M.S. Defense Announcement
Michael DeCaria
Friday, March 26 at 1:00 p.m.

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March 26, 2021
1:00 p.m.

Defense
Virtually through Teams (full link below)

Post Defense Meeting
Virtual

Committee:
Peter Jan van Leeuwen (Adviser)
Christine Chiu
Elizabeth Barnes
Imme Ebert-Uphoff (Electrical and Computer Engineering)

A New Framework for Causal Network Discovery with Application to Tropical Cyclone Rapid Intensification

Causal network discovery using information theoretic measures is a powerful tool for studying new physics in the geosciences. To make this tool even more powerful, the present framework adds two features to the existing information theoretic literature. The first feature is a new factor for normalization tailor made for handling continuous variables. Normalization allows for calculating relative, rather than absolute, influence, making it a valuable asset for determining how much of the physics the considered drivers capture, and in the same stroke determines how much physics is missing. While some studies, causal discovery or not, may use Shannon entropy for normalization, this work shows why this measure cannot serve this purpose for continuous variables. Thus, the measure called certainty is introduced to fill this need. Instead of acting to reduce Shannon entropy to zero, drivers act to increase certainty from an initial value. The initial value, called self-certainty, is representive of noise and unresolved processes, the relative influence of which decreases by including relevant drivers.

The second feature is a way to decompose mutual information into contributions from individual or coupled drivers. Other methods for decomposition exist but are ultimately unsuitable for studying continuous variables. The decomposition in this work calculates the influences coming from unique combinations of drivers. The influences from couplings are recombined according to the number of drivers coupled to each driver in turn, which gives an impression on how cooperative or competitive a driver is when combined with other drivers. These are further recombined to calculate a total influence of a driver on a target. The total influences from all drivers constitute a nonnegative decomposition of the total mutual information between the drivers and the target.

This framework was then applied to studying the rapid intensification of Hurricane Patricia (2015). The hourly change in maximum azimuthally averaged tangential windspeed was identified as the target. The four drivers, which were azimuthally averaged, were outflow layer (OL) maximum radial windspeed, u_u, boundary layer (BL) radial windspeed at radius of maximum wind (RMW), u_l, equivalent potential temperature at BL RMW, θ_e, and the temperature difference between the OL and BL, ΔT. These drivers explained 45.5\% of the certainty. This certainty gain was 35.8\% from θ_e, 24.5\% from ΔT, 24.0\% from u_u, and 15.7\% from u_l. The total influence of θ_e came mostly from cooperative action, while the total influence of u_u came mostly from uncoupled action. Physical mechanisms, both accepted in current literature and suggested from this application, as well as future analysis using this framework are discussed.

Finally, the framework is generalized to noncontinuous targets, which may be either discrete or quasidiscrete. This generalization allows for studying any target process. It also introduces the partial Shannon entropy. Future work applying this generalized framework to precipitation and convective initiation is briefly discussed.

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