Convolutional Neural Networks - Generalizability and Interpretations

Sufficient data is key when training Machine Learning algorithms in order to obtain models that generalize for operational use. Sometimes sufficient data is infeasible to obtain and this prevents the use of Machine Learning in many applications. The goal of this thesis is to gain insights and learn from data despite it being limited in amount or context representation. Within Machine Learning this thesis focuses on Convolutional Neural Networks for Computer Vision. The research aims to answer how to explore a model's generalizability to the whole population of data samples and how to interpret the model's function. The thesis presents three overall approaches to gaining insights on generalizability and interpretation. First, one can change the main objective of a problem to study expected insufficiencies and based on this make better a choice of model. For this first approach the thesis presents both a study on translational invariance as well as an example of changing the objective of a problem from classification to segmentation to robustly extract lower level information. The second approach is the use of simulated data which can help by inferring knowledge in our model if real data is scarce. The results show clear advantages both when using rendered Synthetic Aperture Radar images, but also when predictions from physical models are used as target variables which are matched with real data to form a large dataset. The third approach to cope with data insufficiencies is to visualize and understand the internal representations of a model. This approach is explored and concrete examples of learnings that can be obtained are shown. There is no doubt that large quantities of well representing data is the best foundation for training Machine Learning models. On the other hand, there are many tools and techniques available to interpret and understand properties of our models. With these at hand we can still learn about our models and use this knowledge to e.g. collect better datasets or improve on the modeling.

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Improving SAR Automatic Target Recognition Models with Transfer Learning from Simulated Data
Data-driven classification algorithms have proved to do well for automatic target recognition (ATR) in synthetic aperture radar (SAR) data. Collecting data sets suitable for these algorithms is a challenge in itself as it is difficult and expensive. Due to the lack of labeled data sets with real SAR images of sufficient size, simulated data play a big role in SAR ATR development, but the transferability of knowledge learned on simulated data to real data remains to be studied further. In this letter, we show the first study of Transfer Learning between a simulated data set and a set of real SAR images. The simulated data set is obtained by adding a simulated object radar reflectivity to a terrain model of individual point scatters,
prior to focusing. Our results show that a Convolutional Neural Network (Convnet) pretrained on simulated data has a
great advantage over a Convnet trained only on real data, especially when real data are sparse. The advantages of
pretraining the models on simulated data show both in terms of faster convergence during the training phase and on the
end accuracy when benchmarked on the Moving and Stationary Target Acquisition and Recognition data set. These
results encourage SAR ATR development to continue the improvement of simulated data sets of greater size and complex
scenarios in order to build robust algorithms for real life SAR ATR applications.

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Spatial noise-aware temperature retrieval from infrared sounder data

In this paper we present a combined strategy for the retrieval of atmospheric profiles from infrared sounders. The approach considers the spatial information and a noise-dependent dimensionality reduction approach. The extracted features are fed into a canonical linear regression. We compare Principal Component Analysis (PCA) and Minimum Noise Fraction (MNF) for dimensionality reduction, and study the compactness and information content of the extracted features. Assessment of the results is done on a big dataset covering many spatial and temporal situations. PCA is widely used for these purposes but our analysis shows that one can gain significant improvements of the error rates when using MNF instead. In our analysis we also investigate the relationship between error rate improvements when including more spectral and spatial components in the regression model, aiming to uncover the trade-off between model complexity and error rates.

Improving topology optimization intuition through games

This paper describes the educational game, TopOpt Game, which invites the player to solve various optimization challenges. The main purpose of gamifying topology optimization is to create a supplemental educational tool which can be used to introduce concepts of topology optimization to newcomers as well as to train human intuition of topology optimization. The players are challenged to solve the standard minimum compliance problem in 2D by distributing material in a design domain given a number of loads and supports with a material constraint. A statistical analysis of the gameplay data shows that players achieve higher scores the more they play the game. The game is freely available for the iOS platform at Apple's App Store and at http://www.topopt.dtu.dk/?q=node/909 for Win-dows and OSX.
In this paper we present a comparison of the robustness of Convolutional Neural Networks (CNN) to other classifiers in the presence of uncertainty of the objects localization in SAR image. We present a framework for simulating simple SAR images, translating the object of interest systematically and testing the classification performance. Our results show that where other classification methods are very sensitive to even small translations, CNN is quite robust to translational variance, making it much more useful in relation to Automatic Target Recognition (ATR) in a real life context.
Convolutional Neural Networks for SAR Image Segmentation

Segmentation of Synthetic Aperture Radar (SAR) images has several uses, but it is a difficult task due to a number of properties related to SAR images.

In this article we show how Convolutional Neural Networks (CNNs) can easily be trained for SAR image segmentation with good results. Besides this contribution we also suggest a new way to do pixel wise annotation of SAR images that replaces a human expert manual segmentation process, which is both slow and troublesome. Our method for annotation relies on 3D CAD models of objects and scene, and converts these to labels for all pixels in a SAR image.

Our algorithms are evaluated on the Moving and Stationary Target Acquisition and Recognition (MSTAR) dataset which was released by the Defence Advanced Research Projects Agency during the 1990s. The method is not restricted to the type of targets imaged in MSTAR but can easily be extended to any SAR data where prior information about scene geometries can be estimated.
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