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Measuring the convergence and accuracy of trainees' knowledge structures for TFT-LCD visual defect categorization

Sheau-Farn Max Liang*

Department of Industrial Engineering and Management, National Taipei University of Technology, 1, Section 3, Chung-Hsiao E. Road, Taipei 10608, Taiwan, ROC

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Abstract

Despite a large automated portion of the thin film transistor-liquid crystal display (TFT-LCD) manufacturing process, inspectors' eyes are still the main resource for ensuring the display quality of TFT-LCD panels. Since recruiting and training new inspectors is a frequent process in most TFT-LCD manufacturers, and since it takes most novice inspectors at least a year to become proficient, an effective training program is crucial for TFT-LCD manufacturers to secure their process efficiency and product quality. The purpose of this study is to establish a set of methods for measuring the convergence and accuracy of trainees' knowledge structures on TFT-LCD visual defect categorization, so that the development of knowledge during the training can be monitored and further applied to the design of training programs. The card sorting technique was first used to elicit knowledge. The sort data were then converted to the measures of edit distances and Collective Dice Coefficients. Finally, statistical analyses were applied to measure the convergence and accuracy of trainees' knowledge structures. Results showed that the current training program did increase the convergence and accuracy of trainees' knowledge structures. However, there was room for improvement. The training program could be enhanced by explicitly introducing the experts' knowledge structures to trainees. In addition, the inspection process could be improved by redesigning inspection procedures to correspond to the experts' knowledge structures. With these methods, the development of knowledge can be examined promptly and efficiently, and the effectiveness of the training program can be assured.

Relevance to industry

Methods applied in this paper can contribute to the research and applications in the TFT-LCD industry for the design of the inspection-training program and the supervision of trainee's learning progress.

Keywords: TFT-LCD; Defect inspection; Knowledge structures; Card sorting; Edit distance; Collective dice coefficient

1. Introduction

The flat panel display (FPD) industry had been designated as one of the major driving forces in boosting Taiwan's economic development. Within the FPD industry, thin film transistor-liquid crystal display (TFT-LCD) is the fastest growing sector. In fact, Taiwan's TFT-LCD manufacturers are the leading TFT-LCD panel suppliers in the world.

The production of a TFT-LCD panel can be divided into three major processes: the array process, the cell process, and the module assembly process. The array process is to fabricate thin film transistors (TFTs) on a glass substrate. The cell process is to join the arrayed TFT substrate and the color filter substrate, and fill the space between the two substrates with liquid crystal. The module assembly process is to add more components, such as driver integrated circuits and backlight units, to the panel.

Although a large portion of the manufacturing process is automated, inspectors' eyes are still used as the main resource for ensuring the display quality of TFT-LCD panels. The general steps followed for a TFT-LCD panel

*Tel.: +886 2 2771 2171x2345; fax: +886 2 2731 7168.
E-mail address: maxliang@ntut.edu.tw

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visual inspection are as follows: (1) orient the panel, (2) search the panel, (3) detect defects, (4) recognize/classify the defects, (5) decide on the status of the panel and record any appropriate information, and (6) dispatch the panel. While steps (1) and (6) are material handling tasks, steps (2) and (3) are visual search tasks, and steps (4) and (5) are decision making tasks (Drury, 1984). Cognitive demands occurring in steps (2)–(5) include attention, perception, judgment, and memory (Wang and Drury, 1989). Instead of on searching and detecting defects in steps (2) and (3) (e.g., Chan and So, 2006; Nalanagula et al., 2006), the focus of this study was on recognizing and classifying defects in step (4), especially the development and organization of knowledge structures for the categorization of TFT-LCD panel visual defects.

With the acceleration of global competition and the shortage of local labor, recruiting and training new inspectors is a frequent process for most TFT-LCD manufacturers. Furthermore, most novice inspectors require at least a year to become proficient at recognizing and classifying numerous and various defects. Thus, an effective training program is crucial for TFT-LCD manufacturers to secure their process efficiency and product quality.

In a world-leading TFT-LCD manufacturer, an inspection training program is conducted during a 1-month period by senior inspectors who are also in charge of training. The program is divided into four sessions, with one session covered per week through lectures and practices. Product models and inspection procedures are lectured in week 1. Inspection materials, tools, equipment, and screen display patterns are taught in week 2. Common visual defects are introduced in week 3. Trainees then practice how to operate the equipment and inspect various visual defects on a sample of TFT-LCD panels in week 4. Trainees' learning outcomes are assessed by several paper-and-pencil quizzes and a performance test on 200 pieces of panels. Prior to training, trainees are labeled as Level-0 inspectors. After the training, trainees who pass these examinations are promoted from Level-0 to Level-1 and considered ready to enter the inspection job.

The problem with the current training program is that trainees' learning outcomes are unknown until the end of training. If trainees fail the final test, they have to be retrained or dismissed, both resulting in a cost. On the other hand, if trainees pass the final test, whether their knowledge is as good as that of the skilled inspectors is still unclear. Thus, managers want to know if a method can be developed to track trainees' progress in order to reduce the potential training cost and evaluate the effectiveness of the training. In addition, this method should be time-efficient in order to fit into the dense training schedule. To solve this problem, relevant theoretical and empirical literature was reviewed.

1.1. Theoretical background

The purpose of a training program is to facilitate the trainees' learning process, which is defined as the transition from the trainees' initial state of Knowledge, Skills, Abilities, and Other characteristics (KSAOs) before training to the desired state of KSAOs after training (Glaser, 1976). In the context of human–computer interaction, the desired state and the initial state may correspond to the conceptual model and the user's mental model, respectively. The mental model is defined as a representation of a body of knowledge (Johnson-Laird, 1989). The conceptual model is the mental model of the system from trainers or system designers, whereas the user's mental model is the representation of the system from a user when he or she interacts with the system (Norman, 1983). The definition of the user's mental model implies that the model may be less complete or accurate than the conceptual model and may change over time. To some extent, the mental model is analogous to Kelly's (1955) personal construct. In his Personal Construct Theory (PCT), Kelly argued that people understand and interpret the world by using their own personal constructs to categorize events around them. With different experiences, individuals may have different personal constructs, which eventually affects the way that they understand and interpret the world. This is the individuality corollary of the PCT (Kelly, 1955). Conversely, in keeping with Kelly's (1955) commonality corollary, individuals with similar personal constructs may categorize events similarly. This implies that knowledge differences between two groups, such as novice–expert differences, can be explained by the differences in their common personal constructs or their "team mental models." The terms of "team mental models" and "shared mental models" are used to address the knowledge or belief structures regarding the task or the group that are shared by group members (Klimoski and Mohammed, 1994). To further distinguish these two terms, "team mental models" emphasize the collective mental models of a whole group, whereas "shared mental models" could also designate the dyadic mental models between any two individuals in a group (Klimoski and Mohammed, 1994). This distinction indicates the two following research foci: knowledge structures within a group and knowledge structures between groups. Relevant empirical studies were reviewed in the following section.

1.2. Relevant empirical studies

In a military teamwork training study, Smith-Jentsch et al. (2001) found that more experienced trainees exhibited greater similarity in their knowledge structures than less experienced trainees. Also, the knowledge structures of higher-ranking personnel were more accurate than lower-ranking personnel. In another teamwork training study, Rentsch et al. (1994) found that more experienced team members conceptualized teamwork more concisely than less experienced members. In a problem-solving training study, Langan-Fox et al. (2001) found that managers of teams with unstructured tasks exhibited different mental models from team members. The accuracy of knowledge