is that standard mutation leads to interferences between search processes on different subfunctions. Under mild assumptions, we show that such a sequential optimization behavior is worst possible. Copyright © 2013 ACM.
Implementing a Multi-Agent System in Python

We describe the solution used by the Python-DTU team in the Multi-Agent Programming Contest 2011, where the scenario was called Agents on Mars. We present our auction-based agreement, area controlling and pathfinding algorithms and discuss our chosen strategy and our choice of technology used for implementing the system. Finally, we present an analysis of the results of the competition as well as propose areas of improvement.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Department of Informatics and Mathematical Modeling, Algorithms and Logic
Authors: Ettienne, M. B. (Intern), Vester, S. (Intern), Villadsen, J. (Intern)
Pages: 147-179
Publication date: 2012

Host publication information
Title of host publication: Multi-Agent Programming Contest 2011 Edition Evaluation and Team Descriptions
Publisher: Technische Universität Clausthal
Editors: Behrens, T., Dix, J., Köster, M., Schlesinger, F.

Series: IfI Technical Report Series
Number: IfI-12-02
ISSN: 1860-8477
Main Research Area: Technical/natural sciences
Links:
http://www.in.tu-clausthal.de/fileadmin/homes/techreports/ifi1202behrens.pdf
Publication: Research - peer-review › Report chapter – Annual report year: 2012

Implementing a Multi-Agent System in Python with an Auction-Based Agreement Approach

We describe the solution used by the Python-DTU team in the Multi-Agent Programming Contest 2011, where the scenario was called Agents on Mars. We present our auction-based agreement algorithm and discuss our chosen strategy and our choice of technology used for implementing the system. Finally, we present an analysis of the results of the competition as well as propose areas of improvement.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Algorithms and Logic, Department of Informatics and Mathematical Modeling, Algorithms and Logic, Computer Science and Engineering
Authors: Ettienne, M. B. (Intern), Vester, S. (Intern), Villadsen, J. (Intern)
Pages: 185-196
Publication date: 2012

Host publication information
Title of host publication: Programming Multi-Agent Systems: 9th International Workshop, ProMAS 2011 Taipei, Taiwan, May 3, 2011 Revised Selected Papers
Publisher: Springer
ISBN (Print): 978-3-642-31914-3
ISBN (Electronic): 978-3-642-31915-0

Series: Lecture Notes in Artificial Intelligence
Volume: 7217
ISSN: 0302-9743
BFI conference series: International Workshop on Programming Multi-Agent Systems (5000476)
Main Research Area: Technical/natural sciences
Workshop: 9th International Workshop on Programming Multi-Agent Systems, ProMAS2011, Taipei, Taiwan, Province of China, 03/05/2011

DOI:
10.1007/978-3-642-31915-0_11
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012
Multi-Agent Programming Contest 2012 - The Python-DTU Team
We provide a brief description of the Python-DTU system, including the overall design, the tools and the algorithms that we plan to use in the agent contest.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Algorithms and Logic, Department of Applied Mathematics and Computer Science, Algorithms and Logic, Technical University of Denmark
Authors: Villadsen, J. (Intern), Jensen, A. S. (Intern), Ettienne, M. B. (Intern), Vester, S. (Intern), Balsiger Andersen, K. (Ekstern), Frostig, A. (Ekstern)
Number of pages: 4
Publication date: 2012

Publication information
Publisher: Technical University of Denmark (DTU)
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
1210.0437v1.pdf
Links:
http://arxiv.org/pdf/1210.0437v1
http://multiagentcontest.org/
Source: dtu
Source-ID: u::6505
Publication: Research - peer-review › Report – Annual report year: 2012

Multi-Agent Programming Contest 2011 - The Python-DTU Team
We provide a brief description of the Python-DTU system, including the overall design, the tools and the algorithms that we plan to use in the agent contest.

General information
State: Published
Organisations: Algorithms and Logic, Department of Informatics and Mathematical Modeling, Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Villadsen, J. (Intern), Ettienne, M. B. (Intern), Vester, S. (Intern)
Number of pages: 4
Publication date: 2011

Publication information
Publisher: Technical University of Denmark (DTU)
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
4D93Ed01.pdf
Links:
http://arxiv.org/abs/1110.0105
http://multiagentcontest.org/
Source: orbit
Source-ID: 316093
Publication: Research - peer-review › Report – Annual report year: 2011

GeneWiz browser: An Interactive Tool for Visualizing Sequenced Chromosomes
We present an interactive web application for visualizing genomic data of prokaryotic chromosomes. The tool (GeneWiz browser) allows users to carry out various analyses such as mapping alignments of homologous genes to other genomes, mapping of short sequencing reads to a reference chromosome, and calculating DNA properties such as curvature or stacking energy along the chromosome. The GeneWiz browser produces an interactive graphic that enables zooming from a global scale down to single nucleotides, without changing the size of the plot. Its ability to disproportionally zoom provides optimal readability and increased functionality compared to other browsers. The tool allows the user to select the display of various genomic features, color setting and data ranges. Custom numerical data can be added to the plot, allowing for example visualization of gene expression and regulation data. Further, standard atlases are pre-generated for all prokaryotic genomes available in GenBank, providing a fast overview of all available genomes, including recently deposited genome sequences. The tool is available online from http://www.cbs.dtu.dk/services/gwBrowser. [Supplemental material including interactive atlases is available online at http://www.cbs.dtu.dk/services/gwBrowser/suppl/].
**General information**

State: Published
Organisations: Center for Biological Sequence Analysis, Department of Systems Biology, Department of Applied Mathematics and Computer Science, Algorithms and Logic
Authors: Hallin, P. F. (Intern), Staerfeldt, H. H. (Intern), Rotenberg, E. (Intern), Binnewies, T. T. (Intern), Benham, C. (Ekstern), Ussery, D. (Intern)
Pages: 204-215
Publication date: 2009
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Standards in Genomic Research
Volume: 1
Issue number: 2
ISSN (Print): 1944-3277
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- Web of Science (2018): Indexed yes
- Scopus rating (2017): SNIP 0.629 SJR 0.768 CiteScore 1.69
- Web of Science (2017): Indexed Yes
- Scopus rating (2016): CiteScore 1.26 SJR 0.626 SNIP 0.511
- Web of Science (2016): Indexed yes
- Scopus rating (2015): SJR 1.12 SNIP 0.917 CiteScore 2.41
- Web of Science (2015): Indexed yes
- Scopus rating (2014): SJR 0.954 SNIP 0.448 CiteScore 1.3
- Web of Science (2014): Indexed yes
- Scopus rating (2013): SJR 1.206 SNIP 0.819 CiteScore 2.89
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- Scopus rating (2012): SJR 0.847 SNIP 0.516 CiteScore 1.81
- ISI indexed (2012): ISI indexed no
- Scopus rating (2011): SJR 0.516 SNIP 0.303 CiteScore 1.42
- ISI indexed (2011): ISI indexed no
- Scopus rating (2010): SJR 0.344 SNIP 0.285
- Original language: English
- Electronic versions:
  - 28_912_3_PB.pdf
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  - 10.4056/sigs.28177

**Bibliographical note**

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Source: orbit
Source-ID: 258913
Publication: Research - peer-review › Journal article – Annual report year: 2009

**Projects:**

**GÉANT Project**

The GÉANT project is a truly Pan-European collaboration between 41 National Research and Education Networks and their joint organisations NORDUnet and GÉAN, placing Europe at the forefront of high performance networking and AAI.

Department of Applied Mathematics and Computer Science

Algorithms and Logic
Period: 01/05/2016 → 31/12/2018
Number of participants: 1
High speed networking
Acronym: GN4-2
Project participant:
Olesen, Dorte (Intern)
Activities:

**ARQNL 2018**

Period: 18 Jul 2018
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic

**Description**
Formalization of a Paraconsistent Infinite-Valued Logic

**Speaker:** Anders Schlichtkrull

**Abstract:** Classical logics are explosive -- from a contradiction everything follows. This is problematic e.g. when reasoning about contradictory evidence. In paraconsistent logics everything does not follow from a contradiction. In this paper, formalized proofs of two meta-theorems about a propositional fragment of a paraconsistent infinite-valued higher-order logic are presented. One implies that the validity of any formula can be decided by considering a finite number of truth values and evaluating the formula in all models over these. The other implies that there is no upper bound on the size of this finite set -- it depends on the number of propositional symbols in the formula.

Talk "Formalization of a Paraconsistent Infinite-Valued Logic" at ARQNL 2018 in Oxford

**Related event**

**ARQNL 2018: Automated Reasoning in Quantified Non-Classical Logics 3rd International Workshop**
18/07/2018 → …
Oxford, United Kingdom
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

**Local Isabelle Workshop**

Period: 6 Jun 2018
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic

**Description**
Drawing Trees

**Speaker:** Anders Schlichtkrull (joint work with Andreas Halkjær From and Jørgen Villadsen)

Talk "Drawing Trees" at the Local Isabelle Workshop at DTU

**Related event**

**Local Isabelle Workshop**
06/06/2018 → …
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

**Phd Bazaar 2018 DTU Compute**

Period: 9 May 2018
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic

**Description**
IsaFoL - Isabelle Formalization of Logic - a brief overview
Speaker: Anders Schlichtkrull

Talk "IsaFoL - Isabelle Formalization of Logic - a brief overview" at Phd Bazaar 2018 DTU Compute

Related event

Phd Bazaar 2018 DTU Compute
09/05/2018 – …
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Talk in the Computational Logic Group at the University of Innsbruck
Period: 1 Mar 2018
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic

Description
IsaFoL - Isabelle Formalization of Logic - An Overview

Speaker: Anders Schlichtkrull

Abstract: IsaFoL is the Isabelle Formalization of Logic — a project that aims to develop libraries of lemmas and methods for formalizing research on logic. The project contains formalizations of several logics and tools. Examples are: first-order resolution, a first-order proof assistant, SAT solving and a paraconsistent logic. I give an overview of IsaFoL and go into details on the formalization of first-order resolution.

Talk "IsaFoL - Isabelle Formalization of Logic - An Overview" in the Computational Logic Group of the Department of Computer Science at the University of Innsbruck.

Related event

Talk in the Computational Logic Group at the University of Innsbruck
01/03/2018 – …
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Proof Assistants and Related Tools - The PART & PART 2 Projects 2017
Period: 9 Nov 2017
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic

Description
IsaFoL - Isabelle Formalization of Logic - A Brief Overview

Talk "IsaFoL - Isabelle Formalization of Logic - A Brief Overview"

Related event

Proof Assistants and Related Tools - The PART & PART 2 Projects 2017
07/09/2017 – 07/09/2017
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

TCS and PAM seminar
Period: 3 Nov 2017
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Algorithms and Logic
Abstract:
This is joint work with Jasmin Christian Blanchette, Dmitriy Traytel and Uwe Waldmann. We present a formalization of the first half of Bachmair and Ganzinger's chapter on resolution theorem proving in Isabelle/HOL, culminating with a refutationally complete first-order prover based on ordered resolution with literal selection. We develop general infrastructure and methodology that can form the basis of completeness proofs for related calculi (e.g., superposition). Our work clarifies several fine points in the chapter's text, emphasizing the value of formal proofs in the field of automated reasoning.

Talk at the TCS and PAM seminar of the Theoretical Computer Science group at the Vrije Universiteit Amsterdam.

Related event

TCS and PAM seminar
03/11/2017 → …
Amsterdam, Netherlands
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Proof Assistants and Related Tools - The PART & PART 2 Projects 2017
Period: 7 Sep 2017
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science

Description
Anders Schlichtkrull (joint work with Jasmin Christian Blanchette, Dmitriy Traytel and Uwe Waldmann): Formalization of an Ordered Resolution Prover in Isabelle/HOL

Talk "Formalization of an Ordered Resolution Prover in Isabelle/HOL" at PART

Related event

Proof Assistants and Related Tools - The PART & PART 2 Projects 2017
07/09/2017 → 07/09/2017
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

MAS & HOL
Period: 28 Sep 2016
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science

Description
Formalization of Algorithms and Logical inference Systems in Proof Assistants

Talk "Formalization of Algorithms and Logical inference Systems in Proof Assistants"

Related event

MAS & HOL
28/09/2016 → …
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Club2
Period: 11 May 2016
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science
Description
Formalization of the Resolution Calculus for First-Order Logic

Speaker: Anders Schlichtkrull

Abstract: A formalization in Isabelle/HOL of the resolution calculus for first-order logic is presented. Its soundness and completeness are formally proven using the substitution lemma, semantic trees, Herbrand's theorem, and the lifting lemma. In contrast to previous formalizations of resolution, it considers first-order logic with full first-order terms, instead of the propositional case.

Talk "Formalization of the Resolution Calculus for First-Order Logic" at Club2 of the Chair for Logic and Verification at the Technical University of Munich

Related event

Club2
11/05/2016 → …
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Proof Assistants and Related Tools - The PART & PART 2 Projects 2016
Period: 20 Apr 2016
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science

Description
Jørgen Villadsen & Anders Schlichtkrull: Computer-Checked Logical Inference Systems

Talk "Computer-Checked Logical Inference Systems" at PART

Related event

Proof Assistants and Related Tools - The PART & PART 2 Projects 2016
20/04/2016 → 20/04/2016
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Proof Assistants and Related Tools - The PART & PART 2 Projects 2015
Period: 23 Sep 2015
Anders Schlichtkrull (Participant)
Department of Applied Mathematics and Computer Science

Description
Formalization of Resolution Calculus in Isabelle

Talk "Formalization of Resolution Calculus in Isabelle" at PART

Related event

Proof Assistants and Related Tools - The PART & PART 2 Projects 2015
23/09/2015 → 24/09/2015
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Press clippings:
Google-computers triumf er et lille skridt mod store samfundsomvæltninger
Thomas Bolander
16/03/2016
Department of Applied Mathematics and Computer Science, Algorithms and Logic

De fleste har jo tre-fire milliarder linjer kunstig intelligens-kode i lommen
Thomas Bolander
15/02/2016
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Dagen gryr for kunstig intelligens på de finansielle markeder
Thomas Bolander
08/02/2016
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Nu tager robotterne også specialistjob
Thomas Bolander
29/01/2016
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Om Star Wars, robotter og kunstig intelligens
Thomas Bolander
16/12/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Om Star Wars, robotter og kunstig intelligens
16/12/2015
TV2 News, Television
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Har din robot forstået dig i dag?
Thomas Bolander
30/10/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Har din robot forstået dig i dag?
30/10/2015
Ingeniører, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Media contribution (1)

Skal vi frygte robotter?
Thomas Bolander
02/08/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Skal vi frygte robotter?
02/08/2015
BT, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Media contribution (1)

Memristor-hjerne kan revolutionere kunstig intelligens
Thomas Bolander
15/05/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Memristor-hjerne kan revolutionere kunstig intelligens
15/05/2015
videnskab.dk, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Media contribution (1)

Om Blade Runner og menneskelig vs. kunstig intelligens
Thomas Bolander
07/05/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Om Blade Runner og menneskelig vs. kunstig intelligens
07/05/2015
DR P1, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media
Kunstig intelligens får højere IQ
Thomas Bolander
07/04/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Media contribution (1)

Skal vi bekymrede for udviklingen indenfor kunstig intelligens?
Thomas Bolander
12/03/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Media contribution (1)

Om DeepMind og kunstig intelligens
Thomas Bolander
03/03/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Media contribution (1)

Glem dommedagsprofetierne om kunstig intelligens
Thomas Bolander
13/02/2015
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Media contribution (1)

Når våben bestemmer over liv og død
Thomas Bolander
19/12/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Media contribution (1)
Når våben bestemmer over liv og død
19/12/2014
Ingeniøren, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

DR2 Dagen
Thomas Bolander
20/10/2014

Subject
Om kunstig intelligens og fremtidens robotter
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kunstig intelligens og fremtidens robotter
Thomas Bolander
20/10/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kulturen på NEWS: Computeren har narret mennesket
Thomas Bolander
06/10/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

AK24syv på Radio 24syv: Om sociale robotter og etik
Thomas Bolander
17/09/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)
AK24syv på Radio 24syv: Om sociale robotter og etik
17/09/2014
Radio 24syv, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science , Algorithms and Logic , Office for Study Programmes and Student Affairs
Press / Media

Om sociale robotter og etik
Thomas Bolander
17/09/2014
Department of Applied Mathematics and Computer Science , Algorithms and Logic

Media contribution (1)

Om fremtidens dræberrobotter
Thomas Bolander
09/09/2014
Department of Applied Mathematics and Computer Science , Algorithms and Logic

Media contribution (1)

Ghandi på P3: Om fremtidens dræberrobotter
Thomas Bolander
09/09/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science , Algorithms and Logic

Media contribution (1)

Computeren har nærret mennesket
Thomas Bolander
10/06/2014
Department of Applied Mathematics and Computer Science , Algorithms and Logic

Media contribution (1)

Computeren har nærret mennesket
10/06/2014
Television
Thomas Bolander
Computer består afgørende mennesketest
Thomas Bolander
10/06/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Computer består afgørende mennesketest
10/06/2014
Berlingske, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Supercomputer narrer menneske
Thomas Bolander
10/06/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Supercomputer narrer menneske
10/06/2014
Radio 24syv, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Computer består afgørende mennesketest
Thomas Bolander
10/06/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

24syv Morgen: Supercomputer narrer menneske
Thomas Bolander
10/06/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

24syv Morgen: Supercomputer narrer menneske
10/06/2014
Radio 24syv, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs

Press / Media
Thomas Bolander på self-reference og agent introspection
Thomas Bolander
13/04/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Thomas Bolander på self-reference og agent introspection
13/04/2014
Blog of MIRI, Machine Intelligence Research Institute, Web
https://intelligence.org/2014/04/13/thomas-bolander/
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Hvordan bestemmes sudokuers sværhedsgrad?
Thomas Bolander
16/03/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Hvordan bestemmes sudokuers sværhedsgrad?
16/03/2014
Jyllands-Posten, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Hvordan bestemmes sudokuers sværhedsgrad?
Thomas Bolander
16/03/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Hvordan bestemmes sudokuers sværhedsgrad?
16/03/2014
Jyllands-Posten, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs
Press / Media

IBM satser på kommerciel kunstig intelligens
Thomas Bolander
11/03/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

IBM satser på kommerciel kunstig intelligens
11/03/2014
DR P1, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Orientering på P1: IBM satser på kommerciel kunstig intelligens
Thomas Bolander
11/03/2014
Orientering på P1: IBM satser på kommerciel kunstig intelligens
11/03/2014
P1, Radio
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs
Press / Media

Intelligens og maskiner
Thomas Bolander
05/03/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Apropos på P1: Intelligens og maskiner
Thomas Bolander
05/03/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Når robotten bliver en ven
Thomas Bolander
28/02/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

DR2 Dagen: Når robotten bliver en ven
Thomas Bolander
28/02/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media
DR2 Dagen: Når robotten bliver en ven
28/02/2014
DR2, Television
Thomas Bolander
Algorithms and Logic, Department of Applied Mathematics and Computer Science, Office for Study Programmes and Student Affairs
Press / Media

Drop kæresten - elsk dit styresystem i stedet
27/02/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Drop kæresten - elsk dit styresystem i stedet
27/02/2014
Politiken, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic
Press / Media

Drop kæresten - elsk dit styresystem i stedet
27/02/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kan man elske sit styresystem
26/02/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kan man elske sit styresystem
26/02/2014
Information, Print
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs
Press / Media

Kan man elske sit styresystem?
26/02/2014
Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kan man elske sit styresystem?
26/02/2014
Kultursøndag på P1: Om kunstig intelligens i sociale medier
Thomas Bolander
10/02/2014
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Kultursøndag på P1: Om kunstig intelligens i sociale medier
10/02/2014
P1, Radio
Thomas Bolander
Algorithms and Logic, Department of Applied Mathematics and Computer Science, Office for Study Programmes and Student Affairs

AK 24syv
Thomas Bolander
03/02/2014

Subject
Om kunstig intelligens og Spike Jonze-filmen "Her" ("Hende").
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

AK 24syv
03/02/2014
Radio 24syv, Radio
http://arkiv.radio24syv.dk/video/9308414/ak-24syv-03-02-2014-1
Thomas Bolander
Algorithms and Logic, Department of Applied Mathematics and Computer Science, Office for Study Programmes and Student Affairs

Videnskabens Verden på P1
Thomas Bolander
22/10/2013

Subject
Robotter, kunstig intelligens og social perspektivtagning.
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Videnskabens Verden på P1
22/10/2013
P1, Radio
1 time
http://www.dr.dk/radio/ondemand/p1/videnskabens-verden-85#!/22:00
Thomas Bolander
Algorithms and Logic, Department of Applied Mathematics and Computer Science, Office for Study Programmes and Student Affairs

Press / Media

Hjemekassen på P1
Thomas Bolander
15/04/2013

Subject
Kunstig intelligens
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Hjernekassen på P1
15/04/2013
DR P1, Radio
Peter Lund Madsen
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs
Press / Media

Vitek
Thomas Bolander
20/03/2013

Subject
Hjerneforskning og kunstig intelligens
Office for Study Programmes and Student Affairs, Department of Applied Mathematics and Computer Science, Algorithms and Logic

Media contribution (1)

Vitek
20/03/2013
DR2, Television
Thomas Bolander
Department of Applied Mathematics and Computer Science, Algorithms and Logic, Office for Study Programmes and Student Affairs
Press / Media