

Isomorphism Detection of 10-Links Kinematic Chain Using Joint Connectivity Approach

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ABSTRACT: The work present in this paper is the attempt to detect isomorphism among 10-link kinematic chains. To detect isomorphism, developed methodology based on joint connectivity is used. In kinematic chain joints are connected with others at different connectivity level. Based on the level of connectivity its code is generated which is then converted into numerical scheme. This numerical scheme of one kinematic chain is compared with numerical scheme of other chain and if both are identical then chains are isomorphic. For the said work, required computer program is developed

KEYWORDS: Isomorphism, Joint connectivity, Kinematic chain

I. INTRODUCTION

Mechanical design point of view, synthesis of kinematic chains is very important for the invention of mechanism. Synthesis of kinematic chain i.e. a procedure by which a mechanism is developed to meet the desired need. A major problem found during the structural synthesis of kinematic chains is the detection of isomorphism among the kinematic chains. Over the past several years much work has been reported in the literature on the isomorphism identification of kinematic chains. There are number of methods for the recognition and identification of a given kinematic chain isomorphism which are categorized in graphical methods based on the visual inspection of various forms of simplified systematic diagrams and numerical methods.

Most of the numerical methods are based on the adjacency matrix and the distance matrix. For determining the structurally Distinct Matrix of a Kinematic Chain, The link disposition method [1], The flow matrix method [2], Minimum code method [3], Link path code method [4], Summation polynomial method [5] are used to characterize the kinematic chain. Identifying isomorphism of kinematic chains using the characteristic polynomial method is simple, but the reliability of this method is in question, as several apparently incorrect results were found [6]. Rao and Varada Raju[7] presented a method for detecting isomorphs based on Hamming numbers of the adjacency matrix. Some new approaches to these problems, such as eigenvector [8], adjacent-chain table method by Chu and Cao [9] and artificial neural-network method by Kong, Li & Zhang [10] were also investigated. Ding H, Huang Z [11] proposed a new loop theory of kinematic chains. Based on this theory, some key problems that hamper computer-based automatic synthesis of mechanisms are solved.

To detect isomorphism for our 10-links kinematic chain, we used a simple, reliable and efficient method developed by G.S.Bedi and S.Sanyal [12]. Here the connectivity of joints at different levels is used to establish the equality of links. If the connectivity of two joints at different level is same, the joints will be identical. Thus by establishing the equality of joints, equality of links can be established since joints constitute the links. Two chains will be isomorphic if the connectivity of joints at all the levels is same.

II. MATERIAL AND METHODOLOGY

To detect isomorphism among given kinematic chains, first its joints connectivity at different level is determined. Based on the level of connectivity its code is generated which is then converted into numerical scheme. This numerical scheme of one kinematic chain is compared with other.

Determine Joint Connectivity and Code Connectivity

In kinematic chain joints are connected with others at different distance. If the joints are connected at a distance of single joints, the level of connectivity is one. If the joints are connected at a distance of two joints, the level of connectivity is two and so on. As shown in Figure1 joint 1 is connected to three joints (2,5,12) at a distance of single joint i.e. the first level. Similarly joint 2 is connected to four joints (3,4,8,11) at a distance of two joints i.e. the second level.

Code of connectivity is derived from joint connectivity. For figure 1 connectivity code will be 3431, which means that joint one connected to 3 joints at first level, 4 joints at second level, 3 joints at third level and 1 joint at fourth level.

Determine numerical scheme

Using code of connectivity numerical scheme for the kinematic chain is developed. For figure 1 numerical scheme will be [2{344}, 1{362}, 2{2333}, 1{2342}, 2{3332}, 3{3431}, 1{4421}]. This scheme indicates that there are two joints having a connectivity of 3,4 and 4 at first, second and third level, respectively; one joint having connectivity of 3,6 and 2 at first, second and third level, respectively; two joints having connectivity of 2,3,3, and 3 at first, second, third and fourth level, respectively & so on...

Comparison of two numerical schemes

The numerical scheme developed of two kinematic chains by above mentioned procedure is compared. If both are identical then they are isomorphic chains.

III. RESULTS

To follow above mentioned methodology computer program is developed. Program results of joint connectivity and code of connectivity of Kinematic chain of Fig. 1- 2, and Fig. 3-4 will be as per Table 1- 2 & Table 3-4 respectively.

Problem 1

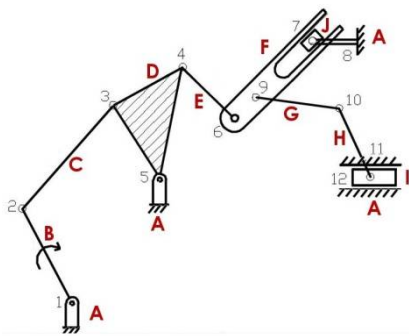


Figure 1 10-links 3DOF kinematic chain

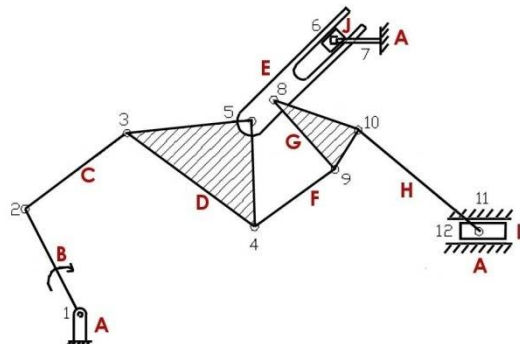


Figure 2 10-links 3DOF kinematic chain

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Table 1 Joint connectivity of kinematic chain as shown in Fig, 1

Joint	Joint Connectivity				Connectivity Code
	Level 1	Level 2	Level 3	Level 4	
1	2, 5, 12	3, 4, 8, 11	6, 7, 10	9	3 4 3 1
2	1, 3	4, 5, 12	6, 8, 11	7, 9, 10	2 3 3 3
3	2, 4, 5	1, 6, 8	7, 9, 12	10, 11	3 3 3 2
4	3, 5, 6	7, 8, 9	10, 12	11	3 5 2 1
5	1, 3, 4, 8	2, 6, 7, 12	9, 11	10	4 4 2 1
6	4, 7, 9	3, 5, 8, 10	1, 2, 11, 12		3 4 4
7	8, 9, 6	4, 5, 10, 12	1, 3, 11	2	3 4 3 1
8	5, 7, 12	1, 3, 4, 6, 9, 11	2, 10		3 6 2
9	6, 7, 10	4, 8, 11	3, 5, 12	1, 2	3 3 3 2
10	9, 11	6, 7, 12	1, 4, 8	2, 3, 5	2 3 3 3
11	10, 12	1, 8, 9	2, 5, 6, 7	3, 4	2 3 4 2
12	1, 8, 11	2, 5, 7, 10	3, 4, 6, 9		3 4 4

Table 2 Joint connectivity of kinematic chain as shown in Fig, 2

Joint	Joint Connectivity				Connectivity Code
	Level 1	Level 2	Level 3	Level 4	
1	2, 7, 12	3, 6, 11	4, 5, 8, 10	9	3 3 4 1
2	1, 3	4, 5, 7, 12	6, 8, 9, 11	10	2 4 4 1
3	2, 4, 5	1, 6, 8, 9	7, 10, 12	11	3 4 3 1
4	3, 5, 9	2, 6, 8, 10	1, 7, 11	12	3 4 3 1
5	3, 4, 6, 8	2, 7, 9, 10	1, 11, 12		4 4 3
6	5, 7, 8	1, 3, 4, 9, 10, 12	2, 11		3 6 2
7	1, 6, 12	2, 5, 8, 11	3, 4, 9, 10		3 4 4
8	5, 6, 9, 10	3, 4, 7, 11	1, 2, 12		4 4 3
9	4, 8, 10	3, 5, 6, 11	2, 7, 12	1	3 4 3 1
10	9, 8, 11	4, 5, 6, 12	1, 3, 7	2	3 4 3 1
11	10, 12	1, 7, 8, 9	2, 4, 5, 6	3	2 4 4 1
12	1, 7, 11	2, 6, 10	3, 5, 8, 9	4	3 3 4 1

Numerical Scheme of kinematic chain as shown in Fig. 1 will be
[2{344}, 1{362}, 2{2333}, 1{2342}, 2{3332}, 2{3431}, 1{3521}, 1{4421}]

Numerical Scheme of kinematic chain as shown in Fig. 2 will be
[1{344}, 1{362}, 2{443}, 2{2441}, 2{3341}, 4{3431}]

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Problem: 2

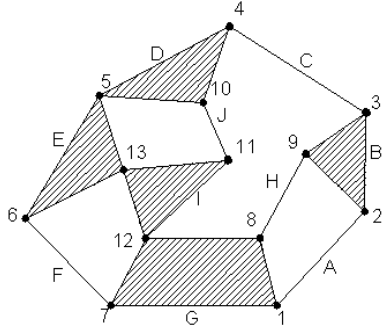


Figure 3 10-links 1 DOF kinematic chain

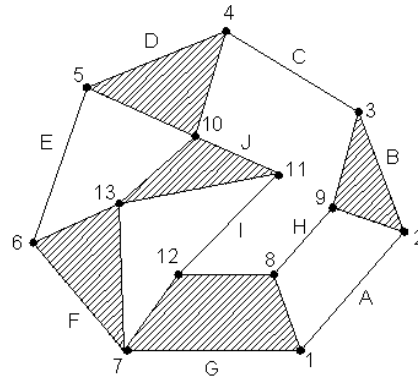


Figure 4 10-links 1 DOF kinematic chain

Table 3 Joint connectivity of kinematic chain as shown in Fig, 3

Joint	Joint Connectivity				Connectivity Code
	Level 1	Level 2	Level 3	Level 4	
1	2, 7, 8	3, 6, 9, 12	4, 5, 11, 13	10	3 4 4 1
2	1, 3, 9	4, 7, 8	5, 6, 10, 12	11, 13	3 3 4 2
3	2, 4, 9	1, 5, 8, 10	6, 7, 11, 12,13		3 4 5
4	3, 5, 10	2, 6, 9, 11, 13	1, 7, 8, 12		3 5 4
5	4, 6, 10, 13	3, 7, 11, 12	1, 2, 8, 9		4 4 4
6	5, 7, 13	1, 4, 10, 11,12	2, 3, 8	9	3 5 3 1
7	1, 6, 12	2, 5, 8, 11,13	3, 4, 9, 10		3 5 4
8	1, 9, 12	2, 3, 7, 11,13	4, 5, 6, 10		3 5 4
9	2, 3, 8	1, 4, 12	5, 7, 10, 11,13	6	3 3 5 1
10	4, 5, 11	3, 6, 12, 13	2, 7, 8, 9	1	3 4 4 1
11	10, 12, 13	4, 5, 6, 7, 8	1, 3, 9	2	3 5 3 1
12	7, 8, 11, 13	1, 5, 6, 9, 10	2, 3, 4		4 5 3

Table 4 Joint connectivity of kinematic chain as shown in Fig, 4

Joint	Joint Connectivity				Connectivity Code
	Level 1	Level 2	Level 3	Level 4	
1	2, 7, 8	3, 6, 9, 12, 13	4, 5, 10, 11		3 5 4
2	1, 3, 9	4, 7, 8	5, 6, 10, 12, 13	11	3 3 5 1
3	2, 4, 9	1, 5, 8, 10	6, 7, 11, 12, 13		3 4 5
4	3, 5, 10	2, 6, 9, 11,13	1, 7, 8, 12		3 5 4
5	4, 6, 10	3, 7, 11, 13	1, 2, 9, 12	8	3 4 4 1
6	5, 7, 13	1, 4, 10, 11, 12	2, 3, 8	9	3 5 3 1
7	1, 6, 12, 13	2, 5, 8, 10, 11	3, 4, 9		4 5 3
8	1, 9, 12	2, 3, 7, 11	4, 6, 10, 13	5	3 4 4 1
9	2, 3, 8	1, 4, 12	5, 7, 10, 11	6, 13	3 3 4 2
10	4, 5, 11, 13	3, 6, 7, 12	1, 2, 8, 9		4 4 4
11	10, 12, 13	4, 5, 6, 7, 8	1, 3, 9	2	3 5 3 1
12	7, 8, 11	1, 6, 9, 10,13	2, 3, 4, 5		3 5 4

Numerical Scheme of kinematic chain as shown in Fig. 3 will be

{1{345}, 3{354}, 1{444}, 1{453}, 1{3342}, 1{3351}, 2{3441}, 2{3531}, 1{4431}}

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Numerical Scheme of kinematic chain as shown if Fig. 4 will be
[1{345}, 3{354}, 1{444}, 1{453}, 1{3342}, 1{3351}, 2{3441}, 2{3531}, 1{4431}]

IV. CONCLUSIONS

Joint connectivity method of detecting isomorphism is very simple and involves no mathematical calculations. It results that our 10-links, 3DOF kinematic chain Fig.1 and 2 are non isomorphic as numerical scheme of both chains are different while Numerical scheme for 10-links, 1DOF kinematic chain Fig. 3 and 4 are identical so that chains are isomorphic.

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