A survey on Causal Discovery

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1. Introduction

Learning causality is considered as the foundation of human intelligence and an essential component of artificial intelligence. Note that causality is different from correlation. Causality is usually manifested as cause and effect, where the cause contributes to the occurrence of the effect and the effect partially depends on it.

2. Method

we introduce the four categories methods on Causal Discovery which are list in the Table 1.

Table 1. This table contains four categories of causal discovery methods

Category	Methods
Constraint-based	SGS[36], PC[37], FCI[9, 38], CIT[31]
Score-based	GES[8], FGES[30], hybrid[40]
Functional Causal Models Based	LiNGAM [34, 35], ANM [16, 27], CGNNs[13]
Continuous Optimization Based	NOTEARS[47], DAG-GNN[45], GAE[23], Gran-DAG[19], RL-BIC[49], LEAST[48], CORL[43], BCD Nets [10], DAG-GAN[11], DAG-WGAN[29]

2.1 Traditional Methods

Constraint-based Methods discover a number of causal graphs that imply the conditional independence found in data by performing hypothesis tests. And faithfulness means that all conditional independences in the data underlying distribution are represented by the causal graph G.

Score-based Methods assign each directed acyclic graph (DAG) $\mathcal{G}$ a score calculated from the observed data via a scoring function $\mathcal{F}$, and then searches the space of all DAGs for $\hat{\mathcal{G}}$ with the best score.

Functional Causal Models Based Methods A Functional Causal Model (FCM) upon a variable vector is a triplet $C = (\mathcal{G}, f, \mathcal{E})$, representing a set of equations:

$$X \leftarrow f_i\left(X_{Pa(i;\mathcal{G})}, E_i\right), E_i \sim \mathcal{E},$$
$$for\ i = 1, \ldots, d$$

Each equation describes the direct causal relationship within a set of causes to observed variable X_i.

2.2 Continuous Optimization Based Methods

NOTEARS first transforms the traditional combinatorial optimization problem into a continuous problem:

$$\min_{\mathbf{A}\in R^{d\times d}} F(\mathbf{A}) \quad subject\ to\ \mathcal{G}(\mathbf{A}) \in \text{DAGs} \qquad \min_{\mathbf{A}\in R^{d\times d}} F(\mathbf{A}) \quad subject\ to\ h(\mathbf{A}) = 0,$$

which can be solved more efficiently. Based on NOTEARS, there are many extension method. DAG-GNN, GAE and Gran-DAG are proposed to discover nonlinear causal relationships. RL-BIC applies Reinforcement Learning (RL) to discover causal structure. More advanced methods are detailed in the paper.

3. Complement Part

3.1 Background

Causal Graph is a particular type of Bayesian network whose edges represent causal effects and satisfy the conditional independence criterion. A causal graph is a directed graph that demonstrates the causal relationships between variables.

Structural Equation Models Wright proposed the equation with a diagram to illustrate the directionality. For example, as shown in Fig, the diagram represents that X has causal effect on Y and the equations describe the quantitative relationships among the variables which are determined from the data.

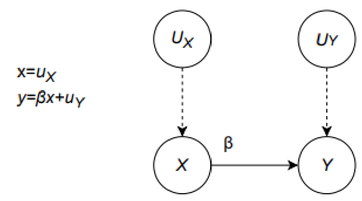

Fig. 1. A simple structural equation model, and its correlative diagrams

3.2 Conclusion

Continuous optimization based methods greatly reduce the time complexity of causal discovery, but the acyclic constraint is still a limitation. In the future, methods for causal discovery can be improved in terms of confounding factors and selection bias.

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