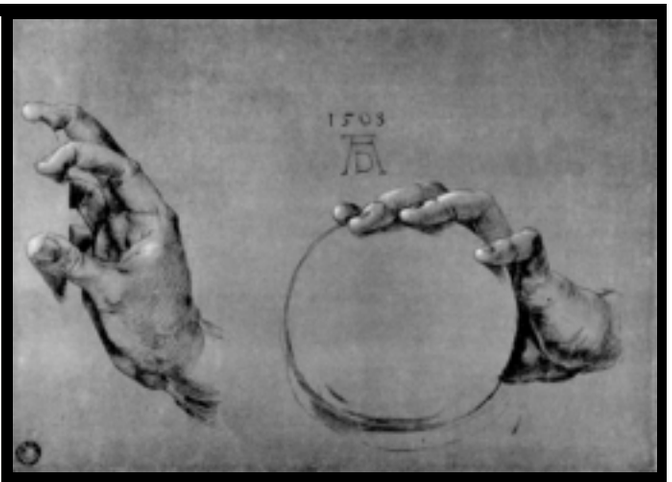
Animating Hands

15-869 September 29, 2015

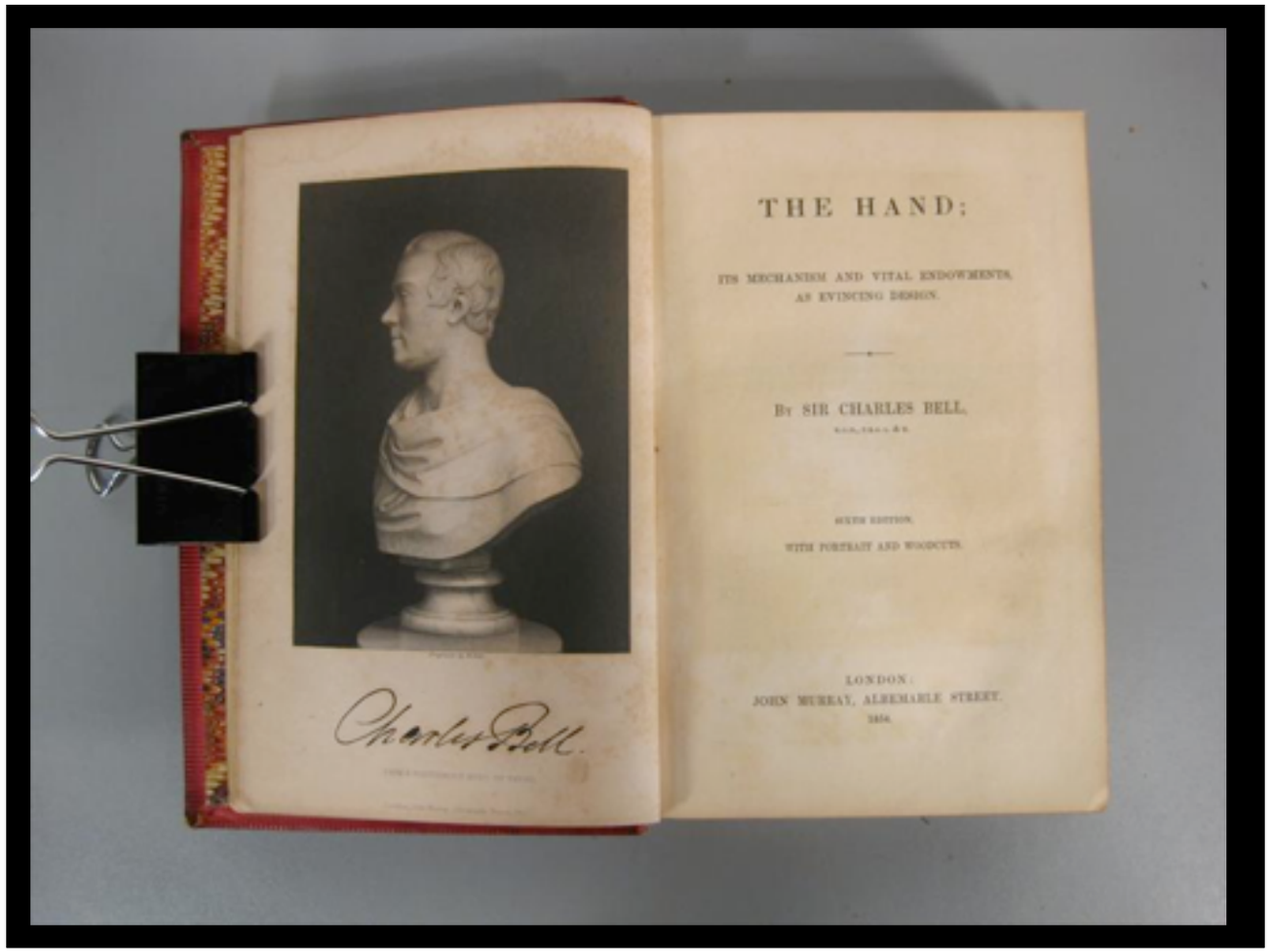
Nancy Pollard

Leonardo Da Vinci (1452-1519)

Hands have been a source of inspiration and study for centuries.

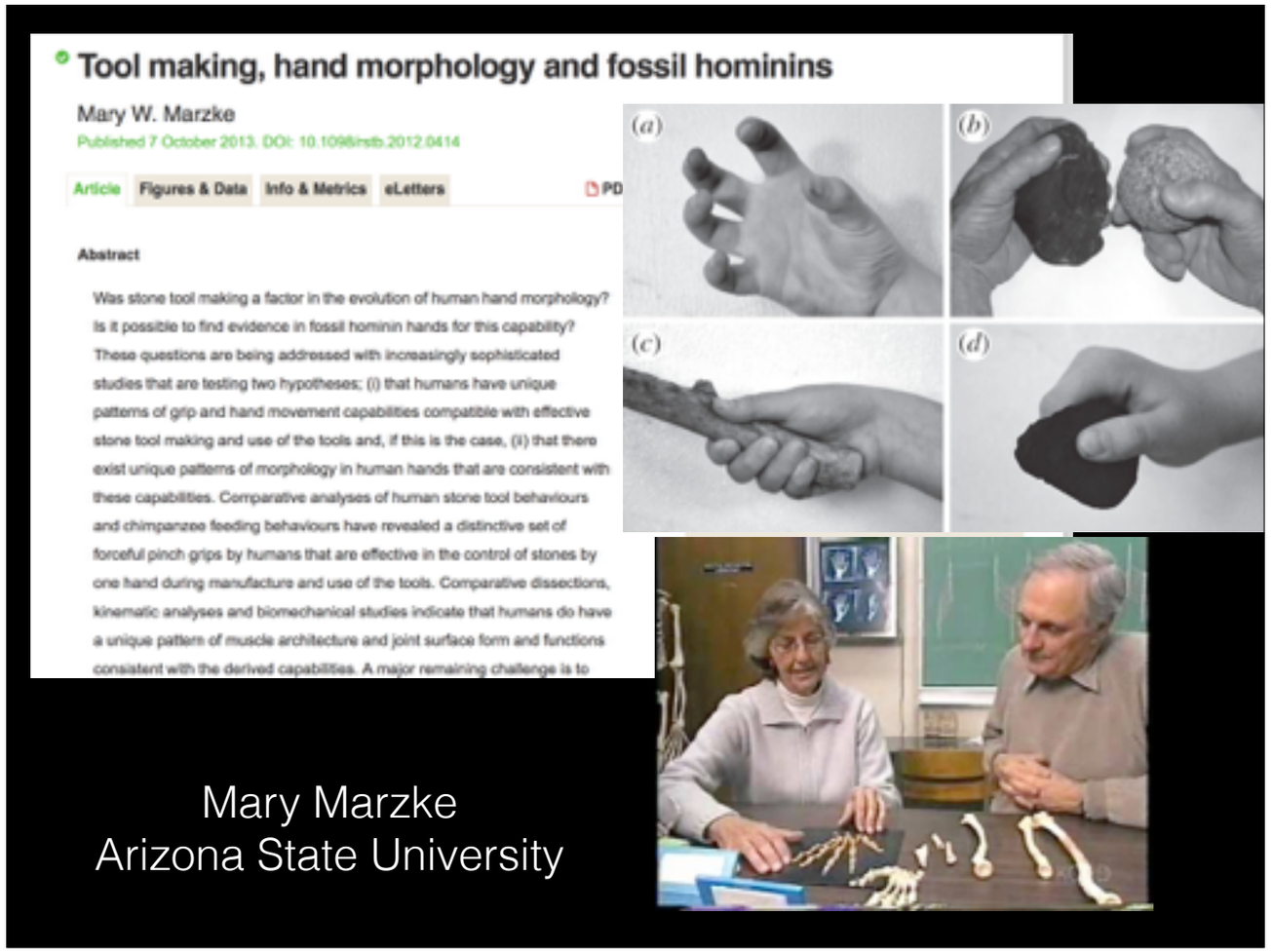


Albrecht Dürer (1471-1528)



Below is a nice description of this book taken from the Cambridge University Press web page. The book has been recently republished in paperback. I also have a pdf file if anyone is interested to take a look.

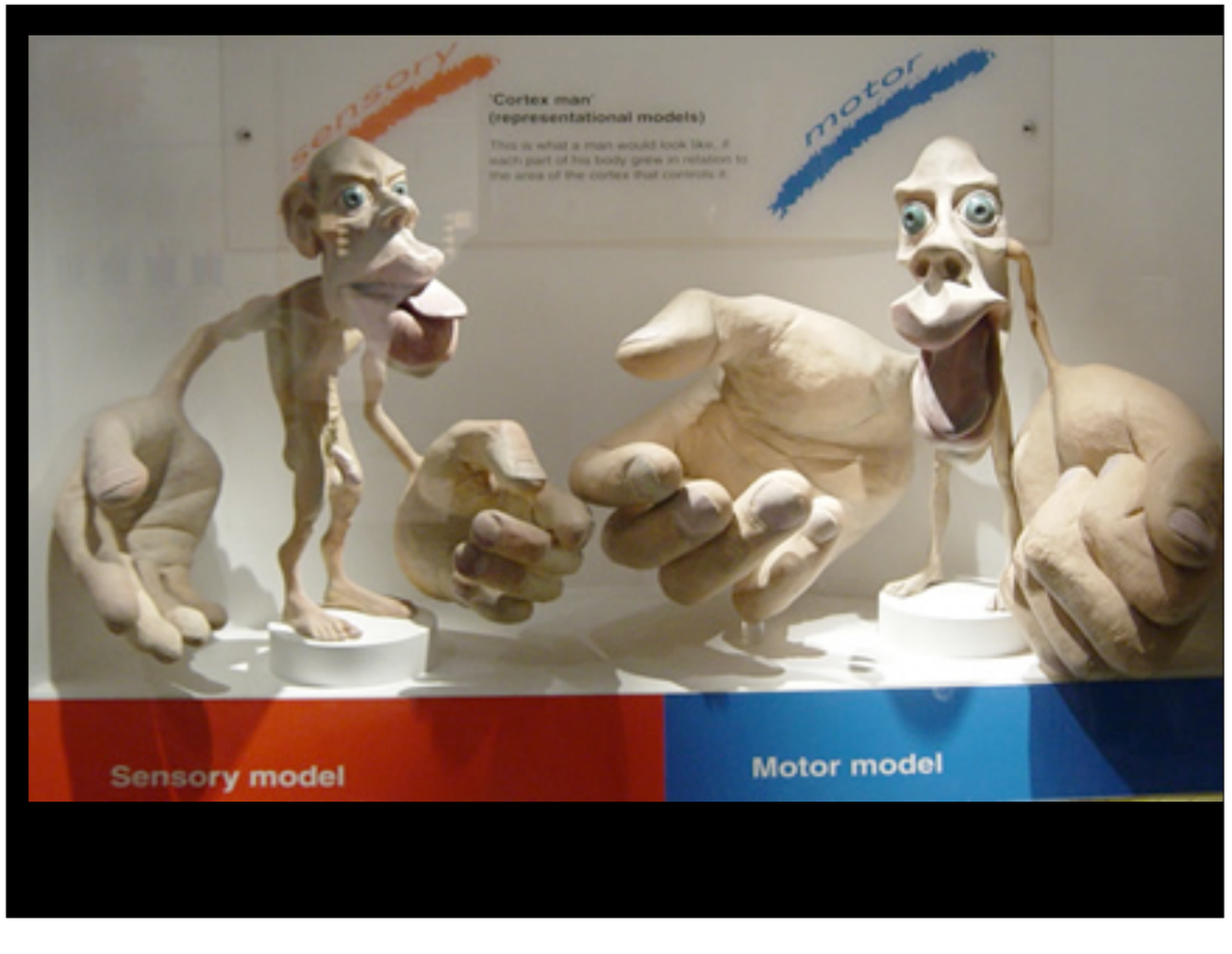
This 1833 study of the hand by Sir Charles Bell, a leading professor of surgery and anatomy, is one of the Bridgewater Treatises, which arose from the preoccupation of nineteenth-century Christians with interpreting God's creation in the light of contemporary scientific developments. Bell's treatise suggests that by looking in close detail at small subjects, God's role in creation can be clearly seen, whereas more general studies of the universe and the great natural cycles of astronomy and geology can obscure the intelligence behind their specific features. Bell stresses the importance of the hand in human history, the progress of society and the development of technology and design. He considers aspects of the mechanical systems of other animals, and sees their structure as a product of their function. This comparison serves to link humans with other creatures, but also defines their superiority through the sublimity of design.



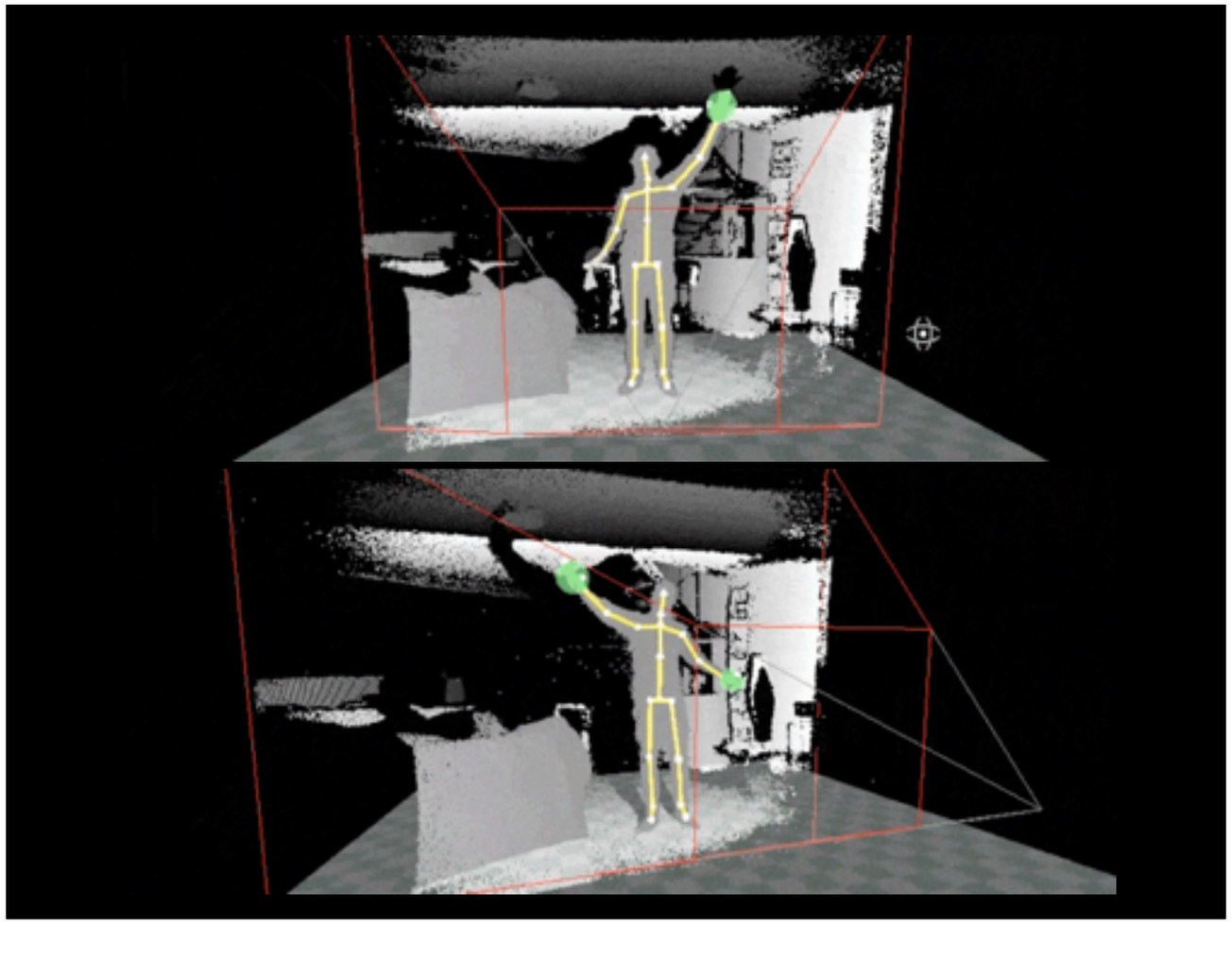
Speaking of evolution… Mary Marzke's lifetime research has been very influential in considering how the hand may have evolved for tool use and production.

- It is genuinely startling to read Bell's Hand now, because its singular message--that no serious account of human life can ignore the central importance of the human hand--remains as trenchant as when it was first published. This message deserves vigorous renewal as an admonition to cognitive science. Indeed, I would go further: I would argue that any theory of human intelligence which ignores the interdependence of hand and brain function, the historic origins of that relationship, or the impact of that history on developmental dynamics in modern humans, is grossly misleading and sterile.

The hand in the popular press, and speculation as to the link between our hands and our intelligence.



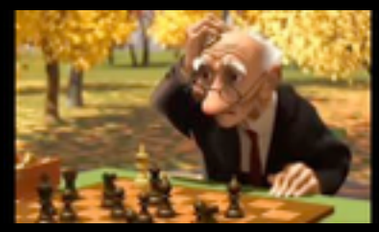
Everyone knows the homunculus indicating space devoted to sensing in the brain (the left statue). The right side shows the equivalent depiction of space devoted to control. The hands stand out dramatically in either case.

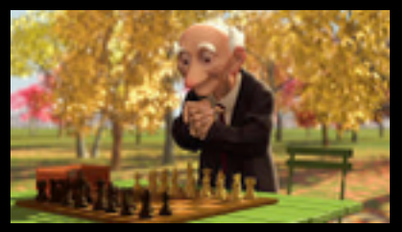


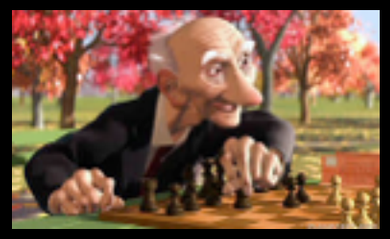
… despite their small size in real life and in these images from a Kinect.

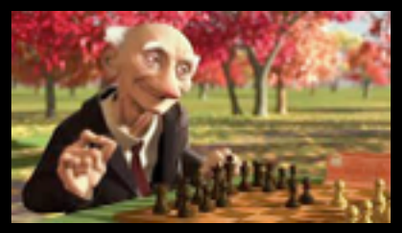
Note the importance of the hands in our impressions of the scene as well. They could be considered actors in their own right.

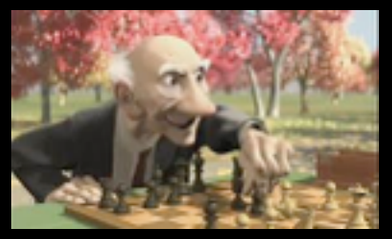
The Hand as Actor











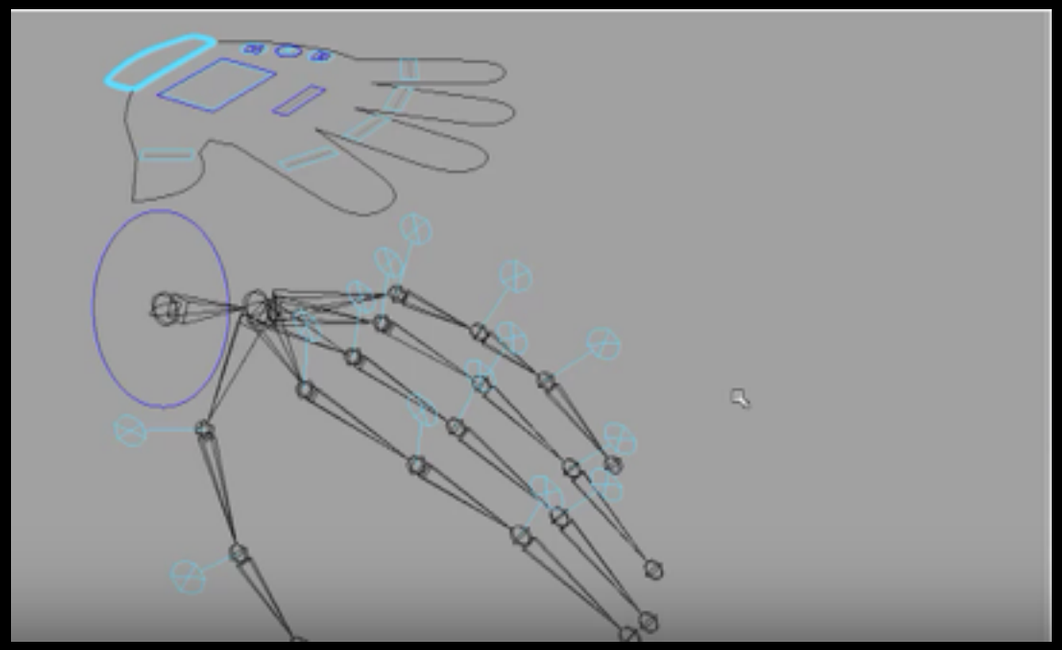
So.. let’s start with the hand as actor.

The Hand as Actor

- Rigging and Posing
- Direct Control
- Capture

We will look briefly at techniques for keyframing, directly controlling, and capturing motion of the hand.

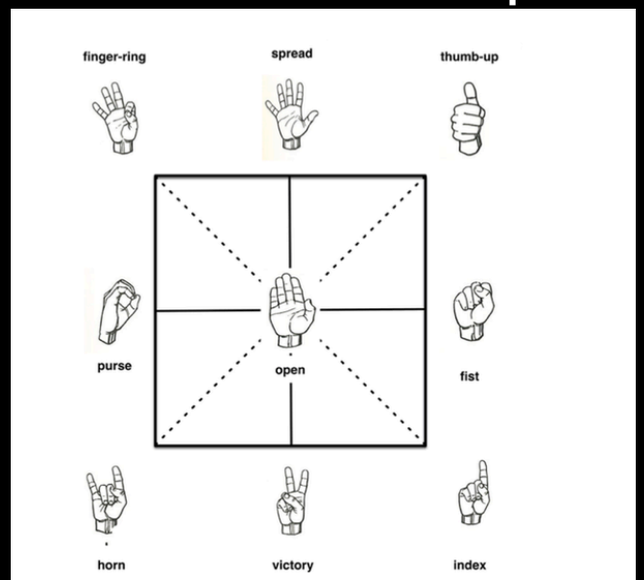
Rigging and Posing



https://youtu.be/ipeTlzIbQT4

When building a simple rig for the hand, animators often focus on finger curl and finger spread. I think this matches our standard mental model of what the hand typically does. Interestingly (or maybe it is not that surprising), if we do PCA analysis on hand motions, the first couple of components look a lot like bend and spread.

Blend Shapes



Multitouch Puppetry:
Creating Coordinated 3D Motion for an Articulated Arm

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Germany
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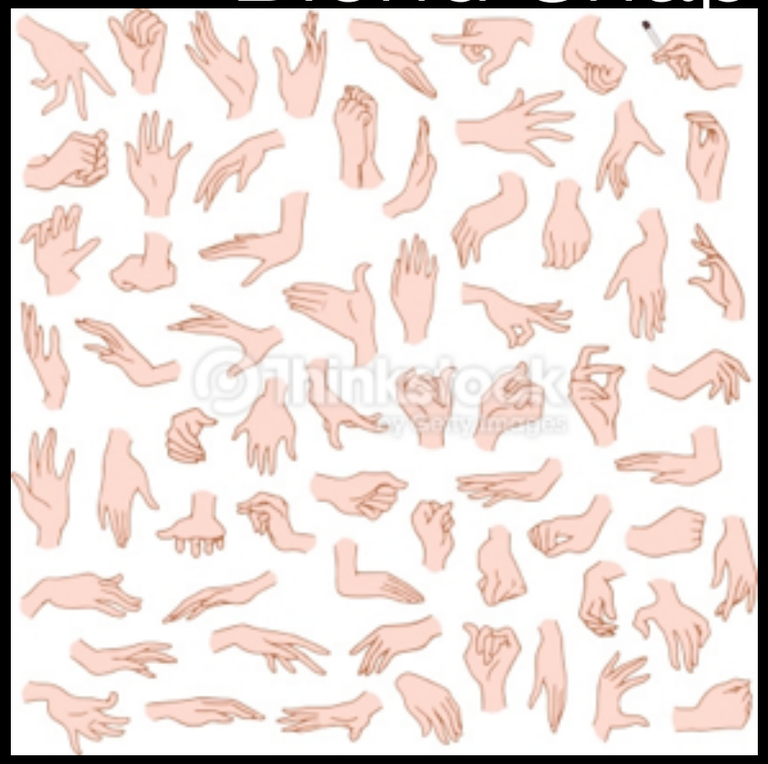
However, the hand does take on other shapes as well. A few researchers have approached this difficulty by considering that we may want to blend between a variety of common (and less common) shapes.

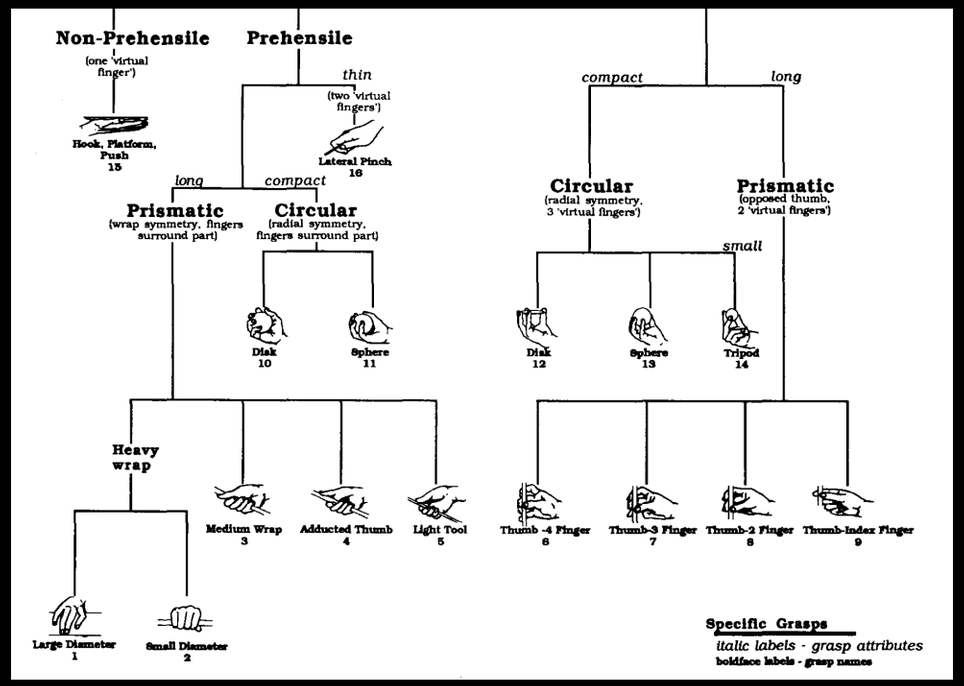
Blend Shapes?



from ThinkStock

Maybe, however, there are quite a lot of shapes that may need to be considered in such an approach.

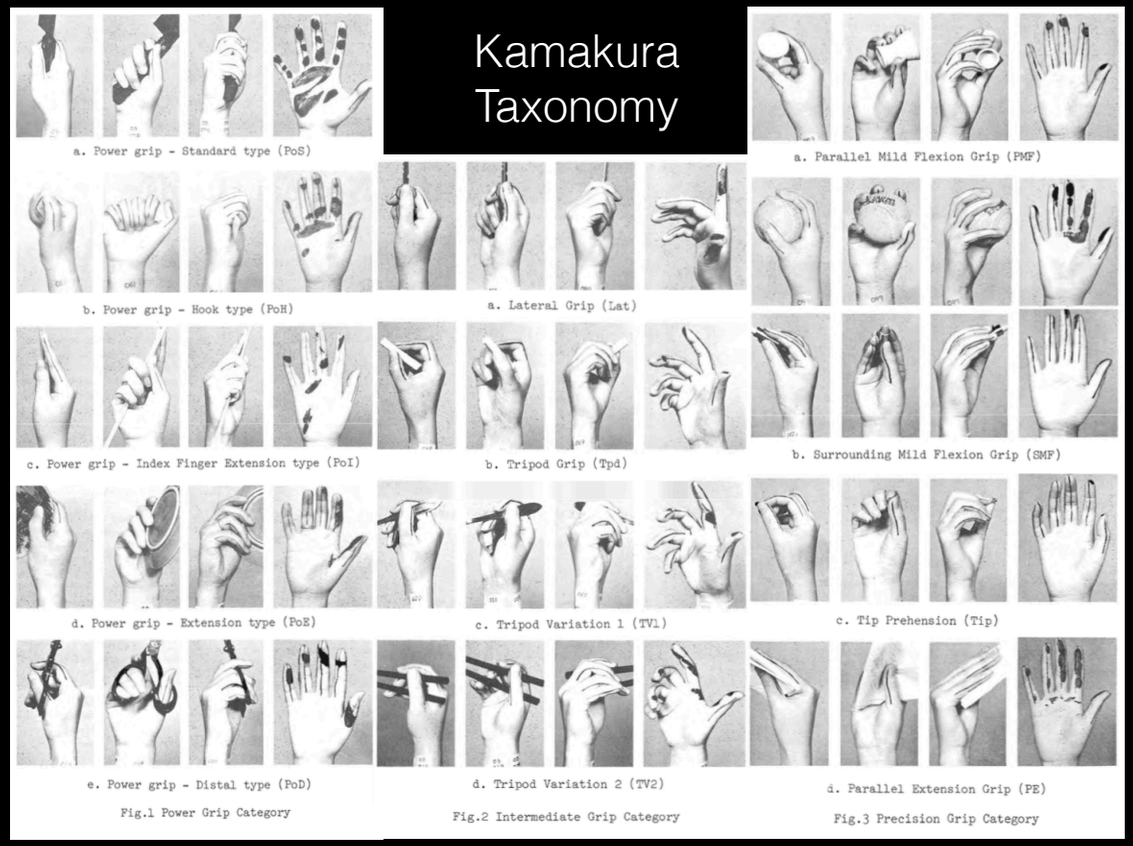
Blend Shapes?



Cutkosky, Mark R., and Paul K. Wright. "Modeling manufacturing grips and correlations with the design of robotic hands." Robotics and Automation. Proceedings. 1986 IEEE International Conference on. Vol. 3. IEEE, 1986.

We should consider the space of shapes the hand takes while grasping…

Kamakura Taxonomy



Kamakura, Noriko, et al. "Patterns of static prehension in normal hands." American Journal of Occupational Therapy 34.7 (1980): 437-445.

.. more grasps, with contacts indicated ..

A CLASSIFICATION OF MANIPULATIVE HAND MOVEMENTS

J. M. Elliott
K. J. Connolly

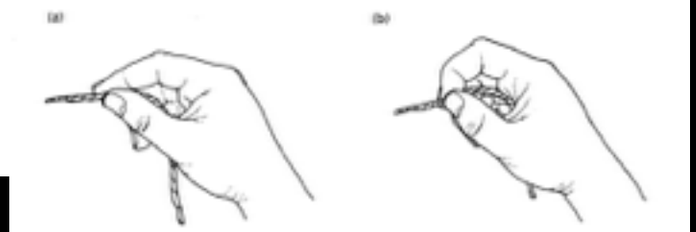


Fig. 4. Pinch: (a) thumb and index extended, (b) thumb and index flexed. These represent terminal positions for digits when executing this pattern of movement.

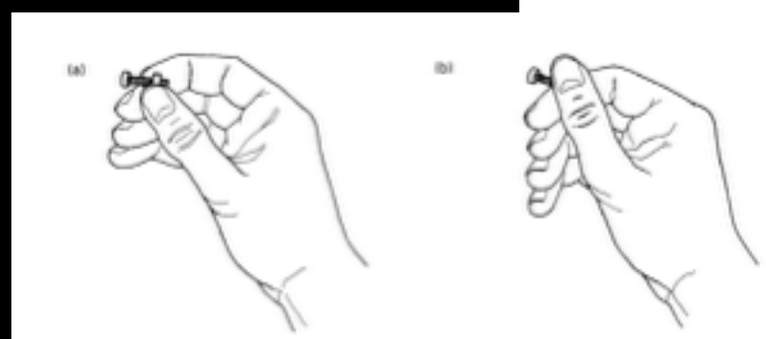
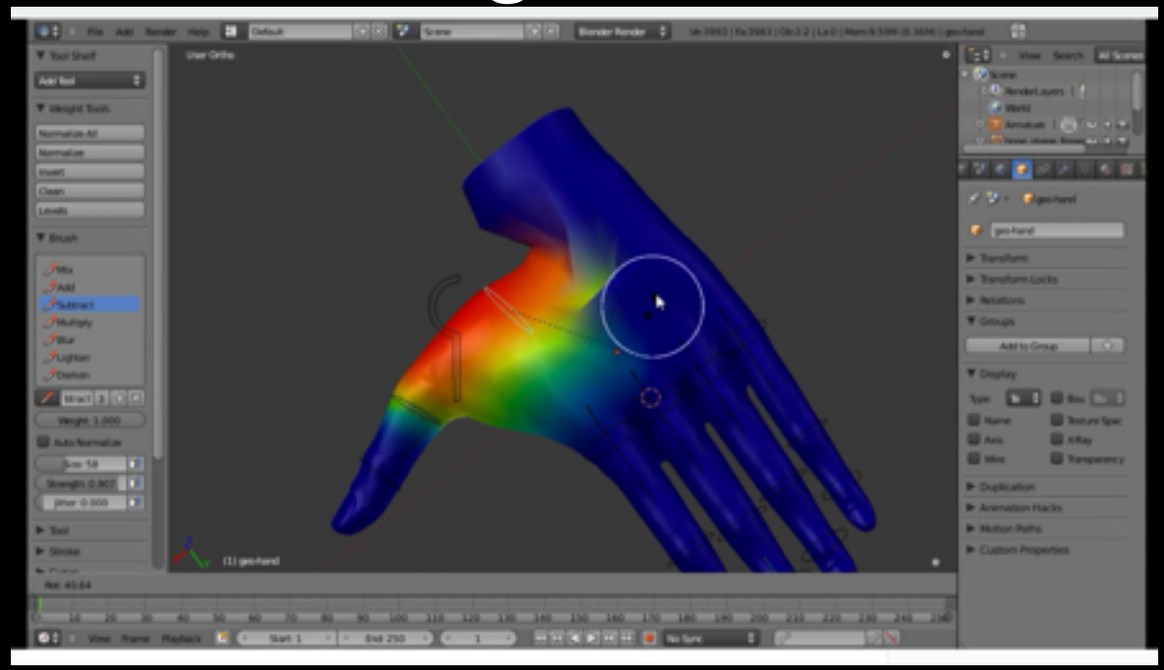


Fig. 7. Twiddle: (a) thumb in full abduction, (b) thumb in partial adduction, with concurrent index flexion. Extent of thumb adduction is quite variable, depending on extent of movement required in alternating between postures illustrated.

Elliott, John M., and K. J. Connolly. "A classification of manipulative hand movements." Developmental Medicine & Child Neurology 26.3 (1984): 283-296.

.. and manipulation. These are just two of more than a dozen manipulation types in this article.

Skinning is Nontrivial



https://vimeo.com/11703344

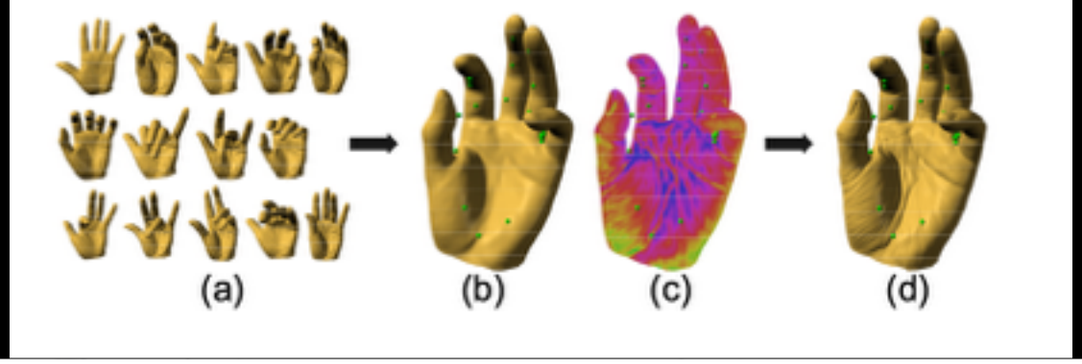
There is a preference for representing pose based on an underlying skeleton. However, providing a nice looking skin is non-trivial. We have used the Pinocchio system with some success as a quick cut at the problem. However, why not just measure how our skin looks and moves in real life?

Eurographics/ ACM SIGGRAPH Symposium on Computer Animation (2011)
A. Bargteil and M. van de Panne (Editors)

Controllable Hand Deformation from Sparse Examples with Rich Details

Haoda Huang[†] Ling Zhao[*] KangKang Yin[‡] Yue Qi[*] Yizhou Yu[§] Xin Tong[†]

[†] Microsoft Research Asia [*] Beihang University [‡] National University of Singapore [§] Univ. of Illinois at Urbana-Champaign



This paper does just that, and attempts to match the geometry and appearance with the positions of a number of control points.

- We have seen two ideas for posing hands: construction of an intuitive rig and the use of key shapes or motions, with blends between them.
- Rigging and posing is the dominant mode of interaction these days. Key poses with blends have not been well exploited to date.
- Rigs could be enhanced to better reflect the scope of natural hand motions.
- Either approach (use of rigs or blend poses) will find challenges in making close contact with an object to grasp or manipulate it.
- There has been progress in realistic skinning, but it is not yet a solved problem.
- No approach discussed considers natural hand dynamics — another interesting research problem to dig into!

Checking in with what we have seen so far…

Direct Control

http://www.malvern-armatures.co.uk/04_hand.html

We can directly manipulate hand shape using an armature such as one of these, which are intended for stop motion puppetry.

Oculus Touch

http://gizmodo.com/oculus-touch-hands-on-so-damn-good-1712031397
https://www.youtube.com/watch?v=asduqdRizqs

In a VR environment, new controllers such as this one are attempting to give users the feeling of direct control of their own hands in the virtual world. I think we can do better still.

Hand Motion Capture

http://people.cs.clemson.edu/~sjoerg/docs/Wheatland15_FingerSTAR.pdf

Moving to motion capture, this is a conventional optical marker setup for hands. We have moved to a 42 marker set with tiny markers in order to capture more detail about orientation of different parts of the hand.

http://people.cs.clemson.edu/~sjoerg/docs/Wheatland15_FingerSTAR.pdf

The cyberglove and friends have been around for decades and are nice because of their direct measurement of joint angles. They have been notoriously difficult to calibrate well and do not offer precision capture as optical techniques do, however, they are cheaper (still $15K) and easier to use, especially for real-time applications.

Leap Motion Controller

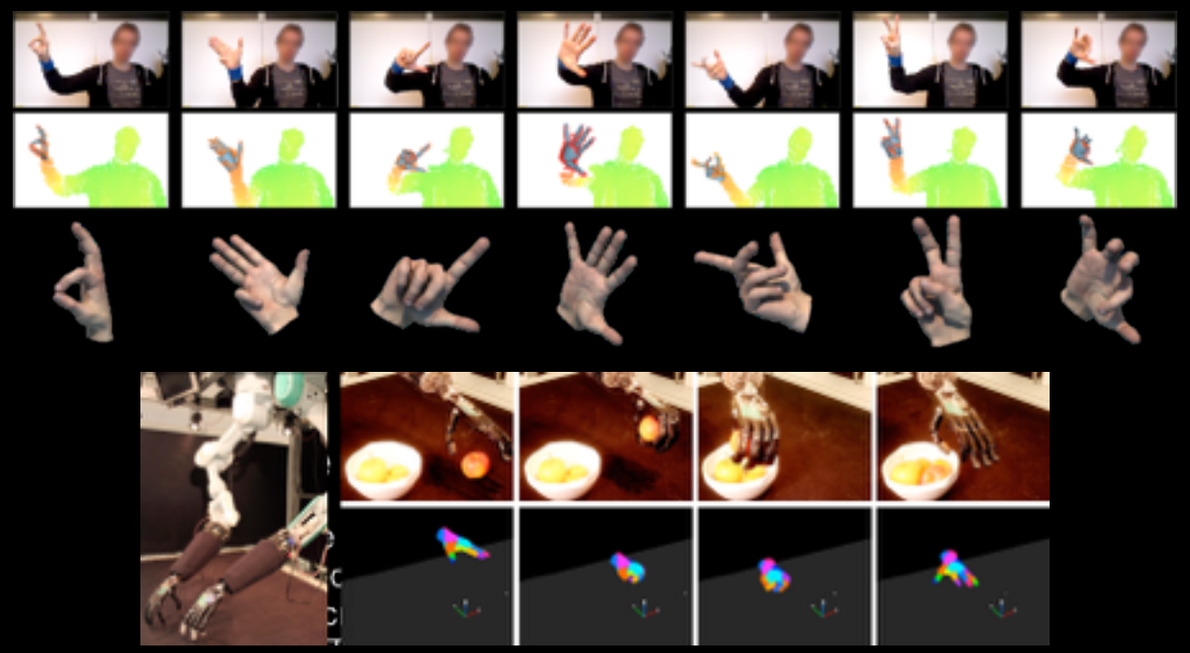
https://www.leapmotion.com/

Real-time capture is very hot right now. You can play around with one of these (we have a couple).

Nimble VR, acquired by Oculus
https://www.youtube.com/watch?v=v_U3BmDlmtc

.. and take a look at this kickstarter demo

Capture State of the Art



http://graphics.uni-bielefeld.de/research/hand_tracking/

State of the art using RGBD cameras is well represented by this research by Mario Botsch’s group.

What about manipulation?

Video-based Hand Manipulation Capture Through Composite Motion Control

Yangang Wang* Jianyuan Min† Jianjie Zhang† Yebin Liu*
Feng Xu* Qionghai Dai* Jinxiang Chai†
*Tsinghua University †Texas A&M University

Figure 1: *Modeling high-fidelity dexterous manipulation data from videos: (top) observed image data; (bottom) reconstructed motion.*

http://dl.acm.org/citation.cfm?id=2462000
https://www.youtube.com/watch?v=oiU4JwUcQnU

This is the paper I meant to show you all! Please take a look at the video. The authors use physically based simulation as one component to attempt to obtain a believable depiction of manipulation actions for a scene observed from multiple camera views.

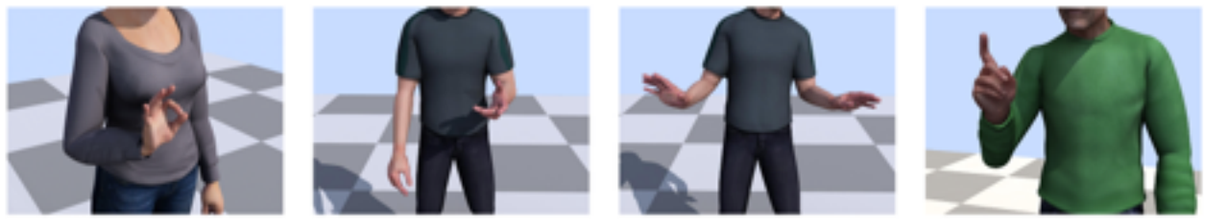
Applications using Hand Motion Capture

Data-driven Finger Motion Synthesis for Gesturing Characters

Sophie Jörg*
Carnegie Mellon University
Clemson University

Jessica Hodgins†
Carnegie Mellon University
Disney Research, Pittsburgh

Alla Safonova‡
Disney Research, Pittsburgh



(a) (b) (c) (d)

Figure 1: *Animations with synthesized finger motions: (a) ok gesture, (b)-(c) extracts from a conversation, (d) attention gesture.*

http://people.cs.clemson.edu/~sjoerg/mocap.html

Here is a nice application of using motion capture data to generate hand motions for conversational characters.

Data-driven Finger Motion Synthesis for Gesturing Characters

Sophie Jörg — Carnegie Mellon University, Clemson University

Jessica Hodgins — Carnegie Mellon University, Disney Research, Pittsburgh

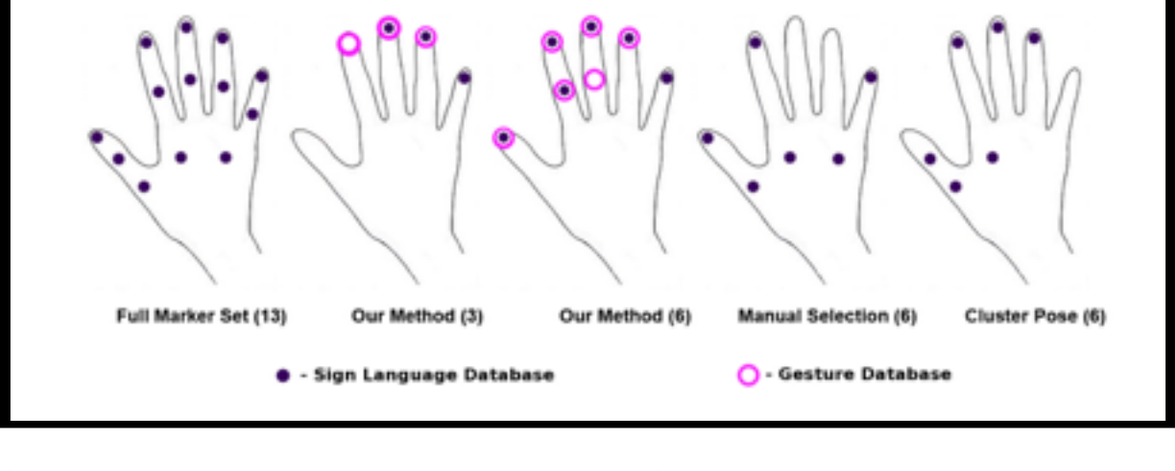
Alla Safonova — Disney Research, Pittsburgh

(with Audio)

Applications using Hand Motion Capture

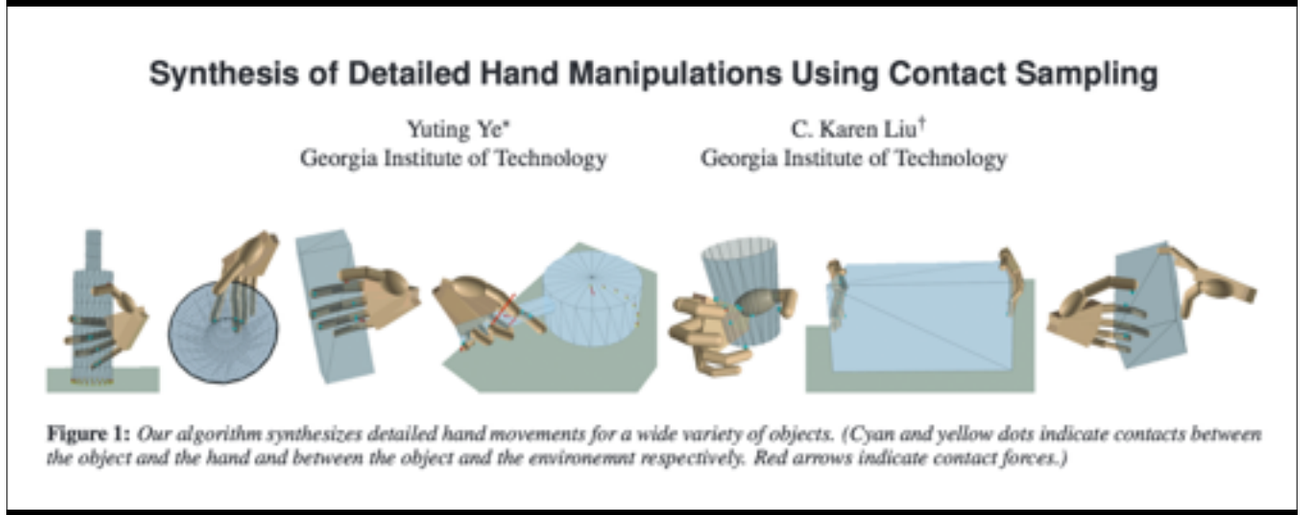
Automatic Hand-Over Animation using Principle Component Analysis

Nkenge Wheatland, UC Riverside*
Sophie Jörg, Clemson University
Victor Zordan, UC Riverside



It is also interesting to consider how much information is required to reconstruct the hand's pose, and where a small set of markers should be placed.

Avoiding Hand Capture Entirely



Synthesis of Detailed Hand Manipulations Using Contact Sampling

Yuting Ye*
Georgia Institute of Technology

C. Karen Liu†
Georgia Institute of Technology

Figure 1: *Our algorithm synthesizes detailed hand movements for a wide variety of objects. (Cyan and yellow dots indicate contacts between the object and the hand and between the object and the environemnt respectively. Red arrows indicate contact forces.)*

http://yutingye.info/SIG12.html

These authors attempt to fill in plausible hand motion from captured full body and object motion alone. It is interesting to see how well they can do without much in the way of a hand “prior,” i.e., a probability distributions for poses and/or motions that the hand is likely to exhibit.

- We looked at direct control and motion capture as modalities for obtaining hand motions.

- The bottom line is that hand capture is getting very good! There are many players in this space right now, and development is being accelerated by industry interest in hand capture for VR and games

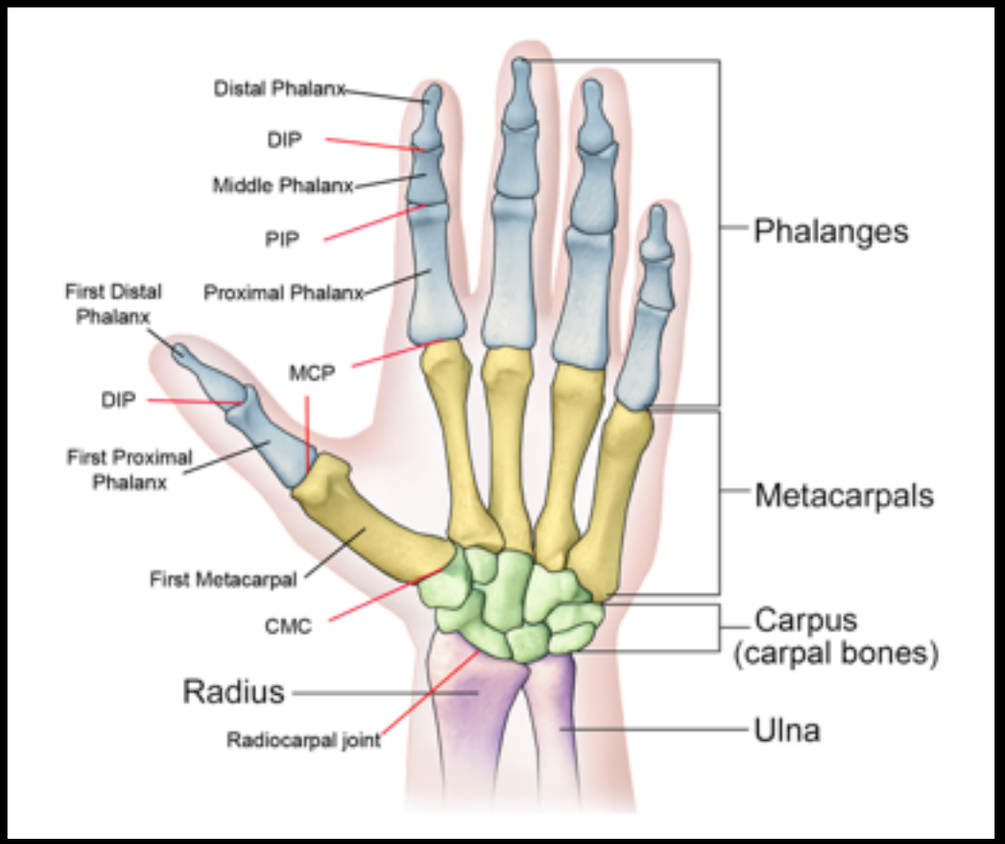
- However, the problem has not been completely solved. We cannot capture hand motion from a single camera when the hand is interacting with objects in the world. Almost everyone has punted on building user specific hand models. Capture of a complete interaction including deformations and forces is not yet in reach.

Checking in on what we've seen so far…

Hand Realism

- Some hand anatomy
- Shopping at Nick’s
- Simulation and Optimization

Let’s talk about what is needed to reach the next level of realism in hand animation.



http://people.cs.clemson.edu/~sjoerg/docs/Wheatland15_FingerSTAR.pdf

I mentioned a few things from this diagram.

(1) Wrist motion is not about a single axis because of how the eight carpal bones rotate with respect to one another. Rather, the rotation axis changes as the wrist flexes and extends.
(2) Not only the thumb, but the ring and pinky fingers articulate at their boundary with the carpal bones.
(3) Joints may not be nice single axis, universal, or ball joints.
(4) Joint capsules, ligaments, and other tissues create a natural compliance in the hand.

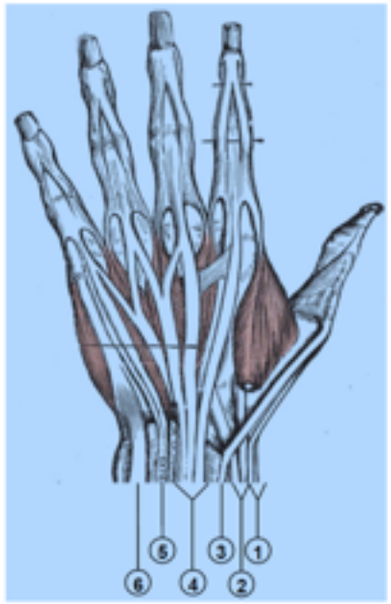


Figure 3: *The muscles of the forearm, wrist, and hand numbers by compartment: 1 – Abductor pollicis longus, Extensor pollicis brevis; 2 – Extensor carpi radialis longus, Extensor carpi radialis brevis; 3 – Extensor pollicis longus; 4 – Extensor indicis, Extensor digitorum communis; 5 – Extensor digiti minimi; 6 – Extensor carpi ulnaris [GL18]*

http://people.cs.clemson.edu/~sjoerg/docs/Wheatland15_FingerSTAR.pdf

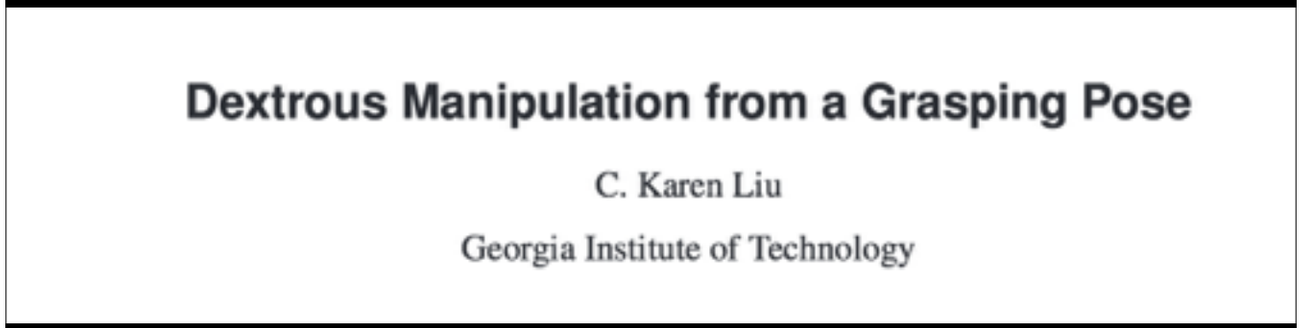
The system of muscles and tendons that drives hand motion is very interesting, including coupling that at least partly explains how our hands move together and a separation of effort between the strong muscles located in the forearm that are used for gripping with force and the many intrinsic muscles of the hand that help to position the fingers and thumb where needed. It is interesting how many of the main thumb gripping muscles are actually located within the hand and form the thenar eminence, the bulge that you see at the base of your thumb.

A Trip to Nick's

http://www.cs.ubc.ca/~troniak/levering.webm

Take a look at this video and notice how the hand complies to objects, adjusts in response to collisions (or is it intentionally using collisions to locate the object relative to the world?), and constantly shifts the grasp.

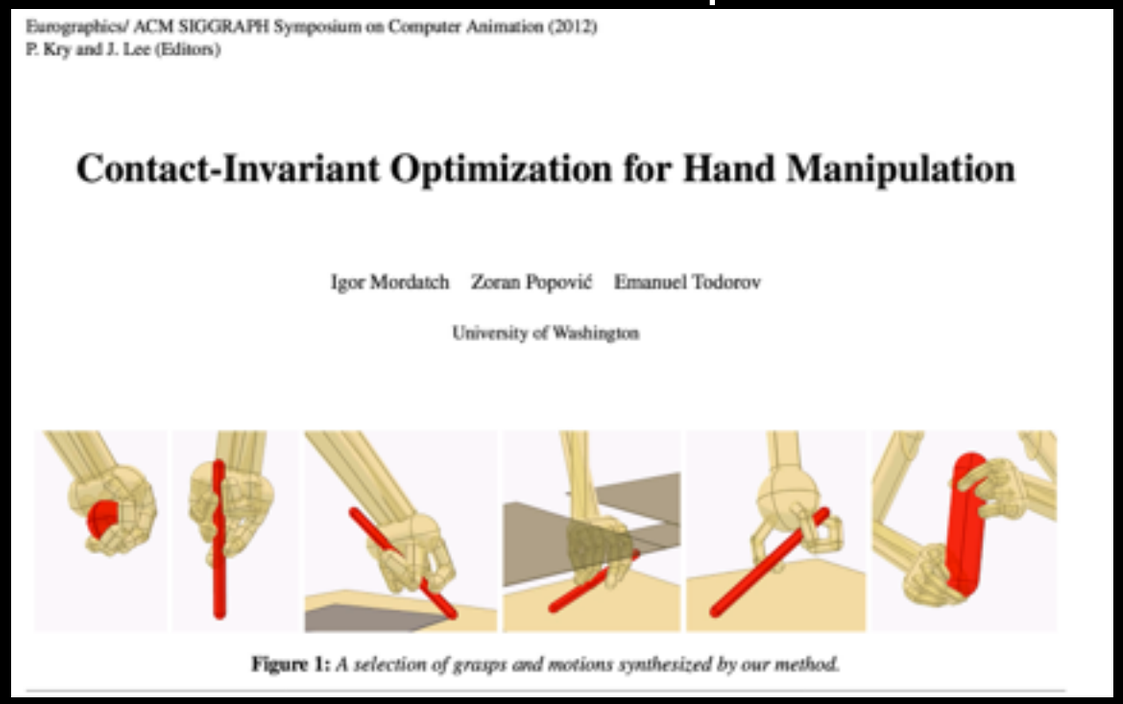
Simulation and Optimization



http://www.cc.gatech.edu/~karenliu/Manipulation2.html

Much research that looks at the physics of hand motion treats grasping from an optimization perspective. I am a fan of this paper, which makes the straightforward assumption that when the hand is holding an object, it attempts to keep the torques at the joints constant through a manipulation or disturbance.

Simulation and Optimization



Eurographics/ ACM SIGGRAPH Symposium on Computer Animation (2012)
P. Kry and J. Lee (Editors)

Contact-Invariant Optimization for Hand Manipulation

Igor Mordatch Zoran Popović Emanuel Todorov

University of Washington

Figure 1: *A selection of grasps and motions synthesized by our method.*

http://homes.cs.washington.edu/~mordatch/hand/

Here is another approach to optimization of manipulation tasks that attempts to create nice looking motion from just a starting position and a target position. It is very remarkable that we can do this at all. However, it seems that we may need some additional information to guide the search for motion that is highly natural. What do you think? Would a better anatomical model help here?

Contact-Invariant Optimization for Hand Manipulation

Submitted to SCA 2012
Submission ID: 1053

Challenges

- Hand capture in natural situations
- Believable contact and detailed manipulation
- The ultimate hand rig
- Realistic hand control for simulation (e.g., reflexes)

To wrap everything up, here are what I see as the main outstanding challenges in animating hands right now. Perhaps you have noticed others as well.

A good reference

State of the Art in Hand and Finger Modeling and Animation

Nkenge Wheatland[1], Yingying Wang[2], Huaguang Song[2], Michael Neff [2], Victor Zordan [1], and Sophie Jörg [3]

[1]University of California, Riverside
[2]University of California, Davis
[3]Clemson University

Just this year, a state of the art report was published with tons more detail, and also covering areas I did not have time to even touch. If you are interested, take a look!