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Characterization of Complex Mechanism Kinematics Chains

Dr. Ali Hasan

Abstract

In this paper, the author used modified distance matrix along with extended adjacency matrix to for characterization and identification of complex mechanisms kinematic chains. The suggested method uses topological graph and is based on theoretic approach. The end users of the paper are B.Tech./M.Tech. students and research scholars in the initial stages of their research work.

Keywords:

Mechanism, Kinematic chain, Topological Graph, Extended Adjacency Matrix

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1. Introduction

A number of researchers have discussed structural synthesis in the earlier days. Crossley [1] proposed a collection of 10-link plane chains. During the compiling of this collection, his greatest problem was to distinguish whether two arrangements, which might appear unlike, were actually the same or different. This led to a definition of isomorphism between linkages. Mruthyunjaya [2] made an effort to develop a fully computerized approach for structural synthesis of kinematic chains. Agrawal and Rao [3] investigated a systematic method of analysis of the mobility properties of the kinematic chains by its loop freedom matrix and its permanent function which are used to identify it. Sethi and Agrawal [4] proposed a classification scheme on the basis of structural properties. Madan and Jain [5] considered the kinematic chains-isomorphism, inversions and degree of similarity using the concept of connectivity. Rao [6] threw the light on the enumeration of distinct planar kinematic chains. They developed a very simple method based on independent loop(s) assorted and their adjacency is reported. Misti [7] presented the position analysis in polynomial form of planar mechanisms with Assur groups of class 3 including revolute and prismatic joints. Uicker and Raicu [8] presented a method for the identification and recognition of equivalence of kinematic chains. Later on, this method failed. Mruthyunjaya and Balasubramanian [9] proved that the method proposed by Uicker and Raicu [8] is not reliable. They proved that the test based on comparison of the characteristic coefficients of the adjacency matrices of the corresponding graphs for detection of isomorphism in kinematic chains failed. Shende and Rao [10] work, which deals with the problem of detection of isomorphism which is frequently encountered in structural synthesis of kinematic chains.Chu Jin-Kui and Cao Wei-Qing [11] proposed a method for identification of isomorphism among kinematic chains and inversions using Link's adjacent-chain-table. Yadav, et.al. [12] Proposed a computer aided detection method of isomorphism among kinematic chains and mechanisms using the concept of modified distance. Yadav, et.al.[13] presented a paper mechanism of a kinematic chain and the degree of structural similarity based on the concept of link path code'. Yadav, et.al.[14] presented a paper 'computer aided detection of isomorphism among binary chains using the link-link multiplicity distance concept. Rao [15] suggested the application of fuzzy logic for the study of isomorphism, inversions, symmetry, parallelism and mobility in kinematic chains with some necessary and sufficient conditions. Kong, et.al. [16] Proposed a new method based on artificial neural network (ANN) to identify the isomorphism of the mechanism kinematic chain. Rao and Deshmukh [17] proposed method does not require any separate test for isomorphism in the generation of kinematic chains. Chang, et.al. [18] proposed method is based on the eigen vectors and eigen values to identify isomorphism of mechanism kinematic chain.. He and Jhang [19] proposed a new method for detection of graph isomorphism based on the quadratic form. Tang and Liu [20] established a method 'the degree code' as a new mechanism identifier. Later on this method also failed. Zhao, et.al [21] put forward and more complete theory of degrees of freedom (DOF) for mechanisms, especially for the complex spatial mechanisms, which may not be solved correctly with traditional theories. Mohd [22], Hasan [23-24] proposed a new method in which kinematic chains are represented in the form of the Joint-Joint [JJ] matrix. Two structural invariants, sum of absolute characteristic polynomial coefficients and maximum absolute value of the characteristic polynomial coefficient are derived from the characteristic polynomials of the [JJ] matrix of the kinematic chains. Dargar et al. [25-26] proposed Link adjacency value method to identify the isomorphism by calculating the first and second link adjacency values. Rizvi et al. [27-28] presented a new method for distinct inversions and isomorphism based on a link identity matrix and link signature. In [28], the authors gave an algorithm for distinct inversions and isomorphism detection in kinematic chains using link identification number. Alam et al.[29] presented weighted squared path technique to determine the structural similarity and dissimilarity in the kinematic chains.For characterizing chains uniquely, invariants of kinematic structure are identified and calculated based on eigen spectrum of [EA] matrix using standard software MATLAB. This [EA] matrix is taken from Yi-Qui [30], where it is used for molecules in chemical engineering.

2. Topological Graph of Complex Kinematic Chain

We convert a kinematic chain into a kinematic graph. The vertex of the graph shows link and edge shows the kinematic pair. The order of a graph is the number of its points (or vertices) and its size is the number of its lines (edges). In drawing the graphs, the following notations are used.

- ● Represents the fixed links of the kinematic chain and
- —— Represents the kinematic pairs of the kinematic chain and known as line or edge.
- ○ Represents the links of the kinematic chain

The degree of vertices means the type of the links in a kinematic graph.

3. Methodology

The types of links in the form of degree of links are added in the diagonal elements of vertex-vertex distance matrix and we call it as modified distance matrix shown as [D] matrix.

$$[D]=\begin{pmatrix} d(l_1) & d_{12} & d_{13} & - & - & - & d_{ln} \\ d_{21} & d(l_2) & d_{23} & - & - & - & d_{2n} \\ & & & & & & \\ d_{n1} & d_{n2} & d_{n3} & - & - & - & d(l_n) \end{pmatrix}$$

The distance matrix and modified distance matrix is not able to explain the multiple joints.

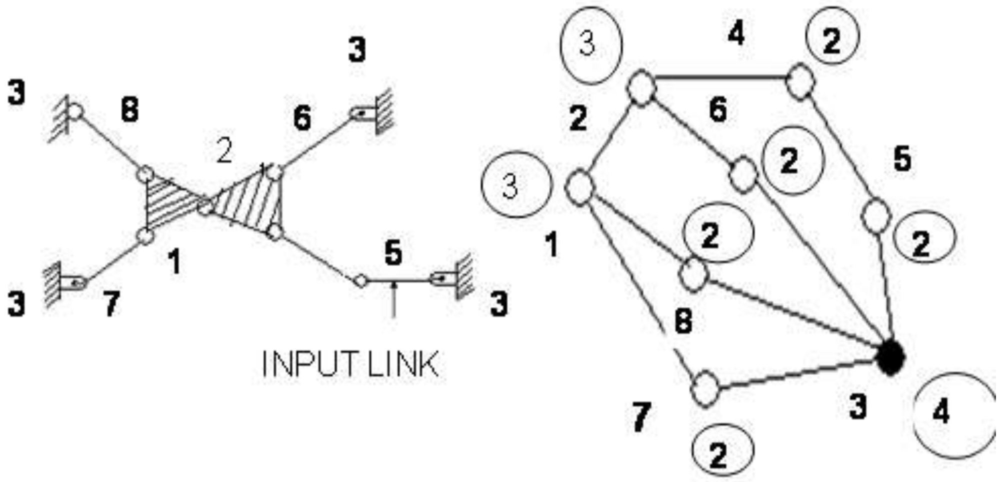
So, now we use an extended adjacency matrix [30] for further structural information of complex mechanism kinematic chains.The form ofextended adjacency matrix is shown [E] matrix.

$$[E]=\begin{bmatrix} d(l_1) & g_{12} & g_{13} & - & - & - & g_{1n} \\ g_{21} & d(l_2) & g_{23} & - & - & - & g_{2n} \\ - & - & - & - & - & - & - \\ g_{n1} & g_{n2} & g_{n3} & - & - & - & d(l_n) \end{bmatrix}_{n\times n}$$

The Eigen values of [E] matrix are found with the help of software MATLAB. The structural invariants [E∑] (sum of absolute values of eigen values) and Emax (absolute maximum eigen value) are same for two isomorphic chains and are different for non-isomorphic chains.

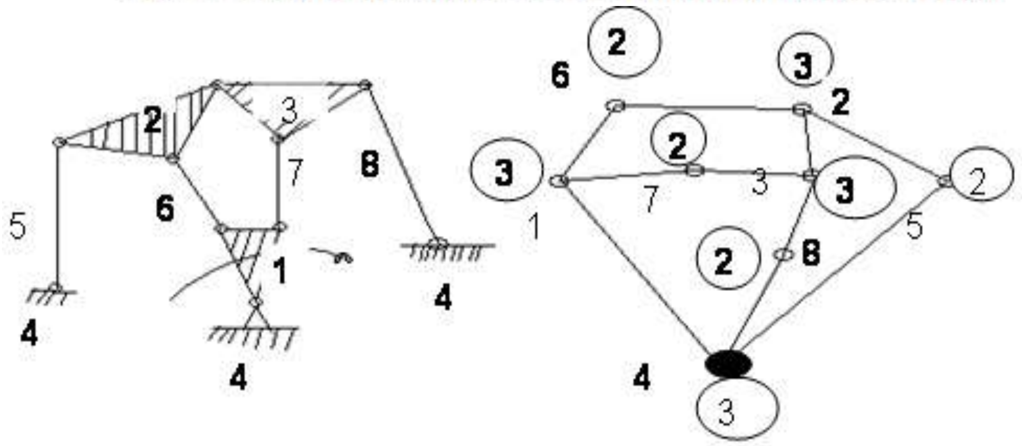
4. Illustrative Example

There are two different complex mechanism kinematic chains of 8-link, 10-joint, IF, kinematic chains as shown in Figure-1(a) and Figure-2(c) in which number of binary links (n_2), and ternary links(n_3) are same. We have to check whether these two complex mechanism kinematic chains are isomorphic or not.



(a) Complex Mechanism Kinematic Chain (b) Topological Graph

Figure-1: Complex Mechanism Kinematic Chain and its Topological Graph



(c) Complex Mechanism Kinematic Chain (d) Topological Graph

Figure-2: Complex Mechanism Kinematic Chain and its Topological Graph

The topological graph of both the mechanisms kinematic chains are shown in Figure-1 (b) and Figure-2(d) respectively. The modified distance matrices are shown by [D1] and [D2] while extended adjacency matrices are shown by [E1] and [E2] respectively.

$$[D1]=\begin{pmatrix} 3 & 1 & 2 & 2 & 3 & 2 & 1 & 1 \\ 1 & 3 & 2 & 1 & 2 & 1 & 2 & 2 \\ 2 & 2 & 2 & 2 & 1 & 1 & 1 & 1 \\ 2 & 1 & 2 & 2 & 1 & 2 & 3 & 3 \\ 3 & 2 & 1 & 1 & 2 & 2 & 2 & 2 \\ 2 & 1 & 1 & 2 & 2 & 2 & 2 & 2 \\ 1 & 2 & 1 & 3 & 2 & 2 & 2 & 2 \\ 1 & 2 & 1 & 3 & 2 & 2 & 2 & 2 \end{pmatrix} \quad [D2]=\begin{pmatrix} 3 & 2 & 2 & 1 & 2 & 1 & 1 & 2 \\ 2 & 3 & 1 & 2 & 1 & 1 & 2 & 2 \\ 2 & 1 & 3 & 2 & 2 & 2 & 1 & 1 \\ 1 & 2 & 2 & 2 & 1 & 2 & 2 & 1 \\ 2 & 1 & 2 & 1 & 2 & 2 & 3 & 2 \\ 1 & 1 & 2 & 2 & 2 & 2 & 2 & 3 \\ 1 & 2 & 1 & 2 & 3 & 2 & 2 & 2 \\ 2 & 2 & 1 & 1 & 2 & 3 & 2 & 2 \end{pmatrix}$$

$$[E1]=\begin{pmatrix} 3.0000 & 1.0000 & 2.0833 & 2.1667 & 6.5000 & 4.3333 & 2.1667 & 2.1667 \\ 1.0000 & 3.0000 & 2.0833 & 1.0417 & 2.1667 & 1.0833 & 2.1667 & 2.1667 \\ 2.0833 & 2.0833 & 2.0000 & 2.5000 & 1.2500 & 1.2500 & 1.2500 & 1.2500 \\ 2.1667 & 1.0417 & 2.5000 & 2.0000 & 1.0000 & 2.0000 & 3.0000 & 3.0000 \\ 3.2500 & 2.1667 & 1.2500 & 1.0000 & 2.0000 & 2.0000 & 2.0000 & 2.0000 \\ 2.1667 & 1.0833 & 1.2500 & 2.0000 & 2.0000 & 2.0000 & 2.0000 & 2.0000 \\ 1.0833 & 2.1667 & 1.2500 & 3.0000 & 2.0000 & 2.0000 & 2.0000 & 2.0000 \\ 1.0833 & 2.1667 & 1.2500 & 3.0000 & 2.0000 & 2.0000 & 2.0000 & 2.0000 \end{pmatrix}$$

$$[E2]=\begin{pmatrix} 3.0000 & 2.0000 & 2.0000 & 1.0000 & 2.1667 & 1.0833 & 1.0833 & 2.1667 \\ 2.0000 & 3.0000 & 1.0000 & 2.0000 & 1.0833 & 1.0833 & 2.1667 & 2.1667 \\ 2.0000 & 1.0000 & 3.0000 & 2.0000 & 2.1667 & 2.1667 & 1.0833 & 1.0833 \\ 1.0000 & 2.0000 & 2.0000 & 2.0000 & 1.0833 & 2.1667 & 2.1667 & 1.0833 \\ 2.1667 & 1.0833 & 2.1667 & 1.0833 & 2.0000 & 2.0000 & 3.0000 & 2.0000 \\ 1.0833 & 1.0833 & 2.1667 & 2.1667 & 2.0000 & 2.0000 & 2.0000 & 3.0000 \\ 1.0833 & 2.1667 & 1.0833 & 2.1667 & 3.0000 & 2.0000 & 2.0000 & 2.0000 \\ 2.1667 & 2.1667 & 1.0833 & 1.0833 & 2.0000 & 3.0000 & 2.0000 & 2.0000 \end{pmatrix}$$

Eigen values of matrices [E1] and [E2] are := 16.2492, -2.8154, -1.9603, 3.2300, -0.2098, 1.2948, 2.2114, 0.0000 and -1.7488, -1.6441,-0.2960, 1.0000, 1.7779, 2.3560, 2.6441, 14.9110 respectively. The Row Sum of matrices [D1] and [D2] are: 23.4166, 14.7083, 13.6666, 16.7083, 15.6666, 14.5000, 15.5000, 15.5000 and 14.5000, 14.5000, 14.5000, 13.5000, 15.5000, 15.5000, 15.5000, 15.5000 respectively.

5. Result

The values of s invariants of complex mechanism shown in Figure-1(a) are: E1∑ = 27.9709 and E1max = 16.2492 respectively. Similarly The values of s invariants of complex mechanism shown in Figure-1(c) are: E2∑ =26.3779 and E2max = 14.9910 respectively. Since these invariants are different, therefore, both mechanisms kinematic chains are non-isomorphic chains. Equal row sums of matrices [E1] and [E2] tell the equivalent link in the mechanism. We see that there are seven different row sum i.e.562/24,353/24,328/24,401/24,376/24,348/24 and 372/24 hence, seven distinct mechanisms are obtained from the mechanism kinematic chain shown in Figure-1(a).Similarly, three distinct mechanisms can be derived from the kinematic chain/mechanism shown in Figure-2(c) having three different row sum i.e. 174/12,162/12 and 186/12.

6. Conclusion

Proposed technique using [EA] matrix has sufficient mechanism information. Therefore, characterization identification and isomorphism of kinematic chains are checked accurately by by the application of proposed structural invariants E∑ and Emax based on Eigen values of [EA] matrix. These constants have more powerful ability to check isomorphism even for co-spectral graphs also. The proposed modified distance matrix [D] contains additional information in the form of degree of links in diagonal elements.

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