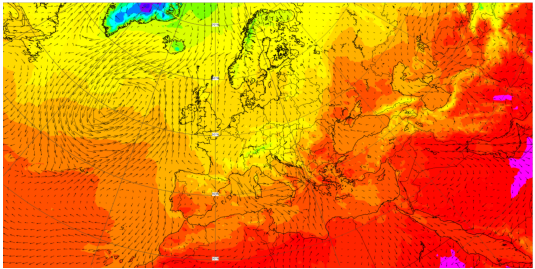
Causal Discovery for Extreme Events

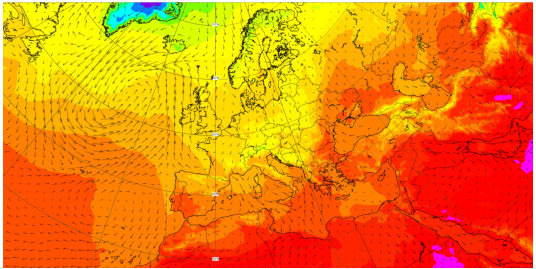
Nicola Gnecco
Gatsby Computational Neuroscience Unit, UCL, London

ICES Biennial Workshop VII, Geneva Oct 1–4, 2024

Machine Learning is advancing at a notable speed



→ ECMWF. *ECMWF Integrated Forecasting System.* 2024.



→ Google DeepMind. *GraphCast.* 2024.

At the same time, it can fail in unexpected ways

Common pitfalls and recommendations for using machine learning to detect and prognosticate for COVID-19 using chest radiographs and CT scans

Michael Roberts ✉, Derek Driggs, Matthew Thorpe, Julian Gilbey, Michael Yeung, Stephan Ursprung, Angelica I. Aviles-Rivero, Christian Etmann, Cathal McCague, Lucian Beer, Jonathan R. Weir-McCall, Zhongzhao Teng, Effrossyni Gkrania-Klotsas, AIX-COVNET, James H. F. Rudd, Evis Sala & Carola-Bibiane Schönlieb

Nature Machine Intelligence **3**, 199–217 (2021) | Cite this article

Need to control flexibility of machine learning models

Causality as theory of intervention

- Control model flexibility with causal inference

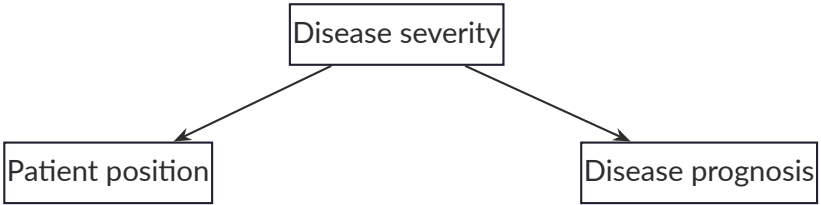
Causality as theory of intervention

- Control model flexibility with causal inference
- Goal: Discover causal model to perform downstream tasks

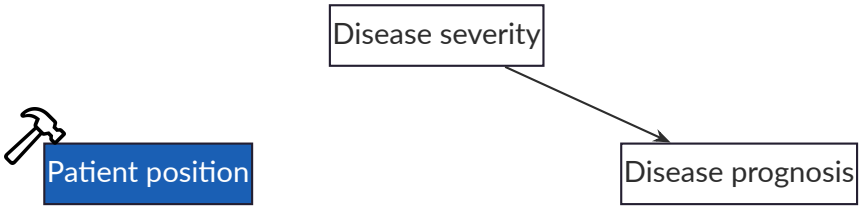
Causality as theory of intervention

- Control model flexibility with causal inference
- Goal: Discover causal model to perform downstream tasks
- Advantage: Describe how a system behaves under intervention

Advantage of knowing a causal model



Advantage of knowing a causal model



Discovering causal models is hard... but

- Discovering causal models from data is hard

Discovering causal models is hard... but

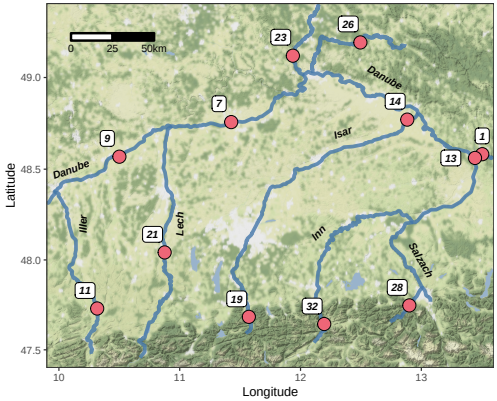
- Discovering causal models from data is hard
- However, in some situations it is possible

Discovering causal models of extreme events

In real-world systems, might want to discover causal models of extreme events.

Discovering causal models of extreme events

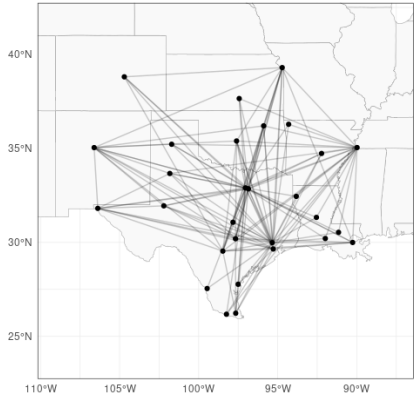
In real-world systems, might want to discover causal models of extreme events.



Example 1: Learn causal structure of river network during floods

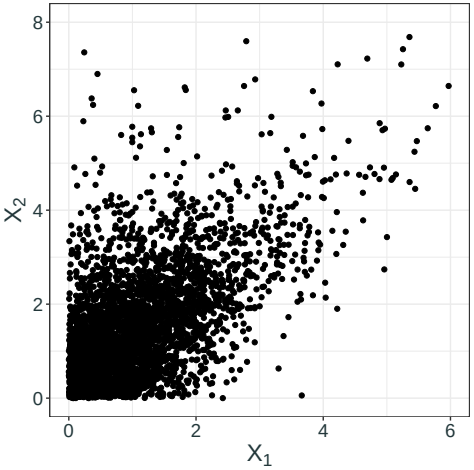
Discovering causal models of extreme events

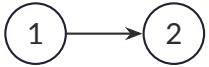
In real-world systems, might want to discover causal models of extreme events.



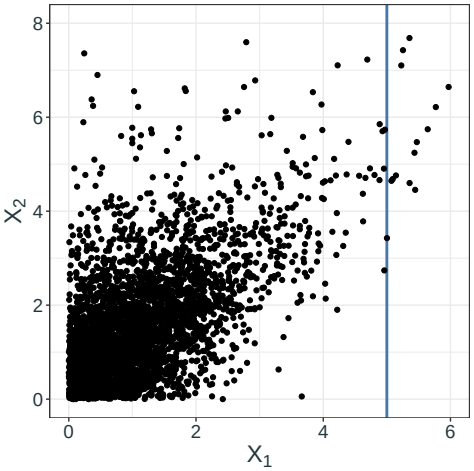
Example 2: Learn causal structure of flight network during disruptions

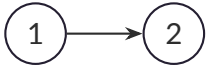
Exploit asymmetry in heavy-tailed systems





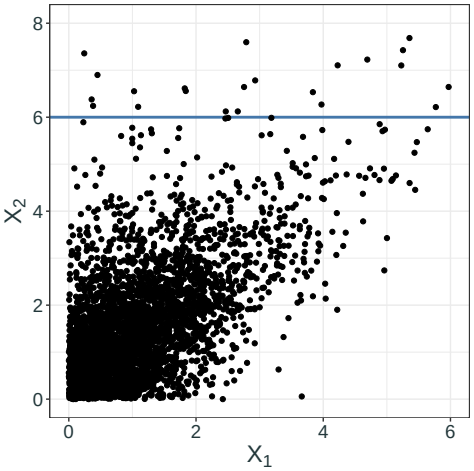
Exploit asymmetry in heavy-tailed systems

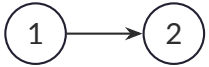




A large cause is always associated with a large effect

Exploit asymmetry in heavy-tailed systems





A large effect is **not** always associated with a large cause

Causal discovery for extremes is getting attention

- Novel methodologies in causal discovery for extremes

Causal discovery for extremes is getting attention

- Novel methodologies in causal discovery for extremes
- Most research focuses on the theoretical aspects of these methods

Causal discovery for extremes is getting attention

- Novel methodologies in causal discovery for extremes
- Most research focuses on the theoretical aspects of these methods
- Focus on end-to-end algorithms rather than integrating with ML models

Moving forward

- In what domains can these methods have an impact?

Moving forward

- In what domains can these methods have an impact?
- How can these methods be integrated with existing ML models?

Moving forward

- In what domains can these methods have an impact?
- How can these methods be integrated with existing ML models?
- Example: Can flexible ML models for weather forecasting benefit from causal discovery from extremes?

Nicola Gnecco

ICES Biennial Workshop VII, Geneva, Oct 1–4, 2024

Gatsby Computational Neuroscience Unit, UCL, London
https://www.ngnecco.com/