

## Medical Image and Signal Analyses

### 研究方法淺介：醫學影像與訊號分析應用

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國立陽明大學 物理治療暨輔助科技學系 兼任助理教授

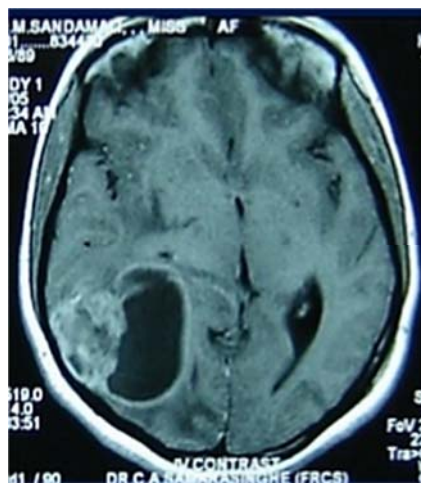
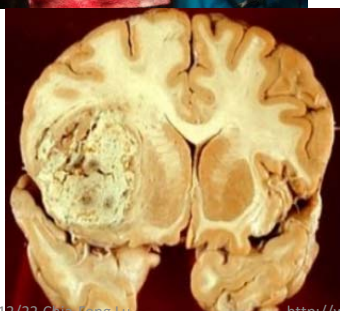
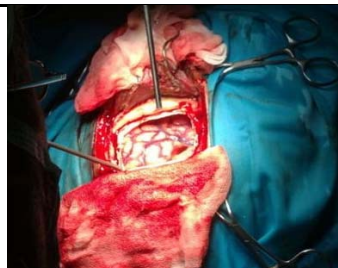
## "Intelligence is Key to Victory against ISIS"

Prof. Bob Uda

Counterterrorist expert

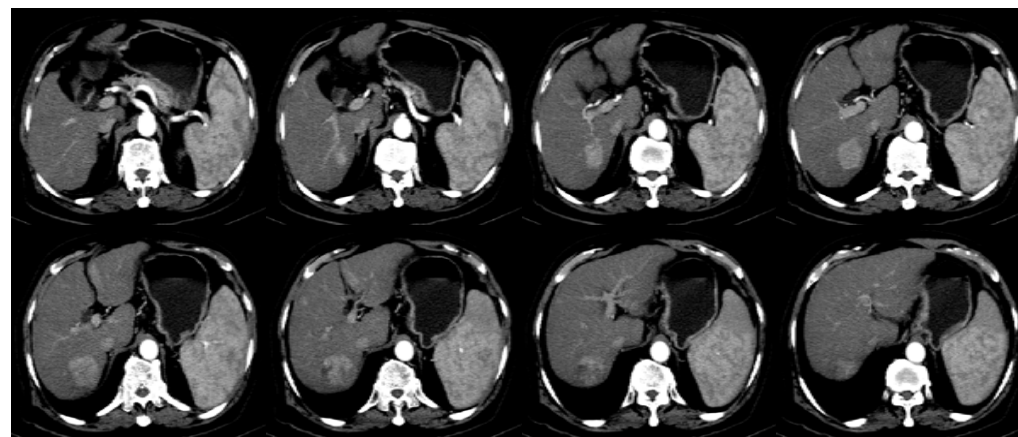
Imaging and signaling techniques are spies in clinical war.

## Glioblastoma – pre-surgery

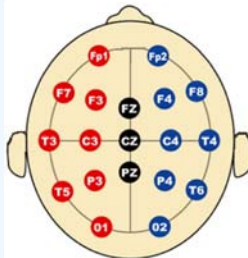
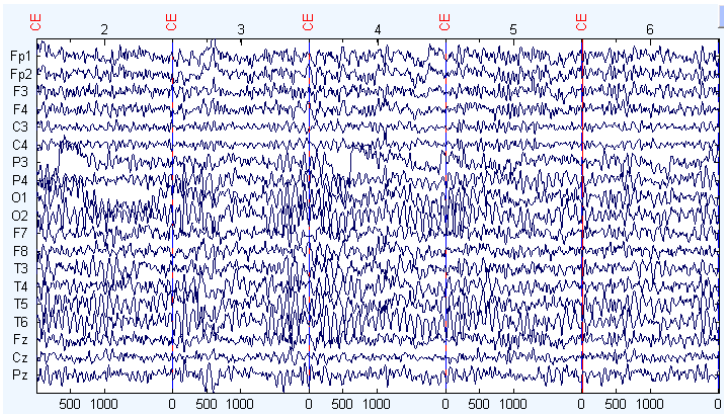


<http://www.slideshare.net/slneurosurgery/gbm-mx>

## Liver tumor - CT Arterial Phase



# Electroencephalography (EEG)



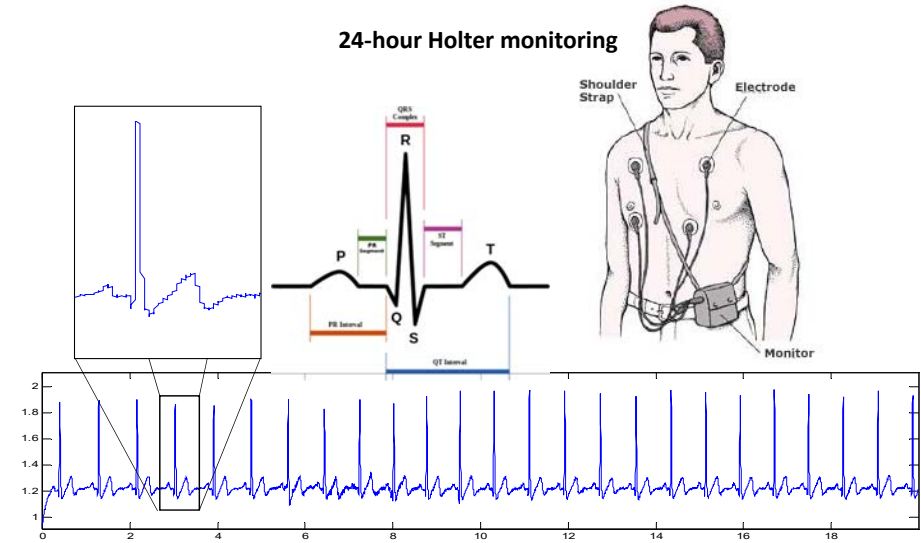
19 channel, 500 kHz

Epilepsy, AD, CJD, ...

# Electrocardiography (ECG)



## 24-hour Holter monitoring



# Medical Images & Signals



**“To see is to believe”**  
**眼見為憑**

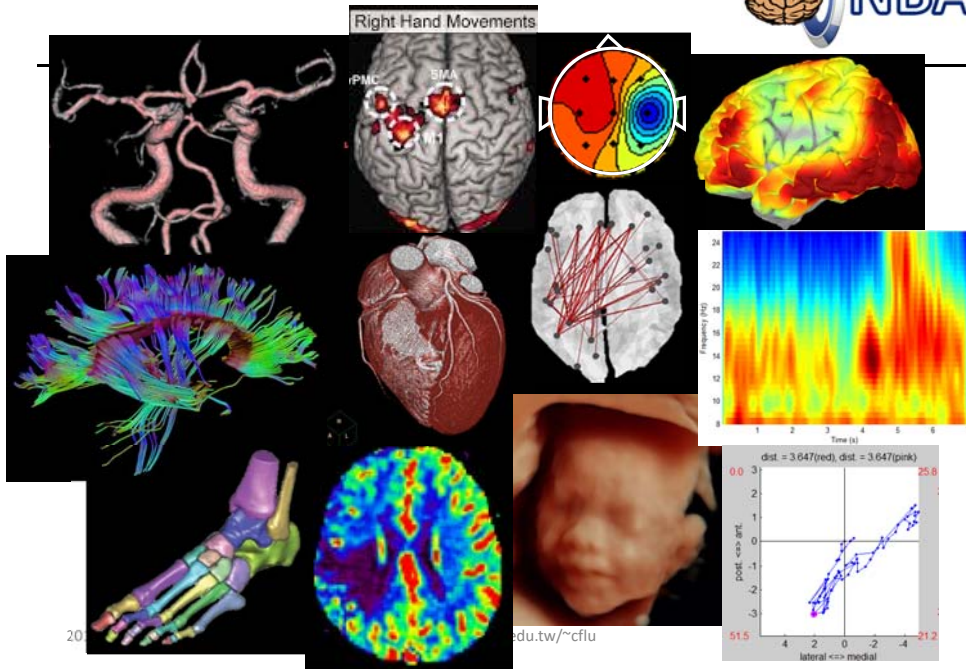
Is everything visible?

Can we make invisible visible?





# Analytic Images & signals



# Imaging & Signaling

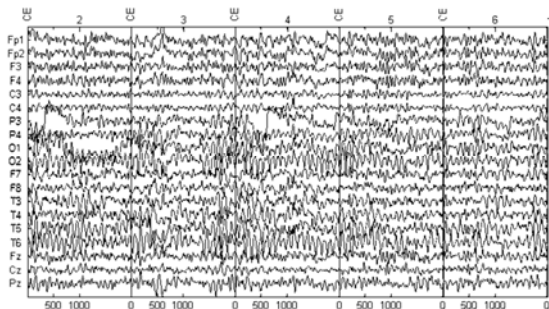


- A **non-invasive** approach to investigate **anatomy** and **function** in vivo.
- A tool for **diagnosis**, **surgical planning**, **monitoring**, and **evaluation of therapeutic effects**.
- The measurement can be further **quantified** through Image & signal **analyses**.

# Analyses are approaches to...



- **Eliminate** bias/noise
- **Quantify** the image features
- **Extract** the hidden information
- **Visualize** the alterations/deficits



看得到?  
看得懂?

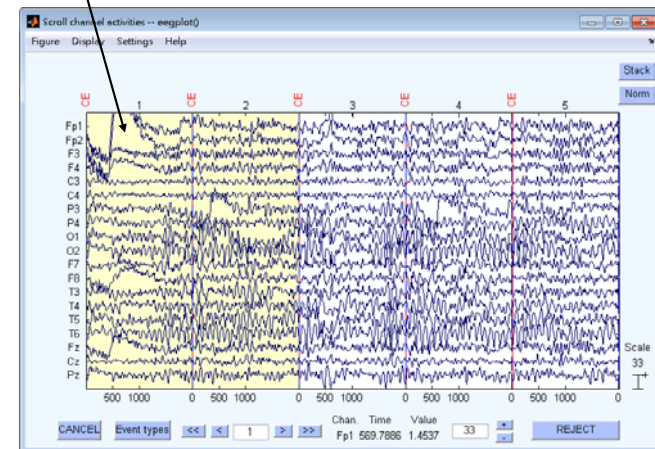
*Analysis is the process of breaking a complex topic or substance into smaller parts in order to gain a better understanding of it.*

# Example 1: Eliminate eye-movement noise



## EEG data

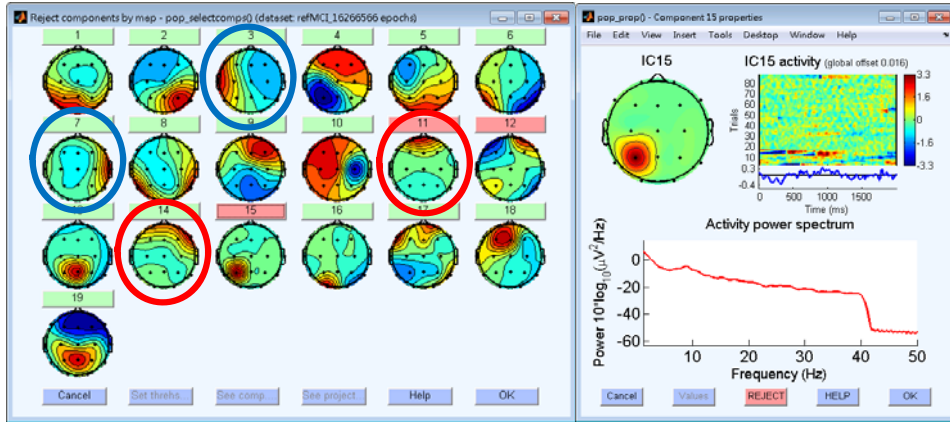
Eye-movement contamination



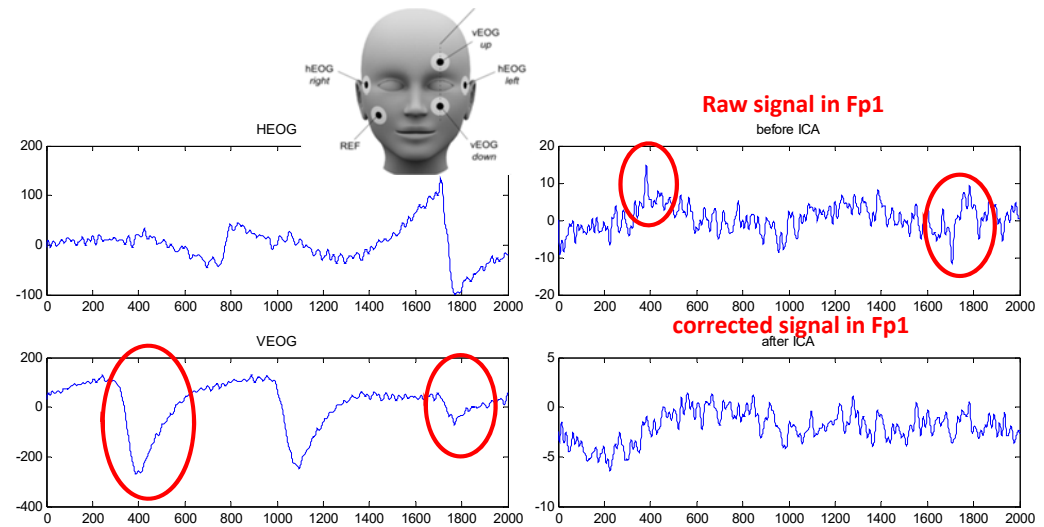
# Independent component analysis



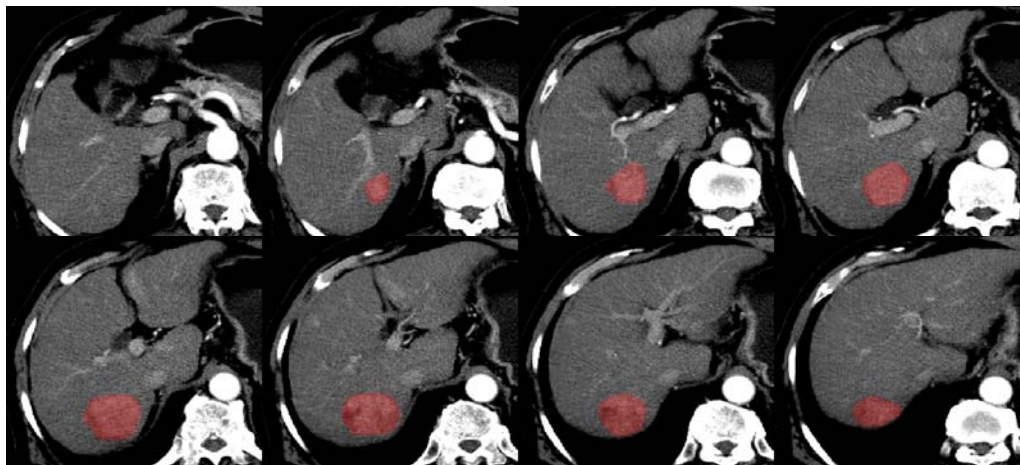
- Eye-movement and facial muscle signal



# Eliminate eye-movement

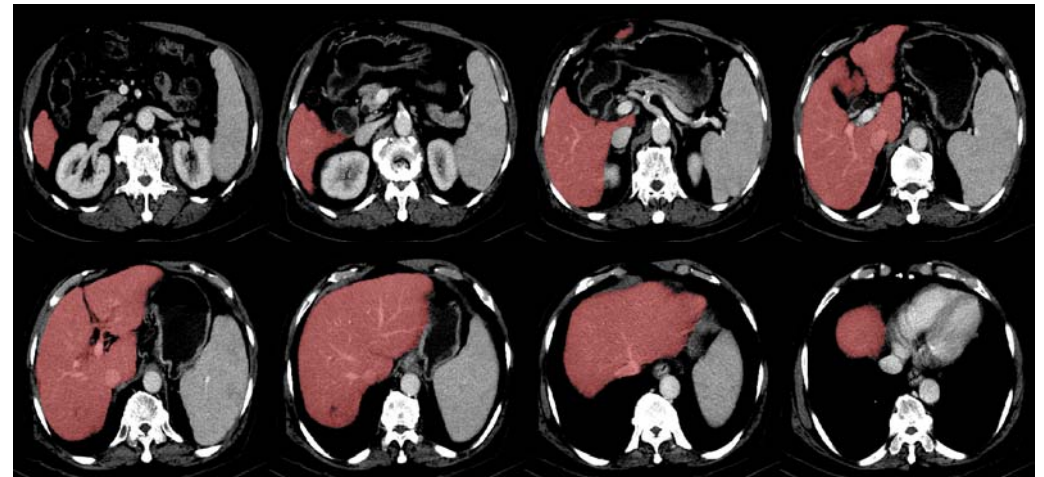


**Tumor Volume: 30.9 cm<sup>3</sup>**



Pixel Number: 13056  
 Mean (Std): 1092.68 (18.92)  
 Area: 6171.00 mm<sup>2</sup>, Volume: 30955.00 mm<sup>3</sup>

**Total Liver Volume: 1100.9 cm<sup>3</sup>**



Pixel Number: 465853  
 Mean (Std): 1118.15 (17.91)  
 Area: 220188.33 mm<sup>2</sup>, Volume: 1100941.66 mm<sup>3</sup>



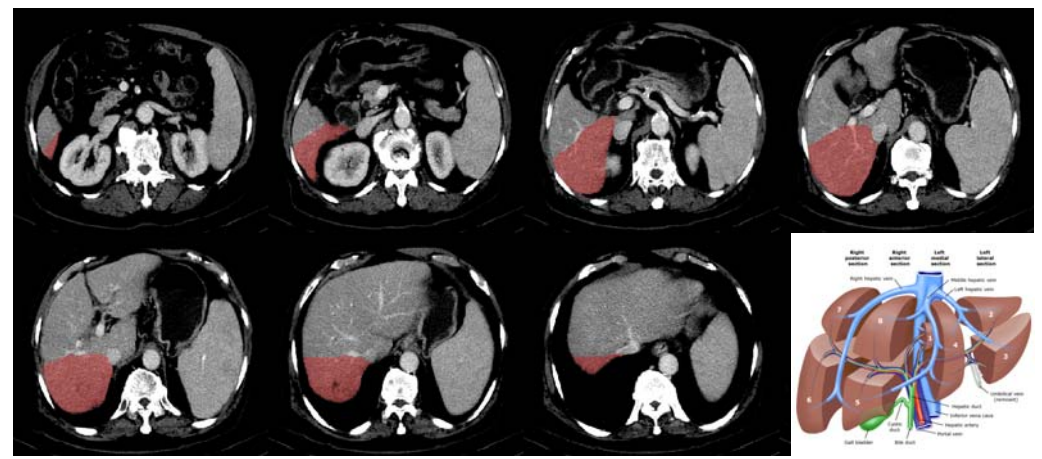
Right Lobe Volume: 562.2 cm<sup>3</sup>



CT Venous Phase

Pixel Number: 237890  
 Mean (Std): 1116.86 (16.45)  
 Area: 112440.20 mm<sup>2</sup>, Volume: 562200.98 mm<sup>3</sup>

Segment VI & VII: 294.4 cm<sup>3</sup>



CT Venous Phase

Pixel Number: 124593  
 Mean (Std): 1114.14 (16.36)  
 Area: 58889.66 mm<sup>2</sup>, Volume: 294448.30 mm<sup>3</sup>

How do we describe a tumor?

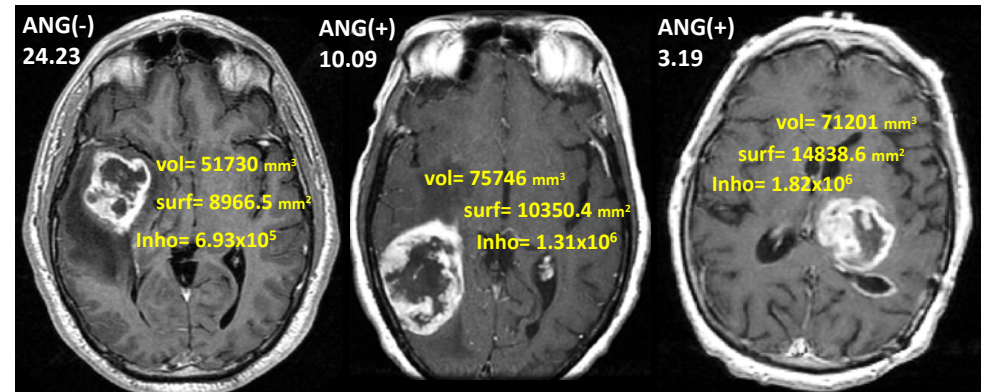


- **Intensity Histogram**
- **Shape and Size**
- **Textural Features**  
  
 (Spatial Inhomogeneity)
- **Location**
  - Subventricular zone
  - Cross-lobe invasion
- **Mass effect**
  - Surrounding tissue compression/distortion

Imaging & gene & prognosis



Which case may have poor outcome?



First order statistics (14)	Shape and size based features (8)	Textural features Gray-Level Co-occurrence matrix (21)	Textural features Gray-Level Run-Length matrix (12)
1. Energy	15. Compactness 1	23. Autocorrelation	45. Short Run Emphasis
2. Entropy	16. Compactness 2	24. Cluster Prominence	46. Long Run Emphasis
3. Kurtosis	17. Maximum 3D diameter	25. Cluster Shade	47. Gray Level Non-Uniformity
4. Maximum	18. Spherical disproportion	26. Cluster Tendency	48. Run Length Non-Uniformity
5. Mean	19. Sphericity	27. Contrast	49. Run Percentage
6. Mean absolute deviation	20. Surface area	28. Correlation	50. Low Gray Level Run Emphasis
7. Median	21. Surface to volume ratio	29. Difference entropy	51. High Gray Level Run Emphasis
8. Minimum	22. Volume	30. Dissimilarity	52. Short Run Low Gray Level Emphasis
9. Range		31. Energy	53. Short Run High Gray Level Emphasis
10. Root mean square		32. Entropy H)	54. Long Run Low Gray Level Emphasis
11. Skewness		33. Homogeneity 1	55. Long Run High Gray Level Emphasis
12. Standard deviation		34. Homogeneity 2	
	<b>55 Radiomic features</b>	35. Informational measure of correlation 1	
		36. Informational measure of correlation 2	
		37. Inverse Difference Moment Normalized	
		38. Inverse Difference	
		39. Inverse variance	
		40. Maximum Probability	
		41. Sum Average	
		42. Sum entropy	
		43. Sum variance	
		44. Variance	
		45. Low Gray Level Run Emphasis	
		46. High Gray Level Run Emphasis	
		47. Short Run Low Gray Level Emphasis	
		48. Short Run High Gray Level Emphasis	
		49. Long Run Low Gray Level Emphasis	
		50. Long Run High Gray Level Emphasis	
		51. Variance	

**Intensity**  
(histogram)

**Geometry**  
(shape & size)

**Spatial distribution of intensities**  
(inhomogeneity)

Nature Communications, 5:4006, 2014.

Example 3: **Extract** radiomic feature



Category	Feature	Value
First order statistic	1. Energy	900861240
	2. Entropy	7.3313
	3. Kurtosis	473184.406
	4. Maximum	632
	5. Mean	420.8539
	6. Mean absolute deviation	39.0991
	7. Median	410
	8. Minimum	358
	9. Range	274
	10. Root mean square	423.7473
	11. Skewness	1.054
	12. Standard deviation	48.4391
	13. Uniformity	0.007954
	14. Variance	2444.2229
Shape/size based features	15. Compactness 1	15.9362
	16. Compactness 2	0.013191
	17. Maximum 3D diameter	74.3956
	18. Spherical disproportion	4.2322
	19. Sphericity	0.23628
	20. Surface area	12619.7185
Textural features	23. Autocorrelation	7.9405
	24. Cluster Prominence	68.6216
	25. Cluster Shade	7.0166
	26. Cluster Tendency	4.4659
	27. Contrast	3.1819
	28. Correlation	0.17779
	29. Difference entropy	1.4379
	30. Dissimilarity	1.298
	31. Energy	0.057905
	32. Entropy	3.1906
	33. Homogeneity 1	0.5666
Gray level run-length matrix	45. Short Run Emphasis	0.46671
	46. Long Run Emphasis	9.5218
	47. Gray Level Nonuniformity	13773.4947
	48. Run Length Nonuniformity	7964.0975
	49. Run Percentage	3.5412
	50. Low Gray Level Run Emphasis	0.67983
	51. High Gray Level Run Emphasis	341390.4541
	52. Short Run Low Gray Level Emphasis	0.23086
	53. Short Run High Gray Level Emphasis	252617.7238
	54. Long Run Low Gray Level Emphasis	7.9541
	55. Long Run High Gray Level Emphasis	1654784.9922



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http://www.ym.edu.tw

Example 3: **Extract** radiomic feature

## Breast cancer



Category	Feature	Value
First order statistic	1. Energy	734878855
	2. Entropy	7.7039
	3. Kurtosis	769979.3337
	4. Maximum	909
	5. Mean	778.3243
	6. Mean absolute deviation	47.7396
	7. Median	782
	8. Minimum	354
	9. Range	555
	10. Root mean square	778.6756
	11. Skewness	0.95932
	12. Standard deviation	68.4926
	13. Uniformity	0.00594
	14. Variance	3059.3555
Shape/size based features	15. Compactness 1	18.0911
	16. Compactness 2	24.1428
	17. Maximum 3D diameter	19.4005
	18. Spherical disproportion	0.346
	19. Sphericity	2.8962
	20. Surface area	171.7702
Textural features	23. Autocorrelation	39.4934
	24. Cluster Prominence	65.9998
	25. Cluster Shade	-4.2416
	26. Cluster Tendency	4.1894
	27. Contrast	1.2296
	28. Correlation	0.54841
	29. Difference entropy	1.0627
	30. Dissimilarity	0.80357
	31. Energy	0.07798
	32. Entropy	3.8668
	33. Homogeneity 1	0.66391
Gray level run-length matrix	45. Short Run Emphasis	0.12095
	46. Long Run Emphasis	37.8825
	47. Gray Level Nonuniformity	2380.7157
	48. Run Length Nonuniformity	1183.5646
	49. Run Percentage	4.6296
	50. Low Gray Level Run Emphasis	0.73328
	51. High Gray Level Run Emphasis	4525.7741
	52. Short Run Low Gray Level Emphasis	0.082111
	53. Short Run High Gray Level Emphasis	726.8858
	54. Long Run Low Gray Level Emphasis	27.7006
	55. Long Run High Gray Level Emphasis	171937.5236

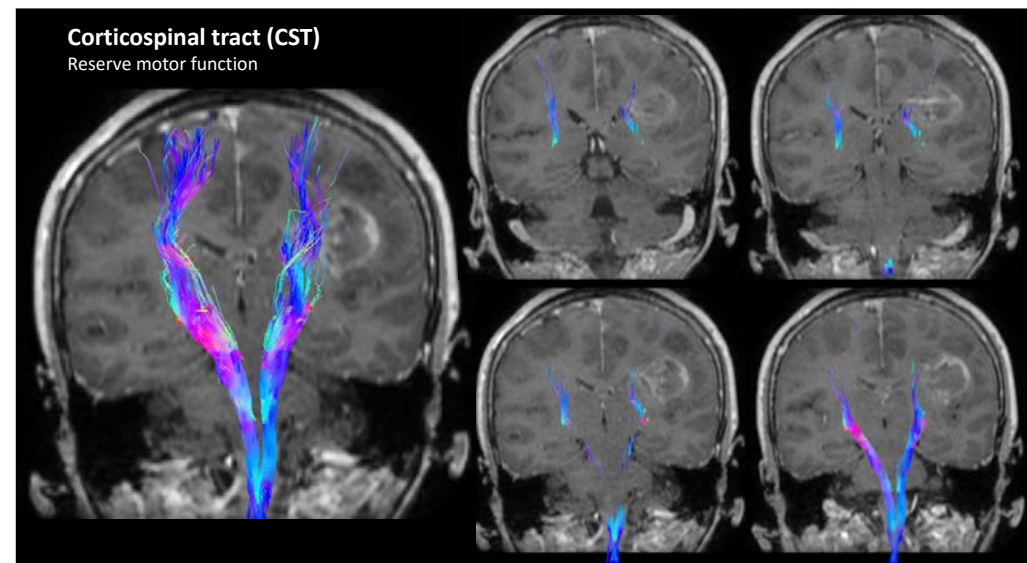
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http://www.ym.edu.tw/~cflu

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Example 4: **Visualize** axonal fiber bundle

## Pre-surgery tractography



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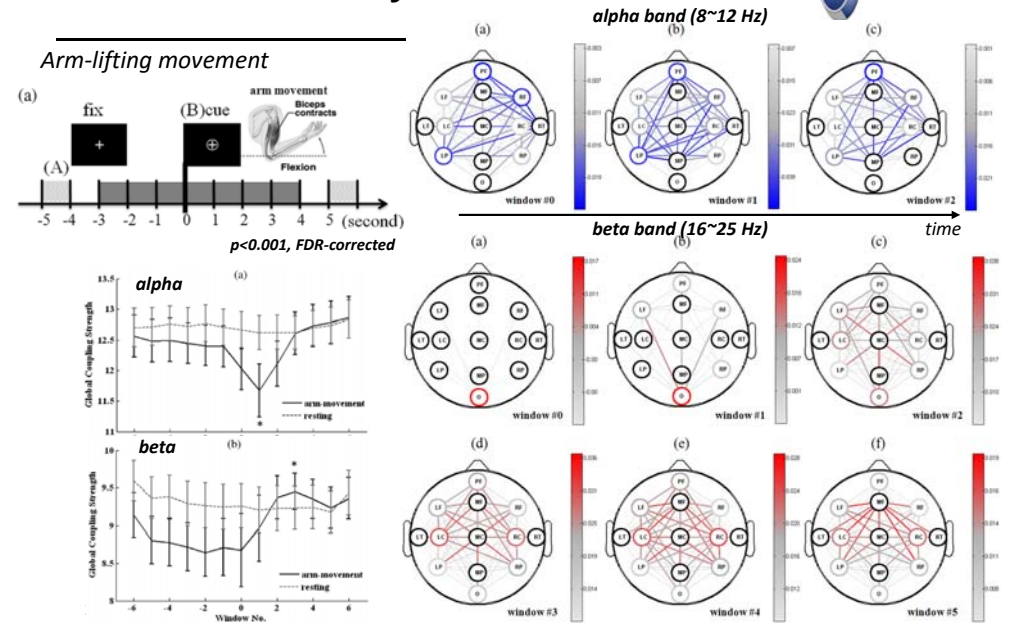
http://www.ym.edu.tw/~cflu

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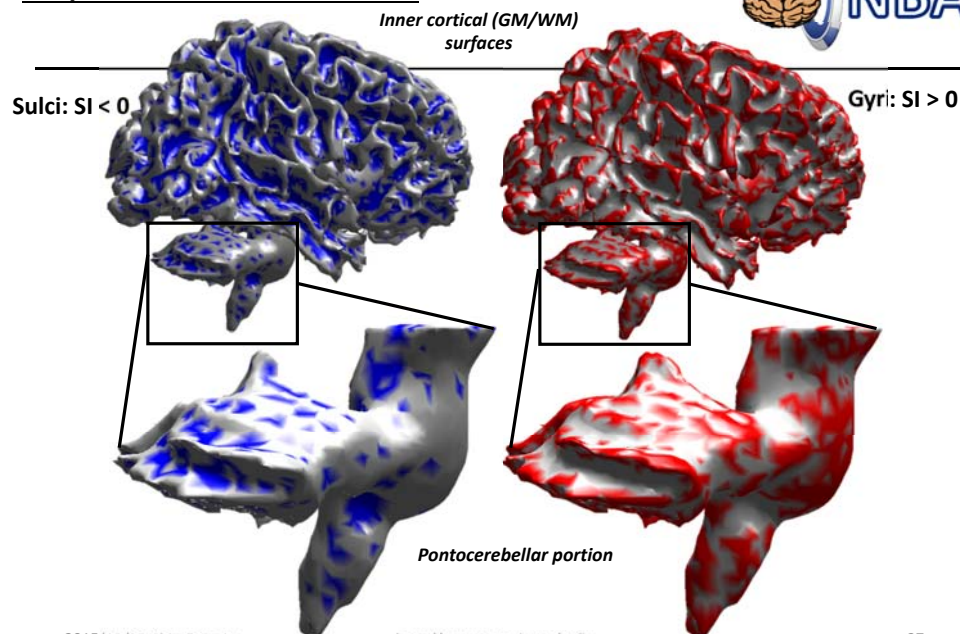


# How do "analyses" improve our knowledge of human function or disease?

## Motor-related dynamics

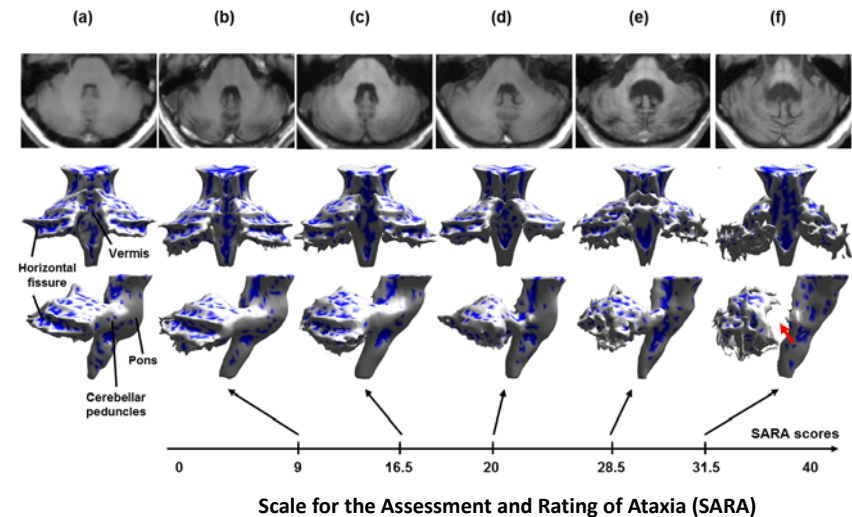


## Shape Index and fold structure

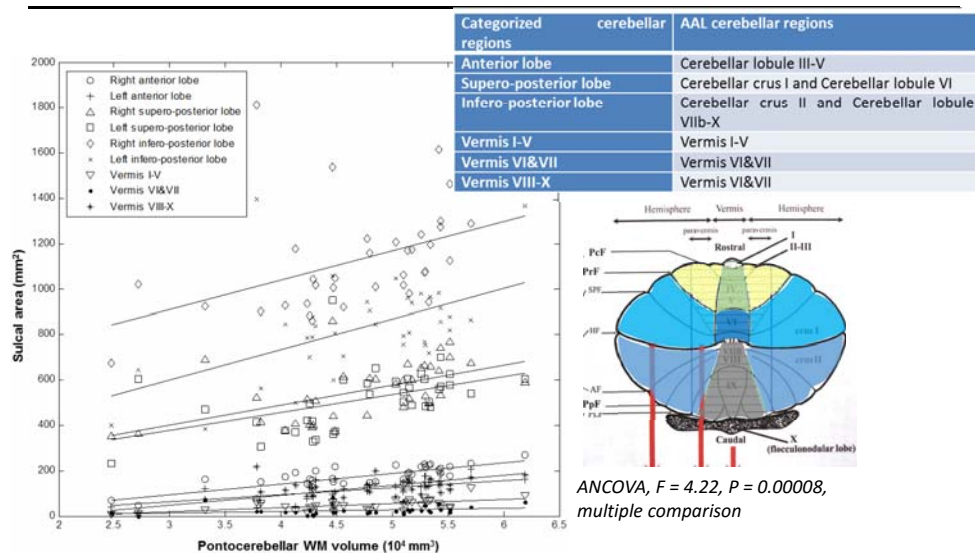


## Neurodegeneration

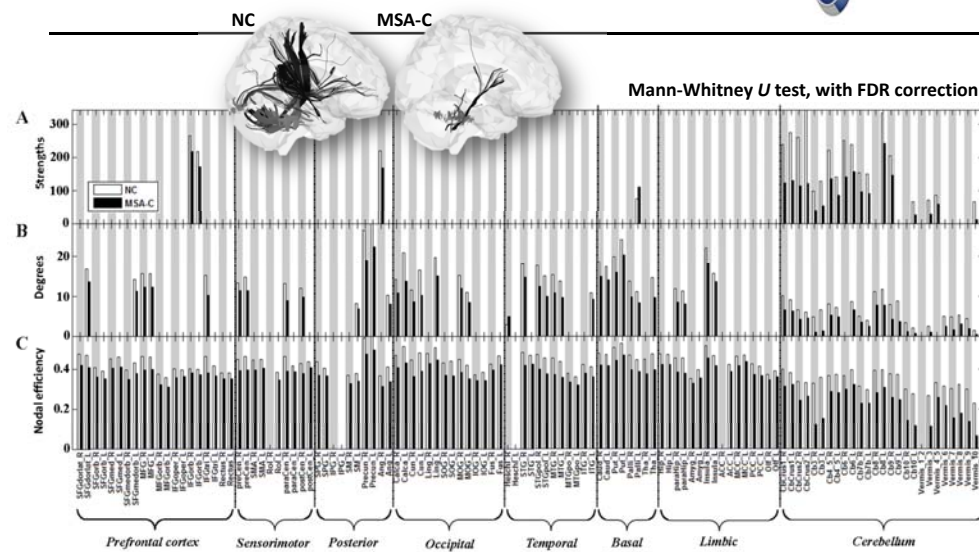
### Cerebellar type of multiple system atrophy (MSA-C)



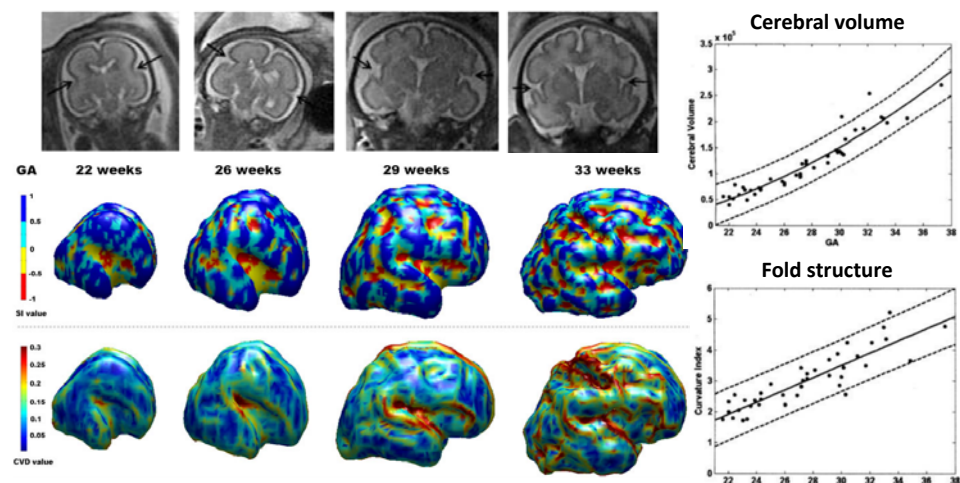
# Various atrophy rate



# Decrease global efficiency

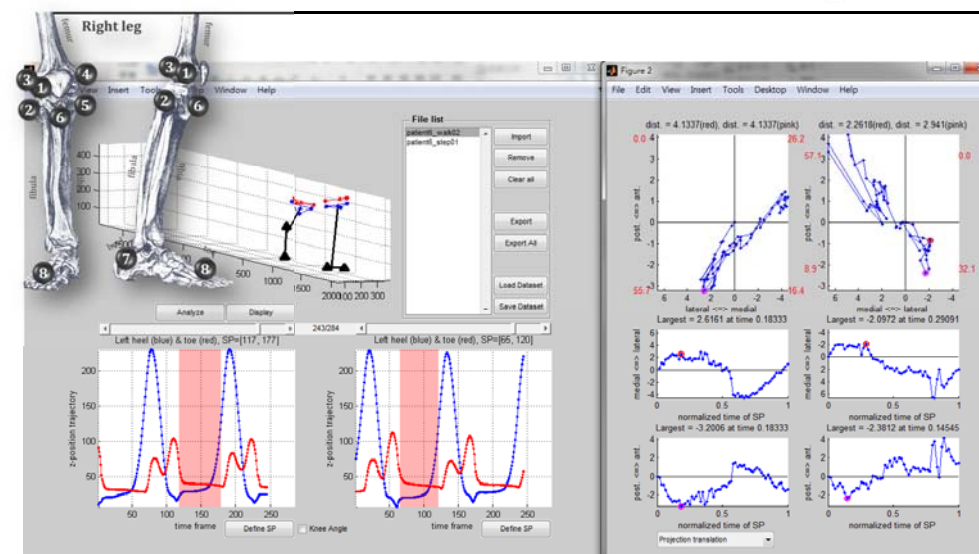


# Cerebral volume & fold development



Hu et al, European Journal of Neuroscience, 29, 1560–1567, 2009.  
 Hu et al, European Journal of Neuroscience, 34, 1310–1319, 2011.  
 Hu et al, Brain Struct Funct 218:1451–1462, 2013.

# Joint stability during gait



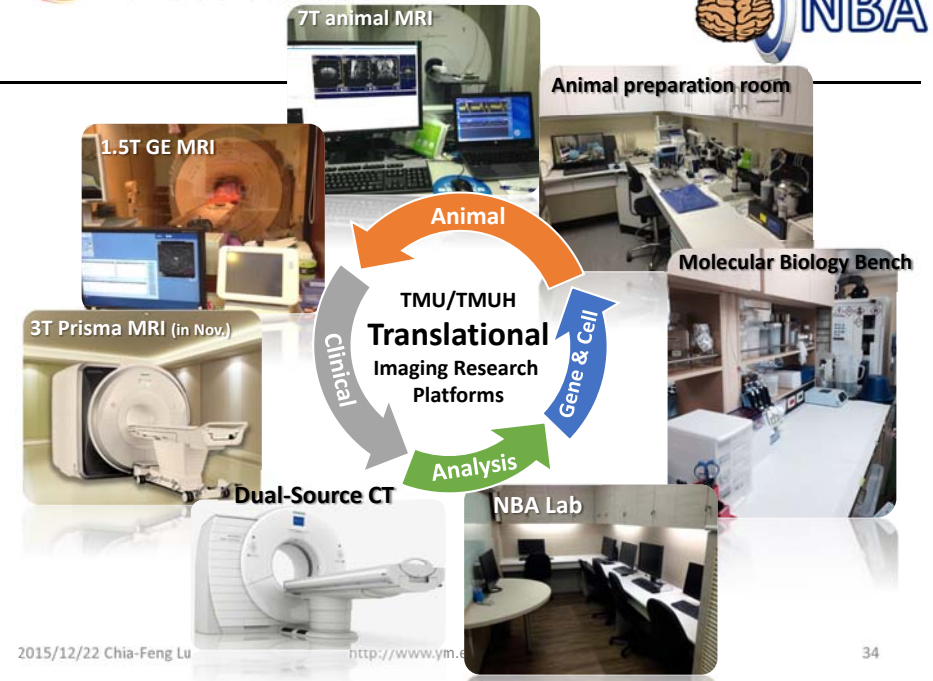


# Analyses are...



- **Tedious** but **delicate** steps to extract and quantify hidden features behind raw images/signals.

**“Soft fire makes sweet malt”**  
**慢工出細活**



**TIRC Team**  
2015.7.20 at TMU

轉譯影像研究中心  
影像醫學部  
醫學系放射線學科  
臨床醫學研究所



# THE END

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