

Human Arm Redundancy and its Application in Wearable Robots

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Abstract

In this paper, an inverse kinematics solution resolving the redundancy of the wearable robotic system is studied to guarantee a seamless integration with the natural human arm movement. According to the 7 Degrees of Freedom (DOF) human arm model composed of the shoulder, elbow, wrist joints, positioning of the wrist in space and orientating the palm is a task requiring 6 DOF. Due to this redundancy of the human arm, multiple arm configurations are possible to complete a given task and they are expressed mathematically by none unique solution for the inverse kinematics. The unique solution can be achieved by adding more constraint such as minimum energy. Resolving this redundancy is becoming critical as the human interacts with a wearable robotic system (exoskeleton) which includes the same redundancy as the human arm. The redundancy of the arm and formulated kinematically by defining the swivel angle - the rotation angle of the plane including the upper and lower arm around a virtual axis connecting the shoulder and wrist joints which are fixed in space. To estimate swivel angle, two different swivel angles are generated based on kinematic and dynamic constraints. Then they are combined with different weight for more accurate estimation. As a kinematic constraint, biological constraint explaining the unconstrained human arm movement based on manipulability concept is applied while for a dynamic constraint well known minimum amount of work constraint is adopted. Experimental results based on the motion capture system indicated that by using the proposed redundancy resolution criteria the error between the predicted swivel angle and the actual swivel angle adopted by the motor control system is less than 5 Deg. This outperformed the estimation based on a single criteria by exploiting synergistic relationship between an operator and a wearable robotic system.