

Discussion: “Kinematics of a New High-Precision Three-Degree-of-Freedom Parallel Manipulator” (Tahmasebi, F., 2007, ASME J. Mech. Des., 129, pp. 320–325)

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The author of Ref. [1] proposes a “new” high-precision three-degree-of-freedom parallel manipulator. The paper discusses the inverse and forward displacement solutions for the 3-PRS manipulator, which is formed by three identical limbs, each containing an actuated prismatic joint (P) followed by a passive perpendicular revolute joint (R), a fixed-length leg, and a passive spherical joint (S), which attaches to the moving platform. In Ref. [1], the three active prismatic joints intersect at the center of the base platform and are contained within the base plane while being separated by 120 deg from one another.

We would like to bring to the readers’ attention that although Tahmasebi [1] presents some interesting implementation issues, the same 3-PRS manipulator was first presented in 1997 by Carretero et al. [2]. In March 2000, an improved version of that paper was published in ASME Journal of Mechanical Design [3]. Both papers present the inverse displacement solution of the manipulator where the lengths of the active prismatic joints are obtained as a function of the pose of the end effector. The pose is defined by three variables: two angles around mutually perpendicular inertial axes parallel to the base plane (tip and tilt) and a displacement normal to the base platform—just as they are in Ref. [1].

Also worth noting is the fact that the forward displacement problem (FDP) for this manipulator was solved by Tsai et al. in Ref. [4] for a variation of the 3-PRS whose prismatic joints are all perpendicular to the base platform. The formulation in Ref. [4] is easily modified to obtain the forward displacement solution of the version where all prismatic joints are parallel to the base. This equivalent formulation of the FDP is presented in Ref. [1] but the work in Ref. [4] is only mentioned in passing in the Introduction.

With respect to the inverse displacement problem, Tahmasebi [1] considered a less general version of the 3-PRS manipulator. That is, in Ref. [3], the angles between the three branches were left as design variables whereas in Tahmasebi’s work, these angles are fixed at 120 deg and -120 deg, respectively. Note that the applications considered in Refs. [2,3,5] are also high-precision tasks, just as those claimed in Ref. [1]. More specifically, in Refs. [2,3], the authors suggested that the 3-PRS manipulator could be used near its singular configuration for high-precision applications such as telescope image correction. This configuration, reached when all three fixed-length legs are close to being parallel, gives

the manipulator higher resolution in that region of the workspace.

As pointed out in Refs. [3,6], motions in the tip and tilt directions come with unavoidable motions in the other three directions. That is, when the platform is tipped and/or tilted, small translations occur along two noncollinear axes coplanar to the base plane as well as a rotation around an axis perpendicular to this plane. These extraneous motions, independent of the platform’s elevation, were deemed *parasitic* and minimized in Refs. [3,6]. Although these motions are noted in Ref. [1] as Eqs. (4) and (5), they are not recognized as having an adverse effect on the payload’s location, particularly for the high-precision applications claimed by the author.

In addition to the aforementioned seminal work by Carretero et al., a number of documents have been published since 1997 discussing different aspects and variations of the 3-PRS manipulator as well as analyzing the manipulators for a number of different applications. Following is a list of some of the works presented to date on the 3-PRS manipulator, grouped by the general topic. These important works on the 3-PRS manipulator were also overlooked in Ref. [1].

- Kinematics: Inverse displacement problem [2,3,7] and later generalized in Ref. [8] for any orientation of the prismatic joints relative to the base. FDP [4]. Reduction of parasitic motions [3,6]. Kinematic calibration [9].
- Workspace size and quality: Dexterity [10,11]. Stiffness [12].
- Design and applications: Medical assistants [13]. Also, Tsai et al. [4] presented a slight variation of the version by Merlet presented in Ref. [13]. Telescope image correction [2]. Machine tool applications [14]. Micromanipulation [5].

References

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