CHAPTER - 5

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A COMPUTERIZED METHODOLOGY FOR RATING OF SIMPLE JOINTED PLANAR KINEMATIC CHAINS

Introduction

A computerized methodology for rating of simple jointed planar kinematic chains is presented. For rating the kinematic chains having similar link assortment, joint values and loop values, uniform disposition of links is considered as the criterion. The uniformity of link deployment can be decided by squaring and summing up of primary Hamming matrix elements. Lower the sum, greater is the uniformity and superior is the expected performance of the chain.

Literature Review

Detection of distinct kinematic chains really becomes significant only when the designer is able to predict the behavior of the chain based on its kinematic structure. For example, one should know which of the chains would generate a function more accurately once its dimensional synthesis is completed. It is, of course, known that a chain with greater number of links will generate specified motion more accurately because more design parameters like link ratios are available to the designer, but out of distinct chains consisting of same number of links it is not known how the type of link and their layout affect the dimensional behavior of the chain in the sense of structural error. As reported earlier [3] the shortcoming noticed in pseudo Hamming distance i.e. Link adjacency matrices resulted in same Hamming values for all chains having equal number of links, types of links and types of joints, was due to symmetry and as such it is desirable to develop computationally efficient and better algorithm.

Key Words

Link assortments, joint values, and family.

Terminology and Definitions

Link assortment: types of link and their numbers forming a kinematic chain

Joint values: at a Simple joints only two links are joined, and the summation of the type of link of the two is the joint value.

Family: Two chains having similar link assortment belong to the same family.

Method

The relative location of the links in the chain can be expected to influence the performance of Kinematic chains. For rating the simple jointed planar kinematic chain the methodology is as follows,

(1) Get the link assortment of the chain. The link assortment of the chain whose participating links have lower connectivity is considered to be superior in performance to the chain having link assortments whose participating links have higher connectivity [36,37]. Arrange all chains in ascending order of link assortments.

(2) Get the joint assortment of the chain. The joint assortment of the chain whose participating joints have lower value is considered to be superior to the chain having joint assortment whose participating links have higher value [36,37]. Arrange all the chains in the ascending order of the joint assortment.

(3) For chains having similar link and joint assortment, loop values of the chain becomes important. The one having higher loop value is considered to be a superior chain [36,37].

(4) Finally, if all the above three are same then symmetry [35] of the chain is used to compare them for their expected performance. Greater symmetry indicates loss of inefficient deployment of links and hence designs parameters. The uniformity of link deployment is decided by

squaring and summing up the primary Hamming matrix elements Lower the sum greater is the uniformity and better is the expected performance of the chain

The fore going theory is illustrated by taking up following numerical example problem to carry out dimensional synthesis for function generation by Watt and Stephenson chains. Detailed solutions are given in the next chapter.

Table-1 Dimensions and structural error of solutions to example problem: Generation of function $y = x^2$ for $0 \le x \le 1$ with Watt and Stephenson mechanisms for 90 degree rotation of input and output crank.

Watt Mechanism.

r (initial)	r (calculated)	θ (deg)	ϕ (precision point) (deg)	ϕ (calculated) (deg)
1.091675	1.009275	0.000000	0.000000	0.000000
0.177780	-0.815452	11.610000	15.480000	15.479998
1.099000	-0.993775	31.770000	38.670000	38.670000
1.277010	-1.011956	55.080000	61.160000	61.160000
1.185089	0.764725	75.240000	77.870000	77.870000
0.941000	-0.994362	86.930000	86.670000	86.670000

Final values of b for optimized value of r

-0.009275	0.000000	-0.178323	-0.011956	0.000000	-0.229637
-0.029735	0.201249	-0.195007	-0.048232	0.266902	-0.257378
-0.159106	0.526511	-0.300504	-0.231198	0.624834	-0.397297
-0.436843	0.819952	-0.526984	-0.529590	0.875970	-0.625485
-0.754504	0.967001	-0.786022	-0.801825	0.977673	-0.833670
-0.955719	0.998565	-0.950103	-0.953869	0.998312	-0.949942

Values of a

a_1	a_2	a_4	A_3	a_7	a_8	a_5	a_6
1.000000	0.990810	1.034692	-1.226314	1.307657	1.056709	-0.988186	1.000000

Structural error = 0.000005

Stephenson mechanism

r (initial)	r (calculated)	θ (deg)	ϕ (precison point) (deg)	ϕ (calculated) (deg)
1.618983	0.300232	0.000000	1.617700	1.617876
0.917778	-0.344280	8.689000	11.820000	11.819833
0.431500	-1.022880	24.346900	30.748200	30.748143
2.074251	0.311224	43.871760	51.034000	51.033948
1.851501	0.402151	63.396522	68.577000	68.576932
2.218311	1.988960	79.050000	81.108000	81.107905
3.673220	1.137587	87.743511	87.574700	87.574579

Final values of b for optimized value of r

-0.699768	-0.000000	-0.678600	0.556478	0.017475	0.535378
-0.688291	-0.151071	-0.682552	0.547171	0.079780	0.524446
-0.610834	-0.412260	-0.709219	0.497384	0.188175	0.464855
-0.420661	-0.693047	-0.774691	0.413849	0.265601	0.358482
-0.147581	-0.894127	-0.868707	0.335661	0.297970	0.253733
0.110280	-0.981793	-0.957483	0.285501	0.306015	0.185479

0 260859	-0 999225	-1 009325	0 262877	0 307475	0 155605

Values of a

a_1	a_2	a_4	A_3	a_7	a_8	a_5	a_6
1 000000	3 330758	1 146713	4 154654	3 256255	1 000000	1 791071	1 674623

Structural error = .000001

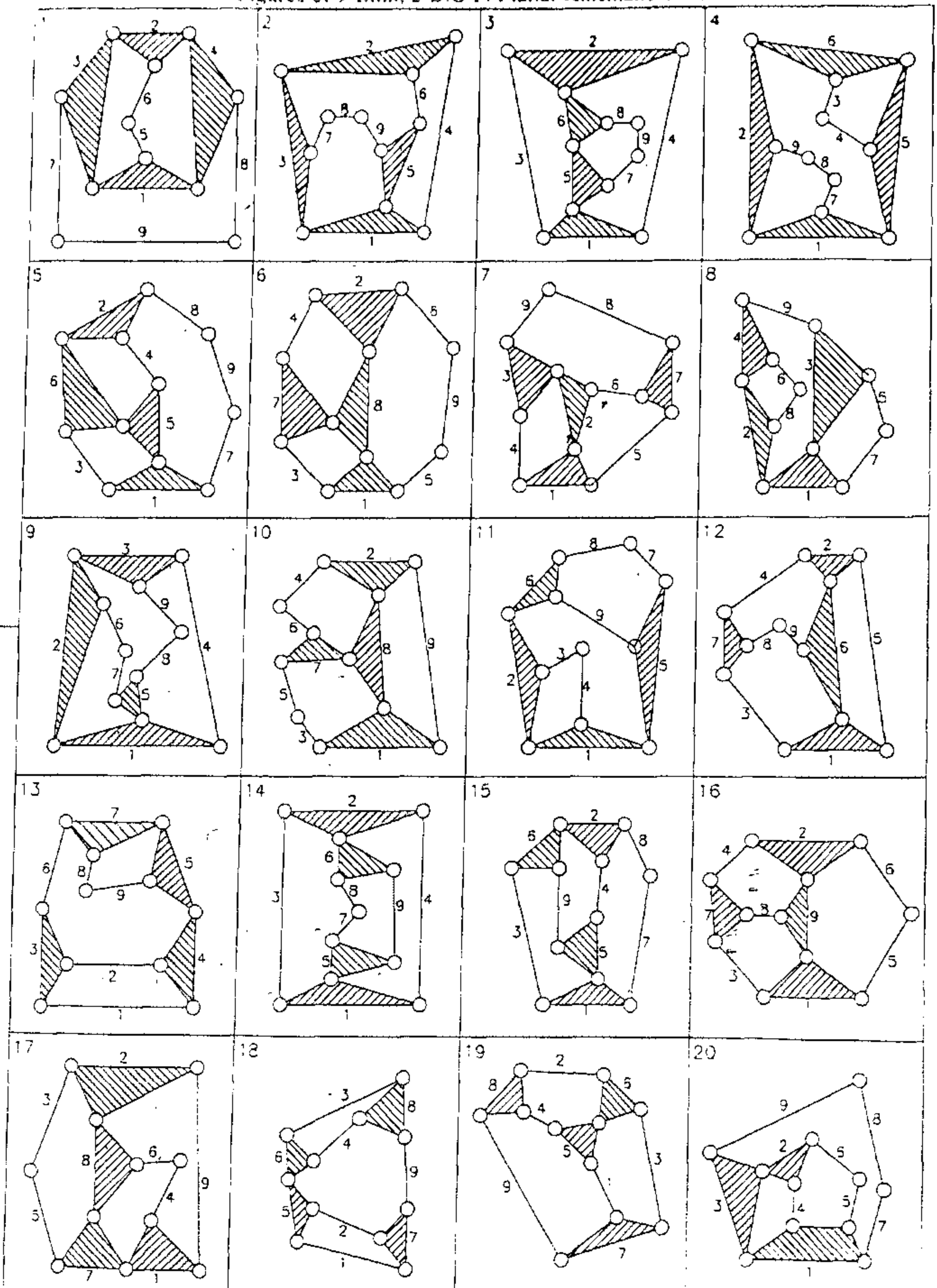
The result of above example problem show that the structural error is significantly less for Stephenson chain compared to watt chain for a given function. Hence Stephenson chain is superior to watt chain in generating a function since its links are more uniformly deployed indicating they are more symmetrical.

Illustration

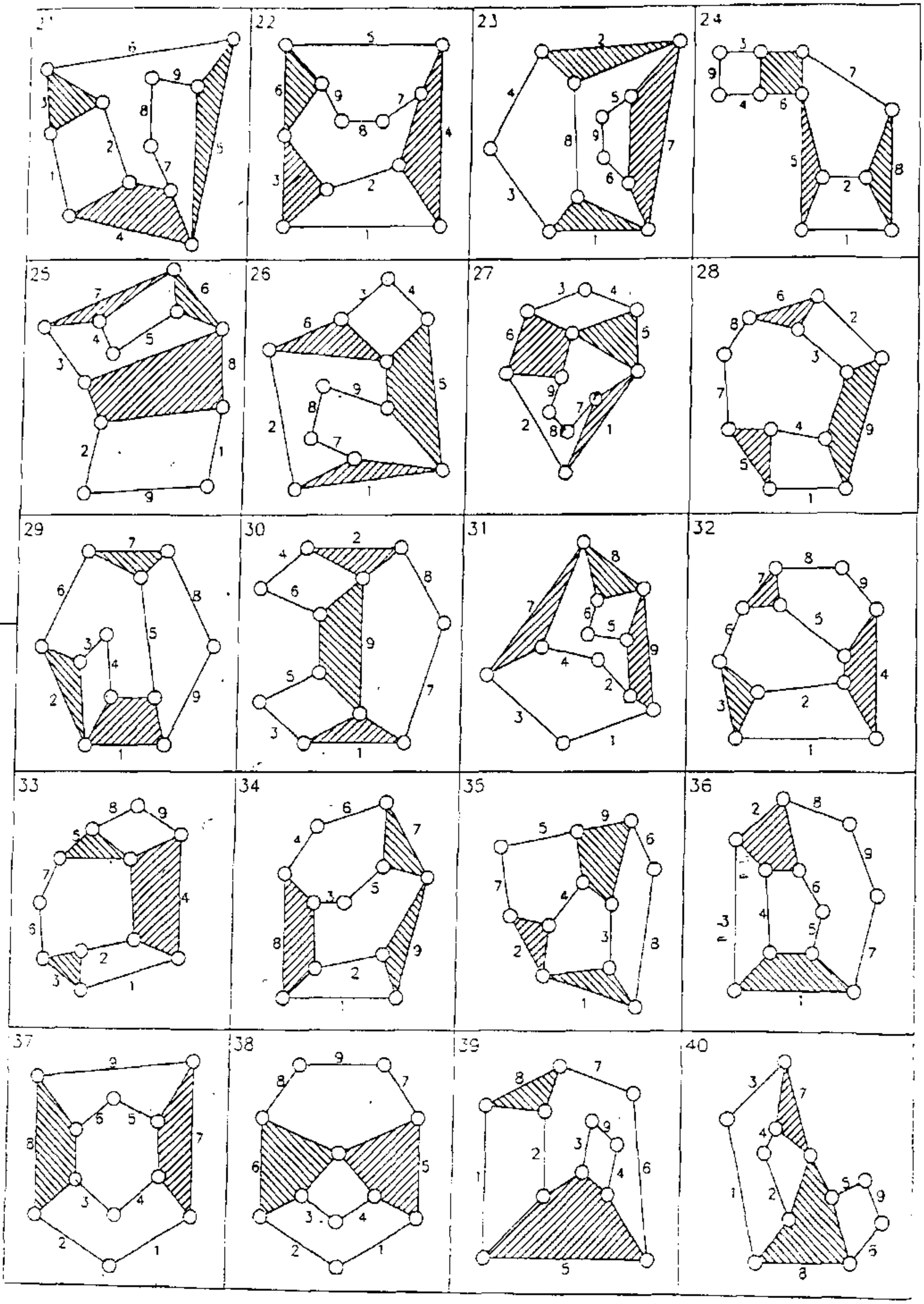
As an example let us compute link assortment, joint values, loop values, and square of primary Hamming elements and their summation for chain in Fig.1. Link assortment is given as 5(2), 4(3) meaning that the chain has five binary link and four quaternary links. Joint assortment is given as 4(3+3), 4(2+3), 3(2+2) meaning there are 4 joints in the chain where two ternary links are connected, 4 joints where binary and ternary links are connected and lastly 3 joints where in only two binary links are connected. Loop value of the chain is 44 and squaring of the primary hamming elements and their summation value is 1216. For comparison let us compare chain 32 in Fig.1 with the above-mentioned chain. The link assortment of the chain is given as 6(2), 2(3), 1(4), joint assortment is 4(2+4), 6(2+3), 1(2+2) loop chain value is 43 and squaring of the primary hamming elements and their summation is 1268. Using steps (1 to 4) it can be seen that chain1 is better compared to chain 32 for the expected performance. Four steps are to be followed in the same sequence till all the chains are arranged.

Chapter - 5

Figures of 9 Link, 2-D.O.F. Planar Kinematic Chains



Chapter - 5



Steps for rating of simple jointed planar kinematic chains are as below.Chains

(I) Consisting of links with lower connectivity is superior compared to the chain consisting of links of higher connectivity; e.g. Chain consisting of 5 binary and 2 ternary links are superior to chain consisting of 4 binary and 3 ternary links

(ii) Consisting of joints of higher value are inferior, e.g., The joint formed by two ternary links have greater joint value than the joint formed by ternary and binary links,

(iii) In case of two chains which have identical links and joints, number and type it becomes necessary to consider loops or loop Hamming values [3 and 4].

Now with the development of concept of symmetry it is not necessary to write loop Hamming matrices in addition to link Hamming matrices as the latter can be used to compare the chains. If two chains have the same type and number of links, joints and loops then symmetry can be used to compare the chains for their excepted performance in the following manner, greater symmetry indicates loss or inefficient deployment of links and hence design parameters. The greater the symmetry, inferior is the chain. An algorithm is developed keeping sequence of events to be same as explained above.

Computer Program

Based on the above algorithm a computer program in C language is developed for rating of simple jointed planar kinematic chains in terms of output error. The input to the program is kinematic chains, and out put is chains arranged in order of best performance in terms of output error. As an application of computer program developed rating of 9-link 2-d.o.f. Is listed below. Result is attached in appendix-5.

Application

The computerized methodology formulated is implemented up to 12-links, 1-d.o.f chains for rating

Table: Rating of 8-link, 1-d.o.f kinematic chains

Chain no.	Link assortment	Joint value	Primary Hamming no.	Secondary Hamming no.	Loop Hamming values	Square of Primary Hamming numbers
4	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2612	40	928
5	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2656	40	960
6	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2600	40	960
7	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2456	40	960
8	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2448	40	912
9	4(2)4 (3)	1(2+2)6(2+3)3(3+3)	216	2576	40	976
1	4(2)4 (3)	8(2+3)2(3+3)	216	2672	40	912
2	4(2)4 (3)	8(2+3)2(3+3	216	2424	40	944
3	4(2)4 (3)	8(2+3)2(3+3	216	2608	40	976
11	5(2)2(3)1(4)	1(2+2)4(2+3)4(2+4) 1(3+3)	212	2448	39	944
12	5(2)2(3)1(4)	1(2+2)5(2+3)3(2+4) 1(3+4)	212	2488	39	960
3	5(2)2(3)1(4)	2(2+2)4(2+3)2(2+4) 2(3+4)	212	2508	39	944
4	5(2)2(3)1(4)	6(2+3)4(2+4)	212	2464	39	960
0	5(2)2(3)1(4)	2(2+2)8(2+4)	212	2072	39	992
5	6(2)2(4)	2(2+2)8(2+4)	208	2096	38	944
6	6(2)2(4)		208	2288	38	944

Conclusion

A computer methodology is reported for the rating of simple jointed planar kinematic chains without carrying out dimensional synthesis. The time on PC, MMX-166 for rating of 9L-2-d.o.f Chains is 5 seconds The methodology is generic and can be implemented on n-Link, f-d.o.f. chains with slight modifications. The data generated during synthesis and analysis is used for rating simple jointed planar kinematic chains with least modifications and no additional computations are required

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