CIFRE PhD thesis

Time series prediction and causation

1 The logistics sector

Logistics, the lifeblood of our global economy, is a fast-growing sector with high strategic stakes. The efficiency of global supply chains has major economic impacts along with significant ecological repercussions. The rapid evolution of the sector is based in particular on the gradual and massive introduction of advanced technological solutions (AI, robotics) whose emergence opens up new horizons to explore.

2 Savoye

Savoye is a fast-growing mid-sized company with around 1,000 employees that offers hardware and software solutions to automatize warehouses and enhance logistics processes. One of our flagship solution pertains to high-density robotic storage systems that Savoye pioneered (`https://https://www.savoye.com/us/ressource/x-pts-shuttles/`). Savoye is expanding quickly, thanks in particular to its expansion into the American and Asian markets (revenue growth $>20\%$/year). Our ambition is to become one of the main players in the intralogistics sector worldwide in the next few years.

3 Scope of the thesis

In 2022, Savoye introduced machine learning for the first time in one of its products as part of a workforce management feature. In order to continue the efforts undertaken in the field of time series prediction, we propose a CIFRE whose purpose is to explore and exploit state-of-the-art techniques. Several topics and strategic issues will support this research :

- The prediction of flows and article demands, for example, is at the heart of our concerns to optimize inventory management by forecasting customers needs,
- The estimation of the time required to carry out logistics operations (ETA, Estimated Time of Arrival) is a major challenge that can allow for a significant improvement in the management of the logistics activities in the warehouse (taking into account the effect of routing decisions on ETA),
- Forecasting of failures and break-down of equipment is also a critical topic with a view to expanding our maintenance service offering.

To address these issues, we will draw on recent developments in artificial intelligence on deep neural networks and causality. In particular, we want to explore transformer-based models ([5]) for flow and demand prediction and time estimation, and discovery and causal inference models for fault prediction ([1]).

One of the major problems lies in the fact that these models have excellent performance on data close to those used for their training and often poor performance on data that differs from those used in training. We

intend to solve this problem by using generic causal representations ([6]) because they are representative of the underlying physical phenomena. The causal graph and associated latent variables can be partly extracted from the available data from discovery and causal inference methods ([1]). This will improve the genericity of models and their transferability to different contexts.

In addition, the available data are often partial, with missing values, and are based on different trends that are repeated at more or less regular intervals. We introduced the notion of pseudo-periods to designate the fact that repetitions are not entirely regular and proposed a mechanism capable of identifying them from patterns of recurrent neurons such as LSTMs ([2]). This thesis will also be an opportunity to explore, on the one hand, new methods for the identification of trends and pseudo-periods to improve predictions and, on the other hand, new methods to optimize the use of partial or missing data (e.g. data produced during lockdowns). These methods will be integrated into LSTM-type models.

It should be understood that these topics/themes are neither fixed nor exhaustive but constitute a basis for discussion and work.

4 The Advanced Research and Innovation service

The PhD student will be part of the Advanced Research and Innovation team, which reports to the group's top executives. Its scope is to explore the state of the art of research to identify and explore (by prototyping or carrying out proofs of concept) solutions that may ultimately significantly improve the company's products or propose radically new solutions.

He will work within a team specialized in AI in the broad sense (from operations research and mathematical optimization to different ML techniques) in direct collaboration with the AI/ML tech lead and will aim to extend the already in-depth research that has been conducted on the subject.

Amazon's research illustrates (but does not guide) our trajectory from a technological perspective ([4]). Experiments based on models focused on attention mechanisms (transformers) are at the heart of our current research activities. We are also interested in exploring innovative approaches like DeepMind for Google Maps ([3]).

5 Academic Supervision

The person recruited will be integrated into the APTIKAL team of the Grenoble Computer Science Laboratory and will be co-supervised by Émilie Devijver (CNRS researcher, mathematician) and Éric Gaussier (professor of computer science at the University of Grenoble Alpes, Director of MIAI - Multidisciplinary Institute in Artificial Intelligence). The APTIKAL team is specialized in machine learning and knowledge acquisition and in particular on statistical learning and causality, with both broad applications and more targeted applications on natural language processing or information retrieval for example.

6 Candidate's profile

We are looking for a passionate candidate willing to explore the state of the art and go beyond it, who wants to accompany his/her ideas from concept to operational application in our most advanced logistics platforms.

Coming from a top engineering school or university, you started to develop expertise in ML, especially in the use of models for sequential data. Ideally you have already dealt with the problems of time series prediction, or at least know the techniques used in NLP and have an idea of how they can be diverted from their initial use.
Interested candidates should send a CV, a motivation letter and a transcript of their M1 and M2 grades to eric.gaussier@imag.fr.

Références

[1] Charles K Assaad, Emilie Devijver, and Eric Gaussier. Survey and evaluation of causal discovery methods for time series. *Journal of Artificial Intelligence Research*, 73 :767–819, 2022.

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[6] Yixin Wang and Michael I. Jordan. Desiderata for representation learning : A causal perspective, 2022.