Successfully learning networks from undersampled neuroimaging data

D. Danks, S.M. Plis, C. Freeman, A. Caprihan, V. D. Calhoun

Carnegie Mellon University, The Mind Research Network

Abstract

- Many structure learning algorithms are based on Granger causality
- Granger causality is unreliable given undersampled time series data
- We developed RASL to learn structure from undersampled data
- In simulated data, RASL algorithms reveal causal timescale structure and improved measurement timescale learning
- RASL algorithms provide additional insight on fMRI data

Problems with "Granger Causality"

- **Granger causality**: $\boldsymbol{X}$ Granger-causes $\boldsymbol{Y} \equiv \boldsymbol{X}$'s history provides information about $\boldsymbol{Y}$'s current state (beyond $\boldsymbol{Y}$'s history)
- Mathematically: $\boldsymbol{Y}^t = \sum_{i=1}^{k} \left[\alpha_i \boldsymbol{Y}^{t-i} + \beta_i \boldsymbol{X}^{t-i}\right]$ is a significantly better predictor of $\boldsymbol{Y}^t$ than $\boldsymbol{Y}^t = \sum_{i=1}^{k} \alpha_i \boldsymbol{Y}^{t-i}$ (perhaps with covariates)
- Granger causality only reliable if key assumptions hold:
  - *Linearity* (but hemodynamic convolution does not create problems)
  - *Causal sufficiency* (but becoming less of a problem)
  - *Equal timescales* for both measurement and underlying causation
- **Undersampling**: Measurement timescale significantly slower than causal or communication timescale
  - Intermediate time points are unobserved
- Granger causality can be arbitrarily wrong given undersampling
  - $\boldsymbol{X}$ GC $\boldsymbol{Y}$ even though $\boldsymbol{Y}$ actually causes $\boldsymbol{X}$
  - $\boldsymbol{X}$ GC $\boldsymbol{Y}$ even though no direct causal connection
  - $\boldsymbol{X}$ doesn't GC $\boldsymbol{Y}$ even though $\boldsymbol{X}$ actually causes $\boldsymbol{Y}$
- Undersampling is a ubiquitous, persistent feature of fMRI data
- **Conclusion**: Structure learning algorithms based on Granger causality are likely unreliable given fMRI data

How to Overcome the Problems

- put figure 1 here and describe succinctly

Synthetic Data

Talk about results and include pictures:

NOTE: do not forget UNM and CMU logo (already added to logo folder but not sure where to place in poster)

FMRI Data

Talk about results and include pictures:

Conclusions

Conclude stuff here

References

[1] Authors Title In *Journal*, year.