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Body guidance syntheses of four-bar linkage systems employing a spring-connected block model

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ABSTRACT

The body guidance synthesis, the task of seeking a mechanism which simultaneously generates a desired path of a point fixed to a link and desired orientation variation of the link, is the most difficult problem in syntheses. In the present study, a unified synthesis method for simultaneously determining the type and dimension of a planar four-bar linkage system is proposed to solve body guidance synthesis problems. A spring-connected block model is employed and parameters of the model including block sizes, spring stiffness constants, spring directions, input joint location and coupler point location are employed as design variables to formulate an optimization problem. Solving the optimization problem yields a simultaneous solution for the type and dimension of a planar four-bar linkage system.

1. Introduction

Engineers often need to design a four-bar linkage system which satisfies special kinematic motion requirements. Both the orientation of the coupler link and the position of a point on the coupler link are required to vary in specified ways. The process of designing such a mechanism is called the body guidance synthesis. To accomplish this task, the type and dimension of a mechanism should be properly determined. In most of conventional mechanism design methods, the type synthesis is usually carried out first based on the intuition or experience of an engineer. Since the intuition or experience cannot be easily implemented in an automated computational procedure, most of conventional mechanism design methods are usually very time-consuming.

Body guidance synthesis problems are more difficult than other kinds of synthesis problems such as path generation and function generation problems. For body guidance problems, a coupler point must pass through a specified path while the coupler link undergoes a specified rotational motion. Various analytical and numerical methods were introduced to solve this kind of synthesis problems more efficiently and precisely. A large number of graphical and analytical techniques with several assumptions have been introduced [1,2]. Sutherland and Karwa [3] proposed a general formulation to solve the four-bar linkage body guidance problem. Dhingra, Cheng, and Kohli [4] introduced an analytical method by which various planar mechanisms, including a six-bar mechanism, could be solved.

Along with the advances of mathematical programming techniques, practical applications of optimization techniques in engineering problems have increased rapidly since the mid-1960s and an increasing number of research works employing optimization methods have been conducted in the area of mechanism design. To solve planar-linkage body guidance problems, Akhras and Angeles [5] applied unconstrained non-linear least-square optimization techniques and Yao and Angeles [6] applied an approximate synthesis

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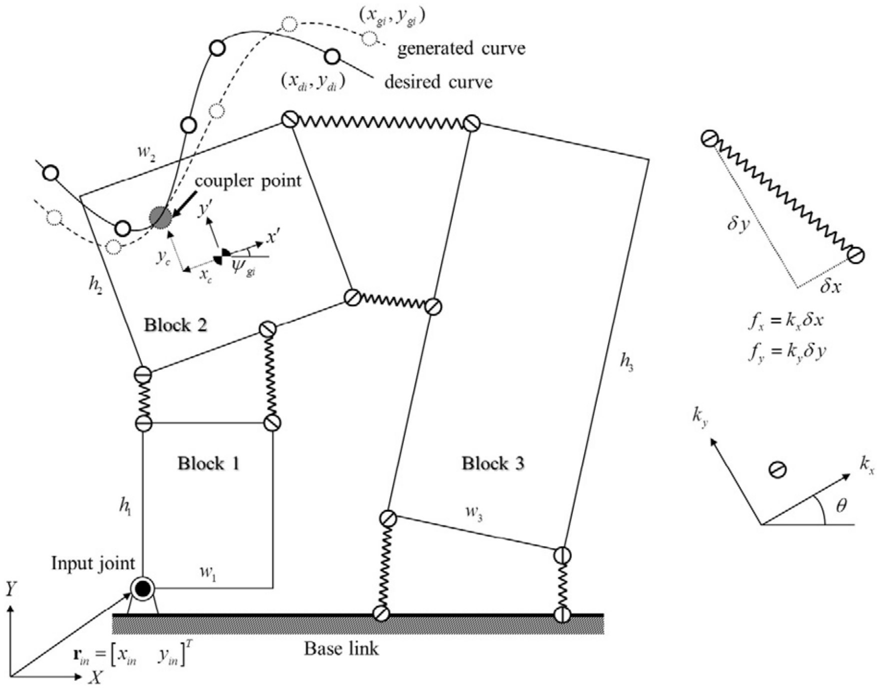

Fig. 1. Spring-connected block model.

contour method. Lio, Cossalter and Lot [7] applied natural coordinates for the synthesis of mechanisms and found the most suitable linkage size using optimization methods. They also showed that their approach is well-suited to kinematic synthesis. Later, Zhixing, Hongying, Dewei and Jiansheng [8] introduced a guidance-line rotation method to solve body guidance synthesis problems with four, five or more sets of precision path points and orientation angles. Although several body guidance problems were solved using optimization techniques, most of previous works focused on dimensional synthesis using a predefined mechanism type.

A more efficient synthesis method, often called the unified mechanism synthesis method, was proposed in the late 1990s. For mechanism syntheses without a predetermined mechanism type, this method simultaneously determines the type and dimension of a mechanism which satisfies given kinematic motion requirements. Vasiliu and Yannou [9] created a database with neural

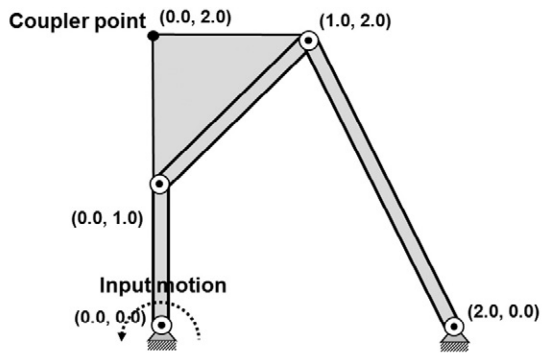

Fig. 2. Four-bar linkage for the first body guidance problem.

Table 1
Ten sets of coupler orientation and coupler point position generated by input-link rotation of a known four-bar linkage for the first body guidance problem.

	1	2	3	4	5	6	7	8	9	10
ϕ	0.0	10.1	20.3	30.2	40.1	50.3	60.2	70.1	80.3	90.0
ψ	0.0	−1.48	−2.38	−2.69	−2.42	−1.49	0.09	2.41	5.58	9.32
x	0.2	0.05	−0.09	−0.23	−0.36	−0.47	−0.57	−0.65	−0.72	−0.77
y	2.0	1.94	1.85	1.74	1.62	1.47	1.32	1.17	1.01	0.85