A classification of configuration spaces of planar robot arms for a continuous inverse kinematics problem. (English) Zbl 1321.70004

Summary: Using results on the topology of moduli space of polygons [B. Jaggi, Configuration spaces of point sets with distance constrains. Bern, Ch.: University of Bern (PhD Thesis) (1992); M. Kapovich and J. Millson, J. Differ. Geom. 42, No. 1, 133–164 (1995; Zbl 0847.51026)], it can be shown that for a planar robot arm with n segments there are some values of the base-length, z (i.e., length of line joining the base of the arm with its end-effector), at which the configuration space of the constrained arm (arm with its end effector fixed) has two disconnected components, while at other values it has one connected component. We first review some of these known results relating the value of z with the connectivity of the constrained configuration space.

Then the main design problem addressed in this paper is the construction of pairs of continuous inverse kinematics for arbitrary robot arms, with the property that the two inverse kinematics agree (i.e., return the same configuration) when the constrained configuration space has a single connected component, but they give distinct configurations (one in each connected component) when the configuration space of the constrained arm has two components. This design is made possible by a fundamental theoretical contribution in this paper – a classification of configuration spaces of robot arms such that the type of path that the system (robot arm) takes through certain critical values of the forward kinematics function is completely determined by the class to which the configuration space of the arm belongs. This classification result makes the aforesaid design problem tractable, making it sufficient to design a pair of inverse kinematics for each class of configuration spaces (three of them in total).

The motivation for this work comes from a more extensive problem of motion planning for the end effector of a robot arm, in which the ability to continuously sample one configuration from each connected component of the constrained configuration spaces of the arm enables us to dramatically reduce the dimensionality of the space in which the planning has to be performed, without sacrificing algorithmic completeness. We start the paper with the general motivation, but address only the problem of sampling such configurations when there is no obstacle in the environment – a problem that in itself is non-trivial. We demonstrate the simplicity and the low complexity of the presented algorithm through a Javascript + HTML5 based implementation available at http://hans.math.upenn.edu/~subhrabh/nowiki/robot_arm_JS-HTML5/arm.html.

MSC: 70B15 Kinematics of mechanisms and robots

Keywords: configuration space; classification; differential topology; Morse theory; robot arm; inverse kinematics; planning

Software: robot_ar; JavaScript; OpenGL

Full Text: DOI arXiv

References:


[18] Liu, G.; Trinkle, J.; Milgram, R.J., Complete path planning for a planar 2-r manipulator with point obstacles, No. 4, 3263-3269 (2004)


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