Research on mechatronics modeling method based on digitalization

To cite this article: Shuqin Yu et al 2018 J. Phys.: Conf. Ser. 1074 012027

View the article online for updates and enhancements.
Research on mechatronics modeling method based on digitalization

Shuqin Yu¹, Gang Zhao¹, Jiale Li¹, Guangli Zhang¹, Honghao Zhao²,³, Xuwei Guo¹ and Ying Qiu¹

¹ Harbin Engineering University, Institute of mechanical and electrical engineering, 145 Nantong Street, Harbin
² Macau University of Science and Technology, Department of Decision Science, School of Business, Macau, People’s Republic of China.
³ E-mail: hhzhao@must.edu.mo

Abstract. The functional analysis method is used to decompose the mechatronics system into several sub-functional elements and the sub-functions are connected by the interface technology, so the functional element is the basic unit of the mechatronics system. It effectively saves the engineer's design time and improves the rationality of the design plan. The concept of a four-screen graphics was proposed based on the original modeling method of bond graphs and the modeling of block diagrams and the graphics library of bond graphs was enriched. What’s more, the modeling and design of three-dimensional modeling and circuit boards were added which makes it possible to express mechanical space and electrical space in a comprehensive space and it makes the establishment of the mathematical model of the system feasible.

1. Introduction

Industry 4.0 makes China to focus their eyes on intelligent manufacturing and with the development of information technology, many new concepts emerge in endlessly, such as big data, cloud computing, the Internet of Things and so on, setting off waves of waves, which has greatly promote the development of information technology [1]. The manufacturing industry embodies the comprehensive national strength of a country, which is the core of improving the country's competitiveness in the world. So, it is of great significance to develop the manufacturing industry to ensure the security of the country. The application of information technology in China's manufacturing industry will effectively promote the integration of information technology and industrialization, and promote industrial progress and development.

The concept of mechatronics has a long history and with the continuous progress of new technology, mechatronics system has become more and more intelligent, networked, modular, automation and so on [2]. Mechatronics technology is the intersection of various disciplines and technology, such as mechanical manufacturing technology, interface technology, automatic control technology and so on. Designers often can’t be proficient in many subjects at the same time. Therefore, there is a phenomenon of separation between mechanical parts and electric parts in the study of mechatronics system at present, it is urgent to study mechanical space and electricity space in a comprehensive space. The integration of information and industrialization provides an opportunity for the development of mechatronics. Traditionally, the system is designed by experienced engineers rely
on a large amount of information and experience [3, 4]. With the information age approaching, it is favorable to form scientific design by summarizing the design experience in the form of knowledge reservoir, which will improve the efficiency of the designers. In recent years, the concept of digital manufacturing is not unfamiliar to us, it includes both digital design, digital manufacturing and digital assembly, so it runs through the whole life cycle of the product. Therefore, the research on digitalized mechatronics modeling method is of great significance.

2. Design unit of mechatronics system
There are many disciplines involved in the mechatronics system, such as machinery, electronic technology, interface technology, sensing technology and so on. In order to meet the requirements of modern design better, the mechatronics system is developing towards more intelligent, systematic and flexible. The design of the mechatronics system needs a more scientific method. At present, the design of mechatronics system is not limited to the traditional design methods, more and more innovative methods are used to design the mechatronics system [5]. The design process of mechatronic system is shown in figure 1.

![Figure 1. Design flow chart of mechatronics system.](image)

Considering the product life cycle, the mechatronics design not only includes the design of the product but also the maintenance of the product. Therefore, the product design process refers to the whole process of the product from concept design to recycling [6]. In the preliminary design of the mechatronics system, the principle of the system is mainly studied and the system will be analyzed and simulated [7], which occupies an important position in the design of mechatronics system. When modeling a mechatronic system, it is difficult to provide a relatively reasonable plan to meet the given requirements [8]. Therefore, the designer often use some conceptual design tools when designing a mechatronic system, which increased the efficiency of design. There are two commonly used functional analysis methods. One is a functional analysis tree, the functional tree structure of the mechatronic system is shown in figure 2.

![Figure 2. Function tree structure of mechatronics system](image)

As is seen in figure 2, it decompose the total system functions into several sub-functions after analyzing the system structure, and then sub-functions can be decomposed into several functional elements, so the system can be designed in detail. It mainly expresses the hierarchical structure between functions and the affiliation between each function. The other tool is the functional structure diagram, which is mainly used to represent the relationship between each sub-function in the same functional layer. The mechatronic system can decompose into different modules and each module is connected through the interface. Mechatronic system is the combination of different functional elements, and function elements will be the basic unit in the design of mechatronic system.
3. Digital interface of mechatronics model

The total function of the mechatronics system will be decomposed into sub-functions and will be combined using the interface technology. The interface of the mechatronics system refers to the components or circuits that connect all parts. For the whole system, the performance of the interface affects the performance of the whole system and the use of standardized interface can be effectively improve the design efficiency [9]. The electromechanical interface technology will be developed in the direction of intelligence, standardization and information [10, 11]. The mechanical and electrical interface is no longer a simple transfer of information and energy, but it is developing towards the intelligent direction of information acquisition, processing and energy control. The electromechanical systems are more and more open and modular. The system can be configured flexibly for any combination [12, 13]. The matching strategy of mechatronics system’s function solution interface is shown in figure 3.

![Figure 3. Matching strategy of mechatronics system’s function solution interface.](image)

After the mechatronic system is decomposed into different sub-functions, its functional solutions are solved respectively. The combination of different functional solutions depends on the interface technology [14, 15]. When describing the expression of components, the data structures of all components include mechanical elements, electronic elements, and sensing elements. When an element does not contain a certain element, the part can be defaulted. For each element, each element
corresponds to a specific physical quantity and value. When selecting the interface components, it can be selected according to the input and output physical quantities and parameters as the known conditions, which greatly improves the work efficiency, which greatly improves the efficiency. The interface can be divided into two modes, the two interface modes are shown in figure 4.

![Interface Composition](image)

(a) Direct Interface
(b) Indirect interface

Figure 4. Two interface modes.

The direct interface uses its own element information for connection, which can only transmit information and cannot convert information, such as screws and bolts. The indirect interface is connected through an intermediate interface module which converts the output element of module A into the required input elements of module B, such as couplings for connecting motors and mechanical equipment.

4. The generation of mechatronic system solution

After the completion of the design of the mechatronic system, the system needs to be modelled, the modeling process needs to simplify the abstract physical system to obtain the simplified model which is easier to be described by using mathematical method. What’s more, the mathematical model is more conducive to the realze computer simulation. At present, there are five commonly used modeling methods: bond graph modeling method, block diagram modeling method, object-oriented modeling method, system diagram method, and hybrid Petri net method. The bond graph modeling is mainly applied to the modeling of mechanical parts. In the modeling of bond graphs, there are only 9 basic graphic signs, so the components in each domain are corresponding to them, such as the damping analogy is regarded as a resistive element and the mass analogy is regarded as an inductive element in the mechanical field, and the flow direction of energy and power are expressed by arrows. Block diagram modeling is widely used in mechatronic control systems. It is composed of a large number of different basic control modules and each module has a transfer function. Through the feedback module and the feedforward module, any model of the control system can be expressed. The object-oriented modeling method can both realize the modeling of the mechanical part and the modeling of the control part. It decomposes the physical entities in the mechatronic system into many basic units that can be described in mathematical form, and packages these units. The system diagram method is mainly used to express the topological relationship of the system and represents the flow direction of energy and signals in the system. The hybrid Petri net modeling method is mainly used to model and simulate the position. The combination of the bond graph modeling method and the block diagram modeling method in the mechatronics modeling will be more conducive to mechatronic system modeling. The mechanical part is expressed with a bond diagram, and the control part is expressed with a block diagram. The four-screen diagram is used to represent the design of the mechatronic system in the paper and the structure is shown in figure 5.
In the paper four important principles and structure diagrams in the design of mechatronic system are expressed in one graph. The mechanical and electrical parts of the system are modeled on a graph, which is conducive to mathematical analysis of the system. The modelling of the mechanical schematic diagram adds logo of other mechanical components on the basis of the bond diagram method, which enriches its basic component library, and expresses the coordination relationship between the components in the mechanical assembly using lines to connect them. The mechanical assembly drawing will refine the mechanical schematic diagram and use the three-dimensional physical entity to express the mechanical structure of the system, which expresses the connection relationships between different components more clearly. Circuit schematic diagram uses the block diagram modeling method to display the principle expression of all circuits of the system according to the requirements of the mechanical part, including both the strong electric circuit and the weak electric circuit. The circuit diagram will make detailed design of the structure of the circuit schematic diagram to make it meet the requirement of the system.

5. Mechanical schematic modeling method

The mechanical schematic diagram is a simple representation of the mechanical assembly. Therefore, the connection between the two motion function elements is represented by a simple connection whether it is a polygonal line or a curved line, as long as both ends can connect the functional elements to meet the requirements. For the sake of simplifying the layout of the drawing, the simple assembly is represented by straight lines and broken lines. The composite assembly includes not only the sub-assembly, but also the sub-assembly of the sub-associated parts, and the assembly of sub-assembly and parts. The number of is uncertain, so the symbol structure of the composite assembly is also uncertain. It depends on the number and position of the included simple assembly pairs; for the sake of simplicity, it is represented by square squares. Parts are represented by square symbols, as shown in figure 6.

![Diagram](image)

(a) Part symbol  (b) Simple assembly symbol  (c)Composite assembly symbol

**Figure 6.** Assembly plan diagram symbols.

Axle hole assembly belongs to the direct restraint assembly relationship and we can use simple assembly to represent the assembly relationship between the parts and parts. The most typical indirectly assembly relationship is the gear meshing assembly and it is mainly used to express the
relationship between shaft and shaft. The assembly relationship of the gear assembly is shown in figure 7.

![Figure 7. Gear engagement assembly.](image)

In the figure above, the main assembly relationship is the assembly relationship between the shaft and the shaft. The shaft 1 and the shaft 2 form a transmission assembly relationship through two gears. This assembly relationship can be represented by a composite assembly pair. We can see that this assembly can be divided into five parts, namely, gear 1, gear 2, gear meshing pair and two shaft hole assembly pairs. Gear 1 and gear 2 are transitional components, gear meshing pairs and two. Axle hole assembly sub-assembly is a simple assembly, these five parts together constitute a composite assembly.

6. Summary
In this paper, the mechatronics system is modeled by means of functional analysis. The mechatronics system is divided into several function elements, and the function element is regarded as the basic unit, which simplifies the design process and forms a scientific design method. Each functional module is connected through interface technology and the connecting strategy is introduced in the paper. The concept of four screen diagram is put forward to express the mechanical part and the electronic control part in a space, which provides the basis for the mathematical analysis of the mechatronics system. The mechatronics modeling method based on digital modeling is an innovation to the traditional design, which promotes the intellectualization and modularization in the design process of the mechatronics system and greatly promotes the integration of industrialization and informationization.

References
[1] Miu Xueqin 2016 Process Automation Instrumention 01(37) 1-5.
[2] Kang Xin 2018 Energy and Energy Conservation 03 148-9
[3] Guo Yuchao 2017 Technology and Economic Guide 23 18
[4] Zhu Maoxin 2017 Technology Innovation and Application 34 163-5
[5] Wang Changren 2016 Scientific and Technological Innovation 30 30
[6] Wang Zhongyuan 2016 Modern Manufacturing Technology and Equipment 09 1-2
[7] Guo Weizhong, Liang Qinghua and Zhou Huijun 2002 China Mechanical Engineering 16 67-71
[8] Xu Yong 2011 Mechanical Science and Technology for Aerospace Engineering 30(10) 1673-8
[9] Li Ruiqin, Zhou Huijun 2004 China Mechanical Engineering 09 44-7
[10] Chen Liang 2016 Inner Mongolia Coal Economy 20 64-80
[11] Liu Jie 2017 New Technology & New Products of China 16 4-5
[12] Yang Zhiwei 2015 Electronic Technology & Software Engineering 06 125
[13] Zheng Gang, Fei Renyuan, Zhang Huihui and Sun Shuwen 2003 Manufacturing Automation 06 1-3
[14] Xu Yong, Zhou Huijun 2006 Computer Integrated Manufacturing Systems 09 1396-1401
[15] Wang Jianbo 2017 Urban Construction Theory Research 17 139