

A Dynamic Control Method based on a Stability on a Manifold for a Family of Redundant Robots and Under-actuated Robots

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In order to judge whether an input signal that controls a robot and is called "a control law" is adequate, it is necessary to analyze behaviors of solutions of the closed-loop dynamics that are obtained by substituting the control law into dynamics of the robot. Most of roboticists have tried to find a control method that is free from the practical scale of physical parameters of robots such as mass, inertia moment, link length and so on. Traditionally, they tried to use the same method for a big robot arm with meters of the total length and a small finger robot with its link lengths of centimeters. In spite of their expectation to find a universal and all-purpose control method, robots have failed to demonstrate the best performance corresponding to each purpose.

This research aims to adopt a new methodology called "stability on a manifold" and apply for a special class of robots. The method explores behaviors of convergence of solutions of the closed-loop dynamics to the equilibrium-point manifold while carefully examining the scale of physical parameters of robots. The adequateness of the control law is analyzed not only mathematically but physically, which has been demonstrated in case of pinching and posture control in finger robots. In this research, the method is applied for another class of robot tasks imposed to robots with joint redundancy or passive joints. This has been regarded as being considerably difficult and therefore remains unsolved so far.

This paper treats, for the purpose of practical uses, a redundant manipulator that mimics human handwriting and an under-actuated robot that can create various types of gymnastic movements on a horizontal bar (intrinsically unstable). As to the redundant robot, a simple control law for robotic handwriting tasks is proposed, which does not introduce artificial cost functions or calculate pseudo-inverse of the Jacobian. This proposed method enables it to handwrite naturally without solving the redundancy problem even if the number of Degree-Of-Freedom (DOF) of the robot dynamics exceeds the dimension in task description space and thereby inverse kinematics becomes ill-posed, which makes it difficult to determine joint motions in executing given tasks. As to the under-actuated gymnastics robot, a control law to realize dynamically the balance and posture control of the robot is proposed, regardless of that the ankle joint does not have any actuator and therefore may fall down easily. The effectiveness of each control method is demonstrated through computer simulations of each closed-loop dynamics. Experimental studies by using the robots constructed in the laboratory demonstrate robustness of the proposed control methods through exhibiting dexterous movements of handwriting in the former case and globally stable movements in the latter case.