UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Causal Networks: Learning and Inference

2425-114R-04

Aims

Causality is central to the understanding and use of data. Without an understanding of cause-effect relationships, we cannot use data to answer questions as basic as “Does this treatment harm or help patients?”. The course presents causal networks by first providing basics probability and introducing graphical models. Then, the problem of predicting the effect of interventions is presented and discussed. Finally, counterfactuals and their applications are presented.
It is worthwhile to mention that the course aims to provide a gentle introduction to causal inference and in particular to causal networks and structural causal models. In particular, the course gives strong motivations because, at the current state-of-the-art, modern machine learning experts need causality, and tools from causal modeling, to correctly address and effectively solve problems of decision making under uncertainty.

Contents

Main contents are as follows; the potential outcome framework, main definitions and properties of probabilistic graphical models with specific reference to Bayesian networks, causal networks and structural causal models, randomized experiments, nonparametric identification of causal effect, estimation of causal effect, structural learning from observational data and from observational and intervention data, basic concepts of tranfer learning and transportability, and finally a basic introduction to counterfactuals.

Detailed program

- **Introduction to causality and why causality matters**
- **The potential outcome framework;** the fundamental problem of causal inference, ITE, ATE, main

properties as ignorability, exchangeability, ...

- **Bayesian networks;** definition, collider, chain and fork, factorization, ...
- **Causal models;** do.operator, backdoor adjustement, structural causal models.
- **Randomized control trials;** comparability and covariate bancing, exchangeability, no backdoor paths.
- **Nonparametric identification;** frontdoor adjustment, identification from the graph structure.
- **Causal discovery from observational data;** constraint-based and score-based algorithms.
- **Causal discovery from interventional data;** structure interventions, parametric interventions, interventional Markov equivalence.
- **Transfer learning and transportability**.
- **Counterfactuals**.

Prerequisites

Basic knowledge of graph theory, optimization, probability and statistics, programming; mainly R and Python.

Teaching form

The course is expected to be delivered in physical presence.

Textbook and teaching resource

Slides from teachers, reading material and main textbooks related to causal inference and causal networks.

Semester

June 2025

Assessment method

Group assignment and final oral examination.

Office hours

Just send me an email message at fabio.stella@unimib.it

Sustainable Development Goals