行政院國家科學委員會專題研究計畫 成果報告

以多專家知識整合為基礎之半導體機台堆貨成因分析系統
研究成果報告(精簡版)

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目錄

1 前言

半導體產業的製造加工流程，往往需要數百個步驟，耗時數個月，才能加工完畢，倘若加工過程中因為機台出了問題而導致加工停滯不前，那麼勢必導致一些產品出貨的時程延誤，引起產能的降低，造成業者莫大的損失。

目前半導體產業所設計的堆貨成因分析系統，都是由單一人員進行整體架構的規劃，並且使用固定程式判斷邏輯進行堆貨原因的分析，如此，將會造成以下的問題：

當機台發生堆貨時，固定邏輯的程式通常只能分析關聯性較單純的堆貨成因。然而生產線上發生堆貨時，通常堆貨成因有許多關聯性，也因此，使得判斷堆貨因素的規則千變萬化。這樣的問題，我們可以利用知識擷取方法去導引專家將判斷堆貨原因的規則擷取出來，便能夠了解各個堆貨原因之間的關聯性。

堆貨成因分析系統的判斷邏輯若僅靠資訊人員一個人決定，便無法觀察到廠房裡機台整體的製造過程，所分析的結果導致過於主觀，在邏輯的判斷上就可能會造成疏忽，分析結果自然也就無法達到真正的成效。我們可以利用多專家系統將多位專家的知識擷取出來並加以整合，以產生客觀的分析規則，而不再有單一專家判斷邏輯過於主觀的問題。

傳統以固定邏輯所開發出的分析程式缺乏調整判斷規則的彈性，因此無法讓決策人員得到適當的協助。我們可以靠專家系統將知識及規則存入知識庫及規則庫中，如此可以方便於參數的新增、修改、刪除、查詢，以解決了每修改參數就必需連同程式一同修改的問題。

從以上所歸納的三點，可以清楚的瞭解必須靠多位專家分析機台堆貨成因的知識納入系統，才能避免系統過於主觀的缺陷。因此，本計劃開發出一套機台堆貨成因分析系統(Pileup Cause Analysis System，PICAS)。此套系統可以擷取出多位專家的知識並加以整合，而不再有單一專家判斷邏輯過於主觀的問題，PICAS 並將整合後的知識儲存至知識庫以便於新增、修改、刪除、查詢，亦解決了每修改參數就必需連同程式一同修改的問題。

2 研究目的

本計劃運用知識工程的技術，針對多位專家對於生產線上所有可能面臨的問題及解決方案的經驗法則，進行萃取以及整合以設計一套機台堆貨成因分析系統(Pileup Cause Analysis System，PICAS)，利用整合多專家知識之後所得到的規則，對於機台堆貨的成因進行分析，以提供給半導體製造廠的決策人員使用。由於 PICAS 之決策知識乃萃取自多位機台管理專家，可避免單一專家知識過於主觀的缺點；同時 PICAS 是以專家系統為設計基礎，其模糊規則可隨時根據機台實際運作情況的改變而調整，因此 PICAS 可提供廠務對於機台上的管理較彈性且客觀的分析結果。

3 文獻探討

本節將介紹相關研究與本論文應用製作系統時所使用的相關技術。本節將分為三節：3.1節經由半導體晶圓生產製造流程的介紹可瞭解在如此錯綜複雜的製程中，各種影響機台加工的潛在因素也隨之複雜。3.2節探討如何將探討目前現階段較好的知識擷取方法，並利用此方法擷取機台的潛在因子。3.3節將探討如何將多位專家的知識擷取出來並加以整合。

3.1 半導體晶片製成

半導體主要加工製造方式是由矽晶圓閉始，經過一連串加工製程步驟，其中包括了光學顯影、快速高溫製程、化學氣相沉積、離子植入、蝕刻、化學機械研磨與製程監控等前段製程，以及封裝、測試等後段製程方始完成[1][2]。

一般將晶圓製造過程稱為前段製程（Front -end ） ，包括構裝製程稱為後段製程小 Ack - end ）、晶圓針浪 J （ Circuit probe ： CP ）以及晶圓製造（Fab ）。其中又以晶圓製造流程最為複雜，製造加工流程往往需要數百個步驟，耗時數個月，才能加工完畢。倘若加工過程中因為發生機台故障導致必須耗費長時間維修、亦或是人員疏失使得原先安排的進度落後等等，使得機台堆貨無法加工而停滯不前，那麼決策人員在尋找機台堆貨的真正原因便是一大考驗。因為如果耗費太多時間或找不出真正原因，那麼勢必影響出貨的時程，導致產能的降低。

3.2 知識擷取的方法

要建立一個可有效分析機台堆貨原因的系統，必須先自專家經驗中的知識擷取出來並將知識儲存至知識庫。本節將分為三個小節介紹各種知識擷取方法：3.2.1 凱利方格技術：本小節介紹知識擷取最為傳統的方法。3.2.2 隱含知識的擷取技術：此方法的優點為擷取出隱含知識。3.2.3 模糊知識的擷取技術：此技術可以將專家對談中的語意強度轉化為模糊值，成為知識產生的一個重要參數，另外，模糊表格中也多了信心度可以讓決策者多一份參考的依據。

3.2.1 凱利方格技術

Kelly認為人類的行為之所以有差異，是因為每個人組織其「個人建構系統」（Personal Construction System）[21]的方式不盡相同。不同的個人建構系統導致每個人有不同的行為與不同的人格，當相同的事件發生時，就會產生不同的反應與解決方式。Kelly於1955年於個人建構理論[18]中（Personal Construct Theory）提出凱利方格技術（Kelly’s Repertory Grid Technique）。Kell所提出的知識表格是一種互動活動所產生的資訊，經由知識工程師與專家對談的過程將專家所具備的知識擷取出來[6]，它分為三個主要成分（1）準備元素（Elements），（2）配對屬性組（Constructs）[10]，（3）連結機制（Linking mechanism）[16]由此構成知識表格[13][14][15][20]。

凱利表格（Repertory Grid）是早期知識擷取的方法，不過此方法只能擷取到簡單顯而易見的知識。在知識的擷取過程之中，常會因為使用的擷取方式或知識工程師的引導方式不同或是知識表達方式的差異，導致一些知識未被擷取出來，如此的問題會影響後段規則產生發生遺漏或偏頗的情形，故在下節中解釋這種演進後的方法。

3.2.2 隱含知識的擷取技術

「隱含的知識」（Embedded Meaning）是由黃國禎及曾憲雄教授於1990年所提出的理論[17]，在知識的擷取過程之中，常會因為使用的擷取方式或知識工程師的引導方式不同或是知識表達方式的差異，導致一些知識未被擷取出來，如此的問題也會影響後段規則產生發生遺漏或偏頗的情形。為了解決這個嚴重的問題，黃國禎及曾憲雄教授提出隱含知識的擷取技術 EMCUD（Embedded Meaning under Uncertainty Deciding）[17]，它使用了一個多資料型態的知識表格，並使用了「屬性序列表格」（Attribute Ordering Table，AOT）來表達各元素之間的相對重要性及其序列關係。再加上屬性序列表格，它便可以從專家的對談中擷取出隱含知識，不過這樣的知識表格依然無法將專家的語意強度表達出來，為了解決這種問題，另一種方法被提出，那就是模糊知識的擷取技術（Fuzzy table）它可以處理模糊型態的資料，此種演進後的技術將在下一節中探討。

3.2.3 模糊知識的擷取技術

傳統的知識表格無法將專家的語意表達出來，所以模糊知識表格（Fuzzy table）[18]被提出，建構模糊表格的程序和知識表格法相類似，它的特點是可以將專家的語意強度轉化為模糊值，成為知識產生的重要參數，不過此方法只能應用在單一專家上，本論文的旨意在於以多專家的知識為基礎去分析機台堆貨成因，既然是多位專家的知識就必須將知識做整合，故我們在2.3節中探討知識整合的技術。

3.3 知識整合的技術

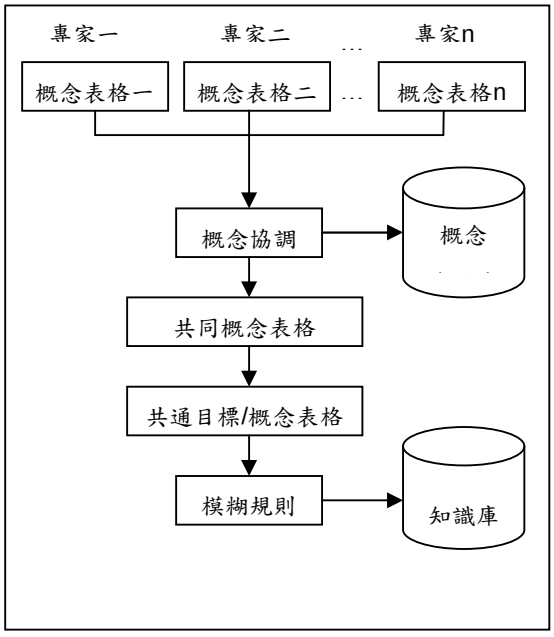
在建置專家系統時，為了取得較為客觀的推論規則，往往需要將多位專家的知識加以整合。例如：多專家知識表格擷取（Multiple-Expert Repertory Grid Elicitation，MERGE）[9]、多專家知識整合法（Fuzzy Integration for Numerous Experts，FINE） [12]，以下就介紹這兩種多專家的知識整合方法。

3.3.1 多專家知識表格擷取

多專家知識表格擷取（MERGE）是一種以知識表格（Repertory Grid）為基礎的方法[9]，用以擷取並整合多專家的知識，如此一來可以有系統的自多專家環境下擷取並整合知識，但是如果要加入專家的語意強度，那麼多專家知識表格擷取（MERGE）就無法進行知識的整合工作，為了解決這種問題，另一種方法本論文將會在下一節中解釋這種演進後的方法。

3.3.2 多專家知識整合法

多專家知識整合法（FINE）是一種以知識表格（Repertory Grid）為基礎 [9]，評等的方法則是改良自傳統的成對比較矩陣的模糊變量成對比較矩陣，除了原來的評定值之外，它還加上了模糊值，可以處理語意強度方面的問題，以做為更精確計算的參數,流程如下圖所示。



多專家知識擷取法（FINE）不但可以從多專家環境下擷取並整合知識，亦可依照不同的專家因擅長不同的領域而對專家有不同的評等，並增加了利用模糊變量用以清楚地表達專家內心對概念的評等，藉此能夠了解各概念之間的相對重要性，另外它也可以處理專家對談中語意強度的問題，將語意強度轉換成確定值。既然多專家知識擷取法（FINE）有如此多優點，本論文將利用它來擷取並整合機台堆貨原因的知識。

4 研究方法

本節將介紹多專家模糊整合法（Fuzzy Integration for Numerous Experts，FINE）如何擷取並整合機台堆貨原因的專家知識，以及本計劃之系統架構。本節分為：4.1 機台堆貨原因之專家知識擷取。4.2 機台堆貨成因分析系統之製作。

4.1 機台堆貨原因之專家知識擷取

目前半導體製造廠內的生產機台因為堆貨的現象，而導致製造時程的延誤及產能的降低。所以我們請由半導體部門經理尋找多位專家制定生產機台有哪些堆貨原因，透過不同專家所看到不同的方向，來設定出堆貨原因的臨界值。當擷取出專家的知識樣本後，我們以知識庫的原理來設計多專家系統的架構進行研究，將生產線上所有面臨過的事件匯整至系統上，最後產生出規則。機台一旦發生了堆貨，我們可以利用這套規則來分析真正的原因來源為何。

定義好管理知識的範圍後，那麼我們知識擷取的目標則訂定為當機台發生堆貨時與它相互影響的關係[3][7]，如下表所示。

平衡指數不佳	一般整體而言，半導體產業希望整個生產線的生產是平順的，我們稱此為平衡指數(Line Balance)，過多的材料在堆在機台上或過少的材料讓機台無載都會影起平衡指數不佳，換句話說，一旦發生堆貨，機台也就很難充份利用，勢必會影響到生產線的平衡指數。
產品週期過長	矽晶圓從投片到出貨的平均時間稱之為產品週期(Cycle Time)，在這段其間如果常堆貨，出貨的時間也跟著拉長，因此產品週期的平均水準連帶受到影響。
超過材料時效	有些材料有時效的特性，為了品質上的考量，我們就會設定材料的時效性(Q-timer)。比如再生產線上當後端的機台發生堆貨時，會造成前端機台所生產的半成品無法及時處理，而發生品質不佳的情況。
出貨時間過久	材料在未出貨前，材料的多寡與機台的狀況，會影響到出貨(wafer out)的數量，當發生堆貨時，出貨的時間很容易延遲。
產量過少	一片材料在一個機台加工後至下一個機台，我們稱為一產量(Move)，當發生堆貨時可能無法達到 Move 既定的目標，所以我們可以藉由一天的 Move 的多寡來分析堆貨的狀況。
週轉率太低	一天所移動的材料片數除以所有材料片數，我們稱之為週轉率(turn over rate)，隨著機況的不同，週轉率也會受到影響，當週轉率太低時，機台發生堆貨的狀況可能是非常嚴重的。

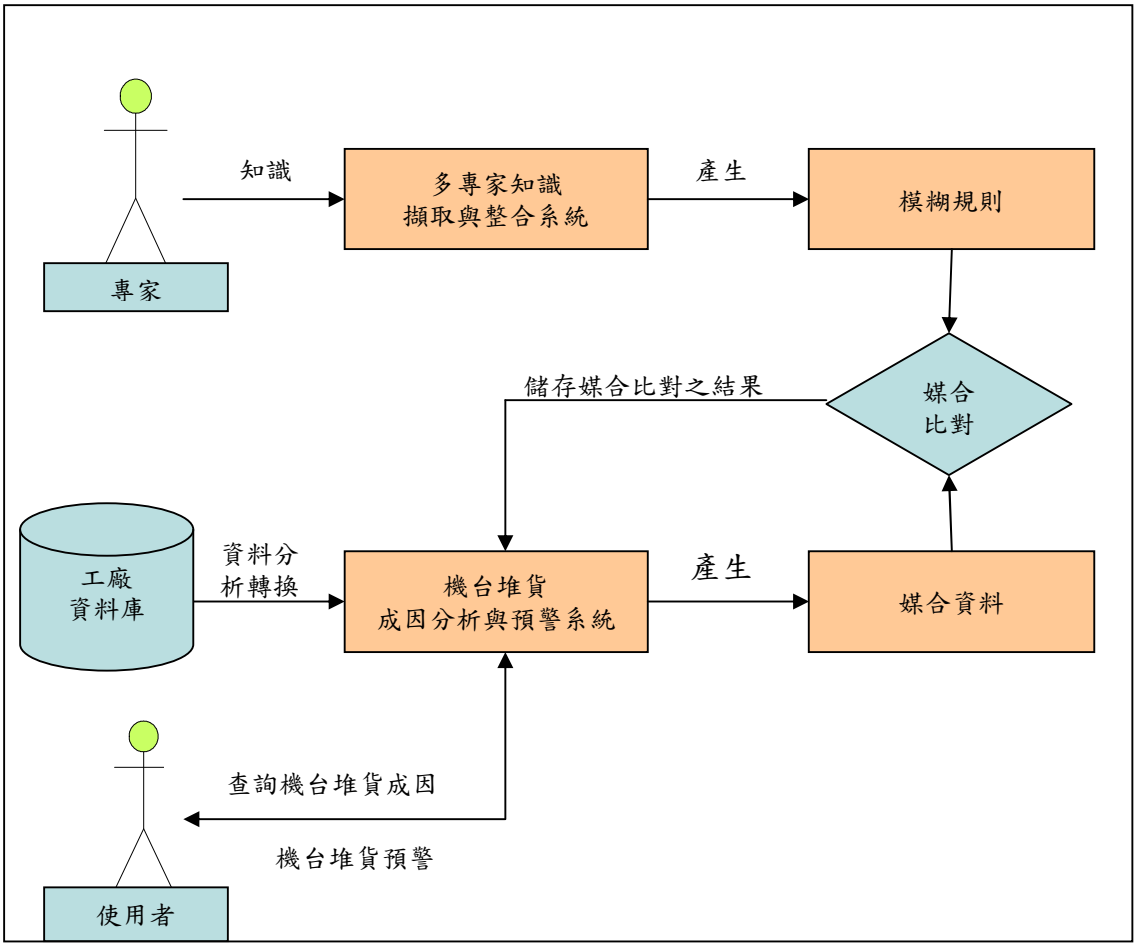
當我們確立好目標與範圍之後，我們就可以開始進行專家知識的擷取及整合工作了。步驟如下：

1. 請每位專家分別建立概念表格
2. 整合各專家之概念表格以建立共同概念表格
3. 請半導體的部門經理對於專家的專業領域加以評等
4. 以模糊變量成對比較矩陣評等概念表格並計算概念權重
5. 評等目標/概念表格
6. 整合模糊知識及產生規則

4.2 機台堆貨成因分析系統之製作

本計畫實作一套通用型的多專家知識擷取與整合系統；接著利用此系統對多位半導體廠務專家進行堆貨原因知識擷取與整合，並產生堆貨成因分析規則；最後運用所產生之堆貨成因分析規則實作一套專家系統，在線上進行堆貨因素即時分析，並在分析出堆貨現象時發出警訊給廠務人員，以便進行盡速排除堆貨因素，使機台維持一定的生產效率。

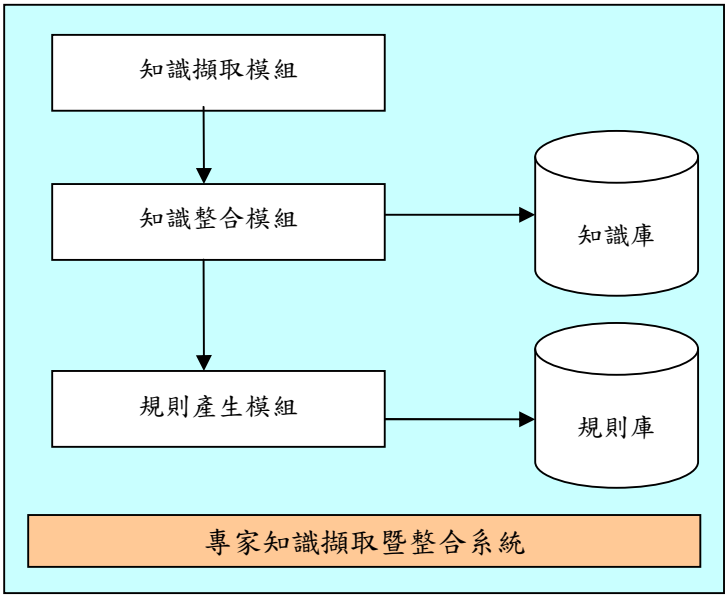
本計劃所規劃之系統架構如下圖所示：



依此系統架構，專家們可以透過多專家知識擷取與整合系統來產生模糊規則；工廠資料庫經過資料轉換後利用機台堆貨成因分析系統產生媒合資料，模糊規則與媒合資料比對後，機台堆貨成因分析系統將結果回饋給使用者，同時也將結果儲存起來，以便使用者可以查詢機台堆貨成因。

4.2.1 多專家知識擷取與整合子系統

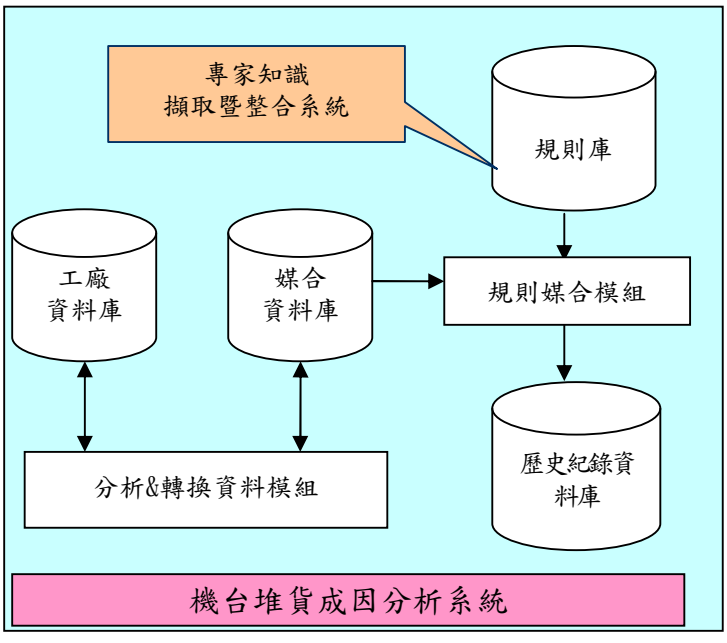
多專家知識擷取與整合子系統之架構如下圖所示。



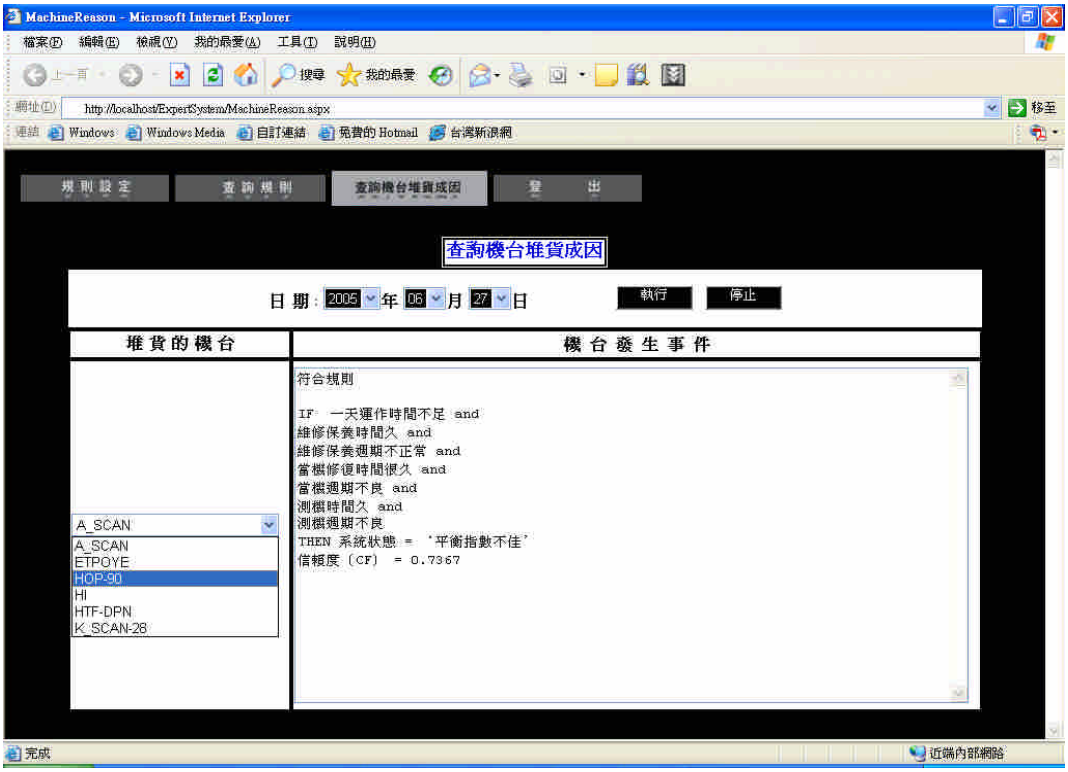
這個系統是負責專家知識擷取暨整合的工作，它包含了知識整合模組、知識庫、規則產生模組、規則庫等五項成員。在這個系統中我們預計提供下拉式選單讓專家可以利用選擇的方式將知識留存下來，再經由知識整合模組將所有專家所儲存的知識整合，繼而產生分析機台堆貨成因的模糊規則。實作完成之系統介面如下圖所示：

4.2.2 機台堆貨成因分析與預警系統

機台堆貨成因分析系統之架構如下圖所示：

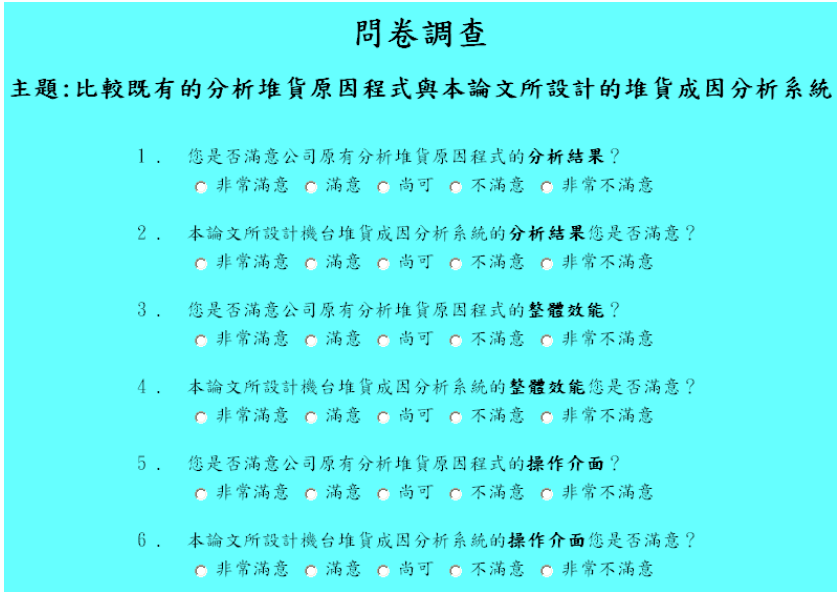


機台堆貨成因分析系統負責的工作是當工廠機台發生堆貨的現象時，分析問題的來源為何，並提供使用者查詢機台堆貨的成因。這個系統包括了：工廠資料庫、媒合資料庫、分析及轉換資料模組、規則媒合模組及歷史紀錄資料庫等，藉由專家知識擷取整合子系統產生的模糊規則與機台堆貨成因分析系統的媒合資料庫媒合，比對完成之後將所發生的事件儲存於歷史紀錄資料庫中。實作完成之系統介面如下圖所示：

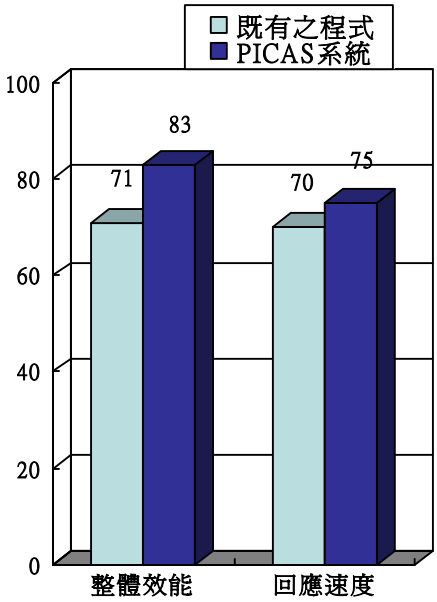


5　結果與討論

為驗證本計劃成果之可行性，本計劃獲得國內某知名半導體廠之首肯，實際上線測試一段時間後，給予決策人員一份問卷填寫既有的系統與 PICAS 之滿意程度，問卷調查的內容包括分析結果滿意度、整體效能滿意度、操作滿意度、回應速度滿意度、查詢功能滿意度，如下圖所示，



問卷調查結果如下圖所示。



經由本研究的初步驗證，發現所擷取的專家知識加上本論文所設計的 PICAS 系統，可以增加製造廠機台運作的流暢度及有效的避免時程延誤。並且達成對於堆貨原因有更快速的分析能力、減少管理人力的浪費、同時對於管理知識的保留以及決策人員經驗的傳承有莫大的助益。

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7 計畫成果自評

本計劃的研究內容與原計畫完全相符，並且 100%達成預期目標。同時本計劃之研究成果已發表一篇 SCI 期刊論文：

[1] Judy C.R. Tseng, Chih-Hsiang Wu (2007/10), “An Expert System Approach to Improving Stability and Reliability of Web Service”, to appear in *Expert Systems With Applications*, Vol. 33, No. 2. (**SCI, Impact Factor 1.247**)

由於半導體產業為我國競爭力的主要來源之一，本研究計畫之成果深具實際應用之價值，後續可進一步尋求合作企業進行技術轉移，以落實本計劃研究成果之推廣。

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

96 年 7 月 31 日

附件三

報告人姓名	曾秋蓉	服務機構及職稱	中華大學資工系 教授
時間 會議 地點	自 96 年 6 月 25 日至 96 年 6 月 29 日 加拿大溫哥華	本會核定 補助文號	
會議名稱	(中文) ED-MEDIA 2007 世界教育多媒體超媒體及電信研討會 (英文) ED-MEDIA 2007 World Conference on Educational Multimedia, Hypermedia and Telecommunication		
發表論文題目	(中文) 無所不在虛擬助教系統之研製 (英文) Development of a Ubiquitous Virtual Tutoring Assistant System		

一、參加會議經過

ED-MEDIA 2007 世界教育多媒體超媒體及電信研討會(ED-MEDIA 2007 World Conference on Educational Multimedia, Hypermedia and Telecommunication) 於今年的六月二十五日至六月二十九日在加拿大的溫哥華舉行。本會議由資訊教育策進協會(Association for the Advancement of Computing in Education, 簡稱 AACE) 主辦，該協會乃是由學界和業界有志於推廣資訊教育發展的專家所組成的非營利國際性組織，致力於創新資訊教育科技專業知識之交流。本會議主要目的在於提供各國數位學習專家學者與業界交流與觀摩的機會。

正式會議開始當天（六月二十五日）本人前往會議現場報到並領取議程及會議論文等相關資料，以便研究會議論文及對會議內容有初步的瞭解。

本人於這一次的會議中發表之論文題目為：無所不在虛擬助教系統之研製「Development of a Ubiquitous Virtual Tutoring Assistant System」，並於會議最後一天（六月二十九日）上午十點的 Session 中發表。本次會議共分五天舉行，本人報告當天的主要的議程如下：

Fri, Jun. 29

10:00 AM	Is Web 2.0 the Future of the Web? *Bebo White, Stanford University, USA*
10:00 AM	Design and Development of ReLOAMS: A Reusable Learning Objects Authoring and Management System *Yin-Leng Theng, Nanyang Technological University, Singapore; Dian Saputra, Nanyang Technological University, Singapore*
10:00 AM	SAmgI: Automatic Metadata Generation v2.0 *Michael Meire, Katholieke Universiteit Leuven, Belgium; Xavier Ochoa, ESPOL Escuela Superior Politécnica del Litoral, Ecuador; Erik Duval, Katholieke Universiteit Leuven, Belgium*
10:30 AM	Designing Presentation Review Environment with Realtime-created Hypervideo of Presentation Rehearsal *Ryo Okamoto, National University Corporation, Kochi University, Japan; Akihiro Kashihara, The University of Electro-Communications, Japan*
10:00 AM	Darwin's Voyage: Evolution of a Learning Object *George Guba, Empire State College, USA; David Wolf, Empire State College, USA*
10:30 AM	Summative eAssessments: Piloting acceptability, practicality and effectiveness

	Christina Keing, The Chinese University of Hong Kong, Hong Kong; Judy Lo, The Chinese University of Hong Kong, Hong Kong; Paul Lam, The Chinese University of Hong Kong, Hong Kong; Carmel McNaught, The Chinese University of Hong Kong, Hong Kong
10:00 AM	An Exploratory Study Of The Open Source Software Environment In A Software Engineering Graduate Course *Xun Ge, University of Oklahoma, USA; Yifei Dong, University of Oklahoma, USA; Kun Huang, University of Oklahoma, USA*
10:30 AM	Developing EFL Students' Hypertext Reading Strategy Awareness *Mohamed Badawi, English Language Department, Tabouk University, Teachers' College, Saudi Arabia; Wafi Albalawi, Computer Science Department, Tabouk University,Teachers' College, Saudi Arabia*
10:00 AM	Design-based research and doctoral students: Guidelines for preparing a dissertation proposal *Jan Herrington, University of Wollongong, Australia; Susan McKenney, University of Twente, Netherlands; Thomas Reeves, University of Georgia, USA; Ron Oliver, Edith Cowan University, Australia*
10:30 AM	Lifecycle Information Management and Utilization in an Authoring by Aggregation Environment *Lasse Lehmann, KOM - TU-Darmstadt, Germany; Christoph Rensing, KOM - TU-Darmstadt, Germany; Ralf Steinmetz, KOM - TU-Darmstadt, Germany*
10:00 AM	A Self-Assessment Tool to Help Learners Develop Teamwork Skills *Mark McMahon, Edith Cowan University, Australia; Joe Luca, Edith Cowan University, Australia; Christina John, University of Applied Sciences, Kiel, Germany*
10:30 AM	Explorations in measuring metacognition: the design of an open source assessment instrument for an online setting *Barnard Clarkson, ECU, Australia; Mark McMahon, ECU, Australia*
10:00 AM	**Development of a Ubiquitous Virtual Tutoring Assistant System** ***Ji-Wei Wu, Yea-Han Tsou, Chuang-Kai Chiou, Judy C.R. Tseng, Department of Computer Science and Information Engineering, Chung Hua University, Hsinchu, 300, Taiwan, ROC, Taiwan***
10:30 AM	E-Language Laboratory; Large Scale e-Learning Environment for Japanese Language Education *Kohji Shibano, Tokyo University of Foreign Studies, Japan*
10:00 AM	Getting Ahead at University: Using Reusable Learning Objects to Enhance Study Skills *Debbie Holley, London Metropolitan University, UK; John Cook, Carl Smith, Claire Bradley, Richard Haynes, Centre of Excellence in Teaching and Learning in Reusable Learning Objects, UK*
10:30 AM	Developing Language Competence in a Bilingual Story Sharing Forum *Nicolas Hine, University of Dundee, UK*
10:00 AM	SketchUML: The Design of a Sketch-based Tool for UML Class Diagrams *Lin Qiu, State University of New York at Oswego, USA*
10:30 AM	Heuristic Evaluations of Computer Assisted Assessment Environments *Gavin Sim, University of Central Lancashire, UK; Janet C Read, University of Central Lancashire, UK; Phil Holifield, University of Central Lancashire, UK; Martin Brown, University of Central Lancashire, UK*
10:00 AM	From the Dead Sea Scrolls to Social Sports, passing through European History: an Effective Pedagogical Format Based on 3D Worlds *Caterina Poggi, Politecnico di Milano, Italy; Aldo Torrebruno, Politecnico di Milano, Italy*
10:30 AM	Developing and Validating the Intentional Internet Search Behavior scale *Chun-Ping Wu, Syracuse University, USA; Tiffany A Koszalka, Syracuse University, USA; Shu-Ling Wu, National Penghu University, Taiwan*
10:00 AM	Cláir Bhána Idirghníomhacha' (Interactive Whiteboards) – Early findings from an Irish Project *Miriam Judge, Dublin City University, Ireland*
10:30 AM	Assessing Professional ePortfolios of Second Language Learners *Elaine Martyn, University of Hong Kong, China*
10:00 AM	An adoption model for IT in secondary schools: The teacher perspective *Gabriel López-Morteo, Universidad Autonoma de Baja California, Mexico; Marcos Galaviz-Férman,*

表 Y04

	Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Mexico; Gilberto López, Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Mexico; María Andrade-Aréchiga, Universidad de Colima, Mexico
10:30 AM	Using Online Simulations to Enhance Preservice Teacher Understanding of Science Concepts *Les Lunce, University of North Texas, USA; Bambi Bailey, Midwestern State University, USA*
10:00 AM	Taking the Case: An Evaluation of Digital Case Study Libraries *Yeong-Tay Sun, Virginia Tech, USA; Laurian Vega, Virginia Tech, USA; D. Scott McCrickard, Virginia Tech, USA*
10:30 AM	On the design of interactive visual representations: Fitness of interaction *Kamran Sedig, University of Western Ontario, Canada; Hai-Ning Liang, University of Western Ontario, Canada*
10:00 AM	Active Course Notes within a Group Learning Environment *Alan Rosselet, University of Toronto, Canada*
10:30 AM	(Re)organizing reading teacher professional development course content *Timothy Yuen, The Vaughn Gross Center for Reading and Language Arts, USA; Edmund Danyal, The Vaughn Gross Center for Reading and Language Arts, USA; Letitia Liamero, The Vaughn Gross Center for Reading and Language Arts, USA; Arnold Cano, The Vaughn Gross Center for Reading and Language Arts, USA; Carlos Tovar, The Vaughn Gross Center for Reading and Language Arts, USA*
10:00 AM	Problem and Solution Oriented Metrics For Web Based Applications *Bala subramanian Bala, RMK Engg College, India*
10:30 AM	Starting with Parallel Processing: A multi-representational learning environment for beginners *Maria Kordaki, Department of Computer Engineering and Informatics, Patras University, Greece, Greece; John Solos, Hellenic Open University, Greece*

本人於會議中也和與會的專家學者作了許多關於論文深入的討論，由討論中對本人將來的研究方向也獲得了相當多的助益。會議結束後休息了一個晚上，於六月三十日深夜搭機返台。

二、與會心得

此次赴加拿大溫哥華參加國際學術研討會，能夠與世界各地相關領域的專家學者共同討論彼此研究的心得是非常大的收穫。而與國際學術領域接軌更是一次難得的經驗。特別是在此次會議中結識來自荷蘭在 Dep. Training & Instruction, TNO Defence, Security and Safety 的 Martin van Schaik 先生，對本人的研究成果表示高度興趣，並期望能有進一步的國際合作機會。目前本人已開始與 Schaik 先生交換相關研究文件，預計在今年年底可提出國際合作計畫，使雙方的研究成果得以交流並發展出更具影響力的研究主題。國際學術研討會能夠幫助國內研究人員瞭解並學習其他相關研究領域的發展與進展，並藉以定位自己的研究方向、研究主題，並與世界各地的專家學者們分享自己的研究成果，更能開拓我們的視野，對將來進一步的研究發展將有莫大的助益。

三、建議：無。

四、攜回資料名稱及內容

1. 研討會論文集一本。
2. 研討會光碟一片。

五、其他

個人非常感謝國科會提供經費補助，俾使此次研討會得以順利成行，在會場也吸收到許多其他專家學者的研究，收穫良多。

Development of a Ubiquitous Virtual Tutoring Assistant System

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Abstract: Pedagogic scholars think that when a student is stuck on a certain problem while learning, an instant tutoring assistant is very helpful to promote his/her study. Nevertheless, the teacher is not always available to answer students' question immediately. Moreover, it would be too time-consuming for a teacher to answer students' questions one by one, especially for a popular e-course where there are thousands of students and most of the students' questions are same-alike. In this paper, a *Ubiquitous Virtual Tutoring Assistant System (UVTAS)* is developed to provide instant assistants for students' learning problems. No matter where a student is, while he/she encounters or thinks about a learning problem, he/she can obtain immediate solutions via his/her mobile device, such as a cell-phone or a PDA. UVTAS not only provides a web-interface for mobile learners, it also incorporates a SMS-interface of question-answering to support mobile learners while Internet access is not available.
Keywords: e-Learning, Ubiquitous Computing, Tutoring Assistant

1. Introduction

The development of network not only facilitates the acquirement of information, but also highlights the value and feasibility of e-learning. Most of the existing e-learning platforms focus on providing contents and performing assessments, however, tutoring assistance is less to be considered.

Pedagogic scholars think that when a student is stuck on a certain problem while learning, an instant tutoring assistant is very helpful to promote his/her study. Nevertheless, the teacher is not always available to answer students' question immediately. Moreover, it would be too time-consuming for a teacher to answer students' questions one by one, especially for a popular e-course where there are thousands of students and most of the students' questions are same-alike.

In this paper, a *Ubiquitous Virtual Tutoring Assistant System (UVTAS)* is developed to provide instant assistants for students' learning problems. No matter where a student is, while he/she encounters or thinks about a learning problem, he/she can obtain immediate solutions via his/her mobile device, such as a cell-phone or a PDA. UVTAS records the problems students ever asked, along with the solutions teachers provided, in its *problem-solving base*. When a new problem is issued, UVTAS will search the problem-solving base to find the most-similar problem and provide the associated solution to the student. If there is no similar problem found, UVTAS will automatically search through the *supplement-material base* to find a suitable fragment of supplement material which might solve the student's problem. If the student is satisfied with the solution provided, UVTAS will add the new problem and the associated solution to the problem-solving base for future problem solving. If unfortunately no suitable fragment of supplement material is

[1] To whom all correspondence should be sent.

found, an instant message will be sent directly to the teacher's mobile device, asking for manual solution from the teacher. While the teacher provides a solution to UVTAS, the solution will be sent immediately to the student's mobile device. UVTAS not only provides a web-interface for mobile learners, it also incorporates a *Short Message Service (SMS)* interface of question-answering to support mobile learners while Internet access is not available. Through our experiments, about 68~84% of students' problems are solved with satisfaction by UVTAS.

2. Relevant Works

Recent progress of computer and network technologies has encouraged the development of web-based learning environments (Hwang 2003, 2006; Tseng & Hwang 2004; Shih et al. 2006), in which students can proceed their learning activities without being limited by location and time. However, as most of the existing web-based learning systems simply provide subject materials for browsing, the students are likely to be stuck while encountering problems during the learning process without instant aid, and hence their learning performances could be significantly affected (Jonassen 2000).

Some researchers attempted to employ on-line discussion groups to cope with the problem. Nevertheless, most of the answers obtained from the discussion groups could be incorrect or incomplete; therefore, the most desirable approach is to obtain the answers directly from the teacher. Unfortunately, for a popular on-line course with thousands of students, it is almost impossible for the teacher to answer every question submitted by the students, not to mention the provision of instant aids to them. Rau et al. (Rau et al. 2004) indicated that, without face-to-face interaction, it is important to provide immediate help and interactions while proceeding online instruction.

Several virtual tutoring assistant systems (Wei and Tseng 2006, Wang et al. 2006) had been proposed based on question-answering systems (Tseng & Hwang 2006). However, most of the services provided are not ubiquitous, which are unable to provide instant problem-solving services for mobile learners. Furthermore, the solutions rely heavily on teachers to add onto the systems manually, which consume a lot of labor hours and thus reduce the efficiency of problem-solving.

To cope with these problems, we propose and develop a ubiquitous virtual tutoring assistant system which incorporates a supplement-material base as well as a solution extraction module to search, analyze, and extract automatically solutions from the supplement-material base, which relief the burden of solving problems manually by the teachers.

3. The Ubiquitous Virtual Tutoring Assistant System (UVTAS)

The system architecture of the ubiquitous virtual tutoring assistant system proposed is shown in Figure 1.

First, learners submit their problems through internet via the mobile user interfaces provided by UVTAS. The mobile user interfaces provided includes a web service and a Short Message Service (SMS). Once a problem is submitted by the learner, the *Problem Matching Module* will search the *Problem-Solving Base* to find the most similar problem that has been solved and recoded in UVTAS. If a similar problem is found, the associated solution is sent to the learner for reference. If no similar problem is found, the *Solution Extraction Module* is incorporated to extract a suitable fragment from the *Supplement-Material Base* for solving the problem. If the student is satisfied with the solution provided, UVTAS will add the new problem and the associated solution to the problem-solving base for future problem solving. If unfortunately no suitable fragment of supplement material is found, the *Manual Solution Module* will sent an instant message directly to the teacher's mobile device, asking for manual solution from the teacher. While the teacher provides a solution to UVTAS, the solution will be sent immediately to the student's mobile device. The teachers can maintain the *Supplement-Material Base* at any time through the *Material Solution Module* to provide teaching materials for UVTAS to extract possible solutions. The more supplement materials the teachers provide, the more accuracy of problem solving can be achieved by UVTAS.

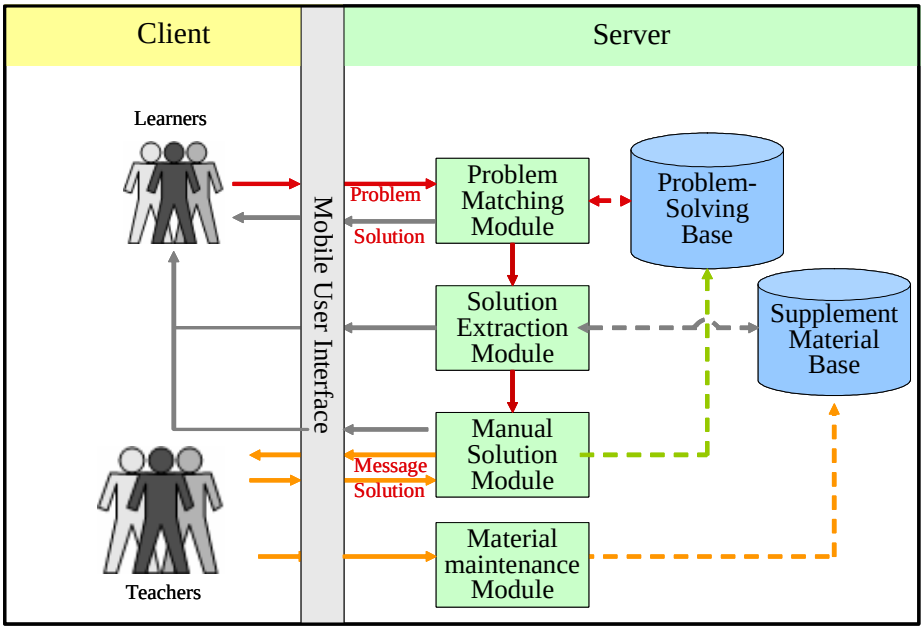

Figure 1: The structure of the Ubiquitous Virtual Tutoring Assistant System

3.1 The Solution Extraction Module

The design of the solution extraction module, which is the most distinguishable feature of UVTAS, is shown in Figure 2. The workflow is given as follows:

(1) Once a problem is passed onto, the solution extraction module will segment the words contained in the problem.
(2) The stop words contained in the problem are identified and removed, and then a *Characteristic Vector (CV)* is composed to represent the problem.
(3) The Google desktop search tool is invoked to select at most twenty related supplement materials for further analysis.
(4) The semantic fragments contained in the candidate materials are then extracted.
(5) According to the titles, the page ranks, the abstracts of the candidate materials, semantic fragments the system extracted are ranked.
(6) The solution of the problem is them selected according to the ranking result.

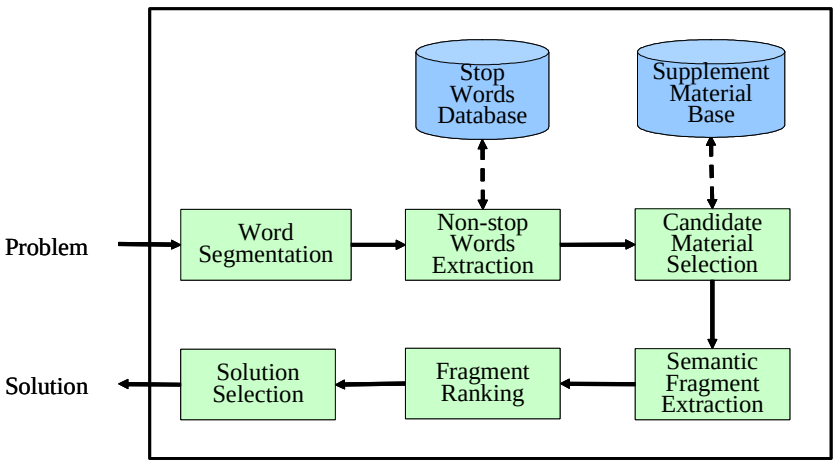

Figure 2: The Solution Extraction Module

For selecting suitable fragments as solutions, the page ranks (R), the titles (T), the abstracts (A) of the selected candidate supplement materials, as well as the semantic fragments extracted from the candidate materials, are used in our ranking algorithm. The formula for computing the similarity of the problem to a fragment of text is followed:

$$S_i = (\mathrm{N} - R_i) * 0.2 + S(\mathrm{F}_i) * 0.5 + S(A_i) * 0.2 + S(T_i) * 0.1,$$

where $S(X) = \frac{|KQ \cap KX|}{|KQ|} \cdot 0.8 + \frac{\sum_{j=1}^{n} L_j}{LX} \cdot 0.2$;

$S(X)$: similarity measurement of the semantic fragment X to the problem;
N: number of supplement materials considered;
R_i: page rank of the supplement materials that contain fragment i;
F_i: content of the semantic fragment i;
A_i: abstract of the supplement materials that contain fragment i;
T_i: title of the supplement materials that contain fragment i;
$KQ = \{K_1, K_2, \ldots, K_n\}$: keyword set of the problem;
$KX = \{K_1, K_2, \ldots, K_m\}$: keyword set of the fragment X;
LX: sum of word length of the fragment X;
L_j: total word length of occurrences of K_j in X.

3.2 The User Interfaces

The user interfaces implemented are shown in Figure 3 and Figure 4. UVTAS not only provides a web-interface for mobile learners (shown in Figure 3), but also a SMS-interface of question-answering to support mobile learners while Internet access is not available (shown in Figure 4). A prefix number (such as 01234 in the left part of Figure 4) is required in the problem submission interface to specify the SMS service incorporated. A prefix number (such as 47496 in the right part of Figure 4) is also included in the solution provided through the SMS service to indicate the problem ID.

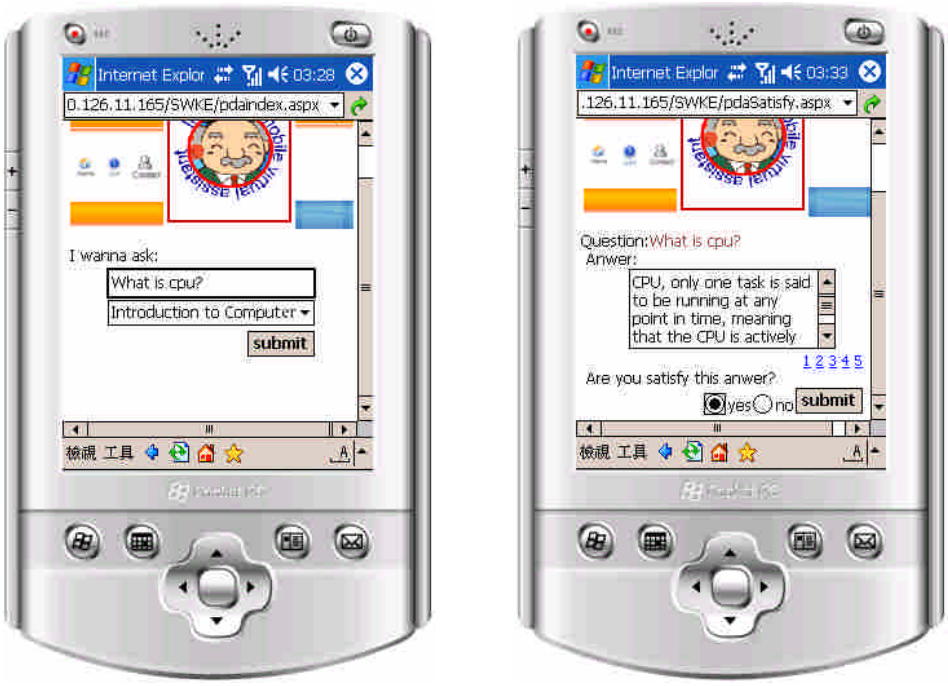

Figure 3: The web-interface for mobile learners

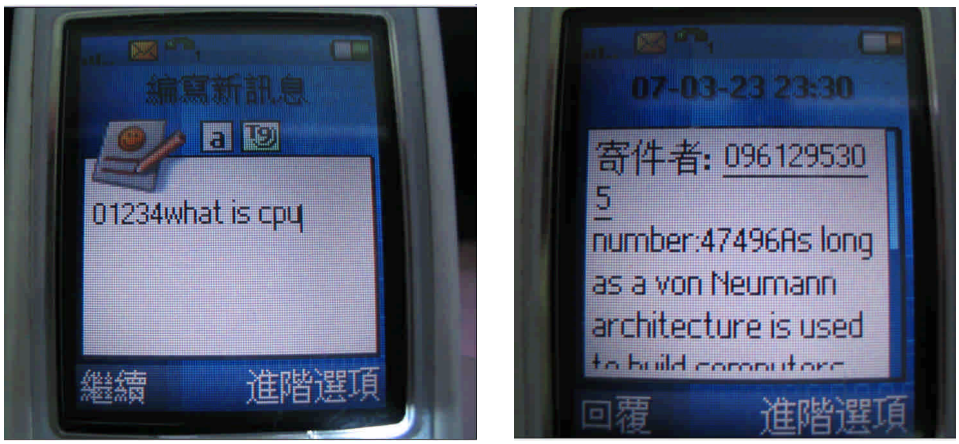

Figure 4: The SMS-interface for mobile learner

4. Experiments and Results Analysis

In order to evaluate the performance of problem-solving of the proposed system, three test banks are conducted in the experiment as shown in Table 1. The test bank 1 includes the same problems exist in the problem-solving base. The test bank 2 includes similar (but not the same) problems as those in the problem-solving base. The test bank 3 includes general problems where no similar (or the same) problem exists in the problem-solving base.

	Type of sample
Test bank 1	Existing problems
Test bank 2	Similar problems
Test bank 3	General problems

Table 1: Test banks used in the experiment

For each of the three test banks, two experiments are performed: (1) search solutions in the problem-solving base (PSB) only; (2) search solutions both in the problem-solving base and the supplement material base (PSB+SMB). The experiment results are shown in Figure 5 to Figure 7.

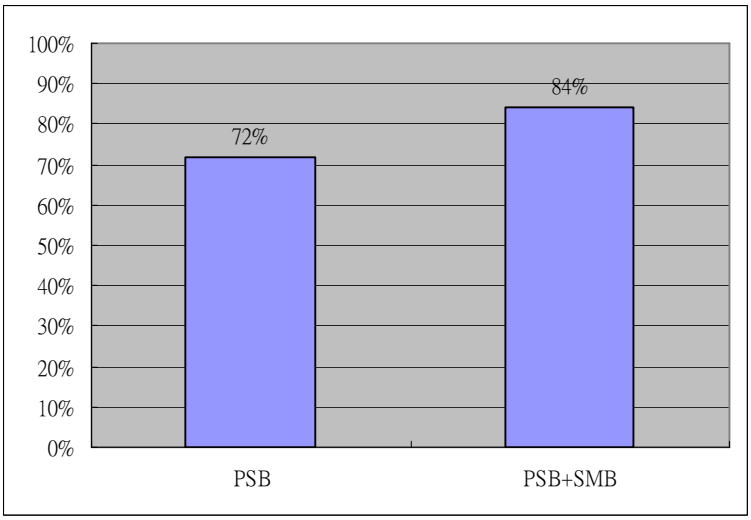

Figure 5: Comparison of the percentages of solved problems for test bank 1 (existing problems)

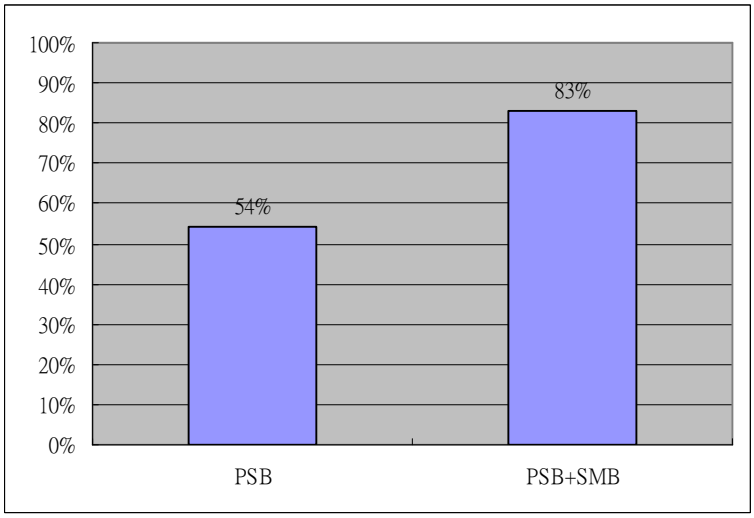

Figure 6: Comparison of the percentages of solved problems for test bank 2 (similar problems)

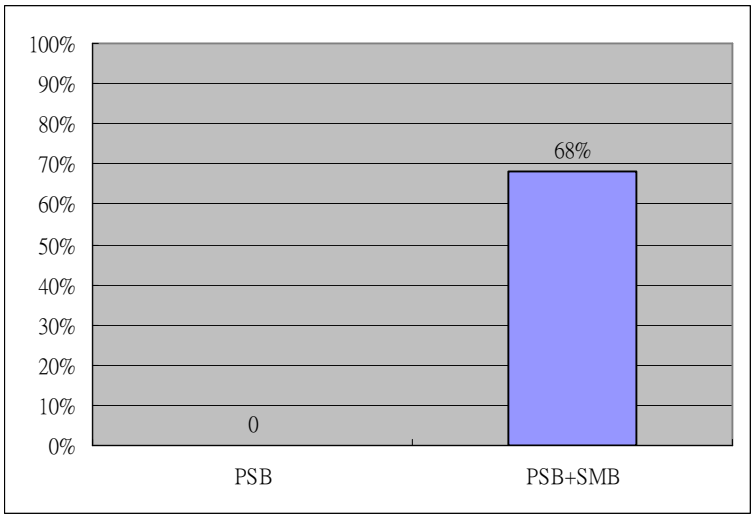

Figure 7: Comparison of the percentages of solved problems for test bank 3 (general problems)

From the experimental results, when the supplement material base is incorporated to supplement the searching of solution, the percentage of solved problems is raised from 72% to 84% for existing problems (see Figure 5); from 54% to 83% for similar problems (see Figure 6); from 0% to 68% for general problems (see Figure 7). The experiment results show that the design of supplement-material base, as well as the capability of automatically searching, analyzing, and extracting solutions from the supplement-material base, significantly increases the percentage of solved problems. That is, less requests to the teachers for manually providing solutions are needed. As most of the problems are solved instantly by UVTAS, there is less possibility for the learners to be stuck in a certain problem. And thus the learning efficiency of mobile learners will be promoted when UVTAS is employed.

5. Conclusions and future work

A ubiquitous virtual tutoring assistant system (UVTAS) is proposed and developed in this paper. UVTAS provide instant assistants for students' learning problems even when the students are on the move. No matter where a student is, while he/she encounters or thinks about a learning problem, he/she can obtain immediate solutions via his/her mobile device, such as a cell-phone or a PDA. UVTAS not only provides a web-interface for mobile learners, it also incorporates a Short Message Service (SMS) interface of question-answering to support mobile learners while Internet access is not available.

Through our experiments, about 68~84% of students' problems are solved with satisfaction by UVTAS. The experiments result also shows that it is advantageous to incorporate a supplement material base, as well as to search, analyze, and extract fragments for solutions from the supplement material that the teachers maintained. About 12% of

improvement on the percentage of solved problems for problems exist in the problem-solving base; 29% of improvement for problems similar to the problem-solving base; 68% of improvement for problems that exist no similar (or the same) problem in the problem-solving base. That proofs the superiority of UVTAS over previous virtual tutoring systems which only search in the problem-solving base.

UVTAS is a self-growing ubiquitous problem solving system. The more problems the learners issued, the more solutions records in the problem-solving base. As most of the problems students encountered are similar, after being used for a certain period of time, UVTAS will be able to solve most of the students' problems without interference with the teachers. Moreover, teachers may add as many supplement materials as they like to the supplement-material base of UVATS at their free time. The more supplement materials add, the more possibility that UVTAS finds suitable fragments for solving the problems, and thus more time is saved for the teachers to provide manual solutions.

The main innovative ideas of UVTAS based on two parts: first, the ubiquitous problem-solving interfaces provided not only through web browsers but also through SMS, which make the ubiquitous problem solving services possible for low-end cell-phones where no browser is built inside, as well as for saving telecommunication cost of Internet connection; second, the design of supplement-material base as well as the capability of automatically searching, analyzing, and extracting solutions from the supplement-material base, which further relief the burden of solving problems manually by the teachers.

In our experiments, we found that although some problems do not match any existing problem or any fragment recorded in the system, they do contain some clues for finding solutions. For example, there might be no solution for the problem "What is the architecture of a CPU?", however, it is possible that there is a solution for the problem "What is the von-Neuman machine?". As we know that nowadays the architecture of a CPU is actually a von-Neuman machine, if we can find out the strong connection between the phrases "architecture of a CPU" and "von-Neuman machine", it is possible to solve the problem "What is the architecture of a CPU?" by providing the solution of the problem "What is the von-Neuman machine?". In the future, a query expansion module (He et al. 2005; Lin et al. 2006; Jones et al. 2006) will be added to UVTAS to deal with such kind of problems by considering related phrases in the automatic problem-solving process.

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