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Efficient constrained synthesis of path generating four-bar mechanisms based on the heuristic optimization algorithms

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ABSTRACT

This paper presents a comparative study of the dimensional synthesis of the path generating four-bar mechanisms using some heuristic optimization techniques. For this purpose, we implement the imperialist competitive algorithm (ICA) as a newly developed powerful optimization tool. The objective of the optimization algorithm is to minimize the tracking error of the mechanism coupler point. It is then modified to include the desired workspace limits. Furthermore, the paper presents an innovative method of imposing Grashof's law for generation of acceptable initial population to improve the optimization performance. In addition to the ICA, the paper implements the parallel simulated annealing approach for the cases of without and with prescribed timing. The results of our work will be finally compared to other heuristic algorithms such as GA, PSO and DE to provide a clear representation of the performance of each approach.

1. Introduction

In the mechanisms design context, the four-bar mechanism is considered as one of the fundamental linkages which is commonly used for performing various required tasks. A four-bar mechanism is designed to generate a prescribed task such as function, motion, or path [1]. A function generator is defined to correlate an input motion with an output motion. In the motion generator, the motion of the mechanism coupler link is controlled to follow some prescribed sequential positions. A path generator controls a point of mechanism coupler link in the plane such that it follows some prescribed path. The design process of a mechanism with unknown link lengths to reach this goal is commonly referred to dimensional synthesis. This important task can be handled by either quantitative or qualitative approaches.

In the quantitative approach, the analytical equations of the dimensional synthesis problem can be generated for obtaining unknowns. Although this approach leads to the exact solution of the synthesis problem, it is strongly limited by the number of precision points. However, in most real design problems synthesizing a four-bar mechanism includes many more analytical equations than unknown variables to describe the system's behavior. Consequently, one cannot simply solve the equations to get a solution. To remedy this undesired situation, the qualitative approach is utilized as an alternative. Based on this approach, in the absence of a well-defined algorithm, potential solutions are created to configure or predict the final solution. Based on this, a set of poses of the coupler point that best approximate a large number of prescribed positions is produced. This will guide us to the treatment of the dimensional synthesis problem by usage of an optimization algorithm. This approach takes precision points as input and finds optimal link lengths as design variables in an iterative procedure.

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