UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Causal Networks

2526-2-F1801Q161

Aims

The course aims to provide a gentle introduction to causal inference and in particular to causal newtworks 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. Furthermore, the course gives mathematical tools and software tools to perform causal reasoning **(DdD 1, DdD 2)**.
Moreover, the organization of the exam, through the development of a program and the presentation of a scientific article assigned by the instructor, will allow the candidate to develop critical thinking skills **(DdD 3)** and communication skills **(DdD 4)**, while the availability of reading materials suggested by the instructor during the course will enable the candidate to continue studying and deepening their understanding of the subject independently **(DdD 5)**.

Contents

The main contents are as follows; the potential outcome framework, basic 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, unobserved confounding, instrumental variables, 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.
- **Estimation;** conditional outcome modeling, grouped conditional causal modeling, propensity score and inverse probability weighting.
- **Unobserved counfounding;** no assumptions bound, optimal treatment selection, sensitivity analysis.
- **Instrumental variables;** nonparametric identification of ATE, nonparametric identification of local ATE.
- **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 organized as follows:

- 18 lectures of 2 hours each of theory in physical presence of erogative nature
- 5 lectures of 2 hours each of hands-on in physical presence of interactive nature
- 4 online seminars of 1 hour each of erogative and interactive nature

Textbook and teaching resource

Slides from teachers and additional reading material.

Semester

First semester, early october.

Assessment method

The exam is structured as follows:

- **Project work;** the student is asked to develop a software program implementing one algorithm described by a scientific paper assigned by the teacher. **(awards a maximum of 8 points)**.
- **Interview on project work;** on topics not directly presented during the course. In particular, oral presentation of 15 minutes when the contents of a specialized literature scientific paper are summarized **(awards a maximum of 15 points)** and subsequent discussion on the mai topics of the course **(awards a maximum of 10 points)**.

No interim assessments are scheduled.

Office hours

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

Sustainable Development Goals