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ABSTRACT

Structural analysis and synthesis of kinematic chains and mechanisms has been a pivotal area of research from last several decades. The basic aim of structural synthesis is to select a suitable mechanism to perform a specified task at conceptual stage of design. Structural synthesis includes the identification of isomorphism or duplication among kinematic chains and mechanisms. Isomorphism problem has been dealt by many researchers in the past and found to be very tedious and troublesome. The type of degree of freedom or mobility of multi-degree of freedom kinematic chains is also required to be identified especially for robotic application. This area of structural synthesis is covered in the present work. The methods proposed by the researchers in the past are mainly based on characteristic polynomial of adjacency matrix, some code, distance and path, artificial intelligence etc. Most of these methods are either lack uniqueness or some counter examples have been reported. Hence there is always a need to develop an easy, reliable and computationally efficient methodology for structural synthesis of kinematic chain.

While developing a methodology of structural synthesis it is required to incorporate all the basic information of kinematic chain. Most of the previous methods lack in this respect. The present method takes care of all the basic building blocks of kinematic chain simultaneously and then it is converted into a code for structural synthesis of kinematic chain. The present method is basically a loop based method and it starts with the identification of independent loops of kinematic chain from its structural representation. The next step is to represent the kinematic chain in the form of a loop-joint matrix. All the other loops are identified with the help of initial loop joint matrix. The loop-joint matrix is the basis of

finding a number of new structural invariants of kinematic chain. Chain String (CS) is used as an index of isomorphism which includes the total number of loops, total loop size (TLS), chain loop value (CLV), loop size frequency string (LSFS) and link identification string (LIS) of links of kinematic chain. Every information of kinematic chain i.e. links, joints, higher order connectivities, loops, loop sizes etc. is included in chain string of kinematic chain. The chain string of kinematic chain is successfully tested for all kinematic chains having upto 10-links.

The link identification strings of links of kinematic chain have potential to distinguish among the links of kinematic chain and hence to identify distinct mechanisms derived from a given kinematic chain. A formula for the number of adjacency required to be checked to distinguish any two links of kinematic chain has been proposed and successful detection of distinct mechanism by this method proves the reliability of proposed formula. The distinct mechanisms derived from all kinematic chains having upto 10-links are displayed in this work.

A new structural invariant, loop participation of joint frequency string (LPOJFS) is proposed which is capable of detecting the type of mobility of multi-degree of freedom kinematic chains. This new invariant along with the loop size frequency string is used to identify the type of mobility of all 9-link M = 2 and 10-link M = 3 kinematic chains and the results are displayed in the text.

A computer program is written in C# for development of loop-joint matrix of kinematic chain and its invariants. Only two inputs namely independent loops and degree of freedom of kinematic chain are required to be entered to run this program. This program roughly takes 4-5 seconds for development of a complete loop-joint matrix having three independent loops. The future scope of this work is correlate these invariants to other mechanism performance like rigidity, parallelism, wear, manufacturing error due to joint clearance and degree of similarity among kinematic chains. The work may be further extended to characterize the kinematic chains having combination of different types of the kinematic pairs like lower or higher pairs.