Postdoctoral proposal: Causal Inference for learning and intervening on welding quality prediction. University Paris-Saclay, CentraleSupélec (Gif-sur-Yvette, France). In partnership with TotalEnergies (Palaiseau, France) and Sinclair lab (Palaiseau, France).

April 14, 2023

1 Context and description

Machine learning methods are meeting increasing success in various domains, such as marketing with customer behavior prediction, health with patient diagnosis, and industry with the optimization of industrial processes. This success is mainly due to their outstanding performance. Still, their complex nature or the fact to be based only on association limits their trustability by the users and decision-makers. This has given rise to the quest for AI model interpretability and explainability. Some well established fields as sensitivity analysis or more ongoing ones such as Causal Inference and Causal Discovery are interesting ways to tackle this quest. Mainly, answering causal questions from data is currently a hot topic. It is often crucial to discover how to intervene in the model to understand how to alter and optimize the system of interest.

The current project fits a general problem that TotalEnergies and Sinclair Lab address in trying to build and apply causal inference approaches to industrial welding problems. The application will involve welding data (wind turbine or pipeline) to optimize their strength by relying on observation data. The impact of "non-quality" in welding is far-reaching because of the risk of failures or project delays. The objective of the postdoctoral researcher is first to make a sensitivity analysis and then to propose new approaches to extract the causal impact of variables from observation data based on the recent advances in causal inference and machine learning.

During the project, the successful candidate will have to address the following points:

1. Make a sensitivity analysis and appropriate some past intern and Ph.D. works did on the same topic;
2. Study the causal inference state-of-the-art to identify promising approaches for the industrial problem and then apply them to the available welding real dataset to extract the causal impact of observed variables. Some issues associated with *sensitivity analysis*, *evaluation effect of binary and continuous treatment*, *multiple causal inferences*, *causal and Bayesian graph*, *missing variables*, *uncertainty characterization*, and explainability of the results should be considered;
3. Study the limitations of the state-of-the-art causal approaches, extend or develop a new one and illustrate it on both (private) welding dataset and a public one;
4. Provide tools to help experts understand and trust the results obtained by the causal inference approach;
5. Publication of the work in top AI conferences (IJCAI, NeurIPs, ECML, ICML, AAAI, AISTATS, etc) or a top AI journal.

This will include:

- Working with a team of computer scientists and mathematicians;

- Developing new Causal Inference methods for more understandable/trustable machine learning models;
- Implementing and testing the approaches developed (Python);
- Writing a research (journal/conference) paper to contribute to the causality field and address modern machine learning research problems such as explainability and generalization.

2 Candidate profile

The ideal candidate is motivated by research application problems in the energy sector, passionate about artificial intelligence, has a solid background in machine or statistical learning, applied mathematics, computing, modeling, optimization, and has good scientific writing and oral communication skills. A proven experience and taste in computer programming (Python and/or R) and data analysis is required. Candidates should hold a Ph.D. in one of the following areas: Applied Mathematics, Machine learning, Computer Science, or related fields and proven ability to solve research problems, with demonstrable research experience in one or more of them. A Ph.D. in Causality Inference would be appreciated. A strong command of the English language is also required.

3 Funding and location

The successful postdoctoral candidate will be affiliated with the Mathematics Interacting with Computer Science (MICS) research laboratory of the University Paris-Saclay and work with Sinclair lab (Palaiseau, France), which is the Saclay INdustrial Collaborative Laboratory for Artificial Intelligence Research. He/she will share his/her time work between Sinclair lab, TotalEnergies' Saclay research center (20%), and MICS lab (80%), which are close to each other (around ten minutes by bus).

4 Application

Application files must be sent to *myriam.tami@centralesupelec.fr*, *antoine.bertoncello@total.com*, *louis.verny@totalenergies.com* and *sebastien.gourvenec@totalenergies.com* as soon as possible and must include:

- A cover letter or email;
- A CV, including contact information for two or more referees;
- A research outcome (Ph.D's thesis or paper) written by the candidate.

Incomplete application files will not be considered.

References

[PJS17] Jonas Peters, Dominik Janzing, and Bernhard Schölkopf. *Elements of causal inference: foundations and learning algorithms*. The MIT Press, 2017.

[WB19] Yixin Wang and David M Blei. The blessings of multiple causes. *Journal of the American Statistical Association*, 114(528):1574–1596, 2019.