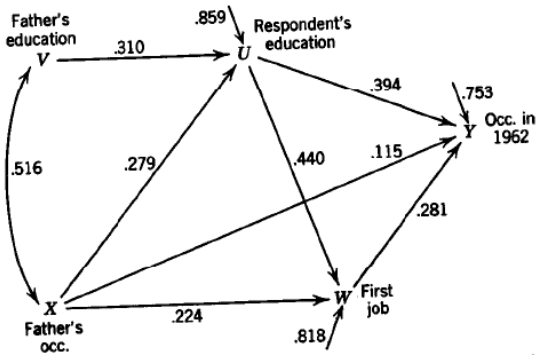
NORMALIZING FLOWS FOR MEDIATION ANALYSIS

The Blau-Duncan model is a classical model in the social sciences that was developed in the 1960s to model the relationships between an individual's social origin and his/her attained occupational status. Specifically, it models the causal relationships between the education and occupational status of fathers and sons. The model can be seen below. Arrows represent causal relationships, bidirected edges represent correlations, and the the numeric labels represent linear regression coefficients. These coefficients can be interpreted as the strength of the causal relationships under the linearity assumption.



This project aims to drop the linearity assumption by using normalizing flows (NFs). These are essentially deep neural networks. The following references to our previous works give further details on the use of NFs for causal modeling and reasoning. The second article is particularly relevant for this project.

- Balgi, S., Peña, J. M., and Daoud, A. (2022). Personalized Public Policy Analysis In Social Sciences Using Causal-Graphical Normalizing Flows. In Proceedings of the 36th AAAI Conference on Artificial Intelligence (AAAI 2022), 11810–11818.
- Balgi, S., Peña, J. M., and Daoud, A. (2022). Counterfactual Analysis of the Impact of the IMF Program on Child Poverty in the Global-South Region using Causal-Graphical Normalizing Flows. arXiv:2202.09391 [cs.AI].
- Balgi, S., Peña, J. M., and Daoud, A. (2022). ρ-GNF : A Novel Sensitivity Analysis Approach Under Unobserved Confounders. arXiv:2209.07111 [stat.ME].

We want to model the domain above with NFs in order to perform causal reasoning. We are particularly interested in mediation analysis. That is, we want to use the NFs to estimate the causal effect of the father's occupation (X) on the son's occupation (Y) mediated by the son's first job (W), i.e. through the pathway that contains W. This is called the natural indirect effect. We are also interested in estimating the effect through pathways other than W. This is called the natural direct effect. Estimating these effects from data is unfeasible because the model includes an exposure-induced mediator-outcome confounder, namely U. That is, X causes U which in its turn causes W and Y.[1]. However, we believe it is possible to solve the problem by using NFs to perform counterfactual reasoning, as shown in our previous works.

This project aims to first show in synthetic data that the effects described above can indeed be estimated from data with the help of NFs. Then, it aims to repeat the analysis with the real-world Blau-Duncan dataset. We will provide access to our implementation of NFs and the curated Blau-Duncan dataset.

Prerequisites

Knowledge of deep learning and Python. No previous knowledge of causality is required.

[1]VanderWeele et al. (2014) Effect decomposition in the presence of an exposure-induced mediator-outcome confounder. Epidemiology, 25(2):300–306.

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