Assembly Information System for Operational Support in Cell Production

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Abstract
In cell production, the output depends heavily on the performance of the worker. Assembly information support is useful to support the worker. The objective of this study is to develop a framework to organize assembly information to support production operation. It is illustrated by an application of a production operation in laboratory simulation. Assembly motion of skilled worker is extracted and the assembly process is decomposed into operational units, which linked with support information to set up the information database. New assembly process with information support can then be generated and implemented with multimodal system to assist production operation.

Keywords:
Cell Production; Assembly Process Planning; Task Analysis; Multimodal User Interface

1 INTRODUCTION

1.1 Towards Better Cell Production

The changing manufacturing requirements from conventional mass production to diversify product design with flexible production quantity, has greatly excited industrial interest in cell production. Also known as cellular manufacturing, this system consists of human worker as the center of the working cell to assemble the product [1]. In a production dell, a highly and multiple skilled worker is required because the manual assembly jobs are normally impractical for automation system. Moreover, the skilled worker is costly and requires frequent job training as the production jobs vary. Therefore, many studies [2] [3] have been conducted to improve working skill in production systems. On the other hands, efficient production cell system design is important to ensure good collaboration between human worker and machines. Physical support [1] [4] such as parts providing can greatly shorten assembly completion time. Besides tangible support, information support is another key research in industrial manufacturing.

1.2 Information Support in Production

In 1991, Gloria Gery had introduced Electronics Performance Support Systems (EPSS) as an electronic environment that provides various types of information to employee to improve job performance [5]. Finnish research team had developed Interactive Task Support Systems (ITSS) to support operative tasks (assembly work tasks) and Information Support System (ISS) that supports different work activities [6] [7] [8]. The importance of information support in production is apparent. However, most of the research works focus more on the overall system functionality rather than the content itself – Information. In this study, the main concern is to support human worker for assembly operation in cell production. The suitability form of information to the corresponding operation task and the effectiveness of the information transfer to the human worker are the core findings of this work. Hence, the objective of this work is to develop a framework to organize assembly information to support production operation. The objective is incorporated with two distinctive approaches: job analysis by Hierarchical Task Analysis (HTA) method and multimodal based operational support system. In this paper, the framework is illustrated by an application in an actual cell production operation in laboratory simulation. The selected cable assembly task and working cell setup are explained in Section 2 together with introduction to the principal system. Section 3 discusses the analysis of cable assembly operation using HTA approach. Section 4 illustrates the assembly information organization in term of development and database structure. The assembly flow design and multimodal assembly support are explained in Section 5. Finally, Section 6 concludes this work with suggestions for further improvement.

2 SYSTEM BACKGROUND

2.1 Assembly Task

An existing cell production assembly operation is selected in this study to ensure the practicability of the developed framework. The operation job is to assemble parts and cables into the assembled product in Figure 1. However, the assembly tasks in this study are limited to cables assembly only (excluding cable binding, terminals and plate assembly).

Figure 1: Assembly components and assembled product.

The selected working cell setup (Figure 2) consists of a workbench and a set of twin six degree-of-freedom manipulators to supply assembly parts to the human worker. The manipulators are located in between the workbench and parts tray rack. Parts are picked up from the blue trays on the rack by bin picking method and placed into the kit tray in front of the workbench.

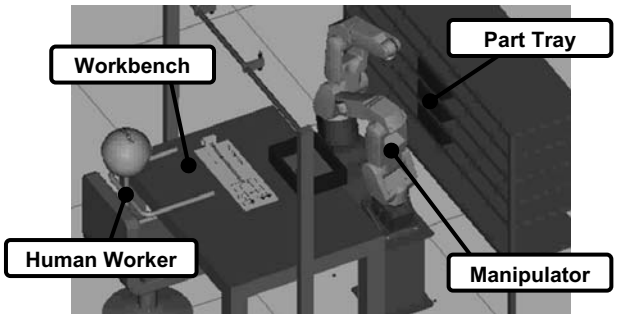

Figure 2: Working cell setup.

2.2 Principle Support System

The framework developed in this work belongs to a larger support system that includes expert worker motion measurement for skill study, Multimodal Assembly Support System (MASS) and also human vital sign monitoring system. Figure 3 shows the entire principle support system flow. The entire system serves for two main purposes: operation information support and operation teaching support. These two supports are key enhancement studies for human worker performance in cell production system. In this work, operation information support is illustrated.

In Figure 3, the elements in red box are the framework components of this work. The process that develops information support in assembly operation involves four main stages: Operational motion and task analysis, information database development, assembly flow design and multimodal assembly support. As shown in Figure 3, the first stage involves two main analyses, expert worker operation motion study and operation task analysis. In this stage, detailed study is conducted on the operation motion by expert worker and also the assembly tasks of given job for skill extraction and task modeling. Operation motion measurement and study are done in another work in the project [9]. However, this input is not included into design consideration in this work but only operation task analysis is concerned. Details on task analysis are discussed in the next section in this paper. The second stage involves assembly information processing and development. Information database is also developed in a collaborative approach to enable team development. The information is then used to construct into operation support in assembly flow design. In the final stage, the operation support is implemented in production with MASS.

3 TASK ANALYSIS

3.1 Task Analysis and Hierarchical Diagram

Task Analysis (TA) is a study to describe activities that must be carried out to achieve a specific goal [10]. It provides a scientific management to model tasks especially in user's task domain which is an important factor in system design [11]. In this work, the first stage of work focuses on the study of the given assembly operation in cell production. HTA which is widely used in various applications for system ergonomic and performance improvements [12], is an excellent task analysis technique for task modeling in this work. The extendibility sub-goal hierarchical structure and the ergonomics approach well addressed the design requirements of this system.

3.2 Cable Assembly Operation

The main task of the given assembly job in this study is the assembly of five cables on a specific marking board. The assembly operation is being modeled in hierarchical diagram as shown in Figure 4. In the diagram, the main goal of the job is 'Assemble cables on marking board' (Super-ordinate goal 0). Under the main goal, there are four sub-goals: 'Secure cable contact on connector', 'Temporary fix cable end', 'Set connector on marking board' and 'Form cable on marking board' (Sub-goal 1, 2, 3 and 4). Plan 0 addresses the working flow of these four sub-goals. Sub-goal 1, 3 and 4 are further

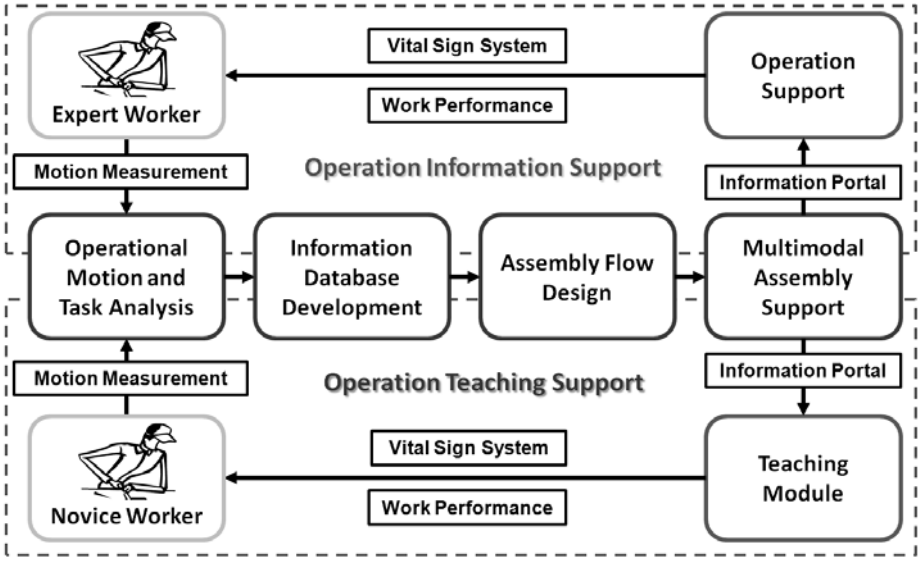

Figure 3: Principle support system flow.

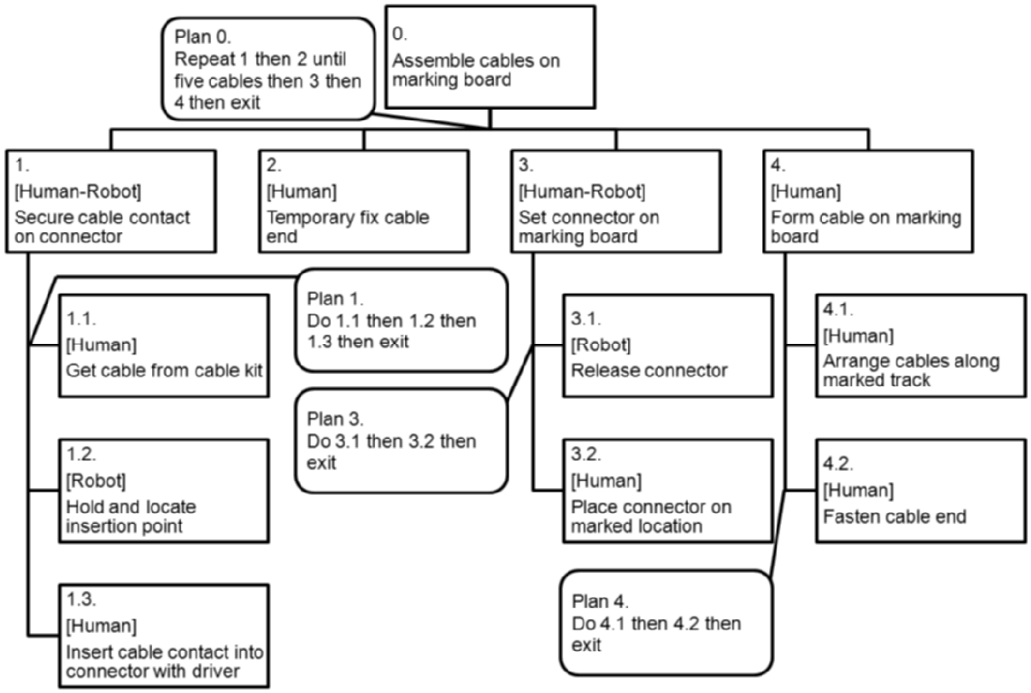

Figure 4: Hierarchical diagram for the cable assembly operation.

branched out to own sub-divisions with respective plans for operation flow. The hierarchical analysis stops at the third layer as the sub-goals on this layer are considered 'fit-for-purpose' [12]. One special parameter has been inserted in this diagram to indicate the working role of tasks between human worker and robot manipulators to address the man-machine collaboration in this work.

4 INFORMATION SYSTEM

4.1 Assembly Information

Based on HTA study, the entire assembly job has been properly modeled into discrete task segments. The next step is to develop the task segment 'descriptions' into assembly information, which will be supplied later to the human worker for assembly operation. These 'descriptions' can be developed in various media formats which traditionally are appeared in text format as in conventional operation manual. However, the studies of human cognitive science and workload theories show that different media formats can influence human cognitive and working performance. Based on Multiple Resource Theory (MRT) by Wickens [13], the usage of multiple media formats can improve the effectiveness of the information supply to the human worker in assembly work. Hence, in this work, the assembly information is developed in text, picture, audio and video formats extracted from expert worker operation recording, operation manual, training materials, operation documentation and other resources. The same reason also leads to the application of multimodal based assembly support system in the next section.

4.2 Information Database

A systematic database structure is essential to handle the vast amount of multi formats assembly information. Raw assembly data from various sources are being processed and edited into the desired forms and saved into digital file system. All the files are stored in online document center on Microsoft Office SharePoint Server platform. To further enhance the information organization, a Task-Information Mapping tool is being developed on Eclipse platform [14] (Figure 5). This tool provides a development environment to map task with all the related information files. This mapping offers great assistance to the multimodal assembly presentation development in the next section.

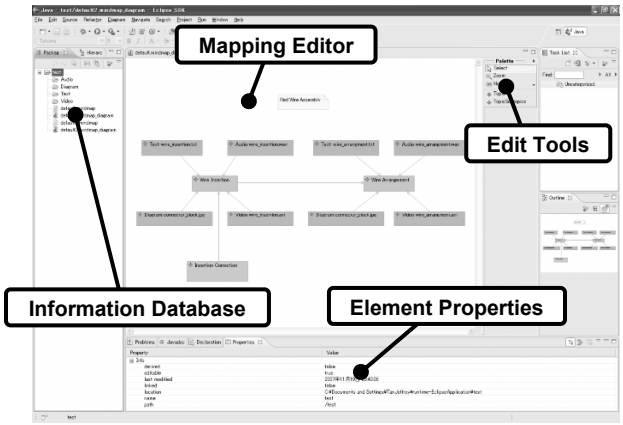

Figure 5: Task-Information Mapping tool.

4.3 Collaborative Development

The information database is managed by Microsoft Office SharePoint Server system. This system enables collaborative development through its online portal system. In the document center, team members can manage the files remotely. Apart from technical development, the information also can be accessible by other parties to serve as an online production information portal.

5 ASSEMBLY SUPPORT

5.1 Multimodal Assembly Support System (MASS)

The final step in this work is the assembly flow design and multimodal assembly presentation development before input into operation. These developments are conducted in Microsoft Office PowerPoint environment. PowerPoint provides a very flexible and user-friendly development environment. Based on the HTA study, the assembly flow is edited into PowerPoint slide presentation and the assembly information are inserted in multimodal approach to improve the information supply effectiveness [15]. Figure 6 shows a sample of multimodal assembly presentation for information support in assembly operation.

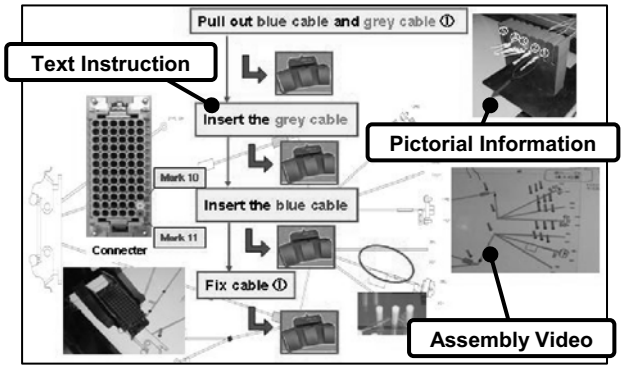

Figure 6: Multimodal Assembly Presentation.

5.2 Laboratory Simulation

Based on the proposed framework, the assembly information support is completed for the given cable assembly operation and implemented in the laboratory simulation. The manipulators are being programmed based on the assembly flow and the man-machine system is collaborated well in the laboratory simulation. The assembly operation is being able to carry out without any major mistake by non skilled worker with better working performance in the production cell with the assistance of the information support.

6 CONCLUSIONS AND FUTURE WORK

In this work, a framework that organizes assembly information to support production operation is developed. Key points of the development:

- The framework is successfully implemented in a cable assembly laboratory simulation.
- HTA method has effectively modeled man-machine collaborative assembly job.
- Information database, a task-information mapping tool and a collaborative development environment are built to manage the assembly information.
- Multimodal based operational support system has enhanced the working performance during assembly operation.

The integration of task analysis technique and multimodal interface to create operational support in term of assembly information is feasible with great potential. The study should continue to investigate the effectiveness of such support system in term of working performance and find out the design parameters. The accuracy of task analysis in assembly operation and the relationship between task and information are also valuable research work to further enhance working performance in cell production.

7 ACKNOWLEDGMENTS

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