Machine Learning Methods in Synthesis of Four Bar Linkages

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Kinematic synthesis of four bar mechanisms is an engineering problem that is difficult to solve by generative methods. The present approach is a variant based method, that makes use of two artificial intelligence paradigms: decision trees and genetic programming.

The goal of the paper is to obtain a partitioning of the mechanism-space, to give a structural description for the class of mechanisms likely to produce the desired coupler curve. The selection of the best suited mechanism can be done afterwards by browsing the class and analyzing its members.

Two methods for classification of four bar mechanisms are shown: decision trees generated by a variant of the C4.5 program by Quinlan [4] and genetic programming (introduced by Koza [3] as an extension to genetic algorithms).

From kinematic point of view a four bar mechanism could be designed for [5]: (1) path generation - the path of a tracer point on the coupler link is of interest, (2) rigid body guidance - the entire motion (path and angle) of the coupler link is of interest, and (3) function generation - the relative motion of links is of interest.

By analytical methods a four bar mechanism could be synthesized for at most five prescribed positions of the coupler point [5].

In the present paper the path generation problem is considered, but the results could be extended to the motion generation and function generation problem, too. The path generation problem consists in finding the appropriate structural parameters of the mechanism (length of links and position of coupler point) which generates a given path (coupler curve). The functional description consists of curve fragments that should be on the coupler curve. A curve fragment is given as a list of points, where the neighboring points are connected with straight lines. For each curve fragment a tolerance is specified.

Bose et al. [1] tries to solve the same problem by using case-based reasoning. He makes use of a multi-level case retrieval procedure followed by case adaptation. For the adaptation of cases he uses a set of very simple adaptation rules, that make slight modifications to one or two parameters of the mechanism. However, the approach is limited to particular classes of mechanisms.

This paper gives two methods for describing a class of four bar linkages generating similar coupler curves. In this case the adaptation step becomes simply a search for the best mechanism within a small class.

Starting from the desired curve fragments, the class of mechanisms generating coupler curves that might be close to these fragments is automatically created. First, a measure of similarity for two curves is defined, then a catalog of four bar mechanisms is browsed and the suited mechanisms are selected . Using an adapted version of the C4.5 program, a decision tree is generated for the chosen class. This decision tree gives in fact the permitted intervals for each structural parameter of any mechanism in the class.

The genetic programming based method generates a set of conditions that have to be satisfied by the members of the class. The conditions are mathematical relations among the structural parameters of the linkage, such as:

$$CouplerLink > FollowerLink + 0.5$$

The two methods are discussed in detail and a comparison with the other approaches is made.

References

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