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A SYSTEM TO UNDERSTAND HUMAN-MACHINE FUNCTION ALLOCATION ISSUES IN VISUAL INSPECTION

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ABSTRACT

Product inspection is an important step in ensuring product quality with one of its most important tasks being visual inspection. If an inspection is to be successful, it is critical that the various functions constituting an inspection task be performed optimally. An inspection task typically consists of the following functions: orientation, search, decision-making, and recording. Orientation and recording, essentially manual activities, are best automated. The search and decision-making functions, however, are essentially cognitive activities and have been shown to be the most important determinants of inspection performance that system designers need guidance in allocating. With the customer demand for zero defects in products, 100% inspection using automated systems has seen more frequent application than traditional sampling inspection using human inspectors. Despite the advantages of automation, these inspection systems often fail to meet expectations primarily because they ignore humans' ability in pattern recognition, as rational decision-makers and their flexibility to adapt to new situations. Thus, designers of systems which include an inspection component need guidance on human/machine function allocation to ensure that the inspection is performed at the very least adequately and, preferably, effectively and efficiently. In response to this need, this paper describes a system that will facilitate the conducting of controlled studies to address issues related to human machine system design and function allocation in visual inspection. The system simulates the search and decision making functions of a Printed Circuit Board (PCB) inspection task. The system can operate in three separate modes: (1) human inspection mode – where all the functions are performed by the human, (2) automated inspection mode – where all the functions are performed by the computer and the role of the human is that of a supervisor, and (3) hybrid inspection mode – where inspection functions can be allocated to the human, the machine or both.

INTRODUCTION

Customer awareness regarding product quality and increased incidences of product liability litigation have caused inspection processes to become an important factor in manufacturing industries (Moll, 1976). Inspection is a careful search for nonconformities in a product. The two functions that are central to inspection are visual search and decision making (Drury, 1988). These functions have also been shown to be the primary determinants of inspection performance (Sinclair, 1984; Drury, 1992). If inspection is to be successful, it is critical that these functions be performed effectively and efficiently.

Unfortunately, while the need for error-free detection is important, human inspectors are less than 100% reliable (Chin, 1988; Drury, 1992). To overcome this deficiency, automated inspection is considered the solution to remove errors from the system. However, it seems that due to the changes in the availability of computer-based systems and microprocessor-based optically-sophisticated devices, designers have been automating the various functions of the inspection task, overlooking the innate abilities of humans to recognize patterns, make rational decisions, and quickly adapt to new situations.

It is known from literature that humans and automated devices have their own advantages and disadvantages. Large individual differences have been reported in human visual inspection performance (Wiener, 1975). The human visual system is adapted to perform in a world of variety and change; the visual inspection process on the other hand requires observing the same type of image repeatedly to detect anomalies. Some studies show that the accuracy of human visual inspection declines with dull, endless routine jobs and often slow, erratic inspection is the result. The advantages of an automated system are well documented, some of which include its ability to work on a dull routine job, sustain performance over time (reliability) and easier record keeping. However, humans are intelligent and flexible to adapt to changing situations. Humans at least for simple tasks are known to behave as rational decision-makers who take into account probabilities and cost/value structure. Besides, human information processing is automated and quick. In signal processing, humans are good at detecting signals in overlapping noise spectra and can make inductive decisions in new situations; however they are limited in their computational ability and short-term memory. On the other hand computers are good at computation, memory storage and retrieving, but are poor at detecting signals in noise and have very little capacity for creative or inductive functions. Therefore neither an entirely human nor a purely automated system may fully achieve the desired performance in an inspection task. It is possible that superior performance could be achieved by a system in which certain machine characteristics are dependant on tasks humans are better at executing. One challenge in designing such an inspection system is determining how best to allocate functions between humans and machines in this hybrid inspection system. There is a need to develop a methodology for using humans and machines in combination as an inspection system and to demonstrate the feasibility of such a hybrid system. We see many practical benefits in such a system if this hybrid system can be demonstrated to perform better than comparable purely human or entirely automated systems. The specific objectives of this research are to:

- investigate issues relating to dynamic function allocation between humans and machines in a hybrid inspection environment
- investigate issues relating to human/machine communication in a hybrid inspection environment
- compare the performance of a human inspection system, automated inspection system, and combined human-and-automated (hybrid) inspection system for select industrial and service-oriented inspection tasks and for different task and environmental factors
- demonstrate the feasibility of a hybrid inspection system
- develop a framework for function allocation between humans and machines in an inspection system as a step toward contributing to "best system performance."

To address issues related to human-machine function allocation, an inspection simulator was developed. The simulator described in the following paragraphs will enable us to conduct controlled studies on human-machine function allocation issues.

System Specification

The Visual Inspection System program runs on a Pentium computer and uses a 19" high-resolution monitor. The program was written in Microsoft Visual Basic (5.0) and the database was constructed and maintained using Microsoft Access 97. The program uses text, graphics and audio. The system's input devices are a keyboard and a mouse. To train the inspectors on different defects, a library of computer images, consisting of good and defective PCBs, was developed. Because the quality of images will directly influence the inspector's performance, special attention was devoted to generating high quality computer images. These images were designed using Adobe PhotoShop 4.0.

System Architecture

The program runs using six distinct modules that reference a database of information. The information stored in the database consists of both fixed, predetermined data such as image ID numbers, and data that is collected by the program and stored in the database at run time such as inspector performance measures. The modules are accessed and executed in a specific order. The basic structure and order of the system is shown in Figure 1.

The program uses a database consisting of six tables to reference system information in order to operate the five separate modules. Figure 1 details the system architecture by showing the relationships between the modules and the database tables. Each module references at least one database table. Figure 2 shows each module and the database tables used by the modules.

Table 1 details the relationship that exists between the modules and the database by detailing the information that is contained in each database. It is important to remember that in some cases the information is drawn from the table by the module and other times the module collects the information for storage in the table.

System Structure

The inspection system consists of the following major modules:

The System Administration Module. Using this system, administrators will be able to add, delete, and update the records of all the tables when necessary. In order to provide system security, different access rights will be granted to different users. For example, instructors can access all the modules while inspectors can not access parameter setup and system administration module.

The Parameter Setup Module. This module will allow system administrators to setup all the necessary parameters for inspection. These include inspection system mode (human inspection mode, computer inspection mode and hybrid inspection mode), images for inspection, detection time for each image, false alarms, classification (Accept or Reject), message (System failure, system comes back and so on.), etc.

The Defect Training Module. This module provides introductions to good and defective images. It also describes various defects in detail. The purpose of this module is to familiarize the subjects with both the search and decision making criteria (defect characteristics and how to use defect weights to classify an image as acceptable or rejectable).

The Inspection Training Module. This module trains the subjects on the search and decision making components of the inspection task. The Inspection Training Module uses the concepts of active feedback and progressive parts training.

The Inspection Module. This module is divided into three different parts. They are Human Inspection, Computer Inspection, and Hybrid Inspection Modules. In the human inspection mode, the human will perform both the search and decision making components. In the computer inspection mode, the computer will do all functions automatically and independently of human intervention. The hybrid inspection can be operated in various modes based on whether the functions are performed by the human, machine or both. Table 2 lists the various hybrid modes (Hou, Lin & Drury, 1992).

CONCLUSIONS

Controlled studies conducted using the simulator will lead to a greater understanding of the issues related to the human-machine inspection system design. The understanding will enable us to make the best use of the respective advantages of humans and machines in designing "best performance inspection systems," ultimately leading to improved inspection performance and quality.

ACKNOWLEDGMENTS

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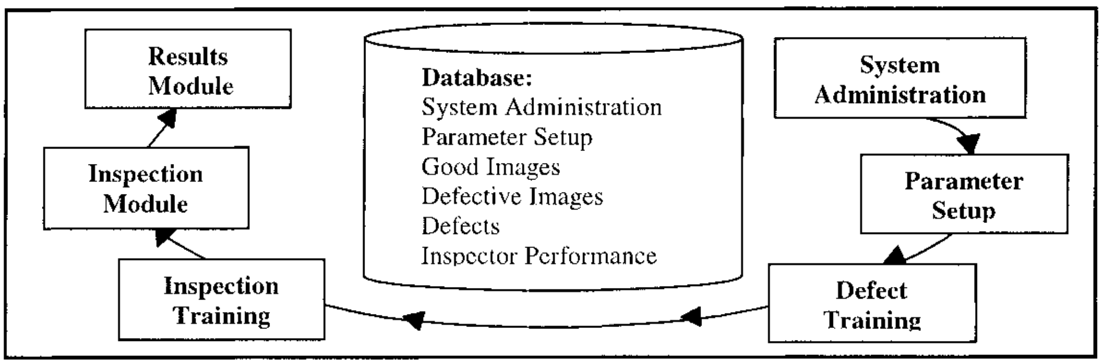

Figure 1: Describes the order in which the modules are accessed at run time

Alternative	Search	Decision Making
1	Human	Computer
2	Computer	Human
3	Human	Human + Computer
4	Computer	Human + Computer
5	Human + Computer	Human
6	Human + Computer	Computer
7	Human + Computer	Human + Computer

Table 2: Allocation alternatives in hybrid inspection task (Hou, Lin & Drury, 1992)

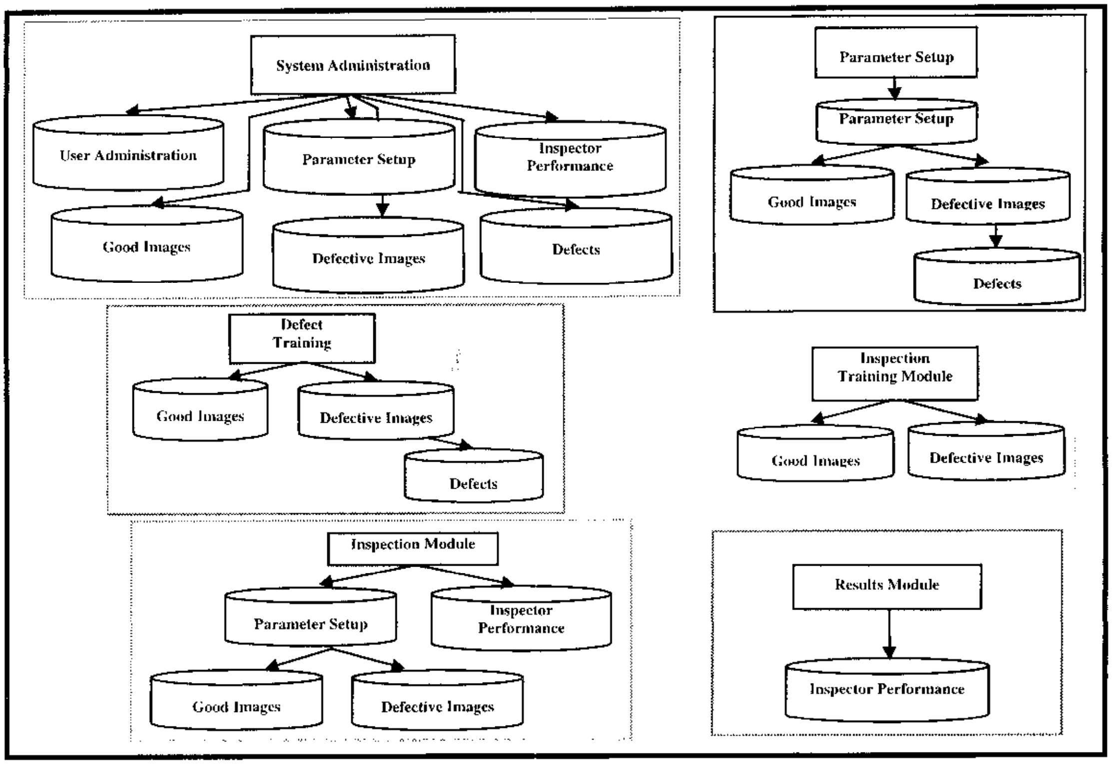

Figure 2: Database table and module relationship

Modules	Database Tables	Information Retrieved or Recorded
System Administration Module	*User Administration*	Add/Delete/Modify user information and/or Privileges
	Parameter Setup	Add/Delete/Modify Image ID, System Mode, Detection Time, Confidence Level, False Alarms, Classification
	Good Images	Add/Delete/Modify Images of Good PCBs
	Defective Images	Add/Delete/Modify Images of Defective PCBs
	Defects	Add/Delete/Modify Images of Defective PCBs
	Inspector Performance	Add/Delete/Modify Data from Inspector Performance Table
Parameter Setup Module	*Parameter Setup*	Records Image ID, System Mode, Detection Time, Confidence Level, False Alarms, Classification
Defect Training Module	*Good Images*	Retrieves Characteristics of a Good Image
	Defective Images	Retrieves Characteristics of a Defective Image
	Defects	Retrieves Defect Classification Criteria
Inspection Training Module	*Good Images*	Retrieves Images of Good PCBs
	Defective Images	Retrieves Images of Defective PCBs
Inspection Module	*Parameter Setup*	Retrieves Image ID, System Mode, Detection Time, Confidence Level, False Alarms, Classification
	Inspector Performance	Records Performance of Inspector for Storage in the Inspector Performance Table
	Good Images	Retrieves Images of Good PCBs
	Defective Images	Retrieves Images of Defective PCBs
Results Module	*Inspector Performance*	Retrieves Data from Inspector Performance Table

Table 1: Describes the information shared by the database and the module