INTERNERSHIP: NEURAL NETWORKS FOR ENERGY DISPERSIVE X-RAY SPECTROSCOPY

Keywords: Neural networks, Inverse problems, Tensorflow

Sioux LIME has developed for one of its clients a methodology to extract elemental compositions from x-ray spectra. The used approach uses a forward model and an inverse solver. The forward model predicts spectra when given an elemental composition. The inverse solvers solve the corresponding optimization problem. As the forward model is made progressively more complex (including higher order physical effects and constraints), the requirements for the inverse solvers become more difficult to satisfy.

In this internship, we investigate and tune the performance of a solution in which the inverse solver is replaced with a trained neural network. The neural network will be trained using artificially generated ground truths using the forward model. The Tensorflow toolkit is recommended for this exercise.

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INTERNship: Optimization Of Noisy Cost Functions

Keywords: Numerical optimization, Python

A common optimization problem is the parameter fitting of a physical model to measurements. We consider the case where the physical model has complex/involved computations which are iterative in nature (differential equation solving, some optimization, ...) and which are terminated well before numerical precision, more typically at 3-4 digits. This makes use of gradient-based optimizers troublesome. On the other hand, global optimizers don’t quite exploit the specific structure of the problem, which is often ‘Rosenbrock-like’ (e.g. having a single global optimum). As the forward model is already computationally heavy, putting a slow optimizer around it is undesirable.

We consider a practical application coming from the bending manufacturing industry. The Nelder-Mead method has been found to perform reasonably well. We expect a more advanced method (e.g. using quadratic interpolation), may still give significant improvements. Investigation and development of such a method is the goal of the internship.

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INTERNSHIP: EXTENDING THE FRENET-SERRET EQUATIONS TO RIBBONS

Keywords: Differential geometry, Integration of differential equations, Computer graphics

Sioux LIME is developing algorithms and tooling for a bending machine manufacturing company. Currently, the use case under consideration is the bending of round (a priori straight) metal pipes into arbitrary shapes. Because of the circular cross-section, representation of a pipe by a curve (0D cross-section) is sufficient. A square tube (not necessarily free-form-bendable by the clients current machinery) would get an extra degree of freedom, such that a curve representation should be replaced by a 'ribbon' representation. No theoretical framework (extending the Frenet-Serret framework) is known for such objects.

In this internship, we try to develop a theoretical framework for such geometrical objects. Additionally, we develop tooling to visualize and manipulate such shapes.

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INTERNSHIP: CIRCULAR EXTRUSION OF 3D MESHES

Keywords: Computational geometry, collision detection

Sioux LIME has developed collision detection methodologies for safe navigation of stages in a vacuum chamber. A particular feature involving ‘blind-folded’ return to a reference position can be solved with extrusion of meshes. For linear/translating axes, a linear extrusion operation has already been developed. For rotating axes, a circular extrusion would be required, which is a much more challenging problem. Furthermore, it may be desirable for the extrusion to be able to run on-line, and thus be fast/dynamic. In this internship, we develop the methodology which performs this circular extrusion.

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INTERNSHIP: PRECISION FARMING

Keywords: data analysis, visualization, data processing, R, multi-sensor data, indirect measurements

Precision farming is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. By using data from various sources, a farmer tries to maximize the yield of a field using as few resources as possible. This can be achieved by using high precision positioning systems (up to 2cm accuracy) on agricultural vehicle: the work place of a farmer gradually shifts from field to office. Example of data sources vary from pictures taken from satellites/drones (remote sensing), information on soil (water content, soil map, …), last year’s harvest quantities and measured amount of biomass. As of this moment, these data sources are unconnected and, due to a lack of standards, difficult to process.

In this internship you will extract as much value as you can from the data sources available for one specific field. As an experienced farmer is more than able to translate the insights from the data to actions (e.g. add fertilizer), an important part of the data’s value is a convenient way to import and visualize the data over time. Eventually you might even be able to predict this year’s harvest based on the intermediate measurements.

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INTERNSHIP: OPTIMIZATION FOR AUTOMATED PACKAGING

Keywords: Optimization, Scheduling

Sioux LIME has developed for one of its clients a solution that concerns real-time optimization algorithms for the automated packaging of products by robots. Both the packaging boxes and the different types of products flow on conveyor belts, leaving a limited amount of time for the robots to perform packaging each product. The algorithm controls the actions of the robots, determining in which order the products should be packed and which product should go in which box.

Typically, given the machine setup, the objective function is to minimize the number of products that leave the conveyor belt unpacked. There are also several constraints that should be taken into account, for instance, each box should contain the correct number of each type of product. An important other type of constraint is that everything should perform real-time. This makes that the algorithm should be fast and even faster with an increased speed of the conveyor belts. There is obviously a commercial incentive to use higher belt speeds.

Our developed solutions perform a last-minute optimization, taking into account (only) all the products that are currently on the conveyor belt. However, the flow of products is typically quite predictable. How can we use this to better optimize the packaging? This requires rethinking the current optimization approach. A second goal is to design a(n) (meta) algorithm that solves a more generic case. For instance, up to now LIME has developed two algorithms for two different machine types and these two algorithms partially differ. As an illustration of a more generic algorithm, imagine that the algorithm can handle any specified number of robots. As a nice-to-have, we would like to obtain a bound on the performance of the algorithm. This would enable us to tell how far the algorithm is maximally off the (in hindsight) optimal solution.

Overall, the goal of this intern project is to design and implement an appropriate method to optimize a(n) (ideally generic) packaging machine aiming to also make use of product inflow predictability.

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INTERNSHIP: SCHEDULING USING REINFORCEMENT LEARNING

Keywords: Reinforcement Learning, Scheduling, Optimization, Markov Decision Processes, Approximate dynamic programming, Deep Learning

LIME has carried out two packaging machine optimization projects for a specific client. This concerned the optimization of two slightly different machine types. The setup of such a packaging machine is that both the packaging boxes and the products flow on conveyor belts. Alongside the belts, robots are placed that can pick and place products. The algorithm controls the actions of the robots, determining in which order the products should be packed and which product should go in which box.

After having developed two distinct solutions, the natural question comes up: can we develop a more generic and potentially even better solution to this kind of scheduling problems? A single solution framework that can easily handle a wide range of different machine instances. Using Reinforcement Learning to tackle these scheduling problems could be part of such a solution. Another alternative could be to use an integer programming approach.

In this assignment you will develop a Reinforcement Learning approach to this kind of scheduling problems. Reinforcement Learning is an area of machine learning. The context is one of agents taking actions in an environment with the goal to maximize the total cumulative reward. The reinforcement learning framework is quite general and can be applied to many problems in different domains. There is also a connection with deep learning. Quite often, the problem size is too large, so that one has to move to approximation methods. Deep learning can be used e.g. to approximate the value function in a high-dimensional state space.

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INTERNERSHIP: ANALYZING SENSOR DATA USING DYNAMIC BAYESIAN NETWORKS

*Keywords: Sensor fusion, Bayesian Networks*

Dynamic Bayesian Networks form a subclass of Probabilistic Graphical Models (PGMs). PGMs use a graph-based representation as the foundation for encoding a complete distribution over a multi-dimensional space and a graph that is a compact or factorized representation of a set of independences that hold in the specific distribution.

PGMs form a very general framework for building probabilistic models with applications in many different directions. PGMs form a key element of so-called model-based machine learning. This is a paradigm that uses a Bayesian viewpoint together with PGMs and generic inference algorithms to build all kind of specific machine learning algorithms. The clean split between model (specification/building) and inference is one of the key benefits.

Dynamic Bayesian Networks (DBNs) can be used to model systems that have a temporal aspect and vary over time. As such they are a very natural candidate for modelling and analyzing systems that are measured by (multiple) sensors (of different modalities) over time.

Typically, the complexity is in doing inference for a specific (type of) DBN. There exist a few rather generic inference engines that can be used, but they might not give fast and accurate results. As such, it might be required to build/develop new inference algorithms or adopt existing ones tailored to the network at hand.

We have several datasets available, but we can also generate (artificial) data and see if and how we can get good inference results for these datasets (where we now the truth). In this assignment you will be building and analyzing specific DBNs.

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