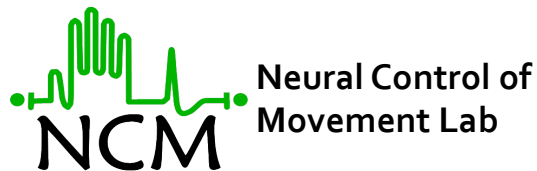


Towards a complete description of grasping kinematics: a framework for quantifying human grasping and manipulation.

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Outline

- Background
 - Human grasping
- New perspective
 - Hand-object interaction
- Approaches
 - Tracking hand kinematics
 - Tracking hand-object interaction
- Experimental validation
- Future directions

Human grasping

- Hand is complex
- What we know:
 - Control of movement/force
 - Dimensionality reduction[Santello et al., 1998]
 - Tactile feedback[Johansson and Flanagan, 2009]
- What is not quite clear...
 - Planning (cognitive aspect)
 - In relation to target object/task.
 - Prior knowledge? Grasping affordance?[Fagg and Arbib, 1998]

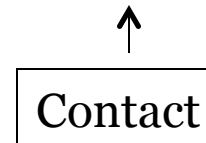
New perspective

■ Gap

- Interaction between hand and object is important
- Quantitative behavioral research focuses more on the hand than the object

■ Key – new methodology

- Record hand, object, and the interaction between them



New perspective

■ Our approach

- Marker tracking + collision model
 - Maximize spatial accuracy

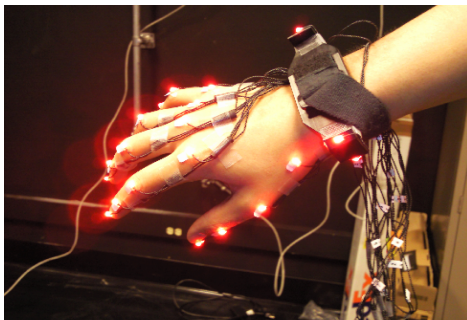
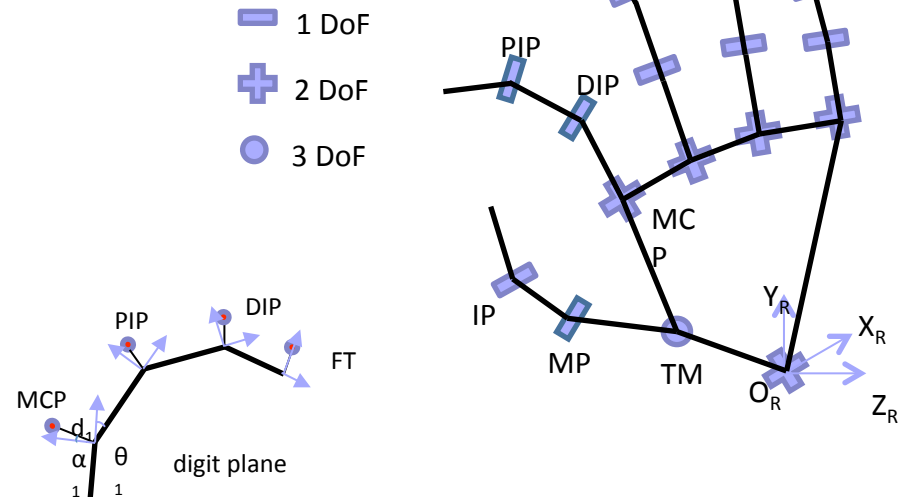
■ Related work

- Computer Vision
 - Gesture recognition^[Romero et al., 2010]
 - Model based, with collision model^[Oikonomidis et al., 2011]
- Marker tracking
 - Bimanual manipulation^[Charusta et al., 2009]

Hand tracking

■ Setup [Fu and Santello, 2010]

- Articulations of rigid links.
- 21 DoF on joints of five digits
- 2 DoF on wrist joint
- 6 DoF on hand root posture

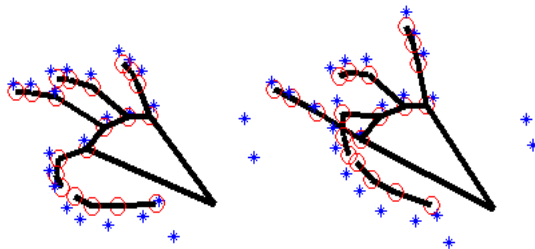


- 4 markers on wrist bracelet
- 4 markers on the dorsal surface of MCP, PIP, DIP joints and nail of each finger (4 x 4)
- 4 markers on the dorsal surface of the TM, MCP, and IP joints and nail of the thumb

120Hz

Hand tracking

Results

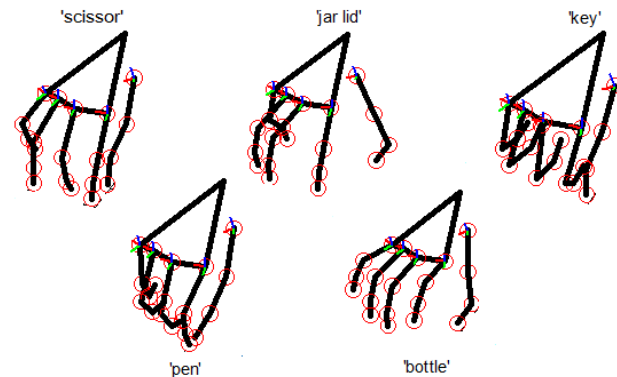


Spatial error of tip to tip contact (mm)

Finger in contact	Subject 1	Subject 2	Subject 3
index	1.9±0.2	2.0±0.1	2.3±0.1
middle	2.1±0.1	1.8±0.2	2.0±0.1
ring	3.6±0.1	3.5±0.2	2.9±0.3
little	4.2±0.2	3.8±0.3	3.5±0.2

Tracking hand kinematics using
Extended Kalman Filter

Neural Control of Movement Lab
Arizona State University



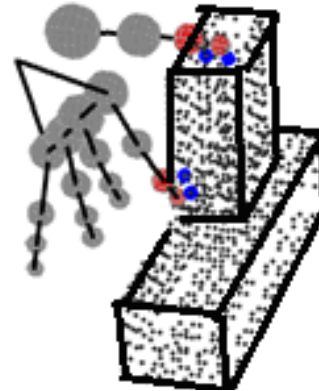
Tracking hand-object interaction

- Contact detection


- Collision detection

- 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 $J_k r_k$
- Other options
 - Cylinder  links
 - Mesh

$$C_j \in \{P_i\}$$

$$\text{minimize } D_{ik} = || C_j - J_k || < r_k + h$$

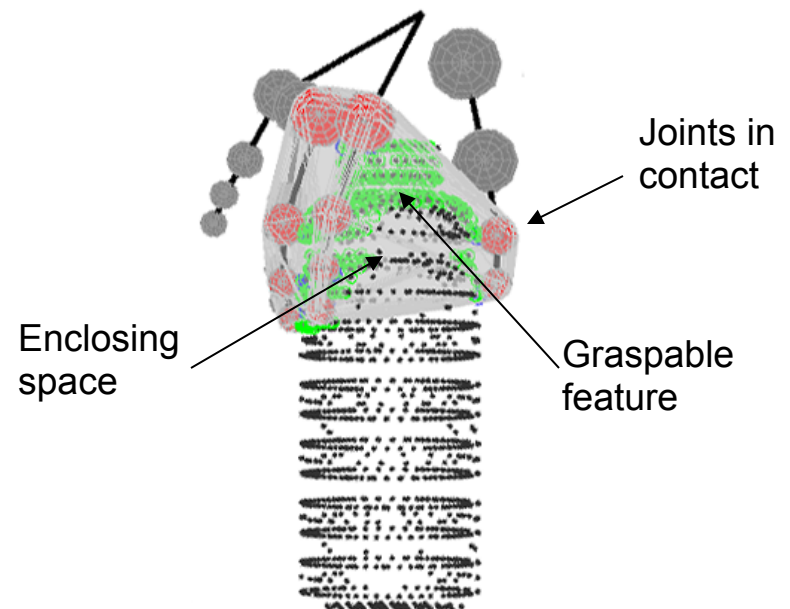
Tracking hand-object interaction

- Hand enclosing space

- Joints in contact
- Convex hull

- Graspable features

- Points enclosed

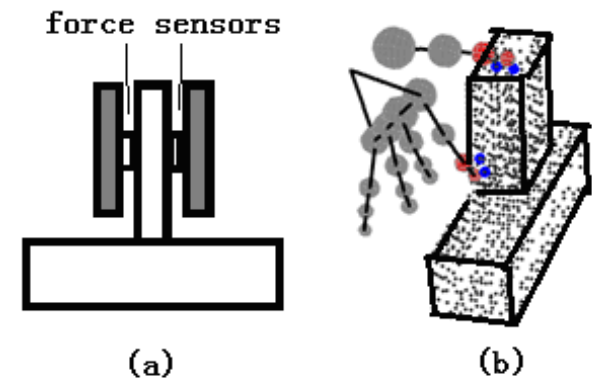


Tracking hand-object interaction

■ Setup

- Validate the estimation of point of contact by measuring center of pressure.

- Preliminary test on detection of graspable features
 - Five self-selected grasps



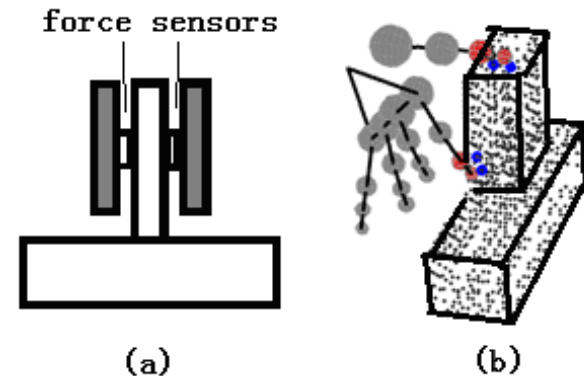
(c)

Tracking hand-object interaction

■ Validation of contact estimation

ERRORS OF CONTACT SITE ESTIMATION (MM)

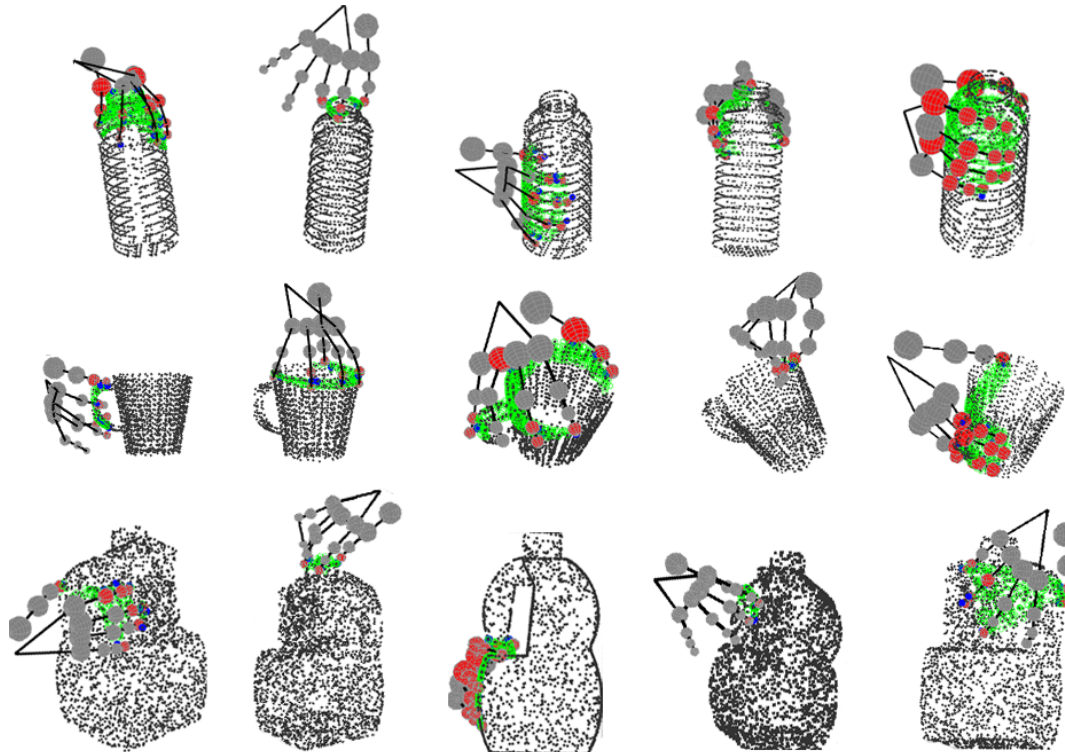
Finger in contact	Subject 1	Subject 2	Subject 3
Thumb/Index	3.9/4.5	2.3/3.2	4.1/4.3
Thumb/Middle	2.1/3.7	3.5/4.2	4.2/2.6
Thumb/Ring	3.6/4.4	3.3/4.1	3.4/2.3
Thumb/Little	3.2/4.9	4.4/3.8	5.0/4.8



Tracking hand-object interaction

- Graspable features

- Subjects tend to choose similar features



Hand-object interaction

- Next step:
 - Graspable geometry (Affordance)
 - Approaching angle
 - Grasp axis
 - Manipulation (finger movement)

Discussion

■ Contribution

- Using collision detection as key to gain insight into hand-object interaction
- Enable quantitative study of how grasp is planned and executed according to object geometry / task.

■ Potential application

- Object representation for manipulation
- Evaluation of human grasping
- Database of human grasping

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Neural Control of
Movement Lab



National
Institutes
of Health



Thanks

