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.) 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.
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:

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

Parallel Evolutionary Algorithms on Maze. We prove that while a $(1 + \lambda)$ EA is unable to track the optimum of the dynamic fitness function Maze for offspring population size up to $\lambda = O(n^{1-\varepsilon})$, a simple island model with $\Omega(\log n)$ 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.

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$(1+1)$ 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.

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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 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.
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.

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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