



## Hello Robot: Democratizing Mobile Manipulation

Aaron Edsinger, CEO and co-founder Charlie Kemp, CTO and co-founder Hello Robot Abstract Mobile manipulators have the potential to improve life for...

🕒 10am

📍 Learning Innovation Center (LINC), 302

📺 Stream Available

I'm Interested



## Hello Robot: Democratizing Mobile Manipulation

Aaron Edsinger, CEO and co-founder  
Charlie Kemp, CTO and co-founder  
Hello Robot

### Abstract

Mobile manipulators have the potential to improve life for everyone, yet adoption of this emerging technology has been limited. To encourage an inclusive future, Hello Robot developed the Stretch RE1, a compact and lightweight mobile manipulator for research that achieves a new level of affordability. The Stretch RE1 and Hello Robot's open approach are inspiring a community of researchers to explore the future of mobile manipulation. In this talk, we will present the Stretch RE1, its academic origins, and the growing community and ecosystem around it. We will also touch on connections with Oregon State University, including participation in our first summer internship program, and Hello Robot's role in the new NSF AI Institute, AI-CARING. We will conclude with a live demo and a question and answer session.

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# Democratizing Mobile Manipulation

**Aaron Edsinger, Ph.D.**  
Co-founder & CEO

**Charles Kemp, Ph.D.**  
Co-founder & CTO



# Founding Team



## **Aaron Edsinger, Founder & CEO**

- Founder Meka Robotics and Redwood Robotics
- Former Director of Robotics, Google
- PhD MIT CSAIL
- Built Meka and Redwood Robotics and sold to Google
- World expert on design for robot manipulation



## **Charlie Kemp, Founder & CTO**

- Associate Professor, Georgia Tech
- Founder & Director of the Healthcare Robotics Lab
- PhD MIT CSAIL
- World expert on assistive mobile manipulation

# Charlie's Conflict of Interest Statement

Dr. Kemp is both an associate professor at Georgia Tech and the chief technology officer (CTO) of Hello Robot Inc. where he works part time. **He owns equity** in Hello Robot Inc. and is an inventor of Georgia Tech intellectual property (IP) licensed by Hello Robot Inc. Consequently, **he receives royalties** through Georgia Tech for sales made by Hello Robot Inc. He also benefits from increases in the value of Hello Robot Inc.

**Summary: If Hello Robot does well, Charlie does well.**

# Outline

Quick Intro

Stretch's Design

The Stretch Community

Live Demo

Q&A



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# Quick Introduction to Hello Robot

# Our North Star

**Mobile manipulators can improve life for everyone.**

---

**It will take time.**

**We can't do it alone.**

**Let's build the future together.**





# The Stretch RE1



**“Beautifully  
Simple, Clever  
Robot Design”**

**- IEEE  
Spectrum**

## **Hardware & Software Platform**

- Compact, lightweight, contact sensitive, calibrated
- \$19,950 for a **complete robot**
  - gripper
  - sensors
  - onboard computer
- Open source software
  - From firmware up
  - Python & ROS

# Transparency & Openness

Simple Pricing

[hello-robot.com](http://hello-robot.com)

Open Source & Open Development

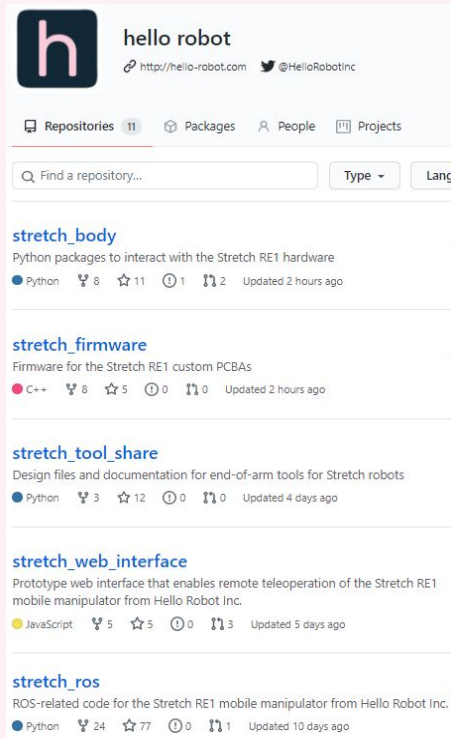
[github.com/hello-robot](https://github.com/hello-robot)

Open Hardware Accessories

[github.com/hello-robot/stretch\\_tool\\_share](https://github.com/hello-robot/stretch_tool_share)

Open Forum

[forum.hello-robot.com](http://forum.hello-robot.com)



The screenshot shows the GitHub profile for 'hello robot'. The profile includes a repository list with the following details:

- stretch\_body**: Python packages to interact with the Stretch RE1 hardware. 8 Python packages, 11 stars, 1 issue, 2 forks. Updated 2 hours ago.
- stretch\_firmware**: Firmware for the Stretch RE1 custom PCBAs. 6 C++ packages, 5 stars, 0 issues, 0 forks. Updated 2 hours ago.
- stretch\_tool\_share**: Design files and documentation for end-of-arm tools for Stretch robots. 3 Python packages, 12 stars, 0 issues, 0 forks. Updated 4 days ago.
- stretch\_web\_interface**: Prototype web interface that enables remote teleoperation of the Stretch RE1 mobile manipulator from Hello Robot Inc. 5 JavaScript packages, 5 stars, 0 issues, 3 forks. Updated 5 days ago.
- stretch\_ros**: ROS-related code for the Stretch RE1 mobile manipulator from Hello Robot Inc. 24 Python packages, 77 stars, 0 issues, 1 fork. Updated 10 days ago.

# Successful Launch in July 2020

IEEE SPECTRUM Topics Reports Blogs Multimedia

Automaton | Robotics | Home Robots

14 Jul 2020 | 4:01 GMT

## Ex-Googler's Startup Comes Out of Stealth With Beautifully Simple, Clever Robot Design

Hello Robot's Stretch wants to reinvent how mobile manipulators perform tasks in home environments

By Evan Ackerman and Eric Guizzo





Photo: Hello Robot

Hello Robot, founded by former Google robotics director Aaron Edsinger and Georgia Tech professor Charlie Kemp, is introducing Stretch, a mobile manipulator that weighs only 23 kg and costs less than \$20,000.

SVR Silicon Valley Robotics supporting the innovation and commerce



### Hello Robot wins Innovation Award in SVR 'Good Robot' Industry Awards

Posted on [December 14, 2020](#) by [Andra Keay](#)



BBC Sign in Home News Sport Reel Wo

## NEWS

Home Prince Philip Coronavirus Video World US & Canada UK Business

Tech



01:30

### Research robot helps with housework and other news

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Cornell University



umbrella research



# The Design of Stretch

[The Design of Stretch: A Compact, Lightweight Mobile Manipulator for Indoor Human Environments](#),  
Charles C. Kemp, Aaron Edsinger, Henry M. Clever and Blaine Matulevich, arXiv, 2021.

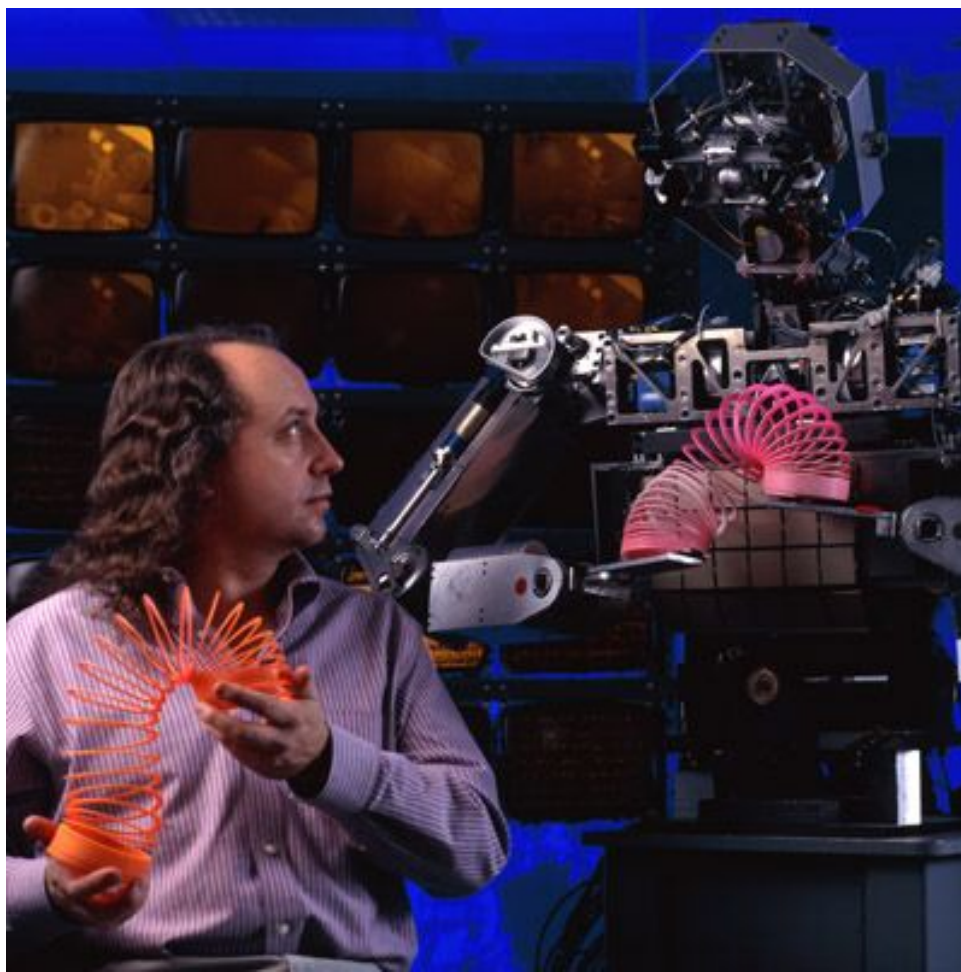


Photo Credit: Peter Menzel/Science Source  
from <https://robots.ieee.org/robots/cog/>

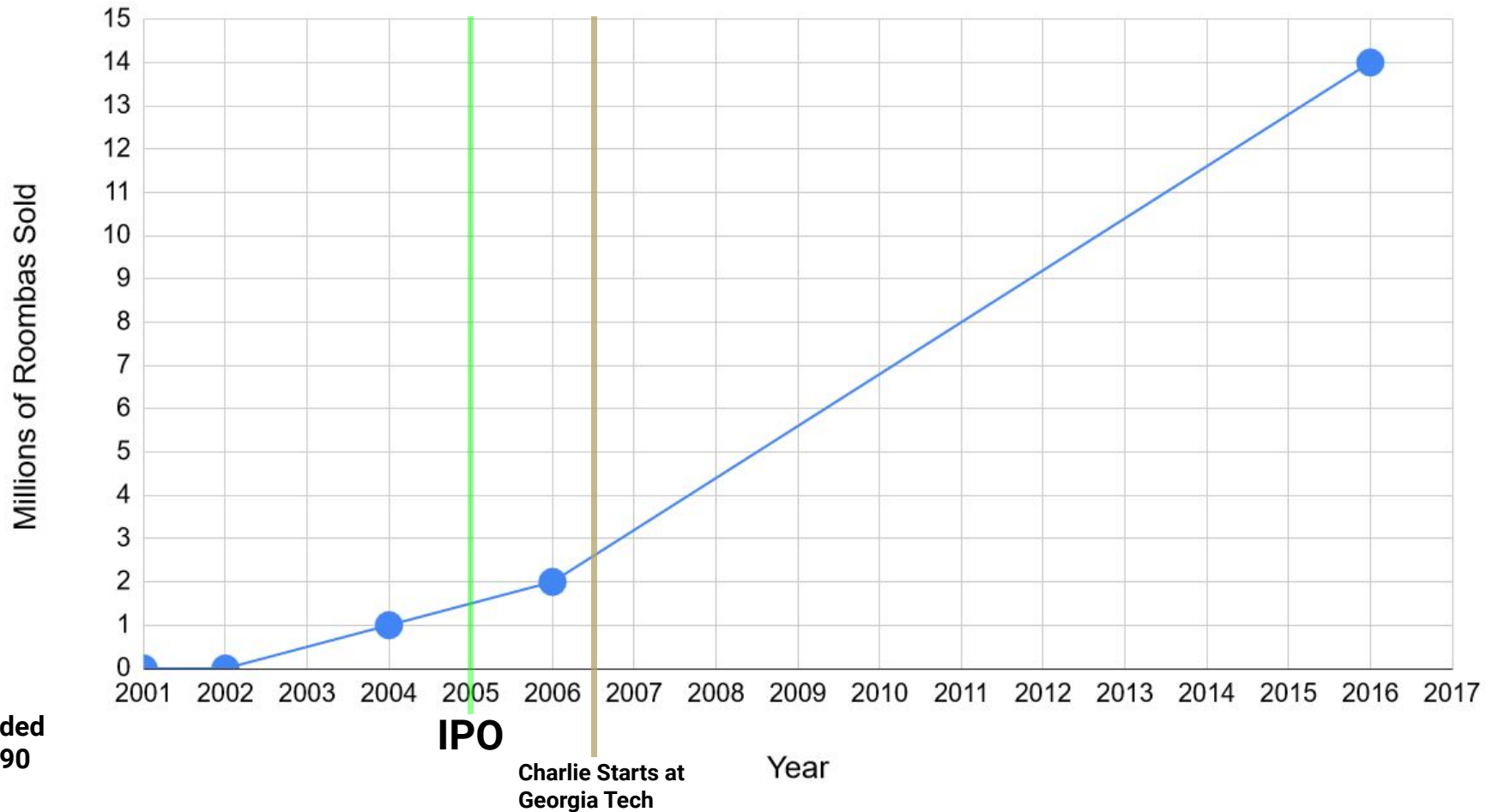
Rodney A. Brooks, "[How To Build Complete Creatures Rather Than Isolated Cognitive Simulators](#)",  
Architectures for Intelligence, K. VanLehn (ed), Erlbaum, Hillsdale, NJ, Fall 1989, pp. 225–239.





**The first Roomba from 2002.  
Almost 20 years ago!**

# Millions of Roombas Sold vs. Year





# Bodies and Brains Working Together

- Body matched to ecological niche
  - Small footprint
  - Circular and flat
  - Giant contact sensor
  - Easy for people to pick up and move
- Brain matched to the body
  - Haptic sensing as primary modality
  - Change direction on contact
  - Wall following
  - Spiraling



*“Viewed as a geometric figure, the ant’s path is irregular, complex, and hard to describe. But its complexity is really a complexity in the surface of the beach, not the complexity in the ant.”*

Herbert Simon,  
The Sciences of the Artificial, 1969



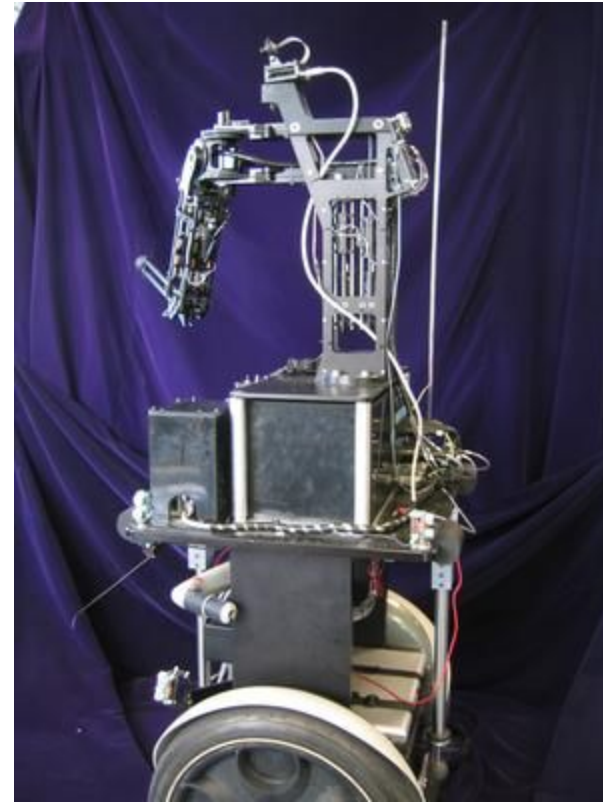
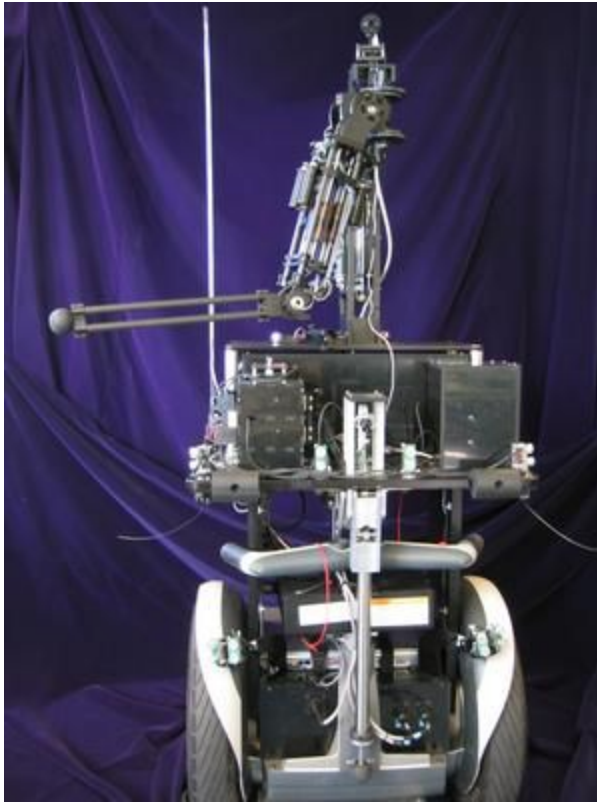
**Photo Credit:**  
Andreas Dantz  
Roomba, first attempt  
Taken on April 14, 2013  
<https://www.flickr.com/photos/szene/8649326807/in/pool-roomba/>

What is the Roomba of mobile manipulation?

# What body for **indoor** mobile manipulation in homes and workplaces?

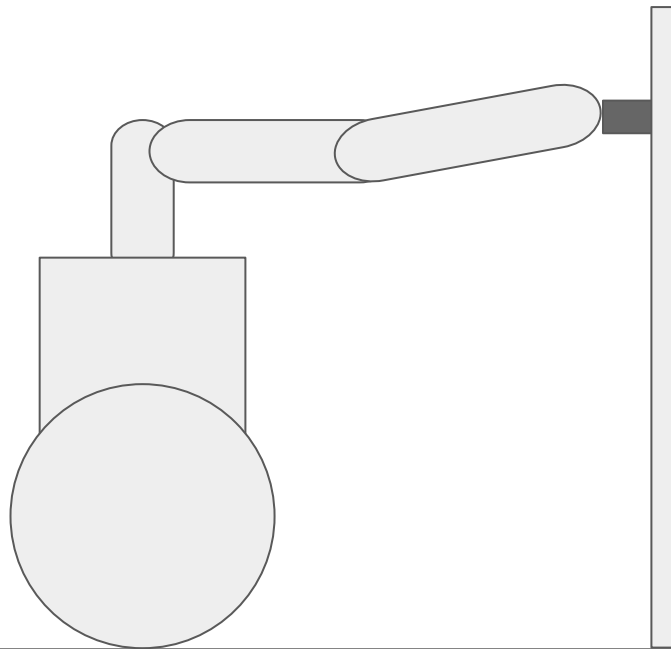
- Flat smooth surfaces
- Visible from human head height
- Reachable by human arms
- Children, older adults, and pets



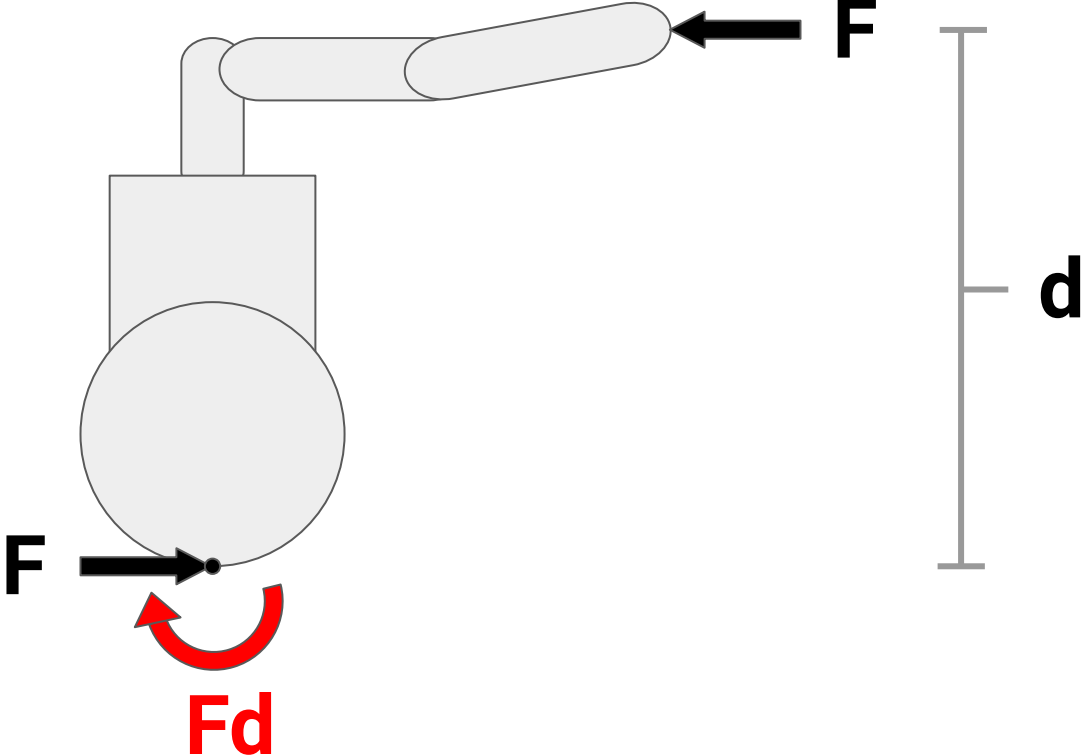


[Sensing and Manipulating Built-for-Human Environments](#), **Rodney A. Brooks**, Lijin Aryananda, **Aaron Edsinger**, Paul M. Fitzpatrick, **Charles C. Kemp**, Una-May O'Reilly, Eduardo Torres-Jara, Paulina Varshavskaya and Jeff Weber. International Journal of Humanoid Robotics, Vol 1, Number 1, pages 1-28, 2004.

# Momentary Problem when Balancing on Wheels

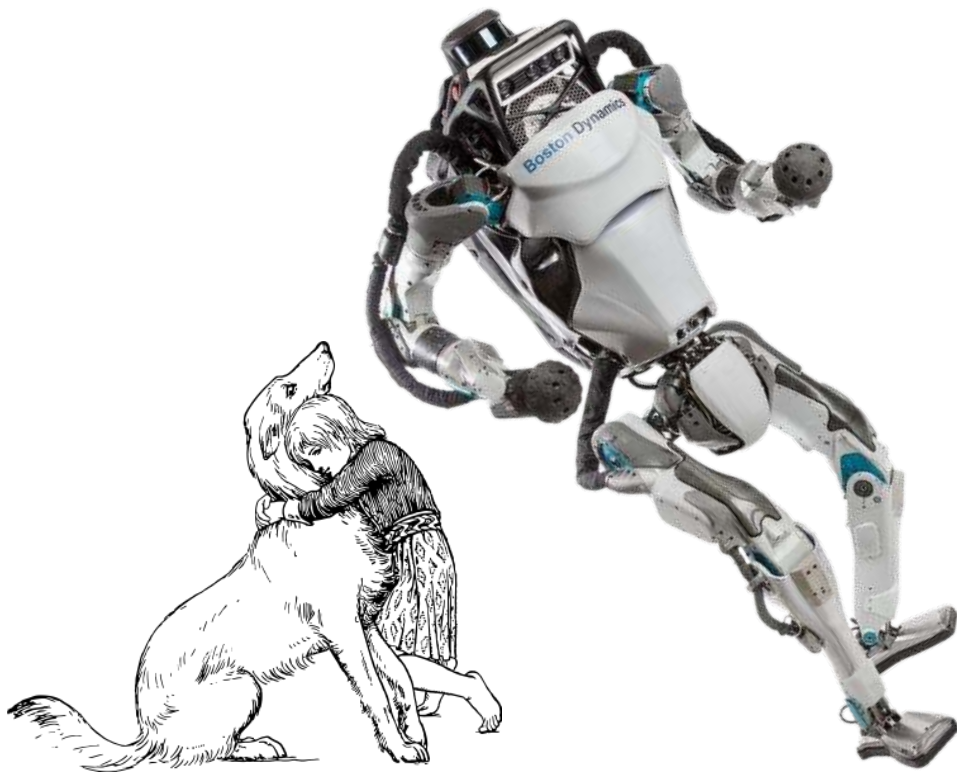


# Momentary Problem when Balancing on Wheels





# It Just Takes One Fall





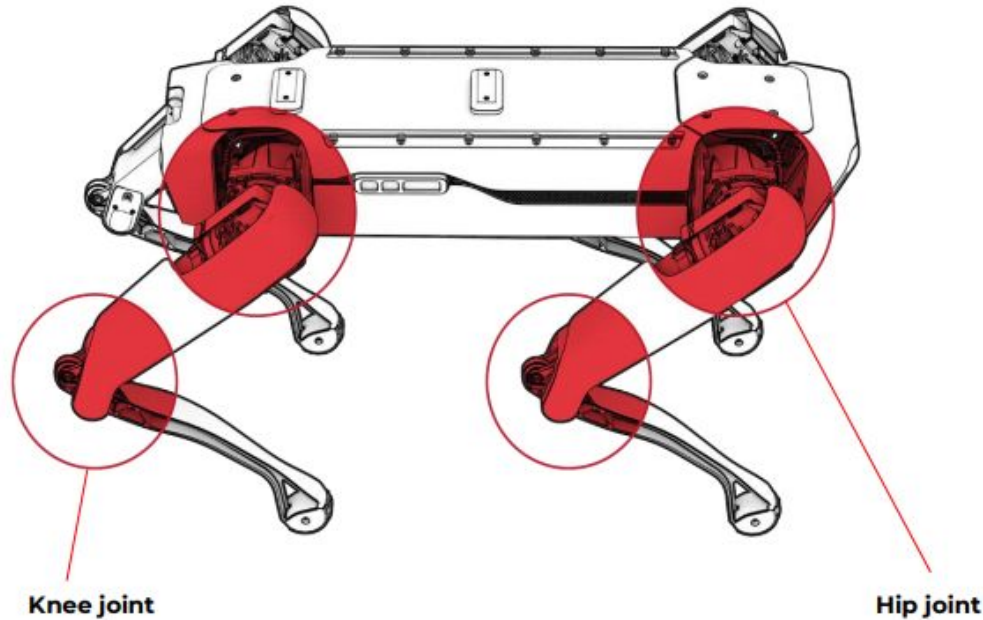


# What about quadrupeds?



# Pinch Points

Spot's joints can pinch fingers and other body parts and entangle loose clothing, long hair, and jewelry.



# Dynamic Stability Risks

Spot will always try to keep balance. This may result in high-acceleration motion of the legs



Failure in locomotion could happen unexpectedly and could result in de-energization of the robot's actuators.

A failure event may cause loss of stability and potential hazards associated with a fall or tipping over.

**Always keep a separation distance of 2 m**

What is the Roomba of mobile manipulation?

# Stretch's Ancestor

## EL-E from 2008

- Statically stable
- Small footprint
- Lightweight
- Cameras high
- Reach flat surfaces







[Hand It Over or Set It Down: A User Study of Object Delivery with an Assistive Mobile Manipulator](#), Young Sang Choi, Tiffany L. Chen, Advait Jain, Cressel Anderson, Jonathan D. Glass, and Charles C. Kemp, IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2009.

# In 2010 the World Changed







[Domestic robots for older adults: Attitudes, preferences, and potential](#), Cory-Ann Smarr, Tracy L. Mitzner, Jenay M. Beer, Akanksha Prakash, Tiffany L. Chen, Charles C. Kemp, and Wendy A. Rogers. *International Journal of Social Robotics*, 6(2):229–247, 2014.





# Mobile Manipulators Can Provide Meaningful Assistance



research from the Healthcare Robotics Lab ([healthcare-robotics.com](http://healthcare-robotics.com)) at Georgia Tech

# Mobile Manipulators Can Provide Meaningful Assistance



research from the Healthcare Robotics Lab ([healthcare-robotics.com](http://healthcare-robotics.com)) at Georgia Tech

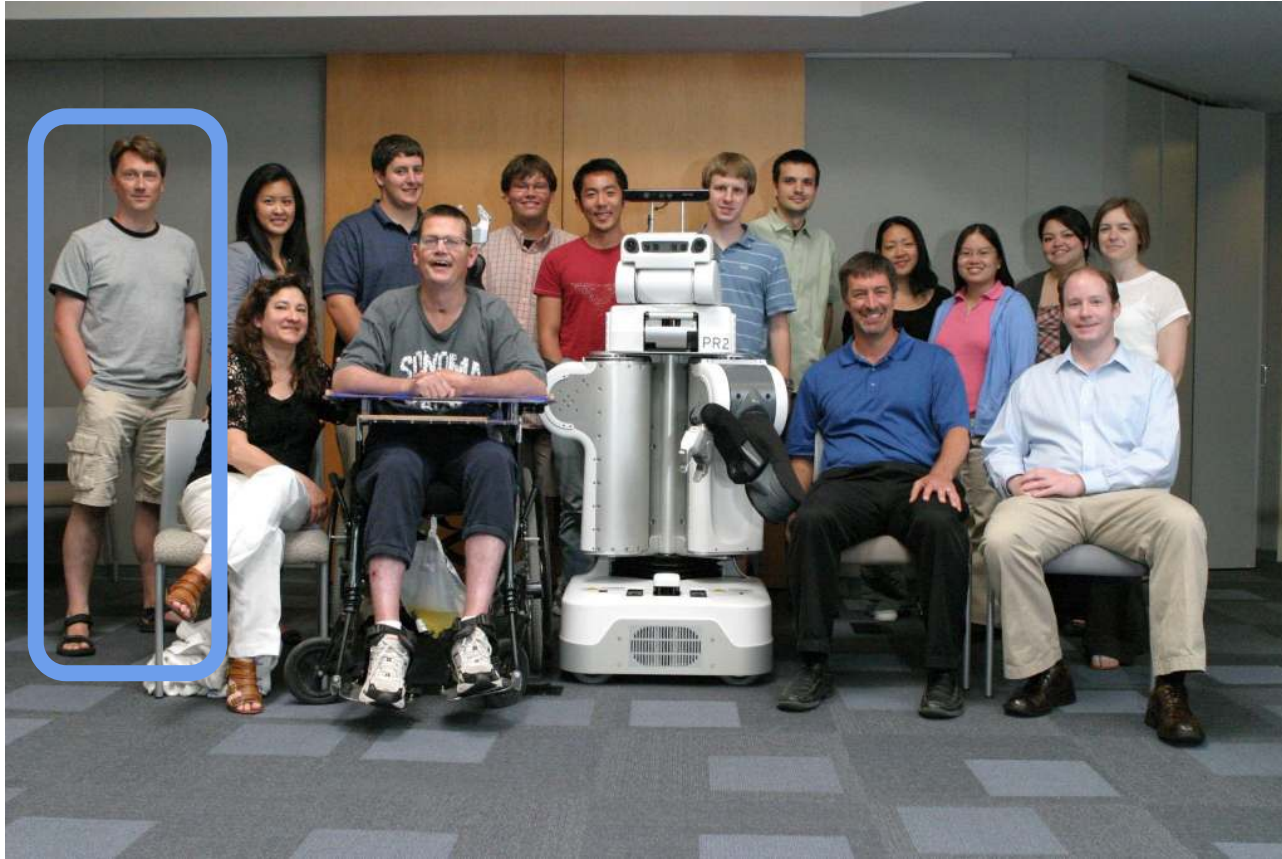
# The Robots for Humanity Project



[Robots for humanity: using assistive robotics to empower people with disabilities](#), Tiffany L. Chen, Matei Ciocarlie, Steve Cousins, Phillip Grice, Kelsey Hawkins, Kaijen Hsiao, **Charles C. Kemp**, Chih-Hung King, Daniel A. Lazewatsky, Adam Leeper, Hai Nguyen, Andreas Paepcke, Caroline Pantofaru, William D. Smart, and Leila Takayama, IEEE Robotics & Automation Magazine, 2013



# The Robots for Humanity Project



Robots for humanity: using assistive robotics to empower people with disabilities, Tiffany L. Chen, Matei Ciocarlie, Steve Cousins, Phillip Grice, Kelsey Hawkins, Kaijen Hsiao, **Charles C. Kemp**, Chih-Hung King, Daniel A. Lazewatsky, Adam Leeper, Hai Nguyen, Andreas Paepcke, Caroline Pantofaru, **William D. Smart**, and Leila Takayama, IEEE Robotics & Automation Magazine, 2013

# Two Problems



- Willow Garage shut down in 2014
- PR2 was impractical
  - \$400,000
  - 227 kg (~500 lb)
  - 67 cm wide (~2.2 ft)



**2002**



**2008**



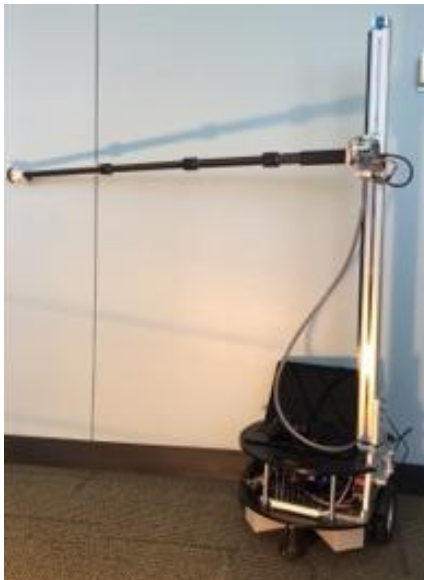
**2010**



**2017**



**Georgia Tech's Prototype**  
March 2017



**Hello Robot's Product - A Robot for Research**  
July 2020



2016	2017		2018	2019	2020
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July 2020

**3 years  
8 versions  
tested in Charlie's home**

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# Two Modes of Operation



**Manipulation Mode**  
*(Cartesian Manipulator)*

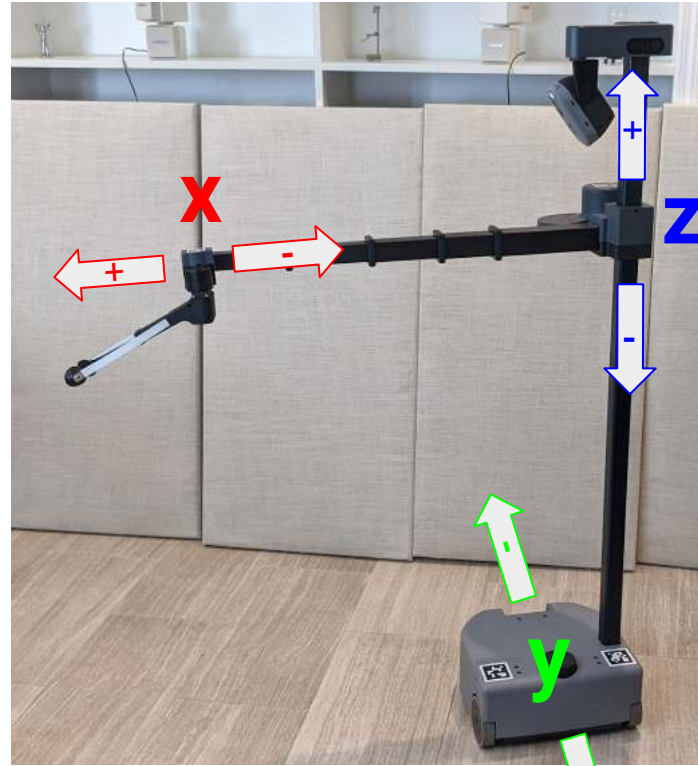


**Navigation Mode**  
*(Differential Drive Mobile Robot)*



**Arm & Tool Stow  
into the Footprint**

# Manipulation Depends on the Mobile Base



**Manipulation Mode**  
(*Cartesian Manipulator*)

# Robotic Cubism

- Dimensions matched to human environments
- The human form deconstructed and reassembled

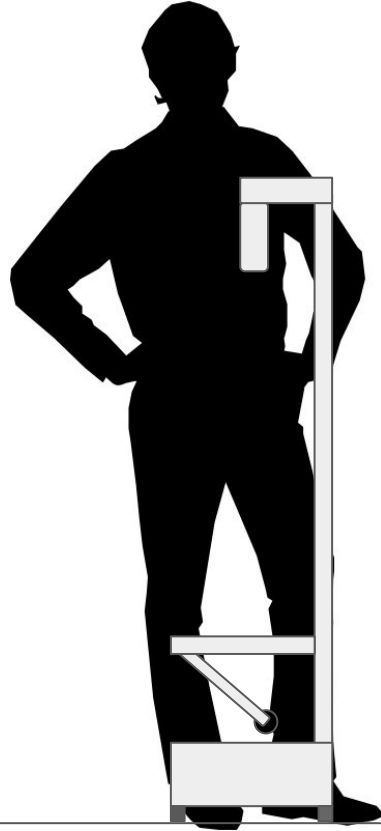
[La Femme au Violon - Pablo Picasso. 1911](#)



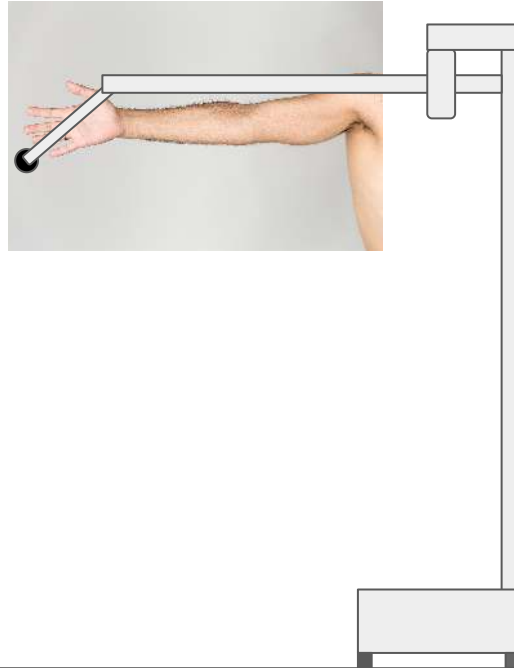
“In Cubist artwork, objects are analyzed, broken up and reassembled in an abstracted form”

- <https://en.wikipedia.org/wiki/Cubism>

# < 50th Percentile Hip Width

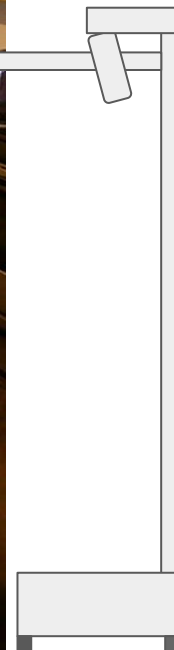


# 50th Percentile Arm Length

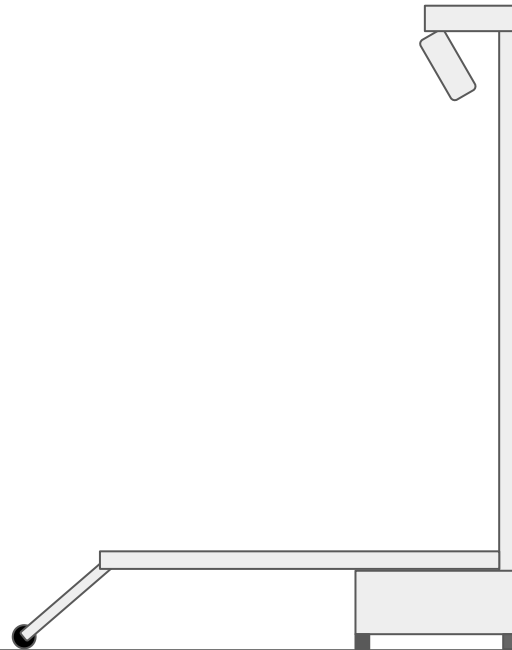




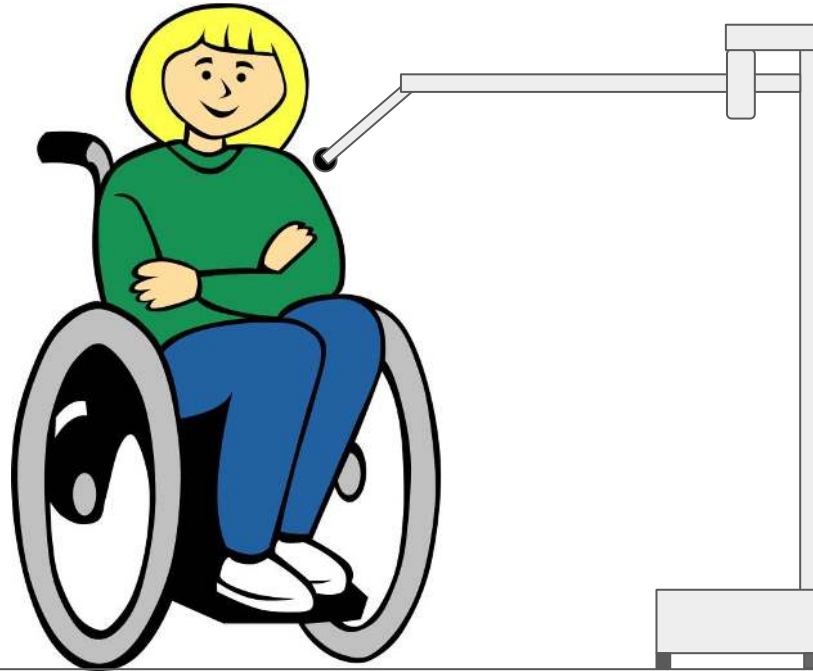
# Reaches 36" Countertops



# Reaches the Floor



# 95th Percentile Shoulder Height for Wheelchair Users



23 kg (51 lb)





Image from <https://sites.gatech.edu/robotic-caregivers/> .









# A Capable Robot

<https://www.youtube.com/c/HelloRobot/videos>

# Teleoperated Home Examples



<https://www.youtube.com/c/HelloRobot/videos>

# Teleoperated Workplace Examples



**Shelf Picking**



**Inspection with a Camera**

<https://www.youtube.com/c/HelloRobot/videos>

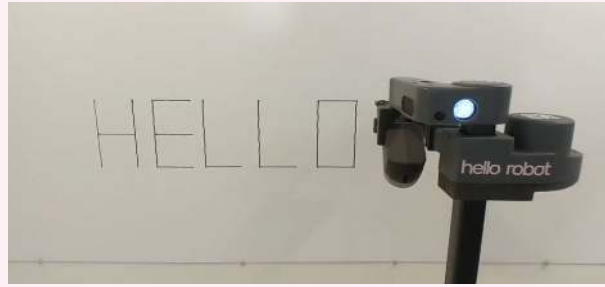
# Teleoperated Examples with the Dexterous Wrist



<https://www.youtube.com/c/HelloRobot/videos>

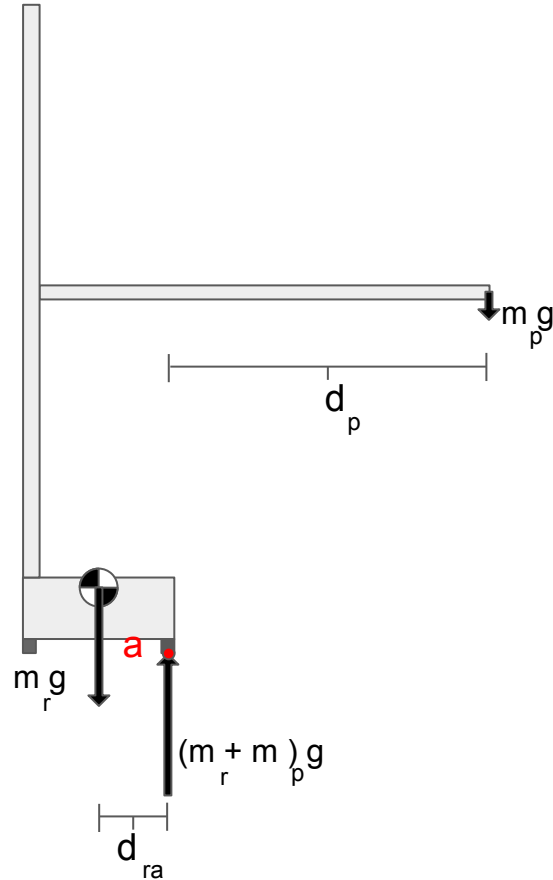


# Autonomous Examples

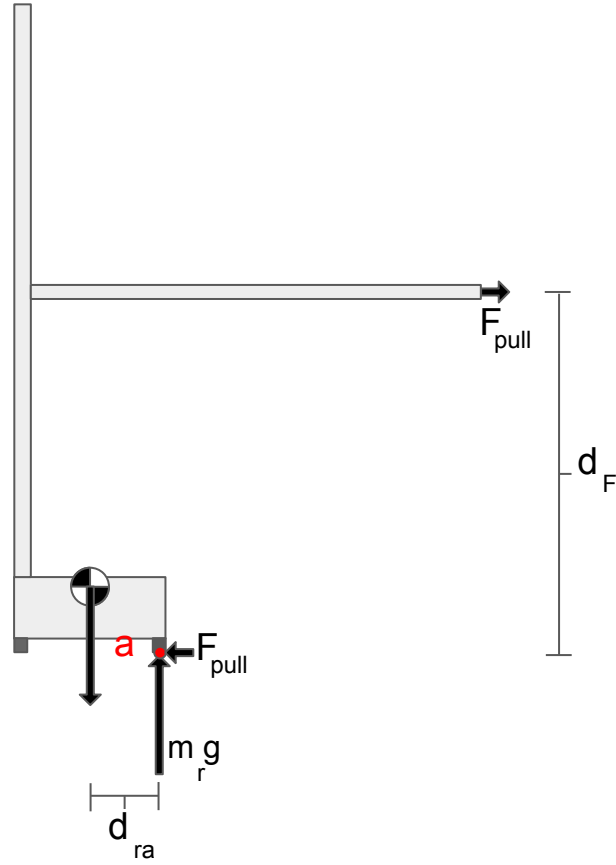


<https://forum.hello-robot.com/t/autonomy-video-details>

# Tipping from Payload

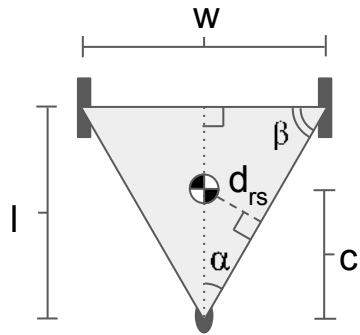


# Tipping from Pulling

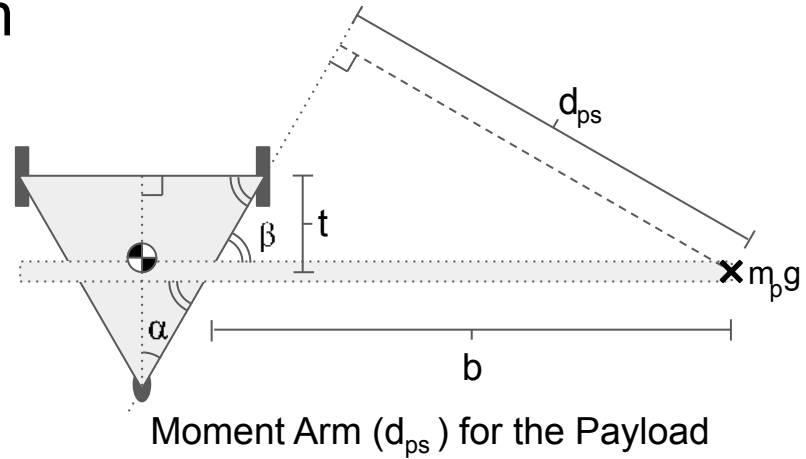




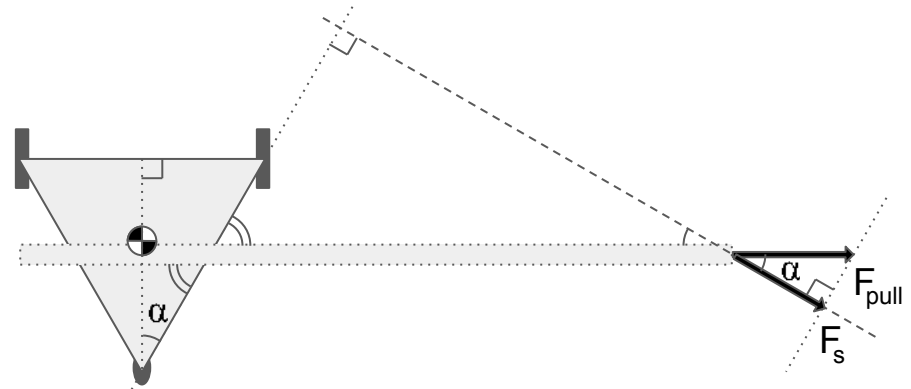
# Triangular Support Polygon



Moment Arm ( $d_{rs}$ ) for the Robot's Center of Mass



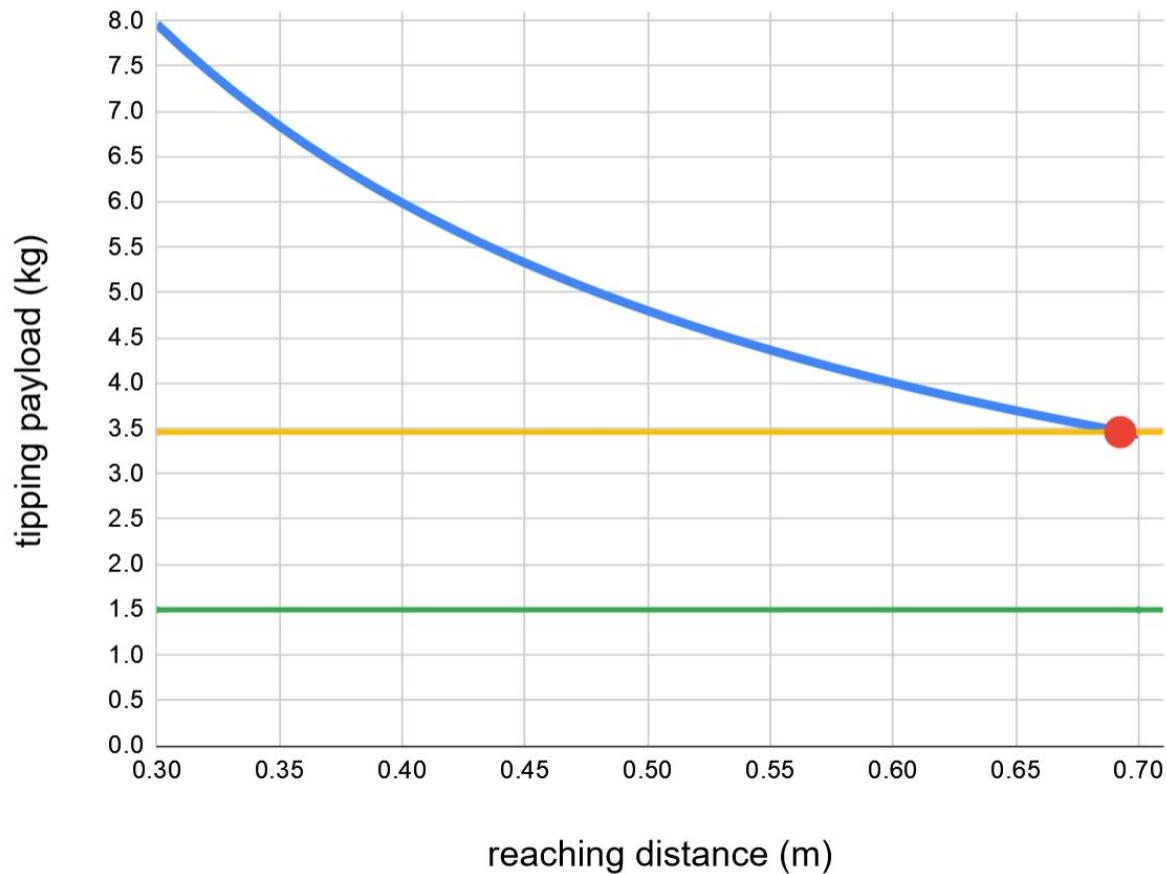
Moment Arm ( $d_{ps}$ ) for the Payload



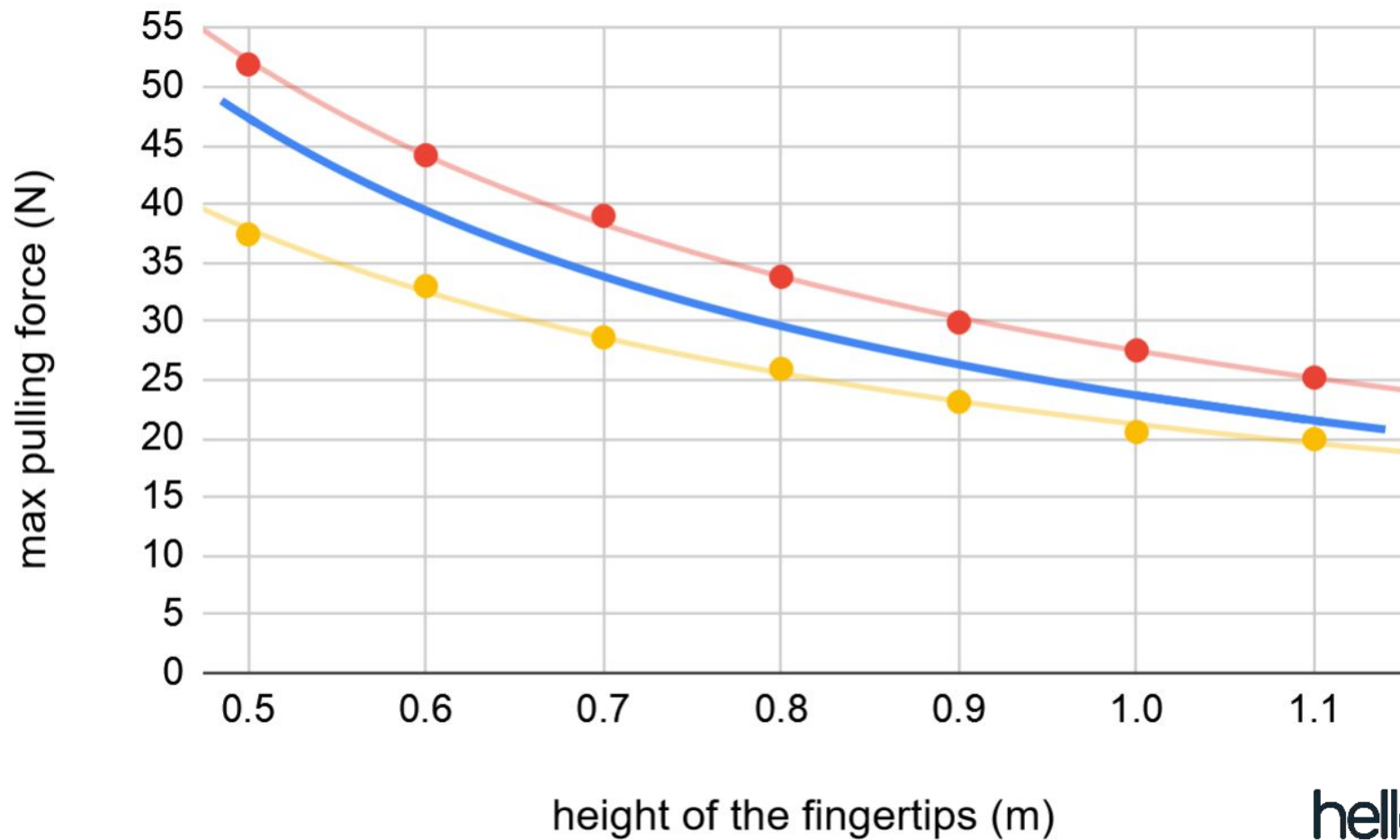
Tipping Component ( $F_s$ ) of the Pulling Force

# Maximum Payload with Gripper

— Modeled ● Measured — No Safety Margin — Specification (no gripper)



— model predictions   ● arm fully retracted   ● arm fully extended



Community is our Priority

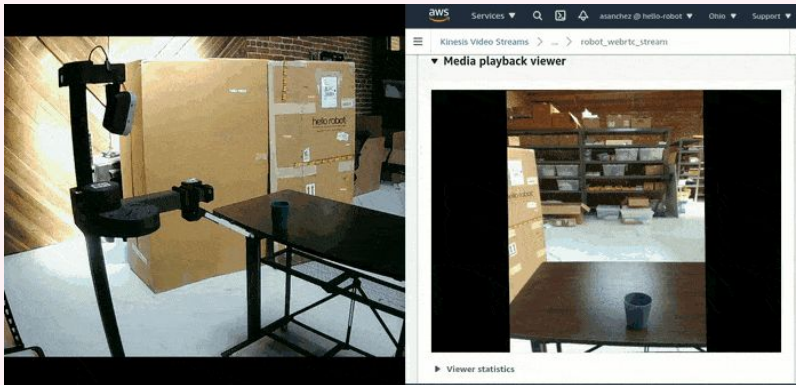
# First Internship Program (Summer 2021)

Alan Sanchez

from Prof. Bill Smart's lab!



## AWS RoboMaker with Stretch



<https://forum.hello-robot.com/t/using-stretch-with-aws-robotics-streaming-video/269>

[https://github.com/hello-robot/stretch\\_aws\\_robotics\\_video\\_streaming](https://github.com/hello-robot/stretch_aws_robotics_video_streaming)

## Excellent Tutorials

*already used in Prof. Kemp's class at Georgia Tech!*

### Stretch ROS Tutorials

1. Getting Started
2. Gazebo Basics
3. Teleoperating Stretch
4. Internal State of Stretch
5. RViz Basics
6. Navigation Stack
7. MoveIt! Basics
8. Follow Joint Trajectory Commands
9. FUNMAP
10. Microphone Array
11. ROS testing
12. Other Nav Stack Features
13. Perception
14. 4 Modes of Stretch

### Other ROS Examples

To help get you get started on your software development, here are examples of nodes to have the stretch perform simple tasks.

1. **Teleoperate Stretch with a Node** - Use a python script that sends velocity commands.
2. **Filter Laser Scans** - Publish new scan ranges that are directly in front of Stretch.
3. **Mobile Base Collision Avoidance** - Stop Stretch from running into a wall.
4. **Give Stretch a Balloon** - Create a "balloon" marker that goes where ever Stretch goes.

[https://github.com/hello-sanchez/stretch\\_ros\\_tutorials](https://github.com/hello-sanchez/stretch_ros_tutorials)



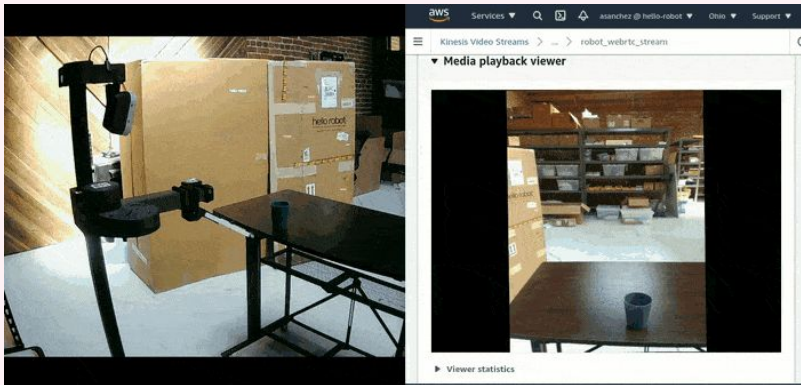
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## AWS RoboMaker with Stretch



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[https://github.com/hello-robot/stretch\\_aws\\_robotics\\_video\\_streaming](https://github.com/hello-robot/stretch_aws_robotics_video_streaming)

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[https://github.com/hello-sanchez/stretch\\_ros\\_tutorials](https://github.com/hello-sanchez/stretch_ros_tutorials)

Open Development!

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[David Lu!!](#) from [PickNik](#) was recently [featured at Inc.](#)

*He earned his PhD with Prof. Bill Smart!*

<https://www.inc.com/kevin-j-ryan/picknik-robotics-inc-5000.html>

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**SOME PEOPLE THINK YOU CAN'T GET GOOD PUBLICITY  
IF YOU RELEASE YOUR CODE TO OPEN SOURCE**



**BUT THAT'S NONE OF MY BUSINESS**



[David Lu!!](#) from [PickNik](#) was recently [featured at Inc.](#)

*He earned his PhD with Prof. Bill Smart!*

<https://twitter.com/probablydavid/status/1456734989245198336>

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# Community Contributions



**[Nathan Wright](#)**

UMass Lowell, Computer Science undergrad

Octomap and RTabMap for Stretch now in official repository!

[https://github.com/hello-robot/stretch\\_ros/pull/37](https://github.com/hello-robot/stretch_ros/pull/37)



**[Nick Walker](#)**

University of Washington, Computer Science PhD Student

Improved PID gains for Gazebo simulation

[https://github.com/hello-robot/stretch\\_ros/pull/40](https://github.com/hello-robot/stretch_ros/pull/40)



# Human Fusions at ANA Avatar XPRIZE Semifinals



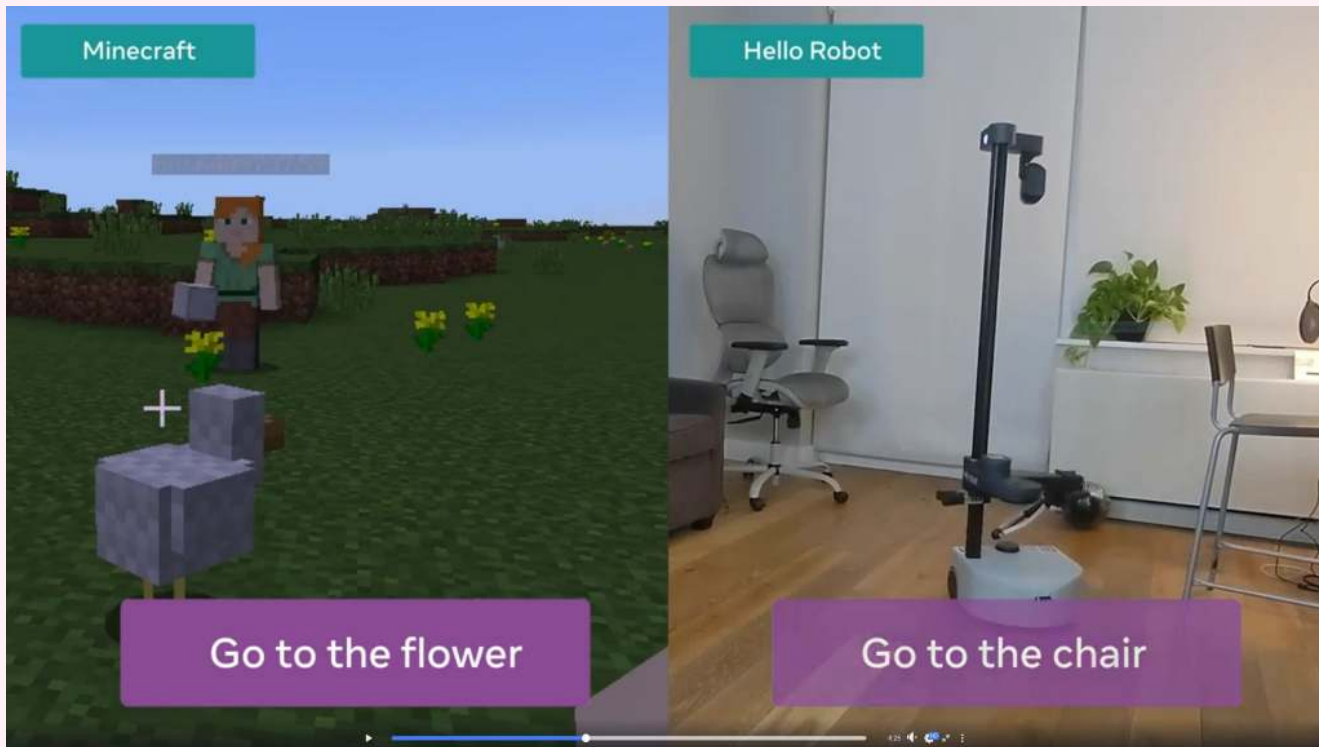
**Prof. Veronica Santos from UCLA**



<http://humanfusions.org/ana-avatar-xprize.html>

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# Droidlet from Facebook



<https://ai.facebook.com/blog/droidlet-a-one-stop-shop-for-modularly-building-intelligent-agents>

# Assistive Robotics at the University of Washington

21 people, including 3 people with disabilities, remotely operated Stretch

Cabrera, Maria E., Tapomayukh Bhattacharjee, Kavi Dey, and Maya Cakmak. "[An Exploration of Accessible Remote Tele-operation for Assistive Mobile Manipulators in the Home.](#)" In *2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN)*, pp. 1202-1209. IEEE, 2021.



**Maru Cabrera**

Assistant Professor  
UMass Lowell



**Tapo Bhattacharjee**

Assistant Professor  
Cornell University



**Kavi Dey**

Research Intern  
Seattle Academy



**Maya Cakmak**

Associate Professor  
University of Washington



[UW's open source web interface](#), which significantly improved [Hello Robot's original version](#).

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# Occupational Therapy Doctoral Project



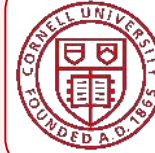
Vy Nguyen



Maya Cakmak



Kavi Dey



Tapo Bhattacharjee



Harshal Mahajan Travis Kadylak Wendy Rogers Megan Bayles



Henry & Jane Evans



Elliston Franks



Charlie Kemp



Blaine Matulevich



Binit Shah



# Stretch Provides Meaningful Assistance



<https://forum.hello-robot.com/t/summer-research-on-in-home-use-by-henry-evans>

# Stretch Provides Meaningful Assistance



<https://forum.hello-robot.com/t/summer-research-on-in-home-use-by-henry-evans>

# AI-CARING : New NSF AI Institute



- Hello Robot is an official industry partner
- Participating Institutions with Stretch
  - Umass Lowell
  - CMU
  - Georgia Tech
- Already an affiliated class at Georgia Tech
  - [Robotic Caregivers: From Dreams to Reality](#)
  - Project-based class using 3 Stretch robots
  - Taught by Prof. Kemp [using open materials](#)
- New forked class at CMU in Spring 2022
  - [Robotic Caregivers and Intelligent Physical Collaboration](#)
  - Two projects with Stretch
  - Taught by [Prof. Zackory Erickson](#)

# Live Demo of the Stretch RE1



# Questions?

Learn more at  
[hello-robot.com](https://hello-robot.com)

