

References for 16-848 for January 31, 2024

We spoke about a number of taxonomies. Here are the ones that are mentioned in the slides. It is interesting to read the papers as well.

The first reference was to the work of Napier, who elegantly describes the differences between power and precision grasps.

Napier, John R. "The prehensile movements of the human hand." *The Journal of bone and joint surgery. British volume* 38, no. 4 (1956): 902-913.

We then looked at the Cutkosky taxonomy taken from machinist grasps. Notice that the goal is to develop an expert system to decide on grasp choice given needs of the grasp:

Cutkosky MR. On grasp choice, grasp models, and the design of hands for manufacturing tasks. *Robotics and Automation, IEEE Transactions on.* 1989 Jun;5(3):269-79.

This one has the pictures showing contact (and the comment that maybe these are all the grasps we need!)

Kamakura N, Matsuo M, Ishii H, Mitsuboshi F, Miura Y. Patterns of static prehension in normal hands. *American Journal of Occupational Therapy.* 1980 Jul 1;34(7):437-45. <http://ajot.aota.org/Article.aspx?articleid=1889836>

We have seen this one before, earlier in the class. The grasping part, "Modes of Prehension" begins on page 265 of the pdf.

Kapandji IA. *The physiology of the joints: upper limb, Vol 1.* Elsevier Health Sciences; 1987. <http://graphics.cs.cmu.edu/nsp/course/16899-s16/papers/Kapandji.pdf>

Here are some additional references from today's slides:

Iberall, Thea. "Human prehension and dexterous robot hands." *The International Journal of Robotics Research* 16, no. 3 (1997): 285-299. <https://journals.sagepub.com/doi/abs/10.1177/027836499701600302>

Thomas Feix, Javier Romero, Heinz-Bodo Schmiedmayer, Aaron M. Dollar, and Danica Kragic, *The GRASP Taxonomy of Human Grasp Types*, IEEE TRANSACTIONS ON HUMAN-MACHINE SYSTEMS 2015. <http://grasp.xief.net/>
<http://ieeexplore.ieee.org/document/7243327/>

Liu, Jia, Fangxiaoyu Feng, Yuzuko C. Nakamura, and Nancy S. Pollard. "Annotating everyday grasps in action." In *Dance notations and robot motion*, pp. 263-282. Springer, Cham, 2016.
<https://www.ri.cmu.edu/wp-content/uploads/2017/12/LaumondBookChapter.pdf>

You can find the database itself at this link. Check it out!
<http://www.cs.cmu.edu/~jiali1/database.html>

The project that involved the pizza box and salad container is written up here:

Nakamura, Yuzuko C., Daniel M. Troniak, Alberto Rodriguez, Matthew T. Mason, and Nancy S. Pollard. "The complexities of grasping in the wild." In *2017 IEEE-RAS 17th International Conference on Humanoid Robotics (Humanoids)*, pp. 233-240. IEEE, 2017. <https://ieeexplore.ieee.org/abstract/document/8246880>

My favorite reference for in-hand manipulation is the following:

Elliott JM, Connolly KJ. A classification of manipulative hand movements. *Developmental Medicine & Child Neurology*. 1984 Jun 1;26(3):283-96.
<http://graphics.cs.cmu.edu/nsp/course/16899-s16/papers/Elliott1984.pdf>

We talked about manipulation taxonomies, including from these references:

Krebs, Franziska, and Tamim Asfour. "A bimanual manipulation taxonomy." *IEEE Robotics and Automation Letters* 7, no. 4 (2022): 11031-11038.
<https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9849068>

Bullock, Ian M., Raymond R. Ma, and Aaron M. Dollar. "A hand-centric classification of human and robot dexterous manipulation." *IEEE transactions on Haptics* 6, no. 2 (2012): 129-144.
<https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6298887>

Kamakura, Noriko. *Postures and Movement Patterns of the Human Hand: A Framework for Understanding Hand Activity for Clinicians and Engineers*. Universal-Publishers, 2022.

In speaking about synergies, we referred to the following papers:

Santello, Marco, Martha Flanders, and John F. Soechting. "Postural hand synergies for tool use." *Journal of neuroscience* 18, no. 23 (1998): 10105-10115.

Della Santina, Cosimo, Cristina Piazza, Giorgio Grioli, Manuel G. Catalano, and Antonio Bicchi. "Toward dexterous manipulation with augmented adaptive

synergies: The pisa/iit soft hand 2." *IEEE Transactions on Robotics* 34, no. 5 (2018): 1141-1156.

Brown, Christopher Y., and H. Harry Asada. "Inter-finger coordination and postural synergies in robot hands via mechanical implementation of principal components analysis." In 2007 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2877-2882. IEEE, 2007.

Dollar, Aaron M., and Robert D. Howe. "The highly adaptive SDM hand: Design and performance evaluation." *The international journal of robotics research* 29, no. 5 (2010): 585-597.

We then took a look at some human benchmark tests, including these:

The Kapandji test:

https://en.wikipedia.org/wiki/Kapandji_score

<https://ars.els-cdn.com/content/image/1-s2.0-S0266768103000160-gr6.jpg>

Block and Box test:

<https://www.youtube.com/watch?v=jmpNXj5oOo0>

Purdue Pegboard test (fine dexterity):

<https://www.youtube.com/watch?v=xXT9E4OY9tw>

ARAT test (different shaped objects):

<https://www.youtube.com/watch?v=f8oiH50A1Cw>

Jebsen Hand Function test (daily living):

<https://www.youtube.com/watch?v=ZUzS00Rtz6M>

<https://www.sralab.org/rehabilitation-measures/jebsen-hand-function-test>

Sollerman test (daily living, including bimanual actions):

<https://www.youtube.com/watch?v=adaoXVzp3ks>

<http://www.swisswuff.ch/images/adl/adl-pdf/sollermann1995handfunctiontest.pdf>

SHAP test (a more recent test):

https://www.youtube.com/watch?v=5Lby_R0EDeQ

The subject in this video is using Otto Bock's Michelangelo Prosthetic Hand, which you can read about here:

<https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/michelangelo-prosthetic-hand/>

If you want to read more on benchmarks in robotics, benchmarks often take the form of competitions, such as the DARPA ARM challenge:

<https://www.youtube.com/watch?v=jeABMoYJGEU>

The National Institute of Standards and Technology is making a strong effort to establish a variety of benchmarks for evaluating robot hands, and their current benchmark set can be found here:

<https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1227-draft.pdf>

This paper introduces the YCB object dataset, designed to at least standardize the object set that we use for benchmarking. I have one of these sets in my office.

<http://www.ycbbenchmarks.com/object-set/>

The benchmarks that we browsed, posted to the YCB website are here:

<http://www.ycbbenchmarks.com/protocols-and-benchmarks/>

Here are a few more interesting references:

Cruciani, Silvia et al. "Benchmarking In-Hand Manipulation." IEEE Robotics and Automation Letters 5.2 (2020): 588–595.

<https://arxiv.org/abs/2001.03070>

Cruciani, Silvia, Christian Smith, Danica Kragic, and Kaiyu Hang. "Dexterous manipulation graphs." In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 2040-2047. IEEE, 2018.

<https://ieeexplore.ieee.org/abstract/document/8594303/>

Llop-Harillo, Immaculada, Antonio Pérez-González, Julia Starke, and Tamim Asfour. "The Anthropomorphic Hand Assessment Protocol (AHAP)." Robotics and Autonomous Systems 121 (2019)

<https://www.sciencedirect.com/science/article/pii/S0921889019300946>

Yang, Boling, Patrick Lancaster, Siddhartha Srinivasa, and Joshua R. Smith.

"Benchmarking Robot Manipulation with the Rubik's Cube." IEEE Robotics and Automation Letters (2020).

<https://ieeexplore.ieee.org/abstract/document/8972349/>

This paper discusses the "reachable configuration manifold." Especially see Figure

13 <https://journals.sagepub.com/doi/pdf/10.1177/0278364914558494>

These videos <https://youtu.be/5V6FLd7KvNk> <https://youtu.be/6ry0j2YUQBc> are from different papers, but still helpful in understanding what's going on.

There's also this paper

<https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8793727>

(Morgan, Bircher, Calli, Dollar, 2019) which discusses several different dexterity metrics in Section III A