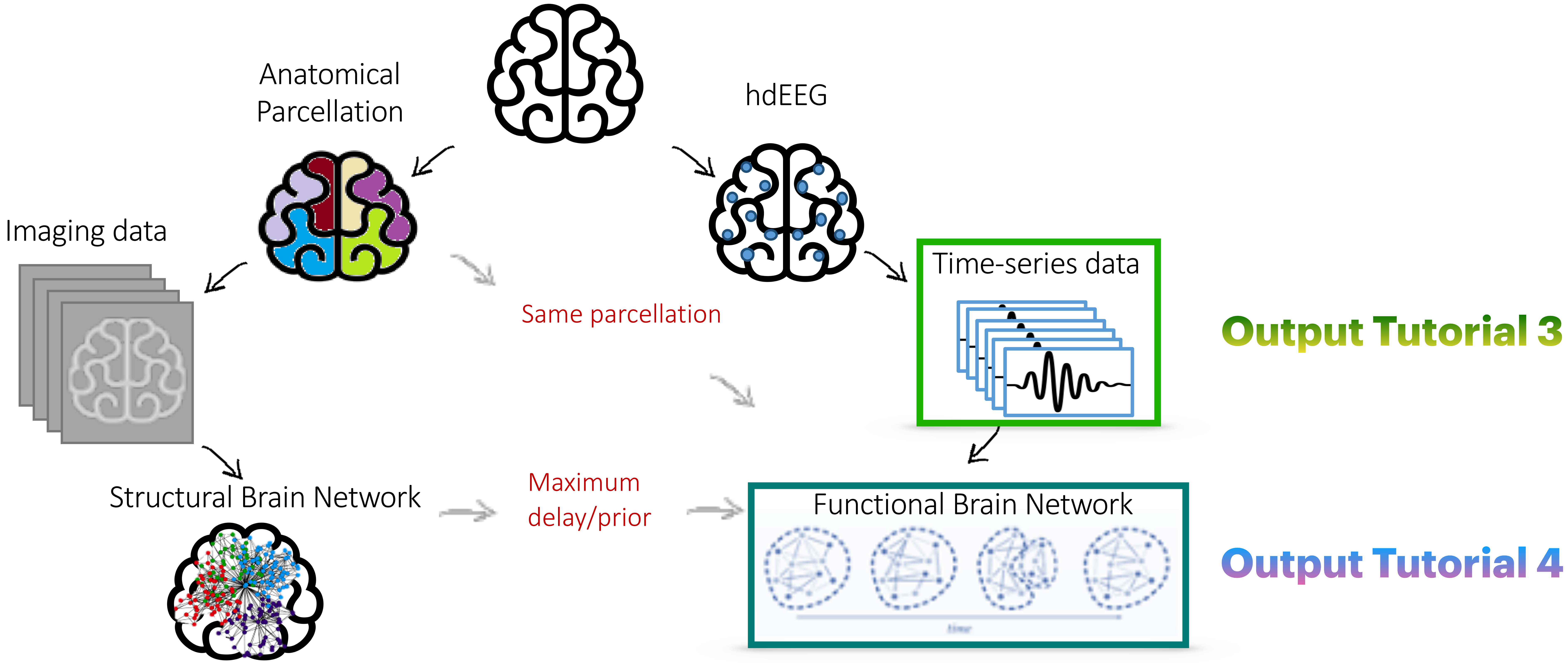
Dynamic Brain Connectivity

Tutorial 4

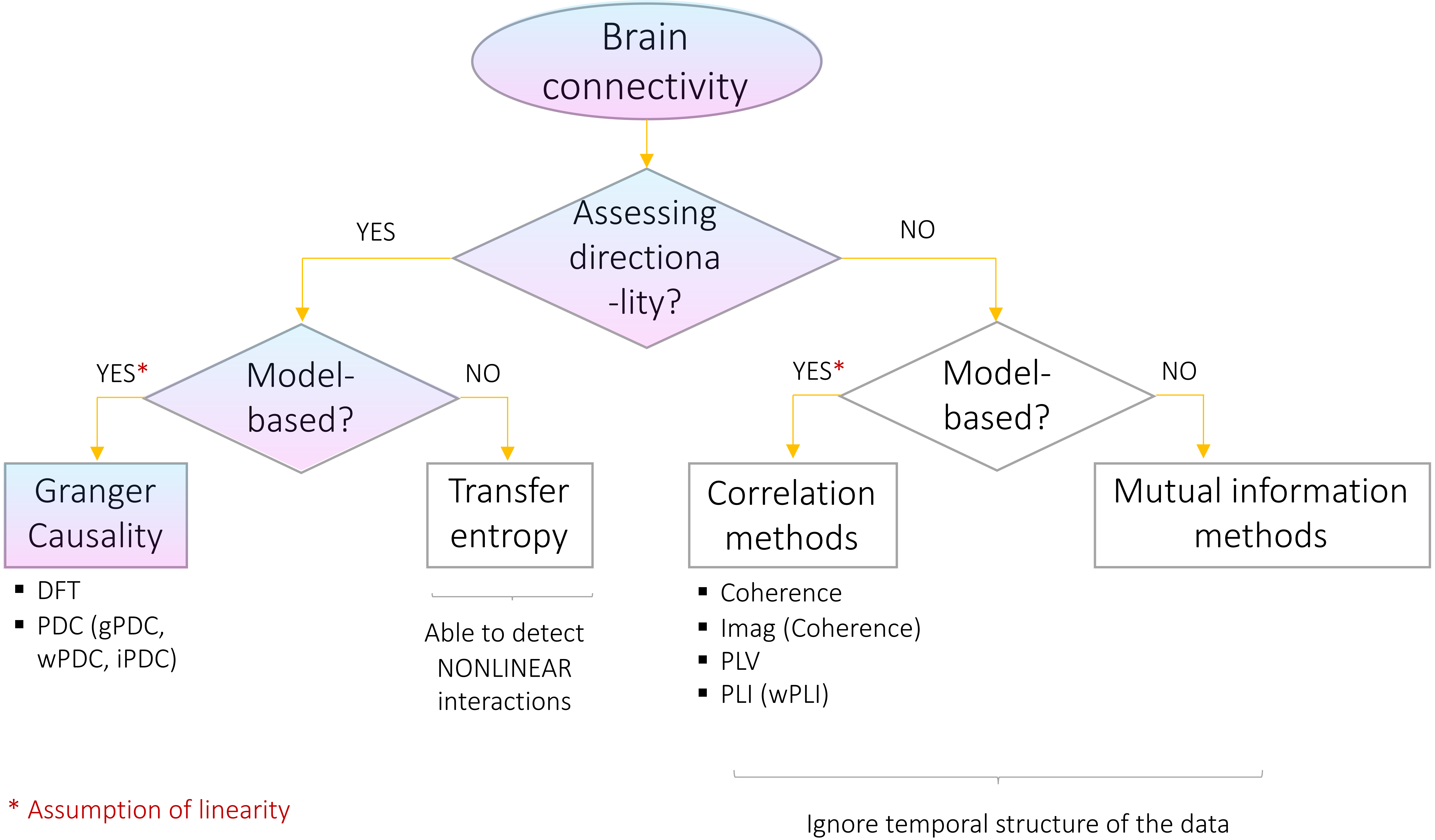
Brain Dynamics on the Connectome Summer School 2021

Maria Rubega and Jolan Heyse, Oct 12, 2021

Extraction of brain network

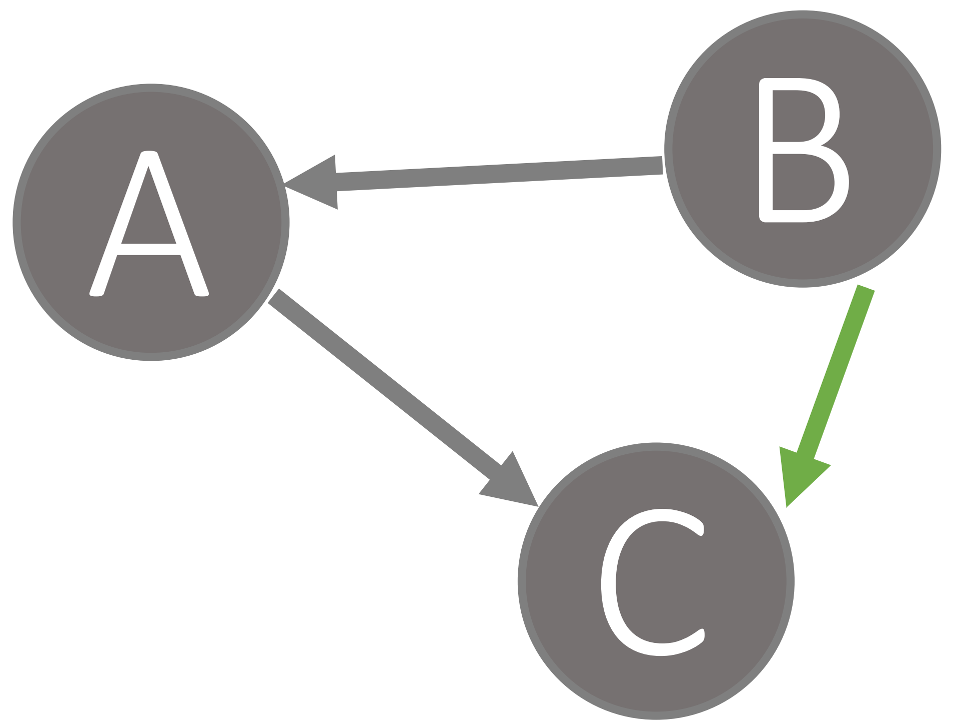


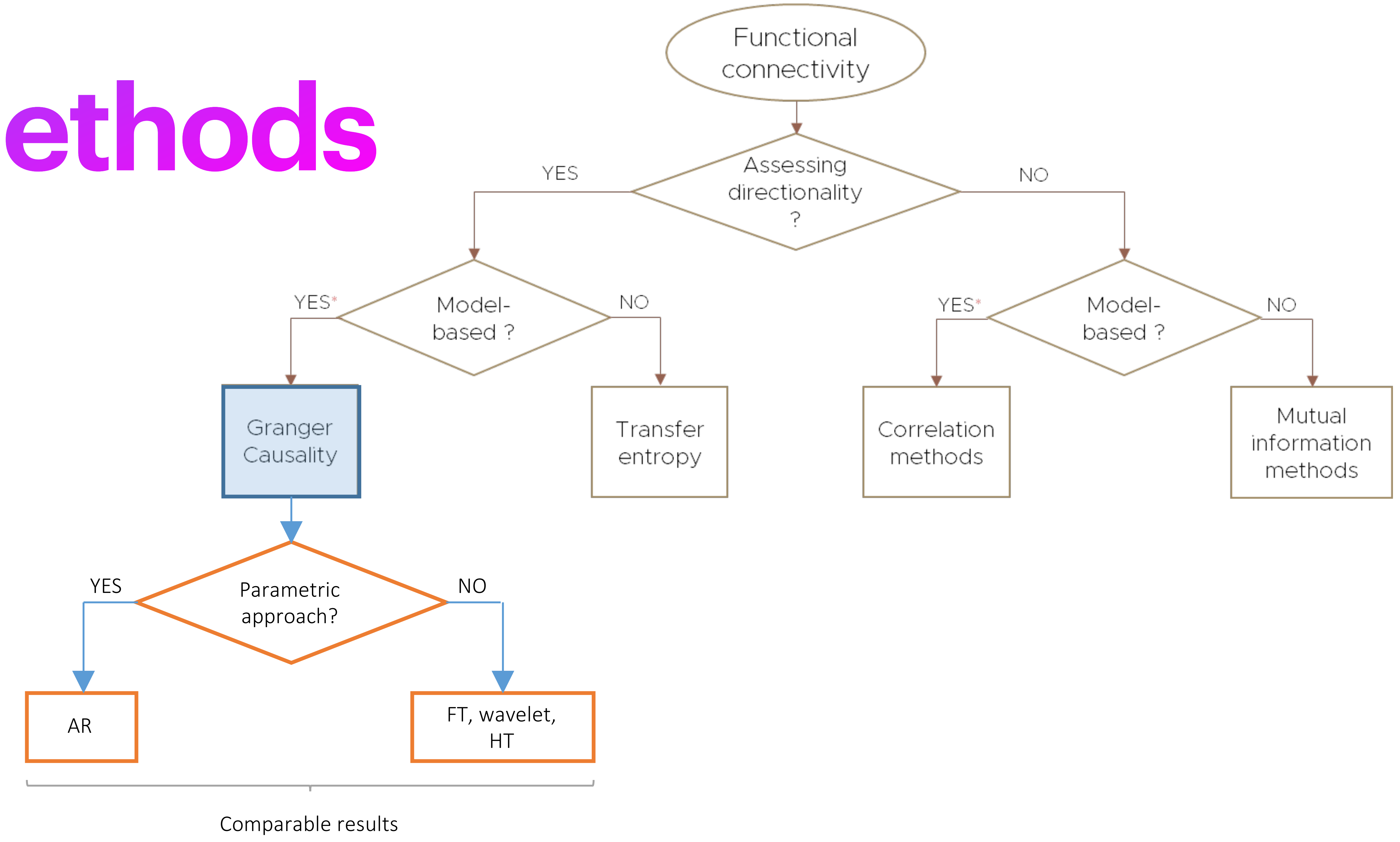
Brain connectivity methods



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.

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

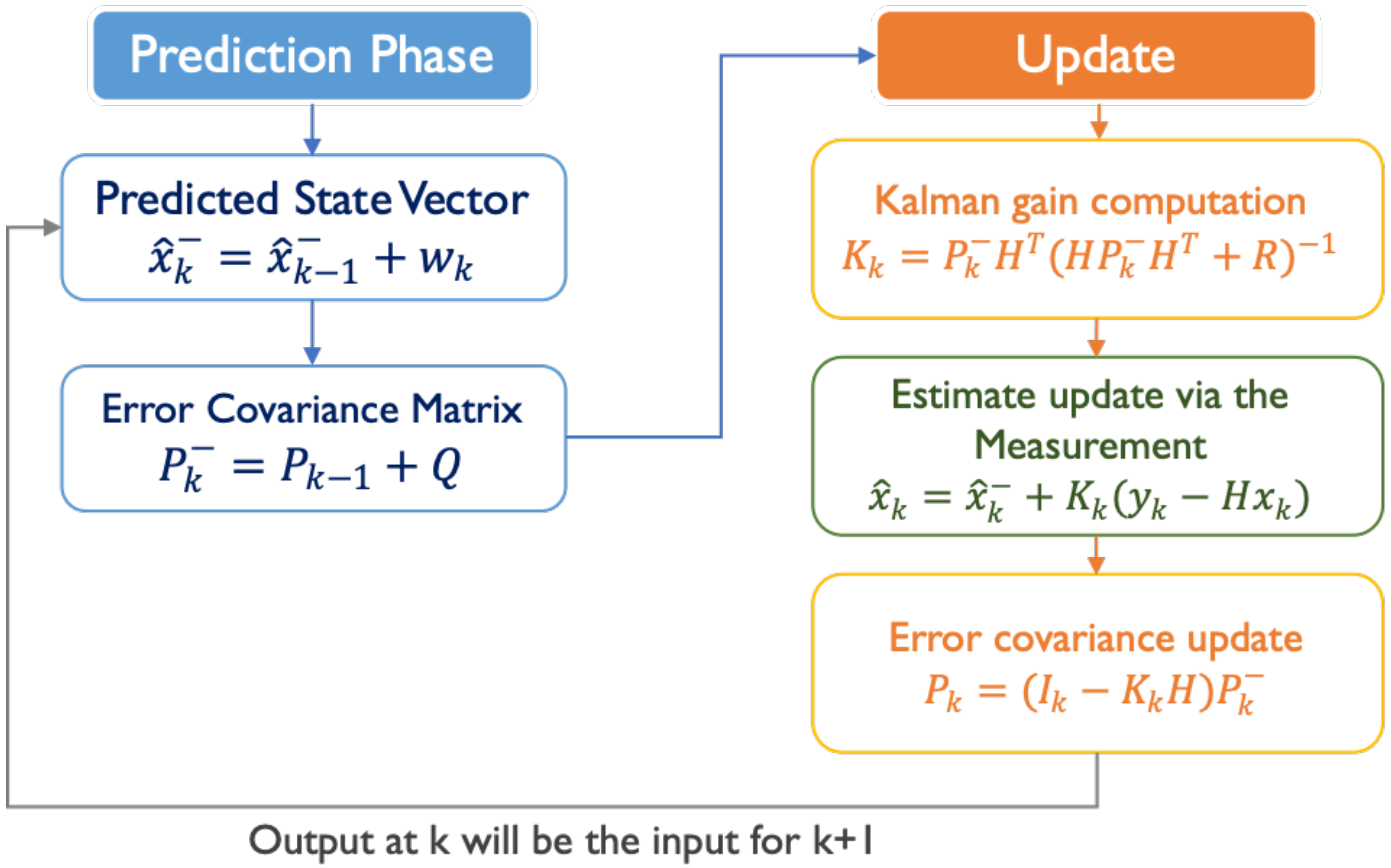
The process is defined by an integer **order** parameter **p**, a stationary d-dimensional **white noise process** and p parameter matrices at each time step, the so-called **AR matrices**. Nonzero entries in the AR matrices at *(i,j)* describe connections from source *j* to source *i*.

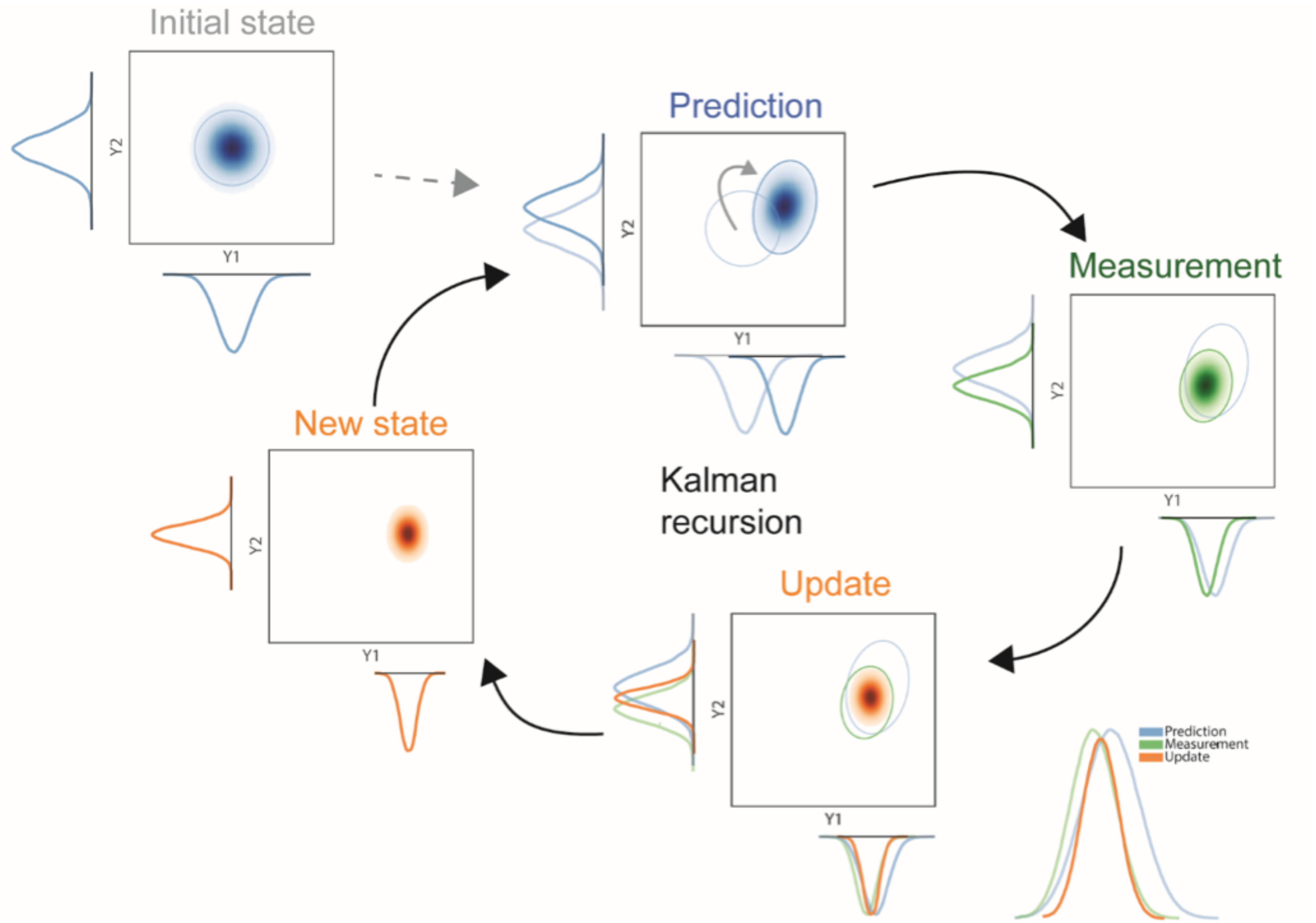
$$Y_k = \sum_{\mathrm{n}=1}^{p} X_{\mathrm{n},k} Y_{\mathrm{k}-n} + \varepsilon_k$$

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

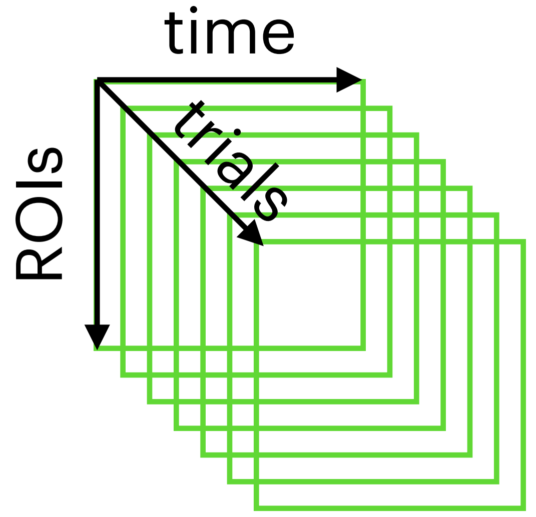
Adaptation constant c of the Kalman gain

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

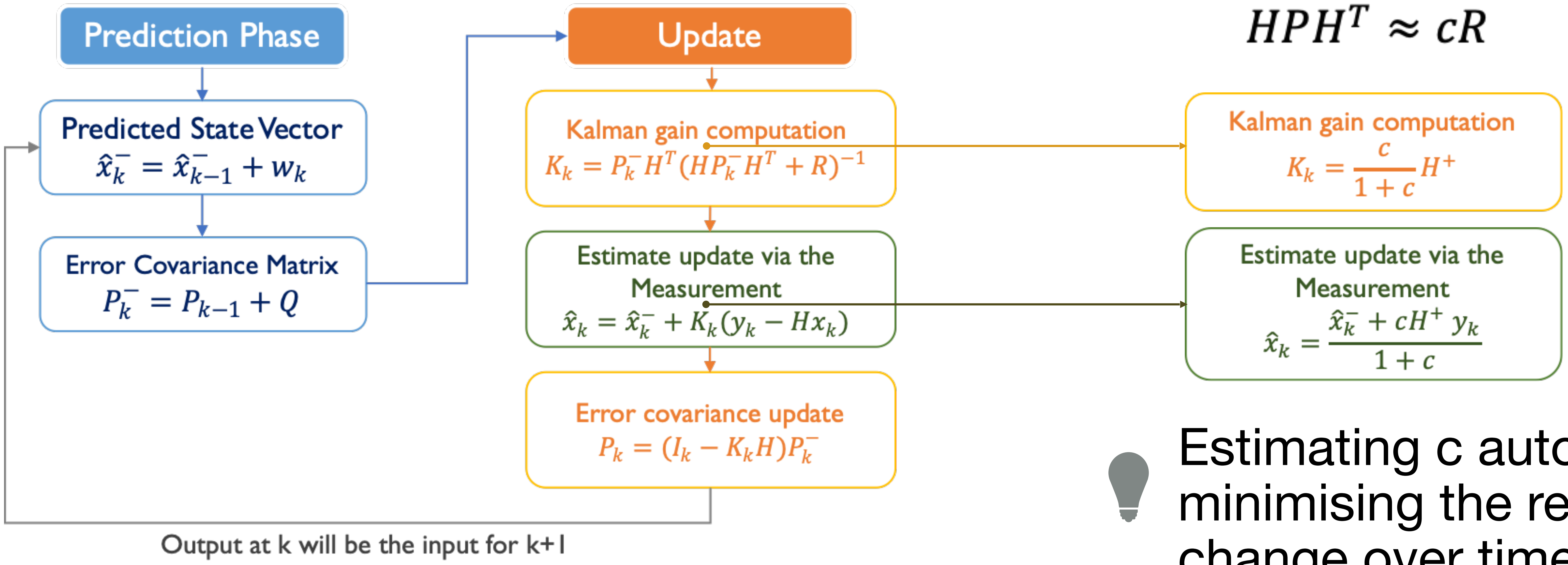
Time-varying connectivity

Self-tuning Optimized Kalman (STOK)

For systems with unknown R and Q:

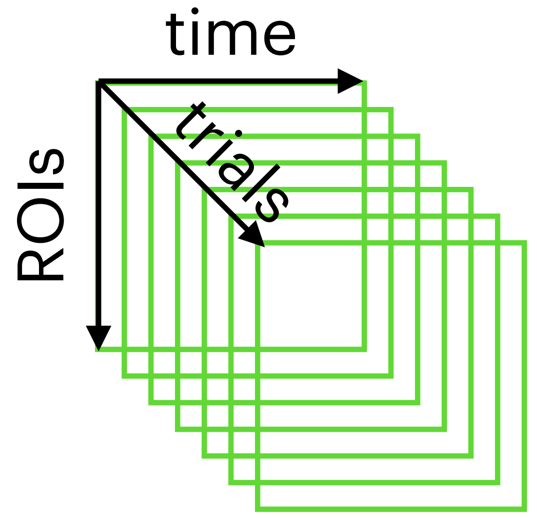
$$HPH^T \approx cR$$

Nilsson 2006



Estimating c automatically minimising the residuals change over time

Pascucci, Rubega and Plomp, 2020



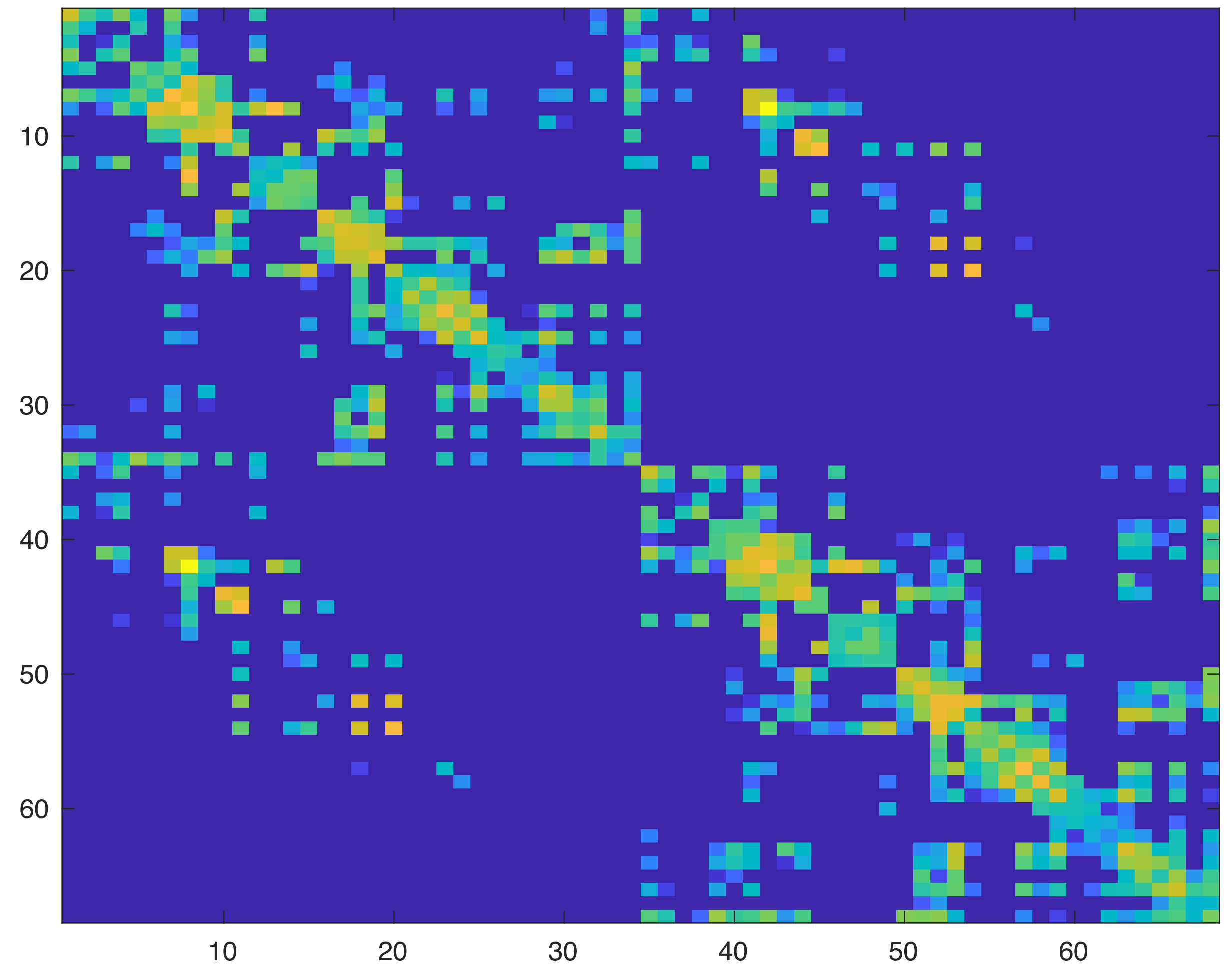
p-order of the multi-variate autoregressive model

```
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