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GA Based Case Study for Testing of Isomorphism

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ABSTRACT

Test for isomorphism among kinematic chains consists of comparing the chain strings with the first, second and third generation strings of the other chain. The concept of fitness and successive generation introduced enables the selection of best chain, best inversion and best -input links and makes the test for isomorphism unique. Fixing a link with least connectivity will lead to a better inversion. Links with higher connectivity are preferable as input links. This is a genetic approach for testing isomorphism among kinematic chains and to select the best frame and input link. The computational effort involved is minimum and the method is unique as it satisfies both the necessary and sufficient requirements. Fitness of binary string corresponding to a link is indicative of its design parameters. Consequently, the fitness of a chain indicates the number of design parameters active in motion generation. Chains are compared for function generation on the basis of the fitness of first generation and second-generation "fitness" etc., Greater the fitness indicates involvement of more design parameters in generating the motion. Thus it can be noted that greater the family fitness of a link, its contribution to the motion generation is greater.

Keywords:— *Isomorphism, fitness, Genetic algorithm.*

I. INTRODUCTION

Effort has been put till now to observe and derive conclusions on Topological cteristics of Kinematic Chains. All the methods need tests for isomorphism in order to isolate distinct kinematic chains. With the belief that kinematic analysis and synthesis should not end up only with the generation of kinematic chains, attempts are made to compare the kinematic chains and inversions for their anticipated behaviors such as Mechanical Advantage, Dynamics, Workspace and Rigidity etc.

However, with the increasing applications of neural networks in engineering and realizing its potential and lack of its application in the area of kinematics, an attempt is made in this work to utilize the principles (i) to detect isomorphism among kinematic chains, (ii) to compare the chains from the motion generation point of view and (iii) to select the best ground and input links.

Direct joining of two links is considered to be the first generation mating. Combination of links are separated by one link with respect to every link in the chain is considered as the second generation mating and so on. Any method based on mating concept to test isomorphism among chains, it is necessary to test isomorphism generation wise i.e. depending upon the number of links obviously it is adequate to test up to the last generation possible. The notable feature is that unlike other methods which proposed tests necessary but not sufficient this method fulfils both necessary and sufficient requirements making it unique.

II. METHODOLOGY

2.1 Degree of Freedom

Degree of freedom of a pair is defined as the number of independent relative motions, both translational and rotational.

Degree of freedom = $3(N-1)-2P_1-P_2$........(1)

N= Number of links

P_1 = Number of pairs having one degree of freedom

P_2 = Number of pairs having two degrees of freedom

For the four link chain, degree of freedom =1

2.2 First generation binary strings of links

First generation deals with the links that are directly joined.

A matrix "A" called Adjacency Matrix can be written for every chain in which the element.

a_{ij} = 0; if there is no direct contact between links i & j.

a_{ij} = 1; if there is direct contact between links i & j.

a_{ii} = 0; since a link cannot connect itself.

For the four-link chain:

links	1	2	3	4
1	0	1	0	1
2	1	0	1	0
3	0	1	0	1
4	1	0	1	0

Adjacency matrix

$$A=\begin{pmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{pmatrix}$$

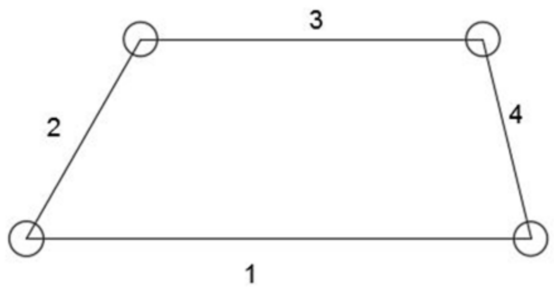

Figure 2.1: Four-link chain

Each row of a "A" matrix can be considered as a binary string of the concerned link with well defined digital positions for 0's and is depending upon its connectivity with the other links i.e., the position of 1 in the binary string is dictated by the environment i.e., disposition of the other links, the number of times the element one occurs in a row is the links connectivity or "fitness". Fitness of a link is indicative of the number of design parameters. It possesses, viz., a binary link as one design parameter while a ternary link has three design parameters.

2.3 Mating Rules

From the adjacency matrix, each link, having regard to its environment, i.e., to its disposition in relation to other links can be assigned a binary string with 0's and 1's taking definite digital positions, the sum of the non zero elements being equal to the fitness, the relationship between any two links or the role of the two links taken together can be studied by mating the binary strings of the concerned link. The rules followed mentioned below.

1. Mating only among the bits (elements) occupying the same digital positions in respective binary strings is possible. For example, consider two binary strings.

   STRING A – 0 1 0 1 0 1

   STRING B - 1 0 1 0 0 0

   Mating of the first bit of string A is possible only with the first bit of the string B: similarly, second bit of string A can mate with the second bit of string B only.

1. The mating of two strings results in a third string (off. spring) C of the same order i.e., same number of digits. It may be noted that mating is not productive among equal bits i.e., outcome is no offspring while mating between unlike bits is possible and productive. For example,

BIT OF STRING A + BIT OF STRING B = BIT OF STRING C

1	+	1	=	0
0	+	0	=	0
1	+	0	=	1
0	+	1	=	1

Following the above, the string C for the example string A and B will be STRING C – 1 1 1 1 0 1

Therefore, the fitness of the offspring i.e., string C is sum of all non-zero elements which is equal to five.

2.4 Adjacency Matrix

In a similar way, the Adjacency matrix for the six-link Stephenson chain (Figure 1) can be written as:

$$A_1 = \begin{pmatrix} 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \quad (2)$$

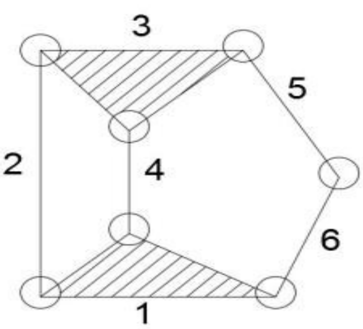

Figure 2.2: Six link Stephenson-chain

Each row of the above matrix can be considered as the binary string of the concerned link with well-designed digital positions for the elements 0 and 1 preserving the fitness of the link. For example, the binary string of the ternary link 3 is 0 1 0 1 1 0. Relabeling of the links does not matter, as the relative positions of the links and hence the matrix elements do not change.

2.5 Mating of first generation strings

Consider the links 2 & 3 of Stephenson chain, the first generation binary string of link2 (from the matrix) is 1 0 1 0 0 0 and the first generation binary string of link 3 is 0 1 0 1 1 0. The mating of links 2 & 3 yield son offspring of fitness 5 represented by the binary spring 1 1 1 1 1 0.

2.6 Fitness Matrix

Mating of each link with the other links one by one can be considered and the fitness of the resulting offspring can be presented in the form of matrix F1. Therefore, for the Stephen chain F1 matrix will be

$$F_1 = \begin{pmatrix} 0 & 5 & 2 & 5 & 3 & 5 \\ 5 & 0 & 5 & 0 & 2 & 2 \\ 2 & 5 & 0 & 5 & 5 & 3 \\ 5 & 0 & 5 & 0 & 2 & 2 \\ 3 & 2 & 5 & 2 & 0 & 4 \\ 5 & 2 & 3 & 2 & 4 & 0 \end{pmatrix} = \begin{matrix} =20 \\ =14 \\ =20 \\ =14 \\ =16 \\ =16 \end{matrix} \qquad (3)$$

It may be seen that the mating of links with identical binary strings, e.g. links 2 & 4 do not yield any off-spring as evidenced by the element S24 = S22 = 0, from the fitness matrix F1.

Some of the elements of each row represent the fitness of the family of the concerned link.

The fitness of the family of the link 5 for e.g., can be represented in the form of the string as follows: 16~ 5, 4, 3, 2(2) where 16 is the total fitness of the link-6 family. The diagonal zero elements are not included. Other zeroes, if any, must be included and the elements 5,4,3, etc. represent, in the descending order, the fitness of the link with respect to the other links. The presence of 2(2) in the above string means that the element 2 appears twice in the row of the elements. Likewise, the string for every link can be written and when all such strings are arranged in the descending order of fitness, a string for the chain results.

2[20-5(3),3,2] – 2[16-5,4,3,2(2)] – 2[14-5 (2),2(2)]

The presence of 2 before the square brackets indicate the existence of the two links with the same strings. A string for every chain can be written in the above manner.

2.7 Mating of Second Generation Strings

Second generation strings are developed in a manner similar to that of the first generation but the elements '1' in the adjacency matrix A2 correspond to the links separated by only one link and all the other elements will be zero, For the 6 links Stephenson chain, with respect to link -1, links 3 & 5 are separated by only one link. Hence, only the elements corresponding to links 3& 5 in the first row of the adjacency matrix A2 will be 1, all other elements will be zero. Similarly, links 4, 5 & 6 are separated by one link from the link 2. With this understanding the matrix A2 for the above chain is

$$A_2 = \begin{pmatrix} 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 \end{pmatrix} \qquad (4)$$

Each row of the above matrix is considered as the secondary binary link of the concerned link e.g., for the link 5 the binary string is 1 1 0 1 0 0 and hence its secondary fitness is 3.

The secondary binary strings can be mated following the rules stipulated earlier, which in turn yields the secondary fitness matrix F_2.

$$F_2 = \begin{pmatrix} 0 & 3 & 4 & 3 & 5 & 3 \\ 3 & 0 & 3 & 2 & 4 & 4 \\ 4 & 3 & 0 & 3 & 3 & 5 \\ 3 & 2 & 3 & 0 & 4 & 4 \\ 3 & 2 & 3 & 0 & 4 & 4 \\ 5 & 4 & 3 & 4 & 0 & 2 \end{pmatrix} = \begin{matrix} 18 \\ 16 \\ 18 \\ 16 \\ 18 \\ 18 \end{matrix} \quad (5)$$

Following the lines of first generation the chain string for second generation can be written for every chain. For the Stephenson's chain, it is

2[18-5,2(4),3,2]-2[18-5,4,2(3)]-2[16-4(2),3 (2),2]

Likewise, third generation, fourth generation strings, etc., can be generated for every chain.

III. Isomorphism

Test for isomorphism among kinematic chains consists of comparing the chain strings generation wise i.e. First, second and third generation etc strings of a chain need, to be compared respectively with the first, second and third generation strings of the other chain. If these are identical, the chains are isomorphic otherwise distinct. Comparison of the first generation strings of both the Watt and Stephenson chains reveals that they are identical and hence comparing further for second generation it reveals that they are distinct. Comparison of all possible generation strings constitutes the complete test satisfying both the necessary and sufficient requirements, thus making this method unique.

3.1 Six Link Stephenson-Chains

3.1.1 First generation strings and their mating

First generation adjacency matrix & fitness matrix are written in equation (2) & (3) Family fitness of the first generation mating is obtained as 100 by adding the fitness of all strings in F_1 as shown in equation (3).

3.1.2 Second-generation strings and their mating

Second generation adjacency matrix & fitness matrix are written in equation (4) & (5)

Family fitness of the second generation mating is obtained as 104 by adding the fitness of all strings in F_2 as shown in equation (5).

IV. Comparison Between 8 Link Chain

4.1 First chain

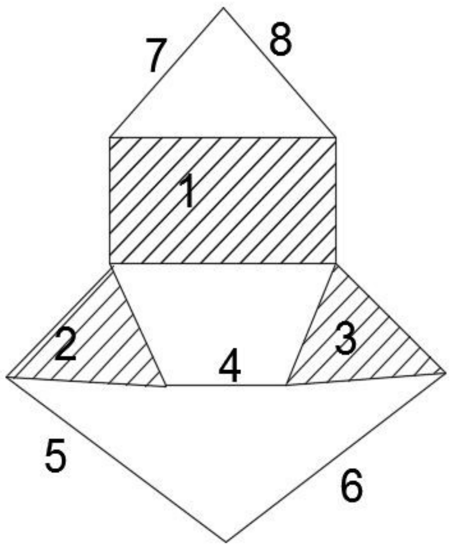

Figure 4.1 Eight link first chain

4.1.1 The first generation adjacency matrix & Fitness matrix are

$$A_1 = \begin{pmatrix} 0&1&1&0&0&0&1&1 \\ 1&0&0&1&1&0&0&0 \\ 1&0&0&1&0&1&0&0 \\ 0&1&1&0&0&0&0&0 \\ 0&1&0&0&0&1&0&0 \\ 0&0&1&0&1&0&0&0 \\ 1&0&0&0&0&0&0&1 \\ 1&0&0&0&0&0&1&0 \end{pmatrix} \quad \text{and} \quad F_1 = \begin{pmatrix} 0&7&7&2&4&4&4&4 \\ 7&0&2&5&5&3&3&3 \\ 7&2&0&5&3&5&3&3 \\ 2&5&5&0&2&2&4&4 \\ 4&5&3&2&0&4&4&4 \\ 4&3&5&2&4&0&4&4 \\ 4&3&3&4&4&4&0&2 \\ 4&3&3&4&4&4&2&0 \end{pmatrix} \begin{matrix} =32 \\ =28 \\ =28 \\ =24 \\ =26 \\ =26 \\ =24 \\ =24 \end{matrix} \qquad (6)$$

Family fitness of the first generation mating is obtained as 212 by adding the fitness of all strings in F1 as shown in equation (6).

4.1.2 Second generation adjacency matrix & fitness matrix are

$$A_2 = \begin{pmatrix} 0&0&0&1&1&1&0&0 \\ 0&0&1&0&0&1&1&1 \\ 0&1&0&0&1&0&1&1 \\ 1&0&0&0&1&1&0&0 \\ 1&0&1&1&0&0&0&0 \\ 1&1&0&1&0&0&0&0 \\ 0&1&1&0&0&0&0&0 \\ 0&1&1&0&0&0&0&0 \end{pmatrix} \quad \text{and} \quad F_2 = \begin{pmatrix} 0&5&5&2&4&4&5&5 \\ 5&0&4&5&5&7&4&4 \\ 5&4&0&5&7&5&4&4 \\ 2&5&5&0&4&4&5&5 \\ 4&5&7&4&0&2&3&3 \\ 4&7&5&4&2&0&3&3 \\ 5&4&4&5&3&3&0&0 \\ 5&4&4&5&3&3&0&0 \end{pmatrix} \begin{matrix} =30 \\ =34 \\ =34 \\ =30 \\ =28 \\ =28 \\ =24 \\ =24 \end{matrix} \qquad (7)$$

Family fitness of the second generation mating is obtained as 232 by adding the fitness of all strings in F_2 as shown in equation (7).

4.1.3 Third generation adjacency matrix & fitness matrix are

$$A_3 = \begin{pmatrix} 0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&1&1 \\ 0&0&0&0&0&0&1&1 \\ 0&0&0&0&0&0&1&1 \\ 0&0&0&1&1&1&0&0 \\ 0&0&0&1&1&1&0&0 \end{pmatrix} \quad \text{and} \quad F_3 = \begin{pmatrix} 0&0&0&2&2&2&3&3 \\ 0&0&0&2&2&3&3&3 \\ 0&0&0&2&2&2&3&3 \\ 2&2&2&0&0&0&5&5 \\ 2&2&2&0&0&0&5&5 \\ 2&2&2&0&0&0&5&5 \\ 3&3&3&5&5&5&0&0 \\ 3&3&3&5&5&5&0&0 \end{pmatrix} \begin{matrix} =12 \\ =12 \\ =12 \\ =16 \\ =16 \\ =16 \\ =24 \\ =24 \end{matrix} \qquad (8)$$

Family fitness of the third generation mating is obtained as 132 by adding the fitness of all strings in F_3 as shown in equation (8).

4.2 Second Chain

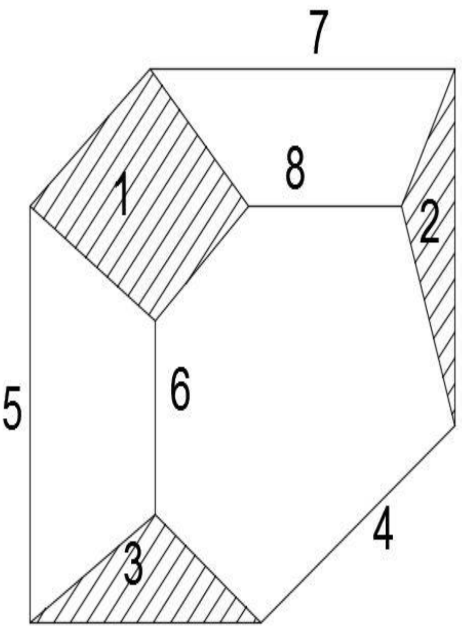

Figure 4.2. Eight Link Second Chain

4.2.1 The first generation adjacency matrix & Fitness matrix are

$$A_1 = \begin{pmatrix} 0&0&0&0&1&1&1&1 \\ 0&0&0&1&0&0&1&1 \\ 0&0&0&1&1&1&0&0 \\ 0&1&1&0&0&0&0&0 \\ 1&0&1&0&0&0&0&0 \\ 1&0&1&0&0&0&0&0 \\ 1&1&0&0&0&0&0&0 \\ 1&1&0&0&0&0&0&0 \end{pmatrix} \quad \text{and} \quad F_1 = \begin{pmatrix} 0&3&3&6&6&6&6&6 \\ 3&0&4&5&5&5&5&5 \\ 3&4&0&5&5&5&5&5 \\ 6&5&5&0&2&2&2&2 \\ 6&5&5&2&0&0&2&2 \\ 6&5&5&2&0&0&2&2 \\ 6&5&5&2&2&2&0&0 \\ 6&5&5&2&2&2&0&0 \end{pmatrix} \begin{matrix} =36 \\ =32 \\ =32 \\ =24 \\ =22 \\ =22 \\ =22 \\ =22 \end{matrix} \qquad (9)$$

Family fitness of the first generation mating is obtained as 212 by adding the fitness of all strings in F_1 as shown in equation (9).

4.2.2 Second generation adjacency matrix & fitness matrix are

$$A_2=\begin{pmatrix}0&1&1&0&0&0&0&0\\1&0&1&0&0&0&0&0\\1&1&0&0&0&0&0&0\\0&0&0&0&1&1&1&1\\0&0&0&1&0&1&1&1\\0&0&0&1&1&0&1&1\\0&0&0&1&1&1&0&1\\0&0&0&1&1&1&1&0\end{pmatrix} \text{ and } F_2=\begin{pmatrix}0&2&2&6&6&6&6&6\\2&0&2&6&6&6&6&6\\2&2&0&6&6&6&6&6\\6&6&6&0&2&2&2&2\\6&6&6&2&0&2&2&2\\6&6&6&2&2&0&2&2\\6&6&6&2&2&2&0&2\\6&6&6&2&2&2&2&0\end{pmatrix}\begin{matrix}=34\\=34\\=34\\=26\\=26\\=26\\=26\\=26\end{matrix} \qquad (10)$$

Family fitness of the second generation mating is obtained as 232 by adding the fitness of all strings in F_2 as shown in equation (10).

4.2.3 Third generation adjacency matrix & fitness matrix are

$$A_3=\begin{pmatrix}0&0&0&1&0&0&0&0\\0&0&0&0&1&1&0&0\\0&0&0&0&0&0&1&1\\1&0&0&0&0&0&0&0\\0&1&0&0&0&0&0&0\\0&1&0&0&0&0&0&0\\0&0&1&0&0&0&0&0\\0&0&1&0&0&0&0&0\end{pmatrix} \text{ and } F_3=\begin{pmatrix}0&3&3&2&2&2&2&2\\3&0&4&3&3&3&3&3\\3&4&0&3&3&3&3&3\\2&3&3&0&2&2&2&2\\2&3&3&2&0&0&2&2\\2&3&3&2&2&0&2&2\\2&3&3&2&2&2&0&0\\2&3&3&2&2&2&0&0\end{pmatrix}\begin{matrix}=14\\=22\\=22\\=16\\=14\\=16\\=14\\=14\end{matrix} \qquad (11)$$

Family fitness of the third generation mating is obtained as 132 by adding the fitness of all strings in F_3 as shown in equation (11).

V. CONCLUSIONS

The concept of fitness and successive generations enables the selection of best chain and best-input links and makes test for isomorphism unique. From the motion generation point of view, chains consisting of links with higher connectivity appear to be inferior. For six link chains up to second -generation fitness, matrices are required for testing isomorphism and for eight links up to third generation are necessary. Fixing a link with least connectivity will lead to a better inversion. Links with higher connectivity are preferable as input links.

REFERENCES:

[1] Tischler. C.R Samuel A F And Hunt K 1975. –"Kinematic chains For Robot Hands-1 orderly Number synthesis". Mechanism And Machine Theory.

[2] RuoAC 1975. "Topological Characteristics of Linkage Mechanisms with Particular Reference to Platforms-Type Robots." Mechanism & Machine Theory.

[3] Rao. AC., 2000, "A Genetic Algorithm for Topological characteristics of Kinematic Chains". Journal of Mechanical Design.

[4] Goldberg. David E., 1989, Genetic Algorithms in Search, optimization and Machine Learning, Addison - Wesley, Reading, A.

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