Detecting direct influences in complex systems from observational time series

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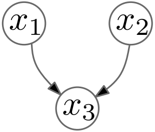
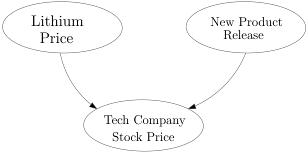
Causal Graphs[1]

Causal Graphs

- Directed graphs
- A link denotes a causal relationship





Important Question

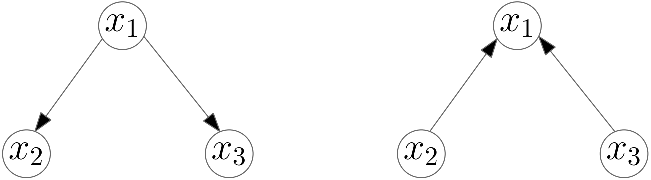
How do we detect direct causal relationships from observed data (in particular, observational time series)?

[1] Judea Pearl. "Causality. Cambridge". In: *New York* (2000).

PC-algorithm[2]

Atemporal causal detection in Graphical Models

- Searches for a set that makes two processes conditionally independent



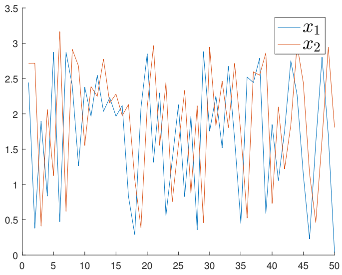
$$\mathbb{P}(x_2, x_3 | x_1) = \mathbb{P}(x_2 | x_1)\,\mathbb{P}(x_3 | x_1)$$

$$\mathbb{P}(x_2, x_3) = \mathbb{P}(x_2)\,\mathbb{P}(x_3)$$

[2] Peter Spirtes, Clark N Glymour, and Richard Scheines. *Causation, prediction, and search*. MIT press, 2000.

Granger Causality[3]

Temporal causal discovery in time series



- A cause precedes its effect
- A direct cause should significantly contribute for the prediction of its effects, given all the information from the past: regress x_1 on past of every signal in the system.

[3] Clive WJ Granger. "Testing for causality: a personal viewpoint". In: *Journal of Economic Dynamics and control* (1980).

MD Algorithm[4]

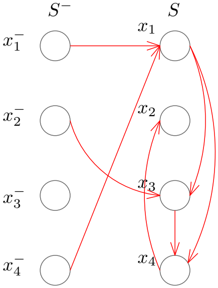
Combining PC and Granger

Step 1: $x_i^- \to x_j(t)$?

Search for S s.t. *regress*$(x_j, \{x_i^- \cup S\})$ leads to zero coeff. in front of x_i^-.

Step 2: $x_i(t) \to x_j(t)$?

Search for S s.t. *regress*$(x_j, \{x_i \cup S\})$ leads to zero coeff. in front of x_i.



Computational Challenges

- Combinatorial search for a separating set.
- Size of regression increases by increasing the number of lags we consider.

[4] Mihaela Dimovska and Donatello Materassi. "Granger-causality meets causal inference in graphical models". In: *CDC, IEEE 56th Annual Conference*. IEEE. 2017.