論文の内容の要旨

論文題目　Assembly Skill Transfer System for Cell Production

（セル生産のための組立技能伝達システムの開発）

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（本文）(Abstract)

Human operator enables a cell production system to meet the diversified production and quantity requirements flexibly. However, due to the negative or zero growth of population in Japan, it will become difficult to maintain the cell production system with enough multiple skilled human operators in the near future.

To overcome this problem, it is absolutely necessary to analyze and extract the assembly skills of skilled operators, synthesize human understandable assembly skill models, and then transfer these models to the new operators. In this way, assembly efficiency of the cell production system can be improved. Therefore, even under the aging society and facing the shortage of human operators, the cell production can be maintained with enough assembly efficiency.

Human assembly skill is a subclass of human skill. Many researchers have already extracted and transferred human skill to either novices or robots in their own fields. These studies can be classified into three kinds: 1) extracting and transferring human cognition skills; 2) extracting and transferring human decision skills; 3) extracting and transferring human motor skills. The objective of this thesis is to extract and transfer human skill in assembly field, which is a kind of human-to-human skill transfer process. Human decision skill mainly remains in human minds, and it is not difficult for human operator to make a decision to select the appropriate action according to the state. Hence, in this thesis, human decision skill will be viewed as Black Box, and only human cognition skills and human motor skills will be investigated in details. All of these will be introduced in Chapter 1.

Chapter 2 introduces a series of definitions about assembly and its characteristics. Furthermore, a sample assembly operation is proposed. Since human assembly skill is a large concept, before investigating it, specific concepts about human assembly skill are defined and its evaluation criterions are proposed. To facilitate understanding of human assembly skill and promote its practical applications, an assembly skill conceptual model is designed.

In a typical assembly filed, especially in cell production system, although all of the assembly steps are predesigned, and the operators only need to execute the assembly tasks according to the requirements; however, the assembly performance results of skilled operators and novice operators are different. The differences between skilled operators and novice operators mainly lie in cognition skill (the ability to recognize the assembly state) aspect and motor skill (the assembly movement to execute the assembly task in an assembly step) aspect. These will be discussed in Chapter 3.

In Chapter 4, taking a “Cable-Insert” operation as an example, a group of skilled operators were required to point out their own feelings about assembly skills in cognition aspect through questionnaire. In order to extract the advantages of skilled operators’ motor skills, videos of their entire assembly processes were divided into each assembly motions, and evaluated by the evaluation criterions introduced in Chapter 2.
In the real manufacturing companies, operator needs to execute the assembly task for a long time. Executing the same assembly task under different assembly poses, the muscle forces of the operator are different. In order to reduce the operator’s assembly burden, motion capture equipment and electromyogram (EMG) sensors were used to find the most appropriate assembly pose that requires the least muscle forces. These will be introduced in the latter of Chapter 4.

Synthesized assembly skill models can be saved as several kinds of assembly skill instructions (i.e. text, picture, video, etc.). Which kinds of assembly skill instructions facilitate understanding of human assembly skill models and promote their practical applications will be discussed in Chapter 5. To achieve this aim, a group of novice operators were required to execute the “Cable-Insert” operation under the guidance of manual (assembly skill models embodied in text format and picture format) and Multi-Media PowerPoint slide (assembly skill models embodies in PowerPoint slides in multi-media format). Based on the assembly

results and NASA-TLX method, assembly skill transfer effects of different assembly skill instructions were evaluated.

In Chapter 6, an operator monitoring system was developed to monitor and optimize operator's assembly poses. Based on the joint-angle database, which stores the extracted representative joint angles of the operator's assembly poses introduced in Chapter 4, this operator monitoring system can provide information to guide the operator and optimize his assembly pose.

Finally Chapter 7 concludes the entire thesis and points out the future work.