Relative Kinematic Analysis of Serial and Parallel Manipulators

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Relative Kinematic Analysis of Serial and Parallel Manipulators

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Abstract: Day by day the applications of parallel and serial manipulators become evident and with high industrial applications in the fields of manufacturing, space equipments, pick and place robots and medical equipments. In this paper a comparison is made between kinematic analysis of serial and parallel manipulator is made in terms of workspace, position, synthesis, orientation and applications. In this article sensitivity comparison of serial and parallel manipulator with different actuator positions taken as parameter.

Key words: Serial manipulator, Parallel Manipulator, kinematic analysis, Comparison.

1. Introduction:
The robot manipulators are classified into serial type open loop kinematic chain and parallel type closed loop chains. Robot was born out with integration of two earlier technologies NC milling machines and teleoperators which were used during the days of Second World War to clear hazardous materials. Robot should be pointed out that the implementation of robotics is not limited to those industrial jobs where the robot is replacing a worker.

The parallel manipulator has more applications in recent days, because of parallel manipulator posse’s large load carrying capacity and precision and accuracy. Whereas serial manipulators have large workspace and adroit transportability,Serial manipulator has cantilevered structure that made the serial robot as susceptible to bending at heavy loads and also high vibrations at high speed. As industries are need of high load and high precision manipulators thus the usage of parallel manipulator is obligatory.

2. Motivations and need of Parallel Manipulator
In industrial automation the Parallel Manipulators were considered as an alternate to the traditional automation to achieve high load carrying capability, smart dynamic performance and precise positioning that provides higher quality and more economical processes. The most recent innovation within the field of artificial intelligence is that the Parallel Manipulator that finds its application altogether areas, especially for its high load carrying capability and superior positioning.
capability with larger rigidity. The fascinating thing concerning the Parallel Manipulator is that, the degrees of freedom vary up to six. The need arises for scheming the motion exactly and instructing to drive the link consequently. Hence, the use of computers and therefore the electronic are interfacing to actuators become significant.

One of the fundamental highlights of parallel maneuvers like Stewart plat form, hexapods, Hexa glides and delta robots obliges appropriate conduct for dynamical applications wherever rapid activity makes vital the elements of the framework. Because of the expressed advantages, with the uses of small scale machines running at rapid, Mechatronics and parallel manipulators are useful in health industry, Ocean handling support during oil and gas extraction can be enhanced and be less complex by investigation of parallel controllers applications during this space. Wire driven parallel controllers focus for the space applications for present condition of research. A proceeding and unending exertion by scientists can develop and advance in expanding the inclination and viability of differed parallel controller applications to push towards new skylines for automated exchange.

Zoran Pandilov, Vladimir Dukovski [1] studied the basic differences of serial and parallel manipulators. It is extremely tough to mention decide which type of manipulator is accurate, parallel or serial. A manipulator choice processes is extremely tough and complicated activity. It depends on many alternative factors like kind of application (repetitive and boring, precise, accuracy etc.), task needs (DOF, speed, accuracy, repeatability), load requirements, workspace, economic justification, programming time, maintaining, etc. Parallel robots are most successful in most of industrial applications like motion simulators, immoderate preciseness positioning devices, medical applications, ultra-fast pick and place robots and micro-robots. However serial robots dominate nearly all told producing applications. Probably this can modification with unendingly solving of the open issues in parallel manipulator Mohammed Hussein, saadatzi Mehdi tale[2] they researched the translation and figuring of different varieties of the kinematic sensitiveness of planar parallel components. As a contextual investigation, the 3-RPR planar component was dissected and furthermore the comparing kinematic sensitivities got geometric elucidations. Diagnostic connections to ascertain everything about varieties were acquired and examined. In addition, the count of the kinematic sensitiveness inside the instance of repetitive and ward DOF planar parallel components are examined, and a couple of new perceptions are accounted for. At last, the kinematic sensitiveness is reached out to be thought of as an overall execution list for improvement capacities. The standards of this paper is connected similarly well to alternate sorts of parallel systems, similar to the Stewart–Gough stage. In advance work incorporates, the occasion of a solid way to deal with get agent worldwide kinematic sensitiveness for enhancement capacities Arockia Selvakumar [3] Presented the Work space analysis has been dealt thoroughly and it had been found that the link length and radius of moving platform have a scaling impact over work volume. The rise in link length and also the radius of the moving platform will increase the work area volume and the other way around, as the radius of moving platform is increased the work volume will increase for constant link length and the other way around. And once the link length is increased the work volume increases for a constant radius of the moving platform and the other way around.

Damien chablat, Philip Wenger[4] formulated A kinematic analysis of a planar 3-RRR parallel manipulator with symmetrical properties was conferred during this paper. The eight operating modes are characterized and twenty two generalized aspects are recognized. Within such
domains, any continuous trajectories are attainable. In such domains, are unit non-singular changing trajectories but not any kinematic index will acknowledge such property. An example of non-singular dynamical trajectory is given and the characteristic surface are computed which enable, in a future works, to define closely the individuality domains of the manipulator studied.

Chanhee Han, Jinwook Kim, Jongwon Kim[5] the lessons to be drawn from this work is that the importance of kinematic sensitivity analysis of parallel mechanisms their results indicate that some parallel mechanism designs are inherently more strong than others, it's particularly vital to verify that each one potential design parameter variations, clearances, manufacturing and other assembly errors are accounted for in the kinematic model used for sensitivity analysis. Stephane Caro, Nicolas Binaud [6] implemented a methodology to obtain the sensitivity coefficients of the pose and orientation of the moving platform of the planar parallel manipulator to variations in actuated variable. He compared parallel manipulator with regard their workspace, and sensitivity, prismatic joint clearances and link flexibilities can be studied as future work.

Nicolas Binaud, Stephane Caro[7] contrasted 3-PPR parallel controllers and Delta and U-shaped base were contrasted with deference with their workspace and sensitiveness to joint clearances. Error expectation model appropriate to both parallel and serial controllers has created. Therefore, two non raised obliged quadratic projects were defined to locate the greatest position blunder and introduction mistake of the moving-stage for given joint clearances. [8] It creates the impression that the workspace of a 3-PPR planar parallel controller with a U-shape base is bigger than Delta shape for given kaleidoscopic joint points of confinement. Despite the fact that the U molded base parallel controller decently superior to anything the old one as far as kinematic affectability to joint clearances

3. Parallel manipulator vs. Serial manipulator

The basic differences between parallel manipulator (PM) and serial manipulators (SM) are structure and load carrying capacity, Serial manipulator carry less load compared to parallel manipulator due to cantilevered structure. The schematic sketches of serial and parallel manipulator shown below.

![Fig 01: Different Configurations of the 3PRR Parallel manipulator.](image1)

![Fig 02: Different Configurations of serial manipulator.](image2)
The problem with serial manipulator is the error in the arm is creating moment effect with that the deflection at the fixed end increases which leads to less load carrying capacity. The workspace of SM is large due to open structure, whereas PM is small and complex due to close loop structure. All the characteristics of SM and PM compared in the following table.

**Table:** Showing the basic differences between Serial and Parallel Manipulator

| Parameter                                | Serial Manipulator | Parallel Manipulator |
|------------------------------------------|--------------------|----------------------|
| Work space                               | Big                | Complex and short    |
| Forward Kinematic analysis               | Typical            | Easy                 |
| Inverse kinematic analysis               | Solution is typical| Easy solution        |
| Force error accumulation                 | More               | Less error           |
| Position Error                           | Accumulated at fixed end | Less       |
| Max stiffness                            | Less               | More                 |
| solving of Dynamics and Modeling         | Easy               | Very tough           |
| Inertia                                  | High               | Small                |
| End effectors                            | Gripper            | Platform             |
| Preferred Property                      | Dexterity          | Stiffness            |
| force transformation                     | Not well defined   | Well defined and single |
| stiffness                                | Less               | High                 |
| Natural Description                      | In joint space     | In Cartesian space   |
| Size of robot for same work space        | Big size           | Small size           |
| Pay load to weight ratio                 | High               | Less relative to serial one |

**4. Proposed work**

Stephane Caro brought a method to derive the sensitivity parameters of the transferring platform variation to position in the geometric parameters in algebraic form. He suggested that the same method can be applied to derive the sensitivity coefficients of other Parallel Planar Manipulators i.e. 3-RPR, 3-RRR, 3-PRR, 3-RR, and 3-RPR PPMs. In this line, R, P, and P represents revolute, prismatic, actuated prismatic joints, and actuated revolute joint, respectively. First, the structure of the manipulator is explained. Then, the sensitivity coefficients of the moving platform pose to variations in the geometric parameters and in the prismatic actuated variables are expressed algebraically. Moreover, two combination sensitivity indices are determined, one associated to the orientation of the manipulator moving platform and another one associated to its position. Then, a methodology is proposed to evaluate 3-RPR PPMs with regard to their dexterity, workspace size, and sensitivity. Finally, the sensitivity of an arbitrary 3-RPR PPM is analyzed in detail, and four 3-RPR PPMs are compared as illustrative examples [11].
The comparison is made between triangular (both moving and fixed plate 3-noded) elements only. If the interchanging of number of node points and the actuation position among them with different sensitivity indices, with these comparisons the selection of serial and parallel manipulator would be easy for any industrial application.

Table: II The possible lower pair leg structure

| RR Type | PR Type | RP Type |
|---------|---------|---------|
| RRR     | RPR     | RRP     |
| RRR     | PRP     | RRP     |
| PRP     | PRP     | RRP     |
| RRP     | PRP     | RRP     |
| RRP     | PRP     | RRP     |

5. Conclusion
In recent days usage of parallel manipulator is increasing day by day because of serial manipulator has disadvantages like high payload to weight ratio. The sensitivity indices also place a major role to function manipulator with high performance. High sensitivity of manipulator parameters leads to poor and unanticipated performance. In parallel and serial manipulators the dissimilarities in the geometric parameters of the parallel manipulator can be magnified. Researcher did a sensitivity analysis for 3 RPR parallel manipulator. In the proposed work 4 RPR, or any other combinations can be done by taking a square or pentagonal moving plate into consideration, similar type of analysis can be carried out for 5 RPR manipulator. In my future work I will compare the 3, 4 and 5 RPR parallel manipulator performance based on sensitivity indices, as sensitivity is a prime parameter to select parallel manipulator. This work may extended to actuator position change like form RPR to PRP, PRP etc with these all different analysis the manipulator selection for better performance is simple.

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