行政院國家科學委員會專題研究計畫　成果報告

知識結構在故障診斷輔助系統上的應用-以機車維修廠為例

計畫類別：個別型計畫
計畫編號：NSC93-2213-E-327-016-
執行期間：93年08月01日至94年07月31日
執行單位：國立高雄第一科技大學資訊管理系

計畫主持人：蘇國瑋

計畫參與人員：周裕發、吳俊廷、郭孟芳

報告類型：精簡報告
報告附件：出席國際會議研究心得報告及發表論文
處理方式：本計畫可公開查詢

中　華　民　國 94年9月9日

行政院國家科學委員會補助專題研究計畫 ■ 成果報告
□期中進度報告

知識結構在故障診斷輔助系統上的應用-以機車維修廠為例

The Application of Fault Diagnosis Assistance System Using Knowledge Structure in Motorcycle's Maintenance Plant

計畫類別：■ 個別型計畫　　□ 整合型計畫
計畫編號：NSC 93－2213－E－327－016－
執行期間：93 年 8 月 1 日至　94 年 7 月 31 日

計畫主持人：蘇國瑋 助理教授
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成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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中 華 民 國 九 十 四 年 九 月 一 日

中文摘要

本研究提出一套應用於機車維修工作上的故障診斷輔助系統，從專家的知識結構面，擷取出專家維修之豐富經驗與知識，成為知識法則庫，同時建構出具親和力的人機使用介面。本研究為以知識網路組織工具建立出專家群的知識結構圖，進而發展故障診斷輔助型的專家系統；並利用 PRX、GTD 和 PFC 三種相似性指數，以專家的指數為基準值，評估新手在使用本系統與新手在使用傳統手冊的知識網路結構間的差異，最後以可用性觀點綜合評估其系統運用的必要性。

由知識網路組織工具裡的相似性指數及可用性評估驗證了本研究所發展出的故障診斷輔助系統之可行，使用系統的新手確實比使用手冊的新手較接近專家解決問題的模式。本系統除了可以提升維修人員故障診斷之正確性，並可彌補台灣機車產業技術維修人才短缺、經驗不足及流失的危機，同時亦可作為維修人員教育訓練之工具而有效的縮短訓練時間，提供高品質的維修服務。

關鍵詞：知識結構、專家系統、人機介面、教育訓練

英文摘要

This study proposes a fault diagnosis assistance system（FDAS） that applied in the motorcycle maintenance. An expert's knowledge structure was measured, to construct a knowledge base that derived from expert's wonderful experience and knowledge and then to build a friendly human-computer interface. This study also examined the knowledge structures of a novice group and an expert group by using knowledge network organizing tool. The similarities between novice's and expert's networks are assessed using the indices PRX, GTD, and PFC.

The results indicate that the knowledge structure of the using FDAS group is better than that of the using manual group. Additionally, the usability test confirms the well-used system interface. It also proved the evidence that the novice's knowledge structure is changed better after using FDAS. It can, of course, serve as an educational training tool for maintainers and shorten learning time effectively and also make up for the shortage of Taiwan motorcycle's maintainers.

Keyword: Knowledge Structure, Fault Diagnosis Assistance System (FDAS), Human-Computer Interface, Educational Training

報告內容

1 Introduction

The Taiwan motorcycle industry got its start in 1952 when gas engines were installed on bicycles to create the island's first motorbikes. As a result of 30 years of hard work by the government and the private sector, the Taiwan motorcycle industry now offers both sophisticated production capabilities and superior export competitiveness.

According to statistics from the ministry of transportation and communications (MOTC), 12,366,864 motorcycles were owned in the domestic market in 2003 [8]. Obviously, the motorcycle maintenance tasks are very heavy to servicing domestic owners now. We explored some problems of maintenance quality happened in Taiwan motorcycle servicing factories that is as follows,

- There is no a good educational training between master and apprentice, they usually teach and learn by oral method.
- Most of the maintenance masters don't have a systematical educational training.
- The records of maintenance didn't be well conserved and utilized.
- Maintenance staff usually uses trial and error to learn relevant technique.

In our opinions, if the maintenance technique can be promoted, the consumer's right should be more guaranteed. Based on accumulating maintenance data and knowledge, we tried to develop a tool, the fault diagnosis assistance system (FDAS), which can suggest solutions for a novice worker when he or she confronts with a new problem or makes a maintenance decision.

The study as reported here was to design a FDAS like expert system (ES) as a decision aid to avoid or eliminate misjudgments in the maintenance operation. Furthermore, we also evaluated and compared the knowledge structure of the expert and novice after using this FDAS-ES.

The objectives of the study are described as follows,

- To acquire experts' knowledge from their knowledge structure by the Knowledge Network Organizing Tool (KNOT) Software and to build up a knowledge base.
- To understand the experts on the aspect of problem-solving, and to reduce human errors through human experts' domain-specific knowledge sharing.
- To make sure a good FDAS-ES used for maintenance tasks from the interface development viewpoint by usability evaluation method.
- To compare the knowledge structure between experts and novices and to evaluate the learning efficiency of the novices.
- To accumulate technique knowledge of maintenance may avoid working flow of maintenance personnel, and can also develop a self-training system.

2 Relevant Analysis

This session is referred to previous relevant analysis from Su, Hwang, & Chou (2004).

2.1 Failure modes and effects analysis (FMEA)

FMEA originated as a formal methodology in the 1960s when demands for improved safety and reliability extended studies of component failures to include the effects of the failures on the systems of which they were a part. By the FMEA report, the critical effects and risk priority will be easily found and provide potential failure mode, failure effect, and failure cause and to prevent system breakdowns.

2.2 Pathfinder network analysis

After obtaining key failure mode, the corresponding test questions can be developed as input of KNOT. Then the novice's and expert's knowledge structure and concept diagrams can be obtained, so as to acquire expert's knowledge to improve novice's cognitive representation.

According to Goldsmith, Johnson, & Acton (1991) a better methodology for assessing the expert's and novice's knowledge domain is a structural assessment approach. Three distinct steps comprise the structural approach: (a) knowledge elicitation, (b) knowledge representation, and (c) evaluation of a learner's knowledge representation [6] [10].

2.3 The basic components of an expert system

A team of the expert system usually made up of domain expert, programming designer and knowledge engineer, and knowledge engineer is the center of a role to build up expert system. Knowledge engineer utilized the method of expert knowledge structure measuring to acquire strategic decision and knowledge in expert system and continuously tested and revised to develop more effective expert system [5] [7].

A complete expert system consists of three basic components. The first component is the knowledge base, which has been developed using a commercially available expert system shell called VRS (Visual Rule Studio). It is a hybrid application development tool that installs as an integral part of Microsoft Visual Basic 6.0 as an Active Designer [4].

The second is the inference engine, which drives the knowledge base through reasoning processes that are similar to experts. VRS supports three types of inference strategies: Backward-Chaining, Forward-Chaining and Hybrid-Chaining.

The third is the user interface, which is the means by which the user communicates with the knowledge base. It also allows user to question the expert system and to provide some advice. A good user interface is a necessity for the success of knowledge-based expert systems. The relationships between the user, computer system, user model and system model, via the user interface, and how the design of a good user interface should take into account both these two models [1]. Usability is a well-known and well-defined concept in the HCI research. It has been defined as ease of learning, efficiency of use, memorability, error rates, and preference in the HCI area. The four-component framework including user, product, activity, and environment has long been accepted as the principal components in a human-machine system upon which good system design depends [3] [9].

3 Method

3.1 Participants

In this research, three participants were sampled in each expert group and novice group. The novice's participants were asked to read a paper about the introduction of key component of the motorcycle. Then the novices are asked to do a test to obtain their knowledge structure. The sample of the expert group and novice group must have the unity of a sample that is described as follows:

- *Expert:* the participants who have over five years of working-experience and professional license are sampled. They are working in different motorcycle shops.
- *Novice:* the participants who have no working-experience are sampled. They are graduate students of Industrial engineering department at National Tsing-Hua University.

3.2 Materials

The examination questions of motorcycle technique test can be used to evaluate and compare the difference of knowledge structure between experts and novices. This research analysed three distributors that have about 10% shares in Ji Long city. The component of every month orders were collected from 2002.06.01 to 2003.02.01.

The computer program of KNOT was employed for pathfinder network analysis and to draw the knowledge structure of novices and experts with different experienced level. The expert system was developed through employing VRS, a hybrid expert system shell, as an ActiveX Designer under Microsoft Visual Basic 6.0 environment since it combines the advantages of both production rules and object-oriented programming technology.

3.3 Procedure

The framework construction procedure is described below and the flow chart of research is shown in Figure 1. that can achieve the objective of the study as the previous descriptions,

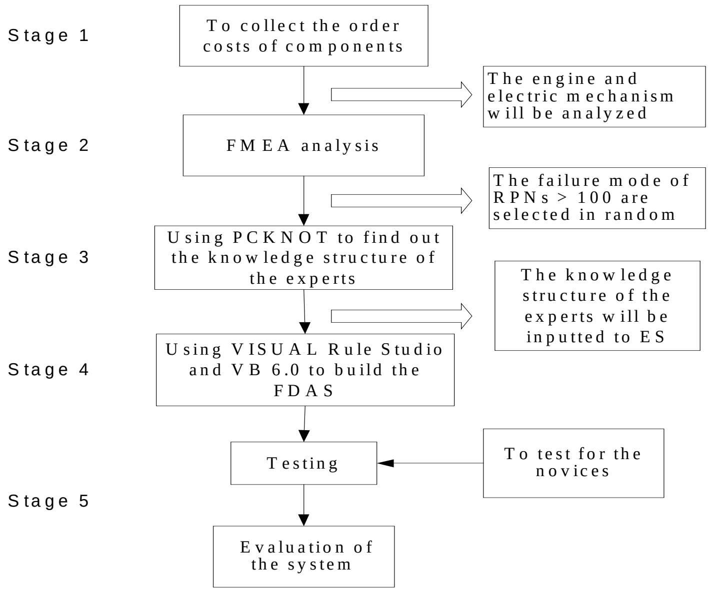

Figure 1　Research Framework

4 Results

4.1 The comparison of the knowledge structure between using system group and using manual group

After comparing the knowledge structure of the experts and novices, the PRX, GTD and PFC-indexes can be obtained by KNOT.　The results are shown in Table 1.　It revealed that PFC (0.114>0.083) and PRX-indexes (0.65>0.006) in FDAS group is better than manual group from the knowledge structure testing but not in term of GTD indexes (-0.003<0.006).　The research by Goldsmith et al. (1991) indicated that the PFC indexes have more accurate than PRX, and PRX is more accurate than GTD.　In other words, the knowledge structure of the FDAS group is better than manual group.

Table 1. The results of the PRX, GTD and PFC- indexes

Indexes	**PFC**	**PRX**	**GTD**
expert v.s manual	0.083	0.006	0.006
expert v.s FDAS (After using FDAS)	0.114	0.65	-0.003

Table 2. shows that the PFC, GTD and PRX-indexes before and after using FDAS are all different.　We would conclude that the knowledge structure after using FDAS group is better than before using FDAS group.

Table 2. The results of the PRX, GTD and PFC- indexes

Indexes	**PFC**	**PRX**	**GTD**
expert v.s FDAS (Before using FDAS)	0.05	0.21	-0.085
expert v.s FDAS (After using FDAS)	0.114	0.65	-0.003

4.2 Usability Testing

Perceived usefulness (PU) and perceived ease of use (PEOU) are two components to evaluate usability. There is no significant difference between the experts and novices as shown in Table 3. In Figure 2, the results of questionnaire indicated that novices' knowledge in motorcycle fault diagnosis is not very clear because they do not understand some terminology of motorcycle. However, the average evaluation in PU 3.76 degree in 1~5 of score that mean both of the experts and novices think the usability in FDAS do assist to diagnosis. In PEOU, item 7 lower than others that mean the expressiveness of FDAS is not good enough, and item 13 is a mistake in the meaning of the questionnaire. Overall of FDAS, the total averages are more than 3 degrees in 1~5 of score, which means this expert system was usable.

4.3 Summary of Results

In this study, the results and the concluding remarks are as follows,

- Through the KNOT package, the knowledge structure between novices and experts are compared and the PRX, GTD and PFC indices were calculated. These indices proved that the knowledge structure of the FDAS group is better than the knowledge structure of manual group. It also proved the novice's knowledge structure is better after using FDAS.
- To utilize expert knowledge structure in designing the expert system that applied to motorcycle's fault detection and maintenance. It will help for novice to improve the capability of fault detection and can also be an educational training. The experts can also use it, if they forget how to detect the faults.
- The maintenance staffs can understand quickly and detect the faults correctly in using FDAS. Therefore, the diagnostic errors that result in wasting customers' time and money will be reduced. The FDAS can make up the lack of knowledge sharing and provide consistent direction.
- The FDAS has knowledge base that can store the record of maintenance consultation when the experts used. The records supply the reference materials for component supplier to do forecast and to replenish the stock.

Table 3. Usability Testing

t-test：The variances 1 and variances 2 are equal

PU	Novice	Expert
Mean	3.76	3.666667
Variances	0.920816327	0.666667
n	50	15
DF	63	
T-value	0.3410113	
P(T<=t) two-side	0.734229751	
C. V：two-side	1.998341759	

t-test：The variances 1 and variances 2 are equal

PEOU	Novice	Expert
Mean	3.68	3.866667
Variances	0.825858586	0.533333
n	100	30
DF	128	
T-value	-1.028887782	
P(T<=t) two-side	0.305472726	
C. V：two-side	1.978669388	

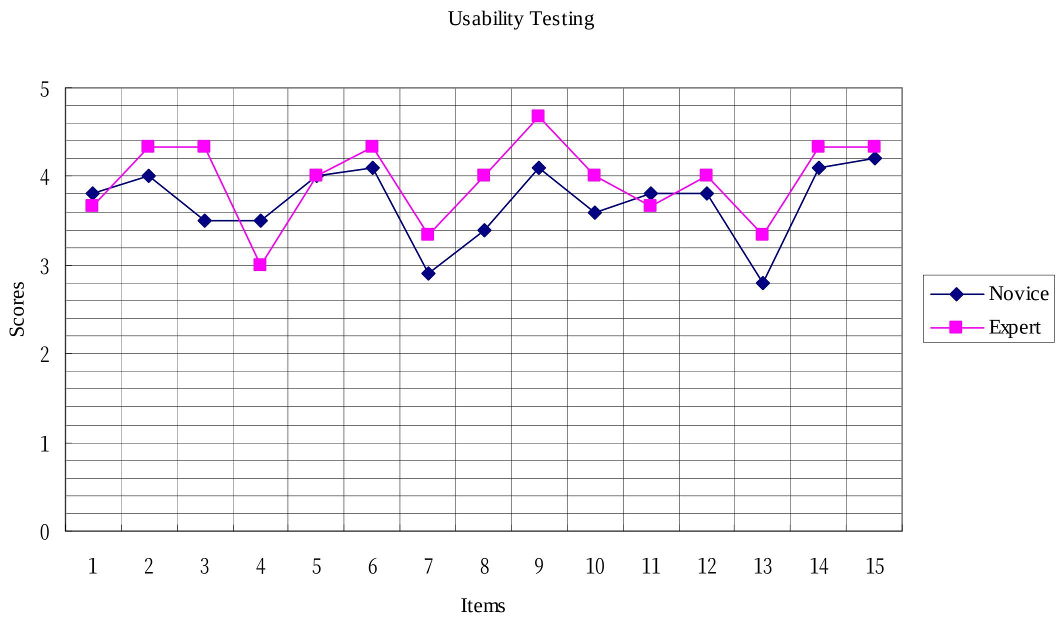

Figure 2. The line plot of the usability testing

5 Discussions

The reasoning method of FDAS is based on service manual, the handbook of motorcycle and expert's knowledge structure. Then, we talked with experts and picked up their knowledge structure to find out rules. For example, if the ignition system fails, then a spark plug will be broken down and should be fixed. The Case-Based Reasoning needs a large data to be collected but cannot solve first-time problem, and it is time-consuming in user interaction. However, the knowledge acquisition of Case-Based Reasoning is easier than FDAS and CRB can learn by adding new cases.

The KNOT is used to test experts' and novices' knowledge structure and to verify system usability. The results show that novices who used the FDAS are better than who didn't use it. The Case-Based Reasoning, system can only be evaluated by used subjective opinion but not by KNOT.

Some advantages and disadvantages of FDAS are as follows,

- Advantages
  - The interface is simple and provides information directly.
  - It has the tolerance of interface design and is base on expert knowledge structure.
  - It can be applied in educational training for novices and promote their capability of fault detection.
  - It can be used in any fault detection and maintenance or provide recommends for decision, such as automobile industry, aircraft industry, commerce etc.
- Disadvantages
  - FDAS is only a prototype that can't provide large fault diction information, so the fault detection rules are not complete.
  - Though the experts' knowledge structure was picked up from KNOT, we also needed to talk about knowledge structure graph with experts to find out how they solve problems.

In the follow-up research, some directions for maintenance system developers are suggested as follows.

- To provide a hand-held of the FDAS for maintenance workers.
- To connect with supplier via FDAS, the supplier can understand the sales volume about motorcycle materials, and the supplier can replenish the stock depending on sales volume.
- To provide selling price for maintenance workers and customers immediately.
- To utilize the network to contact other maintenance workers via FDAS for discussing and sharing their maintenance experience.

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計劃成果自評

本研究提出一套應用於機車維修工作上的故障診斷輔助系統，從專家的知識結構面，擷取出專家維修之豐富經驗與知識，成為知識法則庫，同時建構出具親和力的人機使用介面。本研究為以知識網路組織工具建立出專家群的知識結構圖，進而發展故障診斷輔助型的專家系統；並利用 PRX、GTD 和 PFC 三種相似性指數，以專家的指數為基準值，評估新手在使用本系統與新手在使用傳統手冊的知識網路結構間的差異，最後以可用性觀點綜合評估其系統運用的必要性。

本研究過程與成果不僅達成原計畫之預期目標-建立機車故障診斷輔助型之專家系統，更由知識網路組織工具裡的相似性指數及可用性評估驗證了本研究所發展出的故障診斷輔助系統之可行性，並以實驗確認使用系統的新手比使用手冊的新手較接近專家解決問題的模式。本系統除了可以提升維修人員故障診斷之正確性，並可彌補台灣機車產業技術維修人才短缺、經驗不足及流失的危機，同時亦可作為維修人員教育訓練之工具而有效的縮短訓練時間，提供高品質的維修服務。本研究成果除在國際會議（*the 17th International Conference on Industrial & Engineering Applications of Artificial Intelligence & Expert Systems & The 11th International Conference on Human - Computer Interaction*）發表之外，並於六月份投稿至 *Expert Systems with Applications* 的國際期刊(SCI 等級；2004 Impact Factor: 1.247)，已經接受，預計於 2006 年中刊登。

可供推廣之研發成果資料表

□ 可申請專利　　■ 可技術移轉　　日期：94 年 9 月 1 日

國科會補助計畫	計畫名稱：知識結構在故障診斷輔助系統上的應用-以機車維修廠為例 計畫主持人：蘇國瑋 計畫編號：NSC 93－2213－E－327－016 學門領域：工業工程與管理
技術/創作名稱	機車故障診斷輔助系統
發明人/創作人	蘇國瑋
技術說明	中文： 本研究提出一套應用於機車維修工作上的故障診斷輔助系，從專家的知識結構面，擷取出專家維修之豐富經驗與知識，成為知識法則庫，同時建構出具親和力的人機使用介面。本研究為以知識網路組織工具建立出專家群的知識結構圖，進而發展故障診斷輔助型的專家系統；並利用 PRX、GTD 和 PFC 三種相似性指數，以專家的指數為基準值，評估新手在使用本系統與新手在使用傳統手冊的知識網路結構間的差異，最後以可用性觀點綜合評估其系統運用的必要性。
	英文： This study proposes a fault diagnosis assistance system（FDAS）that applied in the motorcycle maintenance.　An expert’s knowledge structure was measured, to construct a knowledge base that derived from expert’s wonderful experience and knowledge and then to build a friendly human-computer interface.　This study also examined the knowledge structures of a novice group and an expert group by using knowledge network organizing tool.　The similarities between novice’s and expert’s networks are assessed using the indices PRX, GTD, and PFC.
可利用之產業 及 可開發之產品	產業：機車維修產業 產品：故障診斷輔助型專家系統。
技術特點	本研究為以知識網路組織工具建立出專家群的知識結構圖，進而發展故障診斷輔助型的專家系統；並利用 PRX、GTD 和 PFC 三種相似性指數，以專家的指數為基準值，評估新手在使用本系統與新手在使用傳統手冊的知識網路結構間的差異，最後以可用性觀點綜合評估其系統運用的必要性。

推廣及運用的價值	本系統除了可以提升維修人員故障診斷之正確性，並可彌補台灣機車產業技術維修人才短缺、經驗不足及流失的危機，同時亦可作為維修人員教育訓練之工具而有效的縮短訓練時間，提供高品質的維修服務。

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