Artificial Intelligence Review (2023) 56:10613–10649
https://doi.org/10.1007/s10462-023-10411-9

Disentangling causality: assumptions in causal discovery and inference

Maarten C. Vonk[1,2] · **Ninoslav Malekovic**[2] · **Thomas Bäck**[1] · **Anna V. Kononova**[1]

Accepted: 1 February 2023 / Published online: 27 February 2023

Abstract
Causality has been a burgeoning field of research leading to the point where the literature abounds with different components addressing distinct parts of causality. For researchers, it has been increasingly difficult to discern the assumptions they have to abide by in order to glean sound conclusions from causal concepts or methods. This paper aims to disambiguate the different causal concepts that have emerged in causal inference and causal discovery from observational data by attributing them to different levels of Pearl's Causal Hierarchy. We will provide the reader with a comprehensive arrangement of assumptions necessary to engage in causal reasoning at the desired level of the hierarchy. Therefore, the assumptions underlying each of these causal concepts will be emphasized and their concomitant graphical components will be examined. We show which assumptions are necessary to bridge the gaps between causal discovery, causal identification and causal inference from a parametric and a non-parametric perspective. Finally, this paper points to further research areas related to the strong assumptions that researchers have glibly adopted to take part in causal discovery, causal identification and causal inference.

Keywords Causal discovery · Causal identification · Causal inference · Observational data · Causal assumptions

1 Introduction

Causality is a field that has percolated multiple research areas such as medical treatment (Shalit 2020), policy-making (Kreif and DiazOrdaz 2019), social science (Sobel and Legare 2014) epidemiology (Halloran and Struchiner 1995) and cybersecurity (Andrew et al. 2022; Dhir et al. 2021). Historically, the fundamental problem of causality, the fact that we cannot observe the outcome under treatment as well as control in a single unit of observation, has long precluded researchers from making causal claims (Holland 1986). Therefore, the earliest methods for drawing causal conclusions from data were the *randomized controlled trials* (RCTs), where units of analysis were randomly assigned treatment

✉ Maarten C. Vonk
maartencvonk@gmail.com

[1] LIACS, Leiden University, Niels Bohrweg 1, 2333 CA Leiden, The Netherlands

[2] The Hague Centre of Strategic Studies, Lange Voorhout 1, 2514 EA The Hague, The Netherlands