Modelling

AS-0221

MODELING COORDINATED JOINT RANGE OF MOTION OF THE HUMAN HAND -- CHARACTERISTICS OF COORDINATION AND GRASPING IN RELATION TO THE ROM BOUNDARY --

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Introduction and Objectives: For deeper understanding of the human hand function, joint range of motion (ROM) should be measured and described precisely. Traditionally, ROM of the hand was defined by independently bounding each joint angle from observation of extreme posture. However, it is difficult to express actual human's complex ROM with such simple boundaries because human hand has multiple joints that move in coordination. Therefore, we have developed a new method to model ROM of the hand by defining outer boundary of collected various posture data through motion capturing.

Objective of this study is to find characteristics of the coordinated motion of the human hand by measuring and comparing several subjects ROM. In addition, grasping postures are analyzed in terms of location in ROM, which can be utilized to plan rehabilitation with quantitative goal.

Methods: The human hand is a multidimensional system that consists of many joints and its posture is expressed with multiple variables. It is difficult to directly deal with all the couplings among the joints at the same time. We therefore proposed a model of the range of motion of the whole hand as a set of all the relationships between two of the posture variables[1]. Each relationship between two of the joint angles was presented as a united area in which all the projected measured postures on the plane were minimally bounded using the alpha-shape algorithm. We call this smallest unit a coupled ROM. As can be seen in the examples in the Figure, each derived boundary occupies smaller area than a rectangle corresponding to the traditional ROM.

On motion measurement, we gave subjects the same set of 21 exercises selected to include various joint postures both in the middle and on the boundary. This was because our precedent observation showed the difficulty for the subjects to move widely across their ROM when instructed to “move arbitrarily.” Furthermore, it was necessary to evenly spread the variety of motions among the subjects as much as possible for proper comparison.

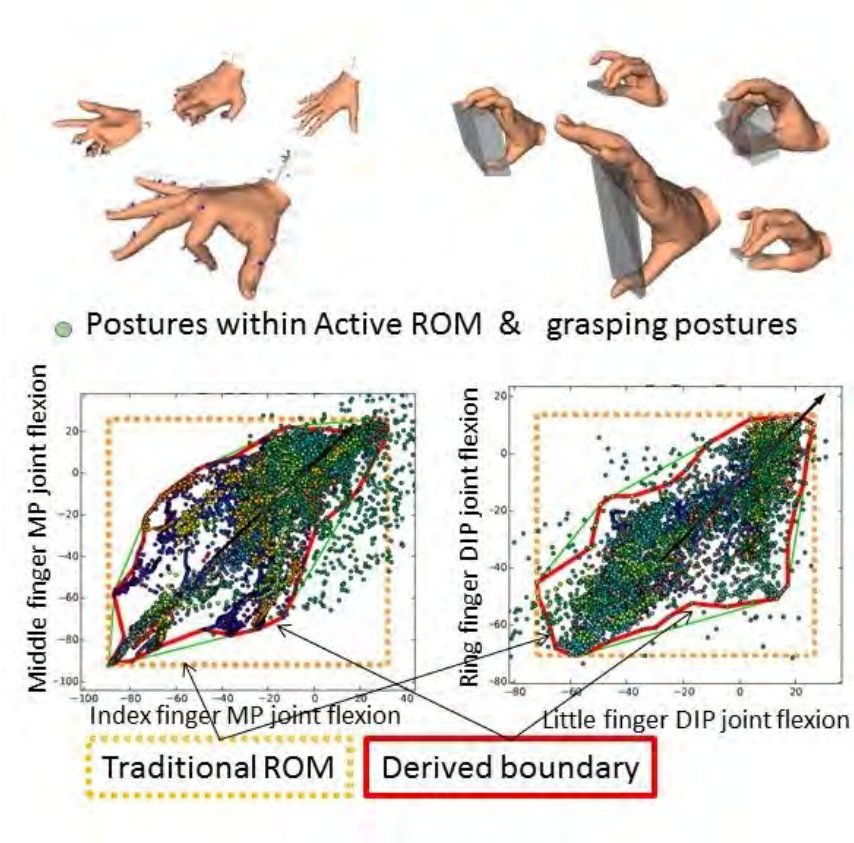
These exercises to model ROM are all unloaded motion. Such ROM can be called “active” ROM. The ROM would be slightly expanded when an external force is applied as in grasping. To analyze such grasping posture with our active ROM, we additionally collected 801 grasping postures. We determined grasping postures by adding variations to grasp taxonomy proposed by Feix [2] which considers contact regions when grasping.

Results: Measurement and modeling experiments on four subjects were conducted to analyze characteristics of the coordinated motion. To study the coordination of the joints of the hand, we ranked the coulpled ROMs for each subject by the index “Coord” defined in [1], which can be calculated considering the area reduction rate compared with traditional rectangle ROM and coefficient of determination. The comparison showed that strong coordination were observed similarly

for all the subjects in (1) the adjacent metacarpophalangeal (MP) joints and (2)proximal and distal phalangeal joints of the same fingers.

As for the grasping postures, some of the postures were located outside the active ROM as expected. In addition, our results showed that MP joints were largely extended when grasping (in the left graph of Figure).

Figure:



Caption: Two examples of the modeled active ROM with grasping postures. Some of the grasping postures were observed to lie outside the active ROM boundary.

Conclusion: This study analyzed the coordinated human hand motion by comparing active range of motion that modeled by appropriately deriving boundary from a variety of measured postures. Comparison based on the coordination index showed that the coordination categories were similar among subjects. Plotting of the grasping postures with the active ROM clearly showed the deviation of passive ROM difference from active one.

References: [1]N. Miyata, et al., "A Measuring and Analysis Method of Coupled Range of Motion of the Human Hands", Proceedings of the 2013 IEEE Int. Conf. on Systems, Man, and Cybernetics, pp.2623--2628, 2013.

[2] T. Feix, et al. “A comprehensive grasp taxonomy,” in Robotics, Science and Systems Conference: Workshop on Understand the Human Hand for advanced Robotic Manipulation, 2009.

Disclosure of Interest: None Declared