Introduction to Structural Causal Models

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Overview

- Foundations of SCMs
  - Assumptions
  - Comparing Causal Tools
- Pearl's Causal Hierachy
  - Prediction
  - Intervention
  - Counterfactuals
- Graphical Models
- Causality and Time

Definition & Assumptions SCM

- Noise terms independent (N_c, N_e)
- Mechanisms independent (other variables invariant)(local changes)

Definition 1: A structural causal model M is given by a set of variables $X1, ..., Xd$ and corresponding assignments of the form $X_i := f_i(Pi, Ui), i = 1, ..., d$. Here, $P_i \subseteq f_{X1}, ..., X_{dg}$ is a subset of the variables that we call the parents of Xi. The random variables $U1, ..., Ud$ are called noise variables, which we require to be jointly independent. The directed graph corresponding to the model has one node for each variable Xi, which has incoming edges from all the parents Pi. We will call such a graph the causal graph corresponding to the structural causal model.

Example

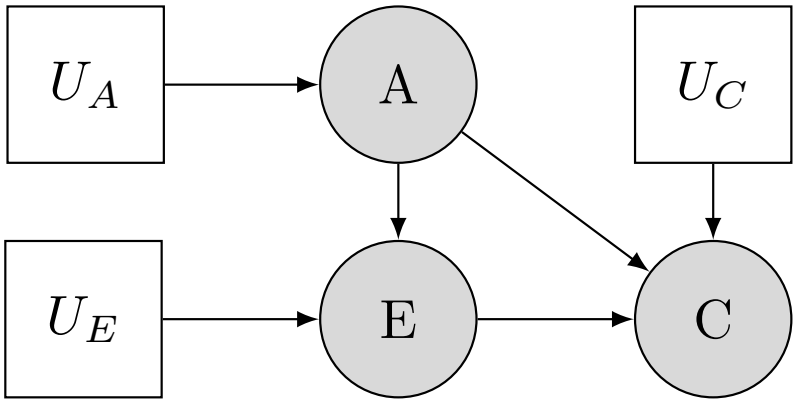

Figure 1: Structural Causal Model

$\{U_A\}$ - Numeric Ability
$\{U_E\}$ - Literary Ability
$\{U_C\}$ - Quality of the Student
$\{A\}$ - Math Test
$\{E\}$ - English-Test
$\{C\}$ - GPA

Pearl's Causal Hierachy

Table 1: Pearls Hierachy of Causation (2009)

Method	Action	Example	Usage
Association $P(a\|b)$	Co-occurrence	What happened...	(Un-)Supervised ML, BN, Reg.
Intervention $P(a\|do(b), c)$	Do-manipulation	What happens if ...	CBN,MDP,RL
Counterfactual $P(a_b\|a', b')$	Hypotheticals	What would have happened if...	SCM ,PO

Questions for Discussion

1. How do you think causal model will impact machine learning in the upcomming future?
2.