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Weight criteria detection to find work volume of 3–PRSParallel Manipulator using Fuzzy Logic

Manisha Mahapatro[a], Arockia SelvakumarA[b,*]

[a]*M.Tech. Mechatronics Student, SMBS, VIT University, Chennai – 600127, India*
[b]*Associate Professor, SMBS, VIT University, Chennai – 600127, India*

Abstract

This paper focuses on finding the weight criteria to determine the work volume of a 3-PRS (Prismatic-Revolute-Spherical) parallel manipulator (PM) using Fuzzy Logic approach. The Analytic Hierarchy Process (AHP), being an uncomplicated Fuzzy logic techniquebut an authoritative decision-making toolthat has been applied to solve differentmanufacturing problems till now. In this work, the AHP has functioned to calculate the weight criteria to find work volume of the Parallel Manipulator. The results of this research may be utilized to improve the architecture of 3 degrees of freedom (DOF) parallel manipulator.

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*Keywords:*Parallel manipulator, link length, analytic hierarchy process, work volume

1. Introduction

The escalating demand of robotic structure presentation leads to the application of higher strategies. Manipulators in Robotics can be used in perilous situations for an alternate to manual labor for routine work. Comparing with conventional serial manipulator that consist of rigid body links and joints connected serially, construction of parallel manipulator provides advantages over rigidity of structure and enhanced payload shipping ability.Thus it is suitable for situations needing high precision, stiffness, velocity, and heavy load carrying is essential within a limited workspace [2]. All these advantages come up due to presence of closed loop kinematic chain mechanism

* Corresponding author. Tel.: +91 44 3993 1206; fax: +91 44 3993 2555.
*E-mail address:*arockia.selvakumar@vit.ac.in

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which is connected to a fixed base platform that permits the load to transmit through several chains and cause for limiting of work space for parallel manipulator [8]. Apart from workspace parallel manipulator struggles for its complicacy of structure, highly economic and challenges for scrutiny in control. To avoid these complicacies 6 DOF might has been designed but 3DOF parallel manipulator is still struggling for its limited workspace issues and accurate positioning. Figure 1 shows the schematic representation of 3 PRS PM. The base of research lies in translation of motion between pairs of joints through links. So links play a vital role in designing a parallel manipulator. But there are many factors which affects calculating work volume of parallel manipulator.

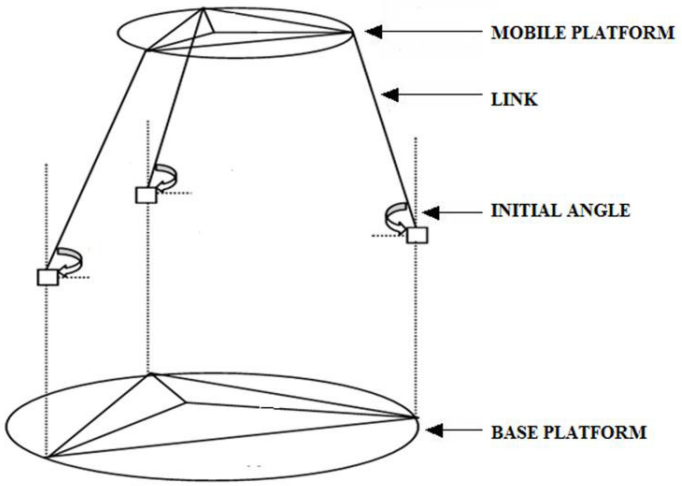

Fig. 1. 3 – PRS parallel manipulator

Analytic hierarchy process (AHP) is a simple decision making tool that can resolve many multi faced multi-criteria decision-making problems hierarchically [1]. The proposed paper addresses to find weight criteria while designing 3 DOF parallel manipulator by considering geometrical parameters.While establishing mechanical architecture of a parallel manipulator, they suffer problem during forward kinematics, for finding optimal functional workspace and intricate multi degree of freedom joints. The AHP gives the best solution towards whom to give the most importance while designing a parallel manipulator. As per great mathematician Henri, comparisons of objects regarding a property is fundamental mathematical procedure to derive measurements as because direct comparison is necessary for establishing measurements of intangible properties having no scales of the same. Using Analytical hierarchy process it has been possible to compare mutually even between the most equal parameters. The factors are arranged in a hierarchic or in a network organization and calculated as per the criterion represented within these structures. There are numeric issues which factor to be given the most importance and whom to least and also which is nearly equal. Numeric based rank criteria would have been better. AHP can deal with the theme of structuring complexity of these kind of problems, measurement and synthesizing. These characterizations make AHP effective for broader range of uses. AHP proceed with a neat solution for these kind problems. The methodology applied for acquiring the result is as follows [3, 4],

- Defining the problem clearly and get the information sought
- Structure the decision from the top along with the goal of decision.
- Architect the parameters in a set of pair wise comparison matrices
- Use the priority results from previous step to calculate the weight priority.

2. Prospective of parallel manipulator

Coming to a robotic manipulator, we can see two types of manipulator. The open type chains called serial manipulator and the closed type looping system called parallel manipulator. Robots opted for industries made up of several rigid links, might be in series or parallel connected through revolute or prismatic joints. A robot needs a base for supporting purpose and the other end is a gripper for holding purpose that we can call it an end effecter as well. Serial manipulators mainly suffer for their series cantilever structure. For high load carrying capability it leads to vibration. On the other hand, if we opt for large work space it comes in a bulky space with poor precision capacity. The past decades have witnessed for considerable research of parallel manipulators that has increased tremendous demand over industrial field just because of its enhanced coupling and rotational effects that eliminates disturbance and independent of being a précised dynamic model with higher accuracy. But while designing for higher adaptability and robustness, it disturbs inner coupling and takes for architecture of different sliding pair and rotation pairs for joining purpose of links and the mobile platform [12] for different rotations of angle of tilt and different work volume. The architect of parallel manipulator also deals with initial angle and mobile platform radius. But it has not attracted the interest of researchers yet for whom to give the most important criteria in constructing a parallel manipulator and the order in which we have to give importance for the factors influencing in constructing parallel manipulator. So the calculating link length solves this dilemma adequately. List of factors impacting to decide work volume are listed below and their abbreviations are given

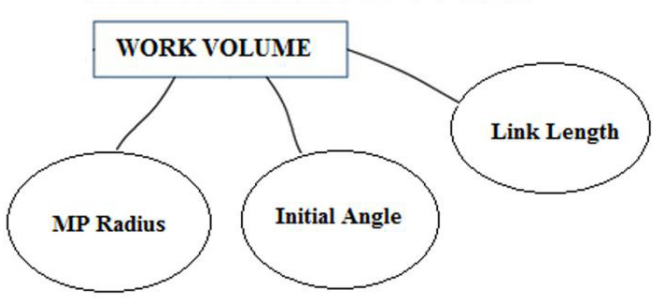

Fig. 2. factors influencing work volume of parallel manipulator

Table 1.Symbolic presentation of factor influencing work volume.

Factor Name	Symbol
MP Radius	A
Initial Angle	B
Link Length	C

The Analytic Hierarchy process one of the matured method, that allow evaluation of each criterion functionally considered to context rationally. It is a method proposed by Satty in 1980. He had divided the problem in few hierarchical levels that makes the evaluation easy.

AHP explains its application logic. AHP assist for measurement and synthesisof couple of factors involved in complex decision, subdividing is the adaptable way to finite intelligence to identify a complex situation. The exaggerated demand of AHP takes over for defining the mutual competency in between the impacting factors on base of a “10 point scale” as shown in Table 2 [6, 4]. That makes quite easier to set a numeric rank order for influencing criteria.

Table 2.Assignment of Rank.

Scaling Factor	Situation
1	Equal Importance
2,3,4	Moderate importance
5,6	Strong importance
7,8	Very Strong Importance
9	Extreme importance

3. Relative weight allocation

Mutual weights to be assigned on base of a "10 point scale" [7]. Weights assigned to individual criteria in a particular group first then mutual rank is to be assigned. This will make a square matrix of a number of criteria influencing Work Volume. The sum of individual weights of the group is normalised to one. In this way, effective weight of a particular criteria is equal to product of own weight and weight criteria of the whole group [7]. Assigning weight for the upper triangular matrix is enough; the reciprocal of these values make over a lower triangular matrix. As mentioned previously, mutual weights to be assigned on each of the factor influencing link length. According to AHP an 'n' X 'n' square matrix is to be formed assigning weight as shown in Table 3 [5]. When two factors having same importance, weight factor assigned in that case is 1.

In the first row of matrix the importance of MP Radius is shown over the rest impacting factors of work volume. Similarly 2nd row shows comparative importance of Initial Angle (B) with respect to other factors playing Role in determining work volume of parallel manipulator. The lower matrix of Table 3 is calculated using Equation 1.

$$W_{B/A} = 1 / W_{A/B} \quad (1)$$

$W_{B/A}$ = Weight of B with respect to A
$W_{A/B}$= Weight of A with respect to B

Table 3. Square Matrix to assign mutual weight.

Goal	MP Radius	Initial Angle	Link Length
MP Radius	1	3	9
Initial Angle	0.3333	1	7
Link Length	0.1111	0.1428	1

From the above square matrix, we can calculate the weight as follows inTable 4.

Table 4. Weight vector.

MP Radius	0.6529
Initial Angle	0.2910
Link Length	0.0560

After the calculation of mutual weight, we can calculate Lambda (λ) using the Equation 2 [7].

Where

$$[A].w = \lambda * w \quad (2)$$

[A] = The Rank Matrix obtained in Table 3.

w = weight matrix obtained in Table 4.

So λ found as 3.1019, in addition CR can be calculated from the Equation 3 [7, 10].

$$CR = [\lambda - n] / [RI * (n-1)] \quad (3)$$

Where

n = the number of criteria

The R.I. is the average Random Coherence index, extracted from the simulation Table with samples matrices of various dimensions.Table 5 shows R.I. values related to n [7].

Table 5.RI for corresponding 'n'.

Order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

The number of criteria is 3, n=3

So, RI = 0.52

From the above values, CR value is found to be 0.06.

i.e. CR < 10%. Thus Consistency Ratio (CR) obtained has been found quite consistent [9, 10]. As per Satty (2008) CR > 10% needs to be reviewed. Otherwise, result can be concluded as reliable i.e. ranking obtained for individuals influencing work volume are correct.

4. Conclusions

This paper proposes the Fuzzy logic approach using AHP technique to find the factors influencing PM work volume. From the work, we get the Consistency Ratio (CR) < 10%. According to Satty (2008) the result obtained for weight vector is consistent. So we can conclude that the MP radius is the major factor decidingwork volume of a 3-PRS PM. The next major factors are the initial angle and link length respectively. Work volume occupied by the PM has been calculated by giving proper priority to influencing factors while constructing the PM. The soul of the architecture is involved in setting geometric parameter of the 3-PRS PM. It may help to make the task easier for design purpose and will be quite helpful to make the architecture of the Parallel Manipulator easier. It may help to optimize the total work volumeof the PM reliably.

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