

結合生物反饋之新世代腦機介面及其在移動載具控制之應用—

子計畫三：運動想像腦電波之腦機介面系統(I)

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摘要

本研究計畫中，我們將設計不同的運動想像實驗，並使用小波轉換、時間頻率分析、事件相關同步/非同步分析等許多離線訊號分析的方法，觀察受試者在各種不同的運動想像中量測到的腦電波訊號，藉以針對變化最顯著的運動想像來發展有效的空間濾波器技術。同時，我們將根據腦電波訊號源逆向估算的技術，搭配不同的限制式設計空間濾波器，對量測到的腦電波訊號作整體的濾波，得到較具代表意義的訊號，以提升後續研究工作的效能。後續再搭配總計畫與其他子計畫之推展與需求，設計由簡單到進階的腦機介面訓練系統，藉由生物反饋的機制，讓受試者能根據訓練系統的指示做自我訓練，此時就可以配合已發展的空間濾波器技術來最佳化量測的訊號，使生物反饋的根據有更高的準確度。由於使用者在不同的心智情況下腦電波生理訊號量測的結果會有所差異，因此我們也擬藉由多次的訓練實驗，發展自動化調整空間濾波器的技術，在線上的實驗中根據使用者當下的心智情況，對濾波器做即時的最佳化調整，使長時間訓練中濾波器仍保有準確的分辨效果。這一系列的研究工作相當繁複且環環相扣，我們規劃為三年期研究計畫，以循序漸進地推展各個重點項目。第一年我們將設計難易度不同、部位不同、動作不同的想像運動實驗，配合許多已發展的技術分析離線訊號，確定在未來將使用何種活動作為命令控制的基礎。而在第二年我們將開發有效的空間濾波器技術，根據先前相關研究成果，使用不同的限制式來設計濾波器，以最佳化訊號的特徵。第三年我們將配合總計畫與其他子計畫的研究發展，進行設計具有生物反饋的機制的線上腦機介面訓練系統，並發展線上自動調整濾波器的技術，同時也進行系統整合測試與評估。

關鍵詞：生醫訊號處理、生理回饋、腦電波儀、腦機介面系統

研究目的

這項計畫第一年預定達成的目標，是設計各種不同的運動實驗並量測進行中的腦電波訊號，使用訊號分析的技術觀察受試者在各種不同的想像運動腦電波的差異，並對運動想像時腦電波的變化做完整的分析與探討。為了後續研究時的方便，並且能更有效達成腦機介面應用的目標，我們希望可以運用能使腦電波產生最顯著變化的運動想像，以及決定最有顯著結果的特徵擷取方法以及實驗流程（task or paradigm），經過設計搭配之後作為系統命令的基本來源，因此在後續研究之前先對此作全面的研究是必要的。接下來第二年我們將開發有效的空間濾波器技術，根據先前相關研究成果，使用不同的限制式來設計以 maximum-contrast beamformer 為主建立 model-based 空間濾波器，以最佳化訊號的特徵，做為之後開發線上腦機介面系統良好的基礎。

研究方法

實驗流程的設計主要分為兩大類，分別是以提示為基礎的運動（cue-based movement）以及自發性的自我節律運動（self-paced movement），將在以下分述。而運動的設計有幾種區分方式，例如以部位區分：手部、腳部、舌頭，以複雜度區分：抓取動作、抬起動作等等，以及一些重要的其他比較研究例如慣用手與分慣用手的研究、運動次數不同的研究等等，將在以下條列式分述一些設計方法以及相關研究。而由於研究腦電波時量測到的訊號訊雜比（Signal-to-Noise Ratio, SNR）非常低，很難從原始資料去觀察分析出有用資訊，因此良好的資料前處理步驟能更有助於提高對處理完的訊號做後期分析的效能，而資料前處理又可分為訊號重新參考（Re-reference）、人為雜訊去除（Artifact removal）等二個重要步驟。而訊號經由腦電波或腦磁波量得且前處理後，仍屬於高維度的資料，因此我們必須進行特徵擷取以降低資料維度且突顯有意義的腦波特徵，特徵的好壞對於後續的分辨處理有著極大的影響，因此如何找到好的特徵實為整個腦機介面系統中重要的一環。

（a） 不同形式的運動想像實驗設計

i. 以提示為基礎的運動以及自我節律運動的實驗流程（experiment paradigm）

以提示為基礎的運動（cue-based movement）的實驗設計中必須有提示（cue），來提示受試者現在應做何種運動，自我節律運動（self-paced movement）中則不需任何提示，受試者在一定間隔時間範圍做自發性的運動。這便帶出一個問題，在以提示為基礎的運動中應以何種形式來呈現提示，我們實做兩種作法，一是以視覺刺激為提示，二是以聽覺刺激為提示。無可避免的是無論用何種方式來呈現提示（cue）都會對受試者的腦電波造成一定的影響[Pfurtscheller 04]，這種事件刺激造成的腦電波改變可以稱為事件相關電位（Event-related potential），因此我們實驗設計應盡量減少這種刺激的影響。

我們設計以提示為基礎的實驗中，受試者在沒有干擾的實驗地點接受實驗，

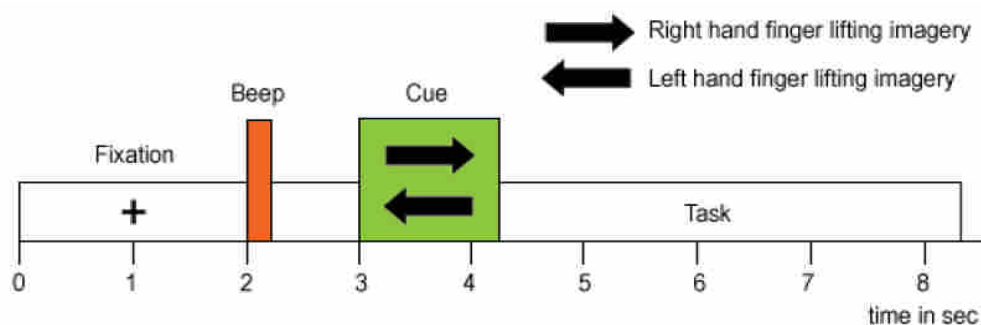


圖 1：實驗流程

坐在有椅背的舒適椅子上，雙手自然平放在桌上，再根據前方螢幕的指示做運動想像或實際運動，而實驗的流程如圖 1，在每個 trial 的一開始螢幕中間會出現一個十字持續兩秒，此時受試者便專心盯著十字的中心並且放輕鬆，兩秒過後會有一個警告聲音（warning tone）提醒受試者提示要出現了，聲音持續一秒後

iii. 不同複雜度的運動比較

針對不同複雜度的運動實驗設計，我們分別針對手部、腳部與舌頭設計幾種不同複雜度的運動：手部分別為食指抬動與手腕抬動的比較、抓取動作與抬起動作的比較、快速抬起與緩慢抬起的比較。腳部分別為腳趾抬起運動與腳掌抬起的比較、單腳運動與雙腳同時運動的比較。而舌頭為水平、垂直移動、舌頭捲曲運動的比較。以上實驗根據研究文獻指出，人在做較為複雜的運動時，腦電波所呈現的變化將會比簡單的運動來得顯著，以手腕和手指為例，當受試者在進行手腕運動時，所表現出的事件相關同步（event-related synchronous, ERS）現象比手指運動時來得強烈，因為手腕運動需用到較多的肌肉，相對於手指顯得更為複雜。

iv. 其他比較

另外我們也比較運動想像與實際運動時的大腦活化反應，動作的想像可以被視為是一種動作執行的狀態演練，研究指出動作想像應會與真正執行動作時的準備、計畫狀態具有相似的大腦活化現象：在真正執行運動時，在運動區中相對的位置量測到的腦電波會有特定的事件相關同步及非同步現象，這些現象在運動想像時也能被觀察出來，只是相較之下較為微弱，而這些事件相關非同步現象在 alpha（8-12 赫茲）和 beta（18-32 赫茲）頻帶又會有些許的差異性在，因此我們根據上述這些基本的生理現象，對我們的實驗設計反覆地做驗證，以設計出更完善的實驗工作以及實驗流程。

慣用/非慣用手、腳的比較，研究指出非慣用的四肢運動時，運動區相對位置會有特別明顯的訊號強度變化，並且這種情形在對側腦又更為顯著，因此若是我們的實驗驗證達到一樣的結果，就可以增加後續研究實驗設計的變化性，例如以左手腕抬動以及右腳趾抬動作為兩種工作的實驗等。

(b) 主要資料前處理步驟(Data pre-processing)

一. 訊號重新參考 (Re-reference)

我們選擇使用之主要方法為 Laplacian reference; 而 Laplacian 的計算方式為，各個電極訊號在每個時間點測到的訊號減去周圍四個電極訊號的平均，藉此得到受周圍干擾較小的新訊號。

二. 人為雜訊去除 (Artifact removal)

此步驟依訊號強度以及頻率而使用兩種雜訊濾除方法

i. 去除眼動(EOG rejection)

由眼動（Electrooculogram，EOG）形成的電位差主要影響分布於前大腦區域，在量測腦電波的過程中，眼動干擾會很明顯地在時間域的訊號上觀察到，若是在分析時保留眼動的干擾，則會降低分析的準確度。因此我們使用以下方法去

除眼動干擾。簡單的作法是我們在眼睛周圍擺放四個電極，根據實驗觀察結果得知，當這四個電極的訊號強度大於 $-100\sim 100\mu V$ 時，表示有眨眼等眼動發生，因此我們便以此為偵測的標準，在離線分析之前把包含眼動干擾的實驗 trial 捨棄。

ii. 帶通濾波器 (Band-pass filter)

我們使用 5 – 30 Hz 之帶通濾波器對訊號進行濾波，一方面可避免較低頻之心跳干擾，另一方面可去除 60Hz 市電干擾。

(c) 特徵擷取 (Feature extraction)

i. 時間-頻率分析 (Time-Frequency analysis)

經過小波轉換後的分析的方法為時間-頻率分析，我們可以藉由觀察時頻圖得到在某一頻率，某段時間區段之內的能量大小變化，可以在頻率之間以及時間區段間交叉觀察比較。而在我們這裡使用 Morlet wavelet 來進行時頻分析，再依此項資訊對訊號做濾波處理，且更有利於對運動想像極為重要的 alpha 頻帶和 beta 頻做進一步觀察比較。

ii. 事件相關同步/非同步 (Event-related synchronous / desynchronous, ERS/ERD)

在這些實驗資料的觀察中，我們將主要觀察事件相關同步/非同步現象，這種現象大量地被用在運動相關的實驗資料分析上，以訊號的呈現來解釋的話，事件相關同步現象便是指訊號強度的提高，而事件相關非同步則是訊號強度的降低，因此在觀察這兩種現象時須決定兩件事，一是用來當做基準強度的時間區段 (baseline)，一般取休息狀態 (resting state) 的腦電波來當基準，二是將時序訊號換算為強度的計算方式，一般簡單地將時序訊號平方後便能代表強度，而我們所使用的是 Pfurtscheller 於 1999 所提出之 ERD/ERS 訊號分析流程，來算出訊號強度的變化。

研究成果與討論

目前我們已經完成手部運動的相關實驗分析，針對手部運動的方式做比較分析，包括慣用手與非慣用手的比較、手指與手腕運動的比較、持續運動和單一次運動的比較。也進行了手部與腳部的運動比較，也更進一步的完成了真實運動和運動想像之間的比較。我們主要使用與大腦運動區接近的三個頻道 C3、Cz、C4 訊號，接著使用時間-頻率圖的訊號分析技術來對不同的實驗作觀察。

我們目前測試了一位 24 歲的男性受試者，依照上述的實驗流程進行了多種運動的實驗，以下是成果與討論。

■ 手指 vs. 手腕

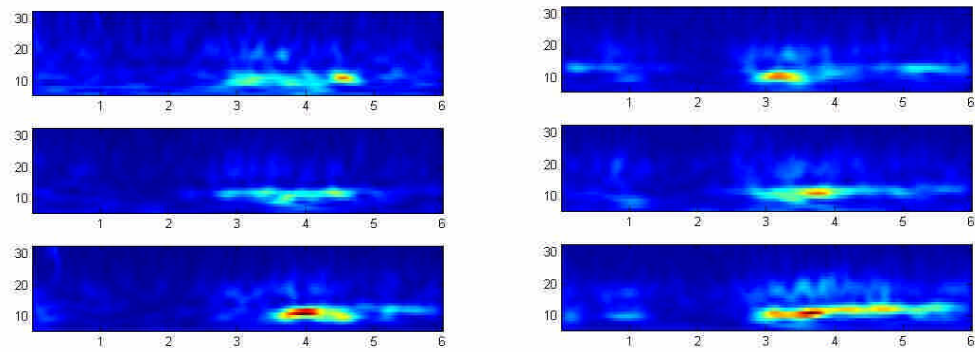


圖 3：手指與手腕運動在時間-頻率分析圖的表現，由上而下分別是 C3、Cz、C4 三個頻道，圖中左圖為左手腕運動，右圖為左手指運動，縱軸為頻率，橫軸為時間。本圖頻率為 6-32Hz

如圖 3 所示為手指和手腕的比較圖，圖中可以觀察到幾件事，第一是左手的運動在 C4 這個頻道能觀察到比 C3、Cz 還要明顯的頻率強度變化，由於專司左手運動的運動區在右腦的部位，因此這點是符合預期的。第二是手腕的運動能觀察到更為 focal 的時間頻率圖，而不像手指運動呈現長時間的黃色區塊，這有可能是因為手腕運動需要較多的肌肉參與，使得這強度的變化較為劇烈。

■ 動一次 vs. 動三次

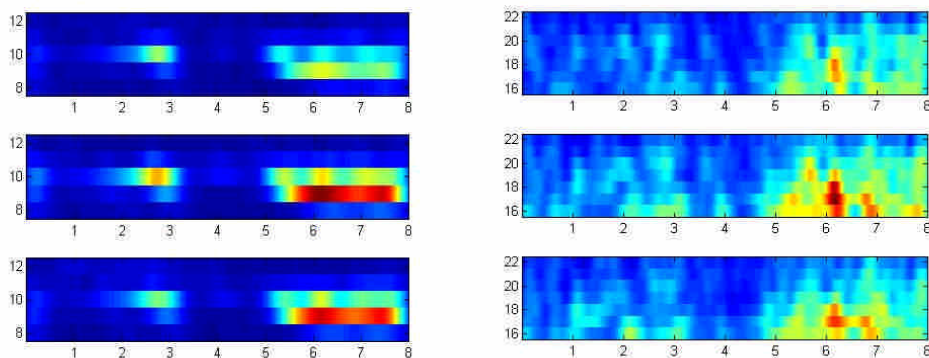


圖 4(a)：「手腕抬動一次」實驗在時間-頻率分析圖的表現，由上而下分別是 C3、Cz、C4 三個頻道，圖中左圖為 alpha band (8-12Hz)，右圖為 beta band (6-22Hz)，縱軸為頻率橫軸為時間

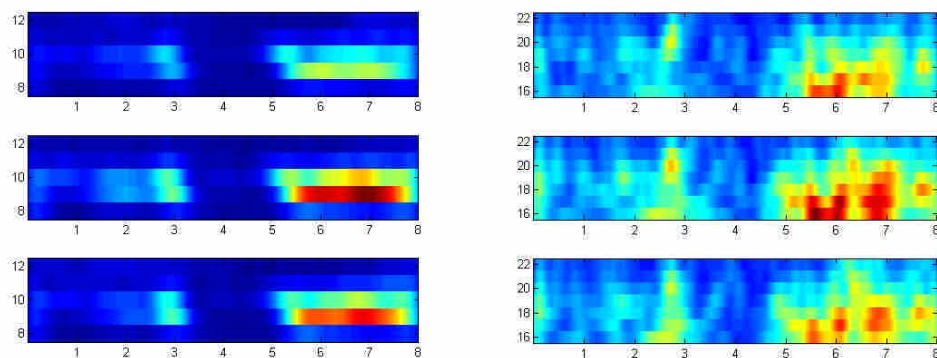


圖 4(b)：「手腕連續抬動三次」實驗在時間-頻率分析圖的表現，由上而下分別是 C3、Cz、C4 三個頻道，圖中左圖為 alpha band (8-12Hz)，右圖為 beta band (6-22Hz)，縱軸為頻率橫軸為時間

如圖 4 所示，a 圖為左手腕抬動一次的實驗，b 圖為左手腕連續抬動三次的實驗。在此我們將兩個頻率區段 alpha (8-12Hz) 和 beta (6-22Hz) 分開來觀察。從圖中我們仍然可以發現在左手的運動能在 C4 頻道觀察到較為明顯的變化，在兩個情況下都是這樣。這兩種運動在 alpha band 比較沒有明顯的差異，但在 beta band 能明顯地看見圖上有三個紅色的 peak，而在只抬動一次的實驗當中 peak 顯得比較集中，因此後續的實驗將沿用只抬動一次的設計。

■ 手 vs. 腳

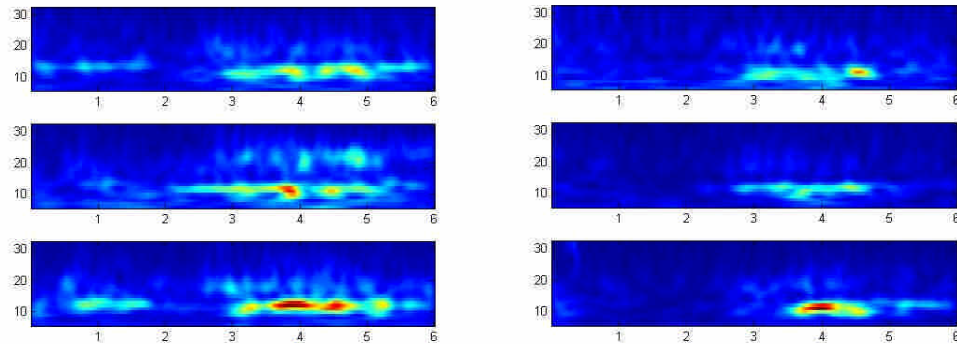


圖 5：手指與手腕運動在時間-頻率分析圖的表現，由上而下分別是 C3、Cz、C4 三個頻道，圖中左圖為雙腳抬動運動，右圖為左手腕運動，縱軸為頻率，橫軸為時間。本圖頻率為 6-32Hz

如圖 5 所示，我們觀察到雙腳的運動在 Cz 和 C4 頻道有較劇烈的強度變化，另外 C4 右為最劇烈。理論上來說應該是 Cz 位置是最能代表腳部運動的頻道，結果並不如預期，但是其中若只觀察 beta band 的變化，可以看到 Cz 位置的確非常顯著，比起手部的運動，腳部的運動更能在 beta band 上呈現強度的改變，因此後續的實驗將在腳部運動的分析上著重於 beta band。而手腕運動的在 C4 有明顯且集中的強度變化，相對於腳部運動，手腕運動對應的腦部活動有較突出的表現，所以之後會著重於手部的實驗分析。

■ 真實運動 vs. 運動想像

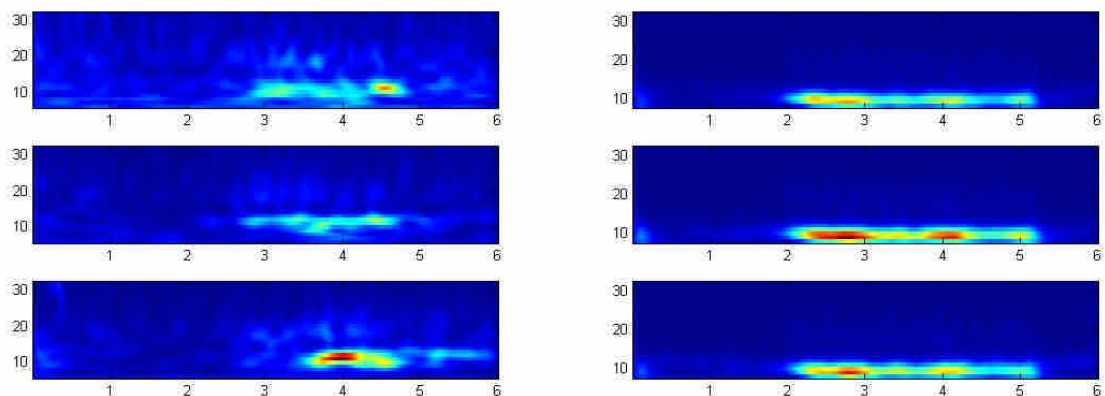


圖 6：手腕運動及手腕運動想像在時間-頻率分析圖的表現，由上而下分別是 C3、Cz、C4 三個頻道，圖中左圖為左手手腕運動，右圖為左手手腕運動想像，縱軸為頻率，橫軸為時間。本圖頻率為 6-32Hz

從圖 6 中觀察出，真實手腕運動在 C4 的 alpha band 上有明顯的強度變化，而在想像運動雖不如預期般在 C4 有相對明顯變化，但仍能看出 C4 較 C3 的有一定的差異，強度仍是 C4 有較大的能量，在之後的目標是希望透過這樣的差距，來達到分辨的效果。

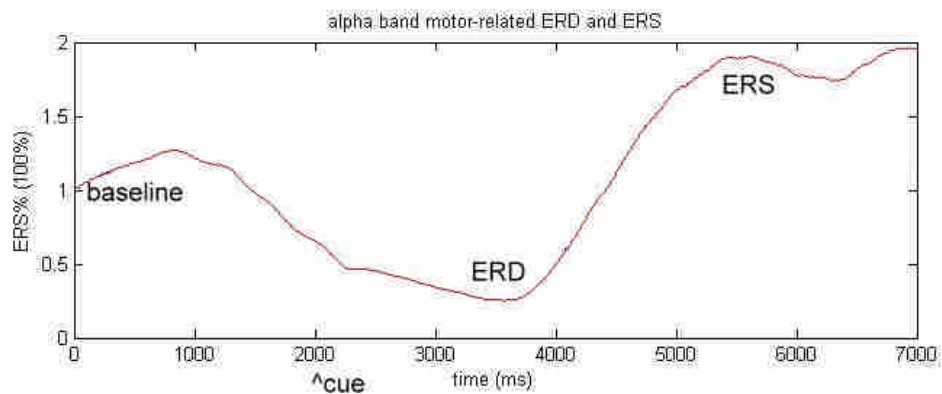


圖 7:此為運動相關之 ERD 和 ERS，cue 點為提醒受試者做運動

圖 7 為手部運動所量測到之 ERD 和 ERS，可以看到在受試者接受到指令做運動準備時，訊號強度相對變小即為 ERD，而在運動結束後，訊號強度相對提升稱為 ERS，這和我們預期相穩合，而在之後空間濾波器的設計，也希望能針對這點，來拉大 ERD 和 ERS 的差距，讓分辨技術的開發能更簡單分出受試者是否有做運動想像。

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出席國際學術會議心得報告

計畫編號	NSC 96-2221-E-009-221
計畫名稱	結合生物反饋之新世代腦機介面及其在移動載具控制之應用—子計畫三：運動想像腦電波之腦機介面系統(I)
出國人員姓名 服務機關及職稱	陳永昇 助理教授 國立交通大學 資訊工程學系
會議時間地點	June 15-19, 2008, Melbourne, Australia
會議名稱	14 th Annual Meeting of the Organization for Human Brain Mapping
發表論文題目	1. Classification of Brain Magnetic Resonance Images for Bipolar Disorders Based on Voxel based Morphometry and Bayesian Theorem 2. Affine and Nonlinear Spatial Normalization Techniques using Derivatives of Brain Magnetic Resonance Images 3. Magnetoencephalographic Evidence of Right Frontal Impairment of Negative Emotion Processing in Bipolar Disorder

參加會議經過與與會心得：

Human Brain Mapping 是由人腦造影國際組織所籌辦的年度會議，為腦科學研究領域最重要的會議之一。今年會議在澳洲墨爾本舉行，可能是由於距離較遠的關係，與會人數較往年減少很多，大會邀請的 Keynote Speech 也似乎不若往年精彩，但仍然有許多優秀的演講讓我們滿載而歸。如同往年，在正式會議的前一天大會安排了教育訓練課程，包括：basic MEG/EEG, Advanced fMRI, Diffusion Imaging and Tractography, 及 From Dynamic Modeling to Cognitive Neuroscience 等四項課程，每一項都是邀請相關領域佼佼者當授課講師，課程內容相當豐富，對於初學者或已有相關研究經驗的人來說都相當值得一聽。

緊接著從 6 月 16 日至 19 日，我們參與了 Human Brain Mapping 正式會議，並發表了兩篇研究論文：“Classification of Brain Magnetic Resonance Images for Bipolar Disorders Based on Voxel based Morphometry and Bayesian Theorem”、“Affine and Nonlinear Spatial Normalization Techniques using Derivatives of Brain Magnetic Resonance Images”、與“Magnetoencephalographic Evidence of Right Frontal Impairment of Negative Emotion Processing in Bipolar Disorder”。第一篇論文重點在我們根據體素型態計量法與貝式理論，開發出腦磁振造影影像分類器，並對躁鬱症病人腦部影像進行分類，開發一個醫療輔助診斷系統雛形。第二篇論文則是利用腦磁振造影影像差分技術為基礎，藉以擷取腦部結構資訊，而開發出全世界首創之腦影像剛體運動對位 closed-form 解法，並延伸發展出目前文獻上最準確、最快速之 affine 運動對位、non-rigid 對位等技術，對於腦部結構影像分析的進展有很大的貢獻。第三篇論文則是利用腦磁波儀探討躁鬱症病人在處理負向情緒人臉影像刺激時，腦部在右額葉區的活動動態比起正常人為小的現象。

這三篇會議論文的摘要分別列出如後。

Classification of Brain Magnetic Resonance Images for Bipolar Disorders Based on Voxel-based Morphometry and Bayesian Theorem

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Introduction: Neuroanatomical abnormalities often exist in patients with bipolar disorder(BD). Volumetric changes of some particular regions, such as caudate, putamen, amygdala, hippocampus, and the subgenual prefrontal cortex, are found in the patients during the early stages of the disease (Hajek 2005). In order to provide an objective index for early diagnosis, we applied machine learning techniques to develop a computer-aided evaluation system that can estimate the probability of being a BD patient according to the whole-brain magnetic resonance images (MRI).

Methods: 15 patients with BD and 76 healthy volunteers without neurological or psychiatric disorders were recruited by the Psychiatric Department at the Taipei Veterans General Hospital. MR Images of all subjects were acquired by a 1.5T GE scanner (GE Medical Systems, Milwaukee, WI) with the imaging parameters of TR = 8.672 ms, TE = 1.86 ms, FOV = 26x26x10 cm³, and image size of 256x256x124. The proposed system consists of three main procedures: region of interest (ROI) determination, feature selection, and model learning, as shown in Figure 1. The ROI was determined by voxel-based morphometric analysis to reveal significant anatomical discrepancy between BD patients and normal controls. The most representative features were then extracted from the ROI by applying principal component analysis followed by significance calculation. Finally, the two-group classification model was constructed based on Bayesian theorem in which the likelihood function was estimated with the Parzen window method.

Results: Hotspots shown in Figure 2 are the ROIs indicating the gray matter atrophy of BD patients revealed by VBM analysis. Figure 3 shows the histogram of the estimated probability belonging to the “patient” group for each group (gray-color bars are for healthy controls and black for BD patients). Based on the maximum-a-posterior criterion, the sensitivity (1 - missed detection rate) of the proposed system is 100% and the specificity (true negative rate) is 84.2%.

Conclusions: The proposed computer-aided evaluation system can accurately distinguish the MRIs of BD patients from those of normal controls. Such system provides a possibility of early diagnosis for bipolar disorders.

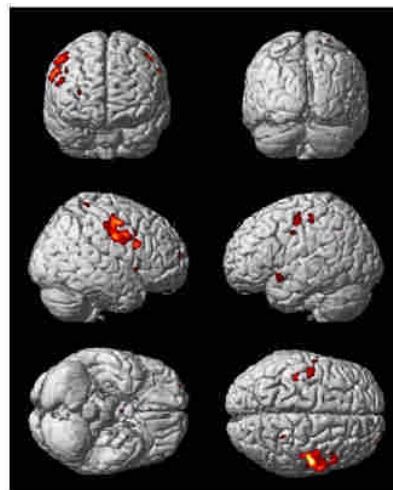
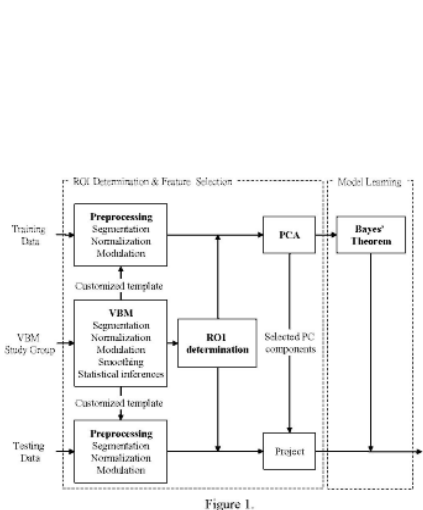


Figure 2.

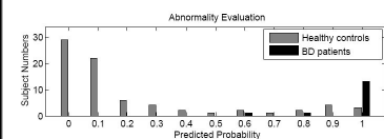


Figure 3.

Affine and nonlinear spatial normalization techniques using derivatives of brain magnetic resonance images

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Introduction: Registrations of structural brain images typically include affine transformation followed by nonlinear deformation. In general, each registration involves several nonlinear optimization tasks and good initial estimates dominate the results in efficiency and accuracy. This work, from this point of view, developed a novel method which utilized structure information extracted from image derivative.

Methods: In the proposed method, the affine registrations of brain images are analytically initialized by closed form solutions which can robustly approximate brain orientations and escape the local traps in optimizations. For nonlinear registrations, image deformation is modeled by a set of Wendland's radial basis functions (RBFs). To achieve efficient and accurate results, all RBFs are distributed near the brain structures determined by image derivative. Simulation data were used for performance validations. Sixty simulated brain MR images were constructed by applying random affine transformations to compare the proposed affine deformation method with AIR5, SPM2, and FLIRT algorithms. Two simulation experiments were conducted to validate the accuracy and efficiency of the proposed nonlinear registration algorithm. First, simulated brain MR images were generated by thin-plate spline transformations and then used to compare the proposed method with the SPM2 algorithm. In the second simulation, we applied SPM2 to register numerous brain images and regarded the obtained deformation fields as the ground truths for comparison with HAMMER and ART algorithms. Moreover, a VBM study with different cerebellum atrophy degrees was conducted to assess the effects of registration accuracy upon the analysis results.

Results: The simulation results shown in Figures 1 and 2 clearly indicated that our proposed methods were superior to other algorithms in both accuracy and efficiency. Figure 3 showed that the structure discrepancies discovered by VBM (p -value=0.005) using the proposed registration method (Figure 3.(a)) were more focal than SPM2 (Figure 3.(b)). The ROC curves and the correlation coefficients between the ground truths and the t-maps obtained from VBM analysis results, as shown in Figure 4, clearly indicated that our method can relatively reported structure discrepancies with high accuracy.

Conclusions: In this work, we developed an affine and a nonlinear registration method which can be applied to normalize brain images into standard stereotaxic spaces for VBM structural analyses. Our simulation results showed that the proposed registration methods can efficiently register brain images with high accuracy compared to several presented algorithms, including SPM2, AIR5, FLIRT, ART, and HAMMER. Our simulation results also demonstrated that the accuracy of VBM analysis is highly dependent on the accuracy of registration method. Accurate registrations can facilitate the exactitude of structural analyses.

(a)				
	Our Method	FLIRT	SPM2	AIR5
Errors (mm)	0.06	0.14	0.97	3.43
Time (sec)	252	345	161	118

(b)							
	Origin	Initial	Rigid	L1	L2	L3	L4
Errors (mm)	32.10	18.91	7.85	2.66	0.69	0.22	0.06
Time (sec)	/	17	27	27	29	53	252

Figure 1

(a)			(b)			
	Our Method	SPM2		Our Method	HAMMER	ART
Errors (mm)	0.09	1.24	Errors (mm)	0.19	0.54	0.60
Time (sec)	179	93	Time (sec)	300	13176	3934

Figure 2

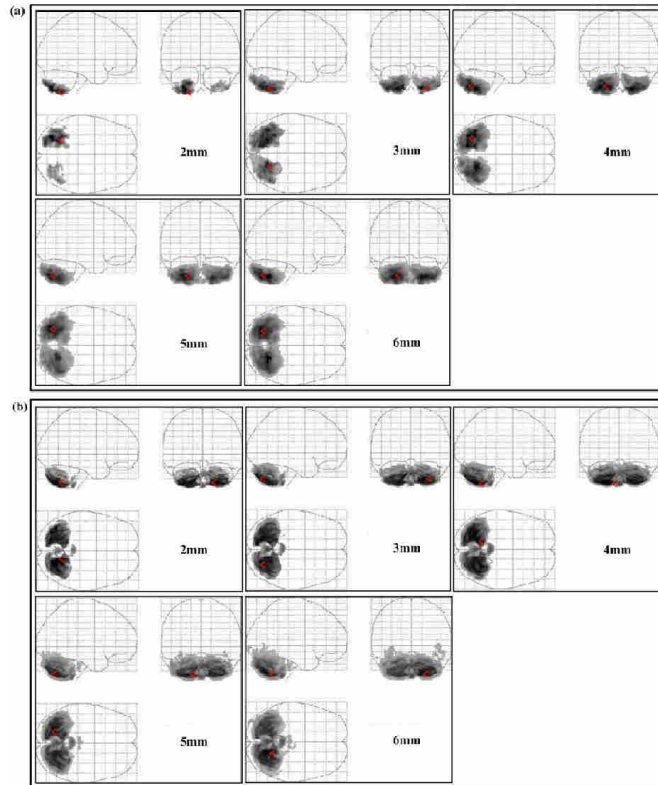
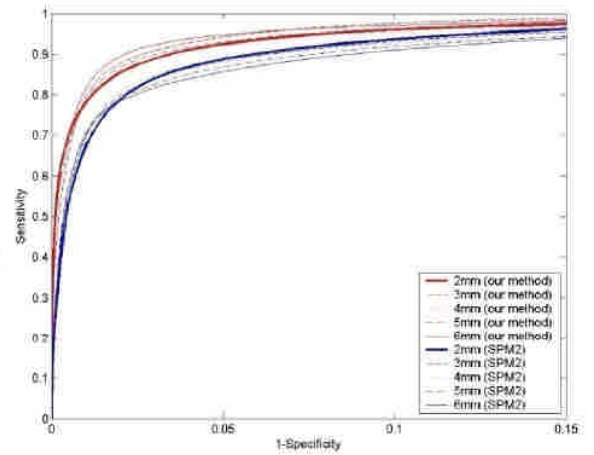


Figure 3



Atrophy scale	2mm	3mm	4mm	5mm	6mm
SPM2	0.61	0.61	0.63	0.60	0.58
Our Method	0.65	0.67	0.74	0.74	0.74

Figure 4

Magnetoencephalographic evidence of right frontal impairment of negative emotion processing in bipolar disorder

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Introduction: The neural network associated with emotion perception is distributed and dynamic. In this work we investigated the emotion processing in human brains by using the magnetoencephalography (MEG) due to its advantage of high temporal resolution. We hypothesized that there exists asymmetric cortical activities of emotional responsive areas between two hemispheres in normal controls and examined if such asymmetry exists in bipolar affective disorders.

Methods: There were 11 bipolar disorder (BD) patients (mean ages 34 ± 10 y/o, 8 females) selected from outpatients of the Psychiatry Department of Taipei Veterans General Hospital and 11 healthy normal controls (NC) (mean ages 34 ± 12 y/o, 5 females) recruited in this study. Each subject was asked to perform gender judgment task with visual stimuli containing faces with three different expressions (neutral/happy/angry, 72 trials each). The MEG signals (sampling rate 1000 Hz) were recorded with a whole-head 306-channel MEG system (Neuromag Vectorview-306, Finland). Four main ERMF components, M85, M145, M200 and M230, for each emotion of each individual were selected manually from the on-line averaged data. The image of the current density reconstruction (CDR) for each component was calculated with the sLORETA method (Curry 5.0). All CDR images were spatially normalized into a standard stereotaxic space by using SPM2 and then smoothed with a 12mm Gaussian kernel for statistical analysis. Furthermore, 38 volume of interest (VOI) were created by using the Marsbar toolbox and were used to investigate the regional effects between BD and NC groups.

Results: Figures 1 and 2 show the second-level statistics ($n=11$, cluster size > 20 voxels, $p < 0.001$, uncorrected) of CDR images for each component (M85, M145, M200, M230) in response to positive (happy), negative (angry) and neutral facial expression for BD and NC groups, respectively. The statistics of each VOI is shown in Figure 3 where horizontal axis is for VOI index (anterior-posterior) and vertical axis is for F-statistic value of the corresponding VOI. For the M85/M145 components in the NC group, there is no significant difference of F-statistic profiles between positive and neutral expressions. Whereas the F-statistic profiles in negative expression show that the right frontal lobule (inferiorfrontal) has more significant activities than left frontal lobule in M85 component. However, we cannot see this asymmetry phenomenon in BD patients.

Conclusions: The results indicated that the right hemisphere (especially frontal regions) may be involved in processing the information of negative emotion context in the M85 component. The right frontal impairment in bipolar disorder patients was found while implicitly processing of negative emotion. Our finding is consistent with the hypothesis that the function disturbances in the right cerebral hemisphere may be related to the pathogenesis of bipolar disorder (Michael et al. 2004). Our results might provide the evidence that the right hemisphere dominates in mood regulation.

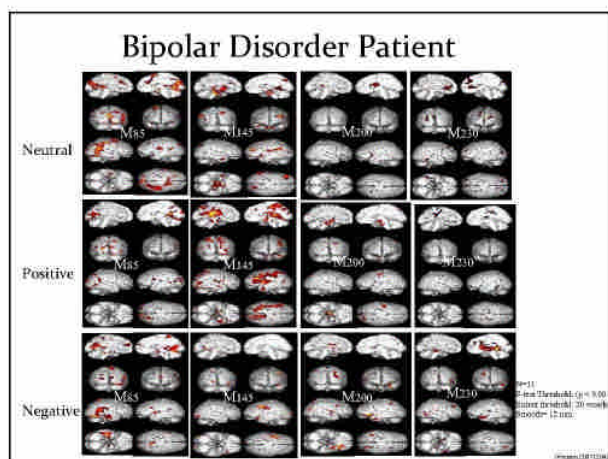


Figure 1.

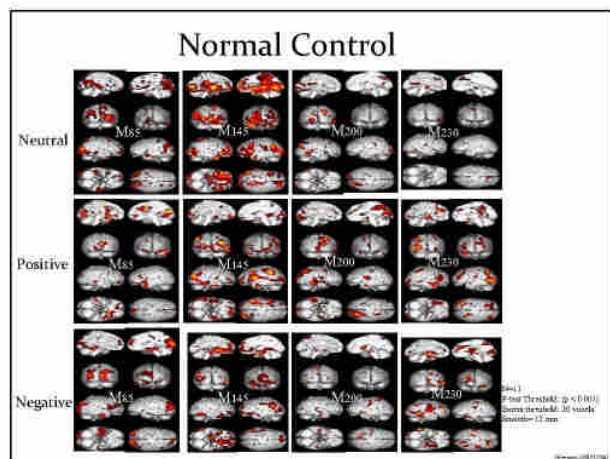


Figure 2.

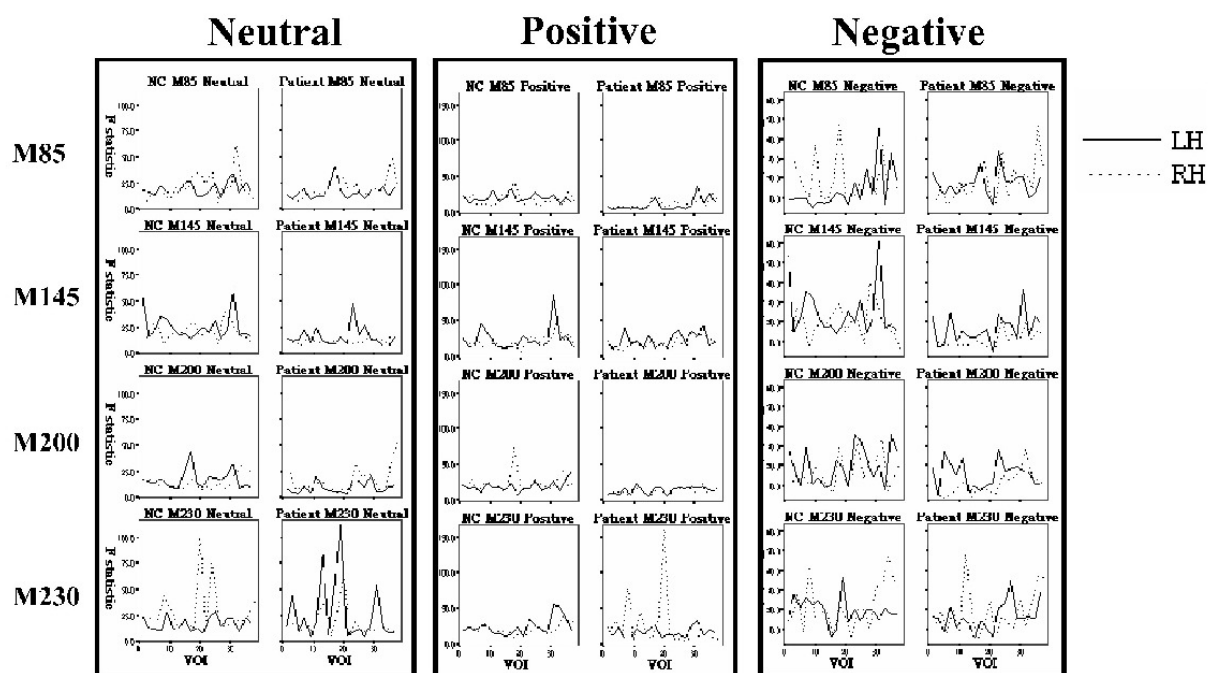


Figure 3.