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Research paper



Design, Analysis and Selection of Planar Parallel Mechanisms

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Abstract

This paper presents the application of methodology for ten bar single degree mechanisms and selecting the best among them at the conceptual design stage itself. This saves lot of time for one wants to carry away analysis for getting desired output of the mechanism at the design stage. The methodology has been applied to Tiscler robot hands successfully and has obtained the best mechanism in motion distribution among the links of the chain.

Keywords: *Mechanisms, Robot Manipulator, designing, function generation, motion..*

1. Introduction

In order to get the desired output for the given input, rigid bodies are connected with the joints and form the mechanisms. It is the one thing to obtain from the mechanisms is that for the given input as force to which motion needed to be generated by the mechanisms. we have parallel mechanisms in which all links are connected in such a way that base link is grounded and having movable platform provides good stiffness and many other advantages. Another type of mechanisms is special mechanisms which having six degrees of freedom can have rotation and translation motions. Another group of mechanisms we are having is planar parallel mechanisms (PPMS) which can able to translate along X and Y directions and able to rotate along Z-axis. Analysis of these mechanisms referring to design the link connectivity such a way that it gives the desired motion of the end effector.

2. Literature review

RR-R, and R-P-R serial chain geometries used by Huang and the bert [1] which are in such a way that three in parallel operated kinematic structure.

A synthesis methodology was proposed by Boudreau and Arsenault [2] for selecting the optimal planar parallel mechanism based on geometrical param- eters. Gallant and Boudreau [3] synthesized planar parallel manipulators of 3 d.o.f by the application of genetic algorithm technique. Selection of mechanisms based on workspace and Rigidity is been presented by A.C.Rao [4] later the same author A. C. Rao presented the selection of mechanisms based on characteristics of mechanisms and their linkages [5] and later A. Srinath and A.C.Rao proposed the selection of mechanisms based on grasp and rigidity [6] and another methodology for rating and selection of mechanisms depending upon parallelism and loop number was proposed by A. Srinath and A. Jagadeesh [7].

Ashok Dargar [8] was proposed methodology based on design parameters to rate the kinematic chains and many others were proposed different methodologies [8] [9] [10] [11] [12] for evaluation and selection of mechanisms and kinematics chains proposed different methodologies.

3. Objective of this work

The main objective of this to work is to rate the Tiscler robot hands which are ten bar single degree freedom designed by Tiscler [4] by the application of the methodology proposed by Ashok Dargar [8] to nine robot hands which are ten bar single degree of freedom and select the best among them. The same robot hands are shown in the figure-1 Robot Hands which are from a to I.Ashok Dar- dar proposed methodology for rating of the kinematic chains and successfully applied up to eight bar link mechanism. This work had applied successfully the methodology and rated the nine mechanisms which are of ten bar single degree of freedom.

Ashok Dargar proposed his methodology based on the methodology the design and selection and the rating was done. For the given mechanism first calculate the matrix of link by link (MLL) which is the square matrix of the order L X L

Then calculate the mechanism value (Mv) by having algebraic sum of the all values of Link by Link Matrix.

M1×1 = link by link matrix = LX L

Mv = summation of all the values of M1×1

The rating was done as the per the mechanism value Mv for which it is less that mechanism can be considered as the best mechanism i.e., best in the sense that lower the mechanism value high the quality of motion distribution among the links. Tiscler robot hands are been taken and are rated and selected the best among the mechanisms by calculating the link-by-link matrix and finding out the mechanism values for the same and by comparing the mechanism values the best was selected. The figure-1 shows the Tiscler robot hands from (a) to (i).

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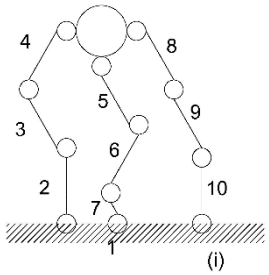


Figure 1: Tiscler Robot hands.

4. Design and Analysis

Consider the robot hand (a) which consisting the total number of links =10. Let first give numbering to the mechanism as 1 to 10 as shown in the figure -2.

$$M_{1\times1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 3 & 2 & 1 \\ 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 & 2 \\ 2 & 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 3 & 2 & 1 & 0 & 1 & 2 & 3 & 6 & 5 & 4 \\ 4 & 3 & 2 & 1 & 0 & 1 & 2 & 7 & 6 & 5 \\ 5 & 4 & 3 & 2 & 1 & 0 & 1 & 8 & 7 & 6 \\ 6 & 5 & 4 & 3 & 2 & 1 & 0 & 9 & 8 & 7 \\ 3 & 4 & 5 & 6 & 7 & 8 & 8 & 0 & 1 & 2 \\ 2 & 3 & 4 & 5 & 6 & 7 & 7 & 1 & 0 & 1 \\ 1 & 2 & 3 & 4 & 5 & 6 & 6 & 2 & 1 & 0 \end{bmatrix} \quad (1)$$

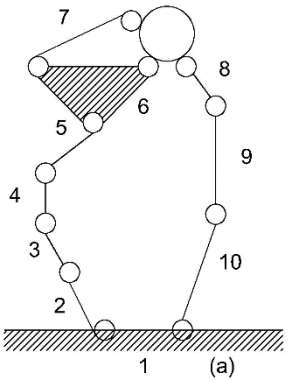
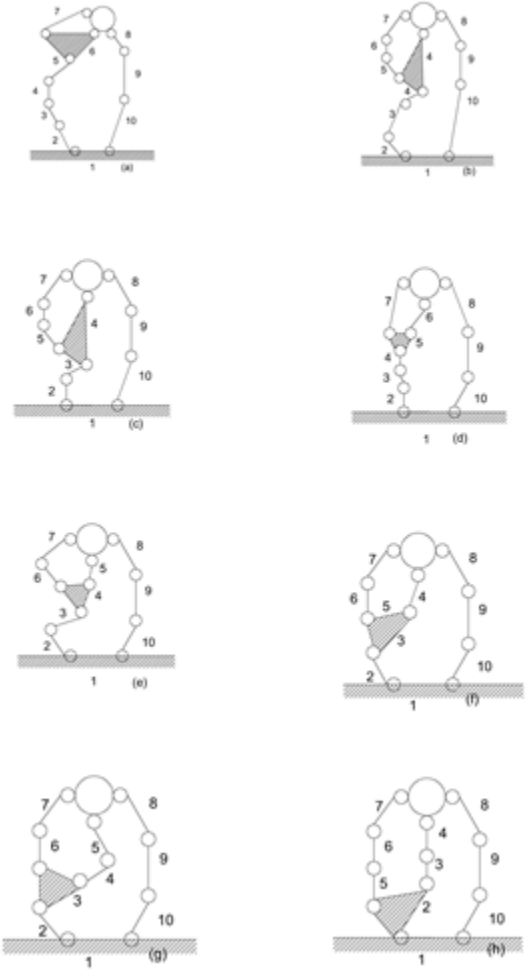


Figure 2: Robot Hand

Now, for the above robot hand i.e., (a) let us find out the link by link matrix as follows by the way link 1 is fixed and link 1 to link 1 number of joints present are zero i.e., 1 – 1 joints = 0 so first value of the matrix is 0, 1 – 2 joints = 2, 1 – 3 joints = 3 etc., in that way the above matrix had been calculated. Then, Mechanism value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix.

Mv = 329

$$M_{1\times1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 3 & 2 & 1 \\ 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 & 2 \\ 2 & 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 3 & 2 & 1 & 0 & 1 & 2 & 3 & 6 & 5 & 4 \\ 4 & 3 & 2 & 1 & 0 & 1 & 2 & 7 & 6 & 5 \\ 5 & 4 & 3 & 2 & 1 & 0 & 1 & 8 & 7 & 6 \\ 6 & 5 & 4 & 3 & 2 & 1 & 0 & 9 & 8 & 7 \\ 3 & 4 & 5 & 6 & 7 & 8 & 9 & 0 & 1 & 2 \\ 2 & 3 & 4 & 5 & 6 & 7 & 8 & 1 & 0 & 1 \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 2 & 1 & 0 \end{bmatrix} \quad (2)$$



Similarly let us calculate for robot hands (b),(c),(d),(e),(f),(g),(h) and (i)

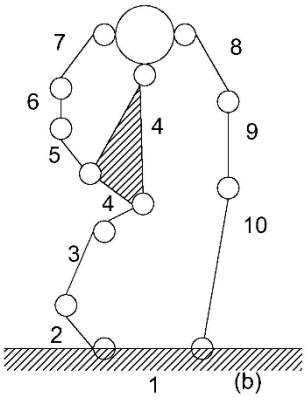


Figure 3: Robot Hand

Now, similarly consider the fig – 3 Robot hand (b) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and link four is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link by link mechanism was calculated as follows. Number of joints present between link 1 to 1 is zero, hence the first value in the first column of matrix is zero. Number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1. Similarly number of joints present between link 1 and link 3 is 2, etc.,. Similarly column 2 is calculated as number of joints present between link – 2 and link-1, link 2 – 2 , link 2 – 3 etc.,. In the same manner column 3,4,5,6,7,8,9

and 10 are calculated and hence M1×1 matrix was formed. Then, mechanism value for robot hand (b) i.e.,

$$M_{1\times1} = \begin{bmatrix} 0&1&2&3&4&5&6&3&2&1\\ 1&0&1&2&3&4&5&4&3&2\\ 2&1&0&1&2&3&4&5&4&3\\ 3&2&1&0&1&2&3&6&5&4\\ 4&3&2&1&0&1&2&7&6&5\\ 5&4&3&2&1&0&1&8&7&6\\ 6&5&4&3&2&1&0&9&8&7\\ 3&4&5&6&7&8&9&0&1&2\\ 2&3&4&5&6&7&8&1&0&1\\ 1&2&3&4&5&6&7&2&1&0 \end{bmatrix} \quad (3)$$

Mv = Summation of all the elements of the above matrix

Mv = 332

Now, similarly consider the fig – 4 Robot hand (c) shows the mechanism with

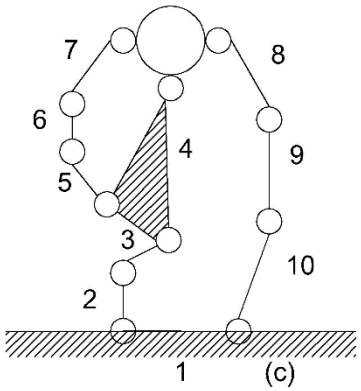


Figure 4: Robot Hand

total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and link four is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero. Number of joints present between link 1 and link

2 is 1, hence the second value in the first column of the matrix is 1. Similarly number of joints present between link 1 and link 3 is 2 etc., Similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then, Mechanism Value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix

Mv = 332

$$M_{1\times1} = \begin{bmatrix} 0&1&2&3&4&5&6&3&2&1\\ 1&0&1&2&3&4&5&4&3&2\\ 2&1&0&1&2&3&4&5&4&3\\ 3&2&1&0&1&2&3&6&5&4\\ 4&3&2&1&0&1&2&7&6&5\\ 5&4&3&2&1&0&1&8&7&6\\ 6&5&4&3&2&1&0&9&8&7\\ 3&4&5&6&7&8&9&0&1&2\\ 2&3&4&5&6&7&8&1&0&1\\ 1&2&3&4&5&6&7&2&1&0 \end{bmatrix}$$

Now, similarly consider the fig -5 Robot hand (d) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given

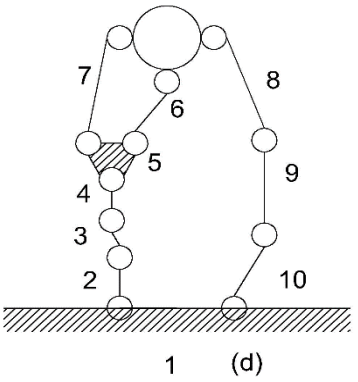


Figure 5: Robot Hand

from 1 to 10 as link-1 is fixed and link five is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero, number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

Mechanism Value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix

Mv = 330

$$M_{1\times1} = \begin{bmatrix} 0&1&2&3&4&5&6&3&2&1\\ 1&0&1&2&3&4&5&4&3&2\\ 2&1&0&1&2&3&4&5&4&3\\ 3&2&1&0&1&2&3&6&5&4\\ 4&3&2&1&0&1&2&7&6&5\\ 5&4&3&2&1&0&1&8&7&6\\ 6&5&4&3&2&1&0&9&8&7\\ 3&4&5&6&7&8&9&0&1&2\\ 2&3&4&5&6&7&8&1&0&1\\ 1&2&3&4&5&6&7&2&1&0 \end{bmatrix} \quad (5)$$

Now, similarly consider the fig -6 Robot hand (e) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given

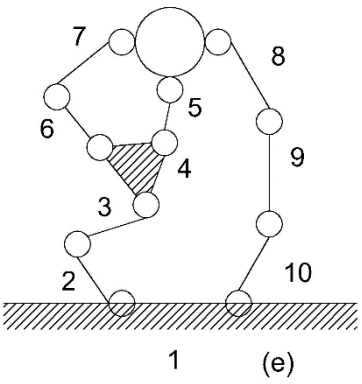


Figure 6: Robot Hand

are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero,

number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

Mechanism Value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix

Mv = 330

$$M_{1x1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 3 & 2 & 1 \\ 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 & 2 \\ 2 & 1 & 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 3 & 2 & 1 & 0 & 1 & 2 & 3 & 6 & 5 & 4 \\ 4 & 3 & 2 & 1 & 0 & 1 & 2 & 7 & 6 & 5 \\ 5 & 4 & 3 & 2 & 1 & 0 & 1 & 8 & 7 & 6 \\ 6 & 5 & 4 & 3 & 2 & 1 & 0 & 9 & 8 & 7 \\ 3 & 4 & 5 & 6 & 7 & 8 & 9 & 0 & 1 & 2 \\ 2 & 3 & 4 & 5 & 6 & 7 & 8 & 1 & 0 & 1 \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 2 & 1 & 0 \end{bmatrix} \quad (6)$$

Now, similarly consider the fig -7 Robot hand (f) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and link three is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero, number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

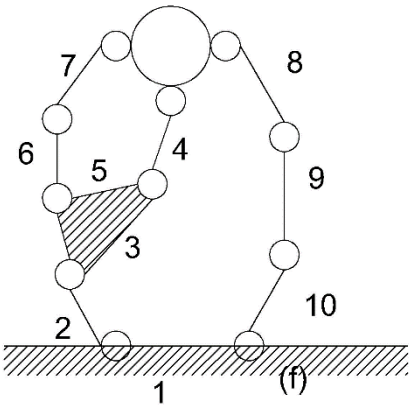


Figure 7: Robot Hand

Mechanism Value for robot hand (b) i.e., Mv = Summation of all the elements of the above matrix

Mv = 332

$$M_{1x1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 4 & 5 & 3 & 2 & 1 \\ 1 & 0 & 1 & 2 & 3 & 3 & 4 & 4 & 3 & 2 \\ 2 & 1 & 1 & 1 & 2 & 2 & 3 & 5 & 4 & 3 \\ 3 & 2 & 2 & 0 & 1 & 1 & 4 & 6 & 5 & 4 \\ 4 & 3 & 1 & 1 & 0 & 0 & 5 & 7 & 6 & 5 \\ 4 & 3 & 2 & 1 & 3 & 3 & 1 & 7 & 6 & 5 \\ 5 & 4 & 5 & 2 & 4 & 4 & 0 & 8 & 7 & 9 \\ 3 & 4 & 4 & 6 & 7 & 7 & 8 & 0 & 1 & 2 \\ 2 & 3 & 3 & 5 & 6 & 6 & 7 & 1 & 0 & 1 \\ 1 & 2 & 2 & 4 & 5 & 5 & 6 & 2 & 1 & 0 \end{bmatrix} \quad (7)$$

Now, similarly consider the fig -8 Robot hand (g) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and link three is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number

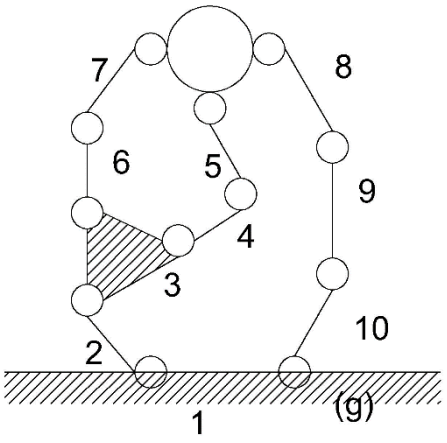


Figure 8: Robot Hand

of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero, number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

Mechanism Value for robot hand (b) i.e., Mv = Summation of all the elements of the above matrix

Mv = 316

$$M_{1x1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 3 & 4 & 5 & 3 & 2 & 1 \\ 1 & 0 & 1 & 2 & 2 & 3 & 4 & 4 & 3 & 2 \\ 2 & 1 & 0 & 1 & 1 & 3 & 5 & 5 & 4 & 3 \\ 3 & 2 & 1 & 0 & 3 & 4 & 6 & 6 & 5 & 4 \\ 3 & 2 & 1 & 3 & 0 & 1 & 2 & 6 & 5 & 4 \\ 4 & 3 & 2 & 4 & 1 & 0 & 1 & 7 & 6 & 5 \\ 5 & 4 & 3 & 5 & 2 & 7 & 0 & 8 & 7 & 6 \\ 3 & 4 & 5 & 6 & 6 & 6 & 8 & 0 & 1 & 2 \\ 2 & 3 & 4 & 5 & 5 & 5 & 7 & 1 & 0 & 1 \\ 1 & 2 & 3 & 4 & 4 & 4 & 6 & 2 & 1 & 0 \end{bmatrix} \quad (8)$$

Now, similarly consider the fig -9 Robot hand (h) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and link two is the ternary link and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows. Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero, number of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

Mechanism Value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix

Mv = 313

$$M_{1\times1} = \begin{bmatrix} 0 & 1 & 2 & 3 & 3 & 2 & 1 & 4 & 3 & 2 \\ 1 & 0 & 1 & 2 & 4 & 3 & 2 & 5 & 4 & 3 \\ 2 & 1 & 0 & 1 & 5 & 4 & 3 & 6 & 5 & 4 \\ 3 & 2 & 1 & 0 & 6 & 5 & 4 & 7 & 6 & 5 \\ 3 & 4 & 5 & 6 & 0 & 1 & 2 & 6 & 5 & 4 \\ 2 & 3 & 4 & 5 & 1 & 0 & 1 & 5 & 4 & 3 \\ 1 & 2 & 3 & 4 & 2 & 1 & 0 & 4 & 3 & 2 \\ 4 & 5 & 6 & 7 & 6 & 5 & 4 & 0 & 1 & 2 \\ 3 & 4 & 5 & 6 & 5 & 4 & 3 & 1 & 0 & 1 \\ 2 & 3 & 4 & 5 & 4 & 3 & 2 & 2 & 1 & 0 \end{bmatrix} \quad (9)$$

Now, similarly consider the fig -10 Robot hand (i) shows the mechanism with total number of links ten connected as shown in the figure. Numbering was given from 1 to 10 as link-1 is fixed and all other links are binary links and all the ten links are connected with the joints. For the same mechanism the link-by-link mechanism was calculated as follows.

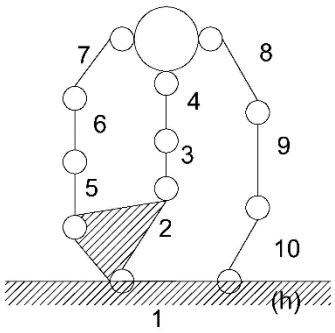


Figure 9: Robot Hand

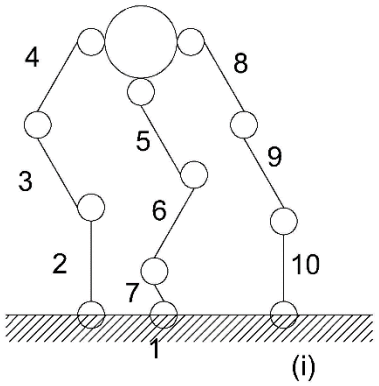


Figure 10: Robot Hand

Number of joints present between link-1 to 1 is zero, hence the first value in the first column of matrix is zero, num- ber of joints present between link 1 and link 2 is 1, hence the second value in the first column of the matrix is 1, similarly number of joints present between link 1 and link 3 is 2,etc similarly column 2 is calculated as number of joints present between link-2 and link-1, link 2-2,link2-3..etc in the same manner column 3,4,5,6,7,8,9 and 10 are calculated and hence M1×1 matrix was formed. Then,

Mechanism Value for robot hand (b) i.e., Mv =Summation of all the elements of the above matrix

Mv = 300

5. Results and Discussion

The table gives values of mechanisms from (a) to (i) and the rating of mecha- nisms as per the mechanism values is shown and the selection of the mechanism can be done as per rating done in the table as shown below. The rating of the mechanisms is depending upon the value of its mechanism value. The low the mechanism value the more the rating can be done and is considered the same.

6. Conclusions

A simple method to select the best mechanisms among the designed is been applied successfully for the nine mechanisms which are of ten bar single degree planar parallel mechanisms and the rating of mechanisms is been done. The mechanism for which mechanism value is less is the best and can be rated highly [8]. In the present work, mechanism (i) is having the mechanism value as

300 is the least among other so it is highly rated and which is the best among total nine in which motion distribution parameters holds best.

Table 1: Mechanisms values and their rating

MECHANISM	MECHANISM VALUE(MV)	RATED HIGH/LOW
i	300	1
h	313	2
g	316	3
a	329	4
d	330	5
e	330	5
b	332	6
c	332	6
f	332	6

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