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（要　旨）
(Summary)

Robotic arms with redundant degrees of freedom are known to exhibit characteristics that make them more desirable than their non-redundant counterparts in many manipulation tasks. Indeed, the provision of redundant degrees of freedom allows them to achieve additional tasks such as singularity and obstacle avoidance all without disturbing the end-effector task. Besides having more complex kinematics and dynamics, hyper-redundant arms also have complex tasks specification. A wider adoption of hyper-redundancy could be achieved if simpler task specifications were available. In this thesis, an intuitive task specification for hyper-redundant robotic arms using 3D spline posture curves and a control framework specialized for it are proposed. Most redundancy resolution schemes applied to manipulation tasks found in the literature are concerned with end-effector placement and leave the posture of the arm as by-product of the fulfillment of some other constraint equations or as the outcome of the optimization of some objective function. However, as the degree of redundancy increases, the importance of the arm posture over the end-effector pose becomes more prominent. This is because tasks leverage redundancy by having the arm adopt a certain posture. Therefore, the posture of the arm is the primary focus of this work and its explicit and direct control is studied. In summary, the goal of this work is to devise a posture control framework capable of tracking user-specified arbitrary posture target curves while being operable in and around singular postures. The requirement of operability around singular postures stems from the fact that user-specified arbitrary posture target curves can lead the arm into singular postures. The overall strategy to posture control is to select points along the arm which are termed posture control points and move them in such way to conform the posture of the arm to a user-defined posture target curve. The arm is segmented into identical modules and posture control points are considered at the boundaries of these modules. The target position of each of these posture control points on the user-specified posture target curve is found by an algorithm that uses the continuous target curve along with the module’s kinematics in order to iteratively find each target position along the curve. The posture target positions constitute the target posture to be achieved. Attempting to move simultaneously all posture control points to their corresponding posture target positions would lead to algorithmic singularities, therefore a scheme for selecting a subset of posture control points that can be moved at any given time is necessary. The Jacobian matrix at each control point is simply stacked into a large posture control matrix and it is

found that this matrix is rank deficient whenever one of two conditions are not observed. The first condition termed absolute manipulability condition stipulates that the Jacobian matrix at the first posture control point must have a high manipulability. The second condition named relative manipulability condition says that the Jacobian matrix of any arm section between two adjacent posture control points must have a high manipulability. Thus, a search algorithm is used to determine all sets of possible posture control points which fulfill the above two conditions. These sets are named candidate control sets and each set is assigned a score. At each iteration time, the candidate control set with the highest score (termed active control set) is selected and the posture control matrix is built with its member posture control points. The score of candidate control sets can be set to prioritize the set which produces the posture control matrix with the highest manipulability or the set that corresponds to the highest posture error. The constructed posture control matrix is then guaranteed high manipulability and the inverse kinematics is solved through the standard pseudo-inverse method. Care is taken in the formulation to also ensure the error minimization of posture control points which are not present in the active control set. This leads to a posture control that selects control points in order to safely move towards to any target posture. However, if the target posture is singular, this method tends to produce higher residual posture errors and will get stranded at singular postures. An alternate formulation which mitigates these issues is proposed. In this formulation, a space termed manipulability space is formed from a subset of the left singular vectors of the Jacobian matrix at each posture control point. The manipulability space captures the subspace of achievable task space velocities. The dimension of the manipulability space changes depending on the proximity to singularities. The desired task space velocities are projected onto to manipulability space to produce feasible task space velocities and the posture control matrix is rewritten to pursue the feasible velocities instead of desired velocities. The result is more posture control points being used at each iteration reducing residual errors, and also the ability for the control to depart from a singular posture. Numerical simulations on a 40-DOF spatial arm and 45-DOF planar arm are conducted to assess the validity and performance of the methods. Both methods were successful in tracking arbitrary target postures and typical singular postures. The manipulability space projection method produces unpredictable intermediate postures and is meant for use only when the primary method fails to achieve low posture error convergence. The proposed method has demonstrated the ability to safely steer the arm towards intermediate postures which reduce the overall posture tracking error. It copes well with singularities and is capable of tracking target postures that are significantly distinct from the arm’s initial posture.