Spatial Confounding & Interference

GIScience 2023

Where do we go from existing frameworks

JING ZHANG
jing.zhang.2021@bristol.ac.uk
School of Geographical Sciences, University of Bristol

Overview

- Review of key methodology issues,
  ft. : Confounding, interference; PO, SCM.
- Research agenda:
  Extend existing concepts and frameworks !

Overview

Disclaimer : POV from someone who believes

All causal modeling problems are counterfactual prediction problems.

- **Review of key methodology issues,**
  ft. : Confounding, interference; PO, SCM.
- **Research agenda:**
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Overview

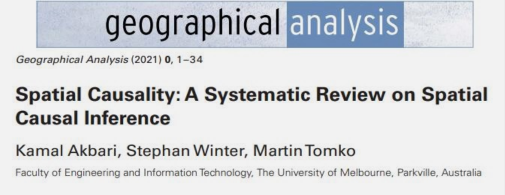
Disclaimer : POV from someone who believes

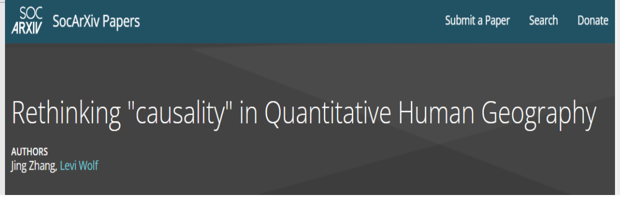
All causal modeling problems are counterfactual prediction problems.

And evaluates models by asking:

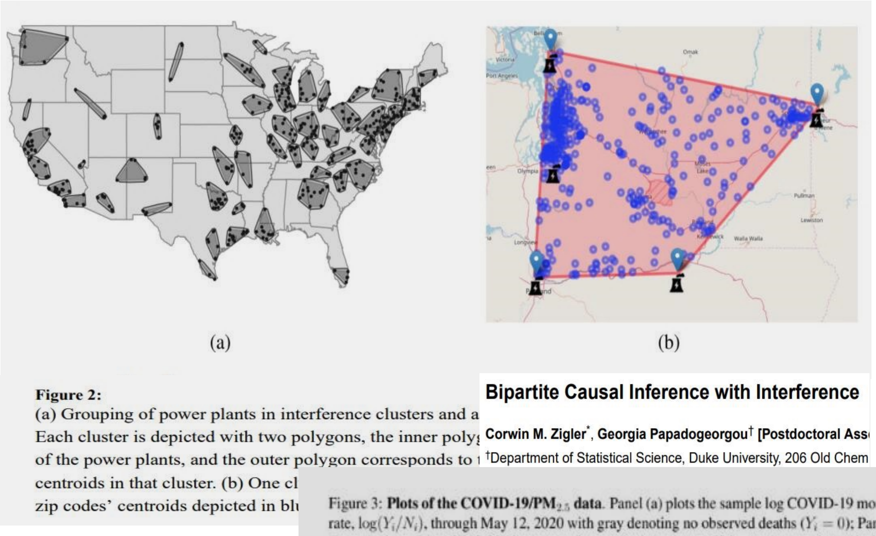
Is this good for counterfactual prediction?

Can we use computational methods to make it better?





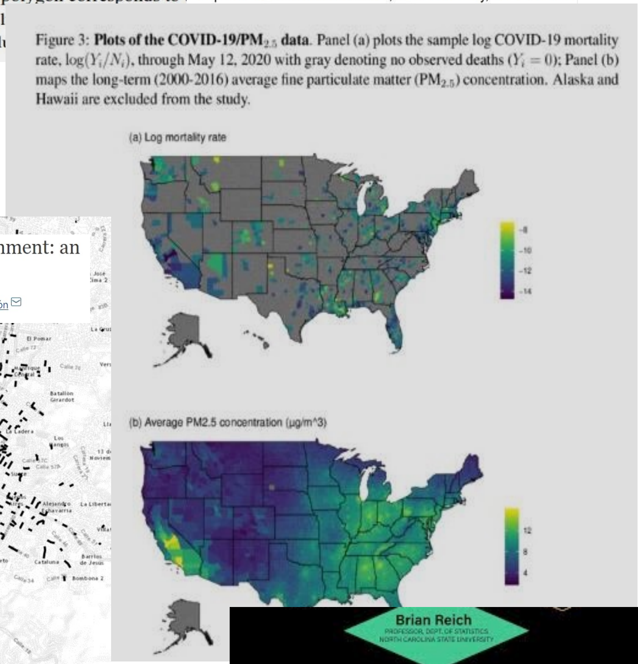
Background: spatial causal modeling

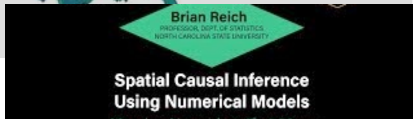


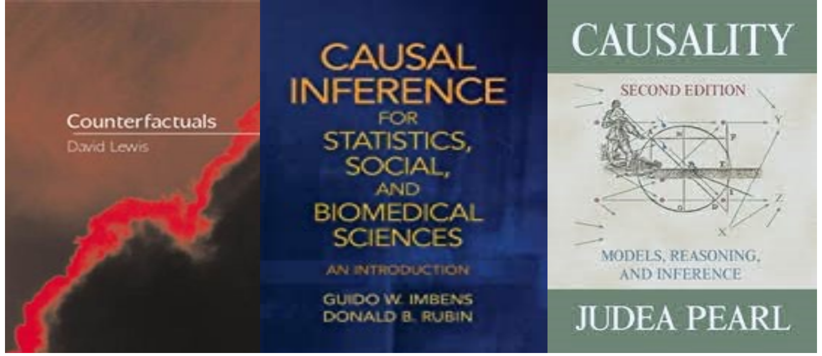
Geography needs to engage with causality

Understanding causal relations is fundamental for **science and engineering**.

Bringing geographic and causal modeling together is still an **ongoing** project.







Standard PO and SCM frameworks

Causation is **difference** making.

Potential Outcomes (PO) : Outcome difference between treated /control. Counterfactuals from randomised treatment.

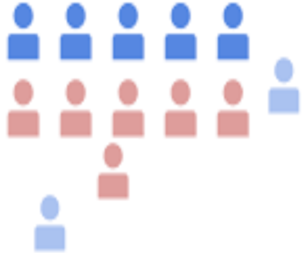
Structural Causal Models (SCM) :

Known for its graphical model (DAG) language. Affords more detailed/faithful representation of causal process.

The Spatial dimension is there

Spatial relations complicates the disentanglement

of **Non-causal** from **Causal**.



An additional **dimension of change,**

beyond the time dimension against which to

foreground causal change/ variation.

The Spatial dimension in PO and SCM

PO

Strength : Closely grounded in measurement.

Limitation : Restricted representation of causal process and abstraction of causal effect.

SCM

Strength : Affords representation of spatial process.

Limitation : Potential complexity hinders communication efficiency and computation tractability.

In brief:
Current concepts,
Conceptual models

We are still seeking **well fitted** statistical language for spatial causal process, as solid **scaffolding** for spatial causal modeling.

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Causal Effects Under Spatial Confounding and Interference (Short Paper)

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JOURNAL ARTICLE

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Charles F. Manski

The Review of Economic Studies, Volume 60, Issue 3, July 1993, Pages 531–542, https://doi.org/10.2307/2298123

Published: 01 July 1993 **Article history** ▼

geographical analysis

Geographical Analysis (2021) **0**, 1–34

Spatial Causality: A Systematic Review on Spatial Causal Inference

Kamal Akbari, Stephan Winter, Martin Tomko

Faculty of Engineering and Information Technology, The University of Melbourne, Parkville, Australia

International Statistical Review (2021), 89, 3, 605–634 doi: 10.1111/insr.12452

A Review of Spatial Causal Inference Methods for Environmental and Epidemiological Applications

Brian J. Reich[1] and Shu Yang[1] and Yawen Guan[2] and Andrew B. Giffin[1] and Matthew J. Miller[1] and Ana Rappold[3]

Summary of core issues in spatial causal

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Zhang, Jing

Causal Effects Under Spatial Confounding and Interference (Short Paper)

pdf-format: LIPIcs-GIScience-2023-91.pdf (0.8 MB)

Specifically:
Confounding, interference

The two concepts are currently pillars of methodological development.

Key interface where **theory meets empirics, abstraction meet measurement.**

Summary of core issues in spatial causal

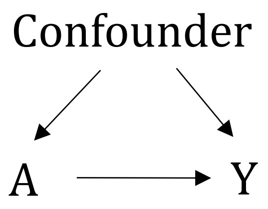
February 1999
Confounding and Collapsibility in Causal Inference
Sander Greenland, Judea Pearl, James M. Robins
Statist. Sci. 14(1): 29-46 (February 1999). DOI: 10.1214/ss/1009211805

A causal inference framework for spatial confounding
Brian Gilbert[1], Abhirup Datta[1], Joan A. Casey[2], Elizabeth L. Ogburn[1]
[1] Department of Biostatistics, Johns Hopkins University
[2] Department of Environmental Health Sciences, Columbia University

Elements of estimation theory for causal effects in the presence of network interference
Daniel L. Sussman*, Edoardo M. Airoldi†
February 14, 2017
Abstract
Randomized experiments in which the treatment of a unit can affect the outcomes of other units are becoming increasingly common in healthcare, economics, and in the social and information sciences. From a causal inference perspective, the typi-

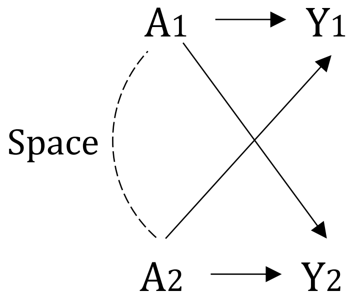
Journal of the American Statistical Association
ISSN: 0162-1459 (Print) 1537-274X (Online) Journal homepage: https://www.tandfonline.com/l
Toward Causal Inference With Interference
Michael G Hudgens & M. Elizabeth Halloran

Confounding



Classic notion: **Spurious Correlation** between treatment and outcome due to influence of common source.

Interference



Classic notion: **Outcome** of a unit dependent on **treatment of others.**

Regional Science and Urban Economics
Volume 33, Issue 5, September 2003, Pages 557-579

Specification searches in spatial econometrics: the relevance of Hendry's methodology

Raymond J.G.M Florax, Hendrik Folmer, Sergio J Rey

For and Against Methodologies: Some Perspectives on Recent Causal and Statistical Inference Debates

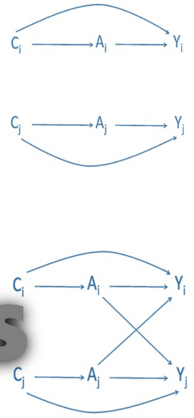
Sander Greenland[1]

CAUSAL EFFECT UNDER SPATIAL INTERFERENCE
A GENERALISED PROPENSITY SCORE WEIGHTED CONFORMAL APPROACH

Jing Zhang
School of Geographical Sciences
University of Bristol
Bristol, UK
jing.zhang.2021@bristol.ac.uk

ABSTRACT

Jing Zhang. 2023. Causal effect under spatial interference: A generalized propensity score weighted conformal approach. In Proceedings of The

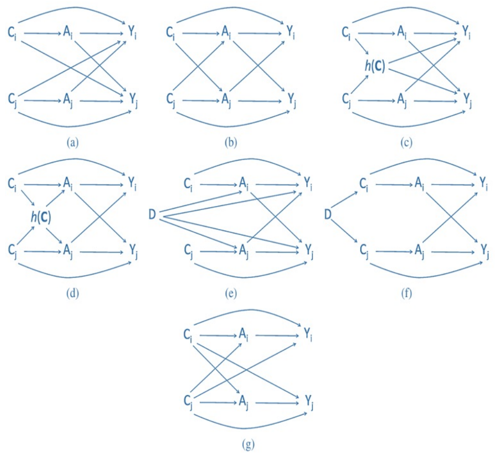


A Review of Spatial Causal Inference Methods for Environmental and Epidemiological Applications

Brian J. Reich and Shu Yang and Yawen Guan and Andrew B. Giffin and Matthew J. Miller and Ana Rappold

Causal Diagrams for Interference

Elizabeth L. Ogburn and Tyler J. VanderWeele



Challenges and Opportunities

PO

Restricted representation.

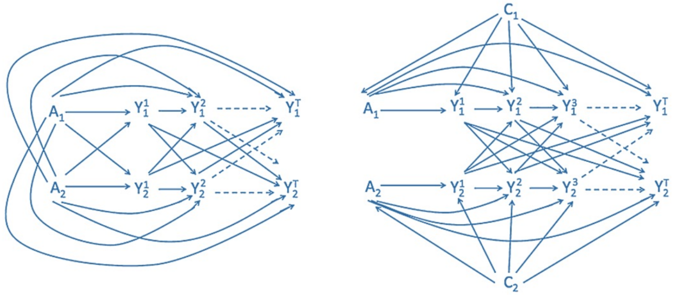
Unable to generalise over confounding & interference.

Packing spatial complexity in auxiliary tasks:

Bespoke causal **estimands**.

Flexible counterfactual **prediction**.

Model specification **search**.



October 2021
Translator Discl

Foundations of structural causal models with cycles and latent variables

Stephan Bongers, Patrick Forré, Jonas Peters, Joris M. Mooij
Author Affiliations +

Ann. Statist. 49(5): 2885-2915 (October 2021). DOI: 10.1214/21-AOS2064

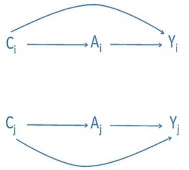
Beyond Structural Causal Models: Causal Constraints Models

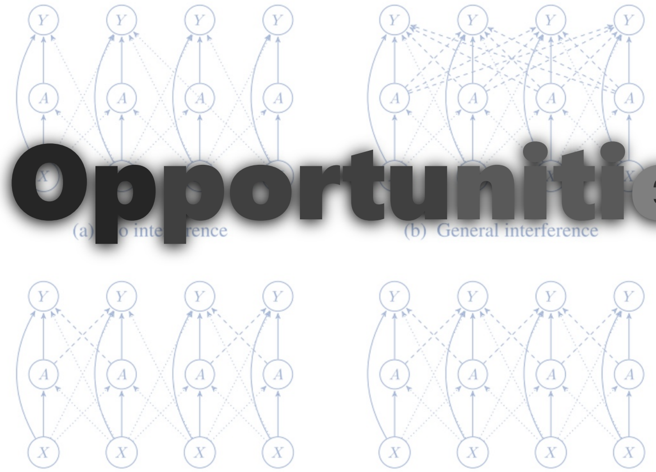
Tineke Blom
Informatics Institute
University of Amsterdam

Stephan Bongers
Informatics Institute
University of Amsterdam

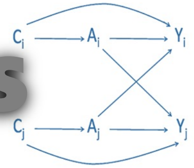
Joris M. Mooij
Informatics Institute
University of Amsterdam

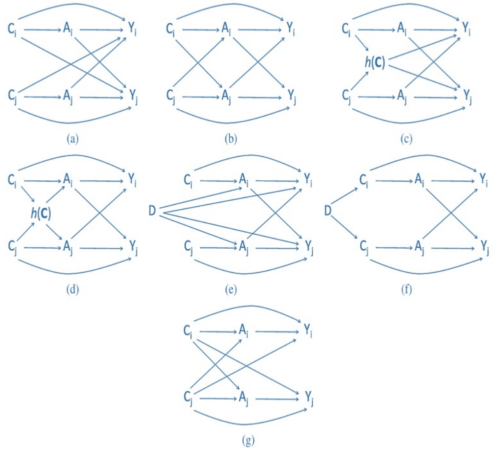
Research agenda





Challenges and Opportunities





SCM

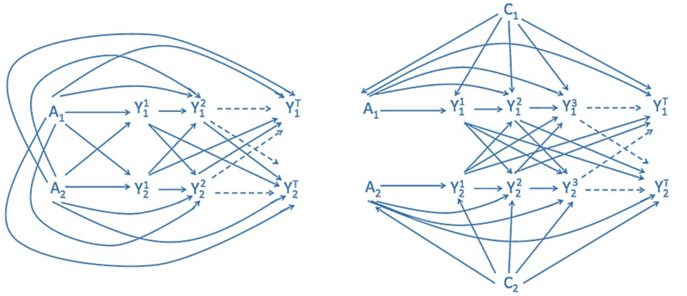
Potential complexity.

Confounding & interference tends to lead to unidentifiable models.

Packing spatial complexity in the nodes/ skeleton:

Handling high dimensional data.

Generative models and uncertainty quantification.



Spatial Data Science Symposium 2022 Short Paper Proceedings

Title
Operationalizing Spatial Causal Inference

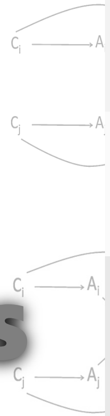
Permalink
https://escholarship.org/uc/item/2sh2c3w0

Authors
Hoffman, Tyler D.
Kedron, Peter

Rethinking causality in quantitative human geography

*Jing "Mirah" Zhang[1]**

Levi John Wolf[1]



Interdisciplinary Physics | Published: 27 January 2010

Differentiating information transfer and causal effect

J. T. Lizier & M. Prokopenko

Open Access

Information flow and causality as rigorous notions *ab initio*

X. San Liang
Phys. Rev. E **94**, 052201 – Published 1 November 2016

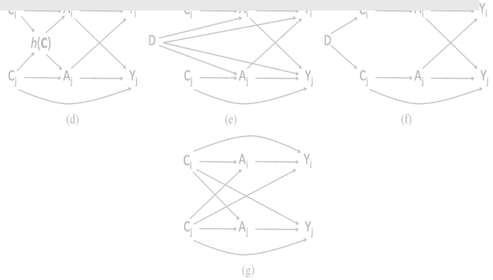
Advances in Complex Systems | Vol. 11, No. 01, pp. 17-41 (2008) | Physics and Mathematics

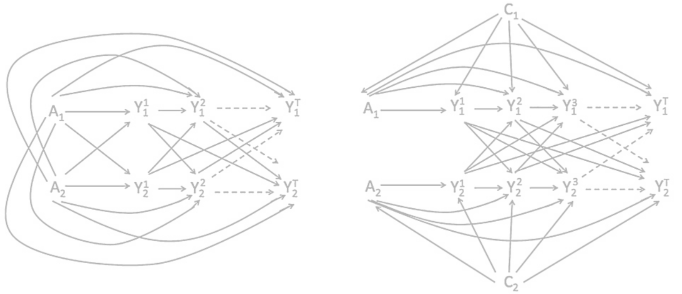
INFORMATION FLOWS IN CAUSAL NETWORKS

Full Access

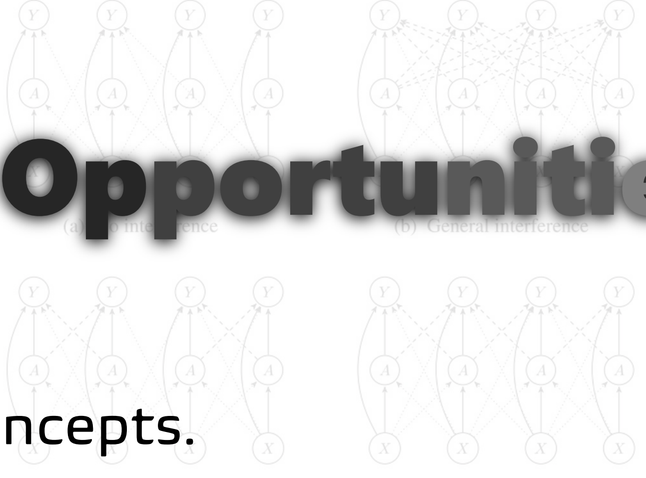
NIHAT AY and DANIEL POLANI

https://doi.org/10.1142/S0219525908001465 | **Cited by:** 156





Challenges and Opportunities



(b) General interference

(c) Partial interference

(d) Spatial network interference

Theories

Refining existing theory and concepts.

New directions, e.g. information theoretic definitions/ measurements of causality for geographic systems.

Recap:
On analytical concepts and conceptual models.

Causal modeling problems are counterfactual prediction problems.

Ample space for further development

Slides from the talk

Law and causality in quantitative geography

Conformal prediction for spatial causal inference

Spatial Confounding & Interference

Where do we go from existing frameworks

JING ZHANG

jing.zhang.2021@bristol.ac.uk

Twitter @MirahJZ