Tracking hand-object interaction: towards a database for human grasping and manipulation

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Background

Extensive effort has been devoted on tracking finger joint kinematics to quantify the high dimensional space of the human hand during grasping and manipulation However, the kinematics of the hand is only one component of grasping tasks. The other important component of grasping is the object that is being interacted with. Surprisingly, the systematic identification of object graspable features has been largely overlooked in the investigation of human grasping. Although the concept of grasping affordance has been studied for many years, there have been lack of quantitative analysis using kinematic data of hand-object interactions. This has prevented further understanding of how object properties are represented and how grasping is planned in the central nervous system. These gaps stem from lack of efficient measurement of (a) where the object is grasped and (b) what parts of the hand make contact with the object. The present work proposes a framework that could bridge these gaps and advance our understanding of human grasp planning and control.

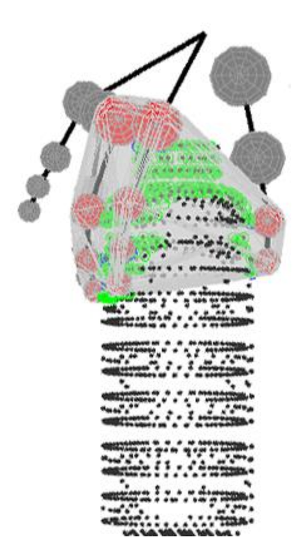
Preliminary Setup

Hand tracking

- 4 markers on wrist bracelet
- 4 markers on the dorsal surface of MCP, PIP, DIP joints and nail of each finger (4 x 4)
- 4 markers on the dorsal surface of the TM, MCP, and IP joints and nail of the thumb

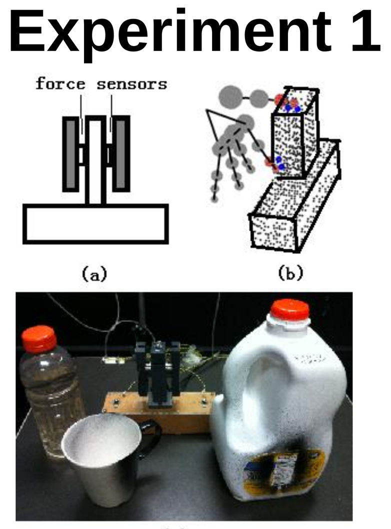
Interaction tracking

- Modeling the object
  Point cloud P_i
  CAD model + marker tracking
  $P_i(t) = R(t)\,p_i + P(t)$
- Modeling of the hand
  Spheres @ joints & tips
- Contact detection
  Collision detection

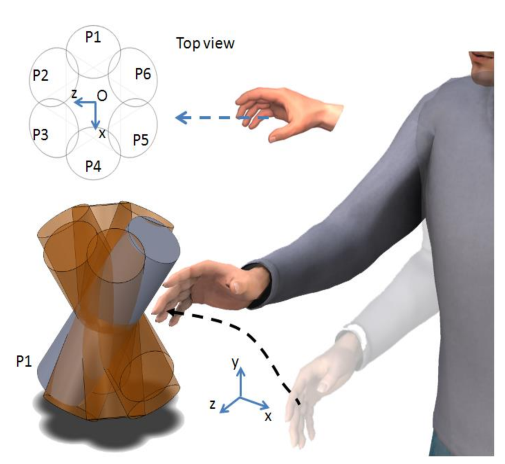


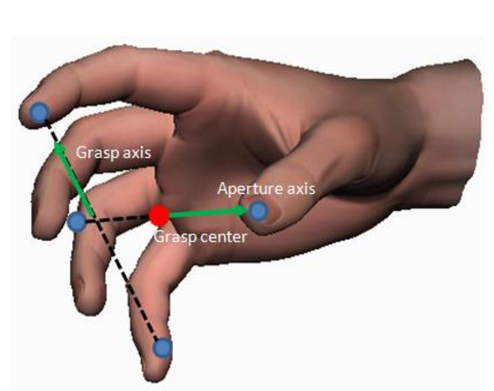
- Hand enclosing space
  Joints in contact
  Convex Hull
- Graspable features
  Points enclosed

Experiment 1



Experiment 2





[1]Fu Q, Santello M. (2011), Proc of EMBC,.pp 6893-6896, Osaka, Japan
[2]Fu Q, Santello M (2013). Proc of EMBC,, pp 8247-8250, Boston, USA.
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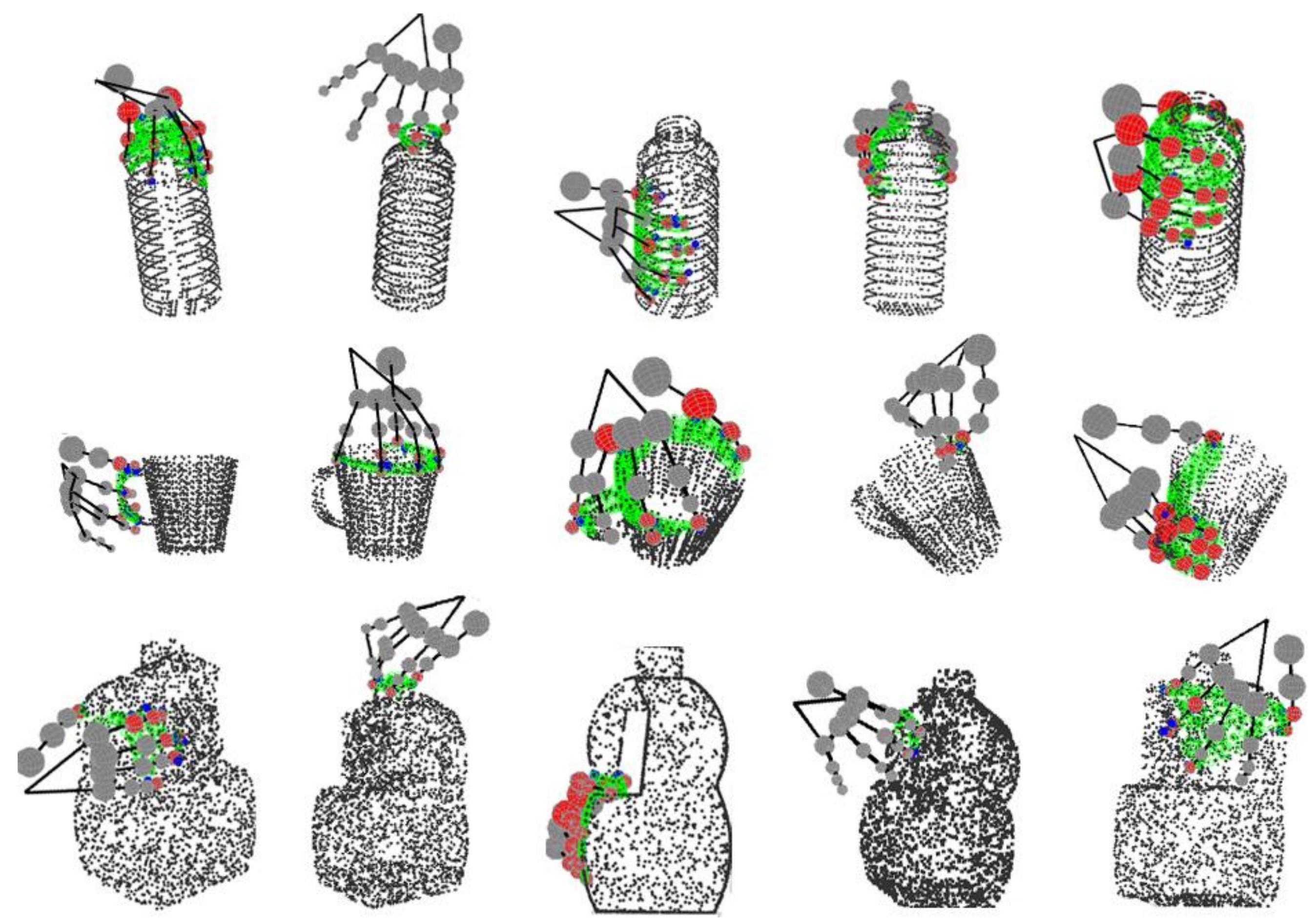
Preliminary results

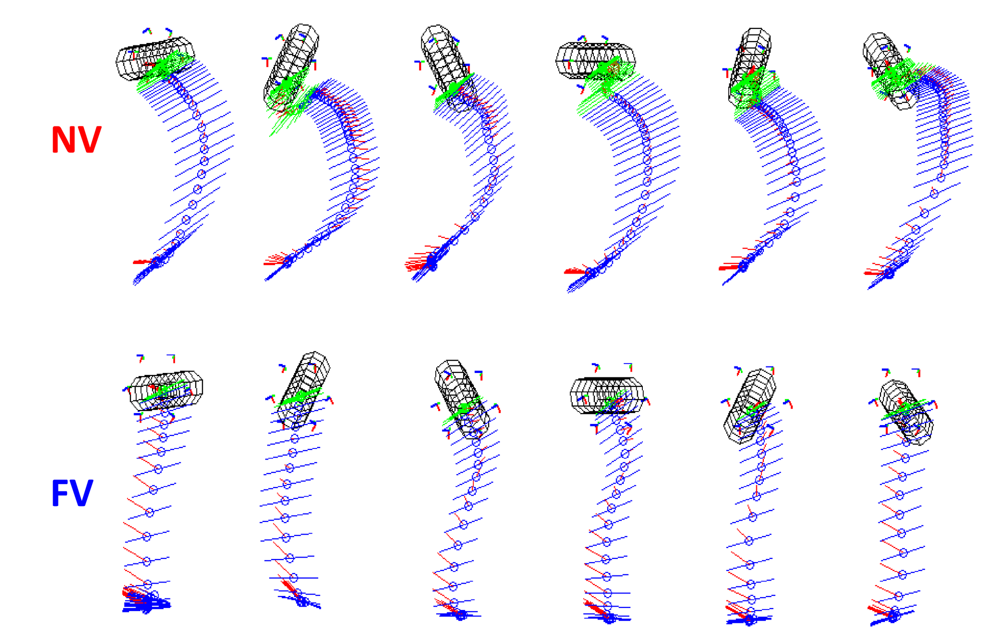
Experiment 1

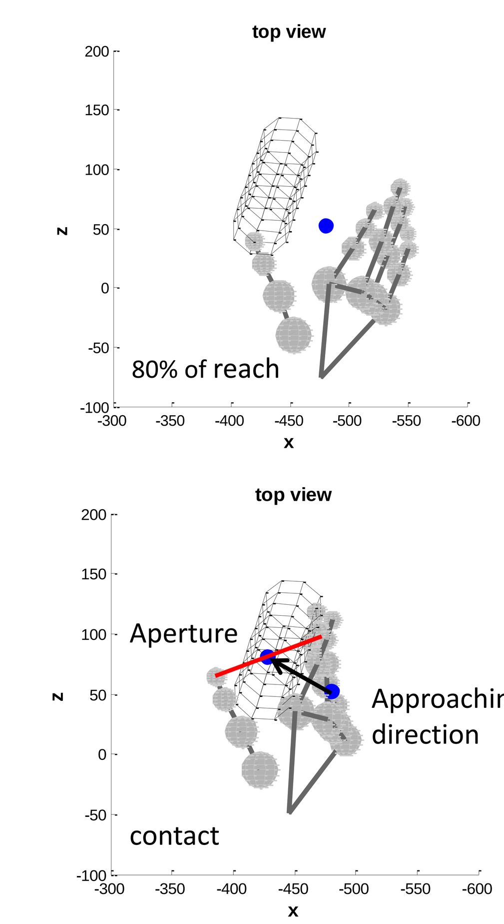
- Geometric cues, together with familiarity with the object's intended use and properties, can significantly constrain the way humans grasp objects.



Experiment 2

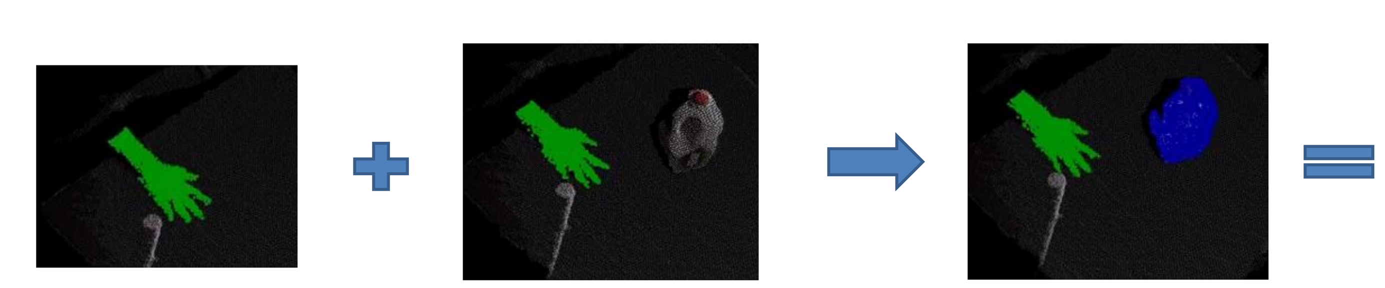
- Subjects did not try to minimize post contact adjustment but rather maximized the probability of initial contact within grasp aperture.
- Reaching movement was adjusted to compensate sensorimotor noise for more efficient sensing of actual object orientation.





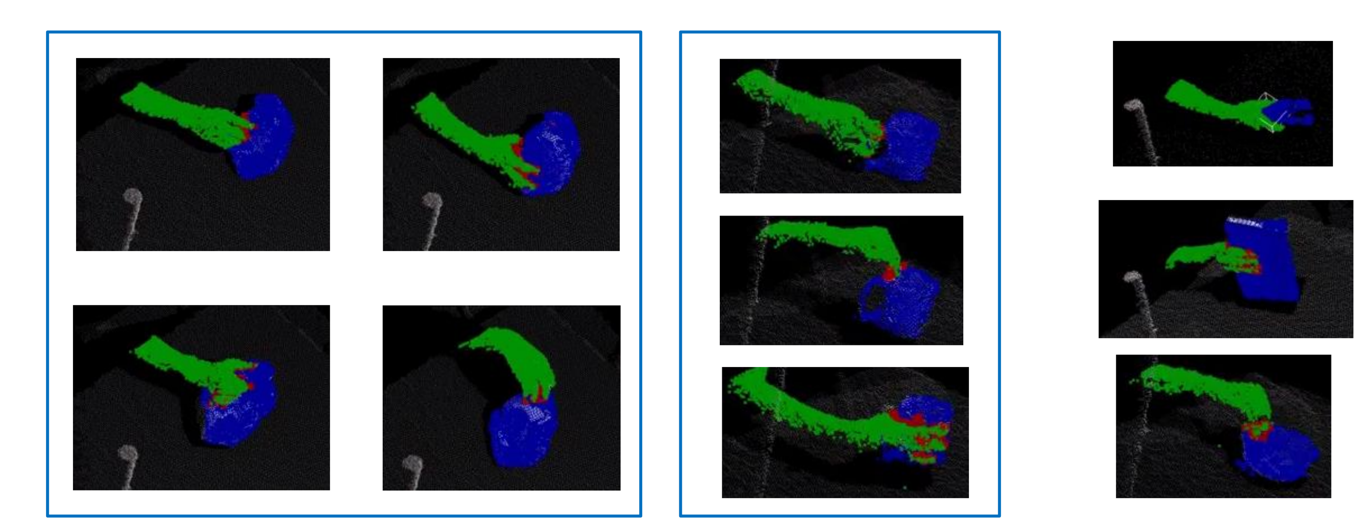
Work in Progress

Objective: Using Kinect to simplify experimental setup for enabling collection of hand-object interactions across a large set of objects/activities in real time.



Hand tracking
Skin color blob

Object tracking: particle filter
Interaction estimation: octree collision



Future work

In robotics, there have been attempts to quantify the mapping between cues derived from perception of object features and the interaction between robotic hands and objects. The robots can use data generated from human as a training set to learn how and where to grasp objects. This can be attained through two main methods: one is to track position and orientation of the human hand as a demonstration for the robots, but without considering the geometry of the object; the other is to label graspable features heuristically, such as grasping points and graspable parts, but the hand posture is generated computationally. Additionally, the knowledge of human hand-object interactions would help generate more robust and human-like grasps for robots. Therefore, a better understanding of where humans make contact with the object in common scenarios could potentially advance grasp planning for robots. Furthermore, we propose that our tracking framework would provide a database of human grasps that could be used as benchmark and/or training data for robotic grasping, in similar fashion as computationally generated grasp databases.

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