Causal Foundations of AI

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*https://causalai.net*

Outline

Causal Model
1. Structural Causal Model (SCM)
2. Pearl Causal Hierarchy (PCH)
3. The Causal Hierarchy Theorem (CHT)

- Where supervised, unsupervised, and reinforcement learning fits into PCH
- What is causal inference & cross-layer inferences
- On the Design of AI with causal capabilities
- Modern ML methods (RL & DL)

Structural Causal Model
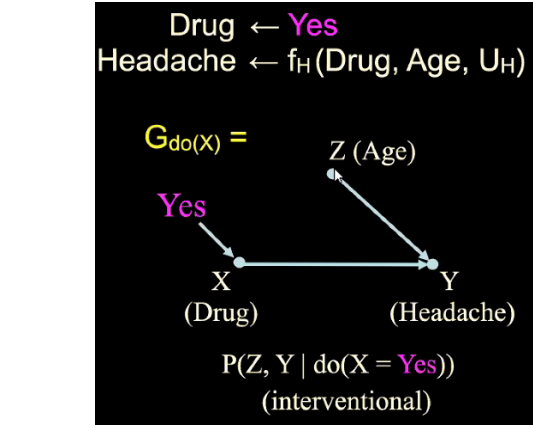(The data generating model)

Processes
- A graph to reflect functional direction of causal relationship
- Interested in join distribution (observation of facts)

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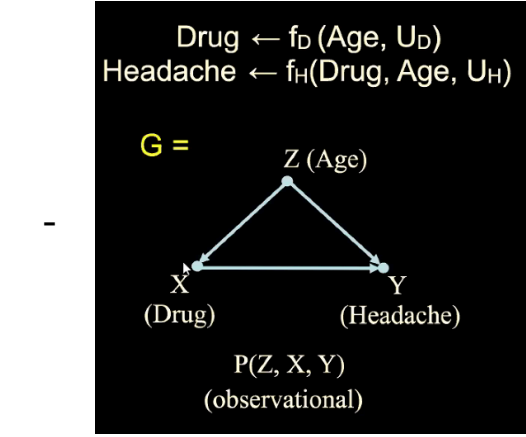
Intervention
- Similar, but interested in conditional distribituional (decision making)

Definition
- A structural causal model M (or data generating model) is a tuple (V, U, F, P(u)) where
  - V: endogenous variables
  - U: exogenous variables
  - F: functions determining V, for each V_i
  - P(u) is distribution over U
- Theorem: SCM M implies Pearl Causal Hierarchy

Pearl Causal Hierarchy

Cross-layer inferences
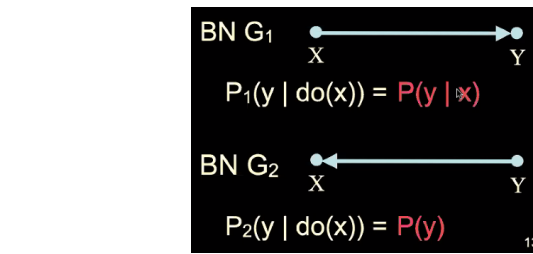- Task: infer the causal quantity Q = P(Y | do(X)) (layer-2) from observational data P(X, Y) (layer-1)
- Theorem: the effect of X on Y is not identifiable from the observed data

Causal Hierarchy Theorem
- For almost any SCM, the PCH does not collapse, i.e. the layers of the hierarchy remains distinct.

Bayes Nets v.s. Causal BNs
- Predictions are completely different. Example:

How does reinforcement learning fit here
- CHT: lower layers data underdetermines high layers. Here, this means that there are multiple neural nets fitting the data equally well, which will lead to different causal conclusions

CausalAI Lab Big Picture
Structural Causal Models
1. Explainability: effect identification and decomposition
2. Decision-Making: Reinforcement Learning, Randomized Clinical Trials, Personalized Decision-Making
3. Applications, Education, Software