Mapping Statistical Models to Causal Structures

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Utrecht University,
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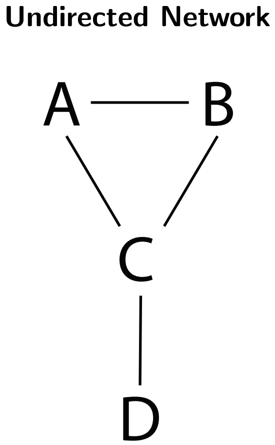
May 6, 2019

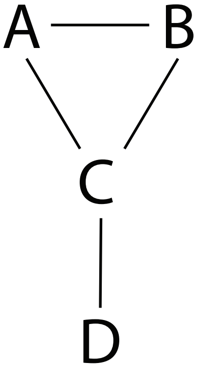
Project 1: Undirected Networks and Causal Skeletons [1]



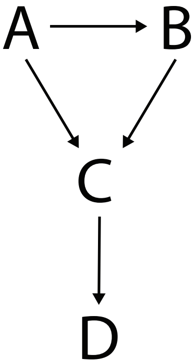
[1] Borsboom & Cramer (2013), van Borkulo et al. (2015), Boschloo et al. (2016), Fried et al. (2016)

Project 1: Undirected Networks and Causal Skeletons [1]

Undirected Network



Directed Causal Structure



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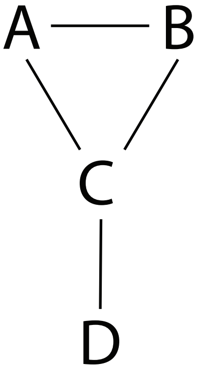

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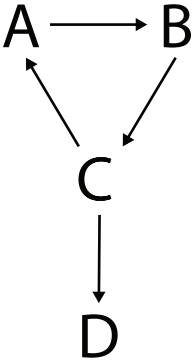

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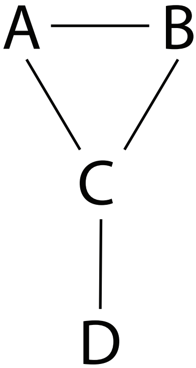

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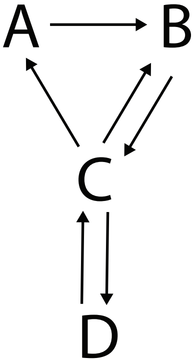

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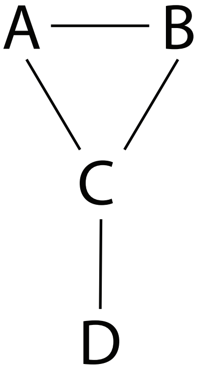

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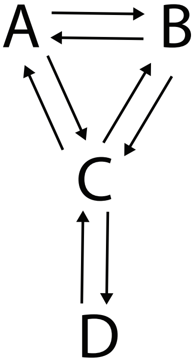

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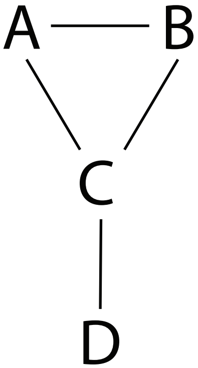

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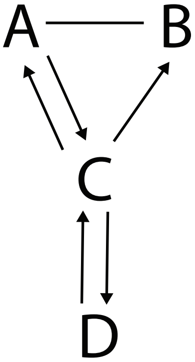

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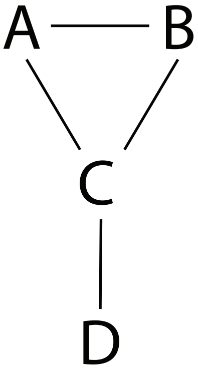

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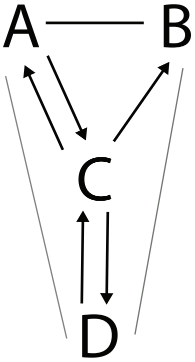
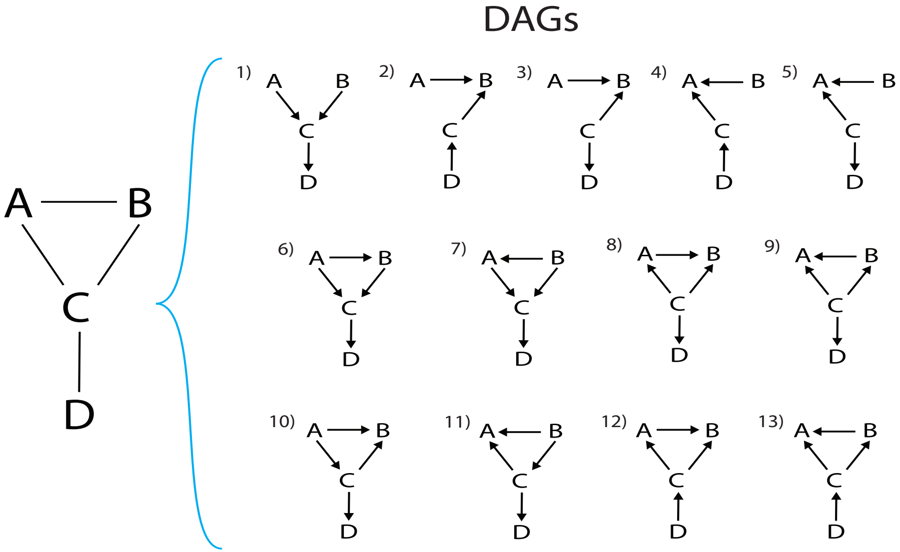
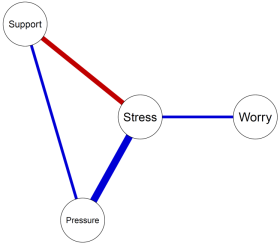


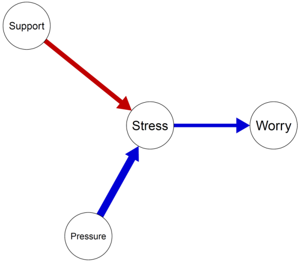
One-to-many mapping



SEset: Mapping GGMs to linear DAGs



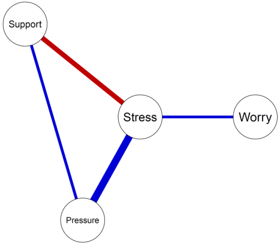
$$
\begin{array}{c c}
 & \begin{array}{cccc} Su & P & St & W \end{array} \\
\begin{array}{c} Su \\ P \\ St \\ W \end{array} &
\begin{bmatrix}
\sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\
\sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\
\sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34} \\
\sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44}
\end{bmatrix}
\end{array}
$$



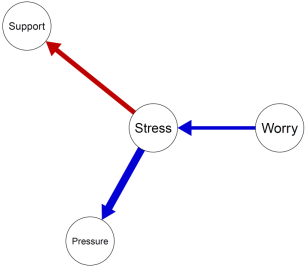
$$\hat{\Sigma}^{-1} \Longrightarrow \hat{\Sigma}_{MI} \Longrightarrow \left(I - B_j\right)^{-1} \Psi_j \left(I - B_j\right)^{-T}$$

Ryan, Bringmann & Schuurman (under review)

SEset: Mapping GGMs to linear DAGs



$$\begin{array}{c|c} & \begin{matrix} W & St & Su & P \end{matrix} \\ \begin{matrix} W \\ St \\ Su \\ P \end{matrix} & \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44} \end{bmatrix} \end{array}$$



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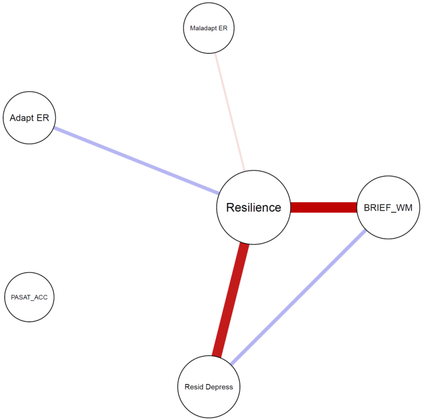
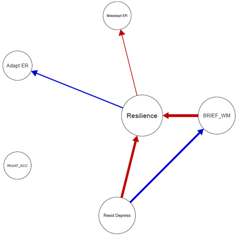
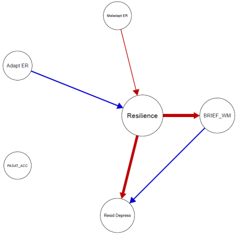
Example (Hoorelbeke et al. 2016)

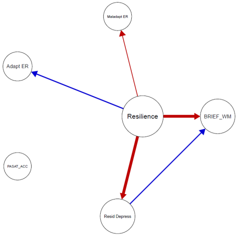




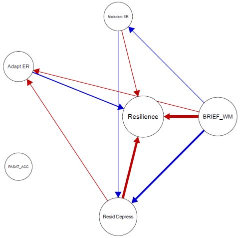
(a) DAG #12



(b) DAG #52



(c) DAG #14

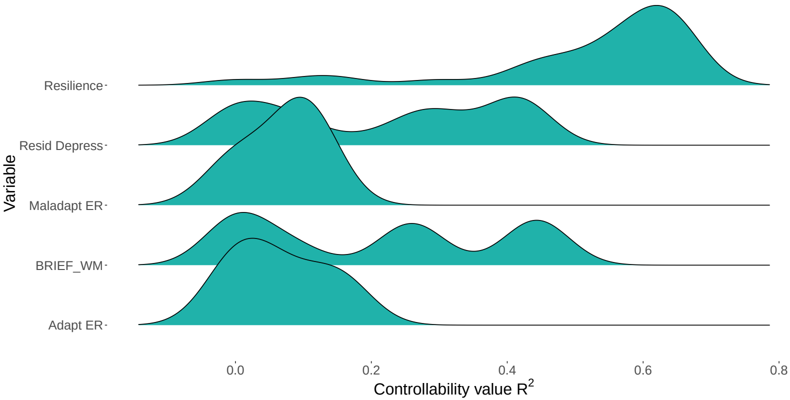


(d) DAG #20

Exploring Uncertainty

Predictability: R^2 if all variables cause Y

- "Upper bound" on controllability [2]



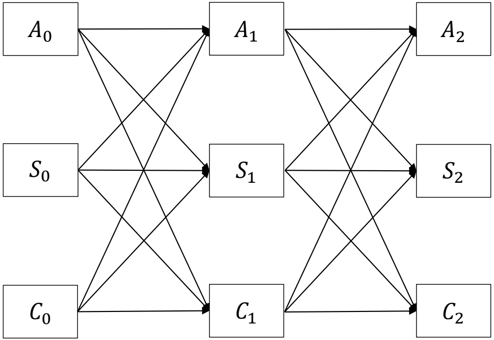
Future Directions 1

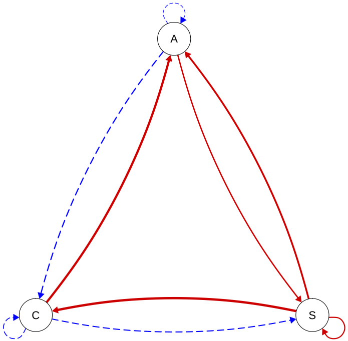
Beyond DAGs

- What other kinds of structures might cross-sectional networks be informative for?
- Dynamic structures - causal loops and systems in equilibrium
- Check undirected networks for consistency with theoretical models

Project 2: Continuous-Time Modeling of ESM data

$$\boldsymbol{Y}_{\tau} = \boldsymbol{\Phi}\boldsymbol{Y}_{\tau-1} + \boldsymbol{\epsilon}_{\tau}$$





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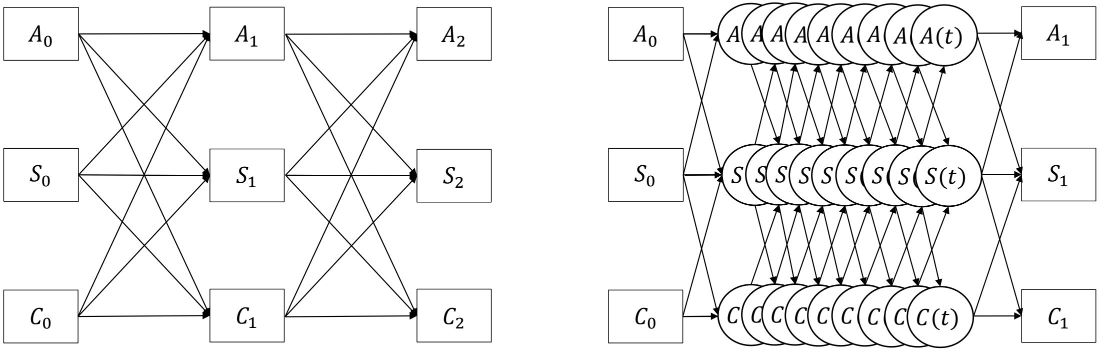
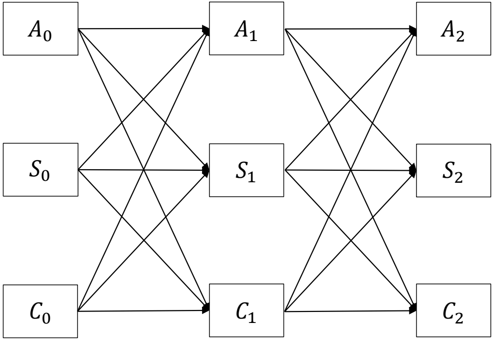
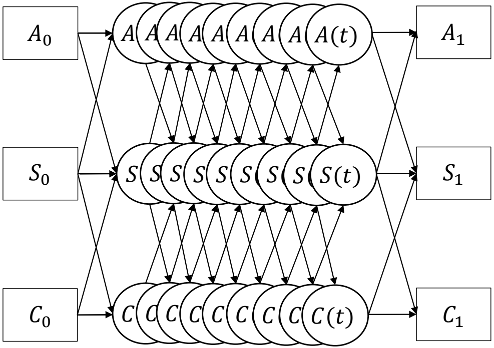


Boker (2002), Voelkle et al. (2013), Ryan, Kuiper & Hamaker (2018), Montfort, Oud & Voelkle (2018)

Project 2: Continuous-Time Modeling of ESM data

$$\frac{d\boldsymbol{Y}(t)}{dt} = \boldsymbol{AY}(t) + \epsilon$$





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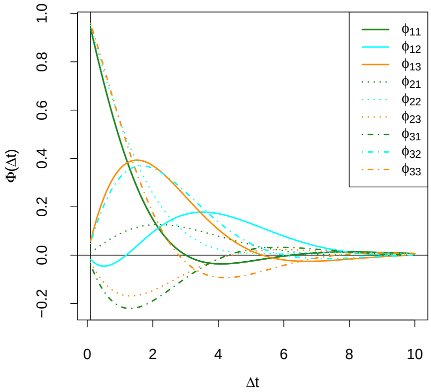
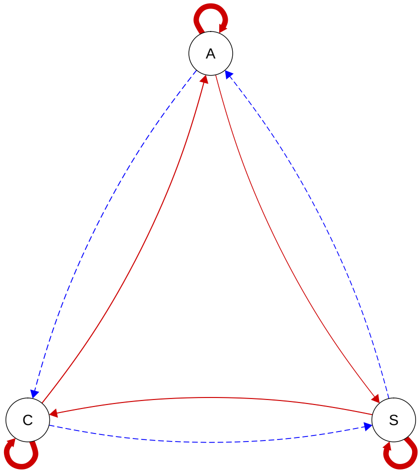
Implications of an underlying CT model





Ryan, Kuiper & Hamaker (2018), Ryan (2018, Psyarxiv), Ryan & Hamaker (in preperation)

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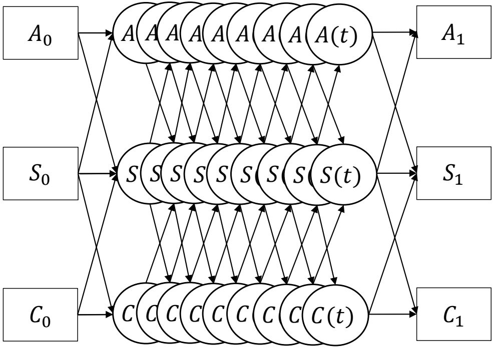

- Causal interpretation of VAR(1) paths misleading
- "Direct" effects made up of indirect pathways
- Centrality measures misinterpreted for any time-interval

Deboeck & Preacher (2015), Ryan (2018, Psyarxiv), Ryan & Hamaker (in preperation)

Future Directions 2

Better selection of intervention targets

- Take into account time-interval dependency
- Place centrality measures, path-specific effects within a formal interventionist causal framework

Broaden the scope of CT models considered

- Build from theory - check with VAR(1) dependencies observed in real data
- One-to-many mapping to more complex dynamic models

Contact info

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- `ryanoisin.github.io`