Development of a Fuzzy Logic Based Tool for Detection of Distinct Mechanisms

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Abstract: ***Mechanisms are building blocks of any machine. Robots which are becoming popular with the advent of new and modern technologies deploy mechanisms for its functioning. One of the problem associated with development of machines or mechanisms is synthesis of numerous structures which are possible from a given combination of links, the basic element of any machine. However very few methods have been found to distinguish unique mechanisms which can be derived from a given chain. For identification of isomorphism of kinematic chains methods reported sofar deal with identification of structural equivalence between the two given structures. However very few methods have been found to distinguish unique mechanisms which can be derived from a given chain. This work deals with validation of some representative methods regarding their ability to derive mechanisms with the help of testing them to a set of established and well known cases.***

Keywords: about four key words separated by commas.

1. Introduction

Mechanical engineering design is incomplete without kinematics. Kinematics fundamentals are a must for any study on kinematic chains and mechanisms. This chapter presents background and denitions of a number of terms and concepts fundamental to the synthesis and analysis of mechanisms.

1.1 Links, Joints and Kinematic Chains

One of the first tasks in any machine design problem is to determine the kinematic configurations needed to provide the desired motions. Virtually any machine or device that moves contains one or more mechanisms comprising of various kinematic elements such as links, cams, gears, belts, chains etc. Therefore, study of mechanisms becomes important for a designer of machines. Studies related to kinematic structure of mechanisms are largely concerned with synthesis and analysis of kinematic chains, degree-of-freedom analysis, enumeration of epicyclic gear trains, automated sketching of mechanism and isomorphism problem.

Kinematic chains or linkages are the basic building blocks of all mechanisms. Kinematic chains are made up of links and joints. A link is defined as a rigid body that possesses at least two nodes that are points for attachment to other links. Thus, a binary link consists of two nodes, a ternary link three nodes and quaternary link four nodes. Different types of links are shown in Fig.1.1.

With the kinematic elements of links and joints now defined, the kinematic chain, mechanism and machine are defined as [

Kinematic Chains: An assemblage of links and joints interconnected in a way to provide a controlled output motion in response to a supplied input motion.

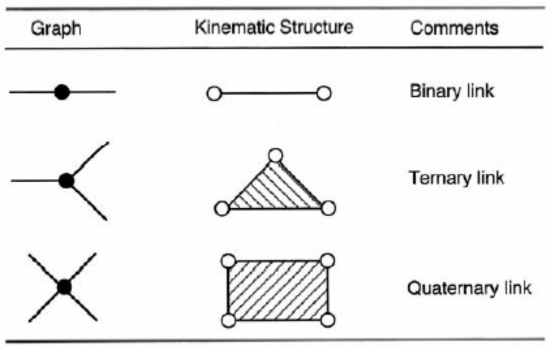

Figure 1.1: Different Types of Links

Mechanism: A kinematic chain in which at least one link has been grounded, or attached, to the frame of reference.

Machine: A combination of resistant bodies arranged to compel the mechanical forces of nature to do work accompanied by determinate motions.

Different kinematic chains are shown in the Fig.1.2

1.2 Representation of Mechanisms

The kinematic structure of mechanisms consists of links, joints and loops. These are represented in several ways to facilitate the analysis. The following representations are useful in structural analysis.

1. Functional schematic representation
2. Structural representation
3. Graph representation and
4. Various matrix representations

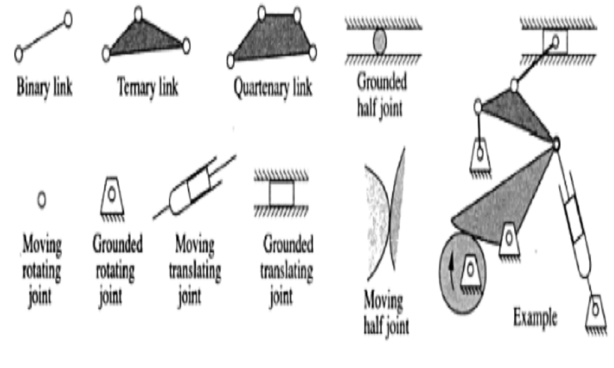

Figure 1.2: Kinematic Elements

The representations are shown in Fig.1.3 and explained in the paragraphs to follow. In functional schematic representation of mechanisms, for clarity and simplicity, only those functional elements that are essential to the structure topology of mechanisms are shown. In a structural representation, each link of a mechanism is denoted by a polygon whose vertices represent the kinematic pairs. Specially, a binary link is represented by a line with two end vertices, a ternary link is represented by a cross-hatched triangle with three vertices, a quaternary link is represented by a cross-hatched quadrilateral with four vertices, and so on.

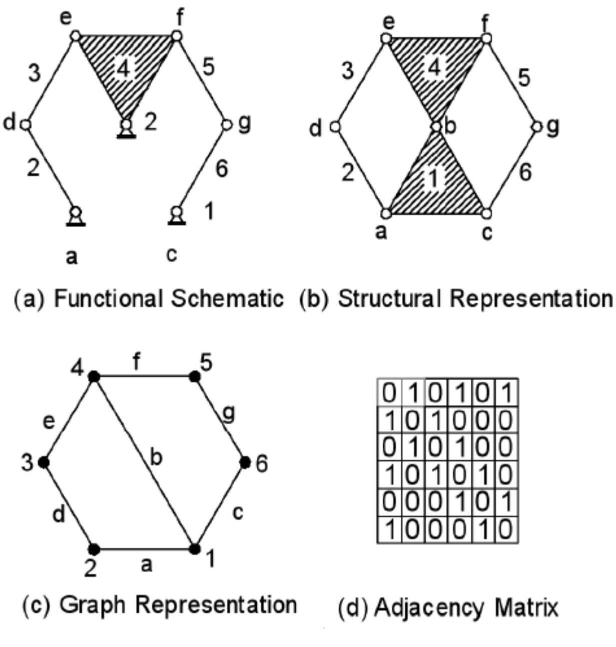

Figure 1.3: Representation of Kinematic Chains

1.3 Kinematics of Mechanisms

A rigid body is said to be under motion when it is instantaneously changing its position and/or orientation. Since the change of position can only be observed with respect to another body, the motion of a rigid body is a relative measure. Kinematics of a mechanism is the study of relative motion among the various links of a mechanism or machine by neglecting the inertia effects and the forces that cause the motion. In studying the kinematics of a mechanism, the motion of a link is often measured with respect to a fixed link or a reference frame, which may not necessarily be at rest.

There are two branches of kinematics known as kinematic analysis and kinematic synthesis.

1.3.1 Kinematic Analysis

It is the study of relative motions associated with the links of a mechanism or machine and is a critical step toward proper design of a mechanism. Specially, given a mechanism and the motion of its input link(s), the relative displacement, velocity, acceleration, etc., of the other links are to be found. These characteristics can be derived by considering the constraints imposed by the joints. The problem can be formulated by the graphical, vector algebra, matrix, or other mathematical methods.

1.3.2 Kinematic Synthesis

It is the reverse problem of kinematic analysis. In this case, the designer is challenged to devise a new mechanism that satisfies certain desired motion characteristics of an output link. The kinematic synthesis problem can be further divided into three interrelated phases:

1. Type synthesis refers to the selection of a speci_c type of mechanism for product development. During the conceptual design phase, the designer considers as many types of mechanism as possible and decides what type has the best potential of meeting the design objectives. The type of mechanism cam, linkage, gear train, and so onis determined. The selection depends to a great extent on the functional requirements of a machine and other considerations such as materials, manufacturing processes, and cost.
2. Number synthesis deals with the determination of the number of links, type of joint, and number of joints needed to achieve a given number of degrees of freedom of a desired mechanism. During this phase of study, the designer makes sure that a mechanism has the correct number of links that are connected with proper types of joints to ensure mobility. Number synthesis also involves the enumeration of all feasible kinematic structures or linkage topologies for a given number of degrees of freedom, number of links, and type of joints. For this reason it is sometimes called structure synthesis or topological synthesis.
3. Dimensional synthesis deals with the determination of the dimensions or proportions of the links of a mechanism. Laying out a cam prole to meet a desired lift specification is a dimensional synthesis problem. Determination of the center distance between two pivots of a link in a bar-linkage is also a dimensional synthesis problem. Both geometric and analytical methods of synthesis may be used to perform dimensional synthesis.

1.4 Objectives

In view of the growing importance of mechanisms in modern machines and robotics the project aims at finding the structural properties of kinematic chains essential for synthesis of mechanisms. The project objectives are listed in this section.

1. To explore application of fuzzy logic in structural analysis of mechanisms.
2. To develop a method for identi_cation of distinct mechanisms that can be derived from kinematic chains using fuzzy logic.
3. To develop an algorithm for computerised analysis of mechanisms.

2. Review of Literature

A review of literature of various methods in connection with the structural analysis of kinematic chains and mechanisms is presented in this chapter.

Dr. Rao [2] Proposed a method on fuzzy logic to investigate isomorphism among kinematic chains and their inversions. Necessary and su_cient conditions are specified. Numerical measures to compare the various distinct chains with the same number of links and DoF for characteristics like symmetry, parallelism and mobility are proposed.

Dr. Rao [3] suggested application of Fuzzy logic for detection of isomorphism and inversion of kinematic chains and spatial mechanisms.

Shin and Krishnamurty [5; 6] defined standard code and canonical code and proposed these indices for testing isomorphism.

Chu and Cao [7] proposed that a link's CACT can be used as an index to distinguish inversions derived from a chain. Using this method they confirmed the total of 1834 ten-link, single degree-of-freedom mechanisms and also pointed out the discrepancy of Hamming number based test of Rao and Varda Raju [8].

The discrepancy was later recti_ed by secondary Hamming number and reported [9].

Quist [10] attempted to enumerate distinct mechanisms from a kinematic chain. They assigned a sense of direction for tracing each independent loop of the chain and employed all the closed, continuous paths originating at a frame link that can be obtained with individual loops, as the index of that particular mechanism. Though the method had several ambiguities they arrived at a number of 1836 for the 10-link, single-freedom mechanisms which is just two in excess of the correct total.

3. Methodology

3.1 Basic Concepts of Fuzzy Logic

A closed kinematic chain with speci_ed number of links and degrees of freedom (DoF) is as a parallel chain, the extent of parallelism depending upon its structure. Each chain can be represented by a graph in which the link becomes vertices and the joint becomes edges. A graph of N vertices is considered fully connected of completely parallel if every vertex is connected to every other vertex. Such a graph or the corresponding chain will have negative DoF i:e: highly redundant but is considered ideally parallel. The fact that the chain corresponding to such a graph is highly immobile should not impede the comparison of the actual chains ($F > 1$) for parallelism is all the chains to be compared retain the same features such as number of links, joints, etc. but di_er a structure only. Thus, it is possible to compare these chains against a standard chain or fully connected graph. The actual chain with N links and speci_ed DoF (DoF = 1, 2, 3, ...) deviate considerably from the ideal or fully connected graph in the matter of (i) number of edges and (ii) their adjacency. [2]

The degree of a vertex of fully connected or ideal N- vertex graph being ($F>1$), each vertex of the actual chain-graph can be assigned a fuzzy number in the scale 0 to 1. The crisp number 0, zero in the scale represents a link (vertex) isolated from the structure while another crisp number one (1) means that the vertex is fully connected. For a closed kinematic chain, both the crisp number can not exist and the actual links (vertices) have intermediate values. The number assigned to a vertex or the link of an actual chain is

$$n_c/(N-1)$$

where, n_c is the number of the other links to which the link under consideration is directly joined and N the total number of the link in the chain. For example, the value of nc for a binary link is 2 while that for quaternary link is 4.

4. Structural Analysis of Kinematic Chains

Structural properties of kinematic chains make it easier for the designer to select a particular chain for a speci_ed task. Studies in structural analysis were largely concentrated on finding distinct inversions and detection of type of freedom of a given kinematic chain. Rao and his co-workers reported several ideas related to structure-based performance assessment of mechanisms. With the help of these methods, the performance parameters like rigidity, possible workspace extent and best location of actuator can be assessed prior to dimensional synthesis.

5. Conclusion and Future Scope

Application of fuzzy logic for structural analysis of kinematic chains and mechanisms is presented.

6.1 Conclusion

An algorithm was developed using the concepts of fuzzy logic for detection of inversion. With the help of the algorithm complete set of eight link single degree of freedom (DOF) chains were analysed and a total of 71 mechanisms resulted from the sixteen kinematic chains. Comparison of strings of two chains reveals isomorphism if any between the chains along with detection of distinct mechanisms. The proposed algorithm has successfully derived mechanisms from the given set of kinematic chains. The results fully agree with earlier published results.

6.2 Future Scope

Measurement of structural properties like compactness and parallelism are associated with fuzzy vector. These needs to be explored further.

Quantitative measurement and experimental validation of other structural properties of kinematic chains can be taken as further work.

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