I-RIM 3D 2023

Efficient Causal Discovery for Robotics Applications

I-RIM 3D: la Tre Giorni di Robotica e Macchine Intelligenti

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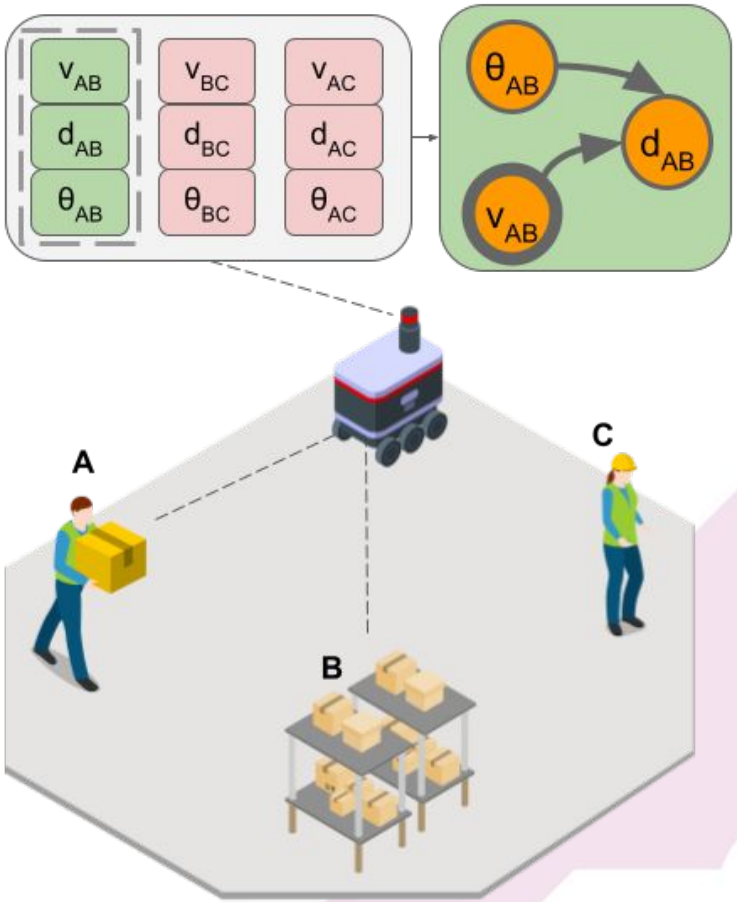
Introduction and Motivation

Causal analysis in complex systems is resource-intensive, especially in robotics with limited hardware and real-time demands.

None of the current causal discovery methods simultaneously extract key system features, establish causal links, and manage computational costs effectively.

Research question:

- Can we speed up the causal analysis and reduce its computational cost in order to make it feasible for autonomous robotics?



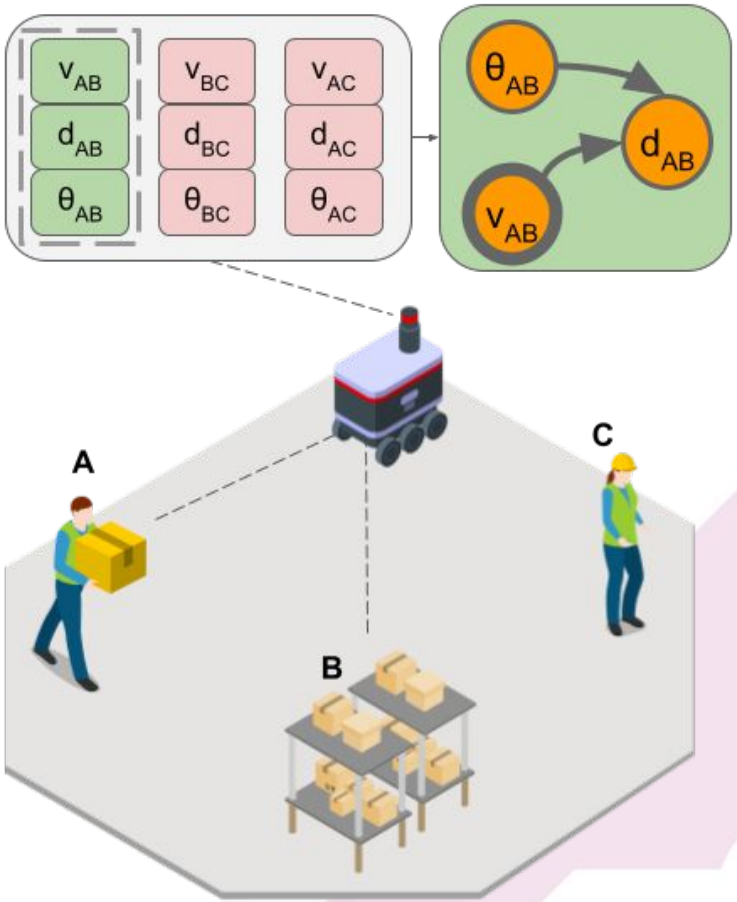
Introduction and Motivation

Research objective

develop an all-in-one algorithm capable of:

- identifying the most significant features from a predefined set of variables
- constructing a causal model based on this selection

→ Removing unnecessary variables leads to make the causal discovery process faster and more accurate.

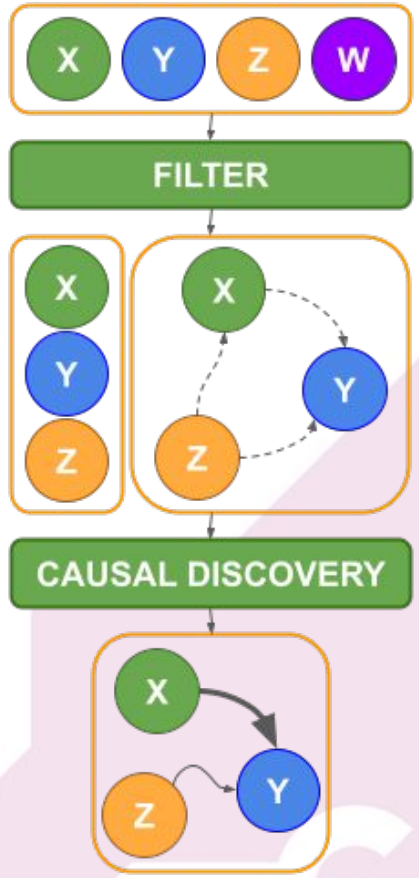


Filtered-based Causal Discovery

F-PCMCI [1] steps:

- takes in input a prefixed set of variables
- the Transfer Entropy-based filter analyses and removes irrelevant variables (e.g., constants or isolated ones). The reduced variable set is used to create a hypothetical causal model
- the latter needs to be validated by a proper causal analysis, which is performed by the PCMCI causal discovery algorithm [2]

This strategy enables **faster** and **more accurate** causal discovery

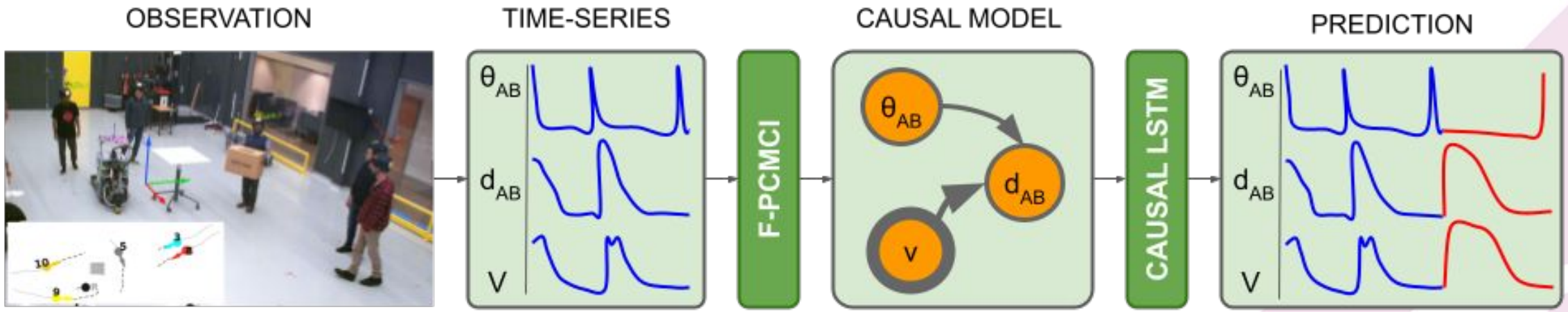


1. Castri, L., et al. "Enhancing Causal Discovery from Robot Sensor Data in Dynamic Scenarios." Proceedings of the Conference on Causal Learning and Reasoning. 2023.
2. Runge, Jakob, et al. "Detecting and quantifying causal associations in large nonlinear time series datasets." Science advances 5.11 (2019).

Robot Application

We used our approach to model and predict spatial interactions, which involved three steps:

- extracting time-series of sensor data from human spatial interaction scenarios using the THÖR dataset [3];
- reconstructing the causal model using F-PCMCI;
- integrating the causal model into a LSTM-based prediction system.



3. Rudenko, Andrey, et al. "THÖR: Human-Robot Navigation Data Collection and Accurate Motion Trajectories Dataset." IEEE Robotics and Automation Letters 5.2 (2020): 676-682.

Thank you

DARKO link - https://darko-project.eu/