行政院國家科學委員會專題研究計畫 成果報告

自動產生 3D 多人虛擬環境中擬真之虛擬角色行為(II)
研究成果報告(精簡版)

計 畫 類 別 ： 個別型
計 畫 編 號 ： NSC 98-2221-E-004-008-
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計 畫 主 持 人 ： 李蔡彥
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報 告 附 件 ： 國際合作計畫研究心得報告

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中 華 民 國 100 年 03 月 01 日

行政院國家科學委員會補助專題研究計畫成果報告

自動產生 3D 多人虛擬環境中擬真之虛擬角色行為(II)

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計畫主持人：李蔡彥
計畫參與人員：
碩士班兼任助理：趙偉銘、梁長宏、陳印似、陳嘉豪、林志忠、劉治宏
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成果報告類型：精簡報告

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執行單位：國立政治大學資訊科學系

中　華　民　國　99　年　1　月　31　日

行政院國家科學委員會
專題研究計畫成果報告

自動產生3D多人虛擬環境中擬真之虛擬角色行為(II)
Automatic Generation of Realistic Behaviors for Virtual Characters in 3D Multi-user Virtual Environments(II)

計畫編號：98-2221-E-004-008
報告期限：98年8月1日至99年10月31日
主持人：李蔡彥　　Email: li@nccu.edu.tw
執行機構及單位名稱：國立政治大學資訊科學系

中英文摘要

（一）、中文摘要

目前3D虛擬環境中虛擬替身(Avatar)的行為，多由真實使用者根據系統所提供的有限功能進行控制。如能由電腦自動控制虛擬角色，不但可增加環境的豐富性，更可做為虛擬社會中社會現象模擬的實驗平台。在本計畫97年度的研究裡，我們以提高個別虛擬角色之動畫的真實性為目標，利用運動捕捉資料改進程序式動畫的擬真性，並以程序式動畫的方式建立人體動畫的情緒風格模型。在第二年(98)的計畫裡，我們除了改進前一年的結果外，主要研究重點放在根據社會心理學的理論基礎，建立個體的認知模型及情緒傳播模型，以進行人群集體行為的模擬實驗。這個研究結果除了可以做為電腦動畫中人群行為自動產生的機制，更可做為社會科學家對人群集體社會行為研究的工具。整體而言，本年度的研究成果已達到階段性目標，而這些成果也已於多個國際研討會中發表，並獲得兩個優良碩士論文獎的肯定。

（二）、英文摘要

In the current 3D virtual environments, the behaviors of an avatar usually are controlled by a real user according to a limited set of functions provided by the system. It is highly desirable for the behaviors to be created and controlled by the computer because we can not only enhance the content richness of the environment with ease but also enable interesting social experiments in virtual environments. In the project of previous year (2008), we aimed at enhancing the realism of the motion of animated characters in virtual environments and using procedural animation to bridge the models of motion and emotion. In the project of this year (2009), in addition to improving the result from the last year, we focused on designing an cognitive and communication model for avatars according to the theoretical foundation of social psychology in order to conduct experiments on collective social behaviors. The experimental results of the implemented system showed that such a system can not only be used to create realistic crowd animation but also used as a tool for conducting simulation experiments for studies in social science. In sum, the results we obtained in the project have reached the goal proposed in the project proposal. These results are being published in international conferences and awarded excellent thesis by several academic association.

一、 緣由與目的

3D電腦動畫是我國極力發展的數位內容產業項目之一。相關軟硬體技術的發展，近年來可謂突飛猛進。3D連線遊戲的多人虛擬環境平台（Multi-user Virtual Environment, MUVE），也是極具市場性及挑戰性的應用。一般用途的3D虛擬環境系統（例如近年來相當受歡迎的Second Life虛擬環境）有別於線上連線遊戲，其系統設計的邏輯並非固定在某一特定的應用情境上，而是取決於該環境設計者的設計目標，因此這類系統所提供的設計彈性及動畫表達的真實性便十分重要。

虛擬動畫角色的真實性來自於兩個層面。第一個層面在於動畫本身的真實性，包含動畫本身

的真實性與一般人的經驗是否一致，及動畫與環境之間的關係是否合理。第二個層面則是動作表現方式的選擇及表現動畫的時機是否與當時的情境內容（Context）是否吻合。本計畫在第一年的研究裡，將重點放在如何有系統的產生擬真且具情緒表達力的虛擬角色動畫。更具體而言，我們提議以運動捕捉資料改進程序式動畫的擬真性，並以程序式動畫的方式建立情緒風格模型，自動產生符合環境限制的動畫。在第二年（今年）的研究裡，我們嘗試以社會心理學的理論，建立虛擬環境中代理人角色的內心認知狀態與人際間的傳播模型，透過電腦模擬的方式，產生即興的人群集體行為。

以下謹就這個主題，說明我們的問題定義及目前的研究成果。

二、 問題描述與相關文獻探討

人群模擬的研究在電影、動畫、電玩、都市規劃、建築設計及社會學研究等領域已有許多應用。然而過去的研究大部分著重於代理人視覺上的運動行為表現，較少考量或過於簡化虛擬代理人的情緒狀態，以及彼此之間的溝通行為與從眾壓力。所以在過去的模擬中往往不能模擬複雜的群體動態。在[4]中，我們根據已知的社會心理學文獻，建立合理適當的傳播模型，並結合Reynolds的轉向力模型(Steering behavior model)[17]與鳥群模型(Flocking model)[16]以及行人避碰演算法[18]等，已創建一具有溝通能力的人群模擬系統 – IMCrowd。

社會學家及心理學家對於人類的群體行為已有多年的研究。他們特別對於哪些不預期、非計劃性且突然浮現的群體行為特別感興趣，尤其那些共同參與此群體行為的個體，往往與其在獨處時有極大的差異。群眾心理學之父Le Bon Gustave認為這樣的群體行為往往最初是透過某種訊息的暗示，然後經由情緒傳染的過程，使群體中的個體逐漸喪失獨特的人格意識，並受一種暫時形成的集體心理所支配[11]。雖然Le Bon的假說基礎來自觀察當時的社會動態，但當代心理學家與腦神經科學家已發現人類腦中某些部分，如：杏仁核及鏡像神經元，確實會接收環境中的情緒信號[1][7]。從功能面來看，情緒傳染的機制是一種幫助人類像其它群居動物一般，能夠快速傳遞利益或危險訊息以助人類迅速掌握當前情況。Blumer亦提出情緒傳染往往又是以「循環反應」的形式，使得個體被傳染後，亦開始加入傳染其它個體的行列，這種正向回饋的行為，會助長群體情緒擴張的速度，及延長群眾待在情境的時間[2]。

Mark Granovetter 於1978 年提出群體行為的門檻模型，以解釋為何在同樣的情境下，群體的表現可能矛盾不一[9]。Granovetter 認為面對任何特定的情況，每個人心中都會有某個門檻值(threshold)，只是這個門檻值很難實際量化。門檻值是指須有多少數量或比例的人先參與此行動，個體才會決定行動。Granovetter 以暴動為例，在任何一群人中，都有一些人永遠不會騷動，有一些人則是幾乎隨時都準備要騷動，但是大部分的人都介於兩者之間。他們願不願意騷動，要看群眾中其他人的行為而定。當群眾中有愈多人參與騷動，或騷動的程度愈是強烈，便會造成愈大的從眾壓力，吸引愈多人加入群體騷動。

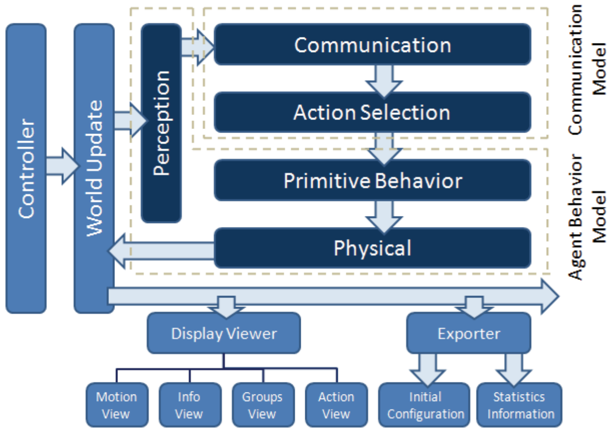
Randall Collins採用微觀社會學理論的方式觀察暴力行為，認為暴力是否會發生，主要決定於當時的情境，而且總是可以在暴動情境下觀察到下面這些有趣的特徵[5]：(1)在暴動中，真正行使暴力的人往往只佔少數比例，絕大多數的觀眾僅是表面行動或情緒上的參與(如:圍觀注視、叫罵、破壞東西)。(2)這些圍觀的觀眾，又稱為情緒支持者，他們的行為會提供情緒能量(Emotion Energy)，使真正會行使暴力的那小群人採取行動對抗敵人。(3)叫罵總是戰鬥之前的第一步。當對峙產生時，往往僅有叫罵和手勢上的比劃，故通常只會有小的傷害發生。(4)戰鬥總是以多攻擊少的形式發生。(5)暴力是否會發生，常常起因於情境中的偶然因素，造成少數人從原本聚集的一方分離出來，使他們被孤立並且遭對方群體圍攻。

Jager等人[10]曾利用細胞自動機模擬兩群體的聚集與暴動過程，其中主要使用了三種簡單的規則：有限視野法則(restricted view rule)、趨進回避法則(approach-avoidance rule)、氛圍法則(mood rule)。有限視野法則是指每個代理人只能觀察到鄰近的其它代理人。趨進或回避法則用來控制一個代理人是否趨近敵對團體或我方團體。氛圍法則使每個agent能夠判定周遭的氛圍，計算侵犯動機，以決定該採取趨進或回避行為。雙方群體各由三種角色的代理人所組成：頑固分子 (hardcore), 逢迎者 (hanger-on), 旁觀者 (bystander)。這三種代理人的差異僅在於他們掃描鄰近環境的頻率，而這將影響他們累積侵犯動機的速度。模擬實驗結果顯示，當雙方群體總數愈大、雙方人數愈不對稱、頑固分子愈多都會造

成較嚴重的暴動結果。

三、 系統設計簡介

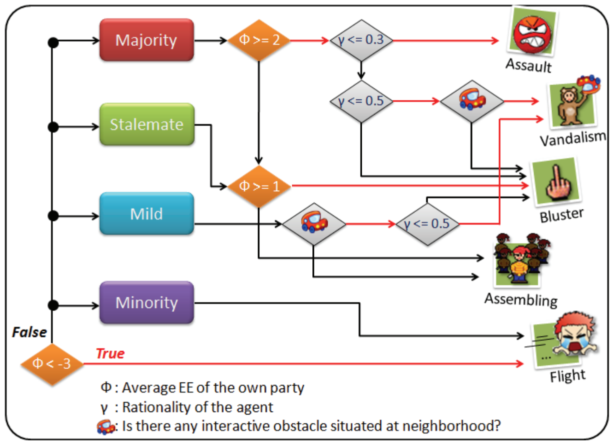
本研究所設計的模擬系統（IMCrowd）是一多代理人的模擬系統，如圖一所示，主要由**代理人行為模組與代理人傳播模組**所組成。前者主要參考了Reynolds的轉向力模型(steering force model)與鳥群模型(flocking model)，賦與代理人在連續空間的運動能力，感知週遭環境的能力，及多種基礎行為能力，如：趨進、追趕、逃離、閒逛、群體移動、閃避靜態障礙物、避免與其它代理人碰撞。後者則參考了Quorum Sensing的機制[15]，賦與代理人傳染情緒、反應從眾壓力，以及根據情境採取適當行動的能力。



圖一、IMCrowd 系統架構

在IMCrowd中，有兩種代理人：**普通代理人和特別代理人**。普通代理人都有自己歸屬的小團體，而模擬的群眾便是由這些小團體所組成。每個小團體中，都有一個領導者，其它則是跟隨者。普通代理人有兩種心智：**個體心智和群體心智**。當普通代理人在個體心智時，其行為是目標導向的及自我決定的，並且會與自己的小團體一同前往在環境初始化時便設置好的多處目標據點。當普通代理人進入群體心智時，它便失去了個體性，不再前往原先的目標，反而是根據週遭人的行為採取相對應的行動。IMCrowd目前可以產生三種群體心智：圍觀、逃難及暴動，並分別由舞群、怪獸、挑撥者三種特別代理人所觸發。這三種特別代理人皆扮演帶原者的角色，身上都擁有獨特的感染源，而這些感染源一有機會便會複製自己到鄰近的其它普通代理人身上，進而促使普通代理人們產生群體行為。

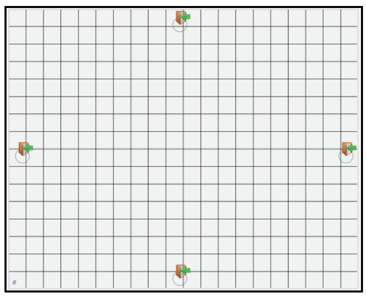
暴動的動態過程非常複雜，每個參與者的行為並非單一且連續，反而像是萬花筒一般，由多種不斷變化的行為所拼湊而成。IMCrowd根據[5][12]等文獻，設定了五種普通代理人在暴動群體心智下可能會採取的行動：聚集(assembling)、叫囂(bluster)、破壞 (vandalism)、攻擊(assault)及 逃跑(flight)。並依據前述Randall Collins[5]的觀察，設計一決策樹以供普通代理人在暴動群體心智下，採取當時情境中最適合的行動，如圖二所示。因此，IMCrowd可以產生非常複雜且豐富的暴動場景，且往往可以觀察到有趣的突現行為，如：對峙、包圍、群體追逐以及群體竄逃等。



圖二、普通代理人在暴動情境下採取行動的決策樹

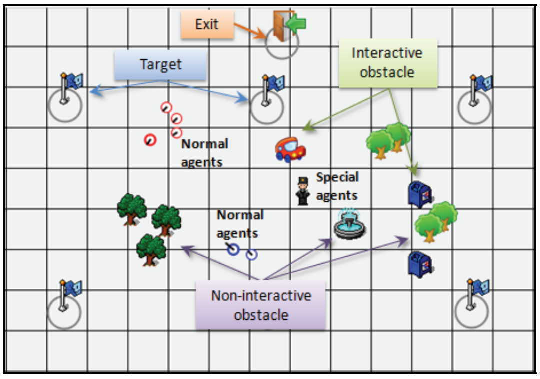
四、 實驗環境

模擬實驗的機器為中央處理器：Intel Core2 Duo T7500 2.20GHz， 主記憶體： 2GB，圖形顯示卡：ATI Mobility Radeon HD 2400。實驗環境是640*800像素的環形連續空間，並且可切割成320個 40*40像素大小的格子，如圖三所示。由於是環狀連續空間，當代理人完全移動出邊界後，便會從反向邊界出現，如從下方移動出邊界，便會從上方出現。每個格子會記錄其所包含的代理人資訊，如密度、熵(entropy)、及優勢度。此外，有四個出口分別位於環境的邊界上，當代理人決定離開環境時，它會選擇最近的出口離開。



圖三、實驗環境是 40*800 像素的環形連續空間

利用IMCrowd提供的互動式介面，我們可以任意設置目標據點(target)，障礙物及代理人，以設計各種實驗需要的初始場景，如圖四所示。初始場景中的目標據點會被普通代理人隨機選定為個體心智下的移動目標。一旦代理人移動到即定的目標據點，便會隨機再挑選另一個目標據點做為新的移動目標。當普通代理人完成了五個目標據點後，便會從最近的出口離開環境。IMCrowd中的障礙物分成可互動的及不可互動兩種，前者包含汽車及垃圾筒等在暴動情境中可能被代理人破壞的環境物件，後者則像是樹、噴水池等不會被代理人視為破壞目標的環境物件。由於IMCrowd的實作中亦有考量破窗效應[8]，一旦環境中的物件被破壞，其週圍的領域將會藉由暫時降低代理人的理性值，可能造成更嚴重的暴動結果。



圖四、場景編輯示意圖

五、 暴動模擬

我們利用IMCrowd設計多組兩群體(藍色方與綠色方)暴動模擬實驗，以觀察並比較下列三個因子：群體大小、雙方群體大小的對稱性、群體初始位置分佈等，對暴動模擬結果的影響。每個因子我們分別賦與兩種可能的值。群體大小可分為數量100個普通代理人與200個普通代理人。雙方群體大小的對稱性可分為對稱(1:1)與非等稱(3:1)。雙方群體初始位置的空間分布則可分為均勻混合或事先結群兩種。藉由兩兩交叉組合，一共便有八組實驗案例，如表一所示。每組實驗案例，我們皆為其設計十個場景，並且執行25,000個幀(frame)，其中群體大小為100的模擬約耗時二到三分鐘，而群體大小為200的模擬約耗時五到六分鐘。最後，每個實驗案例各自跑完十個場景模擬後，我們便可以計算該案例的受害者平均數與標準差，實驗結果如表二所示。

表一、八種實驗設計

Position Distribution \ Crowd Size	100		200	
	Symmetrical (50 v.s. 50)	Asymmetrical (75 v.s. 25)	Symmetrical (100 v.s. 100)	Asymmetrical (150 v.s. 50)
Well-Mixed	A	C	E	G
Clustering	B	D	F	H

表二、八種案例的模擬結果

Victim \ Case	A	B	C	D	E	F	G	H
Mean	11.5	11.8	7.8	8.6	55.9	57.2	21.0	25.1
S.D.	3.4	2.7	2.7	2.9	12.9	9.8	4.8	5.8

（一） 群體大小

首先我們將表二的實驗結果轉換編排成表三，以方便比較群體大小為100與200的差異。從表三可以很明顯的觀察到在其它初始條件相同下，群體大小為200的實驗案例，其平均受害者都明顯大於與群體大小為100的實驗案例，即在IMCrowd中群體大小與暴動結果的嚴重性是正相關的。這是因為在固定大小的環境中，群體大小愈大即群體密度愈高，使得情緒傳染與從眾壓力的效果發揮的愈大也愈快，造成敵對雙方有較多的機會產生衝突；而雙方接觸互動的機會愈頻繁，亦使得他們滯留在情境中的時間較長，因此受害者必然較多。

表三、群體大小為 100 與 200 的比較

		The Size of Crowd	
		100	200
Symmetrical	Well-Mixed	A 11.5	E 55.9
	Clustering	B 11.8	F 57.2
Asymmetrical	Well-Mixed	C 7.8	G 21.0
	Clustering	D 8.6	H 25.1

（二） 雙方群體大小的對稱性

為了方便比較雙方群體大小的對稱性，我們亦將表二轉換編排成表四以方便比較。從表四可以觀察到，當雙方群體大小是對稱時，其平均受害者較高。從模擬過程的觀察中，我們發現當雙方群體大小為對稱時，雙方都擁有許多機會能輪番取得區域的優勢，因此雙方對抗的情況在模擬的過程中常常出現。反觀在雙方群體大小為非對稱的實驗案例中，弱勢方總是儘可能避免與強勢方發生衝突，並較早離開環境，因此無論在雙方的對抗次數與對抗時間，都遠遠不如雙方群體大小為對稱的實驗案例。這說明了為何在IMCrowd中，雙方群體大小為對稱時的平均受害者人數會

明顯大於雙方群體大小為非對稱的案例。然而這樣的模擬結果與Jager等人[10]的模擬結果正好是相反的。這是因為在Jager的模擬環境中，弱勢方的代理人不具智能躲避強勢敵人，而且最終亦無機會離開環境。使得弱勢方的代理人僅能被動地被強勢方持續攻擊，因此產生了大量的受害者。反之在IMCrowd中，由於前述的決策樹(參圖二)已經將情緒能量(E.E.)與相對情勢納入設計考量，代理人不僅會在自己處於劣勢時逃跑，其逃跑行為甚至會造成週圍的同夥一起竄逃。因此當雙方群體大小不對稱時，IMCrowd所產生的受害者遠小於Jager的模擬結果。

表四、雙方群體大小為對稱與非對稱的比較

		Relative Size of Two Parties			
		Symmetrical		Asymmetrical	
100 Agents	Well-Mixed	A	11.5	C	7.8
	Clustering	B	11.8	D	8.6
200 Agents	Well-Mixed	E	55.9	G	21.0
	Clustering	F	57.2	H	25.1

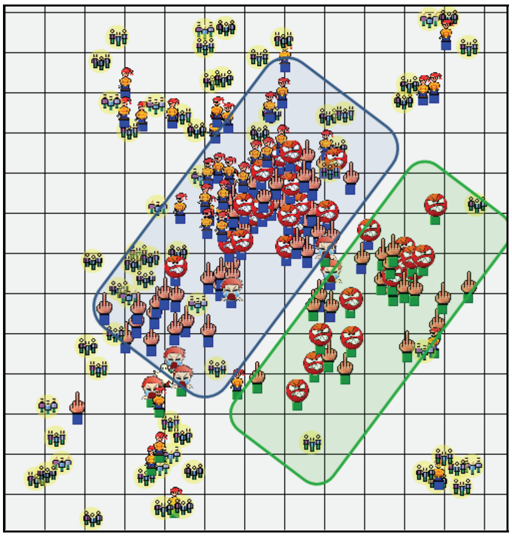
（三） 群體初始位置分佈

同樣地，為了方便比較群體初始位置分佈，我們亦將表二轉換編排成表五以方便比較。從表五中可以觀察到，除了案例G與案例H之外，群體初始位置的空間分佈是均勻混合或事先分群，對於最後的傷亡數僅有些微差異。透過模擬過程的觀察，我們發現當群體大小為100時，群體初始位置的空間分佈與之後雙方展開對抗的空間分佈相差甚多，因此無論群體初始位置分佈為何，並不直接影響之後的群眾動態。這是因為在IMCrowd中，群眾必須透過情緒傳染與從眾壓力的過程，才會逐漸從個體心智轉變至群體心智。如前所述，在個體心智的代理人會在環境中自由的移動，而在群體大小為100的案例中，代理人有充分的移動空間，因此在代理人尚未轉變至群體心智前，有足夠的時間得以造成雙方正式展開對抗時的位置分佈，與初始位置分佈截然不同。因此，當群體大小為100時，群體初始位置分佈對於暴動最後的結果並無直接的關係。

表五、群體初始位置分佈為均勻混合或事先分群的比較

		Position Distribution			
		Well-Mixed		Clustering	
100 Agents	Symmetry	A	11.5	B	11.8
	Asymmetry	C	7.8	D	8.6
200 Agents	Symmetry	E	55.9	F	57.2
	Asymmetry	G	21	H	25.1

然而在群體大小為200的情況下，群眾密度變為兩倍，不但傳播的過程變快，同時也使得代理人降低在環境中自由移動的速度，於是群體初始位置分佈便極可能是雙方最初發生對抗的位置分佈。不過在案例E與F中，由於雙方群體大小是勢均力敵的，無論群體初始位置分佈為何，模擬過程中雙方的對抗發生的相當頻繁，故即使首次雙方對抗時的位置分佈與初始分佈相似，對模擬結果最後所造成的受害者數量並不具關鍵的影響力。反之，在雙方群體大小不對稱的案例中(G與H)，弱勢方極少有機會能集結與強勢方相抗衡，大部分都在竄逃的的狀態，並且較快離開情境，因此首次雙方展開對抗時所造成的傷亡數，便可能是模擬結果傷亡數的主要來源。然而在案例G中，因為群體初始位置分佈是均勻混合的，弱勢方如前所述很難集結，幾乎沒有機會與強勢方對抗；在案例H中，群體初始位置分佈是事先結群的，弱勢方有機會因為區域資訊不足而誤判局勢，與強勢方展開一次對抗，因此會造成比案例G較多的傷亡，如圖五所示。



圖五、在案例 H 中，弱勢方(綠方)可能因為誤判局勢，而展開與強勢方的第一次對抗。

六、 成果自評：

本研究計畫已按預定的研究方向，完成了以下工作：

1. 我們設計了一個以社會心理學及電腦動畫為基礎的模擬系統，嘗試為虛擬人群間的溝通傳播機制，建立一個適當的計算模型，以自動模擬產生擬真之社會集體行為。
2. 我們提出了一個階層式的代理人模擬模型，並以實驗的方式驗證此模型的有效性。
3. 我們進行了一連串的模擬實驗，說明這類工具如何用來產生人群動畫及進行社會學集體行為的實驗。

本計畫所獲致的成果，已整理發表於知名學術研討會中[3][4][5][12][13]，並陸續投稿於國際知名期刊中；另外，計有兩位同學根據本研究的成果，完成碩士論文[20][21]，並已順利畢業投入職場。其中一篇論文更分別獲得中華民國人工智慧學會及中華民國計算學會兩個學會的最佳碩士論文獎。

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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）
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） 這個技術是以社會心理學及電腦模擬技術為基礎，建置一個能模擬虛擬人群中人際間情緒傳播模型的系統，用以自動產生具有集體行為的人群模擬。這個建立在電腦動畫技術的系統具有階層式的模型，是目前文獻上最先完成情緒傳播模型建立的研究。我們已完成這個模擬平台的建置工作，並以暴動模擬及其他集體行為為例說明如何利用此系統自動產生擬真的人群動畫模擬，並如何提供社會學研究者一個新的資訊工具，以創新的研究取向進行模擬實驗研究。這個研究成果以獲得兩個學會最佳論文獎的肯定，預計將成果進一步發表在國際知名期刊中。我們預期這個研究成果將提供動畫及遊戲業者一個提升相關技術水準的參考，並能為社會科學與資訊科學的跨領域研究，找出一個新的研究取向，創造獲得新研發成果的方式。

可供推廣之研發成果資料表

□ 可申請專利　■ 可技術移轉　日期：100 年 1 月 31 日

國科會補助計畫	計畫名稱：自動產生 3D 多人虛擬環境中擬真之虛擬角色行為（II） 計畫主持人：李蔡彥 計畫編號： NSC 98－2221－E－004－008－學門領域：資訊工程
技術/創作名稱	具情緒傳播模型的虛擬人群模擬技術
發明人/創作人	李蔡彥
技術說明	這個技術是以社會心理學及電腦模擬技術為基礎，建置一個能模擬虛擬人群中人際間情緒傳播模型的系統，用以自動產生具有集體行為的人群模擬。這個建立在電腦動畫技術的系統具有階層式的模型，是目前文獻上最先完成情緒傳播模型建立的研究。我們已完成這個模擬平台的建置工作，並以暴動模擬及其他集體行為為例說明如何利用此系統自動產生擬真的人群動畫模擬，並如何提供社會學研究者一個新的資訊工具，以創新的研究取向進行模擬實驗研究。
	Based on the theoretical foundation of social psychology and computer simulation techniques, we have developed a simulation system that can model the communication process of a crowd of virtual agents and generate plausible collective behaviors for virtual crowds. We believe that the hierarchical model proposed with the inter-agent emotion communication model is known to be the first one of its kind in the literature. We have used riot as an example to illustrate how the system can be used to generate realistic crowd animations and how it can be used as a new tool for social scientists to conduct simualtion experiments with a novel approach.
產業別	研究發展服務業
技術/產品應用範圍	電腦動畫；電腦遊戲；社會學研究
技術移轉可行性及預期效益	可用在電腦動畫或遊戲中提供擬真的人群模擬自動產生機制，以提高動畫產生的技術水準，並降低製作成本。

※　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。

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

報告人姓名	李蔡彥	服務機構及職稱	國立政治大學資訊科學系
會議 時間 地點	2010 年 9 月 14 日至 9 月 19 日 荷蘭阿姆斯特丹	本會核定補助文號	98-2221-E-004-008
會議名稱	(中文) 第 9 屆電智慧型虛擬代理人研討會 (英文) 9th International Conference on Intelligent Social Agent (IVA2009)		
發表論文題目	(中文) 以心理學方式驗證具情緒之動畫角色的動畫程序 (英文) Psychological Verification of Animation Procedures for Emotive Animated Characters		

一、參加會議經過

第九屆智慧型虛擬代理人國際研討會（IVA2010），今年在荷蘭的阿姆斯特丹（Amsterdam）舉行。這個研討會的特點在於聚集電腦動畫、人工智慧、及認知心理學的學者於一堂，是典型的跨領域研討會。此次的會議在阿姆斯特丹市區的博物館舉行，參與者除了可以參加學術活動外，也能就近參觀市區內的各項文化活動。此次會議的主辦單位是當地知名的 University of Twente。此次會議的大會主席是以 Zsófia Ruttkay 教授為首的三國四位學者擔任。議程主席則分多由歐洲的學者所組成。此次會議吸引了世界各地十多國的數十位學者共同參與，人數不算多，但因為只有一個場次，因此每場的參與人數及討論狀況都相當踴躍。此次會議的議程共有三天，共分為 8 個論文發表場次、三個大會演講、及一個海報展示的場次。大會的主題演講主要請到了加拿大遊戲產業專家 Casey Hudson、加拿大 Simon Fraser 大學 Steve Di Paola 教授及美國 University of California, Santa Cruz 的 Marilyn Walker 教授發表跨領域研究的專題演講。另外，反映出這個領域的主導研究團體是以美國及歐洲為主。相對而言，台灣前往的學者人數較少。

本人所發表的論文題目為「以心理學方式驗證具情緒之動畫角色的動畫程序」，是有關如何以心理學實驗的方式為基礎，模擬模虛擬人群中個體間之傳播能力對集體社會行為驗證我們以程序式動畫所設計的具情緒之動畫角色是否能反映情緒的特質。這是前一年(97 年)國科會計畫的研究成果之一。發表過程中與參加的學者有許多問答的互動，有相當不錯的收穫。目前世界上能結合心理學與資訊技術特點的研究仍是少數，也是本文可被接受為長篇論文的原因之一。

二、與會心得

智慧型虛擬代理人（IVA）研討會一直是一個相當嚴謹且行之有年的國際研討會，由於其跨電腦動畫、人工智慧、及認知科學等領域的特性，因此一直是我的實驗室進行研究時參考的重要研討會。在此次研討會中，我們可以觀察到純粹以動畫技術為主的論文數量較少，較多是強調以電腦動畫結合其他領域（如自然語言、遊戲等）的研究，而這也是近年來發展的趨勢。此次荷蘭 Twente 大學所舉辦的會議，在行政工作及接待的安排上都十分的貼心，因此結果可說是賓主盡歡。會議中也有機會透過分組討論的方式，探討未來此研討會的走向及舉辦的方式。

三、建議

人工智慧及電腦動畫的研究，過去一直都是由美國、歐洲、及日本所主導。此次研討會的參與仍反映了這個現象。可見台灣在這個領域仍有相當大的發展空間，而這也是少數尚未為中國大陸學者所佔領的領域之一。因此如何振興我國在這方面的研發能量，是相當重要的議題。如有機會，我們可以爭取這些相關的研討會在台舉辦，以提高我國在這些領域的學術地位。

四、攜回資料名稱及內容

1. Lecture Notes in Computer Science, Volume 5773, 2009, DOI: 10.1007/978-3-642-04380-2 研討會論文集

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

報告人姓名	李蔡彥	服務機構及職稱	國立政治大學資訊科學系
會議 時間 地點	2010 年 5 月 31 日至 6 月 2 日 法國聖馬羅市(St. Malo)	本會核定補助文號	98-2221-E-004-008
會議名稱	(中文) 第 23 屆電腦動畫與社會代理人研討會 (英文) 23th Annual Conference on Computer Animation and Social Agents (CASA2010)		
發表論文題目	(中文) 虛擬人群中社會行為的模擬 (英文) Simulation of Social Behaviors in Virtual Crowd		

五、參加會議經過

一年一度的電腦動畫與社會代理人國際研討會（CASA2010），今年在法國的聖馬羅市（St. Malo）舉行。這個研討會早期名為國際電腦動畫研討會，是電腦動畫領域極富盛名的研討會之一。本人從1999 年即參與此研討會，每次參加都能學習到目前電腦動畫最新的知識與發展趨勢。此次的會議在距離法國西方雷恩（Rennes）市約一個多小時車程的觀光勝地：聖馬羅市舉行，在 2003 年的時候，我也曾在此地參與過 Web3D 研討會，留下很深的印象。此次會議的主辦單位是雷恩市雷恩第一大學（Rennes 2 University）與法國 INRIA 資訊與自動化研究院中的 Bunraku 研究群，INRIA 是一個以研究為主的學術機構，但也授予學位學程，以吸引世界各地優秀的學生前往從事研究工作。此次會議的大會主席是由 Bunraku 研究群的領導教授 Stéphane Donikian 所擔任，議程委員會的主席則分由法國、中國、及瑞士的三位學者所組成。此次會議吸引了世界各地十多國的數十位學者共同參與，人數雖然不是很多，但由於研究主題有焦點，因此與會人員參與的程度不輸許多大型的研討會。此次會議的議程共有三天，共分為 14 個發表場次、兩個大會演講、及一個海報展示的場次，我獲邀擔任第一個場次的場次主持人，深感榮幸。大會的主題演講主要請到了人群模擬的始祖 Crag Reynolds 發表演講，Dr. Raynolds 早期的研究論文是人群模擬被引用最多的一位，能有機會聽其演講並與其交換在研究上的心得，實在是十分難得的一件事。另一位大會演講者是史丹福大學虛擬人互動實驗室的主持人 Jeremy Bailenson 教授講授如何在虛擬環境中模擬分析社會行為，是十分跨領域的主題。另外，大會也安排了兩個晚上的社交活動，包括一個起司與酒的歡迎晚會及一個在著名古宅內的大會晚宴，十分具有文化特色，也充分展示了主辦單位的苦心。就整個研討會參與的學者而言，或許是由於地利之便，以歐洲學術團體的代表較多，但是與往年不同的是中國學者的論文與參與人數已是會議中的多數，相對而言，台灣前往的學者人數與往年大致相當，都算是少數。

本人所發表的論文題目為「虛擬人群中社會行為的模擬」，是有關如何以社會科學為基礎，模擬模虛擬人群中個體間之傳播能力對集體社會行為的影響。發表的場次是屬於虛擬人群動畫模擬的場次。要在其他研討會中找到類似的場次並不容易，因為目前世界各地專精此主題的研究團體有限，因此能藉此機會與同好進行交流，機會誠屬難得。

六、與會心得

電腦動畫與社會代理人（CASA）研討會是一個以電腦動畫技術為主，再擴及到其他領域的跨領域研討會。其所擴及的領域從人工智慧、人機介面、社會科學、認知科學、到數位內容創意

應用等，是一個新興的圖學應用領域。在此次研討會中，我們可以觀察到純粹以動畫技術為主的論文雖仍為數不少，但也有許多論文強調電腦動畫研究的多元性，而這也是近年來發展的趨勢，值得進一步觀察。另外，近年來盛行的人群模擬與社會網絡的視覺化計算，也是此次會議中新興的熱門議題。此次在雷恩大學所舉辦的會議，在行政工作及接待的安排上，主辦單位都十分的貼心，因此結果可說是賓主盡歡。會議中也有機會透過分組討論的方式，探討未來此研討會的走向及舉辦的方式。最後的結論是將透過跨領域的宣傳，鼓勵認知科學及藝術相關學者參與，以達到此研討會跨領域研究學者對談的目的。

七、建議

電腦動畫的研究，過去一直都是美國、歐洲、及日本在主導。但從此次研討會的參與來看中國學者在此領域的崛起，已是明顯的事實。台灣則仍有相當大發展的空間。近年來中國大陸在電腦繪圖方面所網羅或培育的人才眾多，但在結合人工智慧及電腦繪圖方面的研究尚稱少數，因此如何振興我國在這方面的研發能量，將是另一個相當重要的議題。如將研究主題稍微擴大，則仍有機會爭取相關的研討會在台舉辦，以提高我國在相關領域的學術地位。因此，建議國內多鼓勵相關領域的研究群，踴躍投稿，並爭取更多相關研討會在台舉辦。

八、攜回資料名稱及內容

2. CASA2010 研討會論文集

國科會補助專題研究計畫項下國際合作研究計畫國外研究報告

日期：___年___月_
日

計畫編號	NSC98－2221－E－004－008－		
計畫名稱	自動產生3D多人虛擬環境中擬真之虛擬角色行為(II)		
出國人員 姓名	李蔡彥	服務機構 及職稱	國立政治大學資料科學系教授
合作國家	法國	合作機構	資訊與自動化研究院(INRIA)
出國時間	99年5月31日至 99年6月2日	出國地點	法國雷恩

一、 國際合作研究過程：

在本次國科會專案計畫的支柱下，本年度與法國 INRIA 雷恩 IRISA 實驗室的國際合作活動共分以下幾項活動進行：

1. 常態性的網路視訊會議：約兩週一次，研究會談對象為計畫合作伙伴(Marc Christie 及 Fabrice Lamarche 教授及其研究生)。
2. Marc Christie 及 Fabrice Lamarche 教授第一次訪台：時間為 98.10.12 至 98.10.18，兩位學者除了在政大發表公開演講外，也造訪成功大學資訊工程學系，在李同益教授的接待下發表演講。一週的行程中，我們透過現場展示，進行了深入的研究心得交換，確認我們兩方研究興趣的相似處及互補性，並訂定了未來研究題目的方向將放在智慧型角色與智慧型攝影機的規劃。
3. 計畫主持人（李蔡彥）造訪雷恩大學及 INRIA 研究院：時間為 99.5.31-99.6.2 透過參加 CASA2010 的機會，我順道造訪合作伙伴的研究機構。造訪過程中與 IRISA 實驗室的其他成員進行會談及展示，瞭解其他研究的情況及可能合作空間，確定將送一位研究生於暑假至該實驗室進行交換研究。
4. 研究生(張允泰)至雷恩 IRISA 實驗室進行短期交換研究：時間為 99.6.15-99.9.15。張允泰研究生至 IRISA，在 Marc Christie 教授的指導下進行三個月的交換研究。
5. Fabrice Lamarche 教授二度訪台：時間為 99.10.25-99.11.1，Lamarche 教授第二度專程訪台商討研究成果投稿事宜，並至東華大學資訊工程系在戴文凱教授的接待下進行訪問。
6. 法國博士生 Thomas Lopez 訪台進行短期研究：時間為 99.12.5-99.12.18，雙方研究的成果發表於在新加坡主辦的 WAFR 國際研討會上，雙方共同指導的博士生 Thomas Lopez 順道到台完進行約 10 天的訪問研究。

二、 研究成果

1. 已共同發表國際會議論文一篇：
   T. Lopez, F. Lamarche, T.-Y. Li, 2010.12, “ToD & DyP: A planning solution for efficient navigation in changing environments,” in *Proceedings of The 9th International Workshop on the Algorithmic Foundations of Robotics*, Singapore.

2. 共同提出國際期刊論文一篇（審稿中）：投稿期刊 Computer Graphics Forum.
3. 共同指導碩士論文一篇（張允泰）：預計於 100 年 6 月畢業並做後續發表
4. 提出新一年度的國科會專題計畫國際合作：已獲通過(99-100 兩年期計畫)。

三、 建議

1. 法國公開徵求計畫的時程（開始時間與計畫期程）與國科會有所差異，因此造成兩方經費運用上多所困擾，如在我們的計畫時程下，他們的計畫已經終止，下一年的計畫尚未能銜接，因此我們的拜訪能補助機票費用，但對方無法依當初規劃補助生活費等。建議能依兩方制度討論較彈性且一致的計畫執行期程。
2. 以法國為例，除了法國 CNRS 及 NSC 附屬在一般專案計畫下的國際合作項目外，國際合作的補助還有歐盟計畫的申請，但似乎可請貴會規劃擇優補助這兩類計畫中間的進一步合作研究計畫，以利兩端類型之計畫的銜接輔導。

四、其他

無

Evaluating Emotive Character Animations Created with Procedural Animation

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Abstract. How to create effective body animations for virtual agents with emotions remains the state of the art for human animators and a great challenge for computer scientists. In this paper, we propose to use a model of hierarchal parameters to represent body animations: *emotional*, *style*, *motion,* and *procedural* parameters. Based on this model, we have created motions for a virtual character with generic animation procedures and mapped these procedural parameters into style parameters as proposed in the literature. The expressiveness of the generated animations was verified through experiments in our previous work. In this paper, we further report the results of two experiments attempting to verify how the style parameters are mapped into various emotions. The results reveal that the participants can successfully distinguish emotions based on the manipulation of style parameters for neutral motions such as walking. When these style parameters were used for emotive motions, including pounding, shivering, flourishing and crestfallen, the generated animations were even more effective for intended contexts.

1 Introduction

Modeling and expressing emotions for virtual agents remains a key issue for believability because of the subtleness involved. Most previous research focused on facial expression since it was the most common way to communicate emotions. Nevertheless, body movements are also crucial for the expression of emotion especially in the virtual world where avatars are usually seen in a distance and their facial expressions become too vague to discern.

Not until recent years, the principles used in analyzing human body motions were extended to computer animations for the composition of expressive motions for virtual characters/agents [5]. Nevertheless, the expressiveness of a character animation remains a subjective matter. In recent years, some research in psychology has started to analyze the relationship between motion and emotion (e.g. [6]) but the body

Zs. Ruttkay et al. (Eds.): IVA 2009, LNAI 5773, pp. 308–315, 2009.

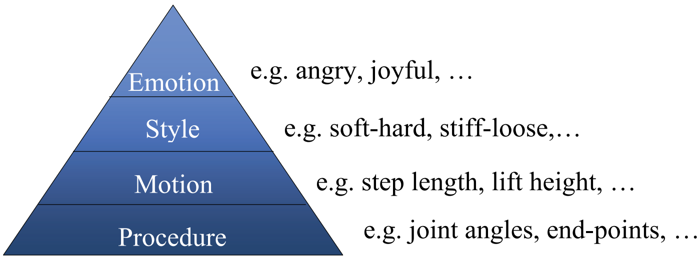

Fig. 1. Hierarchy of parameters for expressing emotive motions

motions used in these experiments were usually performed by professional actors. Therefore, it remains an open question how to generate expressive animations by the computer in a systematic manner in order to deliver emotions to the viewers.

In this work, we aim to design a systematic way to generate human body animations and study the linkage between motion and emotion. We propose to stratify the variables related to expressive motions into four layers: *emotion*, *style*, *motion*, and *procedure* layers with their own respective sets of parameters, as shown in Fig. 1. In the emotion layer, emotions can be modeled with either the basic emotions approach or the dimensional approach [4]. The style layer serves as an intermediate layer for describing the expressiveness of an animation while the parameters specific to a motion are defined in the motion layer. And in the procedure layer, generic animation procedures are used to generate parameterized motions.

In our previous work [6], we have shown that, in terms of style parameters, the expressiveness of an animation can be successfully generated through our animation procedures for walking. In this paper, we investigate how to generate emotive animations by designing appropriate animation procedures for virtual characters and verifying the effectiveness of these generated animations. We conducted two psychological experiments to study the mapping between emotion parameters and style parameters.

2 Related Work

Human body motion always contains subtle emotional ingredients. Wallbott [10] attempted to find the relationship between emotions and body motions by asking motion analyzers to code the characteristics of emotional body movements performed by professional actors. Montepare et al. [6] studied how people of various ages perceive emotions from motions differently. Camurri et al. [2] attempted to find the motion characteristics of expressing emotions in dances. The results of these studies all revealed that human body motions were indeed affected by the emotional states possessed by the human actor.

Most of the studies on the relationship between motion and emotion used professional actors to perform emotional motions for observations. However, in the modeling of virtual agents, it is required to generate these emotive motions by the computer. On the other hand, in the literature of computer animation, there has been much research on analyzing and synthesizing emotional human motions. For example,

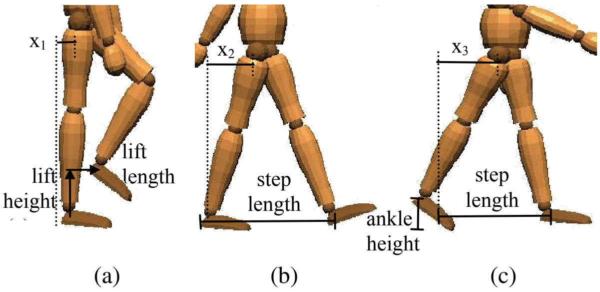

Fig. 2. Definition of the motion parameters for the walking motion

Unuma, et al. [9] used Fourier transform to analyze captured motion clips and synthesized new motions containing various styles. Pelachuad [8] based on a 6-dimesion model to modify gestures of a virtual agent and evaluated its emotional expressiveness. However, for all these approaches, the quality of the final animation relies highly on the quality of the source motions.

Another common approach to the generation of computer animation is by designing parameterized procedures. For example, Bruderlin and Calvert [1] designed a procedure embedded with empirical knowledge to generate the animation of human running. Chi et al. [3] proposed the EMOTE model that made use of the Effort and Shape concepts in Laban Motion Analysis [5] to implement emotional upper-body gestures and full-body postures.

3 Design of Animation Procedures

In this section, we will describe the generic animation procedures that we have implemented to realize parameterized motions for the lower body. We will use the walking motion as an example to illustrate the animation procedures.

The kinematics model that we have used is an LOA1 (Level of Articulation 1) model in the H-Anim standard [11]. We define each branch of the limbs as a 5-bar linkage (including the base) on a plane with four joints. We need to specify at least two constraints in order to uniquely determine this type of mechanism. One common simplification is that we usually make the toes compliant to the ground or parallel to the foot (if it is in the air). Therefore, we need to specify one more constraint to determine the final configuration. According to the type of constraints that we would like to specify in order to determine a key frame, we can classify the procedures for determining the configuration of a leg branch into four different types, each of which is used as a fundamental procedural for composition of a motion.

We use the walking motion as an example to illustrate the generation of a motion with fundamental procedures. We divide the walking motion into three phases separated by three keyframes. In the first keyframe, the two ankles are aligned; the second keyframe is defined when the front leg touches the ground; and the third keyframe is defined when the rear leg leaves the ground. Several motion parameters at various phases are defined to specify the motion, as shown in Fig. 2. These parameters include how the swinging leg is lifted at keyframe 1 (lift_length, lift_height), how two legs are separated (step_length) at keyframes 2 and 3, how the ankle of the rear leg is lifted (ankle_height) at keyframe 2, and how the sacroiliac moves over time (x_1, x_2, and x_3). These motion parameters are used to compute the parameters for the lower-level animation procedures. In addition, the interpolation of in-between frames between two keyframes is performed on the procedural parameters such as joint angles or points in the 3D space.

4 Mapping Motion Parameters into Style Parameters

We have adapted the style attributes defined in [6] as our *style* parameters which originally include *smooth-jerky*, *stiff-loose*, *slow-fast*, *soft-hard*, *expanded-contracted*, and no action-a lot. Since we use only one type of motion at a time, the last attribute (i.e. no action-a lot) is not considered. There could be many ways to map motion parameters into style parameters. Our current implementation is described as follows.

- **Jerky-Smooth:** This parameter is related to the dimension of "fluidity" in [8]. By discretizing the timing curve with different temporal resolution, we can produce different degrees of smoothness/jerkiness.
- **Stiff-Loose:** This parameter is used to specify the stiffness of a motion. We assume that cyclic motions (e.g. walking) are due to a virtual spring embedded in each joint. Therefore, the stiffness can be modeled as the stiffness constant of a spring with a force proportional to its displacement. A stiff joint tends to change acceleration more rapidly than a loose joint.
- **Slow-Fast:** This parameter bears the usual meaning of modifying the tempo or speed of a motion and is related to the dimension of "temporal extent" in [8]. The relative timing between the phases remains fixed.
- **Soft-Hard:** This parameter is related to the dimension of "power" in [8] and is defined on the amount of joint torque (and its angular acceleration) to be applied to each joint. A softer motion results from a smaller torque.
- **Expanded-Contracted:** The parameter is realized by changing the expansiveness of keyframes and is related to the dimension of "spatial extent" in [8].

In our previous work [6], we conducted an experiment to test the effectiveness of the mapping between *motion* parameters and *style* parameters. Participants compared the *target* stimulus (manipulated) with the *standard* stimulus (neutral) and rated the target according to all of the five style parameters listed above. We found that most style parameters are successful except for the soft-hard parameter. As for the ineffectiveness of the soft-hard parameter, we considered a possible explanation that while the zero-order spatial-temporal relationship (i.e. the positions of an object or its displacement) remains fixed, it is difficult to discern second-order changes (i.e. the acceleration of object motion) with human perception. Nevertheless, we have shown that most style parameters have been implemented with satisfactory results on expressiveness.

5 Mapping from Style Parameters to Emotion Parameters

As mentioned above, it is our ultimate goal to have the mapping all the way from *procedure*, *motion*, *style* to *emotion* parameters. For the last step, we need to verify

Table 1. Biserial correlations between style and emotion parameters

style / emotion	jerky-smooth	stiff-loose	slow-fast	soft-hard	expanded-contracted
Angry	-0.24	-0.19	0.27	0.17	0.77**
Fear	0.07	0.61**	-0.56**	-0.01	-0.50**
Joy	-0.11	-0.49**	0.73**	0.06	0.39*
Sadness	0.14	0.43**	-0.73**	-0.04	-0.47**

* $p < .05$，** $p < .01$

the effectiveness of these *style* parameters on expressing various kinds of *emotions*. We follow the basic emotions approach to accept primary emotional responses as *anger*, *joy*, *fear*, *sadness*, disgust and surprise [4]. But we have excluded the last two in this study because the expressions for them depend mostly on facial expressions.

In addition, we regard *walking* as an *emotionally neutral motion*. It means that walking does not relate closely to any kind of emotion.. But we do confront scenarios repeatedly that someone pounds heavily in his rage or that another one flourishes wildly when he is very happy. In other words, there are some kinds of human motions used to express certain emotions. In the present study, we regard *pounding*, *shivering*, *flourishing* and a *crestfallen* posture as *emotional motions* which always come with anger, fear, joy and sadness, respectively. We are not only interested in the expressiveness of style parameters for the emotionally neutral motion of walking but also the adding or canceling effect of these parameters for the emotional motions listed above. To achieve the goal, we designed two experiments.

5.1 Experiment 1: Emotional Expressiveness for Walking

First, we verify the emotional expressiveness of style parameters for the emotionally neutral motion of *walking*. Participants are asked to see two animation movie clips (*standard* and *target* stimuli) shown side by side. The standard stimulus is fixed on all of the five style parameters which are set to the middle range of their intensities. The target stimulus can be one of the 32 (i.e. 2^5) combinations with either high or low in intensity of the five style parameters. Participants need to compare the two stimuli and rate the target from -100 to 100 points to indicate if the virtual character is angry, fearful, joyful or sad (with the standard stimulus as the reference of 0 point).

Thirty-two participants are recruited and the whole procedure is divided into five blocks. The first one is the practice block which is followed by four formal blocks of anger, fear, joy and sadness. The sequence of formal blocks and the presentation of 32 movie clips in each block are set randomly for every participant. Ratings are recorded and then analyzed with biserial correlation.

As shown in Table 1, we have found many significant correlations between *style* parameters and *emotion* parameters. In terms of different kinds of emotions, we can see that anger correlates with only the extend of body expanding while other three basic emotions correlate to stiffness, speed and expanding significantly with different patterns. For example, when the character is fear, its body movement is stiffer, slower and more contracted. On the contrary, when the character is joyful, its movements are more relaxed (loose), faster and more expanded. However, when the character is sad, it will become stiff, contracted and even slower in motion than its fearful reaction.

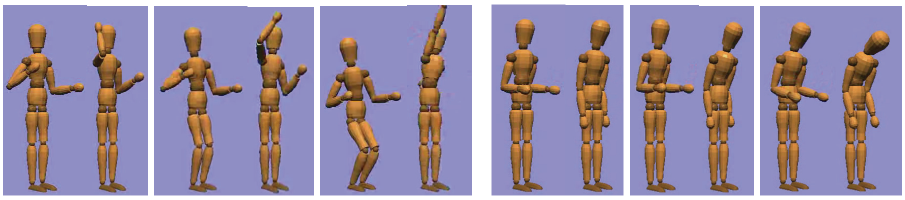

Fig. 3. Examples of emotive motions with different strengths for joy and sadness

Table 2. Ratings of emotive motions by compatibilities of style parameters

emotion strength	mean	stdev	emotion strength	Mean	stdev
angry (incompatible)	35.3	11.5	joy (incompatible)	25.7	12.1
(compatible)	78.9	10.8	(compatible)	85.4	10.4
fear (incompatible)	37.4	15.4	sadness(incompatible)	42.4	10.2
(compatible)	86.8	13.8	(compatible)	68.1	10.3

5.2 Experiment 2: Emotional Expressiveness for Other Motions

Next, we continue to evaluate the adding or canceling effects of style parameters for some emotional motions. We use *pounding* as the typical motion for anger, *shivering* for fear, *flourishing* for joy and a *crestfallen* posture for sadness (Fig. 3). In the movie clips of this experiment, the virtual character starts to talk with some one invisible for a few seconds and then ends up with a particular emotional motion. Participants have to rate the degree of the character's anger, fear, joy and sadness under the conditions of pounding, shivering, flourishing and crestfallen, respectively.

As for the manipulation of style parameters, we design two versions of animations, either *compatible* or *incompatible*, for each emotional dimension. For example, according to the results on Table 1, more expanded motion is compatible with anger while more contracted motion is incompatible with it. For the same reason, motions high in stiffness and low in speed and expanding are compatible with fear while motions with the opposite pattern of style parameters are incompatible. The same rule can be used on the condition of sadness, too. However, for the sake of joy, the motion needs to be low in stiffness and high in both speed and expanding to be compatible.

Thirty-four participants are recruited to compare the target stimulus with the 50-point standard stimulus and rate the character's emotions from 0 to 100 points. The results are summarized on Table 2. For all of the 4 emotional dimensions, compatible conditions always lead to higher ratings of target emotions. We have also verified the effects with *t*-tests between compatible/incompatible conditions and all of the tests are significant with the standard of $p<0.01$. It means that the style parameters can actually have their adding effects on emotional motions.

5.3 Discussions

Based on the results of these two experiments, we can see that three but not all of the five *style* parameters are significantly related to the *emotion* parameters with different patterns. And whether the motions are emotionally neutral or not, the style parameters work as well. The inefficiency of jerky-smooth and soft-hard can be due to the same reasons that we have discussed in Section 4 previously. But it can also be possible that these two style parameters do not matter at all. We need more studies to find out the answer. But up to now, we do have satisfactory results of the mapping from procedure, motion, style to emotion parameters. That is to say, we have verified the emotional expressiveness of the lower-level parameters in our hierarchical model.

6 Conclusions

The objective of our research is to study how to generate emotional animations for virtual agents with a systematic procedural approach. The expressiveness of these animations is determined by the appropriate design of parameters at various abstraction levels. In this paper, we have proposed and implemented such a design and conducted two psychological experiments on human walking and other motions to verify the expressiveness of these parameters. Based on the two experimental studies and previous works, we conclude that three out of five style parameters are implemented with satisfactory expressiveness. We believe that the current work can lead to various applications such as an emotive virtual character on the interactive television. We also believe that this work is one step toward the establishment of affective computers [8] which can recognize, express and even have emotions. We will continue to pursue these two lines of developments, both applicative and theoretical, in the future.

Acknowledgement

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Simulation of Social Behaviors in Virtual Crowd

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Abstract

This paper presents a novel communication model to simulate various crowd behaviors such as riot. Our communication model is heavily based on the results from sociology research. Collective behaviors can emerge out of social processes such as emotion contagion and conformity effect among individual agents. The communication model has been implemented in our crowd simulation system, IMCrowd, in which each agent has a local perception and autonomous abilities to improvise their actions. Simulations on riot formation and riot control are demonstrated as an application example of IMCrowd.

Keywords: crowd simulation, communication model, emotion contagion, agent-based model

1. Introduction

Many applications can be benefited from crowd simulation, including entertainment, urban planning, emergency evacuation, and crowd behavior research for social sciences. However most previous efforts in crowd simulation focused on generating plausible animations for applications targetting more on visual effects without considering how communication among the agents could affect the behaviors of a crowd. These models are in general not adequate for investigating complex crowd behaviors because psychologcial and social factors, such as perception, emotional status, and communicaion mechanism, are either rarely concerned or greatly simplified. However, all of them are essential factors leading to crowd actions. Among them, the nature of the communication that collective behaviors involve is of particularly significant.

In this paper, we propose to use the theories in sociology and psychology to build the model of communications for creating a variety of crowd behaviors. We also propose to build a crowd simulation system, IMCrowd, that can simulate the social behaviors of heterogeneous agents under different communication settings.

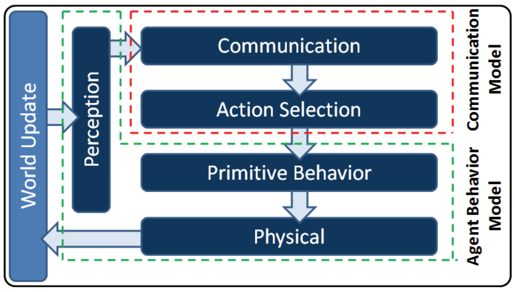

Figure 1. System architecture of IMCrowd

2. Agent Behavior Model

The system architecture of IMCrowd can be split into two models: *agent behavior model* and *communication model*, as shown in Figure 1. The agent behavior model mainly follow Reynolds's work [5][6] and adopt a collision avoidance technique to create autonomous agents moving on the continuous space.

The agent behavior model consists of three levels of modules in a simulation loop: *perception*, *primitive behaviour* and *physical*. In the perception module, a fan-shape area centered at the agent is used to model the perception region. Only the agents in the region are visible. We have used a grid-based partitioning algorithm to maintain the agents in nearby proximity in linear time. The primitive behavior module is responsible for calculating the desired trajectories to satisfy the goals set by the action selection module or to react on the forthcoming entities within the perception field. Several primitive behaviors have been implemented in this module such as seeking, fleeing, arrival, wandering, leader following, flocking, and obstacle avoidance. Each of them produces a steering force that drives an agent to move. Finally, the physical module requests the resultant steering force from the primitive behavior module as its input, and then calculates the agent's physical properties, position and orientation, by the Newton's equations of motion.

3. Communication Model

While the agent behavior model enables agents to move autonomously, the communication model enable them to make social interaction with others and decide what action to take. The communication model is comprised of two levels of modules in the simulation loop: the *communication module* and the *action selection module*. In brief, the communication module receives the surrounding information from the perception module, changes the internal state of the agent according to the perceived information, then passing the information and the internal state to the action selection module. The action selection module makes decisions and notifies the primitive behavior module to perform the selected action. As a result, the behaviors emerge out of the interaction among individual agents through this communication mechanism.

In IMCrowd, the agents can be basically grouped into two categories: *normal agent* and *special agent*. The normal agent can be further divided into agents of two roles: *leader* and *follower*. Every normal agent belongs to a friend group which contains one leader and some followers. A simulated crowd typically comprised a couple of friend groups. Additionally, a normal agent owns two possible minds. The first one is the individual mind which is goal-driven and self-determined. The second one is the collective mind, with which an agent loses its individuality, acts mainly relying on others around itself, and forms a sort of herd behavior. In the current implementation, there are three kinds of collective minds: *panic*, *gathering* and *riot*, triggered by different special agents and then spread throughout the crowd by the communication mechanism.

3.1 Communication framework

The communication framework is composed of six ingredients: *initial carrier*, *suggestive message*, *signal*, *channel*, *transmitter* and *receiver*. The **initial carrier** acts as a special agent carrying a unique **suggestive message** to stir up a certain crowd situation in the beginning of the simulation. A suggestive message can be encoded into three kinds of **signals** – *emotion stimuli*, *bandwagon pressure*, and *hysteria* – by their corresponding **transmitters**. The signals can be absorbed by the corresponding **receivers** of other agents through the face-to-face visual communication channel.

Every agent is equipped with all kinds of signal transmitters and receivers but may not always turn them on. According to the switch statuses of transmitters and receivers, we define four states for a normal agent to reflect the changes of communication ability in the course of the whole simulation: *clean*, *latent*, *engaged* and *disenchantment*. In the beginning of the simulation, every agent is at the **clean state** and behaves with the individual mind. In this state, no transmitter is turned on while the receiver of the emotion stimuli signal is opened up initially. Therefore, the agent passively absorbs the emotion stimuli signals through its channel until it switches to the latent state after receiving enough signals.

An agent is regarded as infected at the **latent state** because the suggestive message has been implanted into the agent. The agent at this state turns on signal transmitter of the emotion stimuli and becomes a new source to infect other surrounding normal agents. In addition, at this state the agent also switches on the signal receiver of the bandwagon pressure such that two kinds of signals, emotion stimuli and bandwagon pressure, can be absorbed.

The latent state works as a buffer state in which the agent has not been entirely dominated by the suggestive message and the agent still behaves with its individual mind in spite of contemplating on taking the collective behavior. On one hand, the agent needs to keep absorbing emotion stimuli signals to sustain the suggestive message alive; otherwise, the agent may switch back to the clean state when the suggestive message dies out. On the other hand, at this state the agent may detect the concentration of the bandwagon pressure, and transform itself into the engaged state when the concentration exceeds a certain threshold [3].

At the **engaged state**, the agent behaves with the collective mind hinted by the suggestive message, and turns on the other two signal transmitters: *bandwagon pressure* and *hysteria*. Through the bandwagon pressure signal, the agent at this state can not only infect nearby agents but also prompts surrounding infected agents to take actions with the collective mind. Furthermore, by transmitting the hysteria signal to each other, the agents can extend the lifespan of the suggestive message and prolong collective activities.

The last state is the **disenchantment state** where the agent enters when the suggestive message dies. At this state the agent terminates its collective action, closes all transmitters and receivers, and finally leaves from the environment.

3.2 Action Selection Module

The actions in the action selection module can be categorized into three groups: *leaving action*, *individual action* and *collective action*. The leaving action selects the nearest exit in the environment and activates the arrival behavior to drive the agent toward the exit. The leaving action is always adopted for agents in the disenchantment state. The individual action will be chosen when the agent is at the clean or latent state. In this state, a leader agent selects a random or specified goal and activates the arrival behavior to move toward the goal. The follower agents who take the individual action will just follow their leader.

The collective action is only executed when the agent is at the engaged state. However, the collective action could be quite different because of the distinct collective minds hinted by different suggestive messages. There are three kinds of collective actions in the current implementation of IMCrowd: *panic*, *gathering*, and *riot*. But in this paper, we mainly focus on the third collective action: riot. The riot in IMCrowd is the particular situation happening between two antagonistic groups. According to [2][4], we regard the collective action taken by an agent in the riot situation as one of five actions: *assembling*, *bluster*, *vandalism*, *assault* and *flight*. And the action selection module selects one of five actions through a decision tree described below.

According to the literature in sociology [2], there are some interesting features that can determine whether violence will happen or not: (1) Violence is always in the form of a small proportion of people who are actively violent and a large number of the audience who behave nominally violent or emotionally involved only. (2) Emotional supporters provide

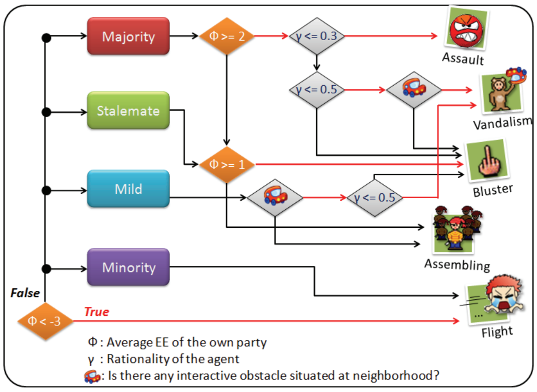

Figure 2. The decision tree for an agent to select a proper collective action in riot situation.

Emotion Energy (EE) to the violent few for going into action against the enemy. (3) Bluster is often the first step in a fight. The confrontation is usually bluster and gesture that usually lead to little real harm. (4) Fighting is always in a form of attacking the weak. (5) Violence is the most dependent situational contingencies – the solidarity of one side suddenly breaks up into little pockets so that an individual or two are isolate and beat up by the opposite group.

We design the decision mechanism of the collective behaviors according to the above features. First, the agents can determine the status (*mild*, *minority*, *stalemate* and *majority*) according to the relative circumstance of its surrounding. Secondly, different actions contribute differently to the EE of its own party and an agent needs to have sufficient EE to take any collective action. Thirdly, according to a rationality model used in our previous work, an agent may take actions with various degree of violence [1]. For example, the assault action is more violent than the vandalism action. The decision tree that we have designed for an agent to select the proper collective action in a given riot situation is shown in Figure 2.

4. Experimental Results

We design a scene where two antagonistic groups of agents, blue party and green party, congregate respectively and an instigator in the midst of the crowd tries to provoke a riot. As soon as the simulation starts, the initial carrier, the instigator, starts to spread the emotion stimuli to infect the surrounding normal agents. The normal agents gradually turn into the latent state through infection and begin to release the emotion stimuli to infect other nearby nor-

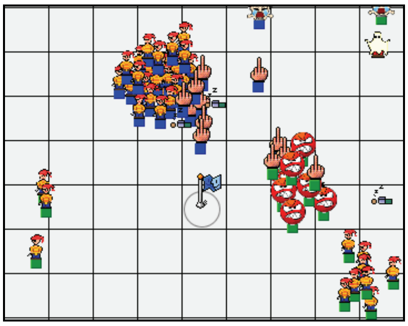

Figure 3. The emerging confrontation between two parties.

mal agents. When more and more normal agents get into the latent state, some agents with low threshold, high-risk group, may enter the engaged state and take the lead in acting with the collective mind. Their action produces the bandwagon pressure to give rise to the bandwagon effect. In addition, they produce hysteria signal to feed each other for enduring the period of collective actions. In the simulation, some agents demolish or turn over the car, and some chase and attack their opponents. Although moments of violence in a riot are scattered in time and space, the emerging confrontation between two parties can always been observed, as shown in Figure 3.

To experiment with the control of riot, we put another special agent –police, for observing its effect on the crowd dynamics in the riot situation. In IMCrowd, a police is an autonomous agent with local perception and they act individually without global coordination. The distinctive ability that a police has over other special agents is that it can disperse agents and ensure that there is no violent activity around its vicinity. We have also designed a policing strategy called entropy strategy for automatically moving the police toward to the stalemated confrontation between the two parties, separating them and averting the violence, as shown in Figure 4.

5. Conclusion and Future Work

In this work, we have developed a novel communication model implemented in IMCrowd to simulate the crowd dynamics based on the social psychological processes such as emotion contagion and bandwagon effect. In addition, we have designed a decision tree based on Collins' micro-sociological theory about violence [2] for an agent to select a proper action

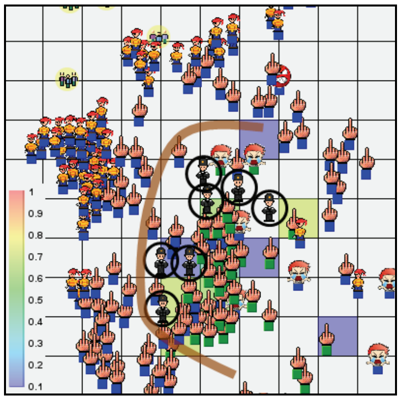

Figure 4. The polices with entropy strategy automatically build a sort of wall to separate two parties.

in a riot situation. We demonstrate the effectiveness of this model by interesting plausible riot scenes.

The communication model in this work can be considered as the first model being used to reveal the emotion contagion and bandwagon effect in the dynamics of crowd simulation. Hence, many elaborations are possible. For example, we will design quantitative indices to measure the collective behaviors in the course of a riot. The personality and social relation among the individuals are also factors to consider in the future.

Acknowledgement

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國科會補助計畫衍生研發成果推廣資料表

日期:2011/02/24

國科會補助計畫	計畫名稱: 自動產生3D 多人虛擬環境中擬真之虛擬角色行為(II)		
	計畫主持人: 李蔡彥		
	計畫編號: 98-2221-E-004-008- 學門領域: 計算機圖學		
研發成果名稱	(中文) 具情緒傳播模型的虛擬人群模擬技術		
	(英文) Virtual Crowd Simulation System with Emotion Communication Model		
成果歸屬機構	國立政治大學	發明人(創作人)	李蔡彥,趙偉銘
技術說明	(中文) 這個技術是以社會心理學及電腦模擬技術為基礎，建置一個能模擬虛擬人群中人際間情緒傳播模型的系統，用以自動產生具有集體行為的人群模擬。這個建立在電腦動畫技術的系統具有階層式的模型，是目前文獻上最先完成情緒傳播模型建立的研究。我們已完成這個模擬平台的建置工作，並以暴動模擬及其他集體行為為例說明如何利用此系統自動產生擬真的人群動畫模擬，並如何提供社會學研究者一個新的資訊工具，以創新的研究取向進行模擬實驗研究。		
	(英文) Based on the theoretical foundation of social psychology and computer simulation techniques, we have developed a simulation system that can model the communication process of a crowd of virtual agents and generate plausible collective behaviors for virtual crowds. We believe that the hierarchical model proposed with the inter-agent emotion communication model is known to be the first one of its kind in the literature. We have used riot as an example to illustrate how the system can be used to generate realistic crowd animations and how it can be used as a new tool for social scientists to conduct simualtion experiments with a novel approach.		
產業別	研究發展服務業		
技術/產品應用範圍	電腦動畫；電腦遊戲；社會學研究		
技術移轉可行性及預期效益	可用在電腦動畫或遊戲中提供擬真的人群模擬自動產生機制，以提高動畫產生的技術水準，並降低製作成本。		

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：李蔡彥	計畫編號：98-2221-E-004-008-

計畫名稱：自動產生 3D 多人虛擬環境中擬真之虛擬角色行為(II)

成果項目			量化			單位	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）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	2	4	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	1	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	5	5	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	1	1	100%		
國外	論文著作	期刊論文	0	3	90%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	2	3	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	本研究所產出的碩士論文已獲得中華民國人工智慧學會的碩士論文獎及中華民國計算機學會的最佳碩士論文獎。

	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	
	研討會/工作坊	0	
	電子報、網站	0	
	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）

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）

這個技術是以社會心理學及電腦模擬技術為基礎，建置一個能模擬虛擬人群中人際間情緒傳播模型的系統，用以自動產生具有集體行為的人群模擬。這個建立在電腦動畫技術的系統具有階層式的模型，是目前文獻上最先完成情緒傳播模型建立的研究。我們已完成這個模擬平台的建置工作，並以暴動模擬及其他集體行為為例說明如何利用此系統自動產生擬真的人群動畫模擬，並如何提供社會學研究者一個新的資訊工具，以創新的研究取向進行模擬實驗研究。