Architecture Design of Intelligent Assembly System Based on Complex System

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Abstract. For complex system and product, the virtual and intelligent assembly system can short the designing and manufacturing time effectively, especially for administration of life cycle of product, it can provide the digital models for different period using. In this paper, the intelligent assembly system architecture was designed which includes three-layers, application layer, data layer, and output layer. By using this intelligent assembly system the virtual assembly of complex system products is realized. Then, the framework of intelligent assembly information modelling was designed further which includes geometric information, assembly constraint information, and assembly relationship information. This assembly information model can not only express the connection between assembly parts and assembly relationships, but also provide information sources and acquisition mechanisms for assembly process planning. At last, an example of product assembly is presented which includes 3D models analysis and attribute set for simulation, the intelligent assembly function is accomplished in the end.

1. Introduction
The performance of complex products is closely related to assembly quality, and assembly error is an evaluation index of assembly quality. After the product is assembled, some key reference features are often used to evaluate its performance indexes. The variation between these reference features and their ideal shape directly determines the quality of the assembly. Therefore, it is necessary to build a part error transfer model to calculate the assembly error[1]. The adoption of digital technology reduces the probability of assembly failure and improves the economic benefits of products. But the digital prototype models tend to ignore a large number of elements in the real environment, which results in inconsistency with the actual assembly conditions of parts and is difficult to meet the performance requirements of products with higher accuracy[2].

There are usually two kinds of problems in manufacturing assembly. One is the error in the product design stage, which directly causes the assembly to not proceed normally, so the product needs to be redesigned; the other is that the assembly process is unreasonable, so the assembly sequence needs to be readjusted. Both types of problems will greatly increase the cost of assembly and cause unnecessary waste. In some relatively developed countries with industries, assembly hours account for 40% - 60% of total manufacturing hours, and the cost of assembly accounts for 25% - 70% of the total cost. In the manufacturing process, about 30% of the manpower is engaged in assembly-related operations, and more than 40% of the expenditure is spent on product assembly. The good assembly design can reduce manufacturing costs by 20% - 40%, and improve the production efficiency by 100% - 200%. In order
to reduce the time used for assembly and improve production efficiency, it is necessary to use virtual assembly technology to preassemble products during the product design stage[3].

2. Intelligent Assembly System Architecture Design

Based on the complex system, the digital twin technology is studied to establish an integrates multiple levels of information digital twin assembly model expression method and intelligent assembly system. What’s more, the system architecture and overall framework are established[4].

Assembly is the most important part of the entire product manufacturing process, and the quality of the assembly directly determines the production quality and production capacity. For the assembly design of complex systems, there are problems such as high assembly accuracy, relatively difficult assembly, and many types of assembly. At present, it is still difficult to guarantee, predict and control the assembly quality by making the crafting process according to the experience of operation workers and using real objects for trial assembly before formal assembly. Due to the lack of visual verification means in the crafting process design stage, the problems that occur during the design stage of the assembly process often need to be discovered during the assembly process, and if problems occur, the process file needs to be changed again, and the assembly operation is also needing to change. It can lead to problems such as long assembly cycle of the complex system, high rework rate, and unqualified quality.

In order to solve the problem, this paper uses virtual reality technology[5], simulation technology and operation monitoring technology to simulate the spatial position and movement form of key components in complex systems in a computer virtual environment, and simulates and analyzes its technological process and operation monitoring. The overall structure of the three-layer intelligent assembly system constructed is shown in Figure 1. The system structure includes three layers: the application layer, the data layer, and the output layer. The application layer mainly includes assembly modelling, simulation parameter settings, and assembly process monitoring. The data layer is mainly provides data support for the application layer, and the output layer mainly outputs various documents.

![Figure 1. Overall architecture of the intelligent assembly system.](image-url)
Through the definition of assembly objects and simulation parameters, the virtual assembly of complex system products is realized. And the interconnection between the reconfigurable system in the physical world and the virtual assembly system in the information world is realized through the application layer. Through calculation and analysis of model data of reconfigurable assembly components, the information such as installation guidance parameters, spatial position and pose offset can be obtained in real time. Through the human-computer interaction program to make a reasonable decision on all kinds of pushed information, including logical decisions, spatial decisions and timing decisions. According to the decision instruction, the system is assembled by interactive assembly programming method [6].

3. Framework Design of Intelligent Assembly Information Modelling

Assembly information modelling is to build a comprehensive information model. This model can not only meet the requirements of the product life cycle applied in a specific stage, but also support all assembly-related activities and processes in the product life cycle. The assembly information model can not only express the connection between assembly parts and assembly relationships, but also provide information sources and acquisition mechanisms for assembly process planning.

The assembly information model accurately expresses the hierarchical structure relationship of products and the assembly relationship between components. The expression of assembly relationship is the basis of the motion relationship and topological relationship between product components. As for the specific assembly model, a general assembly contains several sub assemblies, and the sub assemblies contains more and smaller sub assemblies and parts. This type of organization of the assembly can be well expressed by the hierarchical relationship [7].

The assembly information model supports all activities related to assembly in the life cycle of the product. The assembly process planning includes process planning and assembly process simulation. Therefore, the assembly information model should include the management information, geometric information, assembly hierarchy information, and assembly constraints information used for process planning. What’s more, it’s also need include pose information and bounding box information used for process simulation.

The assembly information model should be able to meet the requirements of the product assembly process, and the assembly relationship and constraint relationship between components can be clearly expressed. Due to the wide range of fields and technical scope involved in assembly process planning, designers need to continuously apply design experience to model design. The reasonable model structure should be able to meet various requirements in production practice.

The functional structure framework of the intelligent assembly information modelling platform constructed in this paper is shown in Figure 2. The assembly modelling information includes geometric information, assembly constraint information, and assembly relationship information. The geometric information refers to information related to the actual structure of the product. It determines the geometric size and shape of the components and the assembly, and plays an important role in determining the position and posture of the components in the assembly. The geometric information required for the assembly model can be directly extracted from the relevant database. The assembly relationship is used to describe the spatial relative position and cooperation relationship between components, and to define the relative motion relationship and constraint relationship between components. According to mechanical knowledge, the relationship information can be divided into four categories: connection, cooperation, motion, and position. Assembly constraint information refers to the mutual constraint relationship between components in an assembly [8].

As an important part of virtual manufacturing, virtual assembly technology can analyze and verify the rationality and feasibility of assembly design, so as to discover and solve the problems in the production process in time. In the virtual assembly system, process designers can model assembly products, plan assembly sequences, analyze and verify the feasibility of assembly processes, and simulate assembly processes according to the demanding need.
Figure 2. Intelligent assembly information modelling.

The ultimate goal of virtual assembly is to verify and analyze the feasibility of assembly. During virtual assembly of the assembly, multiple goals need to be completed. The ultimate goal is to verify whether the assembly of components meets the actual assembly requirements through a virtual environment, and to find the existing problems before the actual assembly.

It is a major research hotspot in current manufacturing products, which the application of digital technology to reproduce the complex product forming and assembly process to guide the actual production and assembly of components. How to realistically reproduce the product manufacturing and assembly process in the real world in the virtual environment, and optimize the design parameters and assembly process of the components by predicting the assembly accuracy of the product is of great significance to improve product performance and market competitiveness. Virtual assembly can use 3D simulation technology to simulate, evaluate and analyze the assembly process of complex system products, and simulate and optimize the process. It’s an problem that need to be solved urgently of establishing physical attribute models of components in the virtual system, simulating the assembly process based on physical attributes and considering the influence of assembly errors in the process of implementing virtual assembly. Intelligent assembly technology based on virtual reality is a good way to solve the above problems, which can effectively improve the response speed of the entire production process, greatly shorten the product design and development cycle. At the same time, it’s also provide a good solution for the lack of agility in the assembly process of complex system
products. Figure 3 shows the 3D models analysis and attribute set for simulation, the intelligent assembly program is designed also.

![3D models analysis](image1)

![Program designing](image2)

**Figure 3.** Program designing of intelligent assembly.

The stage of assembly information modeling mainly consists of two parts: the acquisition of model information and the construction of virtual assembly scene. Process designers obtain various required 3D models from the product design department, including product models, equipment models, workshop or plant models, etc. Then they are beginning to process, convert and lighten these 3D models with geometric, topological and constraint information, generating model data required for product design for process, then importing these model data into the system. These data are restructuring and establishing in the system, so as to form various models in the assembly field and scene.

4. Conclusion

It’s urgent problems that need to be solved in the current application process of virtual assembly, which establishing physical attribute models of components in the virtual system, simulating the assembly process based on physical attributes and considering the influence of assembly errors. Intelligent assembly technology based on virtual reality is a good way to solve the above problems. This paper establishes an intelligent assembly system architecture based on complex systems, builds an overall architecture of the intelligent assembly system, completes the intelligent assembly information modelling framework design, and can realize intelligent assembly rapid modelling and data exchange with the assembly simulation platform. This can shorten the product design and development cycle greatly.
5. Acknowledgments
This work is supported by Changchun Research Institute of Equipment and Technology innovation fund.

6. References
[1] Li Dongying, Mengqi Li, Genbao Zhang et al. 2015 Research on Error Source and Error Transfer Model of Meta-Action Assembly Unit, *Journal of Mechanical Engineering*, vol17 pp 146-155
[2] Soheil Arastehfar, Ying Liu, Wen Feng Lu. 2014 A framework for concept validation in product design using digital prototyping. *Journal of Industrial and Production Engineering*, vol 31 pp 286-302
[3] Xia Pingjun, Yingxue Yao, Jiangsheng Liu et al. 2007 Assembly sequence optimization based on virtual reality and bionic algorithm. *Chinese Journal of Mechanical Engineering*, vol14 pp 44-52.
[4] Y. Cai, B. Starly, P. Cohen, Y.S. Lee. 2017 Sensor data and information fusion to construct digital-twins virtual machine tools for cyber-physical manufacturinng//45h. SME North American Manufacturing Research Conference. *Procedia Manufacturing*, vol10 pp 1031-1042.
[5] Zenner Andre, Makhsadov Akhmajon, Klingner Soren et al.2020 Immersive Process Model Exploration in Virtual Reality. *IEEE transactions on visualization and computer graphics*, vol 26 pp 2104-2114
[6] Zheng Yi, Ruxin Ning, Jianhua Liu et al. 2006 Research on Interactive Virtual Assembly Path Planning and Optimization Method. *China Mechanical Engineering*, vol11 pp 1153-1204.
[7] Liu Zijian, Ping Wang, Yandi Ai. 2011 Research on Process Oriented Product Information Virtual Assembly Modeling Technology. *China Mechanical Engineering*. vol1 pp 60-64.
[8] Feng Fan, Jiang Du, Hu Qiao et al. 2018 The Expression of Mechanical Product Assembly Information in Virtual Reality Environment. *Machinery*, vol11 pp 6-11.