

行政院國家科學委員會專題研究計畫 成果報告

主動式全方位隨處照護系統之設計與實作 研究成果報告(精簡版)

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摘要

由於無線通訊與電子製造技術的快速發展，已可將無線感測器網路應用於室內定位，不僅可監控被照護者行蹤，也可應用於居家照護，用以得知被照護者於家中的實際情況。本研究計畫以符合 ZigBee 聯盟規範之設備來建置室內定位系統。研究中我們利用不同數量的感測器節點來建構三種不同型態的網路拓撲，而定位演算法則是根據無線訊號之強度，採用訊號特徵比對法，透過反覆實驗測試，最終找出適合室內定位的節點部署方式。

關鍵詞：無線感測網路，室內定位，ZigBee，訊號強度，特徵比對

Abstract

Due to rapid advances in RF and MEMS IC design have made possible the use of wireless sensor network for monitoring in indoor localization system, it can trace person' location in the particular area; caregivers can obtain the position of person who need helps in house. We deployed ZigBee device in the interesting environment, and we implemented three types of nodes deployment, which are differ from the number of sensor nodes and positions. In our localization technique, we use the RSS of RF signals and signal pattern matching, in each deployment, we make lots of measurements. The main goal of measurements is to find the appropriate nodes deployment.

Keywords: Wireless sensor network, Indoor localization, ZigBee, Signal Strength, Signal pattern matching.

一、前言

近年來，利用無線技術的室內定位系統是許多研究團體努力的方向，如何獲得準確的使用者定位資訊，一直是定位服務的重點。全球定位系統 (Global Positioning System, GPS) 無法應用於室內空間，如封閉的辦公大樓或是半開放式的校園空間及工廠，而且因為初始定位的秒數長達數十秒至一分鐘，因而無法獲得立即的資訊。所以，近年來有許多可應用在室內空間的定位技術已相繼被發表，且可直接實作於室內定位，使得定位技術不但有應用於商業以及軍事上的潛力，例如倉儲管理、監控被照護者以及安全方面等應用，亦可為無線感測器技術增添其附加價值。

二、研究目的

隨著醫療技術的發達，相對的人口結構也逐漸高齡化，提供年長者必要的照護也成為了政府重要的社會福利政策之一。另一方面，由於雙薪家庭日漸增多，家長常因工作緣故而無法時時掌握幼童或老人的行蹤，因此其走失的案件亦層出不窮。但藉由資訊設備與定位技術的協助，可減少照護者的人力負擔以及增進對年長者與幼童的照護品質。

在本研究中，如何得知被照護者（年長者或幼童）在室內或室外之切確位置是主要

的研究議題。在室外定位的部分，是用以避免失智老人或幼童走失，甚至可以幫助家屬尋找被照護者，而室外定位的方法，許多手機內部已整合全球定位系統晶片，且配合與電信業者相關的輔助全球定位系統 (Assisted Global Positioning System, AGPS)，能夠提供及顯示室外定位之結果。同樣地，在室內定位監控方面，透過室內定位系統的協助，可得知被照護者停留在同一地點的時間，假設被照護者停留在同一地點的時間過長，表示可能發生某些突發事件而導致被照護者需要外界的協助。

本文後續的部分將針對本計畫對室內定位的研究，作詳細地闡述。第三章：文獻探討，內容說明室內定位技術的發展與相關研究，第四章：研究方法，說明本計畫的實驗環境、採用設備及研究方法，接著解釋本計畫所設計的定位演算法以及實驗流程，第五章：結果與討論，主要是呈現實驗的結果，即定位之精準度以及定位之距離誤差，最後是總結本計畫的成果。

三、文獻探討

下面我們將簡單說明目前常用之無線網路室內定位技術及其優缺點：

(一) 到達角度法

顏等人提出之到達角度法 (Angle of Arrival, AOA) [1] 只要利用兩個感測節點接收到的訊號入射角度，就能判斷行動目標的方位。其前提為感測節點上需加裝具有指向性之天線 (Directional Antenna)，如圖 1 所表示，欲定位目標為 X，A 與 B 為事先於室內環境架設好的感測節點，由於 A 與 B 間的距離為已知，根據感測節點收到的訊號角度，代入三角定理可得距離 d_A 、 d_B 以及 d_h ，推斷感測標籤 (Tag) 在室內空間中的相對位置。

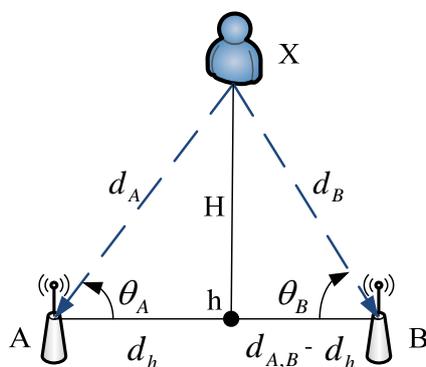


圖 1：利用入射角度判斷距離之示意圖

(二) 到達時間法

王等學者之研究 [2] 提出到達時間法 (Time of Arrival, TOA) 也稱為 TOF (Time of Flight)，此定位法利用目標物發送的訊號 (無線射頻或超音波) 到達感測裝置的傳遞時間，來估算感測標籤與感測節點之間的距離。感測節點送出訊號 A_1 ，訊號由感測標籤接收，隨後感測標籤再發出訊號 A_2 ，最後感測節點接收此訊號。根據時間差，可得知訊號在空氣中傳播的時間，推算出感測節點 A 與感測標籤的距離 d_A [10]。Klee 等學者 [5] 的研究提及，到達時間法要求感測節點以及感測標籤的時間軸須精確地同步，因此對裝置的硬體需求較高，因此花費成本相對來說也較大。

(三) 到達時間差法

Patwari 等學者的研究[8]提出到達時間差法 (Time Difference of Arrival, TDOA)，此

為到達時間法的進階技術，它不同於到達時間法的技術為，感測標籤會發射兩種傳遞速率不同的訊號，感測節點根據這兩種訊號到達的時間差，計算彼此之間的距離，得知感測標籤的位置。

(四) 接收訊號強度法

Lihan 與 Papamantho 等學者文章提及，接收訊號強度法 (Received Signal Strength, RSS) 是根據感測節點的訊號強度，再將訊號強度換算成距離的方法 [7], [9]。目標與接收訊號裝置的距離越遠，訊號的強度將隨著距離 d 做衰減。因為訊號在傳遞過程中，容易受到周圍的干擾，例如：建築物的牆面隔間、建材材質與周圍訊號等，訊號將產生散射、反射、繞射等多重路徑衰減現象，其訊號衰減並不完全根據於距離長度，因此可以引入對數常態 (log-normal) 的數學模型[8]，對訊號衰減程度做修正計算。

以上介紹的到達角度法、到達時間法、到達時間差法以及接收訊號強度法，皆與感測標籤及感測節點的距離有關，所以又稱為植基於距離 (Range-base) 之定位技術。然而，我們接下來要介紹的兩種定位技術，則與距離無關 (Range-free)，它們的特色在於，不需要得知感測標籤與感測節點的距離，也能判斷感測標籤在室內空間的位置。

(五) 區域識別判斷法

顏等學者文章提及，區域識別判斷法 (Connection Base) 根據感測標籤訊號被多個感測節點收到與否的次數[1]，計算出幾何中心，此中心即為感測標籤的所在方位。

(六) 訊號特徵比對法

Bahl 和 Padmanabhan 的研究[4]中說明了訊號特徵比對法 (Signal Patent Matching)，此方法雖然需要得知感測標籤的訊號強度，但其技術並非根據訊號強度大小，來判斷感測標籤與感測節點相差距離遠近。當目標標籤在指定區域出現時，利用事先建立好的訊號強度資料庫，將感測節點收到的訊號強度與資料庫做比對，進而判斷感測標籤在該空間的位置，如圖 2 所示。我們必須事先於該空間內裝設許多感測節點，然後針對該空間的每一個地點做測量，來取得該地點的強度樣本，此步驟稱為實地測定 (Site Calibration)，也稱為場測法[3]。此種定位技術相當簡易，所需成本亦不高，因此已有許多相關的研究基於此技術來發展不同演算法，用以提升定位結果的準確度。

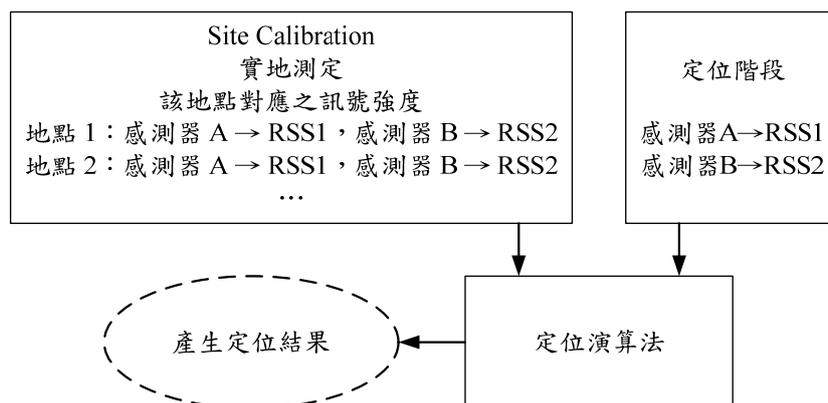


圖 2：訊號特徵比對法之流程圖

四、研究方法

(一) 實驗環境

本論文中的實驗環境為約長十公尺、寬四點五公尺的長方形會議室，包含木製會議桌四張，上課用大型白板一塊，鐵製書櫃及電腦桌若干個 (灰色區域)。實驗將會議室劃分成方格狀，共規劃若干座標點，編號依序為：A1、A2、A3...至 O1、O2、O3 等等，

每點相鄰距離為六十公分。

(二) 實驗設備

本計畫使用之設備符合 ZigBee 聯盟之規範[14]，其利用無線網路 802.15.4 的標準所制定，其特色為低耗電及低傳輸速率。實驗中的設備包含一個閘道器 (Gateway)，多個感測節點 (Location Node)，及一個感測標籤 (Location Tag)，其功能列表如下：

表 1：閘道器、感測節點及感測標籤的特性及功能簡介

閘道器特性及功能	感測節點特性及功能	感測標籤特性及功能
無線網路中心	區域位置信標發射站	低耗電無線技術
無線有線網路橋接器	指向性天線設計	可充電設計
無線資料收集中心	扮演網路中的路由器角色	雙向溝通緊急求救鍵

(三) 設備佈署方式

本論文中針對不同的感測節點數量與部署位置，及閘道器的部署位置，使用相同的定位演算法評估會議室最適合的配置情況。本計畫規劃三種類型，分別為 Type I、Type II 和 Type III，如圖 3 所示。

(四) 定位演算法介紹

本研究採用的定位技術為訊號特徵比對法，定位實驗分為兩個階段，第一階段：建立訊號強度模型，以及第二階段：設計定位演算法。

1. 建立訊號強度模型

第一階段的目標在於建立訊號強度模型，又稱為離線 (off-line) 階段，我們分別部署三種配置類型，依序在會議室裡的每個位置，如 A1、A3、A5 等共計十七個位置，將感測標籤放置於該點，然後進行強度量測，每種配置類型均建立各自的訊號強度模型。

2. 設計演算法

建立好感測標籤於十七個不同地點的訊號強度模型以後，便可進入第二階段，設計定位演算法。此階段的目標為：日後感測標籤回傳之強度訊號要怎麼與強度模型做比較，運算以後又將如何選擇最佳的定位地點。以下將說明本研究的定位演算法，表 2 列出演算法所使用的符號定義：

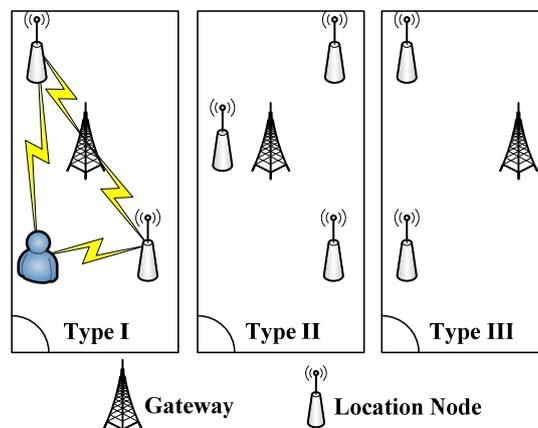


圖 3：感測節點與閘道器的分佈位置

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1  for( $N = 1$  to  $T_N$ )
2    for( $k = 1$  to  $T_K$ )
3      if( $|\{RSS_k\} - M_N^k| \leq Threshold$ )
4        紀錄  $N$  為候選節點，
5         $N \rightarrow \{C\}$ ;
6  while( $\{C\}$  is not null)
7     $\{C\} \rightarrow N$ ;
8    for( $k = 1$  to  $T_K$ )
9       $\{S\}_k \leftarrow SD(\{RSS_k\} + \{rss_k\}_N)$ ;
10      $\{S\}_k \leftarrow SD(\{rss_k\}_N)$ ;
11      $\{E\} \leftarrow \sqrt{(\{S\}_k + \{S\}_k)^2}$ ;
12  紀錄  $\{E\}$  的最小值其對應的地點，
13  該地點即為定位結果

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表 2：定位演算法之符號說明

符號	意義說明
k	感測節點編號
N	座標點編號，總數為 17 個
$\{rss_k\}_N$	記錄在資料庫裡，第 N 個座標之第 k 個感測節點所收到的訊號強度集合
$\{RSS_k\}$	定位階段，第 k 個感測節點所收到的訊號強度集合
M_N^k	在 $\{rss_k\}_N$ 裡，出現最多次數的訊號強度
T_K	感測節點總數為 2 或 3 個
T_N	座標點的總數，為 17 個點
$\{C\}$	定位候選節點
$SD(data)$	對一群 data 做標準差運算
$\{S\}_k$	第 k 節點的標準差值
$\{E\}$	歐幾里德距離的集合

演算法之第 1 行至第 5 行：我們利用回傳的訊號強度將可進行定位，首先，將各節點回傳強度與強度模型裡的每個地點進行特徵值比較，若差值小於所設定的門檻值（例如 6 或 12），即認為感測標籤有可能出現在該地點，便將該地點納入候選地點名單。演算法之第 6 行至第 13 行：針對候選地點，依序將感測標籤回傳之訊號強度，併入候選地點先前所建立的強度樣本，然後計算每個候選地點合併前後的標準差（第 9 以及 10 行），再將此兩個數值帶入歐幾里德距離 (Euclidean distance) 公式來計算其差

異度（第 11 行）。此步驟之目的為，判斷量測到的強度與該地點樣本強度的相似度，當歐幾里德距離值越小代表該筆量測強度與樣本強度相似度越高，值越大表示相似度越小。最後，我們選擇強度資料合併前後相似度最高的，作為我們的定位結果（第 12 及 13 行）。

（五）實驗方法

本計畫的定位實驗分為兩種，分別為靜態定位實驗以及動態定位實驗，透過這兩類型之實驗，希望能探究所設計演算法之精確度以及用於動態定位的效果。

1. 靜態定位實驗方法

選定一會議室作為實驗場所，與此會議室中規畫出 105 個座標位置，並挑出 17 個座標位用以實驗，我們將實驗過程分為下列三個步驟：

I. 於實驗地點放置感測標籤

將感測標籤輪流放置於此 17 個位置，停留時間分別為 5 秒至 30 秒，重複測量直到三種特定的網路拓撲類型都測量完成。

II. 執行定位程式

程式將根據該時間區段收到的多筆回傳強度，來進行定位演算，待時間過後，即能馬上顯示定位結果。

III. 紀錄定位結果及統計

根據不同的實驗秒數，分別記錄定位的結果，待實驗完成以後再統計其定位的準確度。

2. 動態定位實驗方法

我們在此會議室挑出 41 個移動時無阻礙的區域，分別位於此會議室左側及右側，進行動態移動實驗，感測標籤在左側移動路徑為：起點為 A1，終點為 N1。感測標籤在右側移動路徑為：起點 A5 而終點為 N5。移動過程均呈直線的狀態。此外，設定不同的移動秒數：分別為 1 分鐘、2 分鐘以及 3 分鐘。由於須要考慮動態移動時產生之雜訊對訊號強度的影響，所以設定不同的定位間隔秒數，分別為 3 秒、5 秒及 10 秒，用以找出較佳的定位之間隔秒數。同樣地，也必須輪流執行三種不同的感測節點部署類型，直到實驗全部完成為止，動態定位時的移動路徑如圖 4 所示。

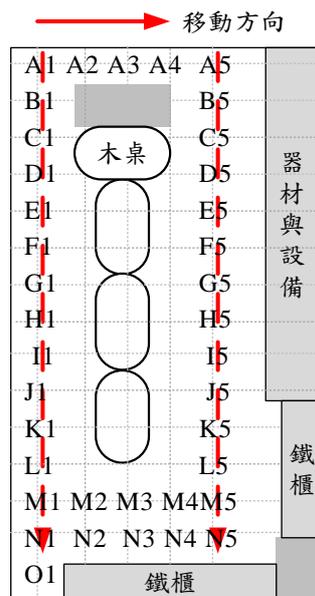


圖 4：41 個地點位置圖與移動方向

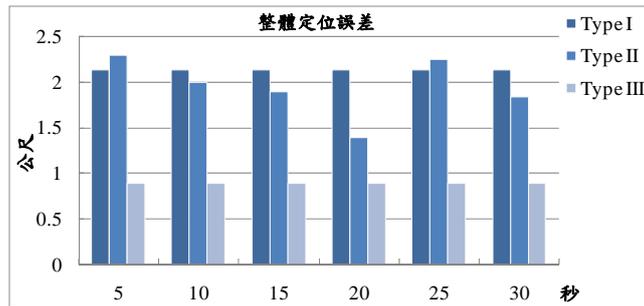


圖 5：靜態定位實驗的平均誤差距離

五、實驗結果與討論

(一) 靜態定位實驗的結果與討論

接著呈現各配置類型之定位誤差結果，圖 5 之 X 座標為定位總秒數，Y 座標為平均誤差距離，由實驗結果得知 Type III 誤差距離最小，定位誤差小於一公尺，約為 0.9 公尺，為三種類型裡定位表現最優異者；而 Type I 定位誤差距離最大，至少兩公尺以上。

(二) 動態定位實驗結果與討論

1. Type I 之定位結果

圖 6、7 為不同定位間隔秒數的定位結果準確率比較，由圖 6 顯示，於會議室左側移動，除了一分鐘的實驗且 10 秒定位間隔秒數準確率較高外，其餘不論定位間隔秒數如何改變，其準確率於 40%~50% 範圍間，無特別突出的表現。圖 7 顯示，以會議室右側移動來說，5 秒為定位間隔的表現較突出，整體平均有 65% 的定位準確率。

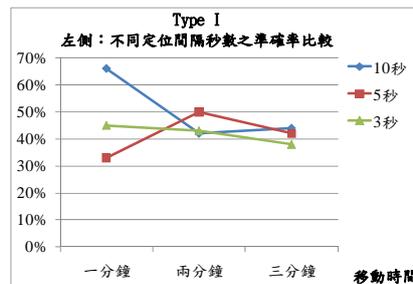


圖 6：Type I 會議室左側定位結果比較

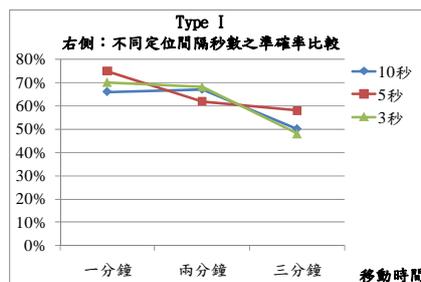


圖 7：Type I 會議室右側定位結果比較

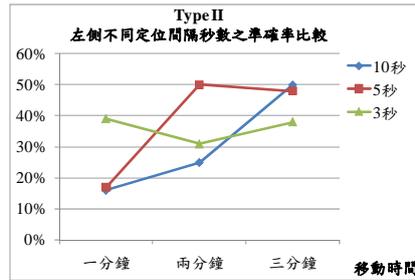


圖 8：Type II 會議室左側定位結果比較

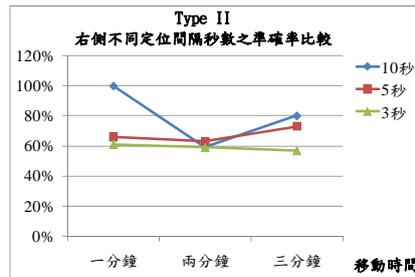


圖 9：Type II 會議室右側定位結果比較

2. Type II 之定位結果

最後為不同定位間隔秒數的定位結果準確率比較，由圖 8 顯示，於會議室左側移動，定位間隔 5 秒及 10 秒的結果呈現不穩定之狀態，且定位準確率也不高，在 17%~50% 間變化，而定位間隔 3 秒之結果較穩定，準確率平均為 36%。由圖 9 顯示，以會議室右側移動來說，10 秒為定位間隔的表現突出，整體平均有 80% 的定位準確率，而以 5 秒及 3 秒定位間隔的準確率較佳，分別為 64% 和 60%。

3. Type III 之定位結果

由圖 10 顯示，於會議室左側移動，定位間隔 3 秒、5 秒及 10 秒的結果均呈現不穩定之狀態，且定位準確率也不高，以 10 秒為定位間隔的準確率只達 17%，是三者中表現最佳之間隔。由圖 11 顯示，以會議室右側移動之動態定位而言，3 秒、5 秒及 10 秒定位間隔的準確率較佳，其準確率平均為 70% 以上，而不同的定位間隔秒數對結果之影響也較小。

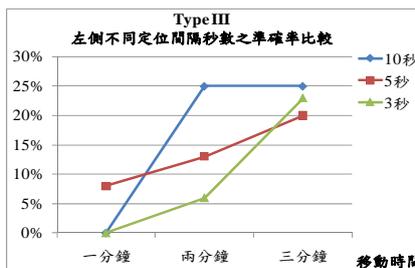


圖 10：Type III 會議室左側定位結果比較

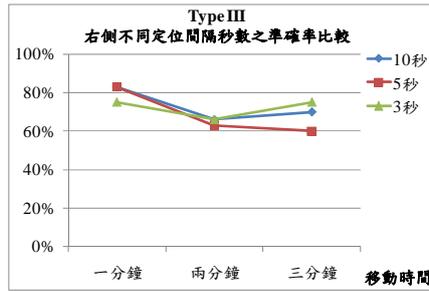


圖 11：Type III 會議室右側定位結果比較

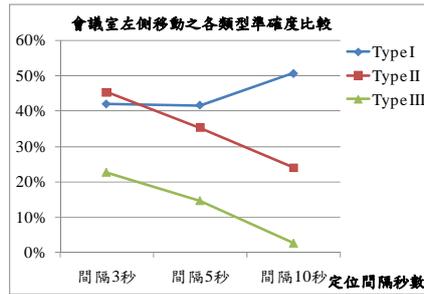


圖 12：會議室左側各 Type 之定位結果比較

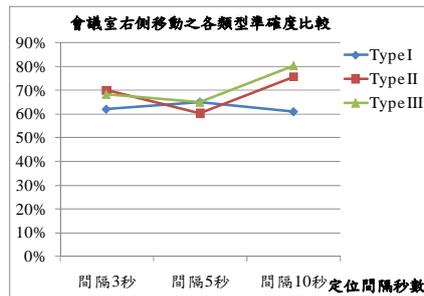


圖 13：會議室右側各 Type 之定位結果比較

4. 動態移動三種節點部署類型的綜合比較

根據實驗結果，我們歸納出較適合用於動態移動定位的節點配置類型。以會議室左側移動實驗數據顯示（圖 12），節點配置類型之 Type II，配合定位間隔 3 秒最適宜；以會議室右側移動實驗數據顯示（圖 13），節點配置類型之 Type II，配合定位間隔 3 秒或 10 秒，均有不錯準確率，因此可知 Type II 最適合用於全會議室空間之動態定位。

六、結論

根據上述的實驗結果，我們分別找出用於動態以及靜態定位，較適合的節點部署類型，且透過本研究實驗過程所累積的經驗，找出最佳適用於室內環境之定位系統。用於室內的靜態定位系統，以 Type II 的節點部署方式最適合；而適用於室內的動態定位系統，亦是 Type II 為最佳，而定位間隔秒數以 3 秒的定位準確度最高。因此，日後於室內環境較適合採用此節點佈署的類型來進行室內定位。

致謝

感謝行政院國家科學委員會補助相關研究經費，使本計畫得以順利完成。

計畫編號：NSC 98-2221-E-029-021。

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行政院國家科學委員補助國內專家學者出席國際學術會議報告

報告人姓名	林祝興	服務機關及職稱	東海大學資訊工程學系教授
時間	98年12月4日~12月7日	本會核定補助文號	NSC98-2221-E-029-021
會議地點	馬來西亞麻六甲 MITC		
會議名稱	(中文) 國際軟計算與模式識別會議 (英文) International Conference on Soft Computing and Pattern Recognition (SoCPaR 2009)		
發表論文題目	(英文) Investigations of Factors Affecting the Genetic Algorithm for Shortest Driving Time		
<p>報告內容：</p> <p>一、參加會議過程</p> <p>二、與會心得</p> <p>三、考察參觀活動</p> <p>四、建議</p> <p>五、攜回資料名稱及內容</p> <p>六、其他</p>			

第一屆國際軟計算與模式識別會議

林祝興

東海大學資訊工程學系

一、參加會議過程

2009 年 12 月 3 日搭乘馬來西亞航空從台灣桃園國際機場出發，經過大約五小時的飛行，到達馬來西亞吉隆坡國際機場。到達後，搭乘大會安排的巴士前往住宿的飯店，而本次與會的地點「麻六甲國際貿易中心 (Malacca International Trade Centre, MITC)」就在飯店的斜對面。MITC 位於馬來西亞麻六甲一個名為 Ayer Keroh 的小鎮，在這邊舉行的主要活動包括：展覽，音樂會，晚宴，研討會，會議和表演。這次大會舉行的時間剛好遇到 MITC 正在舉辦資訊展，在與會的這段時間內可說每天都人山人海。

國際軟計算與模式識別會議 (International Conference on Soft Computing and Pattern Recognition, SoCPaR 2009) 雖說是第一次舉辦，但其會議內容探討的範圍也是相當廣泛，主辦的馬來西亞國民科技大學 (Universiti Teknikal Malaysia Melaka, UTeM) 表現的也可圈可點。由於本人的報告被安排在大會的最後一天，趁著會議還未正式開始前抽空考察了一下麻六甲這個著名的古城。

12 月 5 日，早上八點步行到 MITC 辦理註冊手續、拿取相關資料，並與在場的工作人員及國外學者們寒暄交流，隨後便進入會議場所聆聽演講 (Keynote)。在本次的大會中共安排了七場演講，與兩場討論會 (學術與工業各一場)，使本人獲益良多。此外，大會將接受的論文分成三個 Session (一天一場)，每個 Session 分成六個房間同時舉行，每個房間安排大約 7 到 8 篇論文報告。聆聽其他人的研究成果，使我有種茅塞頓開的感覺，讓我的研究視野更加廣闊。

二、與會心得

在這次的 SoCPaR 2009 研討會中，本人所發表的學術論文，所屬的議題為 Genetic Algorithm Optimization，而論文的題目為 Investigations of Factors Affecting the Genetic Algorithm for Shortest Driving Time，論文所從事的研究以基因演算法為主，其概念源自於自然界中的演化法則，包括遺傳、選擇、突變及染色體交換。而最短行車時間問題改自最短路徑問題，對於圖論中邊的權重加入最高限速，用以計算兩點間的行車時間。本人在 SoCPaR 2009 投稿的論文中，探討基因演算法的各項參數對求取最短行車時間的影響，期望能提升近似最佳解的精確度。報告中主持人和與會者提出的問題讓本人思考更加深邃，挖掘出不少之前未注意到的地方，會後的討論也讓本人跟各國的學者與研究人員有更進一步的交流。

三、考察參觀活動

麻六甲 (又譯馬六甲，馬來文：Melaka，英語：Malacca)，是馬來西亞的一個州，在馬來半島南部，瀕臨麻六甲海峽，首府麻六甲市，有古城之稱。馬六甲州面積 1,650 平方公里，人口約 73 萬。古時明史記載滿刺伽，被葡萄牙侵佔後，改稱麻六甲。根據聯合國教科文組織 (UNESCO)

於 2008 年 7 月 7 日在加拿大魁北克當地時間上午 9 時 30 分（大馬時間 9 時 30 分）召開的世界文化遺產大會後，宣布馬六甲市正式被列入世界遺產名錄。

麻六甲在漢代至唐代稱為哥羅富沙。唐永徽中，曾獻五色鸚鵡。明永樂三年，酋長西利八兒速喇（拜里米蘇拉）遣使上表，願為屬郡。永樂七年，明成祖命三保太監鄭和封西利八兒速喇為滿喇加王，從此不隸屬暹羅。永樂九年，拜里迷蘇喇繼王位，率領妻子和隨從 540 人來朝，進貢麒麟（長頸鹿）。

永樂至宣德年間鄭和下西洋，曾以麻六甲為大本營，建立城牆、排柵和鼓樓、角樓，並建設倉庫儲存錢糧百貨。鄭和船隊開往古里、爪哇等國都先在馬六甲停泊；由阿丹、忽魯莫斯等國回程時，也在馬六甲聚集，打點錢糧，入庫保存，等候信風駛返中國。至今麻六甲還保存不少鄭和遺迹，三寶山為鄭和船隊在麻六甲紮營的地點。在山腳至今仍有一間三寶廟及一口相傳為鄭和下令挖掘的三寶井。

此外 1511 年 8 月 24 日，麻六甲被葡萄牙人在擊敗印度後征服，並成為葡萄牙人在東印度群島擴張的戰略基地。1641 年，荷蘭人得到柔佛蘇丹的幫助，擊敗葡萄牙人佔領麻六甲。荷蘭從 1641 年到 1795 年統治麻六甲，但對將其發展成貿易中心不感興趣，作為治理中心的重要性被印尼的巴達維亞（雅加達）取代。

以其歷史背景來看，有許多與台灣相似的地方，所以在麻六甲看得到不同風格的各種建築，著名的景點包括；荷蘭紅屋、基督堂、雞場街、青雲亭、鄭和廟…等，而其食物的風味也別具特色。

四、建議

International Conference on Soft Computing and Pattern Recognition (SoCPaR 2009) 國際研討會，是具有前瞻性的國際會議，其中討論了許多 Soft Computing 與 Pattern Recognition 的技術和相關應用趨勢，展現出各位學者不同的創新觀念與建議，透過與各學著的學習與討論，讓與會的人員都深感會益良多。希望未來我國能不斷地爭取類似此種國際研討會的主辦權，相信這將對我國的學術活動與國際地位有正面的意義與幫助，並且可以提升我國在軟體技術分面的競爭力。

五、攜回資料名稱及內容

- SoCPaR 2009 INTERNATIONAL CONFERENCE ON SOFT COMPUTING AND PATTERN RECOGNITION 會議行程一本
- SoCPaR 2009 INTERNATIONAL CONFERENCE ON SOFT COMPUTING AND PATTERN RECOGNITION 論文集摘要一本
- SoCPaR 2009 INTERNATIONAL CONFERENCE ON SOFT COMPUTING AND PATTERN RECOGNITION 論文集光碟一片

六、其他

本人參加這次在馬來西亞麻六甲舉辦的 International Conference on Soft Computing and Pattern Recognition (SoCPaR 2009) 國際研討會感覺獲益良多，除了聽取許多外國學者的研究成果之外，在與國外學者的交流中也大大提升了英語的聽、說能力。此外，也順道參觀了古色古香的麻六甲城並享用當地的特色美食，為此嚴肅的學術研討會增添了一絲輕鬆的氣息。最後本人特別

感謝行政院國家科學委員會的補助經費，使本人有機會到麻六甲參與此次盛會。未來，希望國家能讓更多的人有機會能參與類似的研討會，進而提升校內學者的學術涵養與實務能力。

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TENTATIVE SCHEDULE SOCPAR 2009

Tentative Schedule for Tutorial:

Venue:
 Faculty Information and Communication Technology
 Universiti Teknikal Malaysia Malaysia,
 76109 Durian Tunggal, Melaka, Malaysia.

4/12/2009 (Friday)

Time	Event		
07.00am	Pick up from conference hotel		
07.30am–08.30am	Registration		
08.30am–09.00am	Welcoming Message		
09.00am–10.30am	Interactive Evolutionary Computation (Prof Dr Hideyuki Takagi)	Computational Forensic (Prof Dr Sargur N. Srihari)	
10.30am–11.00am	TEA-BREAK		
11.00am–12.30pm	Web Content Mining (Prof Dr Vaclav Snasel)	Parallel and Grid Computing (Prof Dr Md Yazid Mohd Saman)	
12.30pm–02.15pm	LUNCH & FRIDAY PRAYER		
02.15pm–04.00pm	Information Fusion Theory and Pattern Recognition (Part I) (Prof Dr Basel Solaiman)	Content-based image retrieval: techniques, challenges and recent developments (Part I) (Prof Dr Gerald Schaefer)	Crime Science and Cyber Crime (Prof Dr Pieter Hartel)
04.00pm–05.30pm	Information Fusion Theory and Pattern Recognition (Part II) (Prof Dr Basel Solaiman)	Content-based image retrieval: techniques, challenges and recent developments (Part II) (Prof Dr Gerald Schaefer)	
05.30 pm	TEA-BREAK & ADJOURNMENT		

Tentative Schedule for Main Conference:**Venue:**

Melaka International Trade Centre ([MITC](#)),
Ayer Keroh,
75450 Melaka.

5/12/2009 (Saturday)

Time	Event
07.00 am	Pick up from conference hotel
07.30 am – 08.00 am	Registration
08.00 am – 08.30 am	Welcome Message
08.30 am – 09.30 am	Keynote 1 – Sargur Srihari
09.30 am – 10.00 am	MORNING TEA-BREAK
10.00 am – 11.00 am	Keynote 2 – Vaclav Snasel
11.00 am – 01.00 pm	Parallel Session Presentation 1 (6 pax X 6 rooms=36 pax) Poster Presentation 1 (12 pax)
01.00 pm – 02.00 pm	LUNCH & PRAYER
02.00 pm – 05.00 pm	DMDI – SoCPaR2009 Joint Opening Ceremony
05.00 pm – 05.30 pm	AFTERNOON TEA-BREAK
07.30 pm	Pick up from conference hotel
08.00 pm – 10.30pm	Conference Banquet Dinner
10.30 pm	Adjournment of SoCPaR 2009

6/12/2009 (Sunday)

Time	Event
07.30 am	Pick up from conference hotel
08.30 am – 09.30 am	Keynote 3 - Shahrin Sahib
09.30 am – 10.00 am	MORNING TEA-BREAK
10.00 am – 11.00 am	Keynote 4 – Gauri Mittal
11.00 am – 12.30 pm	Forum Discussion (Ajith Abraham, 2 X SoftComp, 1 X Industry)
12.30 pm – 02.00 pm	LUNCH & PRAYER
02.00 pm – 03.00 pm	Keynote 5 – Marzuki Khalid
03.00 pm – 05.20 pm	Parallel Session Presentation 2 (7 pax X 6 rooms= 42 pax) Poster Presentation 2 (13 pax)
05.20 pm – 05.40 pm	AFTERNOON TEA-BREAK
05.40 pm	Back to Hotel
07.30 pm – 08.00 pm	Pick up from conference hotel
08.30 pm – 10.30pm	Umbai Seafood Dinner
10.30 pm	Adjournment of SoCPaR 2009

7/12/2009 (Monday)

Time	Event
07.30 am	Pick up from conference hotel
08.30 am – 09.30 am	Keynote 6 – Dominique Laurent
09.30 am – 10.00 am	MORNING TEA-BREAK
10.00 am – 11.00 am	Keynote 7 – Basel Solaiman
11.00 am – 12.30 pm	Industrial Talk – Dominik Slezak
12.30 pm – 02.00 pm	LUNCH & PRAYER
02.00 pm – 04.20 pm	Parallel Session Presentation 4 (7 pax X 6 rooms = 42 pax)
04.30 pm – 05.00 pm	Closing Ceremony
05.00 pm – 07.00 pm	Historical Malacca Tour
07.00 pm	Back to Hotel

7 th December, Monday - Parallel Session 3 : (ROOM 5)	
Chair : Prof. Dr. Nanna Suryana Herman	
SESSION : GENETIC ALGORITHM OPTIMIZATION	
02.00 pm – 02.20 pm	Mixed Impulse Fuzzy Filter Based on MAD, ROAD, and Genetic Algorithms <i>Nur Zahrti Janah and Baharum Baharudin</i>
02.20 pm – 02.40 pm	A New Solution Approach for Grouping Problems based on Evolution Strategies <i>Ali Husseinzadeh Kashan, Masoud Jenabi and Mina Husseinzadeh Kashan</i>
02.40 pm – 03.00 pm	A Novel Fuzzy Histogram based Estimation of Distribution Algorithm for Global Numerical Optimization <i>Jing-Hui Zhong, Wei-Li Liu and Jun Zhang</i>
03.00 pm – 03.20 pm	Investigations of Factors Affecting the Genetic Algorithm for Shortest Driving Time <i>Chu-Hsing Lin, Chen-Yu Lee, Jung-Chun Liu and Hao-Tian Zuo</i>
03.20 pm – 03.40 pm	A New Parallel Asynchronous Cellular Genetic Algorithm for de Novo Genomic Sequencing <i>Frédéric Pinel, Bernabe Dorransoro and Pascal Bouvry</i>
03.40 pm – 04.00 pm	Disaster Management in Malaysia: An Application Framework of Integrated Routing Application for Emergency Response Management System <i>Safiza Suhana Kamal Baharin, Abdul Samad Shibghatullah and Zahriah Othman</i>

Investigations of Factors Affecting the Genetic Algorithm for Shortest Driving Time

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Abstract—In this paper we investigate the influences on the genetic algorithm for the shortest driving time problem due to factors such as nodes on a map, the population size, the mutation rate, the crossover rate, and the converging rate. When the nodes on the map increase, more execution time is needed and much difference between the approximate solution and the exact solution appear on running genetic algorithms. Also, from the view point of the population initialization, restart type and reback type affect the precision of approximate solutions and the execution time. The characteristics of the factors we find in the paper provide us insight how to improve the genetic algorithm for the shortest driving time problem.

Keywords—shortest path problem; genetic algorithm; shortest driving time; route guidance; approximate solution

I. INTRODUCTION

In recent years, following the traditional 3C (Computing, Communications, and Consumer electronics), the 4C, Car electronics is the latest and most potential product. One of most popular 4C applications, vehicle navigation is used to find the best or shortest path between the starting point and finishing point, where one may not have been there before. One variety of the shortest path problem is the shortest driving time problem.

In graph theory, the shortest path problem is the problem of determining a path between two vertices (or nodes) such that the sum of the weights of its constituent edges is minimized. Looking at the problem from the viewpoint of vehicle navigation, the vertices on the graph are seen as road intersections and the weight of edges are seen as the distance between road intersections.

As a search technique used in computing to find exact or approximate solutions to optimization and search problems, the genetic algorithm (GA) uses techniques motivated by evolutionary biology such as inheritance, mutation, selection, and crossover. A proportion of the existing population is selected to breed a new generation. Individual solutions selected through a fitness-based process, a fitness function, are typically more likely to be selected.

As the diversity of biological evolution, complex operations of mutation, selection, and crossover affect the

approximate solutions in genetic algorithms. The paper tries to solve the shortest driving time problem by using the genetic algorithm and analyzes influences due to factors of operations of evolution on the execution time, the evolution generation, and difference between the approximate solution and the optimal solution. The experimental results provide us essential information to improve the genetic algorithm for the shortest driving time problem.

This paper is organized as follows. In Section 2, the background information of the shortest path problem and the genetic algorithm is given. In Section 3, the shortest driving time problem is defined. In Section 4, experiments and simulation results will be shown. Analysis and discussion will be given in Section 5. Section 6 concludes this paper.

II. BACKGROUND

A. Shortest Path Problem

In graph theory, the shortest path problems can be divided into single-source shortest path problems and all-pairs shortest path problems. The single-source shortest path problem is the problem of determining a path between the source and destination nodes. The most famous algorithms are the Dijkstra's algorithm [1] and the Bellman-Ford [2][3] algorithm. The all-pairs shortest path problem is the problem of finding the shortest path between each two nodes in the graph. The most famous algorithm is the Floyd-Warshall algorithm [4][5].

The shortest driving time problem considers only the source and the destination without negative weight edges. We can apply the Dijkstra's algorithm to solve the problem. The time complexity of the Dijkstra's algorithm is $O(|V|^2 + |E|)$ where $|V|$ is the number of nodes, and $|E|$ is the number of edges. However, when the amount of nodes is large, the Dijkstra's algorithm costs enormous time to find the optimal solution. Another way is to use the genetic algorithm with less time cost to find an approximate solution instead of the optimal solution.

B. Genetic Algorithm

Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology. As stated by John H. Holland in 1975 [6], the

genetic algorithm has a wide scope of applications, including economics, engineering, machine learning, genome biology, game theory, neural networks, et cetera.

Figure 1 show steps of the genetic algorithm, which described as follow:

- Initialization of population
- Choice of a fitness function and evaluation fitness value of each individual in the population
- Selection of better ranked part to reproduce
- Breeding new generation's population by crossover and mutation
- Replacement of the worst ranked part of population with the new generation's population
- Repeating this generational process until the termination condition has been reached

There are several algorithms to solve the shortest path problem by using genetic algorithms such as the Munemoto's algorithm [7], Inagaki's algorithm [8], and Chang's algorithm [9]. Munemoto uses variable length chromosomes and Inagaki uses fixed length chromosomes in their algorithms. Chang's algorithm is shown to be better than the previous two algorithms.

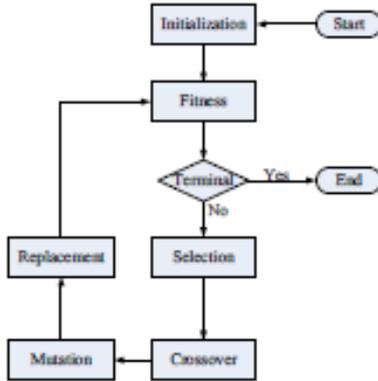


Figure 1. Flowchart of genetic algorithm

III. SHORTEST DRIVING TIME PROBLEM

The shortest driving time (SDT) problem [15] can be formulated into an integer programming model. The notation list of its mathematical model is given as follows:

Problem Parameters:

N	set of all nodes
A	set of all links
S	source node, $\in N$
D	destination node, $\in N$
i, j	index of node i, j , $\in N$
$\langle i, j \rangle$	node i to node j , directional
E_{ij}	link node i to node j
d_{ij}	distance of node i to node j
v_{ij}	velocity of node i to node j

Problem Decision Variables:

T_{ij}	cost time of node i to node j , $\in R^+$
U_{ij}	binary, 1 if the link from node i to node j exists in the routing path, 0 otherwise
t	total drive time, $\in R^+$

The distance d_{ij} is the weight of the shortest path between node i and node j . SDT problem defines another weight v_{ij} as the road speed limit, thus we can compute the time cost $T_{ij} = d_{ij} / v_{ij}$. The Dijkstra's algorithm is rewritten in the following:

Minimize $t = \sum_{i=S}^D \sum_{j=S}^D T_{ij} U_{ij}$ subject to

$$\sum_{j \neq i}^D U_{ij} - \sum_{j \neq i}^D U_{ji} = \begin{cases} 1, & \text{if } i = S \\ -1, & \text{if } i = D \\ 0, & \text{otherwise} \end{cases} \text{ and } \sum_{j=i}^D U_{ij} \begin{cases} \leq 1, & \text{if } i \neq D \\ = 0, & \text{if } i = D \end{cases}$$

Where $U_{ij} \in \{0,1\}$, for all i and $T_{ij} = d_{ij} / v_{ij}$

The steps of our algorithm based on Chang's algorithm to solve the shortest driving time problem as following:

Step 1. Genetic representation:

Chromosomes with various lengths are used, and the maximum length is N (the number of map nodes). Chromosomes start at S and end at D . Figure 2 shows an example of chromosome encoding from node S to node D .

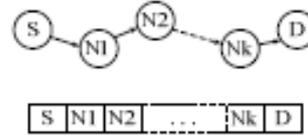


Figure 2. Example of a chromosome

Step 2. Population initialization:

There are two ways to initialize the population. One is called *restart*. During the population initialization stage, the rule states that a node cannot be visited twice to prevent from occurrence of looping. When initialization failed, one restarts the initialization process from the source to find the path again. The other way is called *rollback*. It works by the same rule to initialize population, but it will go back one node when initialization failure occurs.

Step 3. Fitness function:

The fitness function is defined as

$$f = \frac{1}{\sum d_{ij} / v_{ij}}$$

Where f represents the fitness value of the chromosome, d_{ij} represents the distance from node i to node j , and v_{ij} represents the velocity from node i to node j .

Step 4. Selection:

A tournament selection scheme with tournament of 2 is used.

Step 5. Crossover:

The crossover operation finds the same nodes from two chromosomes and randomly sets the crossover point within the nodes. The crossover operation is illustrated in Figure 3. Arrows are used to indicate nodes appeared on both chromosomes and these nodes are suitable candidates to do crossover. As shown in the figure, node 2 (N2) is randomly selected to do crossover.



Figure 3. Example of a crossover operation

Step 6. Mutation:

The mutation operation sets the mutation point in the chromosome randomly to perform the mutation. Figure 4 shows an example of the proposed mutation scheme. The nodes, except the destination node D, after the selected node (N2) have been mutated.

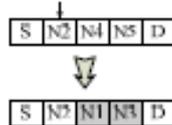


Figure 4. Example of a mutation operation

Step 7. Termination:

The generational process is repeated until a termination condition is achieved. The termination condition defines the max number of generations and the percentage of population converged to a fitness value.

IV. EXPERIMENTS AND RESULTS

The experimental environment is as follows: (1) CPU: Intel Core2 Quad 2.33 GHz (2) RAM: 3.49GB, (3) Windows XP sp3, and (4) Microsoft Visual Studio 2005.

The virtual square matrix maps have sizes of 8 x 8, 16 x 16, 32 x 32, and 64 x 64. As shown in Figure 5, the source is at the upper left corner and the destination is at lower right corner. The distances between nodes are fixed at 40. The maximum velocities between nodes are varied from 5 to 10. And the limit of generational processes is set to 1,000. All experiments are done for 10,000 times.

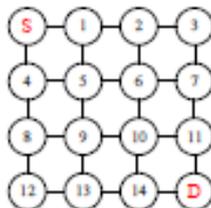


Figure 5. 4 x 4 virtual square matrix map

We evaluate the Dijkstra's algorithm and the genetic algorithm for the shortest driving time by defining a Difference term as follows:

$$\text{Difference} = \frac{\text{Genetic cost} - \text{Dijkstra cost}}{\text{Dijkstra cost}} \times 100$$

Where Genetic cost is the shortest driving time computed by using the genetic algorithm and the Dijkstra cost is the shortest driving time computed by using the Dijkstra's algorithm.

A. Initialization Methods

We investigated the influences on the execution time and Difference of the two kinds of initial population. TABLE I presents the CPU execution time (in ms) for maps of various nodes by using the two population initialization methods and various population sizes. TABLE II presents the Difference between the approximate solution computed by the genetic algorithm and the optimal solution computed by the Dijkstra's algorithm.

TABLE I. RUN TIME OF INITIALIZATION

Pop. size	Restart				Reback			
	64	256	1024	4096	64	256	1024	4096
100	0.4	2.0	20.2	N/A	0.3	1.1	3.5	13.7
200	0.9	4.0	40.1	N/A	0.6	2.1	6.8	26.9
300	1.3	6.0	62.0	N/A	0.9	3.1	10.3	39.9
400	1.8	8.0	81.4	N/A	1.3	4.2	13.7	53.0
500	2.1	10.1	99.9	N/A	1.5	5.3	17.0	66.0

* Pop. Size stands for Population size

TABLE II. DIFFERENCE OF DIJKSTRA'S ALGORITHM

Pop. size	Restart				Reback			
	64	256	1024	4096	64	256	1024	4096
100	12.0	20.4	33.4	N/A	10.9	20.3	36.9	74.2
200	9.2	19.0	30.1	N/A	8.3	19.1	32.4	66.2
300	7.6	18.1	28.5	N/A	6.7	18.2	30.8	62.5
400	6.5	17.2	27.5	N/A	5.8	17.6	29.7	60.1
500	5.9	16.8	26.8	N/A	5.0	17.1	29.2	58.1

From Table I, we observe that in population initialization stage, the restart type does not work for maps with 4096 nodes. For the execution time, the reback type out-performs the restart type as the number of nodes on the map increases. But for the Difference, the restart type is able to find better solutions when nodes numbers are over 256.

B. Mutation Rate

In this experiment we investigate the influence due to the mutation rate on the genetic algorithm by setting the crossover rate to 80%, the converging rate to 80% on a 64 nodes map for the generations, Difference, and the

execution time due to various population sizes and mutation rate on the genetic algorithm shown in Figure 6 to 8.

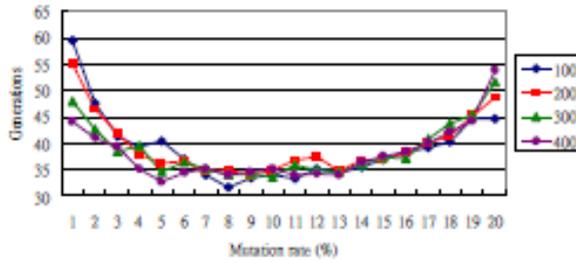


Figure 6. Mutation rate versus generations of various population sizes

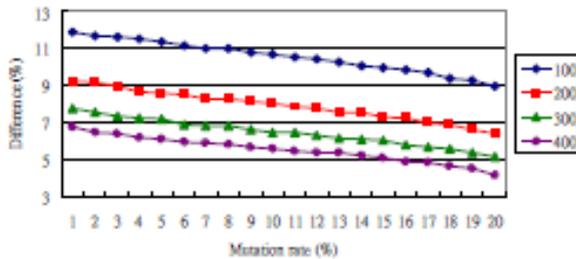


Figure 7. Mutation rate versus difference of various population sizes

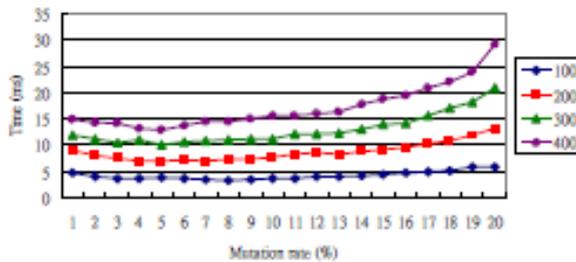


Figure 8. Mutation rate versus execution time of various population sizes

C. Crossover Rate

In this experiment we study how the crossover rate affects the genetic algorithm by setting the mutation rate to 8% and the converging rate to 80% on a 64 nodes map. Figure 9 to 11, trends for generations, Difference, and execution time due to various population sizes.

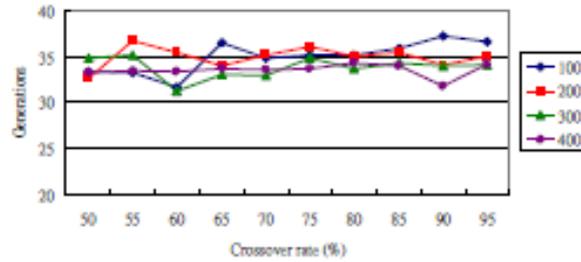


Figure 9. Crossover rate versus generations of various population sizes

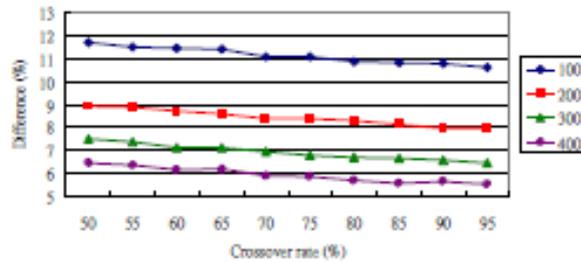


Figure 10. Crossover rate versus difference of various population sizes

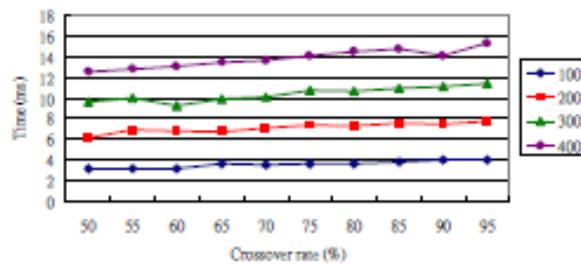


Figure 11. Crossover rate versus execution time of various population sizes

D. Population Size

From the experiments of mutation rates and crossover rates, we find that the chromosome population size plays an important role on the genetic algorithm. In this experiment we continue to investigate the influences of the population size by setting the mutation rate to 8%, the crossover rate to 80%, and the converging rate to 80%. Figure 12 to 14, trend for generations, Difference, and execution time, show the influence due to the population size for a map of 64, 256, and 1024 nodes.

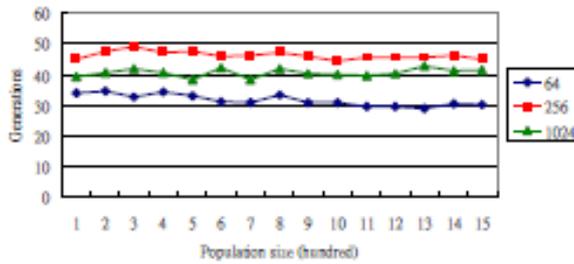


Figure 12. Population size versus generations of various map nodes

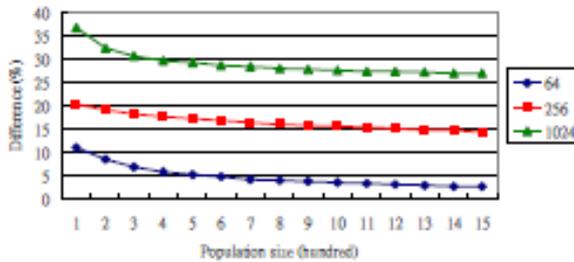


Figure 13. Population size versus difference of various map nodes

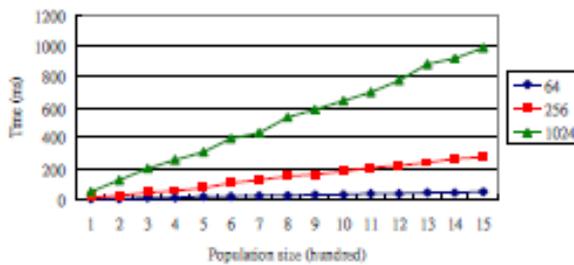


Figure 14. Population size versus execution time of various map nodes

E. Converging Rate

In this experiment we study how the terminal condition affects the genetic algorithm. We fixed the population size as 300, the mutation rate as 8%, and the crossover rate as 80%. Figure 15 to 17, trend for generations, Difference, and execution time, illustrate the influence due to the converging rate for a map of 64, 256, and 1024 nodes.

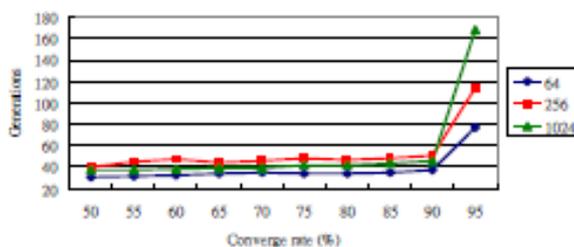


Figure 15. Converging rate versus generations of various map nodes

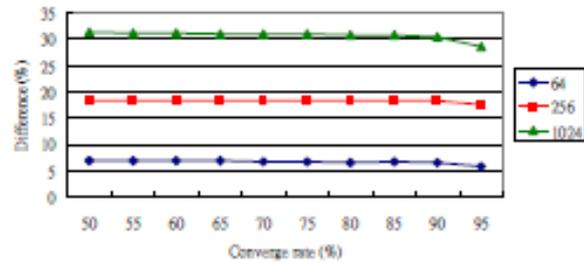


Figure 16. Converging rate versus difference of various map nodes

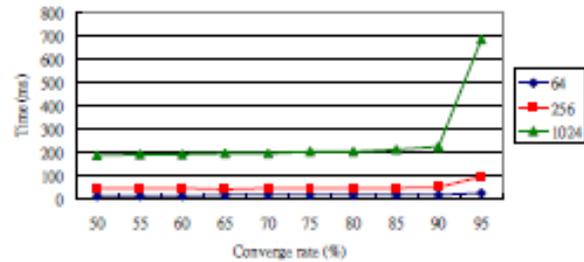


Figure 17. Converging rate versus execution time of various map nodes

F. Genetic Algorithm's Operation Time

In this experiment we analyze the execution time of each operation in genetic algorithm, as shown in Figure 18. The operation time includes times spent on the population initialization, fitness, selection, crossover, and mutation stages. We set the population size to 300, the mutation rate to 8%, the crossover rate to 80%, and the converging rate to 80%, and change the map nodes from 64 to 4096. The plots show that the time cost of the selection stage depends a lot on the population sizes.

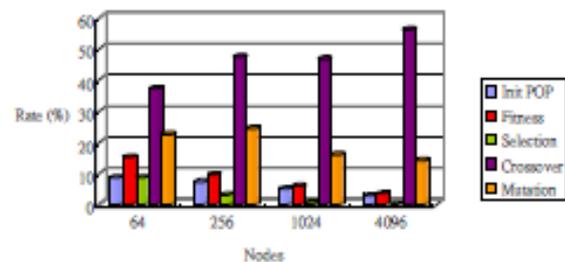


Figure 18. Comparison of genetic algorithm's operation time

V. ANALYSIS AND DISCUSSION

Based on results of above experiments that examine the influences on the execution time and Difference due to factors including nodes on the map, the population size, the mutation rate, the crossover rate, and the converging rate, Table III gives summary of each factor for its influence on

the genetic algorithm for the shortest driving time problem. For time-critical applications, such as in real time systems or in emergency, immediate responses are required. The user may consider the execution time as the key factor when using the genetic algorithm to find approximate solutions.

With the nodes on the map increase, more execution time is needed and much Difference occurs by using genetic algorithms. One can argue that since the number of initial population is relatively small compared to the vast number of nodes on the map, it will cause the genetic algorithm to converge too early to obtain the local optimal solution.

As for the population initialization, the restart type cannot work on maps of vast node numbers and the reback type often results in local optimal solutions. For the crossover operation, it costs a lot of time to find the crossover point and it constitutes most percentage of the execution time in running the genetic algorithm.

TABLE III. SUMMARY OF FACTORS AFFECTING THE GENETIC ALGORITHM FOR SHORTEST DRIVING TIME PROBLEM

Factor	Description	Exe Time	P. D.
MD	The number of nodes on map increases	More	Less
PS	The size of population increases	More	More
MR	The mutation rate is too small (< 5%) or too large (> 15%)	More	More
MR	The mutation rate between 5% and 15%	---	More
COR	The crossover rate increases	More	More
CVR	The converge rate increases (especially > 95%)	More	More

MD: nodes on a map, PS: the population size, MR: the mutation rate, COR: the crossover rate, CVR: the converging rate, Exe Time: the execution time, P. D.: the precision degree compare with optimal solution.

VI. CONCLUSIONS

The shortest driving time problem is very important for 4C applications. With the increase of the nodes on the map, navigators need more time to find the best path to destinations for vehicle drivers. The Dijkstra's algorithm with time complexity of $O(|V|^2+|E|)$ no longer satisfies the requirements when applied on a real world map with complex traffic conditions. As a result, the genetic algorithm is applied to solve the problem and factors affecting the genetic algorithm become an important design issue. The salient characteristics of the factors affecting the genetic

algorithm we find in the paper provide us essential information to improve the genetic algorithms for the shortest driving time problem.

ACKNOWLEDGMENT

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無研發成果推廣資料

98 年度專題研究計畫研究成果彙整表

計畫主持人：林祝興		計畫編號：98-2221-E-029-021-					
計畫名稱：主動式全方位隨處照護系統之設計與實作							
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	2	2	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	1	1	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	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	4	4	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	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%		

<p>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。)</p>	<p>無</p>
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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	
	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）

本計畫利用符合 ZigBee 聯盟規範之感測器設備，建構出適合室內定位的網路拓撲，利用感測節點傳回訊號的強度變化，設計出一種室內快速定位演算法。經過實驗證明，訊號的強度與感測器擺設的角度，將影響定位的精準度，我們針對不同的室內空間，採取不同的感測節點佈署方式，進而得到較精確的定位結果。此外，本計畫亦針對長時間靜止或經常移動的被照護者，找出最佳的節點佈署方式以及最佳定位的間隔秒數，所以本計畫完成之定位系統其應用彈性極高，可針對不同的應用環境進行參數調整。

本計畫所進行的一系列實驗，不僅可驗證定位演算法的正確性，也培養參與人員的高度耐心、分析資料的能力以及團隊合作的精神。實驗之成果及開發之相關程式，日後可供此領域研究人員參考之用，對國內學術發展盡棉薄之力。

