

## Advanced Analyses of Resting-State fMRI (rs-fMRI): PART II

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## Download Demo Materials

心智科學腦研究推動網

心智影像研究(MRI)中心 @成大 活動網頁 → 實作資料

[http://fmri.ncku.edu.tw/tw/download/20160528\\_29rsfMRI/adrsfMRIdata.zip](http://fmri.ncku.edu.tw/tw/download/20160528_29rsfMRI/adrsfMRIdata.zip)

盧家鋒 個人網頁

進階fMRI資料分析理論與實作 → 實作資料

<http://www.ym.edu.tw/~cflu/adrsfMRIdata.zip>

## Course Arrangement

### PART I (5/28)

- Preprocessing of rs-fMRI
- SPM preprocessing batch
- Modification of batch file
- Group independent component analysis (group ICA)

### PART II (5/29)

- Seed-based functional connectivity
- Complex network analysis

## Employed Software/Package

### 1. SPM preprocessing

- <http://www.fil.ion.ucl.ac.uk/spm/>

### 2. REST functional connectivity, ReHo, ALFF, fALFF, VMHC

- <http://restfmri.net/forum/index.php?q=rest>

### 3. IBASPM 64-bit

- [http://www.ym.edu.tw/~cflu/software/Ibaspm\\_64.zip](http://www.ym.edu.tw/~cflu/software/Ibaspm_64.zip)

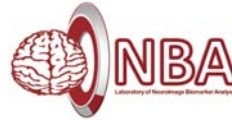
### 4. Brain Connectivity Toolbox/Network Based Statistic Toolbox

- <https://sites.google.com/site/bctnet/>

### 5. GraphVar

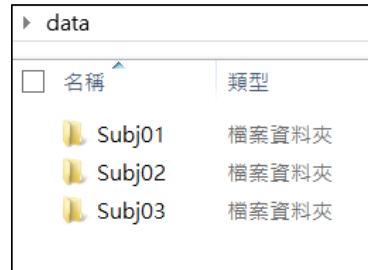
- <http://www.rfmri.org/graphvar>

## Switch current folder to data folder



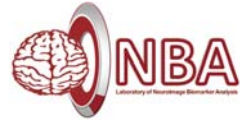
More convenient to execute the subsequent processing steps...

Current Folder: C:\Users\Alvin\Desktop\data\data\Subj01



Do not include REST path!

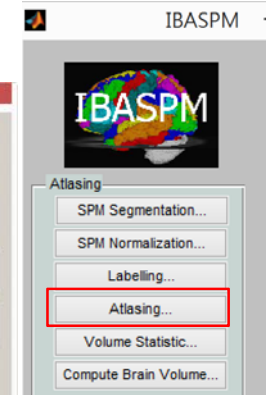
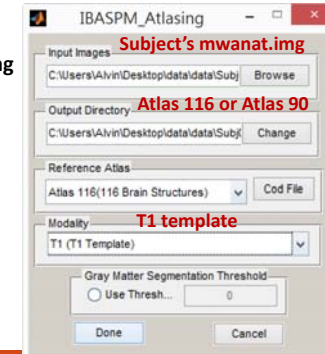
## Extract Subject's Atlas



IBASPM 64-bit version

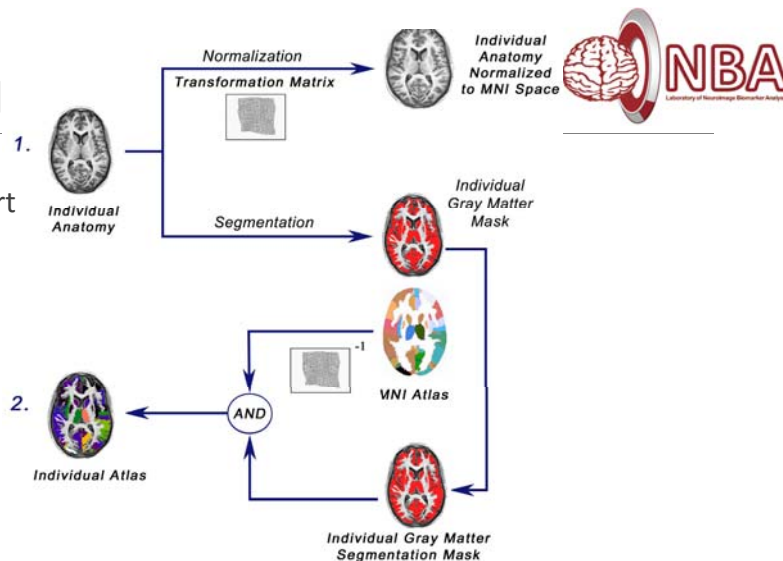
[http://www.ym.edu.tw/~cflu/software/Ibaspm\\_64.zip](http://www.ym.edu.tw/~cflu/software/Ibaspm_64.zip)

/Atlased/mwanat\_Atlas.img



## IBASPM

Individual atlas flowchart



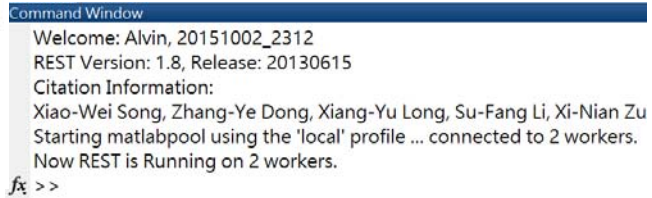
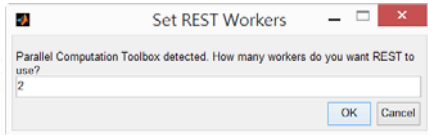
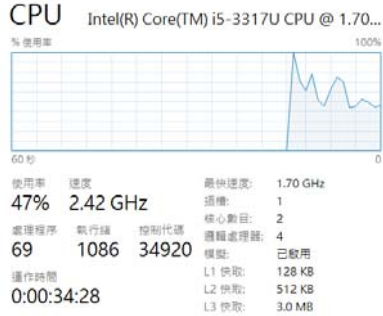
## Seed-based Functional Connectivity Analysis using REST toolbox

Include REST & SPM8 path!

# Initialize REST environment



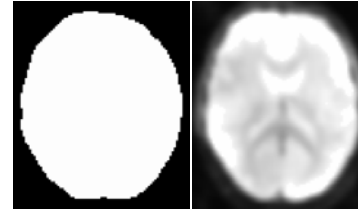
>> rest



# Create Brain Mask

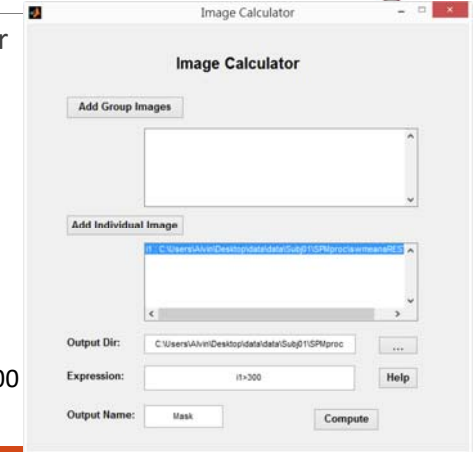


Utilities → REST Image Calculator



Import subject's swmeanaREST.img

i1 > 300



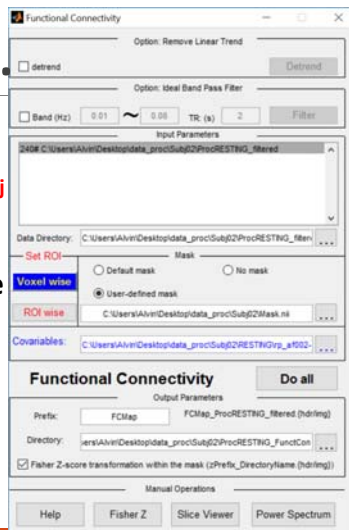
FuncCon

# Functional Con.

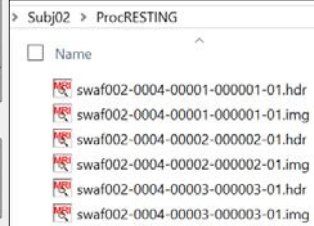


Select folder of Subj

Voxel wise ↔ ROI wise  
Mask file  
6 motion parameters as covariates

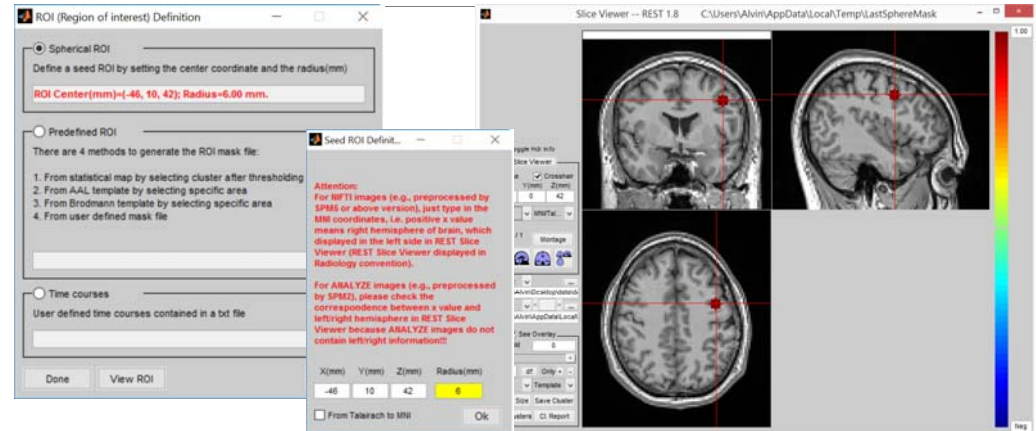


Only put fMRI smooth data in this folder!

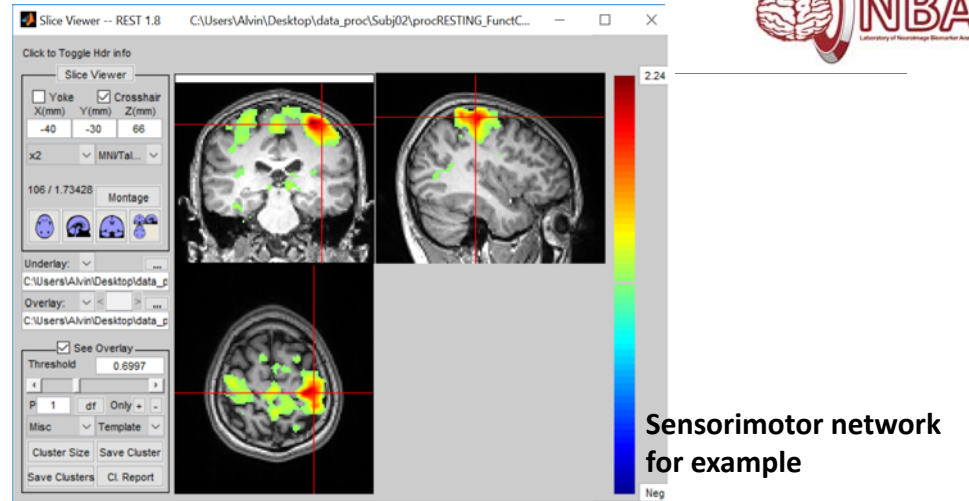
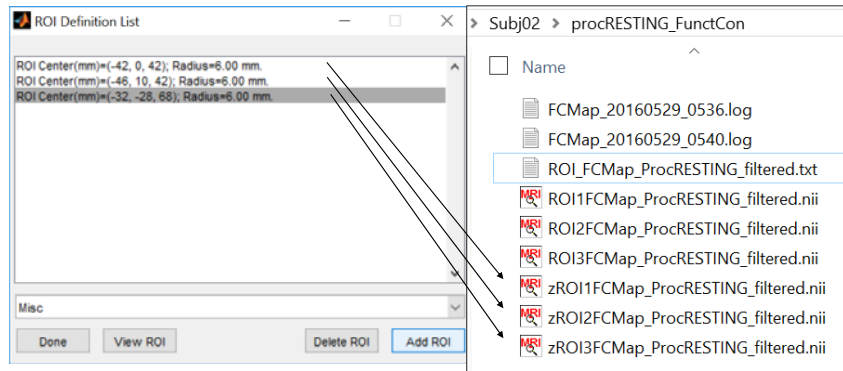


FuncCon

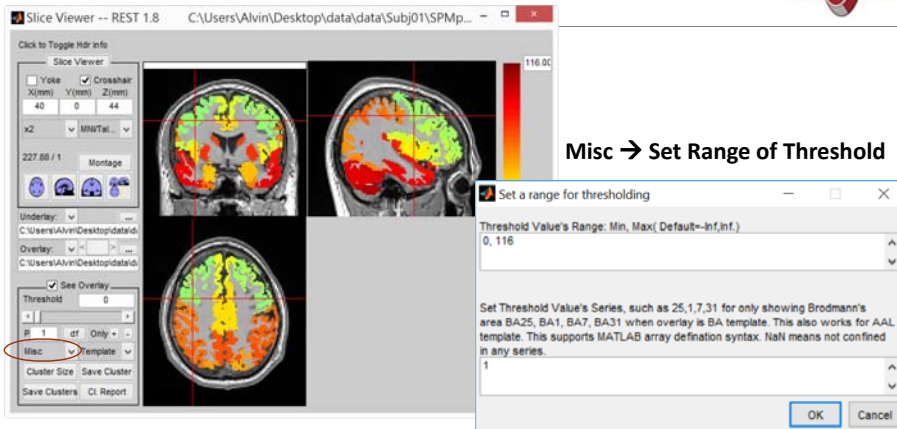
# Spherical ROI



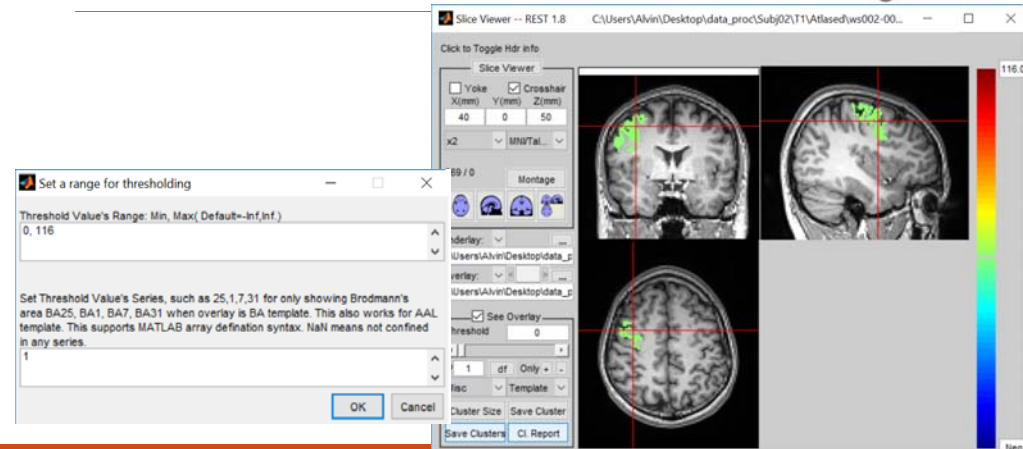
# Functional Connectivity Maps



# Atlas ROI



# Atlas ROI





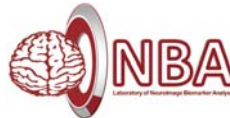
# Create cluster ROI



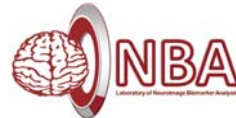
# FuncCon Connectivity Maps



# Functional Connectivity logfile



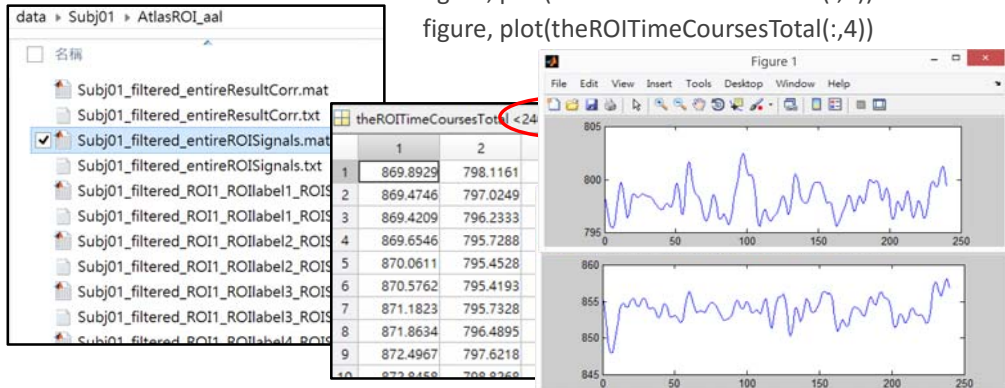
# Extract Atlas ROI signals



## Utilities → Extract ROI Signals

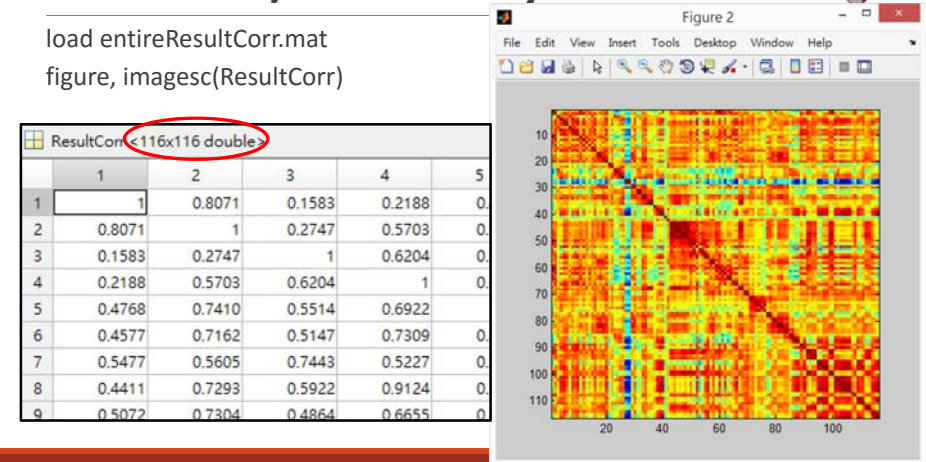
## Extract Atlas ROI signals

figure, plot(theROITimeCoursesTotal(:,2))  
figure, plot(theROITimeCoursesTotal(:,4))

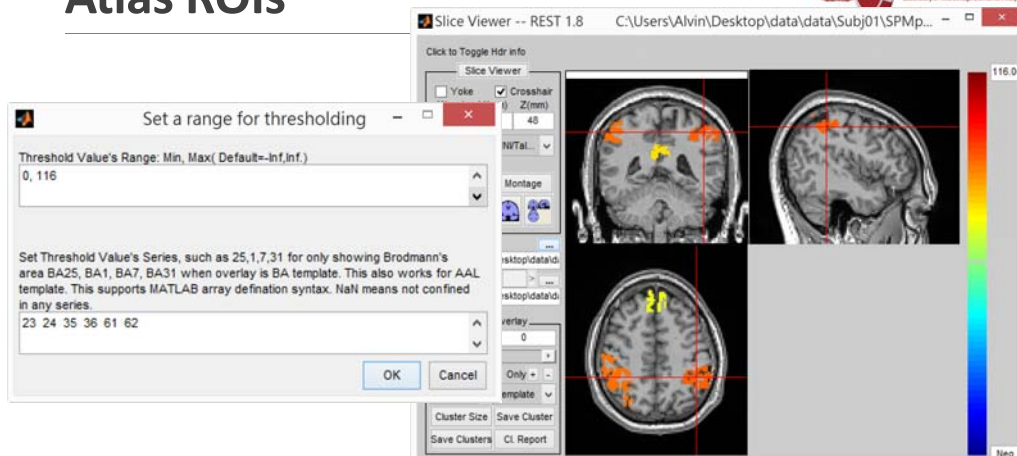


## Correlation/Connectivity Matrix

load entireResultCorr.mat  
figure, imagesc(ResultCorr)



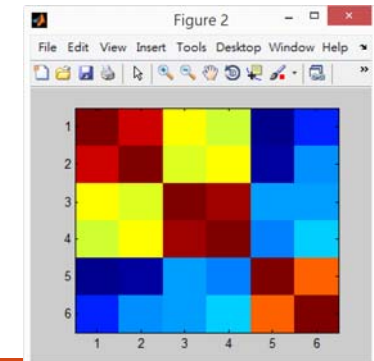
## Atlas ROIs



## Exercise

Extract AAL 23,24,35,36,61,62 ROI signals and correlation matrix.

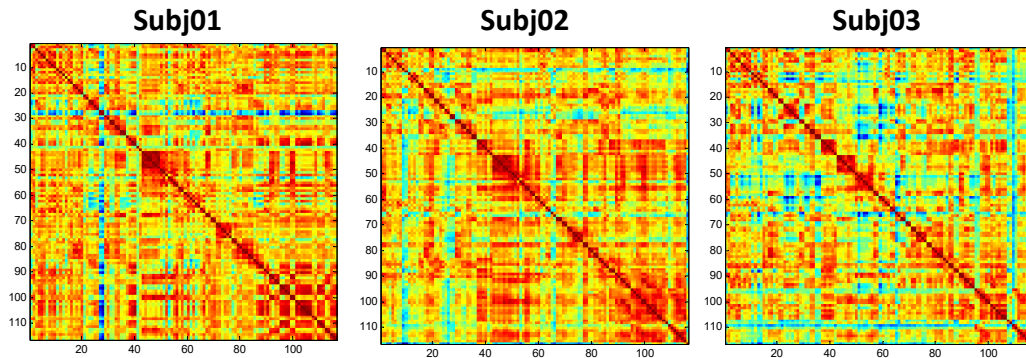
- Create a mask image with selected ROI labels
- Extract ROI signals
- Plot correlation/connectivity matrix



# Statistics on Connectivity Matrices



Descriptive statistics, one-sample t-test, two-sample t-test, paired t-test,....



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[HTTP://WWW.YM.EDU.TW/~CFLU](http://www.ym.edu.tw/~cflu)

25

# Complex Network Analysis

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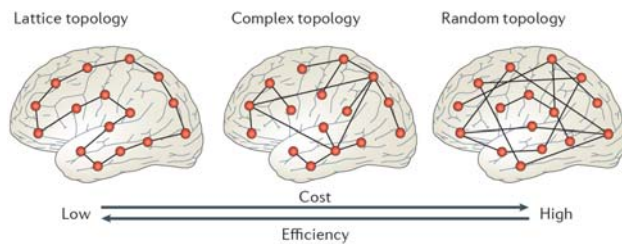
[HTTP://WWW.YM.EDU.TW/~CFLU](http://www.ym.edu.tw/~cflu)

26

# Human brain networks Wiring costs ↔ efficiency



- Clusters of lattice-like short-distance connections between spatially neighboring nodes
- Topologically direct interconnections between spatially remote brain regions → increase efficiency of information processing
- Nodes aggregated topologically and anatomically as modules → minimize wiring cost



Bullmore et al., Nature Reviews Neuroscience, 13: 336-349, 2012.

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27

# Network construction

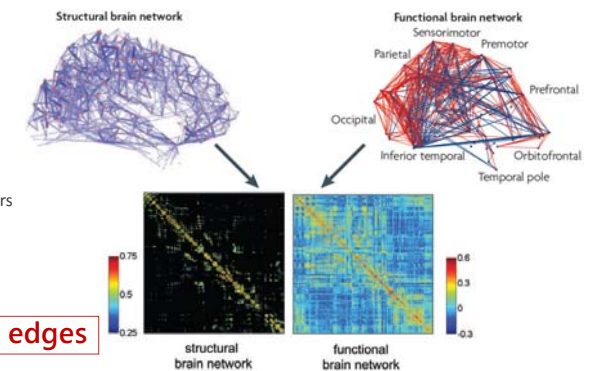


## Nodes

- Cortical regions

## Edges

- Cortical thickness correlations
- Fiber connections
  - DSI, DTI, transneuronal tracers
- Functional connectivity
  - fMRI, EEG, MEG



**Network = nodes + edges**

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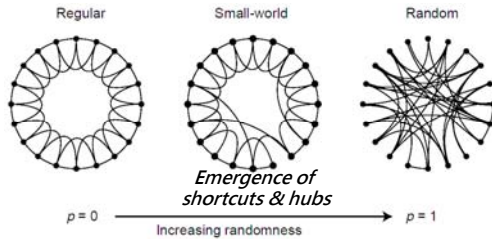
28



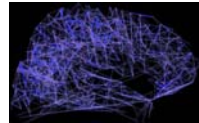
# Complex networks



- Brain have a small-world architecture.



- Complex networks**
- Social network
  - WWW internet
  - Biological system
  - Brain network



- > High local clustering
- > Local segregation
- > Low separation
- > Global integration

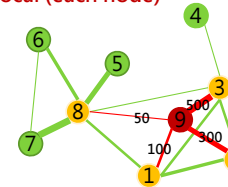
high signal-propagation speed, computational power, and synchronizability

Watts DJ, Strogatz SH, *Nature* 393:440-442, 1998.

# Graph theory: topological properties



**Local (each node)**



- degree** (the number of neighbors)

*e.g. degree of node 9 = 4*

- strength** (the connected fiber number\*FA)

*e.g. strength of node 9 = (50+100+300+500)/4 = 237.5*

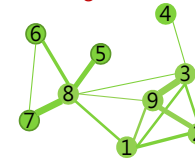
- clustering coefficient** (the connection between neighbors, [0~1])

*e.g. clustering coefficient of node 9 = 5/6 = 0.83*

- path length (separation)** (the minimal steps for connection)

*e.g. path length from node 9 to node 6 = 2 steps (9 → 8 → 6)*

**Global (average over all nodes)**

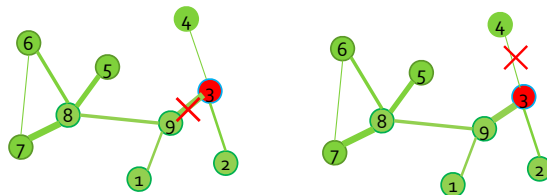


Salvador et al, *Philos Trans R Soc Lond B Biol Sci*, 360, 937-946, 2005

# Network properties



- The topological observations can reveal a "hidden" or "high-level" relations between nodes.



# Brain Connectivity Toolbox



NeuroImage 52 (2010) 1059-1069

Contents lists available at ScienceDirect

**NeuroImage**

journal homepage: [www.elsevier.com/locate/ynimg](http://www.elsevier.com/locate/ynimg)




## Complex network measures of brain connectivity: Uses and interpretations

Mikail Rubinov<sup>a,b,c</sup>, Olaf Sporns<sup>d,\*</sup>

<sup>a</sup> Black Dog Institute and School of Psychiatry, University of New South Wales, Sydney, Australia

<sup>b</sup> Mental Health Research Division, Queensland Institute of Medical Research, Brisbane, Australia

<sup>c</sup> CSIRO Information and Communication Technologies Centre, Sydney, Australia

<sup>d</sup> Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN 47405, USA



# Brain Connectivity Toolbox



Degree: number of links connected to a node

Degree of a node  $i$ ,  $k_i = \sum_{j \in N} a_{ij}$ .

Shortest path length: a basis for measuring integration

Shortest path length (distance), between nodes  $i$  and  $j$ ,

$$d_{ij} = \sum_{a_{uv} \in g_{i-j}} a_{uv}$$

where  $g_{i-j}$  is the shortest path (geodesic) between  $i$  and  $j$ . Note that  $d_{ij} = \infty$  for all disconnected pairs  $i, j$ .

Global efficiency

Global efficiency of the network (Latora and Marchiori, 2001),

$$E = \frac{1}{n} \sum_{i \in N} E_i = \frac{1}{n} \sum_{i \in N} \frac{\sum_{j \in N, j \neq i} d_{ij}^{-1}}{n-1}$$

where  $E_i$  is the efficiency of node  $i$ .

Weighted degree of  $i$ ,  $k_i^w = \sum_{j \in N} w_{ij}$ .  
 (Directed) out-degree of  $i$ ,  $k_i^{out} = \sum_{j \in N} a_{ij}$ .  
 (Directed) in-degree of  $i$ ,  $k_i^{in} = \sum_{j \in N} a_{ji}$ .

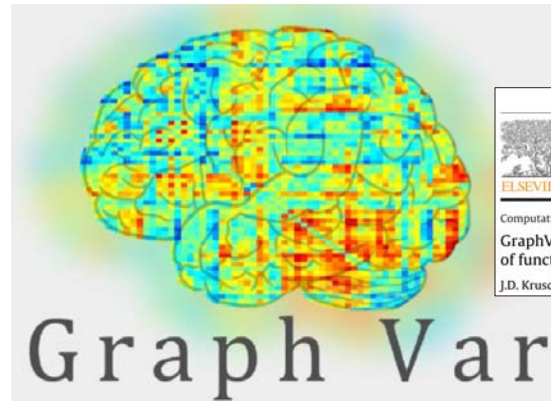
- Binary network
- Weighted network
- Directed network

Shortest directed path length from  $i$  to  $j$ ,  $d_{ij}^- = \sum_{a_{uv} \in g_{i-j}^-} a_{uv}$ , where  $g_{i-j}^-$  is the directed shortest path from  $i$  to  $j$ .

Weighted global efficiency,  $E^w = \frac{1}{n} \sum_{i \in N} \frac{\sum_{j \in N, j \neq i} \left( \frac{d_{ij}^w}{n-1} \right)^{-1}}$

Directed global efficiency,  $E^- = \frac{1}{n} \sum_{i \in N} \frac{\sum_{j \in N, j \neq i} \left( \frac{d_{ij}^-}{n-1} \right)^{-1}}$

# GUI for network analysis



Journal of Neuroscience Methods 245 (2015) 107–115

Contents lists available at ScienceDirect

**Journal of Neuroscience Methods**

journal homepage: [www.elsevier.com/locate/jneumeth](http://www.elsevier.com/locate/jneumeth)

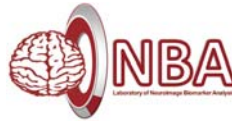
ELSEVIER

Computational Neuroscience

**GraphVar: A user-friendly toolbox for comprehensive graph analyses of functional brain connectivity**

J.D. Kruschwitz<sup>a,b,\*</sup>, D. List<sup>a,b,\*</sup>, L. Waller<sup>a</sup>, M. Rubinov<sup>c</sup>, H. Walter<sup>a</sup>

# Q & A



# THE END

[alvin4016@ym.edu.tw](mailto:alvin4016@ym.edu.tw)

# Error in file\_array function in REST



```
ideal rectangular filter: "C:\Users\Alvin\Desktop\data_proc\Subj02\ProcRESTING"  
Read 3D EPI functional images: "C:\Users\Alvin\Desktop\data_proc\Subj02\ProcRESTING"  
  
Load mask "C:\Users\Alvin\Desktop\data_proc\Subj02\Mask.nii".  
Band Pass Filter working. Wait.....  
Saving filtered images. Wait...
```

Add SPM8 path!!

```
Exception occurred. (MATLAB:UndefinedFunction)  
Error using ==> parallel_function at 598  
Error in ==> rest_Write4DNIFTI at 47  
Undefined function or variable 'file_array'.  
  
598#line, parallel_function, in "C:\Program Files\MATLAB\R2010b\toolbox\matlab\lang\parallel_function.m"  
1224#line, BandPass, in "C:\Users\Alvin\Desktop\softwares\REST_v1.8_130615\fc_gui.m"  
602#line, btnBandPass_Callback, in "C:\Users\Alvin\Desktop\softwares\REST_v1.8_130615\fc_gui.m"  
96#line, gui_mainfcn, in "C:\Program Files\MATLAB\R2010b\toolbox\matlab\guide\gui_mainfcn.m"  
35#line, fc_gui, in "C:\Users\Alvin\Desktop\softwares\REST_v1.8_130615\fc_gui.m"
```