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On adjustable spherical four-bar motion generation for expanded prescribed positions

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Abstract

This work formulates and demonstrates a method to synthesize two-phase adjustable spherical four-bar mechanisms to approximate substantially more prescribed rigid-body positions than with conventional motion generation methods [C.H. Suh, C.W. Radcliffe, Kinematics and Mechanism Design, John Wiley and Sons, New York, 1978]. An alternate set of mechanism constraint equations are formulated using the Method of Least Squares and solved for the adjustable spherical mechanism moving pivot variables. The example included demonstrates the synthesis of an adjustable spherical four-bar mechanism to approximate twice the number of prescribed rigid-body positions per phase than with a conventional method [C.H. Suh, C.W. Radcliffe, Kinematics and Mechanism Design, John Wiley and Sons, New York, 1978].

Keywords: Spherical mechanisms; Motion generation; Adjustable mechanisms; Four revolute spherical mechanisms; Method of least squares

1. Introduction

Several authors have made significant contributions in the area of adjustable spatial mechanism design, analysis and synthesis [1–9]. Sodhi and Shoup [1,2] and Sodhi et al. [3] presented works that included the analysis of the axodes of the four revolute spherical mechanism and the synthesis of these mechanisms via instant screw axes (ISAs) and curve matching. Gilmartin and Duffy [4] examined type and mobility analysis of the four revolute spherical mechanism. Tong and Chang [5] presented the synthesis of four revolute spherical mechanisms via the pole method. McCarthy and Bodduluri [6,7] considered the generalization of planar rectification theory to four revolute spherical mechanisms as well as an approach to the finite position synthesis

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of these mechanisms that unites traditional precision theory with recent results in approximate position synthesis. Ruth and McCarthy [8] described a computer-aided design software system for four revolute spherical mechanisms that is based on Burmester's Theory. Hong and Erdman [9] considered adjustable planar and spherical four bar linkage synthesis.

In this work, an alternate set of constraint equations are using the Method of Least Squares and solved for the adjustable spherical mechanism moving pivot variables. The advantage of Least Squares-based motion generation for adjustable four-revolute spherical mechanisms over conventional motion generation methods [10] is that, with the former, the maximum number of prescribed rigid-body positions is not limited to the number of spherical R–R link dyad variables to be calculated. Using the method presented in this work, designers can synthesize four-revolute spherical motion generators to approximate more extensive phases of prescribed rigid-body positions than with conventional motion generation methods.

2. Conventional and adjustable four revolute spherical mechanisms

Fig. 1 illustrates a four revolute spherical mechanism. The fixed (grounded) pivots are represented by unit vectors $\mathbf{a}_0$ and $\mathbf{b}_0$. The moving pivots are represented by unit vectors $\mathbf{a}_1$ and $\mathbf{b}_1$. In this work, the R–R link including $\mathbf{a}_0$ and $\mathbf{a}_1$ is the designated crank (driving) link and link containing $\mathbf{b}_0$ and $\mathbf{b}_1$ is the designated follower link. Rigid-body position vectors $\mathbf{p}$, $\mathbf{q}$ and $\mathbf{r}$ mark the spatial position of the coupler link.

In this work, the four revolute spherical mechanism has adjustable moving pivots to approximate two phases of prescribed rigid-body positions. A *phase* is a group of prescribed rigid-body positions. When multiple phases of rigid-body positions are prescribed (and a single mechanism configuration cannot produce a reasonable approximation of the phases), a mechanism with adjustable fixed and/or moving pivots is typically of interest for synthesis. With adjustable fixed or moving pivots, multiple mechanism configurations can be produced-each configuration associated with a particular phase. For instance, when the adjustable four revolute spherical motion generator illustrated in Fig. 2 incorporates moving pivots $\mathbf{a}_1$, and $\mathbf{b}_1$, one phase of prescribed rigid-body positions is approximated and another phase of positions is approximated when moving pivots $\mathbf{a}_{1n}$, and $\mathbf{b}_{1n}$ are incorporated. Both moving pivot adjustments, though distinct, incorporate the same mechanism hardware. Such mechanical design flexibility is distinct among adjustable mechanisms. The mechanism in Fig. 2 is a two-phase moving pivot adjustable four revolute spherical motion generator.

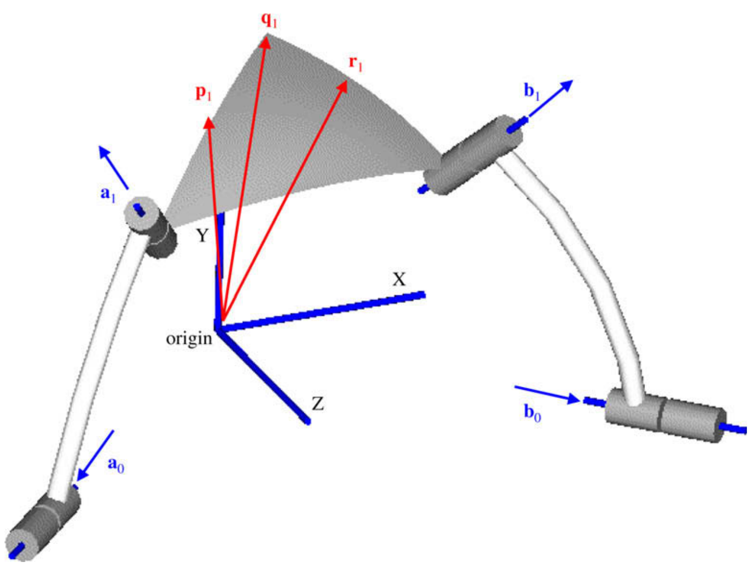

Fig. 1. Spherical mechanism with fixed pivot, moving pivot and rigid-body vectors.