Hello Robot: Democratizing Mobile Manipulation with ROS

Applications

12:20 - 12:40 CDT

Binit Shah, Aaron Edsinger, Charlie Kemp

Hello Robot presents the Stretch RE1, a compact, lightweight, and capable mobile manipulator for indoor human environments. This talk will cover the story of Stretch, the growing community and ecosystem around the platform, and the role of ROS with an emphasis on ROS 2. We will provide examples of ways universities, startups, and large companies are using Stretch, including research on assistance for people with disabilities. Notably, Hello Robot's code for Stretch is primarily in Python and all of it is open source on GitHub, including the firmware, so attendees will be able see the code for themselves.

Relevant URL

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Democratizing Mobile Manipulation with ROS

Charlie Kemp, Ph.D.
Co-founder & CTO

Binit Shah
Lead Software Engineer

www.hello-robot.com

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.

Georgia Tech

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Quick Introduction to Hello Robot

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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

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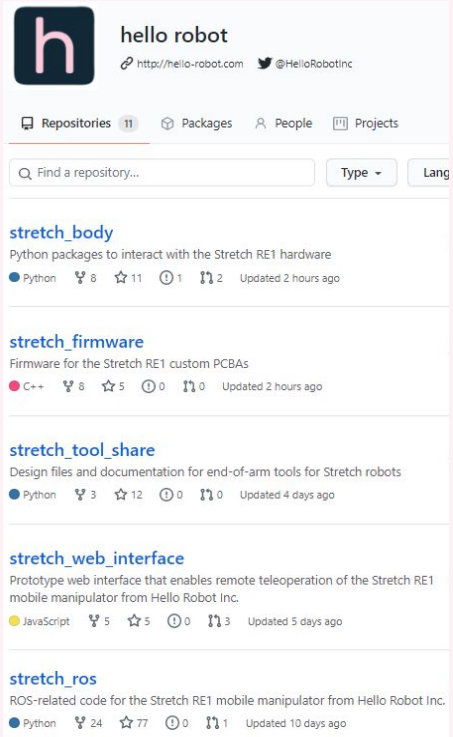
Transparency & Openness

Simple Pricing
hello-robot.com

Open Source & Open Development
github.com/hello-robot

Open Hardware Accessories
github.com/hello-robot/stretch_tool_share

Open Forum
forum.hello-robot.com



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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 Erico 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 commerc

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

Posted on December 14, 2020 by Andra Keay

RBR 50 INNOVATION AWARDS

BBC Sign in Home News Sport Reel Wo

NEWS

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Tech

Research robot helps with housework and other news

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www.hello-robot.com

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Democratizing Mobile Manipulation?

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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.

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Community

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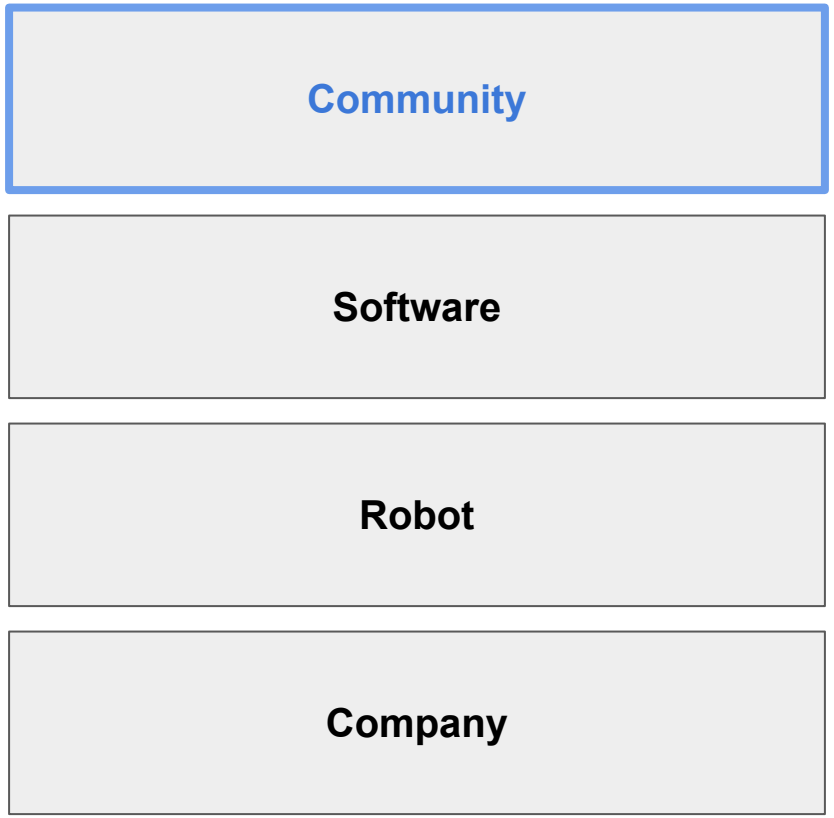
The Full Stack



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A Full Stack for Democratizing Mobile Manipulation

Community: Friendly, Diverse, Inclusive

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Hello Robot’s Origin Story

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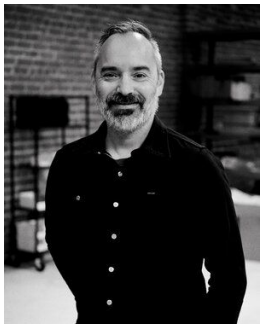
Founding Team



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

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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.

Photo Credit: *Larry D. Moore, CC BY-SA 3.0, Wikimedia Commons.*
from https://en.wikipedia.org/wiki/Roomba

The first Roomba from 2002

Almost 20 years ago!

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

Stretch's Ancestor

EL-E from 2008

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

A Point-and-Click Interface for the Real World: Laser Designation of Objects for Mobile Manipulation, Charles C. Kemp, Cressel Anderson, Hai Nguyen, Alex Trevor, and Zhe Xu, 3rd ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2008

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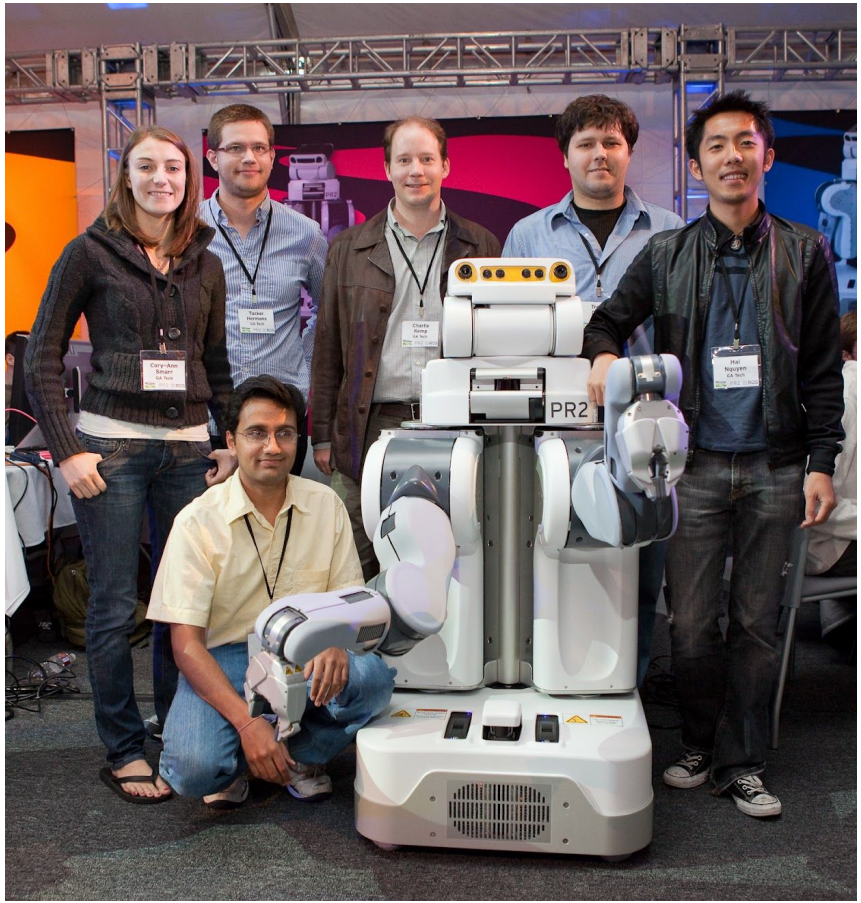
Hand It Over or Set It Down: A User Study of Object Delivery with an Assistive Mobile Manipulator, Young Sang Choi, Tiffany L. Chen, Advait Jain, Cressel Anderson, Jonathan D. Glass, and Charles C. Kemp, IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2009.

Georgia Tech

Then the World Changed

Image from
https://www.roboticstoday.com/institutions/willow-garage

Photo from
https://www.flickr.com/photos/willowgarage/4675655695/



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.

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Photo from
https://www.flickr.com/photos/willowgarage/4648144203/

Mobile Manipulators Can Provide Meaningful Assistance

research from the Healthcare Robotics Lab (healthcare-robotics.com) at Georgia Tech

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Mobile Manipulators Can Provide Meaningful Assistance

research from the Healthcare Robotics Lab (healthcare-robotics.com) at Georgia Tech

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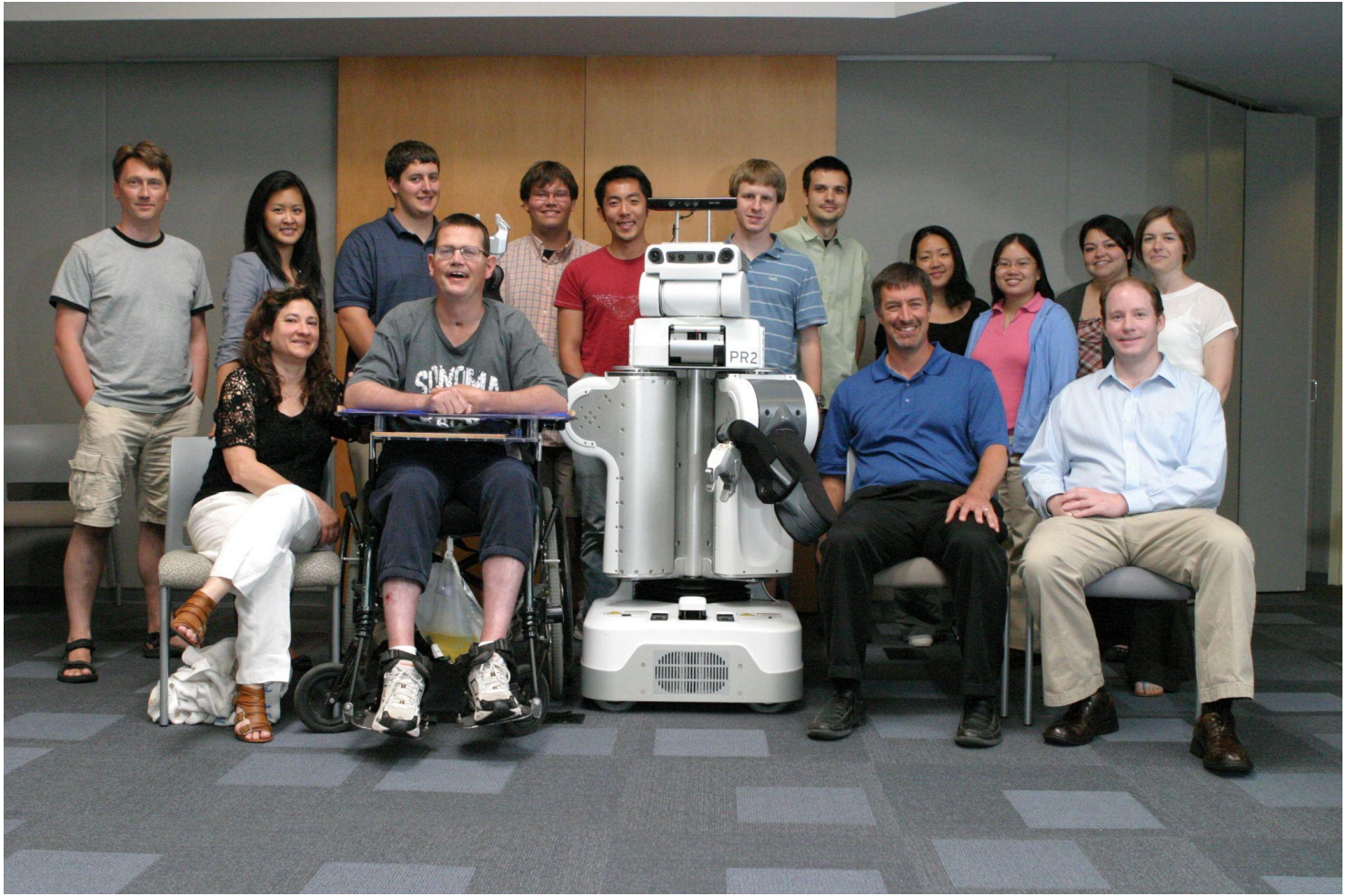
The Start of the Robots for Humanity Project



Original photo taken on June 16, 2011. Image from https://www.flickr.com/photos/willowgarage/5941309642 .

Willow Garage Shut Down in 2014

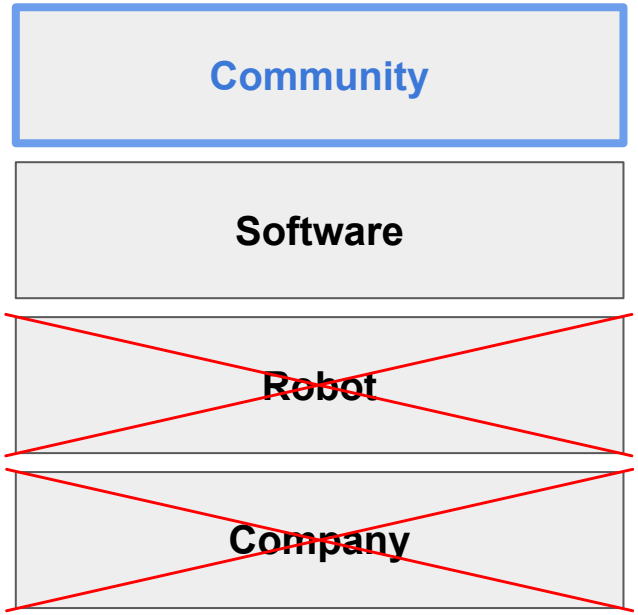


Photo from Willow Garage

PR2 Was Impractical

- $400,000
- 227 kg (~500 lb)
- 67 cm wide (~2.2 ft)

Photo from Willow Garage

2002

2010

2008

?

2017

Hourglass photo from https://commons.wikimedia.org/wiki/File:Wooden_hourglass_3.jpg

Georgia Tech's 1st Prototype
March 2017

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

2016	2017		2018	2019	2020

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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.

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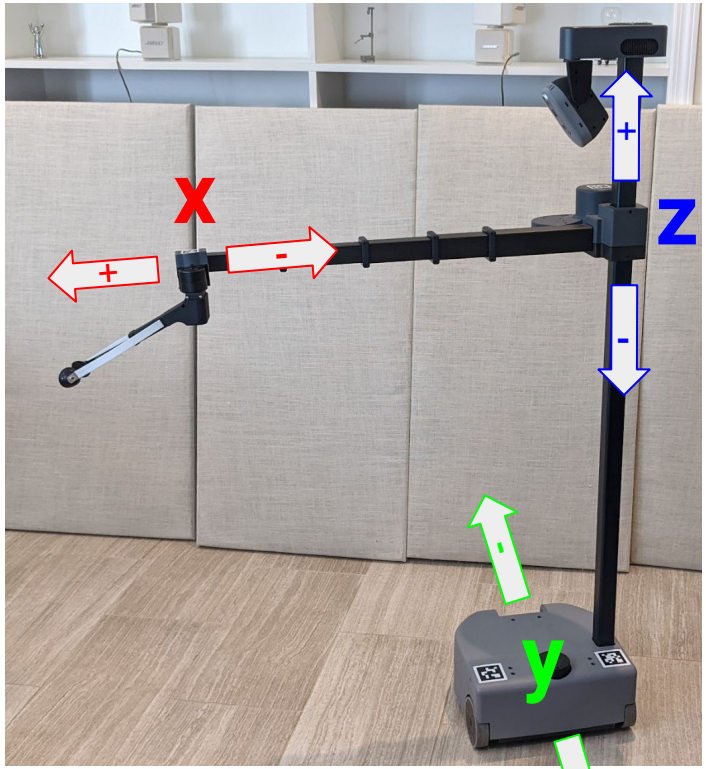
Two Modes of Operation

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)

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July 2020

3 years
8 versions
tested in Charlie's home

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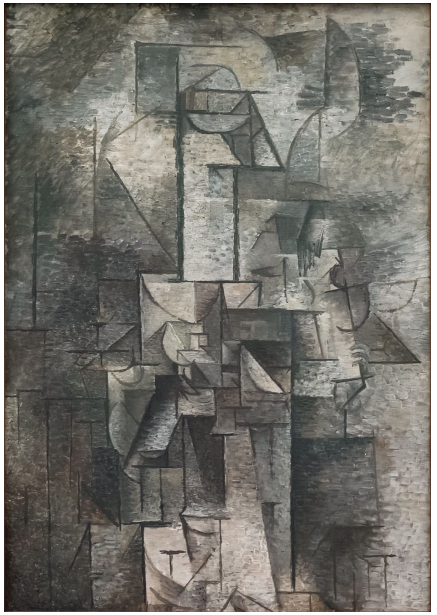
Robotic Cubism

- 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

The Design of Stretch: A Compact, Lightweight Mobile Manipulator for Indoor Human Environments, Charles C. Kemp, Aaron Edsinger, Henry M. Clever, Blaine Matulevich, preprint on arxiv.org, 2021.

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< 50th Percentile Hip Width

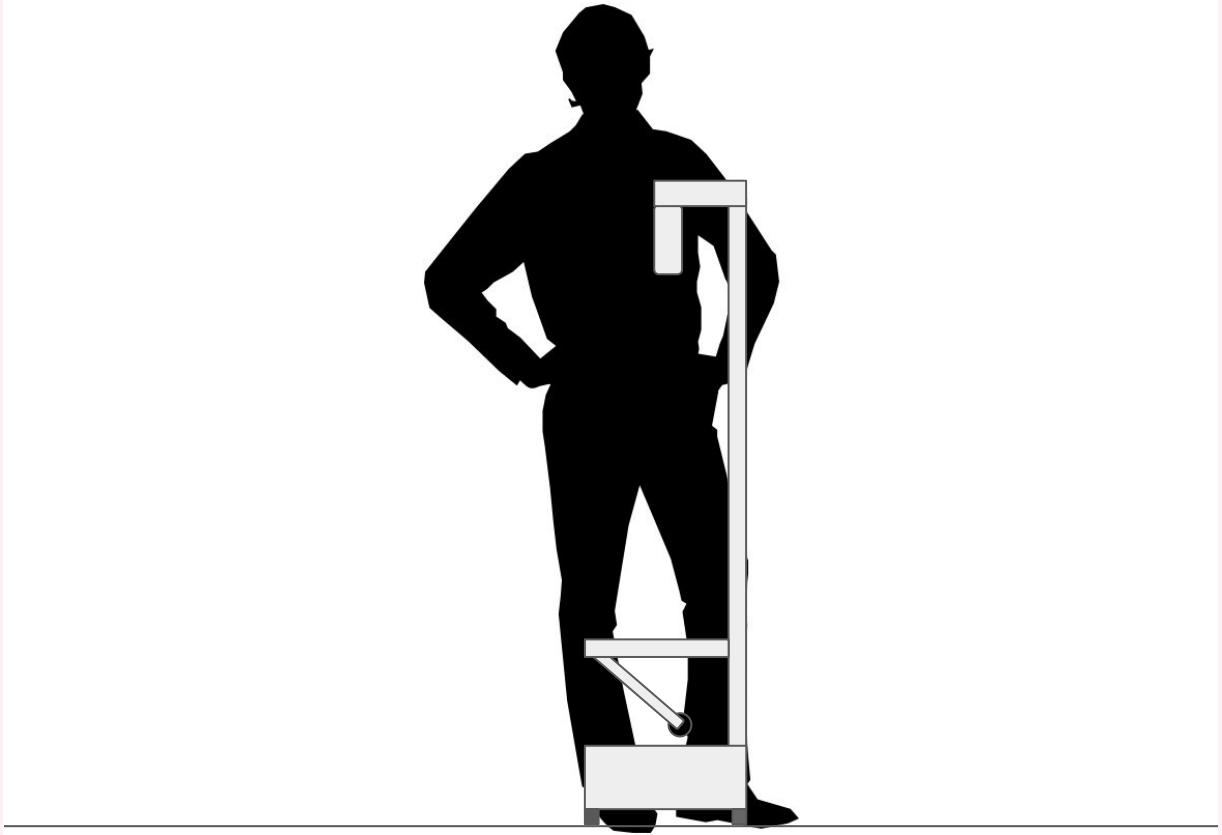

Image: https://openclipart.org/detail/260142/arms-akimbo-male

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50th Percentile Arm Length

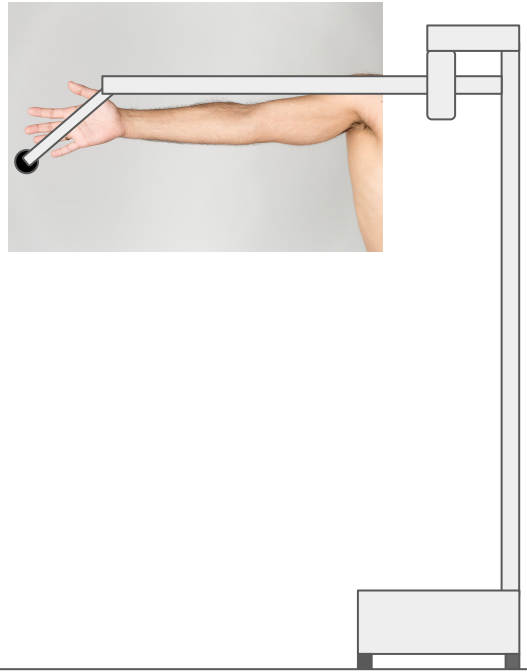

Image: https://en.wikipedia.org/wiki/Arm#/media/File:Extended_arm.jpg

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Reaches 36” Countertops

Image: https://commons.wikimedia.org/wiki/File:Butcher_block_counter_top.jpg

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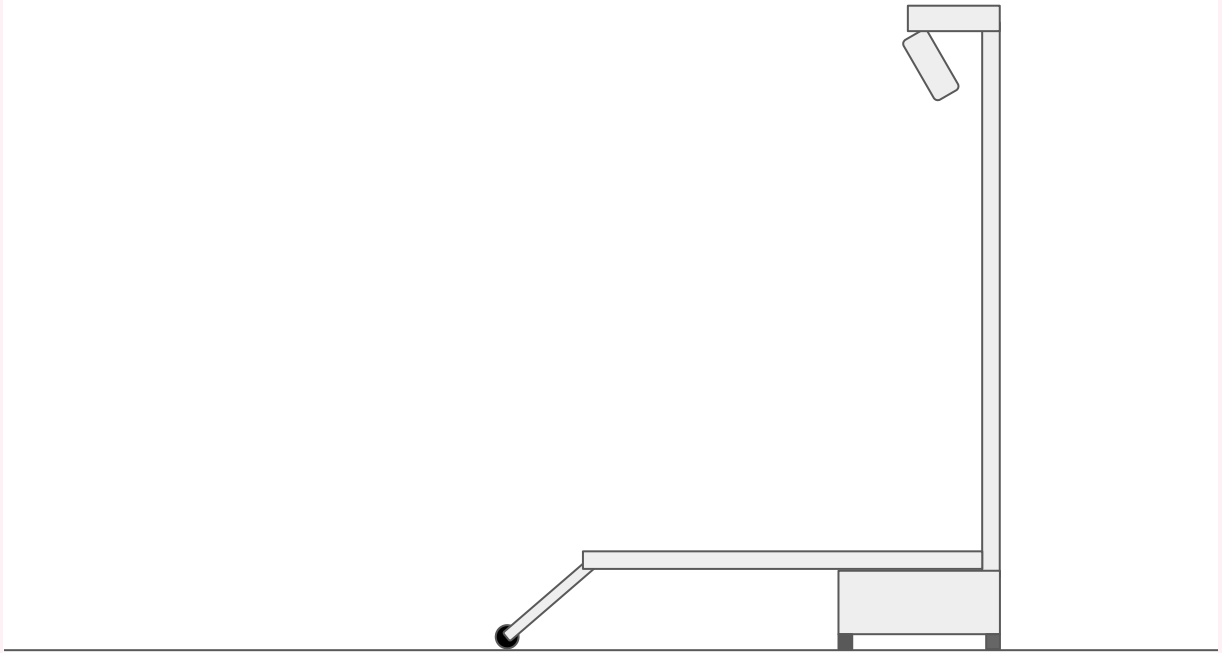
Reaches the Floor



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95th Percentile Shoulder Height for Wheelchair Users

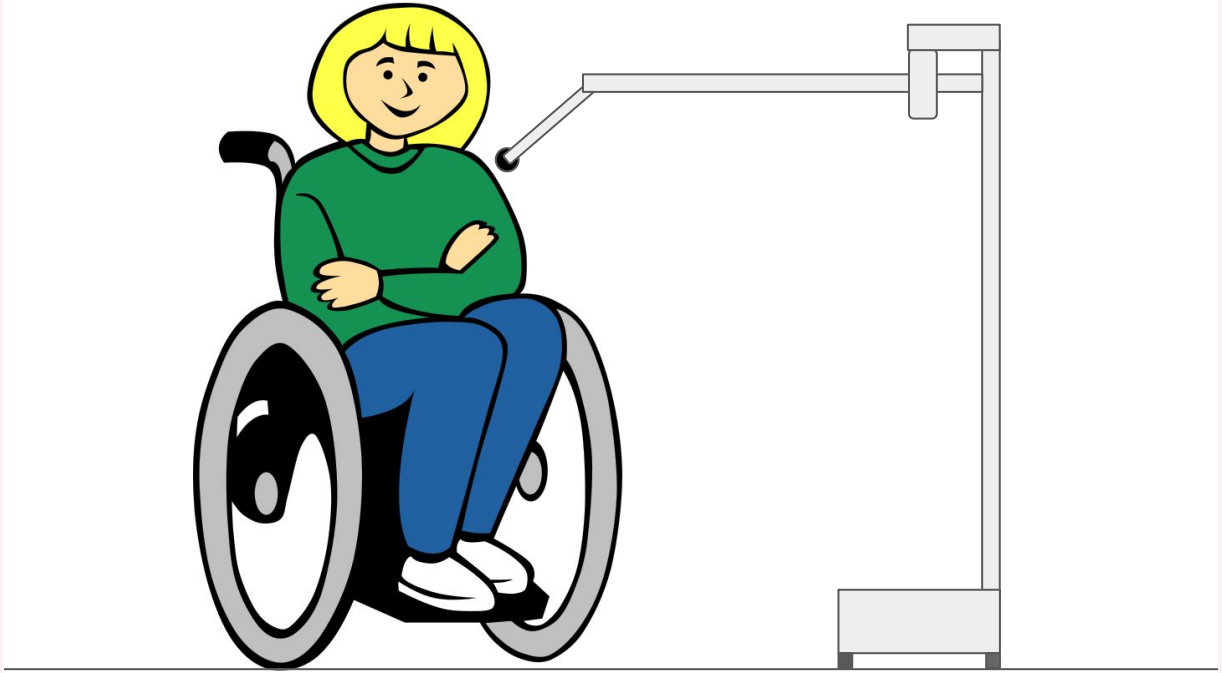

Image: https://openclipart.org/detail/510/girl-in-wheelchair

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23 kg (51 lb)

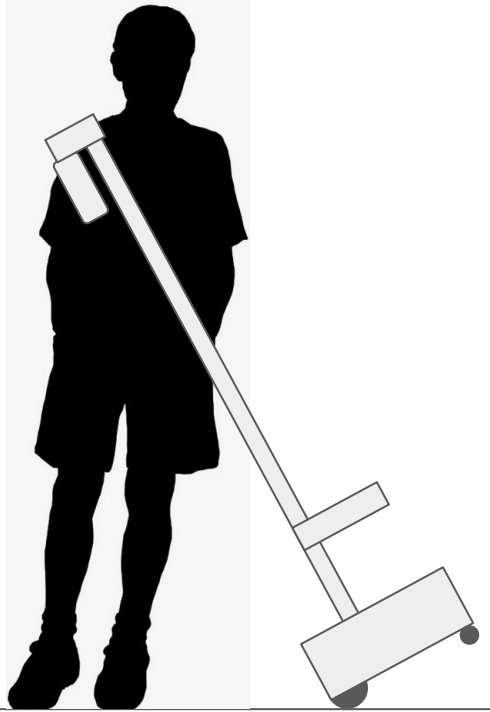

Image: https://www.seekpng.com/ipng/u2q8y3i1o0r5a9o0_beautiful-silhouettes-of-children-boy-silhouette-transparent-background/

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

V6

amp air

A Capable Robot

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

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Teleoperated Home Examples

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

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Teleoperated Workplace Examples

Shelf Picking

Inspection with a Camera

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

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Teleoperated Examples with the Dexterous Wrist

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

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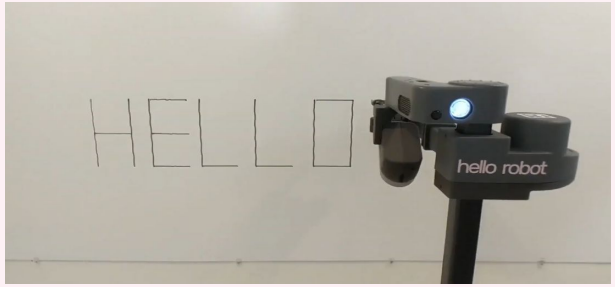
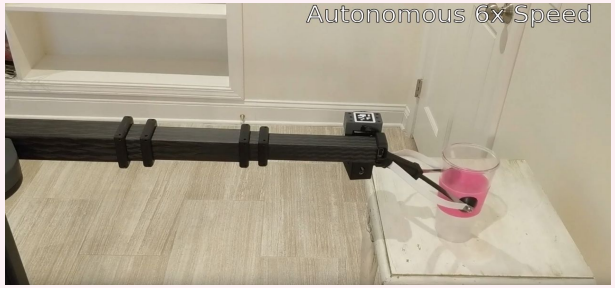
Autonomous Examples





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

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Community: Friendly, Diverse, Inclusive

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Python & ROS Inside

https://github.com/hello-robot

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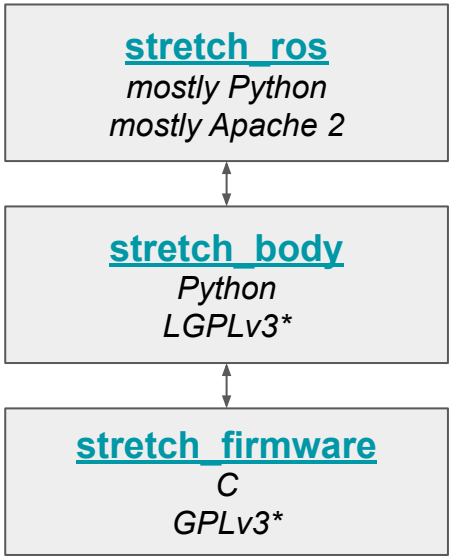
stretch_ros & stretch_ros2

- https://github.com/hello-robot/stretch_ros
  - Melodic & Noetic
  - calibration, simulation, demonstrations
- https://github.com/hello-robot/stretch_ros2
  - Galactic
  - MoveIt 2
    - working in simulation
    - real robot *in progress*
  - *Full ROS 2 support in progress*



*dual licensing available

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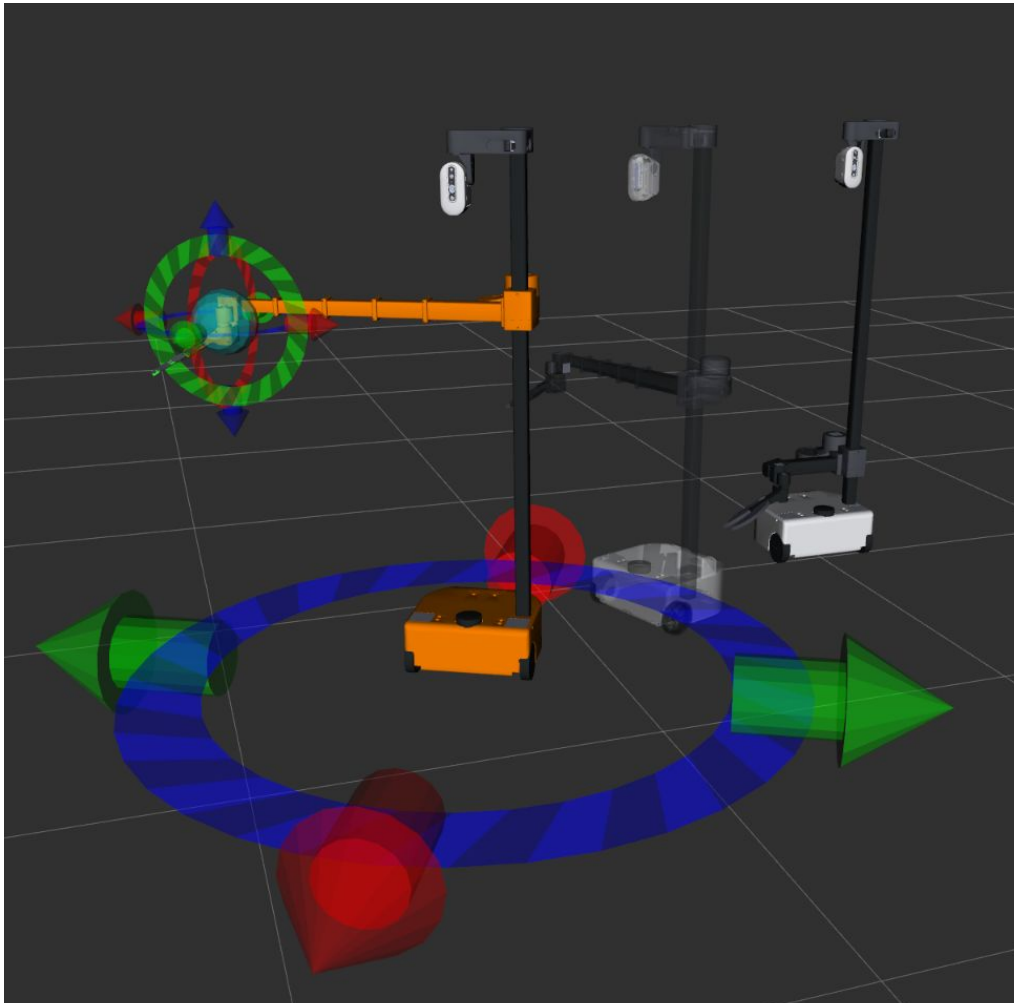
MoveIt2

PICKNIK + hello robot™

https://moveit.ros.org//events/rosworld-2021-workshop/

https://github.com/hello-robot/stretch_ros2/tree/ros_world2021



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The Stretch Community

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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

Nick Walker

University of Washington, Computer Science PhD Student

Improved PID gains for Gazebo simulation
https://github.com/hello-robot/stretch_ros/pull/40

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Human Fusions at ANA Avatar XPRIZE Semifinals

Prof. Veronica Santos from UCLA

Case Western Reserve University · UCLA · Cleveland State University 1964 · Carnegie Mellon University · UW · Tuskegee University 1881

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

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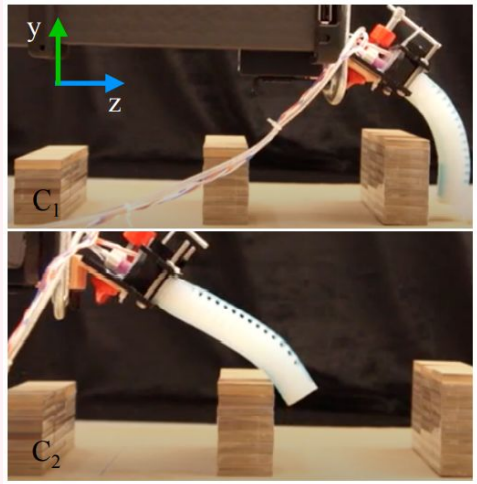
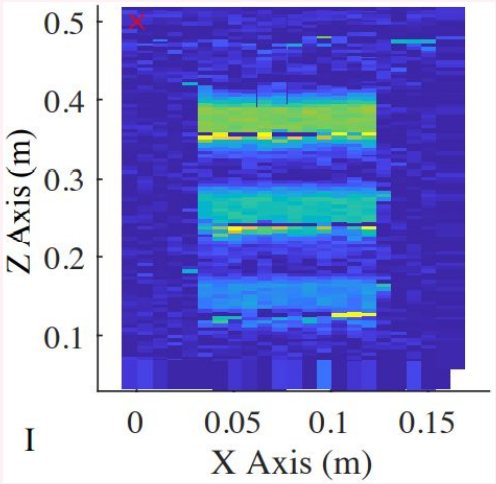
Soft Robotics at UC Santa Cruz

Megan Boivin, PhD





Boivin, Megan. "Study of Kinesthetic Feedback Control for Compliant Proprioceptive Touch for Soft Robotic Finger-Like Actuators." **PhD dissertation**, University of California, Santa Cruz, 2021.

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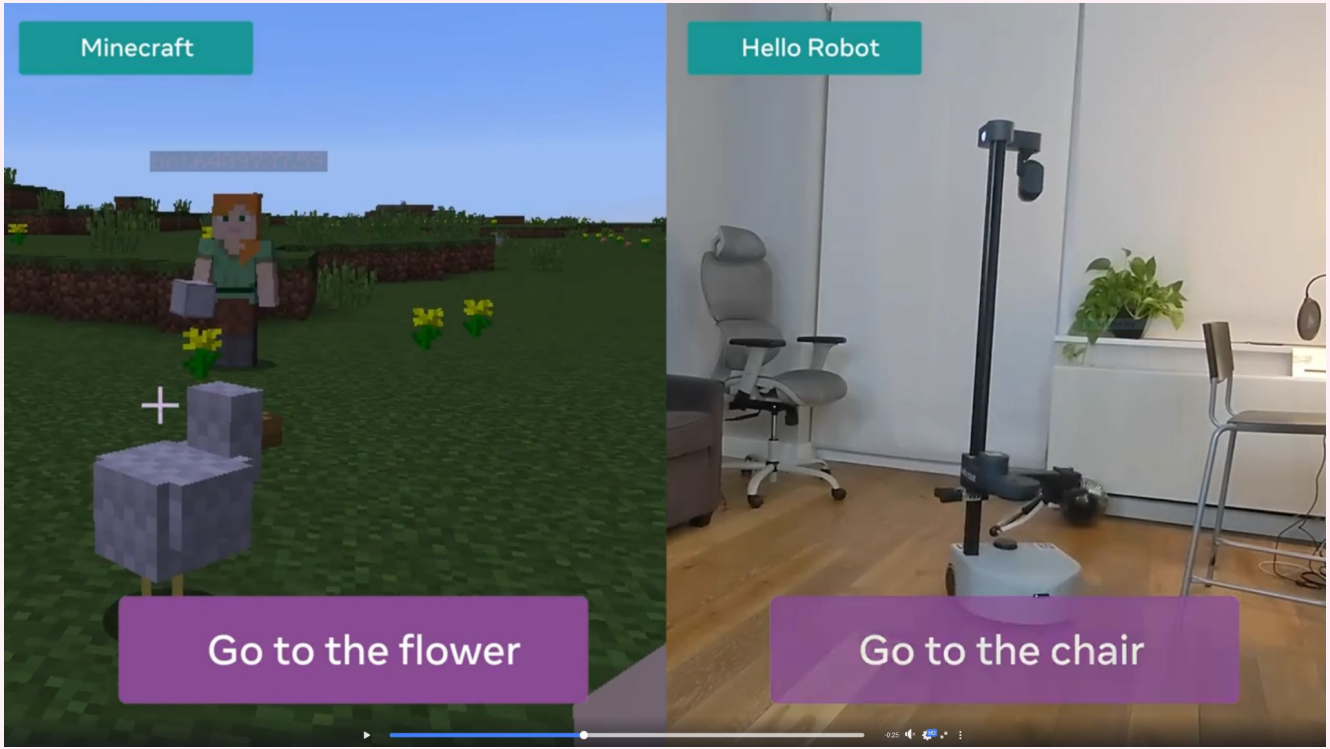
Droidlet from Facebook



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

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Assistive Robotics at the University of Washington

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

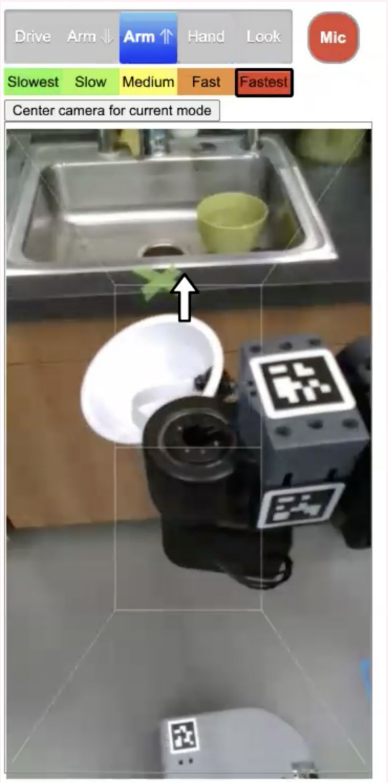
Cabrera, Maria E., Tapomayukh Bhattacharjee, Kavi Dey, and Maya Cakmak. "An Exploration of Accessible Remote Tele-operation for Assistive Mobile Manipulators in the Home." In *2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN)*, pp. 1202-1209. IEEE, 2021.

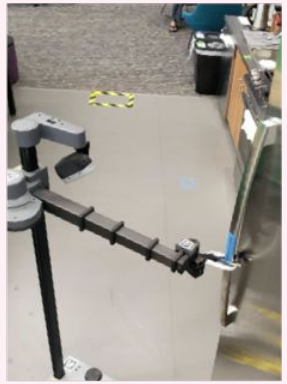
Maru Cabrera
Assistant Professor
UMass Lowell

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

Pacific University Oregon

Vy Nguyen

Henry & Jane Evans

Maya Cakmak

Kavi Dey

Tapo Bhattacharjee

Harshal Mahajan Travis Kadylak Wendy Rogers Megan Bayles

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

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Elliston Franks

Charlie Kemp

Blaine Matulevich

Binit Shah

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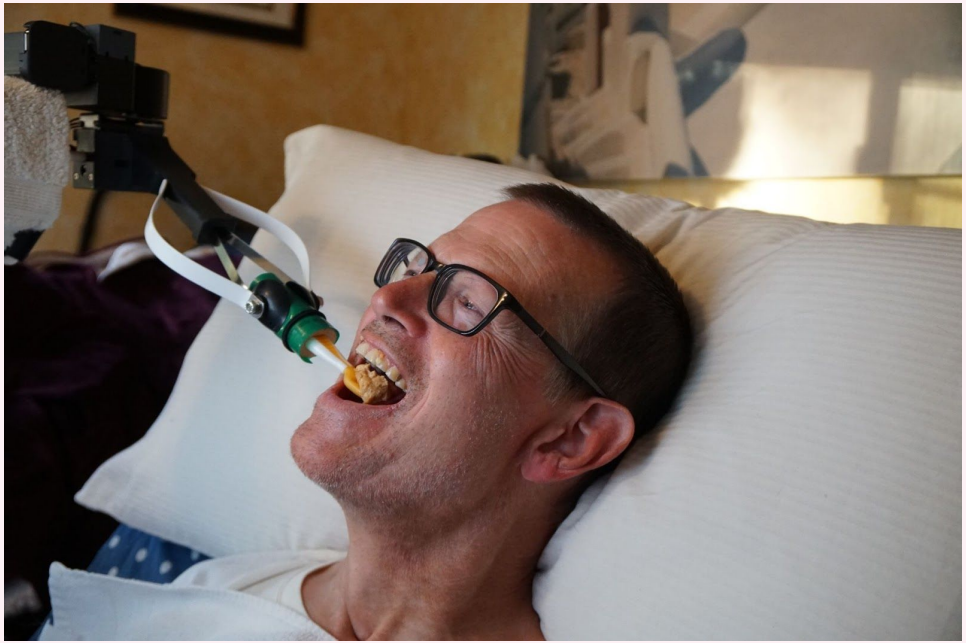
Stretch Provides Meaningful Assistance



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

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Stretch Provides Meaningful Assistance

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

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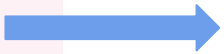
Join us! 

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Stretch: Friendly, Capable, Affordable

Hello Robot: Open, Transparent, Solvent

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Live Demo of MoveIt 2 with Stretch!

Binit Shah
Lead Software Engineer

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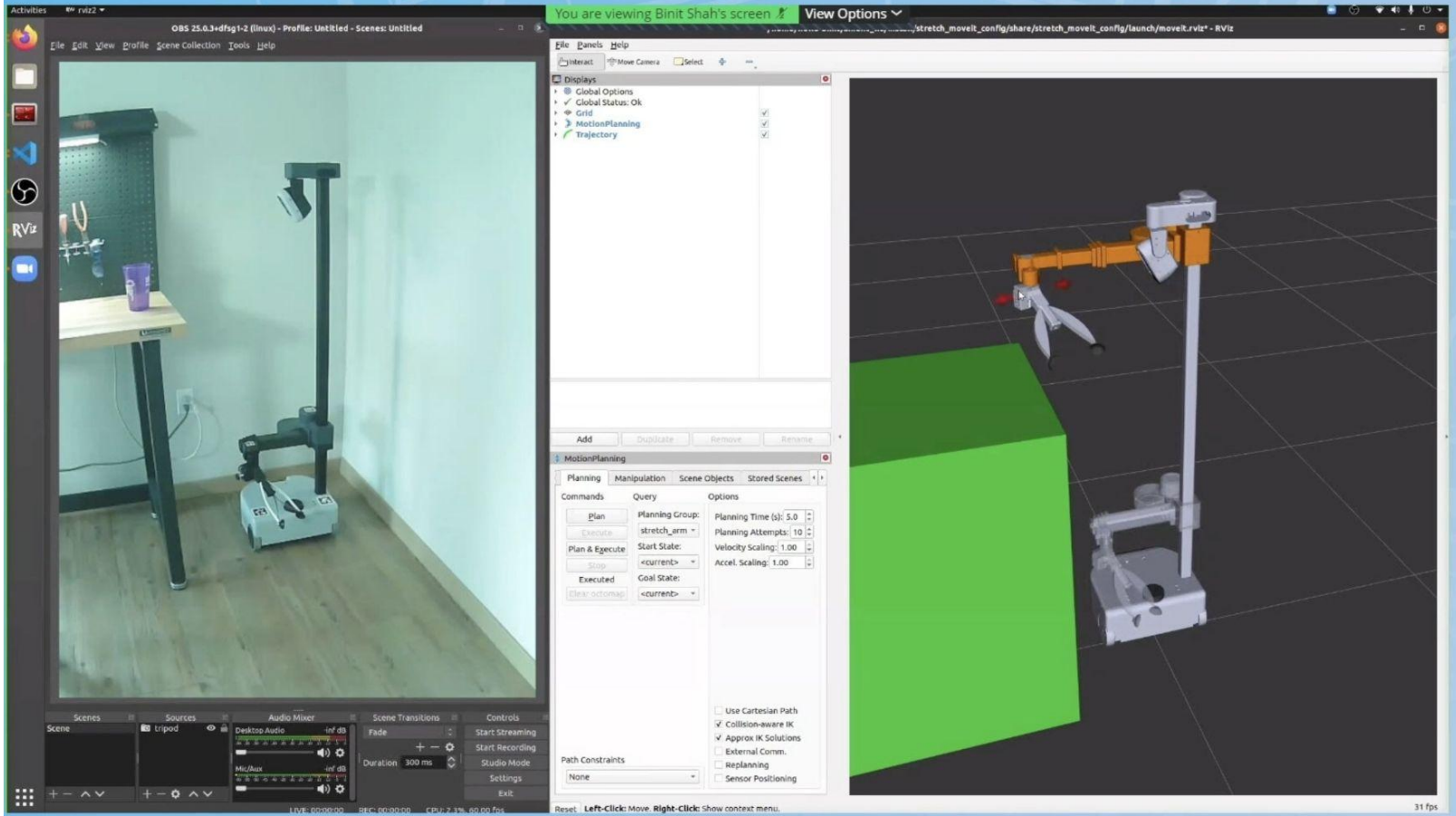

Live demo screenshot from https://twitter.com/OpenRoboticsOrg/status/1450882686256500740 .