The Research on Automatic Generation and Innovation of Three Degrees of Freedom Planar Multi-link Mechanism

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Abstract. Based on the basic principle of regenerative chains and combined with the innovation method of type synthesis and basic chain structure method, the software is produced with Visual Basic 6.0 and is used to program of the automatic design of regenerative motion chains, the establishment of the motion chain map and the topology library within 3 degrees of freedom below 8 links is completed. At the same time, the single hinge and multiple hinges are selected to achieve the establishment of complete graphs of all single hinge and multiple hinges of 8 links. Based on kinematic chains and topology maps, feature constraints are introduced, examples of multiple hinges are given, and a simplified diagram of the innovation mechanism is formed to realize the integrated design of institutional innovation.

Introduction

Machinery manufacturing is an important indicator to measure a country's overall national strength. China has paid more and more attention to the design of mechanical innovation. It is of great significance and value to study the innovative design theories and methods of institutional research and to improve the independent design ability. For a long time, the integration of structural types of institutions is an important way for institutional innovation design [1-2].

This paper is based on the basic theory of the institutional regenerative kinematic chain, combined with the institutional innovation design method, namely the linkage mechanism classification method. This method firstly classifies the linkage of the mechanism's kinematic chain, and then according to the mechanism of the mechanism, the mechanism transformation of various types of linkages and their isomers is found, so that the most basic requirements can be found in all possible solutions. The new design of the agency. Using Visual Basic 6.0 object-oriented programming language, a multi-link library automatic generation and innovative case study software was developed. Combined with the basic chain structure method, the automatic design of the regenerative kinematic chain was realized, and 8 links or less were completed. The establishment of a kinematic chain diagram and a topology library within there degrees of freedom. The software also incorporates single hinge and multiple hinges sorting to provide a complete map that supports the best possible map and its corresponding organization. Finally, combined with the formed map library, the automatic innovation design process of single hinge and multiple hinges motion chain is expounded by examples, and the general institutional automation innovation design is explored, which has great development and guiding significance.

Institutional Type Comprehensive Foundation

The "Regeneration Kinematic Chain," is a highly operational method proposed by Taiwanese scholar Yan Hongsen, which is based on the theory of institutional structure, which transforms the abstraction of an existing mechanical mechanism into a kinematic chain, and according to certain principles and constraints. A number of regenerative kinematic chains have evolved, and a new kinematic chain with better performance than the original kinematic chain has been chosen to conceive a new institution that can perform the same function.

Prototype-based innovative design methods are widely recognized in the process of institutional
innovation design. It is mainly divided into three aspects: institutional type synthesis, number synthesis and scale synthesis [3]. The prototype-based innovative design is based on the existing institutions, summarizing its characteristics, using the type synthesis method to synthesize the kinematic chain of the organization, finally determining the feasible chain type, completing the design of the plan, so as to integrate and exercise the scale of the organization in the future. Learning and dynamics analysis provide the basis.

Multi-link Combination

The formula for calculating the degree of freedom of the link mechanism is $F=3(N-1)-2P_1-P_h$. Therefore, we can derive the number of movements by the formula of the degree of freedom calculation: $P=3N/2-(F+3)/2$. In the innovative design method of the mechanism, the kinematic chain only contains the rotating pair, and $N$ represents the total number of components of the mechanism, $P_1$ represents the low number of pairs of the linkage mechanism, $P_h$ represents the high number of pairs of the linkage mechanism. This paper only discusses the basic kinematics with a component number less than 8 and a simple component with a motion number less than 5. From equations (1) and (2), all the kinematic chains of the selected number of members and the free number are obtained. $n_2$, $n_3$, $n_4$, and $n_5$ in the equation represent two secondary links, three secondary links, four secondary links, and five secondary links in the kinematic chain. This calculation method can derive all the link combinations of the kinematic chain sought. For example, when the total number of components of the kinematic chain is $N=7$ and the degree of freedom $F=1$, the obtained link combination is $n_2=4$, $n_3=3$; $n_2=5$, $n_3=1,n_4=1$ and $n_2=6$, $n_5=1$.

$$n_2 + n_3 + n_4 + n_5 = N$$  \hspace{1cm} (1)

$$2n_2 + 3n_3 + 4n_4 + 5n_5 = 2P = 3N - F - 3$$  \hspace{1cm} (2)

Generalization of Kinematic Chain

The mechanism kinematic chain is a motion system composed of n motion pairs. Therefore, there are many types of structural transformations in the kinematic chain. In order to reduce the complexity and improve the efficiency of the design of the mechanism, a generalized kinematic chain is proposed, which is to convert each movement pair into a rotary pair according to a certain equivalent principle. The components are transformed into rods, which are binary link, ternary link and four-way link... as shown in Fig. 1.

![Diagram of generalized kinematic chain](image)

Figure 1. Generalized kinematic chain.

Adjacency Matrix

The adjacency matrix is widely used in the adjacency relationship between the vertices representing the topological map [4], which is a common mathematical tool for the study of mechanism structure, which is used to describe the topological characteristic features of the mechanism. In recent years, the adjacency matrix has also been greatly developed. For example, Li Shujun and Shan Chuncheng proposed a mechanism synthesis method for the adjacency matrix of the Azul rod method [5-6]. The rules for establishing the adjacency matrix of the program are as shown in equations (3) and (4):}

$$A = \begin{bmatrix} a_{ij} \end{bmatrix}_{\text{adjm}} = \begin{bmatrix} 1 \end{bmatrix}, \text{If there is a connection relationship between the vertex i and the vertex j;}$$  \hspace{1cm} (3)
If \( A = \begin{bmatrix} a_{ij} \end{bmatrix} \cdot \begin{bmatrix} 0 \end{bmatrix} = 0 \), if there is no connection relationship between vertex \( i \) and vertex \( j \); \hspace{1cm} (4)

In the above formula, \( a_{ij} \) represents the elements of the \( i \)-th row and the \( j \)-th column in the matrix \( A \); \( n \) represents the total number of vertices, that is, the total number of components; \( 1 \) indicates that the connection relationship exists, and \( 0 \) indicates that the connection relationship does not exist.

**Topology Diagram**

In the study of kinematic chain structure synthesis, structural diagrams and topological maps are the two most common patterns used to represent the topological structure of kinematic chains, and are widely used in the fields of graph theory, mechanism and mechanical principles [7]. Previously, Yan Hongsen and others improved the Cut-links and Kuratowski algorithms to synthesize the kinematic chain and draw the kinematic chain diagram [8-9]. Each kinematic chain can use dots to represent components, and the edge represents the topological representation of the motion pair. Therefore, according to the point-line relationship, the kinematic chain diagram and the topology map can have a certain conversion relationship, as shown in Fig. 2.

![A. Structure diagram  
B. Topology](image)

**Figure 2. Kinematic chain diagram and topology.**

**Plane Kinematic Chain Type Synthesis**

**Single Hinge Kinematic Chain**

The plane kinematic chain can be divided into a single hinge kinematic chain and a kinematic chain with a multiple hinges. Based on the single-joint kinematic chain, great progress and achievements have been made in today's research. The most widely used methods of embryo mapping, embryonic branching, and kinematic chain basic chain construction are used. Due to the applicability of the design, this paper adopts the basic chain structure construction method of the kinematic chain, which makes the development more simple and fast, and is convenient for computerization.

**Multiple Hinges Kinematic Chain**

The hinged kinematic chain contains at least one composite hinge that differs from the single hinge kinematic chain in that it has more than two hinged connecting rods. The type of multiple hinges used here is a comprehensive method of reducing the motion pair of multiple members in a single hinge kinematic chain to zero, and then transforming into a composite kinematic chain, which is a tradition of constructing a multiple hinges kinematic chain. A common method. At the same time, the conversion process of the multiple hinges kinematic chain and the multiple sub-rods is mutual. When there are \( N \) multiple pairs of rods converted into composite hinges in the single hinge kinematic chain, the generated kinematic chain contains \( N \) composite hinges, and the number of components, degrees of freedom and number of movements of the kinematic chain are reduced by \( N \), and vice versa. In this way, it is possible to generalize the multiple hinges kinematic diagrams that produce a large number of differences, so that the innovative design of the mechanism can be better.
Program Development

Software Function Introduction and System Flow Chart

Based on the basic principle of the regenerative kinematic chain, using the programming language of Visual Basic 6.0 software, a multi-link library automatic generation software was developed. Combined with the basic chain structure method, the automatic design of the regenerative kinematic chain was realized. The establishment of the kinematic chain diagram and topological library within three degrees of freedom, the functions of the software mainly include: (1) through the selection of multi-links, and according to the design criteria of the regenerative movement, form the basic chain, join the basic chain Type construction method to generate a complete single hinge and multiple hinges kinematic chain library. (2) Establish a topology map library of simple kinematic chains. The system's library design flow chart is shown in Fig. 3. (3) Combine with the innovative design method of the institution, carry out the research and development of the single hinge and the multiple hinges, and achieve the simple and clear expression of the innovative design process of the institution, and provide convenient tools and methods for the personnel engaged in institutional research and development.

![Figure 3. Gallery design flow chart.](image)

![Figure 4. Program flow chart.](image)

(1) Implementation process: The program implementation flow chart of the system is shown in Fig. 4.

(2) Interface introduction: Taking the 8-link, 1 degree of freedom as an example, the software interface is introduced. The link selection program interface is shown in Fig. 5. Through the button events set by the programming language, the user can select the required number of links and The corresponding degree of freedom. Click the eight-link button to enter the interface as shown in Fig. 6.

In the interface of Fig. 6, click the degree of freedom 1 button to enter the interface of Fig. 7, and automatically calculate the required data and the link type matching data.

![Figure 5. Software initial interface, Selection of connecting rod.](image)

![Figure 6. Selection of link freedom.](image)

In the Fig. 7 interface, click the Calculation button to generate the required data. Click the NEXT button. If the logic map is used and the topology generation condition is met, the interface of Fig. 7
is entered. In Fig. 8, click on the display to generate a corresponding topology map in the corresponding box.

![Figure 7. Data is derived.](image1)

![Figure 8. Automated generation of kinematic chain diagrams and topologies.](image2)

**Innovative Design Examples**

The development process of the multiple hinges design example is shown in Fig.9. Combined with the practical eight-link mechanism of automobile wiper, it is defined by binary link, and a new mechanism is obtained through the corresponding kinematic chain configuration.

![Figure 9. Example of innovative design of multiple hinges.](image3)

**Conclusion**

Based on the principle of regenerative kinematic chain, combined with the innovative design method and basic chain structure method, the system introduces the program design using Visual Basic 6.0 software, and develops the basic software for automatic generation of planar multi-link map and innovative example development. The software has applied for national software copyright. As long as the number of links and the number of degrees of freedom are simply selected, the sub-bar type data can be calculated by the program, and the basic chain type construction method is used to generate the complete planar link motion according to the single hinge and the multiple hinges sorting. The chain map library can generate corresponding adjacency matrix according to its kinematic chain diagram, and then through the characteristic analysis of the adjacency matrix, it can also generate the topology diagram of the link mechanism, so that the innovative design of the mechanism can be performed. The development of this software program greatly improves the work efficiency of the institutional designer and shortens the work cycle of the institutional innovation design. At the same time, the automatic generation of planar multi-link library provides the possibility to establish the topology map library, as well as the development of innovative examples of single hinge and multiple hinges, which are created the conditions for the automation, innovation and intelligent realization of mechanical design.

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