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The Development of a Training Expert System for TFT-LCD Defects Inspection

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At present, the image quality of LCD panels has been determined subjectively by human visual inspection. In fact, the inspectors need to memorize a large number of instructions. The inspection tasks include a series of complicated procedures that increase the workload of the inspectors. This research focuses on the improvement of LCD inspection. The knowledge extracting of inspection data was to analyze association rules through interviewing experienced inspectors. Then the nested IF-THEN inspection rules between defects and test patterns were analyzed by two-dimensional matrix and group technology (GT). In terms of inspection test patterns, the occurring sequence of pattern was rearranged to make inspection tasks more efficient. Furthermore, this study aimed to construct an expert system for LCD defects inspection. According to the results of the experiment and expert evaluation, the expert system was proposed as a training support system to aid the trainees to learn inspection skills more effectively. Therefore, the performance of the inspection training could be improved.

Significance: The inspectors always have to pay attention to fixate panels for many hours. As a result, the inspection performance and the quality level may go down gradually. To identify defects and classify the quality of panels, it relies on well-trained experienced inspectors making decisions precisely. Therefore, it is essential for TFT-LCD industry to evaluate the human inspection strategies in order to improve inspection performance.

Keywords: TFT-LCD, Mura defects, Human visual inspection, Training support system, Expert System.

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1. INTRODUCTION

The demand of thin-film transistor liquid crystal display (TFT-LCD) arises enormously over the past few years. TFT-LCD is widely used as display in desktop computers, laptops, televisions, and so on. It is known that the defects called "mura" may occur during the LCD panels manufacturing process. According to Video Electronic Standard Association (VESA, 2000), Mura is a Japanese term meaning visible blemish, which has been adopted in English to represent imperfections of a display pixel matrix surfaces. Mura defects appear as low contrast and non-uniform brightness regions, slightly larger than single pixels, and thus they are difficult to be detected.

Quality control can be enhanced through statistical methods (Lee & Kim, 2007; Chen & Huang, 2006), management strategies, work design, etc. At present, the quality of LCD panels is usually evaluated by means of human visual inspection. The inspection task is a complicated work. During the training period, the beginners have to memorize a large number of "instruction documents" which describe the specifications of various defects. Such detecting method increases the inspectors' workload heavily. Additionally, the judgment of muras absolutely depends on the experienced inspectors. Thus, the accuracy of detecting results often appears disagreement because of various shapes and sizes of muras and human errors. For the reasons mentioned above, this study focuses on the improvement of the human visual inspection process. The LCD inspection system is evaluated and analyzed in order to make the inspection system more appropriate for inspectors and to decrease their workload.

The purpose of this research is to rationalize the LCD panel inspection process. This study aims to provide systematic guidelines for LCD inspection by extracting the inspection knowledge. Furthermore, this study attempts to construct an expert system for inspection in order to make the trainees learn inspective skills more efficiently. If the inspection process can be rationalized, the inspectors' workload would be reduced. Additionally, the performance for the inspection task would be increased with the expert system. Consequently, the cost of manufacture would be reduced significantly.

2. BACKGROUND

2.1 Mura Defect

In general, Mura-like blemishes are likely to occur in CRT, LCD and other display devices. There are various physical factors to cause muras as the LCD panels are produced. Traditionally, the causes of muras include non-uniformly distributed liquid crystal material and foreign particles within the liquid crystal. For this reason, there are thousands of appearances for muras. Thus, the mura defects of actual LCD panels vary with different shapes, sizes, degrees of gray levels, and so on (Mori, Tanahashi, & Tsuji, 2000). However, mura defects are usually hard to be detected. A variety of inspection algorithm have been developed for automatic inspection (Chen & Kuo, 2008; Guo,2008; Lee et al, 2007; Kuo, 2008). These algorithms would base on human vision model(Chen et al,2008).

2.2 Visual Inspection Task

Recently, inspection with complete automated systems has been more frequently applied to replace traditional sampling inspection with human inspectors. Although the human visual inspection is a subjectively perceptive judgment, it is known that the performance of inspection with human is still better than machines. The inspection process consists of a series of functions or procedures, and visual search and decision- making are the key tasks to inspection (Drury, 1978; Sinclair, 1984). Usually, automated systems are much more accurate on visual search. Hou, Lin and Drury (1993) proposed that humans were better at the decision-making task, whereas machines were better at the search task. Therefore, it is necessary to improve human visual search performance by the aid of automated system.

2.3 Knowledge Structure

Knowledge is transformed from information with past experience, interpretation, and cognition. Knowledge management is a technology to assist problem solving and decision making. As to the domain of LCD inspection, the knowledge structure of experienced inspectors is accessible and useful to develop the training expert system.

Mental models are cognitive structures of knowledge and experiences used to interpret the world (Norman, Gentner & Stevens, 1987). Johnson (1992) suggested that a mental model could be developed or strengthened by learning and practice. Mental models are different from the system models, often called conceptual models that mean conceptual understanding of how a system works. Users develop their mental models only through conceptualization of system's model.

2.4 Computer Aided Training System

Inefficient performance and a lack of competencies have been found among U.S. employees due to a need for apprenticeship-based training that is difficult to be met in today's large, quickly changing, highly technical, information-rich work environments (Gery, 1991). Electronic performance support systems comprise a new training and job support paradigm of which computer-based training (CBT) is one component. The learner obtains knowledge and improves comprehension with intelligent training systems. Moreover, the user is encouraged to learn. Such features of intelligent training systems have been implemented in many applications.

In this study, architectural design, main objectives and performance of LCD defects inspection are presented. The proposed approach was demonstrated to produce an efficient training system. Experts' judgment about the training process and GUI structure was basically positive. The design of the user interface is influenced by many factors, among these the mental model of the user's thinking processes, aspects of usability and the explanation capabilities of the knowledge-based expert system (KBES), have been discussed in the psychological and artificial intelligence literature (Berrais, 1997; Rook & Donnell, 1993).

3. RESEARCH METHODOLOGY

This section is divided into three parts. Firstly, the inspection process for LCD panels was analyzed. Then the inspection test patterns are presented in detail. The association rule mining between defects and test patterns was conducted for the expert system, which was constructed in order to solve the problem of inspectors' overload. Finally, the inspection association rules and some inspection principles were analyzed for the rule engine of expert system.

3.1 Analysis of LCD Inspection Process

In order to understand the inspection process in detail, the first step is to collect data about how the operators inspect panels. Walking through the LCD factory in the beginning was to collect the inspection data. In that way, one could observe how the operators operate the inspection equipments to identify defects. Besides, a questionnaire was designed with some inspection problems for engineers and operators to reply. Finally, the experienced operators and engineers were interviewed, and open discussion was applied to acquire the inspection knowledge at the same time. The detailed steps are as follows.

The raw data of LCD inspection process were gathered from the above stages. Through integrating the inspection data, the inspection processes can be induced: (1) turn on inspection devices connected to LCD panels; (2) change a series of aiding test patterns in order and repeat to detect the defects on the panel with each pattern; (3) record degrees and positions of the defects; (4) determine the level of the panel quality; (5) turn off the inspection devices.

3.2 Analysis of Inspection Aiding Test Patterns

Among the inspection processes, the test patterns are the interesting scope of this research. Hence, the inspection knowledge is acquired by interviewing the expert inspectors. Moreover, the raw data can be integrated and transferred into inspection rules between defects and test patterns. Subsequently, the sequence of patterns was analyzed and an expert system was constructed for LCD inspection training.

3.3.1 Acquiring Inspection Knowledge

The documents of inspection patterns were collected from two domestic LCD manufacturers. In fact, there are approximately thirty test patterns for each domestic LCD industry. These different test patterns are designed to aid inspectors detecting various defects, but different patterns may assist inspectors to inspect part of the same defects. The data of inspection patterns were investigated and integrated as follows (Table 1) and basic patterns were appended. For instance, the full black pattern is used to help the inspector to detect bright spot defects attributed to faults of polarized light (P/L) board. Another example is that the faults of integrated circuit (IC) usually cause line defects easy to be detected with gradual patterns.

Table 1. The inspection test patterns versus the defect items

Pattern	**Defect item**	**Cause**
Gradual pattern	Gradual defect, line defect	IC
Full white pattern (L255)	Dark spot, dark line, light line, line defect, non-uniform color with the color filter	B/L*
Full color pattern (red, green, blue; L255)		CF*
Full black pattern (L0)	Light Spot	P/L
Mid-gray pattern (L127)	Spot, color gap, rubbing mura	IC
Twinkling pattern	Twinkling image	
Character pattern	Unusual appearance, invariance	
Window pattern	Shadow image, crosstalk image	

* B/L expresses the backlight of LCD structure.
* CF expresses the color filter structure of LCD structure.
*“L” expresses the value of the gray level for the pattern. The value of L is from 0 (called L0) to 255 (called L255).

3.3.2 Analysis of Association Rules between Defects and Test Patterns

The document of inspection test patterns was transferred from raw data into two-dimensional matrix form through Microsoft Excel. In order to find the relationship between defect items and test patterns, the method of Group Technology (GT) was applied to rearrange the sequence of patterns and to adjust some defect items. In other words, the original matrix was transformed into I array (i.e. unit array) to group patterns with the same mura items. It was found that some kinds of defects are checked with different patterns repeatedly. Hence, each item of column and row was amounted in order to analyze the association rules between test patterns and defect items. It was set that the relationship between this column and this row is important if the subtotal is more than five. Consequently, there were some important basic principles and seven association rules.

The important basic principles are as follows:

Principle 1: The gray (L120) pattern is the easiest one to inspect the defects.

Principle 2: The sequence of test patterns is gradual patterns, the saturated (L255) patterns, the gray patterns (L120, L80), the undertone patterns, the black pattern (L0), white pattern (L255), and the special patterns.

Principle 3: The sequence of the inspected defects is line and IC defects, spot and color Mura, Mura, polarize (P/L) defects, backlight (B/L) defects, and special defects.

Principle 4: Lines and IC defects are easy to be inspected with gradual patterns.
Principle 5: The saturated RGB patterns are easy to inspect spots and color Mura.
Principle 6: Dark spots, dark lines and B/L defects are easy to be inspected with the white patterns.
Principle 7: Light spots, light lines and P/L defects are easy to be inspected with the block patterns.
Principle 8: Mura is easy to be inspected with the gray patterns.

Moreover, seven IF-THEN rules were found by GT as follows:

Rule 1: IF gradual patterns => THEN line defects OR IC defects
Rule 2: IF full color patterns => THEN spot defects
Rule 3: IF mid-gray (No.1) patterns AND windows pattern => THEN spot defects OR inner-panel defects OR P/L defects
Rule 4: IF undertone patterns => THEN color muras
Rule 5: IF full black patterns => THEN light spots OR P/L defects
Rule 6: IF mid-gray (No.2) patterns => THEN line defects OR spot defects OR inner-panel defects OR P/L defects OR mura defects
Rule 7: IF full white pattern => THEN B/L defects

For example, the seventh rule is "IF full white pattern => THEN backlight defects". It means if using white patterns, one might find out backlight defects. The inspection principles and rules could be applied in arranging the sequence of test pattern by means of GT and two-dimensional matrix. Moreover, the association rules and the inspection strategies after analyzing the relationship can be coded as information of database through expert system software by the knowledge engineers.

4. REARRANGEMENT ON THE SEQUENCE OF INSPECTION TEST PATTERNS

As mentioned before, the data of inspection test patterns and defects were represented by means of two-dimensional matrix. The method was also used for analyzing the sequence of inspection test patterns. On the other hand, the association rules were used as the principles for arranging the sequence of test patterns. The original sequence of pattern was queried because it seems confusing and unsystematic. Hence, the sequence of pattern was rearranged by the concept of Group Technology (GT) in order to make the test pattern more systematic and organized to shorten inspection time. Finally, this study provided three rearranged patterns with different ranking principles.

4.1 Methods for Rearranging the Sequence of Test Patterns

4.1.1 The Rearranged Pattern A

The concept of the rearranged pattern A is slightly adjusted, which means this kind of rearranged pattern was changed as less as possible from the original one. This way was attempted to avoid increasing the switch cost of LCD manufacturers.

4.1.2 The Rearranged Pattern B

The principle of the rearranged pattern B adapted Group Technology (GT). The similar patterns were arranged together in order to avoid the same defects inspected redundantly according to the inspection association rules. For example, the undertone patterns were rearranged forward and the mid-gray patterns were moved backward nearby.

4.1.3 The Rearranged Pattern C

The rearranged pattern C is using the mid-gray patterns at the beginning to filter out the most hard-to-detected defects. Besides, the principle to make the same class of patterns together is the same as the rearranged pattern B is.

4.2 Evaluation of the Different Rearranged Patterns

The effects of rearranged patterns were evaluated by engineers and inspectors through questionnaire. At beginning, it is necessary to let engineers and inspectors understand the concept of pattern adjusting distinctly. The following step is to design the questionnaire for subjects, engineers and inspectors, in order to evaluate the effect of the various sequences of rearranged patterns upon the performance for inspection tasks. According to the Fishbein Multiattribute Model (1963), the questions were designed to understand the feasibility, usability and effectiveness for the new patterns. Symbolically, it can be expressed as

$$A_o = \sum_{i=1}^{n} b_i \cdot e_i \quad \ldots(1)$$

where

A_o = attitude toward the objective

b_i = the strength of the belief that the object has attribute i

e_i = the evaluation of attribute i

n = the number of salient or important attributes

The model proposes that attitude toward an object (A_o) is based on the summed set of beliefs about the object's attributes (b_i) weighted by the evaluation of these attributes (e_i). Beliefs can be defined as subjective judgments about the relationship between two or more things.

The objective in this study is to rationalize the sequence of pattern patterns for inspecting defects. From Fishbein's formulation, e_i express the estimate toward attributes, which is measured by the seven levels of scale from "not very important" to "very important". And the b_i component represents how strongly subjects believe that a particular rearranged pattern possesses a given attribute. Beliefs are also measured on a 7-point scale of perceived likelihood ranging from "very unlikely" to "very likely".

4.3 Results of Evaluation for Rearranged Patterns

Five people participated in the survey of rearranged patterns. Three of them are engineers and two are inspectors, and they were numbered as E1, E2, E3, O1, and O2. The participants evaluated the attributes of three different patterns subjectively. As to the important attributes, there are six questions for important attributes toward inspection work. The questions were separated into three directions: the inspection performance, the quality of inspection, and switching cost.

The results revealed that the attributes about performance, the efficiency of inspection and the training effect, are the most important attributes for inspection works. In other words, engineers and operators believe that the performance-oriented functions are more important than switching cost of changing patterns.

Therefore, the result of survey was analyzed by Fishbein's equation (Table 2). From the result of the questionnaire, the average of score for the rearranged pattern C is the highest (21.4) and the pattern B is the lowest (13.8). Therefore, it seems that rearranged pattern C is feasible and easy to be accepted by manufacturers. Rearranged pattern B is regarded as less feasible. However, the average of rearranged pattern A is only 0.6 points lower than pattern C. It means that the pattern A is also usable for manufacturers.

Table 2. The result of evaluation for three different rearrange pattern

Subjects	Sum for each subject ($\sum b_i*e_i$)		
	Pattern A	Pattern B	Pattern C
E1	4	5	6
E2	32	14	30
E3	22	18	24
O1	21	22	24
O2	25	10	23
Subtotal	104	69	107
Average	20.8	13.8	21.4

4.4 Discussion

According to the results of evaluation, some engineers thought that the rearranged patterns pattern C extremely was likely to detect defects efficiently. Most of them believed that it would increase the switching cost the most because the inspectors would need to take time to retrain for the new pattern. Relatively, inspection tasks may be performed better than others. The reason is that the rearranged pattern C was arranged mid-gray patterns ahead of the sequence in order to filter out most defects. However, it still needs to be tested in practice.

As to rearranged pattern A, some engineers also thought that it could be adapted to inspect defects in practice because of the low switching cost. The rearranged pattern A was adjusted only one pattern from the original pattern, so it is more likely to be tested in the real site immediately. For this reason, the manufacturers would like to avoid the risk to try rearranged pattern A rather than the rearranged pattern C.

However, there were several limitations in the subjective evaluation. For example, it is hard to inspect defects by new patterns for LCD manufacture firms in practice because it would make the inspection cost increase enormously and take time for inspectors to adjust. Additionally, the sequence of patterns is different from each firm. Therefore, the rearranged patterns in this study only proposed the concepts to organize the sequence of patterns systematically in order to inspect defects efficiently. It is necessary to be readjusted depending on the demands of different manufacturers.

5. THE PROCESS OF EXPERT SYSTEM DEVELOPMENT AND SYSTEM TESTING

The current training on LCD inspection is using the handbooks or manuals for the beginners to understand basic knowledge. As mentioned before, the inspection knowledge was acquired from experienced inspectors and training documents. Then, seven IF-THEN rules were obtained from the results of 2-dimentional matrix and GT. Afterwards, the Panel Inspection Training Expert System (PITES) for aiding training novices was constructed in order to improve the performance of current training system.

5.1 Development of PITES

Based on the collected rules, the Panel Inspection Training Expert System (PITES) was built through 4 stages:

Stage 1 Establish the knowledge database

In the knowledge database of PITES, seven IF-THEN collected rules and eight basic principles of inspection data were included to establish the inference engine. The rule-based engine could provide trainees more organized basic inspection knowledge than the manuals do.

Stage 2 Program coding

The software of Microsoft Visual Basic 6.0 was applied for coding the program of PITES. VB language was coded to link the elements of interface and program compliers together.

Stage 3 Interface design

The application of PITES was designed for novices. Therefore, it is important to design an interface, which is user-friendly and easy to operate. When designing the human-computer interaction system to replace the monotonous manuals, the graphical user interface (GUI) was applied.

Stage 4 Revising training system

After the first vision of PITES was completed, the program has to be tested by experts and novices. Because the first vision of PITES included all the inspection knowledge, the novices complained about too many data to read. In addition, the expert who serves as trainers to train inspectors also commented on huge and complicated information for a beginner. Hence, the training system needs to be simplified.

5.2 Functions and Components of PITES

The PITES was designed as a user-oriented system that fits novices' knowledge structure on their minds. Through program coding, the PITES was completed and could be applied to train on sites. The PITES provides some functions for beginners to learn the knowledge such as defects information subsystem, test patterns information subsystem, and expert system. The three subsystems are described as follows.

1. Defects information subsystem
   The defects information subsystem provides the introduction of LCD concepts. There are a paragraph about the cause of defects and the classification of defects. And the interface used a "tree-form" to view the subordinate relations between defect classes and items. Users can choose the branches and click the confirm bottom to check the detail information of chosen items.
2. Test patterns information subsystem
   The interface of test patterns information subsystem is similar to defects information subsystem. The screen will show a tree-form element to display the relations between classes and items of test pattern. While users click the confirm bottom, the detail information of chosen pattern will appear. The description explains the important message, which pattern is easy to inspect specific defects items, and trainees need to be familiar with the information.
3. Expert system
   Expert system for LCD inspection plays an important role of inference engine to assist trainees to be familiar with inspection rules. Users can check the required rules by different classes of patterns or defects. The information of rules is shown in Figure 2. Frame 1 proposes the outcome of the association rules, which support trainees to memorize the inspection rules. Besides, there is a list of items in Frame 2 to choose from the folders of expert system. It is convenient for users to review the detail inspection information (Frame 3).

5.3 Experiment Design

An experiment was conducted to evaluate the performance of PITES. Experiment was designed to compare the learning performance of novices with PITES, so the traditional training system was also simulated to perform training in the experiment.

5.3.1 Experiment Environment

The experiment was executed in the Ergonomics Lab of Engineering Building I of National Tsing Hua University. The subjects had to complete both the training process of traditional manual system and computer aided system. The materials of traditional system are collected from the training documents in the real LCD factory. The training materials of manuals were the same as PITES. Furthermore, the difference between manuals and PITES was the display method of information; especially PITES provided an expert system.

5.3.2 Subjects

Sixteen subjects participated in this experiment. They are graduate students in the Industrial Engineering Department at National Tsing Hua University. None of them were familiar with LCD inspection knowledge. Subjects were randomly assigned into two groups: Group Ⅰ and Group Ⅱ. Subjects of Group Ⅰ were trained by PITES first and then trained by manuals. On the contrary, Group Ⅱ were trained by manuals firstly and then PITES.

5.3.3 Experiment Procedure

The steps of experiment are as follows,

Step 1. Group Ⅰ: Subjects were introduced to use the computer aiding system (PITES) before starting to operate PITES to learn about inspection knowledge until they felt familiar with the inspection information. The learning time was recorded for each subject.
Group Ⅱ: Subjects were introduced the manuals for inspection training. Then subjects started to read and learn about inspection knowledge until they felt familiar with the inspection information. The learning time was recorded for each subject.

Step 2. Both groups had a test of eighteen inspection questions (Test A). The score of test was recorded for each subject.

Step 3. Group Ⅰ: After using PITES, subjects continued to be trained by manuals until they felt familiar with the inspection information. The learning time was recorded for each subject.
Group Ⅱ: After using manuals, subjects continued to operate the computer aiding system (PITES) until they felt familiar with the inspection information. The learning time was recorded for each subject.

Step 4. Both groups had a test of eighteen inspection questions (Test B). The score of test was recorded for each subject. The questions of Test B different from Test A.

Step 5. Finally, subjects were requested to take questionnaire for usability of PITES.

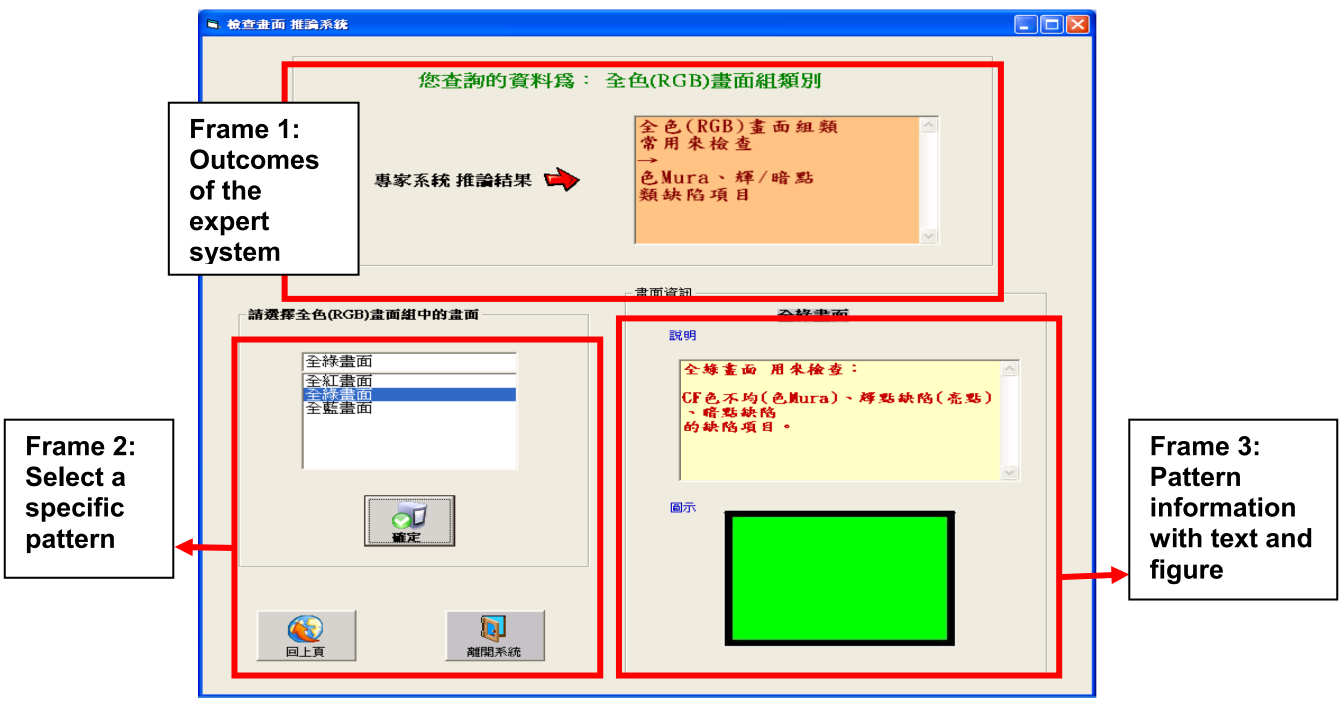

Figure 2. The rule information of expert system of PITES

5.4 Result of Experiment

The participants were randomly assigned to two systems by different order in order to balance the learning effect. Each subject had to receive training through both systems. In terms of learning testing, two different test questions were included in both systems. In other words, the testing variance was considered by experiment design. Therefore, the index of testing score was measured to compare the performance of two training systems.

5.4.1 Testing Score of learning performance

The paired t-test was conducted on the testing scores from PITES and manuals. Table 3 shows results of the statistical analysis. It reveals that the learning performance was significantly different between PITES and manual training system (P-value<0.05). Therefore, the experiment could prove that PITES provides novices a better training environment to learn inspection knowledge effectively.

Table 3 The paired t-test for testing scores of inspection knowledge (α =0.05)

Paired t-test (less than)	N	Mean	Standard deviation	SE Mean	DOF	T-Value	P-Value
Score of Manual	16	13.500	2.633	0.658	15	-2.20	0.022
Score of PITES	16	15.188	2.287	0.572	15		
Difference	16	-1.688	3.071	0.768	15		

5.4.2 Learning Time

The learning time of using PITES was recorded for a referable index, and so was the time of reading manuals. The learning time for the sixteen participants with PITES was analyzed to compare with manuals. The result indicates that there was significant difference between two systems (P-value=0.040 <0.05). It reveals that participants using PITES took more time to learn the inspection knowledge than using manuals.

5.4.3 Analysis of Subjective Questionnaire

When participants completed the experiment, they were asked to express their subjective feelings toward PITES and traditional training system. The ranking score of feelings was 5-point scale from “disagree very much” to “agree very much” for each question. The score of each question could be calculated into the average feelings score for sixteen novices and four experts. Furthermore, there is no significant difference between the experts and novices (P-value= >0.05).

By the sign test, the result reveals that users believed PITES could help them to memorize inspection knowledge systematically (P-value<0.05). Besides, the participants believed that the tree-form information of PITES is more systematic to understand than the manuals (P-value<0.05). As to efficiency of learning, friendly interface, and usability of expert system, participants show strongly positive feelings. More importantly, several participants responded that the expert system of PITES was useful to memorize inspection information. Some subjects of Group I responded that they hadn’t obtained more information from the manuals after using PITES. On the other hand, the replies from open-ended question provide more specific opinions for the system improvement. Especially for experts, they suggested to use illustrations of real defects to replace simulated defects for defects information subsystem. Besides, adding the management interface was proposed in PITES in order to revise information by administrators.

5.5 Discussion

The result of the experiment appears obviously that the computer aided training system could improve the learning performance of novices. From the results of questionnaire, the knowledge structure of PITES (such as tree-form information) was indeed designed to make users absorb inspection knowledge more systematically and clearly. The documents of training handbook seem difficult to remember and the information is complicated without the organized representation. Therefore, PITES plays an important role in complex problem solving for panel inspection training. Moreover, Johnson (1992) mentioned that the mental model can be developed or strengthened by learning and practice. The rules between defects and patterns reveal obviously useful for inspection according to the result of experiment. As a result, it proved that PITES provides the expert system to make users understand the relationships between defects and patterns clearly. Expert system in this research could support trainees to practice and review the rules in their minds, so they may develop and enhance their cognitive structure of inspection knowledge effectively.

Furthermore, the learning environment of PITES was designed friendly to make users easy to access the data. From the result of the subjective questionnaire analysis, users felt comfortable and were interested in the friendly interfaces because of the graphical user interface (GUI). It means that the computer aided training system attracts users likely to stay in PITES to learn the training knowledge, whereas the manual training system would be uninteresting and tired for the trainee’s.

However, participants of the experiment seemed to take more learning time through PITES than traditional training system. Because the PITES possesses additional function of expert system, the participants need to take more time to get inspection rules. But expert system could provide users to review and learn the inspection rules. Although using PITES take more time to train novices, expert system could provide users to learn the inspection rules and improve the training performance significantly.

In general, the training process usually takes a long time. The inspectors require receiving a long-term training in order to be familiar with all the inspection knowledge in the real world. The experiment in this study is limited to train the novices for a short time. Hence, the ability of short-term memory for participants may increase the learning performance. In the future, a long-term training in practice should be conducted.

6. CONCLUSION

The defect inspection is a series of complicated procedures. This study aims on the improvement of the human visual inspection process. Firstly, the inspection test patterns were analyzed and rearranged in order to increase the inspection performance and quality. Additionally, this research is to develop a computer training system to assist trainees to learn more efficiently during training process. The usage of PITES could improve the training effect for novices. From the results of the experiment and the subjective evaluation, some contributions and future works of this research are summarized as follows.

1. The sequence of inspection test patterns should be considered to reset for engineers who have never thought about before. The rearranged patterns in this research could be applied for manufacturers to inspect defects. The sequence of inspection test patterns was adjusted reasonable by the principles of group technology (GT). It is found that the rearranged pattern C is likely to filter most defects and to shorten inspection time. Hence, inspectors may identify defects easily and quickly and their workload may be reduced.
2. The result of experiment indicated that the learning performance of PITES was better than that of manuals. It means that novices could improve their training performance with PITES. According to the results of the questionnaire, the construction of PITES is helpful for training novices because the information model is more systematical than manuals. PITES provides the appropriate display of the inspection information. Users can absorb the inspection knowledge effectively through systematical knowledge structure of PITES.
3. Users feel comfortable and accessible as using PITES. The human computer interface of the computer aided training system is friendly designed to fit users' demand. It indicates that PITES provides trainees an interesting learning environment to improve the learning performance of traditional manuals by graphical user interface (GUI).
4. Developing an expert system is to simulate the strategies of experienced inspectors by extracting the inspection knowledge. Because the expert system provides a useful function of the inference engine, the expert system of PITES plays an important role in complex problem solving for defects inspection. The rules that are verified by experts and the experiment help novices to memorize and understand the relationships between panel defects and inspection test patterns. Therefore, PITES is regarded as a decision support system and the rules could be applied for the synthetic guideline of inspection training in practice.
5. Testing PITES for a long-term evaluation is a future task because of the limited experiment time in this study. Besides, it expects to use PITES for training novices in the real world. The management subsystem is required to be added. The management interface will be accessible for the managers or engineers to modify the inspection data in the future. Adding the practice or testing subsystem into PITES will make the computer aided training system for LCD inspection more complete. The function of testing subsystem could support trainees to get immediate learning feedback by the examination.

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8. ACKNOWLEDGEMENT

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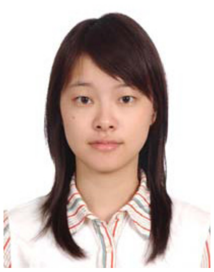
BIOGRAPHICAL SKETCH



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