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可調適性之快速 PNN 分群方法開發

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摘要

PNN(Pairwise-nearest-neighbor)是一種相當有效的資料分群方法，通常可以產生良好的分群結果，但由於計算複雜度高，實用性不高。為了改善這個問題，有許多快速 PNN 方法被開發出來，但大部份快速 PNN 方法易受資料集群組分離度影響，以致執行效率不穩定。為此，本計劃提出一個可調適性快速 PNN 方法，所提方法首先使用其它快速分群方法將資料集分成數個群組，然後記錄群組與群組間以及資料與群組間的距離資訊，最後再利用這些資訊在最近鄰居搜尋過程中過濾不可能的群組與資料，加快程式的執行效率。實驗結果顯示，與現有的快速 PNN 方法相比，所提方法在不同的群組分離度下均可得到穩定的加速效果。

關鍵字：最近鄰居分群方法, 快速演算法, 可調適性演算法

Abstract

Pairwise-nearest-neighbor (PNN) is an effective clustering method, which can always generate good clustering results than others. Since the computational complexity of the PNN method is high, it is seldom applied to solve clustering problems. To improve this problem, many fast exact PNN methods were proposed. The performance of most existing fast PNN methods are unstable and highly influenced by the cluster separation degree of a data set. To solve this problem, this project proposed an adaptive fast PNN method. In our proposed method, clusters from the data set are first separated into clusters of gorups and then the distance information between every pairs of groups and between a cluster and all groups are recorded. Finally, the distance information is used to filter out impossible gorups and clusters in the nearest neighbor finding process of a cluster to increase the efficiency of the PNN method. Experimental result shows that our proposed method can have better performance than existing method under different cluster separation degrees.

Keywords: Pairwise-Nearest-Neighbor, Fast Algorithm, Adaptive Algorithm

1.前言

資料分群技術[1-4]是一項很重要的技術，可應用在影像壓縮[2]、樣型識別[3]、資料探勘與知識挖掘[4]、影像品質改善[5-7]、語音辨識[8]、入侵偵測[9-10]等領域，用來解決不同問題。要將資料分群並不容易[1-4, 11-13]，而且通常需要大量的計算[14-15]。常見的資料分群方法有 K-Means[2,11,15]與 Pairwise-Nearest-Neighbor (PNN)[12]兩種，其中，PNN 方法通常可以比 K-Means 方法產生更好的分群結果[12,16-22]，但是具有較高的計算複雜度，也因此 PNN 的接受度通常較 K-Means 方法低。為了降低 PNN 方法的複雜度，提高 PNN 方法的可用性，目前已有許多快速 PNN 方法被提出來[16-22]，這些方法通常會受到資料集資料分佈情形的影響而有不同的效能表現。一般而言，當資料集的群聚效應(群組分離度)好時，快速 PNN 方法通常有較好的加速效果，反之，則加速效果不佳。

2.研究目的

本計劃希望開發一個受資料集資料分佈情形影響較小的快速 PNN 分群方法。使得不管所處理的資料集分佈情形為何，都能得到很好的加速效果。

3.文獻探討

PNN 分群方法[12]的作法是將資料集內的每個資料點都當成叢集(Cluster)，如果資料集內含 N 個資料點，則一開始會有 N 個叢集，然後再透過一連串的叢集合併過程合併叢集，直到叢集數目降到所要的群組數目為止，最後剩下的叢集便是所要的群組。

叢集合併動作必須先找出所有叢集中距離最近的兩個叢集合併，令資料集的維度為 d，R_a 與 R_b 是兩個叢集，$C_a=[c_{a,1}, c_{a,2}, ..., c_{a,d}]^t$ 與 $C_b=[c_{b,1}, c_{b,2}, ..., c_{b,d}]^t$ 分別是其兩個叢集的中心點，n_a 與 n_b 分別是叢集內的資料點數，則叢集 R_a 與 R_b 的距離計算公式定義如下：

$$D_{a,b} = \frac{n_a n_b}{n_a + n_b} d(C_a, C_b) \tag{1}$$

其中 $d(C_a, C_b)$表示 C_a 與 C_b 的距離，其定義如下

$$d(C_a, C_b) = \sum_{k=1}^{d} \left| c_{a,k} - c_{b,k} \right|^2 \tag{2}$$

令 R_{ab} 是 R_a 與 R_b 合併後的新群組，則 R_{ab} 的群組中心點與群組內資料點數目如下：

$$C_{ab} = \frac{n_a C_a + n_b C_b}{n_a + n_b} \tag{3}$$

$$n_{ab} = n_a + n_b \tag{4}$$

在現有的資料分群方法[1-4]中，PNN 分群方法通常可以產生較佳的分群效果，但需要花費較長的執行時間。假設一資料集有 N 筆資料，要將資料集分成 M 群，使用 PNN 方法需要 $O(N^3)$個距離計算。若 N 很大，使用 PNN 分群方法是很不切實際的作法，也因此 PNN 方法通常較少被使用。

為了降低 PNN 方法的計算複雜度，提高其可用性，Kurita [16] 使用 heap 結構儲存所有叢集對的距離，這個方法可以將 PNN 方法的計算複雜度降到 $O(N^2\log_2 N)$，但空間複雜度為 $O(N^2)$，對較大的 N 而言，龐大的記憶空間需求與記憶體存取時間，反而使這個方法比原來的 PNN 方法更不實用。為了有效降低 PNN 方法的複雜度，Fränti 等人[17]提出一個較實用的快速 PNN 演算法(簡稱 FPNN)，該方法只需 $O(N)$的空間複雜度與 $O(\tau N^2)$的計算複雜度，其中，τ的平均值大約等於 5，也就是在一般情況下，FPNN 的計算複雜度大約為 $O(5N^2)$。接著，Fränti 等人[18]又整合 Lazy PNN[19]、PDS(Partial Distance Search)[20]與 MPS(Mean-Distance-Ordered Partial Search)[21]等技術改善 FPNN 方法(簡稱為 FPNN_LPM)，這個方法針對不同輸入資料集會有不同的計算複雜度，計算複雜度大約落在 $O(0.08*\tau N^2)$到 $O(0.5*\tau N^2)$之間。藉由 Fränti 等人[17,18]的努力，使得 PNN 的複雜度由 $O(N^3)$大幅降低到 $O(0.08*\tau N^2)$到 $O(0.5*\tau N^2)$之間。

為了進一步降低 PNN 的複雜度，Liaw 提出一個 FPNN 的改良方法[22] (簡稱 MFPNN)，該方法利用叢集中心點的四個特徵值（低頻、水平邊、與垂直邊之特徵向量的投影值以及一個投影差），在最近鄰居的搜尋過程中，用來過濾不可能的叢集。MFPNN 可進一步將平均計算複雜度降到 $O(0.025*\tau N^2)$，有效降低 PNN 方法的計算複雜度。跟 FPNN 比，FPNN_LPM 與 MFPNN 方法雖可得到很大的效能改進，但會受到資料集的資料分佈特性影響而有不同的表現，當資料集群聚效應明顯 (群組分離度大)時[15]，FPNN_LPM 與 MFPNN 方法有較佳的效能表現；反之，效能不佳，在某些特殊情況下，FPNN_LPM 與 MFPNN 的表現甚至比 FPNN 還差。

4.研究方法

為了降低資料集群組分離度的影響，本計劃提出一個受群組分離度影響較小的快速 PNN 方法，所提方法首先利用一個簡單快速的分群方法，將資料集分成$\sqrt{N}$個叢集群組，再使用叢集於其所屬叢集群組與其它叢集群組之差異向量的映射值作為過濾條件，在最接近鄰居搜尋的過程中用來過濾不可能的叢集群組與叢集。本計劃所使用的分群方法以及快速最近鄰居搜尋方法分別於 4.1 節與 4.2 節說明，4.3 節則說明如何將所提方法應用到 FPNN 方法上。

4.1. 快速分群方法

有許多方法可用來將資料分群，此處目的是將資料集內的資料作快速分群，提取資料集中可用資訊，供後續使用。為了符合本計劃需求，本計劃修改 Kanungo et al. [15]的 kd-tree 方法將資料集切割成所要數目的叢集群組，以求均勻分割資料集，然後再執行數次 GLA 方法[11]調整群組以及確保群組成員距離所屬群組中心點距離較近。本計劃使用的快速分群方法說明如下：

令快速分群方法的目的群組數目 $P=\sqrt{N}$、$C_q=[c_{q,1}, c_{q,2}, \ldots, c_{q,d}]^t$ 是叢集 R_q ($q=1, 2, \ldots, N$) 的中心點、S_G 是所有叢集群組的集合、ng 是叢集群組數目。一開始，令 $ng = 1$、$S_G=\{G_1\}$、以及 $G_1=\{R_q: q=1, 2, \ldots, N\}$，也就是一開始只有一個叢集群組 G_1，且 G_1 包含所有的叢集。令 $span_{i,k}$ 是叢集群組 G_i 於第 k 軸的涵蓋範圍(span)，其定義如下：

$$span_{i,k} = max\{c_{q,k}: R_q\in G_i\} - min\{c_{q,k}: R_q\in G_i\} \tag{5}$$

令 la_i 是叢集群組 G_i 最長的軸，也就是

$$la_i = \arg\ \max_k \{span_{i,k}\} \tag{6}$$

計算完所有叢集群組的 la_i 後，找出所有叢集群組中具最大 la_i 的叢集群組，也就是找到資料最分散的叢集群組，令該叢集群組為 G_L，接下來的工作是將叢集群組 G_L 分成兩群。要將 G_L 分成兩群，我們必須先求出 G_L 最長軸的資料中位數 med_L，求法如下：

$$med_L = median\{c_{q,la_i} : R_q \in G_L\} \tag{7}$$

接著便可使用 med_i 將叢集群組 G_L 分割成 G_L 跟 G_{ng+1} 兩群，分法是檢查 G_L 下的每個資料 R_q，假如 $c_{q,la_L} > med_L$ 則將 R_q 由 G_L 移到 G_{ng+1}；否則，R_q 留在叢集群組 G_L。分割過程完畢，則將叢集群組 G_{ng+1} 加入 S_G 並將 ng 加 1。假如 $ng < P$ 則繼續分割過程直到 $ng=P$ 為止。叢集群組分割完畢後，再執行 GLA 方法，以計算各分群的中心點並確保分群內的資料確實距離其所屬分群中心點最近，綜合時間及分群效果考量，執行三次 GLA 迴圈可得到不錯的分群效果。

4.2. 快速最近鄰居搜尋方法

給定一組分群 $S_G = \{G_i: i=1, 2, ..., P\}$ 以及一個查詢叢集(cluster)$R_q \in G_L$，最近鄰居搜尋是由 S_G 中找到一個距離 R_q 最近的叢集。此處，最近鄰居搜尋過程分成兩個階段：區域最近鄰居搜尋階段以及全域最近鄰居搜尋階段。

區域最近鄰居搜尋階段的作法是由叢集 R_q 所屬的群組 G_L 中找到一個距離最近的叢集 R_l，R_l 的找法如下：

$$l = \arg\min_s \{D_{q,s} : R_s \in G_L \text{ and } R_s \neq R_q\}. \tag{8}$$

由於叢集 R_q 與叢集 R_l 屬於相同群組，因此我們預期這兩個叢集的距離不會太大而且可以當成搜尋全域最近鄰居的一個很好的起點。在我們的觀察中，區域最近鄰居其實有很大的可能也會是全域最近鄰居。在使用 32 張真實影像的實際測試中，區域最近鄰居也是全域最近鄰居的機率大約是 68%。當區域最近鄰居找到後，叢集 R_q 與叢集 R_l 的距離在全域最近鄰居的搜尋過程中，可被用來過濾不可能的群組與叢集。

全域最近鄰居搜尋階段用來檢查除了 G_L 之外的所有群組內的叢集，以求找到全域最近鄰居 R_g。全域最近鄰居 R_g 尋找方式如下：

$$g = \arg\min_s \{D_{q,s} : R_s \in (G_i \cup R_l), G_i \in S_G, \text{and } i \neq L\} \tag{9}$$

由以上公式可知，要找到全域最近鄰居需要耗費許多計算時間，為了加速全域最近鄰居尋找過程，我們先計算兩兩叢集群組中心的差異向量，並計算每個叢集到其所屬叢集群組的各個差異向量的投影值。令 $v_{i,j}$ 是兩群組 G_i 與 G_j 的差異向量，$v_{i,j}$ 定義如下：

$$v_{i,j} = \frac{(C_{G_i} - C_{G_j})}{|C_{G_i} - C_{G_j}|} \tag{10}$$

其中 C_{G_i} 與 C_{G_j} 分別是叢集群組 G_i 與 G_j 的叢集群組中心，叢集 R_s 到向量 $v_{i,j}$ 的投影值計算方式如下：

$$p_{i,j}^{s} = C_s \cdot v_{i,j} \tag{11}$$

令 $d_{\min}$ 是查詢叢集 R_q 及其候選最近鄰居的距離，在全域最近鄰居搜尋過程一開始，$d_{\min}$ 的值設定成叢集 R_q 與其區域最近鄰居叢集 R_l 的距離。有了 $d_{\min}$ 後，針對 G_L 之外的每個叢集群組 $G_i \in S_G$，我們可以使用以下不等式檢查是否該叢集群組內不可能有全域最近鄰居存在。

$$\left(p_{L,i}^{q} + p_{i,L}^{I_{i,L}}\right)^2 \times \frac{n_q}{n_q+1} > d_{\min} \tag{12}$$

$$I_{i,L} = \arg\min_{s}\left\{p_{i,L}^{s} : R_s \in G_i\right\} \tag{13}$$

其中，$I_{i,L}$ 是叢集群組 G_i 內對差異向量 $v_{i,L}$ 具有最小投影值之叢集的索引值，而 $p_{i,L}^{I_{i,L}}$ 則是其投影值，$I_{i,L}$ 跟 $p_{i,L}^{I_{i,L}}$ 可事先計算及儲存。

如果公式(12)針對某個叢集群組 G_i 成立，則叢集群組 G_i 內的每個叢集都不可能是最近鄰居，所以叢集群組 G_i 可以整個被過濾掉。假如叢集群組 G_i 不能被公式(12)過濾，則叢集群組 G_i 內的每個叢集必須再使用公式(14)檢查。

$$\left(p_{L,i}^{q} + p_{i,L}^{s}\right)^2 \times \frac{n_q \times n_s}{n_q+n_s} > d_{\min} \tag{14}$$

其中 $p_{i,L}^{s}$ 是叢集 $R_s \in G_i$ 到向量 $v_{i,L}$ 的投影值。

如果叢集 R_s 不能被公式(14)拒絕，則叢集 R_s 與叢集 R_q 必須使用公式(1)計算距離，如果該距離小於 $d_{\min}$ 則 $d_{\min}$ 必須被更新。使用上述方法可為所有叢集找到最近鄰居，並找到最近叢集對 R_a 與 R_b，然後對叢集對 R_a 與 R_b 進行合併動作。

叢集合併過程會導致合併後的叢集 R_{ab} 所屬的群組不同於叢集 R_a 所屬的群組，因此，在經過合併過程後，叢集 R_{ab} 必須重新尋找其所屬的群組。再者，叢集 R_b 的刪除與叢集 R_{ab} 的遷移也會導致叢集群組中心的改變，改變叢集群組中心會導致所有叢集必須重新尋找最近的中心點，為了避免重新配置所有叢集，在合併過程後，我們並不重算叢集群組中心，不過，必須重算叢集 R_{ab} 的投影值以及叢集 R_a 與叢集 R_b 所屬群組的最小投影值。為了加速最小投影值的更新速度，當 $I_{L,i}$ 不等於 R_a 或 R_b 的索引值且叢集 R_{ab} 仍留在叢集群組 G_L，則叢集群組 G_L 對其它叢集群組 G_i 之差異向量 $v_{L,i}$ 的最小投影值的更新過程可簡化成只計算叢集 R_{ab} 在向量 $v_{L,i}$ 的投影值，假如叢集 R_{ab} 在向量 $v_{L,i}$ 的投影值小於 $P_{L,i}$，則設定 $P_{L,i}$ 等於叢集 R_{ab} 在向量 $v_{L,i}$ 的投影值並設定 $I_{L,i}$ 等於叢集 R_{ab} 的索引值。

4.3. 跟 FPNN 方法整合

為了提昇所提方法的執行效能，可將 FPNN 方法[17]所用的加速方式應用到本計劃所提的方法中。為此，我們必須提供兩個大小為 N 的一維陣列 NN 與 ND 分別用來記錄每個叢集的最近鄰居以及與其最近鄰居的距離。除了以上所提公式(12)與公式(14)兩個不等式之外，並增加一個額外的不等式 $ND[s] \geq d_{\min}$ 來檢查一個叢集 R_s 是否可能是最近鄰居，如果條件成立，則叢集 R_s 不可能是最近鄰居。以上不等式是因為在合併過程中一個叢集的最近鄰居距離必然是單調遞增[17]，因此如果叢集 R_s 的最近鄰居距離大於 $d_{\min}$ 那麼叢集 R_s 便不可能會是叢集 R_q 的最近鄰居。再者，當資料集中有許多叢集的中心點相同時，由

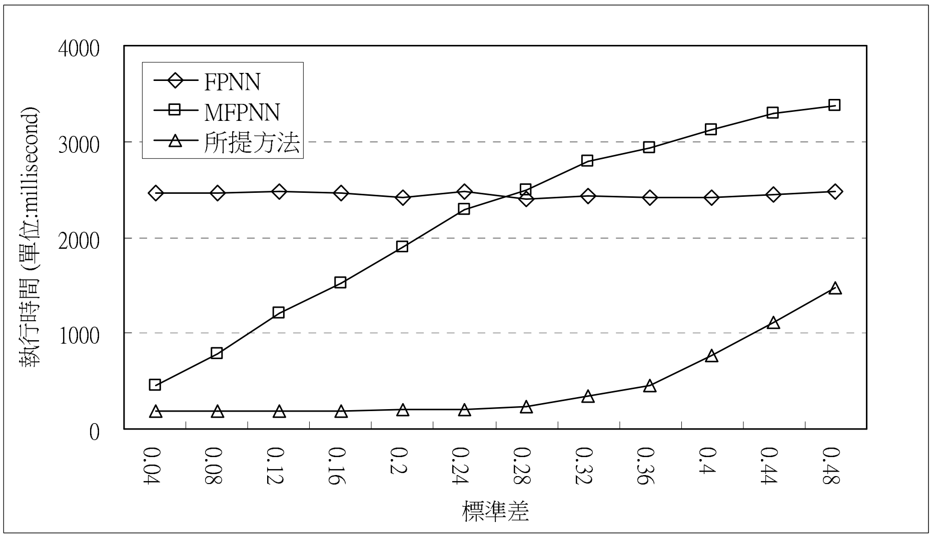
於這些叢集的最近鄰居都相同，且距離為 0，因此使用 FPNN 方法，改善效果不佳。為解決這個問題，本計劃事先檢查資料集中的資料點，在使用 PNN 方法分群前，先將內容相同的資料點併成同一叢集，以加快分群速度。

5.結果與討論

為了評估所提方法的效能，我們做了兩組實驗，每組實驗分別使用 FPNN[17]，MFPNN[22]做為對照組，其中 MFPNN 是目前已知最快的 PNN 方法，第一組實驗使用多個不同群組分離度的合成資料；第二組實驗則使用 32 張真實灰階影像作為測試資料集，其中，每張影像大小為 512×512，測試資料集則為影像中不重疊的 4×4 區塊，也就是每張影像可以看成是一個具有 128×128 個維度為 16 的資料集。所有程式均在 Microsoft Visual C++ 2008 環境開發，並在相同的電腦下執行，所使用的電腦配備有 Intel Core 2 Due P8600 2.4GHz CPU 以及 4GB 記憶體，所使用的作業系統是 Windows XP Professional SP3.

5.1. 使用不同群組分離度的合成資料

為了產生不同群組分離度的資料集，本計劃參考現有文獻的叢集資料集產生方式[15]，產生不同群組分離度的資料集。叢集資料產生方式首先使用均勻(Uniform)亂數產生器產生叢集中心，然後針對每個叢集中心使用高斯分佈產生叢集內的資料點。本實驗所產生的資料集均包含 64 個叢集，資料值域為[-1,1]，以及資料點數為 5000 點。每個資料集用來產生具高斯分佈之叢集資料點時，所使用的標準差分別為 0.04 到 0.48。事實上，真實案例標準差通常不大，當標準差大於 0.32 時，叢集資料點的涵蓋範圍便足以涵蓋整個值域，這表示很難透過分群方法找到其特徵，即使完成分群動作，其分群結果的可用性也不大。圖一所示為使用三種方法對不同標準差之資料集分群的結果，由圖一可見，MFPNN 方法在大部份情況下效果不錯，但當標準差大於 0.24 時效果反而較 PNN 方法差，而本計劃所提的方法在所有標準差情況下都有最好的效果。

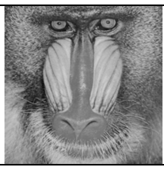
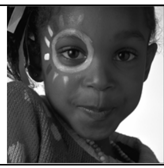
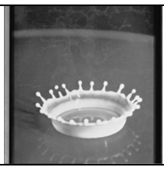
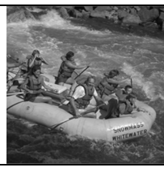
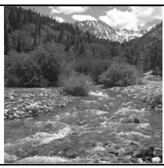
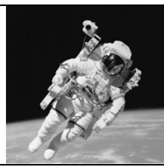
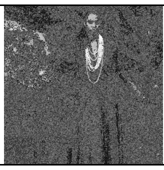


圖一：三種快速 PNN 分群方法在不同群組分離度下的執行時間表現

5.2. 使用真實影像

為了測試所提方法在真實資料的應用表現，本實驗找了 32 張常用的標準灰階影像做為測試資料集，32 張實驗用影像及其名稱如下表所示：

表Ⅰ：32 張實驗影像

					
Airplane	Baboon	Beach	Bird	Boat1	Boat2
					
Coast	Door	Effigy	F16	Flower	Girl
					
Hats	Houses	Island	Lake	Lena	Light House
					
Milk	Parrot	Peppers	Race	Raft	Red House
					
River	Sail Boat1	Sail Boat2	Spaceman	Tiffany	Wall
					
Woman1	Woman2				

表二所示為使用三種方法對 32 張個別真實影像之影像區塊所產生的資料集分群所需的執行時間（表內時間為執行三次後取平均的結果），每個資料集包含 16384 個 4x4 的影像區塊，最後將分成 128 群。由表二可見，MFPNN 方法與所提方法在使用真實影像作為資料集時，表現明顯比 FPNN 方法好，且大部份比本計劃所提方法好，但在某些特殊情況下(Spaceman 影像) MFPNN 的表現則比所提方法差很多，其主要原因在於 Spaceman 影像有一大塊黑色背景，所以使用該影像做為資料集會有很多資料點的內容相同（都是黑色），因此以 FPNN 為基礎的 MFPNN 表現便不好，由於本計劃所提方法有事先對資料集做處理，將內容相同的資料點合併成相同叢集，因此可避免這個現象的發生。

由於 MFPNN 非常適合拿來處理影像資料，而影像資料又常會出現一大塊相同區域的情形，因此，如果要使用 MFPNN 為影像資料分群，可先將相同資料點合併成相同叢集後再處理，如此可得到較穩定的表現。表二中最後一行即為將 MFPNN 方法加上前處理後的結果，由表二所示，修改後的 MFPNN 方法已無原來的問題，但對原本沒有太大問題的影像則會增加一些前處理的時間。

表二：使用真實影像作為測試資料集的執行時間(單位：秒)

Images	FPNN	MFPNN	本計劃 所提方法	MFPNN＋前處理
Aurplane	764.09	4.26	3.21	2.90
Baboon	29.17	7.66	9.03	8.28
Beach	28.05	3.48	4.60	4.06
Bird	29.97	3.04	3.90	3.53
Boat1	31.17	4.13	4.82	4.59
Boat2	28.28	4.42	5.45	5.04
Coast	28.35	4.18	4.96	4.85
Door	30.08	8.27	10.39	8.96
Effigy	27.63	3.51	4.56	4.10
F16	27.39	3.45	4.71	4.04
Flower	25.82	2.92	3.68	3.53
Girl	33.67	3.32	4.51	3.92
Hats	27.14	2.89	4.10	3.53
Houses	26.54	4.81	5.15	5.41
Island	27.18	3.37	4.32	3.98
Lake	27.69	4.09	5.32	4.70
Lena	27.57	3.14	4.23	3.76
Light House	27.10	3.21	3.99	3.82
Milk	27.22	3.23	4.65	3.93
Parrot	28.08	2.79	3.84	3.39
Peppers	28.61	3.28	4.59	3.90
Race	27.25	5.51	6.23	6.15
Raft	28.86	4.52	5.87	5.13
Red House	28.78	4.24	5.48	4.96
River	29.25	6.88	8.72	7.50
Sail Boat1	28.03	3.35	4.35	3.96
Sail Boat2	27.66	3.28	4.32	3.93
Spaceman	1213.73	219.40	1.64	1.56
Tiffany	29.09	4.23	6.04	4.91
Wall	28.64	6.79	7.46	7.46
Woman1	28.91	3.93	5.48	4.62
Woman2	28.53	5.59	6.68	6.27
Average	88.42	10.97	5.20	4.71

由以上兩組實驗結果得知，本計劃所提方法確實可以有效降低 PNN 所需的執行時間，而且受群組分離度的影響小，表現相對穩定。對影像資料而言，MFPNN 由於所使用的特徵較適合影像資料，因此有最好的效果，本計劃所提方法在處理影像資料方面，則跟 MFPNN 方法有差不多的表現。因此，本計劃所提方法非常適合用來處理任意未知分佈情況的資料集。

6.結論

PNN 分群方法是一種有效的分群方法，通常可產生比其它分群方法更好的分群結果，但由於其計算複雜度較高，因此實用性不高。為了提高 PNN 的實用性降低其運算複雜度，目前已有很多快速 PNN 方法被提出來。MFPNN 是目前已知最好的快速 PNN 方法，但會受資料集的群組分離度而影響其效能，當資料集的群組分離度太大時其效能會明顯降低。為

此，本計劃設計及開發一套新的可調適性的快速 PNN 分群方法，所提方法首先將要分群的叢集分成多個叢集群組，然後運用叢集群組間的差異向量及叢集到差異向量的映射值以及兩個不等式過濾不可能的叢集群組與叢集。配合使用 FPNN 的改善方法，本計劃所提方法受資料集的群組分離度影響較小，而且可以比現有方法更快速的產生相同的分群結果。實驗結果顯示，本計劃所提方法確實可以有效降低 PNN 所需的執行時間，而且受群組分離度的影響小，表現相對穩定。對影像資料而言，本計劃所提方法也可得到跟 MFPNN 近似的執行效能，因此本計劃所提方法非常適合處理任意未知資料分佈情況的資料集。

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計畫成果自評

■ 原計畫相符程度與達成預期目標情況

本計劃預計完成一受資料集群組分離度影響較小的快速 PNN 分群方法，分析現有過濾條件並設計一較佳的過濾條件組合，實作現有快速 PNN 分群方法，以及進行相關實驗比較各種快速 PNN 分群方法在不同情況下的效能表現。

計劃執行完畢，已完成開發一受資料集群組分離度影響較小且可有效降低執行時間的快速 PNN 分群方法，經實驗分析，本計劃所開發出來的方法是目前已知可產生跟 PNN 具有相同分群結果之方法中最快的快速 PNN 分群方法。

■ 研究成果之學術或應用價值

學術價值：本計劃已開發完成一套受資料集群組分離度影響較小且可有效降低執行時間的快速 PNN 分群方法，部份成果已發表於國際研討會[23]，完整的成果預計將投稿至 Pattern Recognition 或相同等級的 SCI 國際期刊。

應用價值：本計劃所開發出來的快速 PNN 分群方法是目前已知可產生跟 PNN 具有相同分群結果之方法中最快的快速 PNN 分群方法，此方法可應用到影像壓縮、樣型識別、資料探勘與知識挖掘、影像品質改善、語音辨識、入侵偵測等相關產業，提高辨識率。

■ 影像處理人才培育

本計劃執行人員，主要包括一位碩士班學生以及多位大學部學生，碩士班學生主要負責，閱讀文獻與實作本計劃所需的程式以及進行實驗，對其英文文件閱讀能力，實作能力的提昇，做事態度的養成，與實驗方法的熟悉有很大的幫助。大學部學生則幫忙搜集資料，閱讀文獻，以及協助撰寫程式等，參與人員對英文文件閱讀能力，實作能力的提昇，研究與實驗進行方式的了解，做事態度的養成等方面，都有很大的幫助。

可供推廣之研發成果資料表

☑ 可申請專利　☑ 可技術移轉　日期：99年11月28日

國科會補助計畫	計畫名稱：可調適性之快速 PNN 分群方法開發 計畫主持人：廖怡欽 計畫編號：NSC 98-2221-E-343-008-　學門領域：資訊學門二
技術/創作名稱	可調適性之快速 PNN 分群方法
發明人/創作人	廖怡欽
技術說明	中文：PNN(Pairwise-nearest-neighbor)是一種相當有效的資料分群方法，通常可以產生良好的分群結果，但由於計算複雜度高，實用性不高。為了改善這個問題，有許多快速 PNN 方法被開發出來，但大部份快速 PNN 方法易受資料集群組分離度影響，以致執行效率不穩定。為此，本計劃提出一個可調適性快速 PNN 方法，所提方法首先使用其它快速分群方法將資料集分成數個群組，然後記錄群組與群組間以及資料與群組間的距離資訊，最後再利用這些資訊在最近鄰居搜尋過程中過濾不可能的群組與資料，加快程式的執行效率。實驗結果顯示，與現有的快速 PNN 方法相比，所提方法在不同的群組分離度下均可得到穩定的加速效果。
	英文：Pairwise-nearest-neighbor (PNN) is an effective clustering method, which can always generate good clustering results than others. Since the computational complexity of the PNN method is high, it is seldom applied to solve clustering problems. To improve this problem, many fast exact PNN methods were proposed. The performance of most existing fast PNN methods are unstable and highly influenced by the cluster separation degree of a data set. To solve this problem, this project proposed an adaptive fast PNN method. In our proposed method, clusters from the data set are first separated into clusters of gorups and then the distance information between every pairs of groups and between a cluster and all groups are recorded. Finally, the distance information is used to filter out impossible gorups and clusters in the nearest neighbor finding process of a cluster to increase the efficiency of the PNN method. Experimental result shows that our proposed method can have better performance than existing method under different cluster separation degrees.
可利用之產業及可開發之產品	可利用之產業：影像壓縮、樣型識別、資料探勘與知識挖掘、影像品質改善、語音辨識、入侵偵測等相關產業 可開發之產品：影像壓縮、樣型識別、資料探勘與知識挖掘、影像品質改善、語音辨識、入侵偵測等系統
技術特點	不受資料集群組分離度影響 是目前最快速的 PNN 相容分群方法之一
推廣及運用的價值	可提昇 PNN 分群速度及提高 PNN 方法的可用性。 使用 PNN 方法取代 K-mean 方法以產生較佳的分群結果。

※　1. 每項研發成果請填寫一式二份，一份隨成果報告送繳本會，一份送　貴單位研發成果推廣單位（如技術移轉中心）。

※　**2. 本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。**

※　3. 本表若不敷使用，請自行影印使用。

出席國際學術會議心得報告

計畫編號	NSC 98-2221-E-343-008
計畫名稱	可調適性之快速 PNN 分群方法開發
出國人員姓名 服務機關及職稱	廖怡欽 南華大學副教授
會議時間地點	民國 99 年 8 月 7 日至民國 99 年 8 月 10 日
會議名稱	7th International Conference Computer Graphics, Imaging, and Visualisation (CGIV2010)
發表論文題目	Video Objects Behavior Recognition using Fast MHI Approach

一、參加會議經過

此次出國主要目的是到澳洲雪梨參加 CGIV2010 會議發表論文(附件一)，該會議由雪梨科技大學(University of Technology Sydney, UTS)、科威科大學(Kuwait University)、以及英國倫敦南部大學(London South Bank University)主辦。會議時間 8 月 7 日至 8 月 10 日共四天，8 月 7 日是博士生研討會，8 月 8 日會議開幕及論文發表，8 月 9 日安排大家到藍山參觀以及晚宴，8 月 10 日為論文發表及閉幕。

台灣到雪梨直飛全程需要 9 個小時，台灣的航空公司只有華航直飛，而且國科會計劃也鼓勵搭乘華航，因此決定搭乘華航，搭乘華航並且要準時參加會議，因此必須選在 8/4 日晚上出發，由於投稿時間較晚，又遇到暑假，由台灣出發的經濟艙已沒有座位，因此去乘改搭乘商務艙，會議結束隔天 8/11 再搭經濟艙回國。

8 月 4 日 23:55 搭機出國，8 月 5 日 11:00 到達雪梨，由於提早到達，因此有時間多看一看雪梨。雪梨市不愧為一國際都市，有許多外來移民人口，國外學生，以及許多旅客，雪梨交便相當便利，食物種類很多，是一個對外來人口相當友善的國家，也因此有許多遊客及外國留學生選擇雪梨作為其旅遊及留學的城市。大部份留學生及遊客來自中東、印度、東南亞、大陸、韓國等鄰近國家。其觀光收入及外國留學生收入佔整個城市收入相當大的比例。

會議 8 月 7 日(六)開始，會議地點在雪梨科技大學(UTS)，雪梨科技大學(UTS)座落在雪梨中央車站及中國城附近，由好幾棟建築物組成，建築物就在一般道路旁邊，與雪梨市融為一體，由於前一天已先找好會議地點，因此早上很快到達會場，參與由英國 Banissi 教授所主持的博士生研討會，會中說明博士學位的緣起，以及互相討論各自的研究方向及研讀博士應注意事項，我則提供在台灣讀博士的經驗供參考。

8 月 8 日(日)，會議正式開始，早上 10：40 開幕，接著便是一整天的議程，本會議共有 70 餘篇投稿，最後被接受的論文有 30 餘篇，接受率大約 5 成，被接受的論文分別

來包括瑞典、英國、科威特、伊朗、巴基思坦、澳洲、紐西蘭、日本、韓國、馬來西亞、中國、台灣等 12 個國家，台灣只有我一個參加。今天的議程分三個議程(Session)，所有的論文都在同一間會議室報告，我的論文安排在今天下午最後一場發表，報告完已是 17:40。

8 月 9 日(一)，主辦單位安排藍山之旅及晚宴，早上 8：00 在中央車站集合，共有 9 個人參加，由會議主席 Banissi 及其夫人帶隊，當天除了觀賞藍山的美麗景色，健行強建體魄外，最重要的是能夠跟來自其它國家的學者交換意見，也可增加未來跨國合作的機會。也感謝會議主席及其夫人一路上的照顧。晚宴也認識來自科威特的 Sarfraz 教授及來自馬來西亞的 Sumari 與 Kamarulhaili 教授夫婦。

8 月 10 日(二)，會議最後一天，教室換到另一棟建築物，今天安排了兩個議程，會議到下午 2:00 結束，聽了幾場不錯的演講，休息期間也跟幾個教授交換一些意見，了解一下其它國家的情況。

8 月 11 日(三)，晚上搭機回國。

二、與會心得

參加過許多次會議，這次會議跟以前參加的會議比較不同，參加會議的人數較少，因此所有論文可以在單一場地報告，而不會有多個議程同時進行的情況發生，因此可以很清楚知道參加會議的其它人從事什麼樣的研究，跟其它人的互動也比較多，比較可以有較深入的交談。再者，這次會議時間上的限制比較少，可以讓報告者充分說明其研究內容，問題也比較能夠得到充分討論。

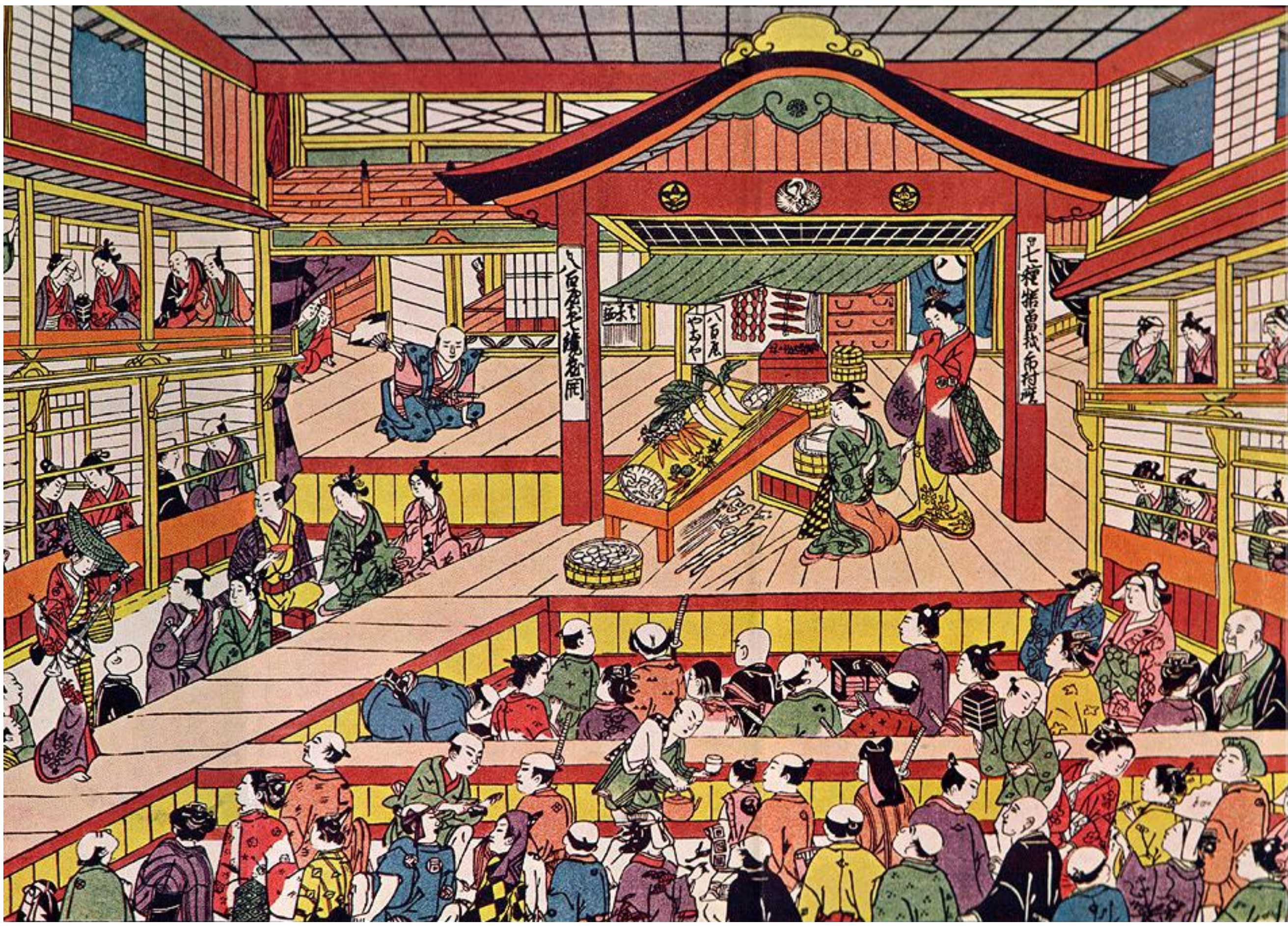
整體而言，參加這個會議，除了聽到其它人的研究內容及成果外，重要的是認識了許多其它國家的學者，增加跨國合作的可能性。事實上，透過跟其它國家學者交談後的結果，發現愈來愈多國家鼓勵學者提出跨國研究計劃，許多學者也都主動提到跨國合作的可能性，或許未來可以多嘗試朝跨國合作計劃方向發展。

CGiV 2010

7th International Conference

Computer Graphics, Imaging & Visualisation

The Preliminary Programme



Perceptually-Guided Design of Nonperspectives Through Pictorial Depth Cues
Kenichi Yoshida1, Shigeo Takahashi1, Hiroaki Ono1, Issei Fujishiro2, Masato Okada
(downloaded from Wikimedia Commons).

University of Technology, Sydney

■ Sydney ■ Australia ■

CGiV2010
SYDNEY ~ AUSTRALIA

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IV10 & cgiv2010 - DIGITAL ART GALLERY Online Exhibition
July 2010 - June 2011

VIRTUAL GALLERY VENUE
www.graphicslink.co.uk/DART.htm

D-Art

Exhibiting Artists:

Akio Yamanaka // Japan

Corrinne Whitaker // member of Contemporary Art in Los Angeles and the Carmel Gallery Alliance, USA

Da Young Ju // Art College Hong-Ik University, South Korea

Dena Elisabeth Eber // Bowling Green State University, OH, USA

Gabrielle Peters // University of Applied Sciences and Arts Computer Science, Germany

Gloria DeFilipps Brush //Department of Art & Design at the University of Minnesota Duluth, USA

Hans Dehlinger // University of Kassel, Germany

Harvey Goldman //University of Massachusetts Dartmouth, USA

James Faure Walker //Kingston University, UK

Jason Nelson //Griffith University Australia

Jing Zhou //New Jersey, USA

Jonathan Craig Hounshell //East Tennessee State University, USA

Joohyun Pyune // USA

Kathy Brew // independent videomaker, USA

Roberto Guerra // Universidad Nacional de Ingenieria, Lima Perú

Kellen Moss // 3D Animator

Leslie Nobler Farber //USA

Mary Visser //Southwestern University USA

Monika Wulfers // USA

Martin John Callanan //UCL Environment Institute, UK

Philip Sanders // New York University USA

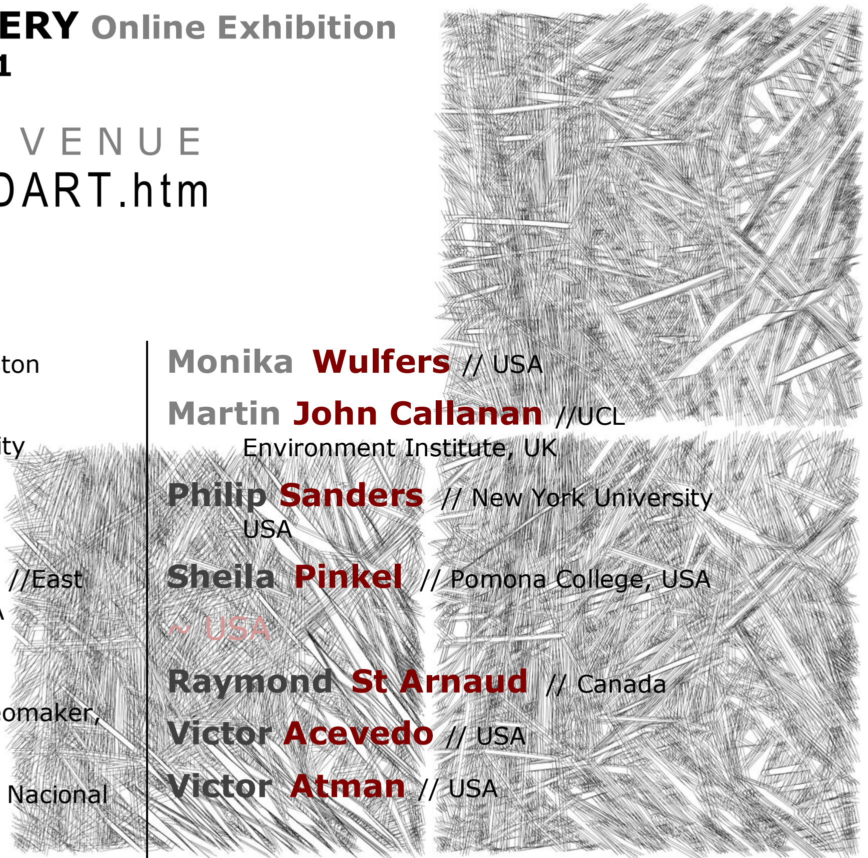
Sheila Pinkel // Pomona College, USA

~ USA

Raymond St Arnaud // Canada

Victor Acevedo // USA

Victor Atman // USA



U_A_f2-3.3 // U_A_f3-1.2 // U_A_f3-2.4
© Hans Dehlinger, Professor Emeritus
University of Kassel, Germany

The subjects are line-oriented generative drawings, executed on a pen-plotter. The drawings make use of straight poly-lines only. By definition, such drawings are “sharp”, because of the nature of the lines used. From photographic images “unsharp”, (blurred, out of focus) images are well known. The ones we are interested in are the result of an intentional effort of the photographer. The question arises, can drawings be produced that appear to be unsharp despite being produced entirely of sharp lines. The drawings are experiments to generate such drawings. They are copsed of three layers of the same drawing which are slightly scaled against each other. The point of origin of scaling is usually not in the center of the drawing.

A full-day Event: Saturday 7th August 2010, Time: 9:30 -17:00

Computer Graphics, Imaging and Visualisation
DOCTORAL RESARCH WORKSHOP

Organised by

Visualisation & Graphics Research Unit of LSBU, UK

&

Department of Computer Systems, Faculty of Information Technology, University of Technology, Sydney, Australia

Computer Graphics, Imaging and Visualization –CGIV- Forum is an annual forum that is held for 7 year running. This year CGIV forum in collaboration with the Visualisation & Graphics Research Unit of LSBU, UK and the Department of Computer Systems , Faculty of Information Technology, University of Technology, Sydney, Australia are pleased to announce Doctoral Research Workshop within the scope of the 7th International conference on Computer Graphics, Imaging and Visualization (CGIV2010). This workshop provides an opportunity for PhD students to present their work, receive feedback and to meet other researchers working in CGIV area. The focus of this workshop will be on the pros and cons of various Computer Graphics, Imaging and Visualization ideas and solutions and its potential impact on both the research community and the industry in general.

All doctoral students involved in Computer Graphics, Imaging and Visualization research area are welcome to attend. The event is organised in four sessions with up to four PhD students per session. Presenters, which are PhD students at various stages of their PhD, will give an outline of their PhD research in order to benefit from feedback about their work and methodology from a combined industry & research panel.

Saturday 7 August 2010

10:00	< UTS - Lecture theatre Foyer > Registration
10:30 - 13:00	< UTS - CB10.02.240 Postgraduate Seminar Room > **A full-day Event: saturday 7th August 2010, Time: 10:30 -16:30** **Computer Graphics, Imaging and Visualisation** **Doctoral Research Workshop** Chair: Professors Ebad Banissi, Muhammad Sarfraz, and Mao Lin Huang 10:30 **An introduction from Doctoral Research Workshop chair and organiser** 11:00 Visutsak, Porawat, King Mongkut's Institute of Technology Ladkrabang, Thailand 11:45 Wahab, Dr. Abd Fatah, University Malaysia Terengganu, Malaysia 12:30 **View of what examiners look for in a PhD**
13:00	< UTS - Dining Hall > *Lunch Break*
14:00	< UTS - CB10.02.240 Postgraduate Seminar Room > 14:00 Choi, Changryoul, Hanyang University, South Korea 14:45 Oh, Hyeongchul, Hanyang University, South Korea 15:30 Break 16:00 **1-1 feedback round table discussion** **Final commentary** **Close**

Sunday 8 August 2010

09:30	**< UTS - Lecture theatre Foyer >** Registration
10:40	**< UTS - CB10.02.230 Postgraduate Seminar Room >** *Opening & Welcome* **Welcome & official opening from UTS** **Conference welcome from cgiv2010 committee** **Co-Chairman:** Prof. M. Sarfraz Department of Information Science, Kuwait University Prof. Ebad Banissi VGRU, LSBU, UK **Organizing co-Chairman:** Prof. Maolin Huang Faculty of Information Technology. University of Technology, Sydney, Australia
11:30	< Lecture Theatre # Foyer > *Morning Coffee Break / Photograph Session*
12:00	**< UTS - CB10.02.230 Postgraduate Seminar Room >** **Session CGIV10_1.1: Computer Graphic, Visualisation and Imaging Application** Chair: Prof Ebad Banissi, VGRU, LSBU, UK Polygonisation of non-Manifold Implicit Surfaces Using a Dual Grid and Points *D. J. Harbinson, R. J. Balsys, and K. G. Suffern* Perceptually-Guided Design of Nonperspectives through Pictorial Depth Cues *Kenichi Yoshida, Shigeo Takahashi, Hiroaki Ono, Issei Fujishiro, and Masato Okada*
13:00	**< UTS - Dining Hall >** *Lunch Break*

14:00 - 15:20

< UTS - **CB10.02.230 Postgraduate Seminar Room** >

Session CGIV10_1.3: Multimedia
Chair: Prof. Ron Balsys; Central Queensland University Australia

Character Skin Deformation: A Survey
E. Chaudhry, L. H. You, and Jian J. Zhang

Caching Scheme for Handheld Device in Mobile Video-on-demand System
Putra Sumari and Amir Rizaan Rahiman

The Height Variance Range for One Frequency Fringe Pattern Profilometry
Yi Ding, Jiangtao Xi, Yanguang Yu, Joe Chicharo, and Wenqing Cheng

Development of Partial Face Recognition Framework
H. F. Neo, C. C. Teo, and Andrew B. J. Teoh

Reviewing Principles and Elements of Animation for Motion Capture-Based Walk, Run and Jump
Jong Sze Joon

15:20

< Lecture Theatre # Foyer >

Break

15:50 - 17:00

< UTS - **CB10.02.230 Postgraduate Seminar Room** >

Session CGIV10_2.5: Image/Video Analysis for Face Recognition II
Chair: Prof Maolin Huang, Faculty of Information Technology. University of Technology, Sydney, Australia

Combining Boundary and Skeleton Information for Convex and Concave Points Detection
Ali Salem Bin Samma, Abdullah Zawawi Talib, and Rosalina Abdul Salam

Shape Analysis and Recognition Based on Skeleton and Morphological Structure
Donggang Yu, Jesse S. Jin, Suhuai Luo, Wei Lai, Mira Park, and Tuan D. Pham

Motion Compensated Frame Interpolation using Adaptive Adjacency Pixel Information
Hyeongchul Oh, Joohyun Lee, Changki Min, and Jechang Jeong

Ordinal Region-Based Representations for Iris Recognition
C. C. Teo, H. F. Neo, and H. T. Ewe

Jawi Character Recognition Using the Trace Transform
Mohammad F. Nasrudin, Maria Petrou, and Leonidas Kotoulas

Video Objects Behavior Recognition using Fast MHI Approach
Yi-Ching Liaw, Wei-Chih Chen, and Tsung-Jen Huang

Monday 9 August 2010

09:00 – 1800	**Cgiv2010_Social Networking Event** <To be finalised>
19:30 - 21:30	**Cgiv2010_ Social Event** **Conference Dinner** <To be finalised>

Tuesday 10 August 210

08:30

Registration

9:30

< UTS - CB02.07.004B - Tutorial Room >

Session CGIV10_3.1: Computer-Aided Geometric Design

Chair: Prof. Ahmad Nasri, Computer Graphics & Animation Lab and Department of Computer Science , AUB, Lebnan

Fuzzy Interpolation Rational Bezier Curve
Abd. Fatah Wahab, Rozaimi Zakaria, and Jamaludin Md. Ali

Differential Evolution Optimization for Bezier Curve Fitting
Priza Pandunata and Siti Mariyam Hj Shamsuddin

NURBS Curve Approximation using Particle Swarm Optimization
Delint Ira Setyo Adi, Siti Mariyam bt Shamsuddin, and Siti Zaiton Mohd Hashim

Interpolation with PH quintic spirals
Zulfiqar Habib and Manabu Sakai

Approximating boundary of bitmap characters using Genetic Algorithm
Muhammad Sarfraz, Malik Zawwar Hussain, Misbah Irshad, and Ayesha Khalid

Generating Elliptic Curves modulo p for Cryptography using Mathematica software
Hailiza Kamarulhaili

Simplified Local Binary Pattern Descriptor for Character Recognition of Vehicle
Lixia Liu, Honggang Zhang, Aiping Feng, Xinxin Wan, and Jun Guo

< UTS - CB02.07.008-g-b LECTURE ROOM >

Session CGIV10_3.2: CGIV

Chair: Prof. jiangtao xi, University of Wollongong, Australia

Low Complexity Weighted Two-Bit Transforms Based Multiple Candidates Motion Estimation Exploiting the Redundant Computations
Changryoul Choi and Jechang Jeong

A Robust Evolutionary Based Digital Image Watermarking Technique in DCT Domain
Majid Rafigh and Mohsen Ebrahimi Moghaddam

Visual Interface Tools to Solve Real-World Examination Timetabling Problem
J. Joshua Thomas, Ahamad Tajudin Khader, Bahari Belaton, and Eben Christy

Evaluating the Usability of Visualizations of Normal Behavioral Models for Analytical Reasoning
Maria Riveiro and Göran Falkman

A Robust Multiple Object Tracking Algorithm Under Highly Occlusion
Dang Xiaoyan, Zhang Ya, Wang Wei, Wang Zhuo, and Wang Zhihua

Expressive MPEG-4 Facial Animation Using Quadratic Deformation Models
Mohammad Obaid, Ramakrishnan Mukundan, Mark Billinghurst, and Catherine Pelachaud

Principles of Photorealism to Develop Photorealistic Visualisation for Interface Design: A Review
Jong Sze Joon

11:00	<Foyer> *Break*
11:30	< UTS - **CB02.07.008-g-b LECTURE ROOM** > **Session CGIV10_3.7: CGIV** Chair: Prof. M. Sarfraz, Department of Information Science, Kuwait University Visual Computer Game Features for Teaching Relativity *David Carr* **<Keynote Lecture>** Sketch-Based Subdivision Models for Graphics and Animation *Ahmad Nasri, Computer Graphics & Animation Lab and Department of Computer Science , AUB, Lebnan* **Conference Closing from cgiv10 committee:** **Co-Chairman:** Prof. M. Sarfraz Department of Information Science, Kuwait University Prof. Ebad Banissi VGRU, LSBU, UK Prof. Maolin Huang Faculty of Information Technology. University of Technology, Sydney, Australia
13:00	< Lecture Theatre # Foyer > Lunch Break
14:00	< meeting room #> cgiv2011-Committee Members Meeting
	Close

NOTES

DIGITAL ART GALLERY

an online exhibition

July 2010 ~ June 2011

VIRTUAL GALLERY
VENUE www.graphicslink.co.uk/DART.htm

Visual Styles of Wayang Kulit Kelantan
Khor Kheng Kia & and Yuen May Chan
Limkokwing University & Multimedia University, Malaysia

Published by:
Visualisation & Graphics Research Unit
London South Bank University, UK

Video Objects Behavior Recognition using Fast MHI Approach

Yi-Ching Liaw[1], Wei-Chih Chen[1], and Tsung-Jen Huang[2]

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[2]Industrial Technology Research Institute, Hsinchu, Taiwan 310, R. O. C.

{ ycliaw@mail.nhu.edu.tw, g7151002@mail.nhu.edu.tw, and PatrickHuang@itri.org.tw }

Abstract

The concept of motion history image (MHI) is widely adopted by many researchers to solve problems of video objects behavior recognition. In the case of predefined behaviors with various durations, the computation time of behavior recognition will increase intensely. In this paper, a fast MHI approach is proposed to reduce the computation time of the MHI approach by storing multiple sets of features for a predefined behavior and using the partial distance computation method. In this paper, 9 local orientations proposed by Cheng et al and squared Euclidean distance are used in our behavior matching process to demonstrate the performance of the proposed approach. Experimental results show that the proposed method can effectively reduce the computation time of the MHI method.

Keywords--- **Video object behavior recognition**.

1. Introduction

A surveillance system is used to obtain a series of images (frames) from real world by using a video camera. The captured images can be recorded or transferred to a remote monitor for displaying. Through watching the captured images, one can realize what is happened in front of the camera without limitations of time and location. The surveillance system can be set up for various purposes, such as the traffic monitoring, living environment monitoring, and remote monitoring.

To identify if a specified behaviour occurs in a video stream usually requires a lot of time and human efforts and is very easy to make mistakes. To solve these problems, many approaches were proposed [1-3] to identify behaviors from video streams automatically. A classical behavior recognition method includes two phases: the training phase and the testing phase. In the training phase, video clips of predefined behaviors performed by a video object are captured. For a predefined behavior, a set of features is obtained from the video clip of the behavior. In the end of the training phase, a batch of feature sets from predefined behaviors is used to create the knowledge base of behavior recognition. In the testing phase, a set of features is first extracted from the input frames which are usually captured in real time and from the surveillance system. Then, the extracted feature set is used in the behavior matching process to identify if a predefined behavior detected.

There are many methods [1-3] were proposed to obtain a set of features from a set of motion frames. Among available methods, the motion history image (MHI) approach [4] usually takes less computation time and requires less prior knowledge. The simplicity of the MHI method has attracted many attentions in recent years. To improve the availability and precision of the MHI method, many methods [5-9] were proposed. In Cheng's method [9], the motion gradient magnitude histogram (MGMH) and local orientations are proposed and used as features of an MHI. Through using these two kinds of features, the accuracy of behavior recognition can be effectively improved.

The motion history image of a behavior is generated using frames captured during the action time of the behavior. For a set of predefined behaviors with different durations of time, to detect if input frames present a predefined behavior, multiple MHIs and multiple features must be generated before the behavior matching process. This will largely increase the computation time of MHI-based methods. To reduce the computational complexity of the MHI-based method, a novel fast MHI approach is proposed in this paper. The proposed approach adopts 9 local orientations as features for it can demonstrate the performance of the proposed method more clearly. However, other feature extraction methods can also be used with our proposed method.

The rest of this paper is organized as follows. In section 2, the MHI generation process and nine orientations extraction method are reviewed. Our proposed method is presented and described in section 3. Experimental result and conclusions are given in section 4 and section 5, respectively.

2. Background

Motion history image (MHI) approach was first presented by Davis and Bobick [4] which uses temporal templates to represent and recognize human actions. Figure 1 shows a typical procedure for behavior recognition using the MHI method. From figure 1, we can see that the training phase consists of object extraction, history matrix updating, MHI generation, and feature extraction process and the testing phase contains object extraction, history matrix updating, MHI generation, feature extraction, and behavior matching processes. The detail explanation for each process is provided in the following subsections.

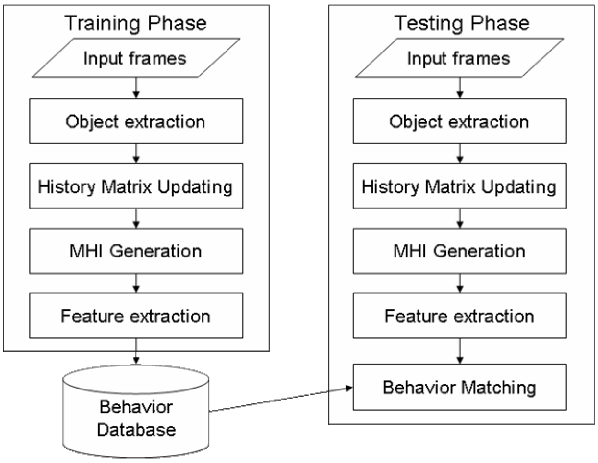

Figure 1. Procedure of a typical MHI approach.

2.1 Object extraction process

This process is used to find where the moving object is located in the input frame and to generate an object mask for the input frame. There are many methods [10] developed and can be used to deal with this problem. After this process, we can have an object mask for the input frame. An object mask is a binary image. For a pixel in the input frame is an object pixel, its corresponding pixel in the object mask of the input frame is set as 1. Otherwise, it is set as 0. Figure 2 gives an example for the input frame, reference frame, and object mask of the input frame.

(a) (b) (c)

Figure 2: An example for (a) reference frame, (b) input frame, and (c) object mask.

2.2 History matrix updating process

The purpose of the history matrix updating process is to record the appearance history for video objects. To accomplish this goal, a history matrix with the same size as input frames is maintained. Each element in the history matrix is initialized to 0 and updated according to the values of the incoming object masks using a timestamp with an initial value of 1.

Let the current value of timestamp be τ and the value for an element in the object mask with coordinate (x, y) at time-point τ be $M^{\tau}(x, y)$. The updating method for an element in the history matrix with coordinate (x, y) at time-point τ is defined in the following:

$$H^{\tau}(x,y)=\begin{cases}\tau & \text{if } M^{\tau}(x,y)=1\\ 0 & \text{if } M^{\tau}(x,y)=0 \text{ and } H^{\tau-1}(x,y)\le(\tau-\delta)\end{cases} \quad (1)$$

where δ is the number of frames in a motion.

Figure 3 gives an example to show how the history matrix is updated under a series of incoming object masks when δ=3.

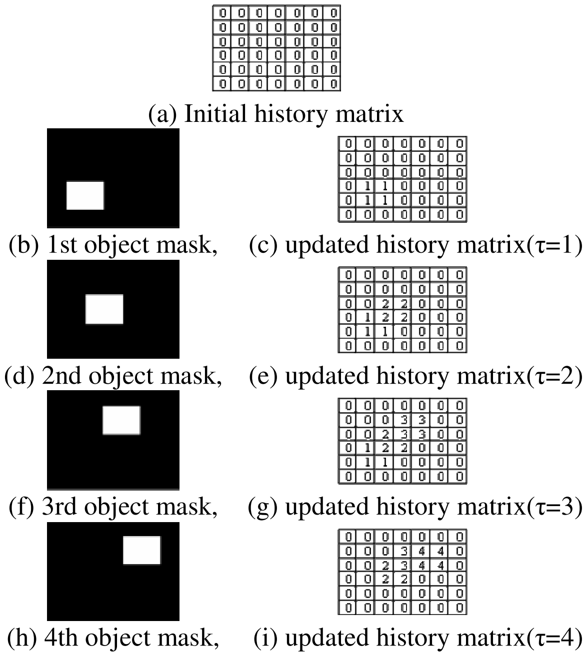

Figure 3. An example to show the updating process of the history matrix.

2.3 MHI generation process

Once the value of τ is equal to or greater than δ, that means we have enough frames for motion recognition and an MHI can be generated using the following equation:

$$MHI^{\tau}(x,y)=\begin{cases}\dfrac{H^{\tau}(x,y)-(\tau-\delta)}{\delta}\times 255 & \text{if } H^{\tau}(x,y)\neq 0\\ 0 & \text{if } H^{\tau}(x,y)=0\end{cases} \quad (2)$$

where $MHI^{\tau}(x, y)$ is the value of a pixel in the MHI at time-point τ with coordinate (x, y). Figure 4 gives an example to show how an MHI is generated for δ=8, where the surrounding black area is removed.

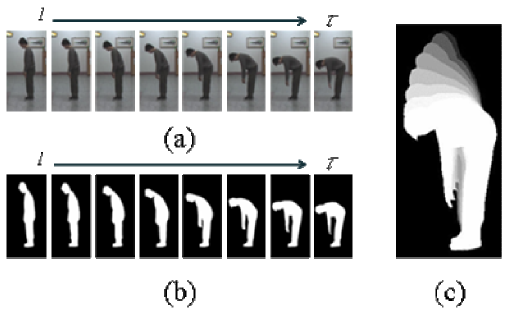

Figure 4. An example for (a) input frames, (b) object masks, and (c) the MHI.

2.4. Features extraction process

In Cheng's method [9], the local orientations of an MHI is obtained by dividing the MHI into 9 blocks as shown in figure 5(a) and calculating the motion orientation for each block. The covering range of each block is given in figure 5 (b). It is noted that the fifth block contains the whole MHI and is also called the global orientation of the MHI.

(a) (b)

Figure 5. MHI local areas

To evaluate the orientation information for an MHI, three blank 2-D arrays G_x^τ, G_y^τ, θ^τ are used to record the horizontal gradients, vertical gradients, and angles for pixels in the MHI at time-point τ, respectively. Here, two sobel masks S_x and S_y as given below are applied to evaluate the horizontal and vertical gradients, respectively.

$$S_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \qquad S_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{3}$$

Once G_x^τ and G_y^τ are evaluated, the angle of a pixel with coordinate (x, y) in the MHI can be computed using the following equation:

$$\theta^\tau(x, y) = \tan^{-1}\left(\frac{G_y^\tau(x, y)}{G_x^\tau(x, y)}\right) \tag{4}$$

Let O_n^τ be the major orientation of nth block for an MHI. The definition of O_n^τ is listed as follows:

$$norm(\tau, \delta, H^\tau(x, y)) = 1 - \frac{\tau - H^\tau(x, y)}{\delta} \tag{5}$$

$$O_n^\tau = \theta_{n,ref}^\tau + \frac{\sum_{x,y} angDiff(\theta_n^\tau(x, y), \theta_{n,ref}^\tau) \times norm(\tau, \delta, H^\tau(x, y))}{\sum_{x,y} norm(\tau, \delta, H^\tau(x, y))} \tag{6}$$

where $H^\tau(x, y)$ is the value of a pixel in the history matrix with coordinate (x, y), $\theta_n^\tau(x, y)$ is the angle of a pixel in nth block with coordinate (x, y), $\theta_{n,ref}^\tau$ is the maximum angle in nth block, and *angDiff* is a function to evaluate the angle difference between $\theta_{n,ref}^\tau$ and $\theta_n^\tau(x, y)$.

2.5. Behavior matching process

There are many different matching methods [5, 15] available. In this paper, the squared Euclidean distance is used to find the most similar predefined behavior from the behavior database for input frames. If the difference between the extracted feature set of the input frames and the most similar feature set from the behavior database is less than a given threshold value, we can say the behavior corresponding to the most similar feature set appears in the input frames. Otherwise, the behavior is not detected.

3. Proposed Method

For a behavior database contains a set of predefined behaviors with various numbers of motion frames, to recognize the behavior of input frames, we must generate several MHIs of various δs. Let the behavior database consists of a delta set $\Delta = \{\delta_1, \delta_2, \delta_3, \ldots, \delta_L\}$. To recognize whether the monitored screen contains a predefined behavior or not, we need to generate L MHIs using different δs. That is, for every input frame, we have to execute the Object Extraction and History Matrix Updating processes once and the MHI generation and Features Extraction processes L times. To reduce the computational complexity, two techniques are proposed and described in the following subsections.

3.1. Storing multiple sets of features for a predefined behavior

To decrease the execution time of the MHI generation and Features Extraction processes, we choose to store multiple sets of features for a predefined behavior. For a predefined behavior with the smallest delta, say δ_1, only one set of features is stored and for a behavior with larger delta, say δ_i, $2 \le i \le L$, i sets of features must be stored in the behavior database. To meet this requirement, the design of the behavior database is given in the following table.

Table I: The design of behavior database

Delta / Behavior	δ_1		δ_2		…	δ_L	
	Features	LF	Features	LF		Features	LF
B_1	$F_{\sigma_1}^{B_1}$	T					
B_2	$F_{\sigma_1}^{B_2}$	F	$F_{\sigma_2}^{B_2}$	T			
⋮							
B_M	$F_{\sigma_1}^{B_M}$	F	$F_{\sigma_2}^{B_M}$	F	…	$F_{\sigma_L}^{B_M}$	T

From table I, we can see that there are multiple behaviors defined in the behavior database and all behaviors are sorted according to their δs. For a behavior with smaller δ, fewer sets of features are stored. Otherwise, more sets of features must be recorded. Where LF means the last flag and is used to recognize if this is the original δ of a behavior. In case of a δ is not the original δ of a behavior, the LF for the δ is set as 'F'. Otherwise, it is set as 'T'. Here, $F_{\sigma_i}^{B_j}$ for $1 \le i \le L$ and $1 \le j \le M$ is the feature set for behavior B_j and $\delta = \delta_i$. In our approach, only the local information of MHI is used. That is, we use 9 block orientations O_n, $1 \le n \le 9$ for an MHI as features.

Let $F_{\sigma_i}^{\tau}$ be the feature set extracted from the input frames at time-point τ with $\delta = \delta_i$. The procedure of behavior recognition using multiple sets of features is described in figure 6. Where $D(F_{\sigma_i}^{\tau}, F_{\sigma_i}^{B_j})$ is the squared Euclidean distance function and *THR* is a threshold value which should be determined experimentally.

```
Set dist[j] = 0, for 1 ≤ j ≤ M
Set done[j] = false, for 1 ≤ j ≤ M
For i = 1 to L {
    Generate MHI^τ_δi and F^τ_δi
    For j = 1 to M {
        If ( done[j] = false ) {
            dist[j] = D( F^τ_δi , F^Bj_δi )
            If ( (dist[j] > THR) or ( LF^Bj_δi = true) )
                done[j] = true
        }
    }
}
Set id = 1
For i = 2 to M
    If ( dist[i] < dist[id] ) id = i
If ( dist[id] > THR ) id = 0
Return id
```

Figure 6: Behavior recognition algorithm using multiple sets of features.

As shown in figure 6, the procedure will find the *id* of behavior which has the less distance to features extracted from input frames. If no behavior is recognized, the value of *id* will be 0.

3.2 Partial distance calculation

For two sets of features F^{B_1} and F^{B_2}, the definition of distance $D(F^{B_1}, F^{B_2})$ is given below.

$$D(F^{B_1}, F^{B_2}) = \sum_{i=1}^{9} (O_i^{B_1} - O_i^{B_2})^2 \qquad (7)$$

Before using the above distance equation, all features of the input MHI must be determined first. In many cases, we don't have to fully compute the distance to know if a predefined behavior is not the behavior of the input frames. According to this observation, a partial distance calculation method is proposed. The partial distance calculation method is to divide distance calculation process into 9 steps. Let $D^i(F^{B_1}, F^{B_2})$ be the *i*th partial distance for feature sets F^{B_1} and F^{B_2}. The definition of $D^i(F^{B_1}, F^{B_2})$ is given below.

$$D^i(F^{B_1}, F^{B_2}) = (O_i^{B_1} - O_i^{B_2})^2 \qquad (8)$$

From equation (8), we can see that the $D(F^{B_1}, F^{B_2})$ can be computed using the following equation.

$$D(F^{B_1}, F^{B_2}) = \sum_{i=1}^{9} D^i(F^{B_1}, F^{B_2}) \qquad (9)$$

By dividing the distance computation into 9 steps, we can check the accumulated distance after each partial distance is computed to see whether current accumulated distance is already excess *THR* or not. If accumulated distances are all excess *THR* for all predefined behaviors, the distance computation process can be terminated earlier. To further reduce the computational complexity, the feature set for the input frames should not be evaluated at a time. That is, a feature of the input frames is evaluated only when it is needed. In such a case, if the feature set of the input frames is quite different from those stored in the behavior database, a lot of computations can be avoided. Figure 7 gives the procedure of using the partial distance calculation method. Where the *order*[] is an array to record the computation order for each feature and is defined as {1,2,3,4,6,7,8,9,5}. It is noted that the fifth block must be compared in the last, since the fifth block covers the whole range of the MHI of the input frames.

```
Set dist[j] = 0, for 1 ≤ j ≤ M
Set done[j] = false, for 1 ≤ j ≤ M
For i = 1 to L{
    Generate MHI^τ_δi
    For block = 1 to 9 {
        Extract the O^τ_blk from MHI^τ_δi
        Set terminate=true
        For j = 1 to M {
            If (done[j] = false) {
                dist[j] += D^block(F^τ_δi , F^Bj_δi )
                If (dist[j] > THR) or ( LF^Bj_δi = true) {
                    done[j] = true
                } else terminate=false
            }
        }
        If (terminate=true) {
            id=0
            Return id
        }
    }
}
Set id = 1
For i = 2 to M
    If ( dist[i] < dist[id] ) id = i
If ( dist[id] > THR ) id = 0
Return id
```

Figure 7: Behavior recognition algorithm using partial distance calculation and multiple sets of features.

4. Experimental Results

To evaluate the performance of the proposed fast MHI method, in the training phase, four behaviors (sit, stand, fall, and hunker) were acted by two persons and captured by a camera from four directions (front, back, left, and right). That is, eight video clips were captured for each behavior. The size of captured frames is 704x480 pixels. In this experiment, there are two different δs are used. The δs assigned to sit, stand, fall, and hunker behaviors are 12, 16, 12, and 12, respectively. That is, there are 40 sets of features are stored in the behavior database. For each of sit, fall, and hunker behaviors, only one set of features is stored, while for a stand behavior, two sets of features (for $\delta = 12$ and 16) must be recorded in the behavior database.

In the testing phase, 146 consecutive frames contain four predefined behaviors and some undefined behaviors with the size of 704x480 pixels are tested under three conditions. The first condition (referred to as Case 1) is performed without using the proposed improving techniques. The second condition (referred to as Case 2) is performed with using the algorithm as listed in figure 6. The final condition (referred to as Case 3) uses all methods presented in section 3. In all conditions, the threshold *THR* is set as 49 to achieve better recognition result. All programs were implemented using Microsoft Visual C++ 2008 Express and executed under a PC with CPU of AMD Phenom 9550 Quad-Core 2.20 GHz and memory of 2 GB.

In the recognition process, we define that a behavior is recognized only if the behavior is detected for three continuous times. To reduce more computation time, the recognition process will be paused for a period of $\delta_1/2$ frames, where the δ_1 is the smallest δ in the behavior database. Table II lists the behavior recognition results under three cases. From table II, we can find that all methods generate the same recognition results.

Table II: Behavior recognition results under three cases.

Behavior	Occurence times	Times for behaviors are recognized		
		Case 1	Case 2	Case 3
Sit	1	1	1	1
Stand	4	3	3	3
Hunker	1	0	0	0
Fall	2	1	1	1
Others	4	0	0	0

Table III gives the computation time of behavior recognition under three conditions.

Table III: Execution time (in milliseconds) for Cheng's method and our proposed method.

	Average computation time per frame
Case 1	64 ms
Case 2	42 ms
Case 3	28 ms

From table III, it is obviously to see that both techniques of storing multiple sets of features for a predefined behavior and the partial distance calculation can effectively reduce the computation time of behavior recognition. Comparing to Case 1, which uses no improving method, the proposed method can reduce about 56% of computation time.

5. Conclusions

In this paper, a new fast MHI approach is proposed to reduce the time complexity of MHI method by storing multiple sets of features for a predefined behavior to decrease the MHI generation time and using the partial distance calculation technique to reduce the distance calculation time. Experimental result show that the proposed method can effectively improve the computation time of the MHI method. However, this paper shows only a preliminary result for the proposed method. In the future, more experiments should be done to show how the proposed method will be influenced by the number of δs and predefined behaviors.

Acknowledgements

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國科會補助計畫衍生研發成果推廣資料表

日期:2010/12/20

國科會補助計畫	計畫名稱：可調適性之快速PNN分群方法開發		
	計畫主持人：廖怡欽		
	計畫編號：98-2221-E-343-008- 學門領域：影像處理		
研發成果名稱	(中文) 可調適性之快速PNN分群方法		
	(英文) Adaptive fast exact PNN method		
成果歸屬機構	南華大學	發明人 (創作人)	廖怡欽
技術說明	(中文) PNN(Pairwise-nearest-neighbor)是一種相當有效的資料分群方法，通常可以產生良好的分群結果，但由於計算複雜度高，實用性不高。爲了改善這個問題，有許多快速PNN方法被開發出來，但大部份快速PNN方法易受資料集群組分離度影響，以致執行效率不穩定。爲此，本計劃提出一個可調適性快速PNN方法，所提方法首先使用其它快速分群方法將資料集分成數個群組，然後記錄群組與群組間以及資料與群組間的距離資訊，最後再利用這些資訊在最近鄰居搜尋過程中過濾不可能的群組與資料，加快程式的執行效率。實驗結果顯示，與現有的快速PNN方法相比，所提方法在不同的群組分離度下均可得到穩定的加速效果。		
	(英文) Pairwise-nearest-neighbor (PNN) is an effective clustering method, which can always generate good clustering results than others. Since the computational complexity of the PNN method is high, it is seldom applied to solve clustering problems. To improve this problem, many fast exact PNN methods were proposed. The performance of most existing fast PNN methods are unstable and highly influenced by the cluster separation degree of a data set. To solve this problem, this project proposed an adaptive fast PNN method. Experimental result shows that our proposed method can have better performance than existing method under different cluster separation degrees.		
產業別	顧問服務業；其他專業、科學及技術服務業		
技術/產品應用範圍	提供相關函式庫或提供技術指導		
技術移轉可行性及預期效益	可技術移轉給相關軟體開發商		

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

98 年度專題研究計畫研究成果彙整表

計畫主持人：廖怡欽	計畫編號：98-2221-E-343-008-
計畫名稱：可調適性之快速 PNN 分群方法開發	

<table>
<tr><th colspan="3" rowspan="2">成果項目</th><th colspan="3">量化</th><th rowspan="2">單位</th><th rowspan="2">備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）</th></tr>
<tr><th>實際已達成數（被接受或已發表）</th><th>預期總達成數(含實際已達成數)</th><th>本計畫實際貢獻百分比</th></tr>
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<tr><td>研究報告/技術報告</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>研討會論文</td><td>1</td><td>1</td><td>100%</td><td>林子翔、陳韋臣、廖怡欽,’’分群式快速音樂檢索方法’’, WOCMAT 2009, Oct. 2009.</td></tr>
<tr><td>專書</td><td>0</td><td>0</td><td>100%</td><td></td><td></td></tr>
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國外	論文著作	期刊論文	2	2	50%	篇	1.Yi-Ching Liaw*, Chien-Min Wu, and Maw-Lin Leou, ’’Fast K-Nearest Neighbors Search Using Modified Principal Axis Search Tree,’’ Digital Signal Processing, Vol. 20, Issue 5, pp. 1494-1501, September 2010. (SCI) 2.Yi-Ching Liaw*, Maw-Lin Leou, and Chien-Min Wu, ’’Fast exact k nearest neighbors search using an orthogonal search tree,’’ Pattern Recognition, Vol. 43, No. 6, June 2010, pp.2351-2358. (SCI；EI)
		研究報告/技術報告	0	0	100%		
		研討會論文	2	2	50%		1.Yi-Ching Liaw, Jun-Feng Lin, Shen-Chuan Ta, and Jim Z. C. Lai, ’’Fast exact pairwise-nearest-neighbor algorithm using groups and clusters rejection criteria,’’ The Eleventh IASTED International Conference on Signal and Image Processing, Honolulu, USA, August 2009. 2.Yi-Ching Liaw, Wei-Chih Chen, and Tsung-Jen Huang, ’’Video Objects Behavior Recognition using Fast MHI Approach,’’ CGIV2010, Sydney, Australia, Aug. 2010.
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
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	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
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	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

初步結果已在 SIP2009 發表,最後結果整理後,將投稿到相關 SCI 期刊(例如:PR, PRL, DSP).

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

PNN(Pairwise-nearest-neighbor)是一種相當有效的資料分群方法，通常可以產生良好的分群結果，但由於計算複雜度高，實用性不高。為了改善這個問題，有許多快速 PNN 方法被開發出來，但大部份快速 PNN 方法易受資料集群組分離度影響，以致執行效率不穩定。為此，本計劃提出一個可調適性快速 PNN 方法，與現有的快速 PNN 方法相比，所提方法在不同的群組分離度下均可得到穩定的加速效果。研究成果可應用到資料探勘與知識挖掘領域，提昇分群效果。