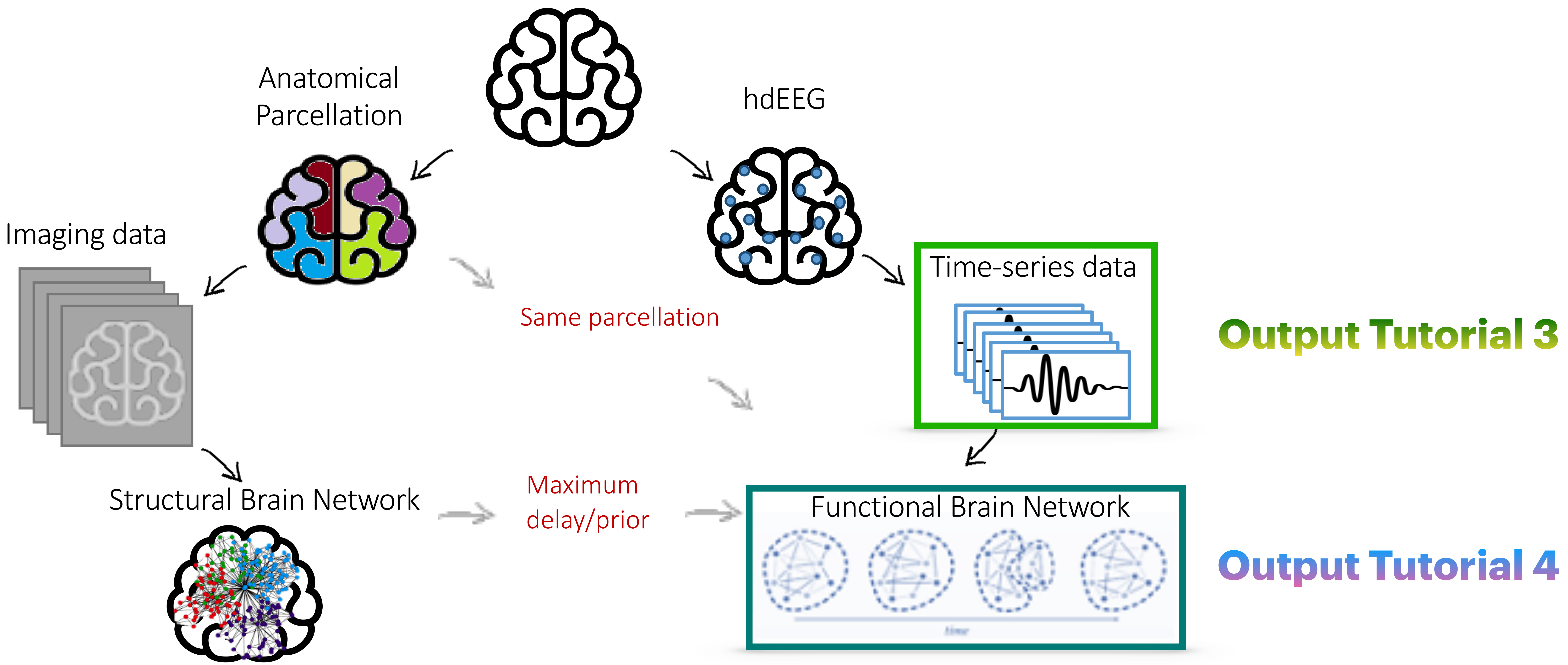
Dynamic Brain Connectivity

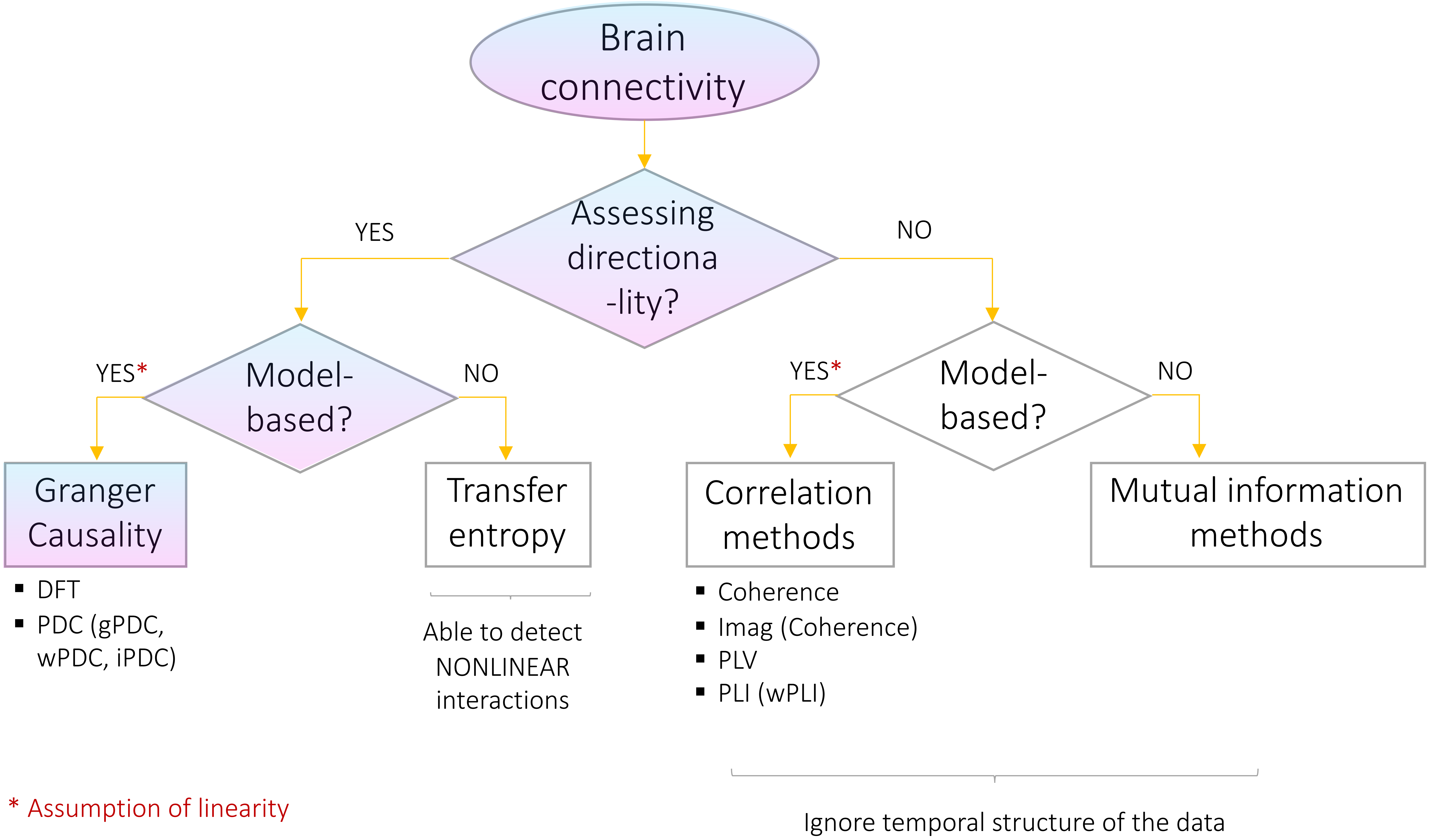
Tutorial 4

Maria Rubega and Jolan Heyse, Oct 12, 2021

Extraction of brain network



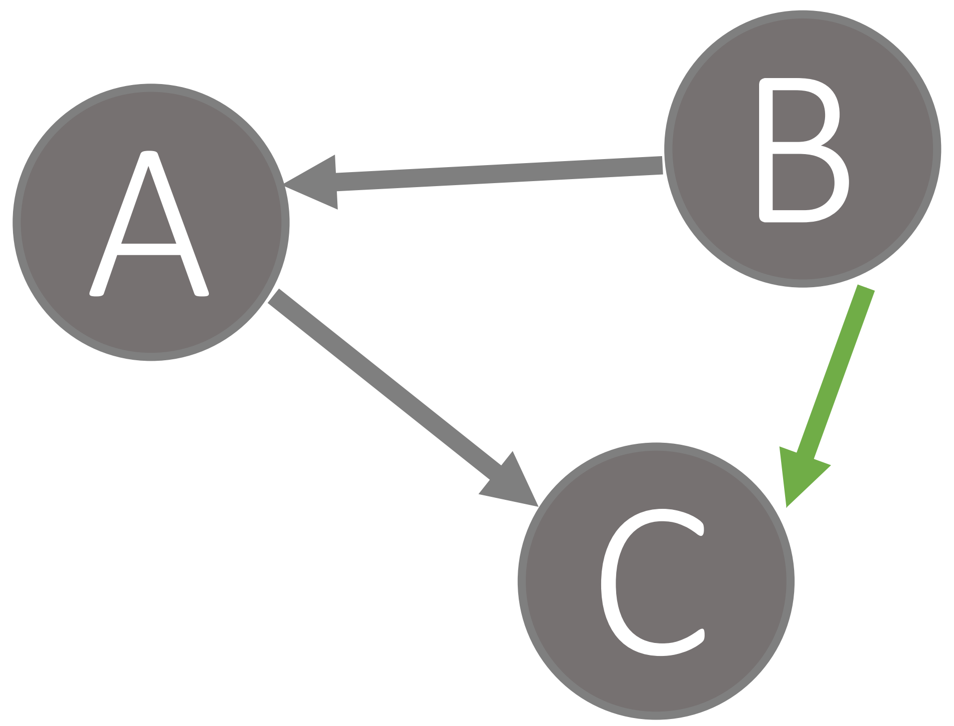
Brain connectivity methods

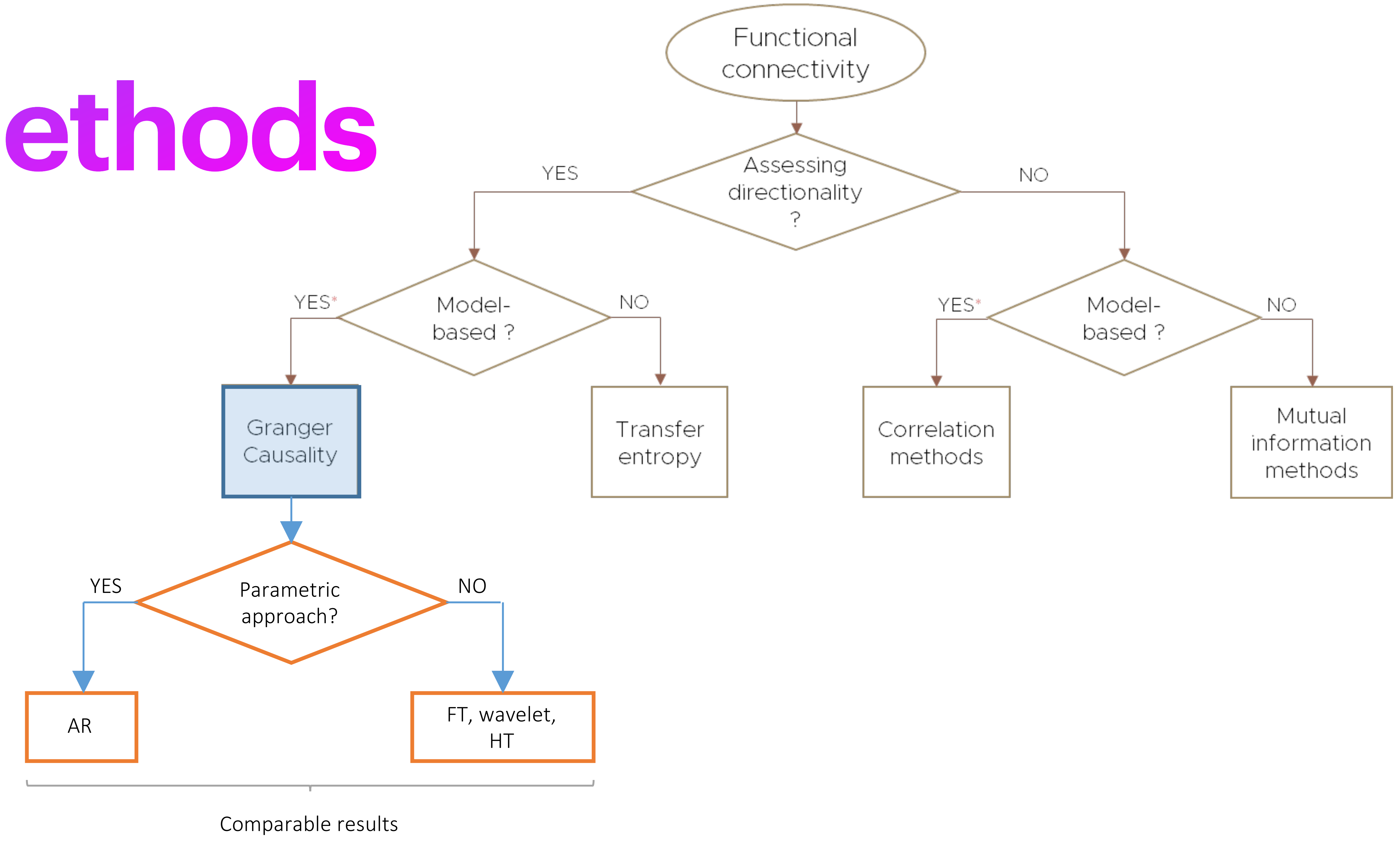


* Assumption of linearity

Effective connectivity methods

Granger causality





1. Direct Transfer function (DTF) → Impossible to distinguish direct or not-direct influences

2. Partial Directed Coherence (PDC) → Estimation of only direct influences

Sameshima, K., & Baccala, LA. (2016). CRC press

Time-varying connectivity

Assumption

The cortical sources computed from the EEG data generate a collection of realisations of a **multivariate stochastic process** which can be combined in a multivariate, multi-trial time series.

$$Y_k = \begin{bmatrix} y_{1,k}^{(1)} & \cdots & y_{d,k}^{(1)} \\ \vdots & \ddots & \vdots \\ y_{1,k}^{(N)} & \cdots & y_{d,k}^{(N)} \end{bmatrix} \quad k = t_1, .., t_T$$

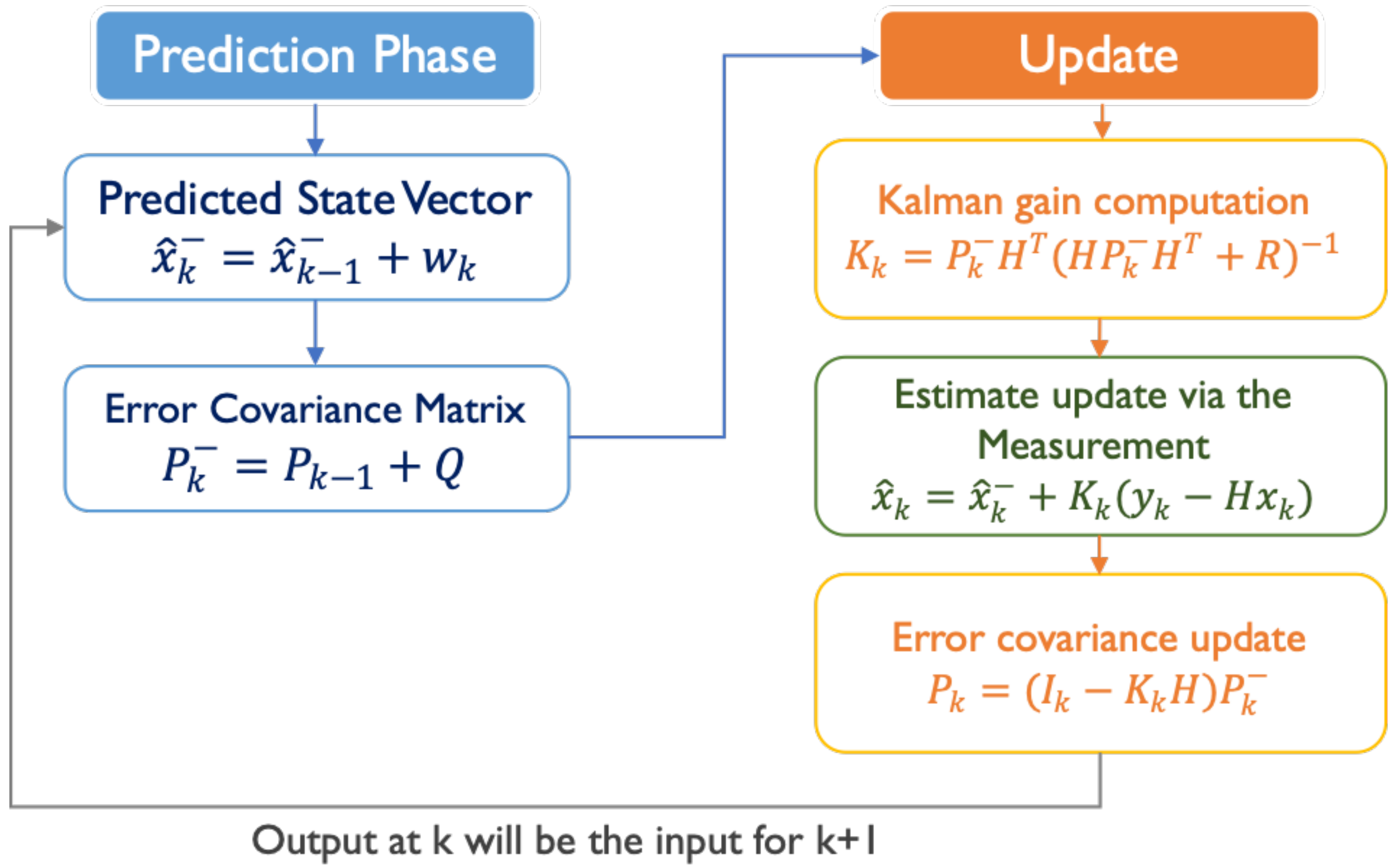
The process is defined by an integer **order** parameter **p**, a stationary d-dimensional **white noise process** and p parameter matrices at each time step, the so-called **AR matrices**. Nonzero entries in the AR matrices at *(i,j)* describe connections from source *j* to source *i*.

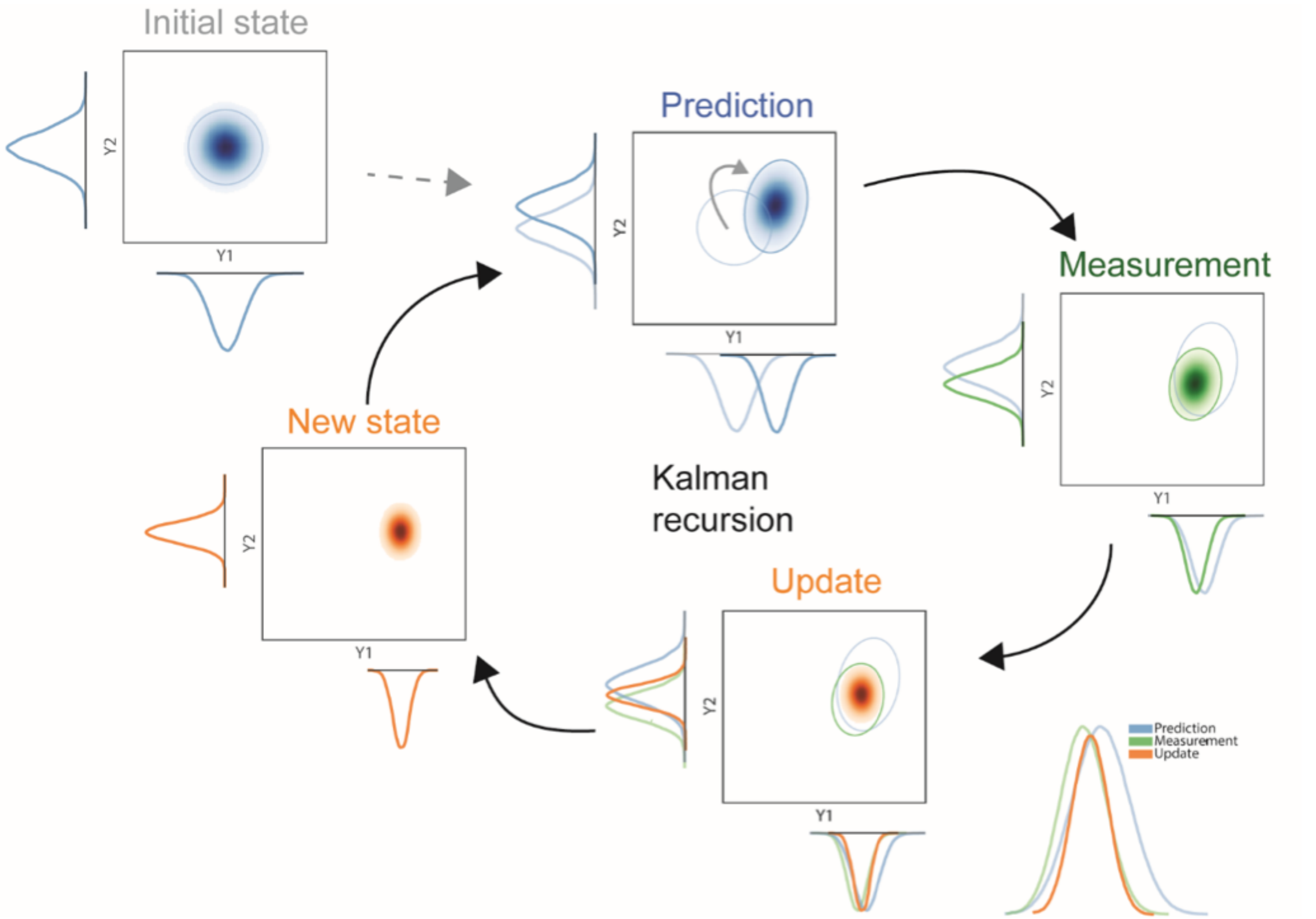
$$Y_k = \sum_{\mathrm{n}=1}^{p} X_{\mathrm{n},k} Y_{\mathrm{k}-n} + \varepsilon_k$$

Rubega et al, 2018; Milde et al, 2010

Time-varying connectivity

Real time Kalman filtering





Milde et al, 2010

Image credit: David Pascucci | EPFL

Time-varying connectivity

Parameters to set

$$Y_k = \sum_{\mathrm{n}=1}^{p} X_{\mathrm{n},k} Y_{\mathrm{k}-n} + \varepsilon_k$$

$$K_k = P_k^- H^T (H P_k^- H^T + R)^{-1}$$

$$\hat{R}_t = \hat{R}_{t-1} + c(\Sigma_r - \hat{R}_{t-1})$$

Σ_r: *measurement innovation covariance matrix*

***p*-order of the multi-variate autoregressive model**

Adaptation constant *c* of the Kalman gain

p-order of the multi-variate autoregressive model

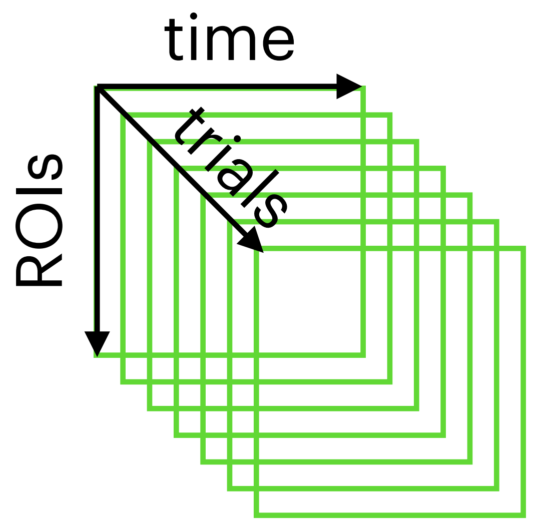
Adaptation constant c of the Kalman gain

trials ROIs time

```
p_value=6;
C=0.02;

temp=VEP_faces(1:30,:,373:501);
t_new=t(373:501);

gKF=dynet_SSM_KF(temp,p_value,C);
```



https://github.com/PscDavid/dynet_toolbox

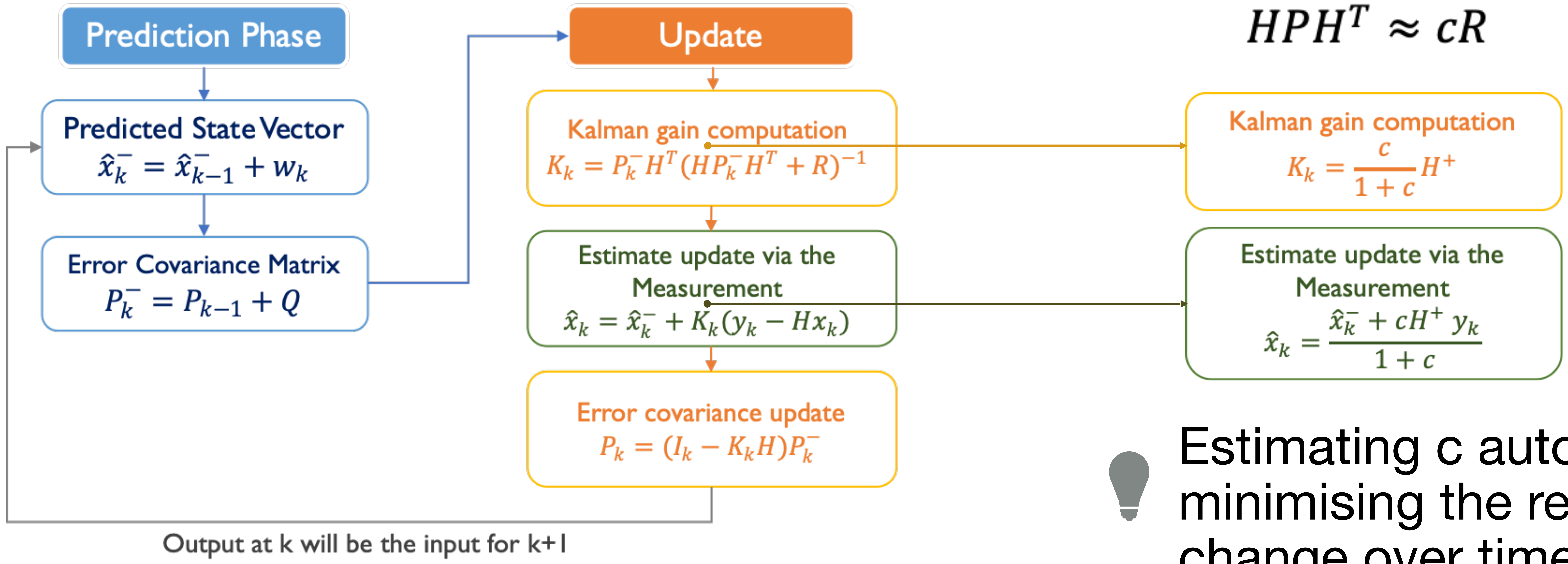
Time-varying connectivity

Self-tuning Optimized Kalman (STOK)

For systems with unknown R and Q:

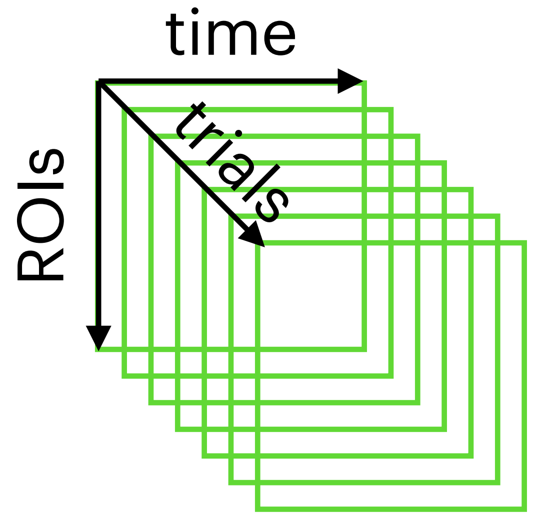
$$HPH^T \approx cR$$

Nilsson 2006



Estimating c automatically minimising the residuals change over time

Pascucci, Rubega and Plomp, 2020



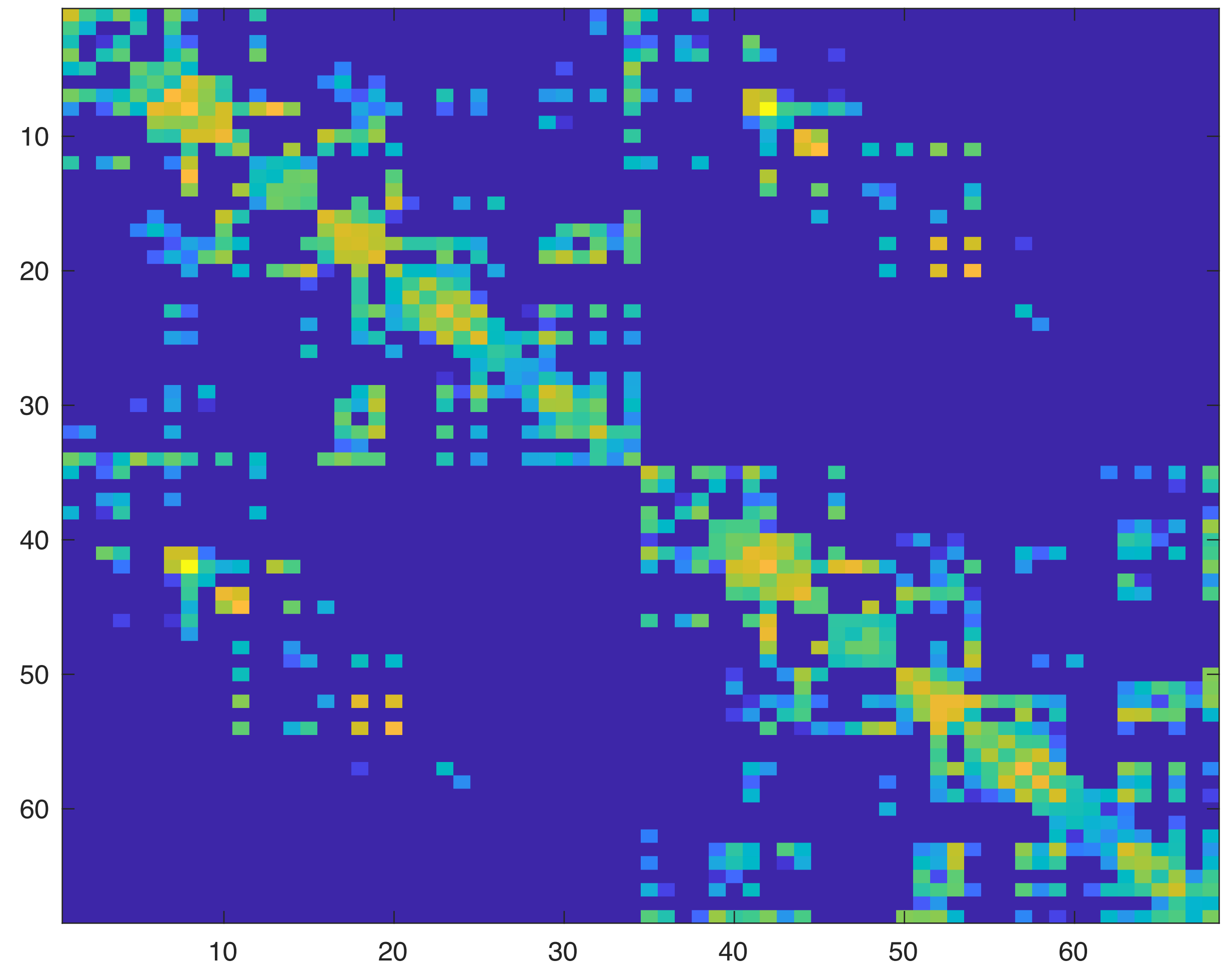
p-order of the multi-variate autoregressive model

```
STOK=dynet_SSM_STOK(temp,p_value);
```

https://github.com/PscDavid/dynet_toolbox

Time-varying connectivity

Structural prior




```
siSTOK = dynet_SSM_siSTOK(sitemp,p_order,SC_prior,.99)
```

https://github.com/PscDavid/dynet_toolbox