BORSA N. 33

DAUSY

D.M. 352/2022

Co-finanziata da: MAFINA S.r.l.
Tematica: “Causal representation learning for time series monitoring in continuous food manufacturing processes”

**Research theme title:**

Causal representation learning for time series monitoring in continuous food manufacturing processes

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**Curriculum of DAUSY:**

C3 AS for Monitoring and Security

**Hosting University/Research Centre**

University of Verona, Italy

**Department:**

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**Prospective Supervisors:**

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## Description:

The Industry 4.0 paradigm is allowing the acquisition of large volumes of data, thanks to the availability of sensors and the easy interconnectivity among machines. However, the correct and useful processing of the data collected is still far from being solved. This problem is affecting industries in all sectors, but it is more significant in continuous production, especially for processed food. Here, product quality is affected not only by the plant variables, but also by external variables, such as humidity, heat, and raw material quality.

In this sector, quality is often demanded to production line workers who know how to adjust the plant parameter based on their experience. Unfortunately, the diversification of products, the variety of supplier quality and the retirement of production experts, makes it necessary to find alternate and more repeatable solutions.

A successful PhD thesis has addressed the problem of process modeling by introducing causality in the data collected to identify more precisely the relations existing among the variables and the steps of product processing. However, the results are still not sufficient to develop an accurate plant monitoring system and an advisory system that could indicate the parameter adjustments to the plant operators.

The goal of this project is to develop a robust plant monitoring system that could predict with a reasonable level of accuracy the product quality and could suggest the appropriate parameter changes to the plant operators. We will expand the causality approach developed so far and will integrate it with other identification and modeling tools, e.g. supervised, unsupervised, and reinforcement learning, to better model the employees experience and to map it to corrective actions for the plant. Attention will be also given to the implementation parts of the project, to design and set up the appropriate infrastructure capable of handling the data flow, at different time rates and resolution.

## Specific Information:

Applicants must hold a master's degree, preferably in Computer Science or Engineering, with a good background in areas related to data driven modelling and control. Solid mathematical and coding skills are necessary. Proficiency in both spoken and written English is required. The candidate should be highly motivated and interested in undertaking innovative and challenging research activities involving both theoretical analysis and experimental validation, in strong connection with an Italian processed food manufacturer, which will be the final user of the applications. Technical and soft skills are strongly required to meet, during the research, a continuous trade-off between industrial needs and research challenges.

## References:

[1]. G. Menegozzo, D. Dall'Alba, P Fiorini, ""Causal interaction modeling on ultra-processed food manufacturing," in 2020 IEEE 16th International Conference on Automation Science and Engineering (CASE), 2020, pp. 200–205.

[2]. G. Menegozzo, D. Dall'Alba, and P. Fiorini, "Industrial time series modeling with causal precursors and separable temporal convolutions," IEEE Robotics and Automation Letters, vol. 6, no. 4, pp. 6939–6946, 2021.

[3]. A. Scavarda, T. Bouzdine-Chameeva, S. Goldstein, J. Hays, and A. Hill, "A methodology for constructing collective causal maps," Decision Sciences, vol. 37, no. 2, pp. 263–283, 2006.
[4]. B. Scholkopf, F. Locatello, S. Bauer, N. R. Ke, N. Kalchbrenner, A. Goyal, and Y. Bengio, "Toward causal representation learning," Proceedings of the IEEE, vol. 109, no. 5, pp. 612–634, 2021.
[5]. J. Peters, D. Janzing, and B. SchÅNolkopf, Elements of Causal Inference: Foundations and Learning Algorithms. Cambridge, MA, USA: MIT Press, 2017.
[6]. J. Pearl, "The seven tools of causal inference, with reflections on machine learning" Communications of the ACM, vol. 62, pp. 54–60, 2019.
[7]. M. Vuković, S. Thalmann, Causal Discovery in Manufacturing: A Structured Literature Review. Journal of Manufacturing and Materials Processing. 2022.
[8]. A.R. Nogueira, J. Gama, C.A. Ferreira, Causal discovery in machine learning: Theories and applications. Journal of Dynamics & Games. 2021.

## Type of scholarship:

DM 352/2022 – Industrial Project

## Study and research period outside the Hosting Institution:

7. Study and research period at the company:
- period length: 12 months;
- Company:
  - Mafin srl
  - Strada degli alberi 7, 35015 Galliera Veneta, Padova – Italy
  - https://mafin.it/

8. Study and research period abroad:
- period length: 6 months;
- Hosting institution:
  - Technische Universität Darmstadt – Computer Science Department
  - Hochschulstr. 10 D-64289 Darmstadt
  - https://www.ias.informatik.tu-darmstadt.de/