

A Brief History of Stretch: A Friendly Mobile Manipulator for Indoor Human Environments



Charlie Kemp, PhD
<https://charliekemp.com>



Associate Professor, Department of Biomedical Engineering



Co-founder & CTO, Hello Robot Inc.

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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.



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

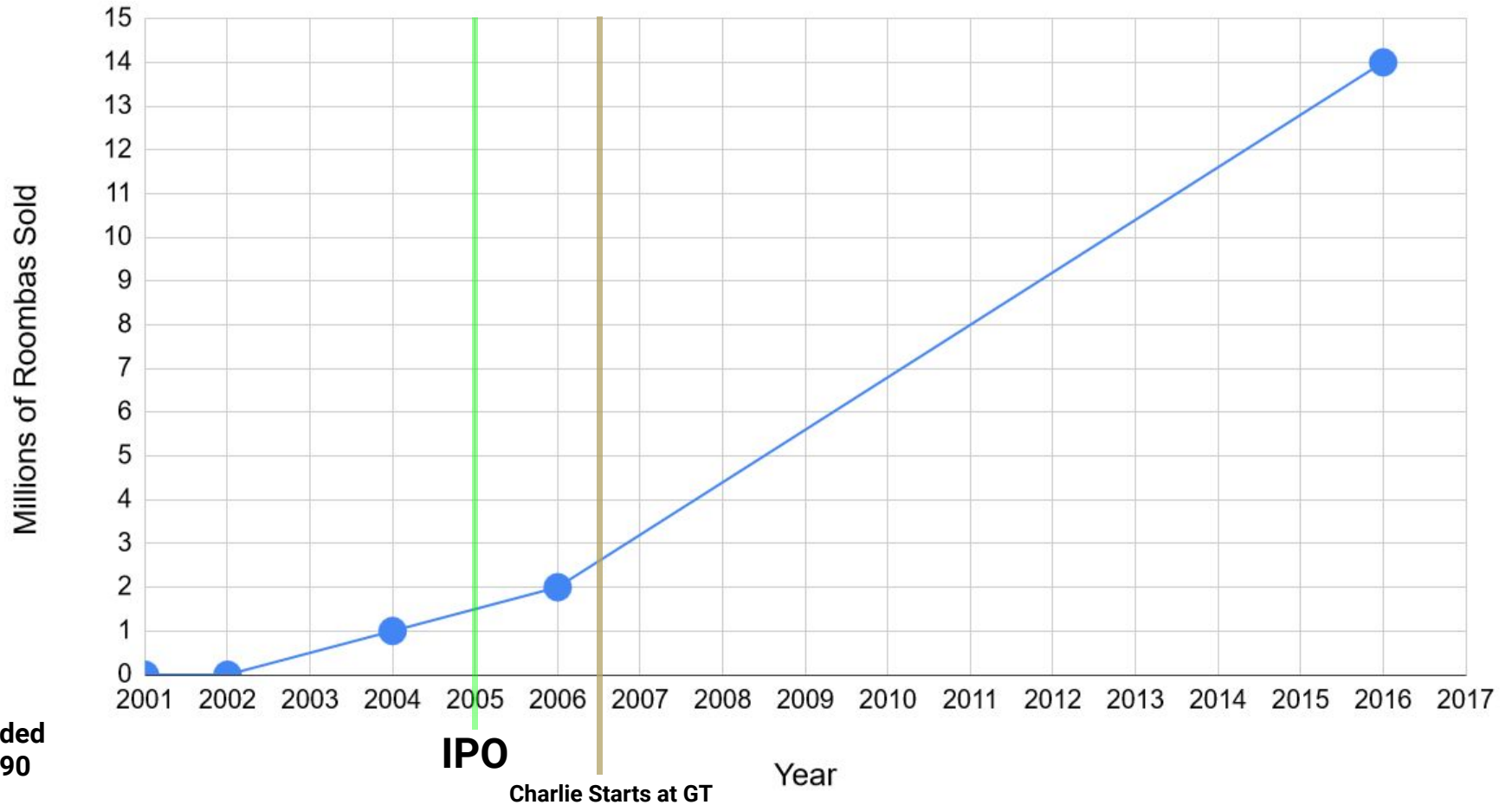
[Building Brains for Bodies](#), Rodney A. Brooks and Lynn Andrea Stein, MIT AI Lab Memo 1439, August 1993.

Photo Credit: Larry D. Moore, [CC BY-SA 3.0](https://commons.wikimedia.org/wiki/File:Larry_D._Moore_-_iRobot_Roomba_Vacuum_Cleaner.jpg),
Wikimedia Commons.
from <https://en.wikipedia.org/wiki/Roomba>



**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



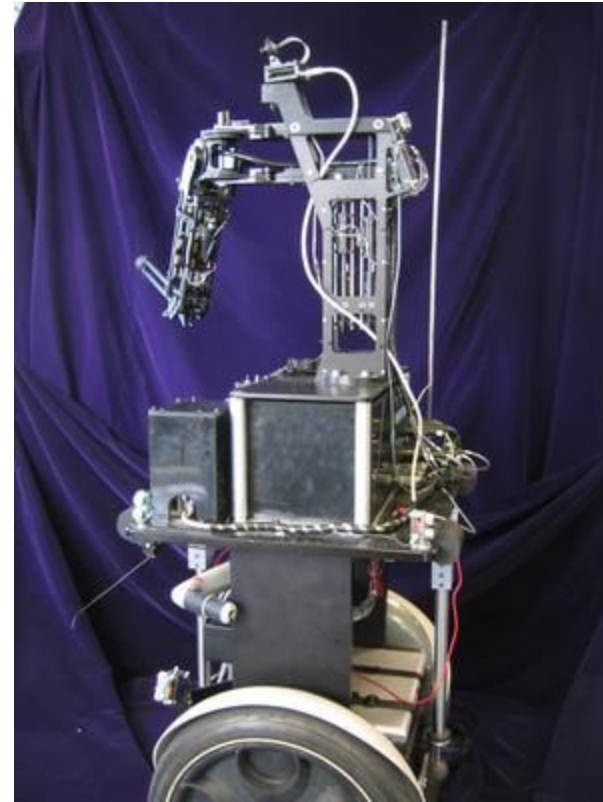
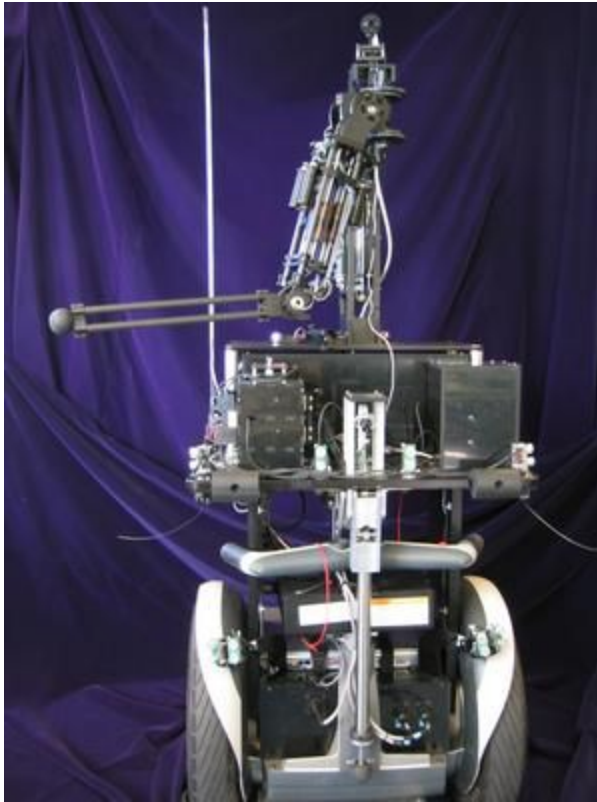
Photo Credit:
Andreas Dantz
Roomba, first attempt
Taken on April 14, 2013
<https://www.flickr.com/photos/szene/8649326807/in/pool-roomba/>

What is the Roomba of mobile manipulation?

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

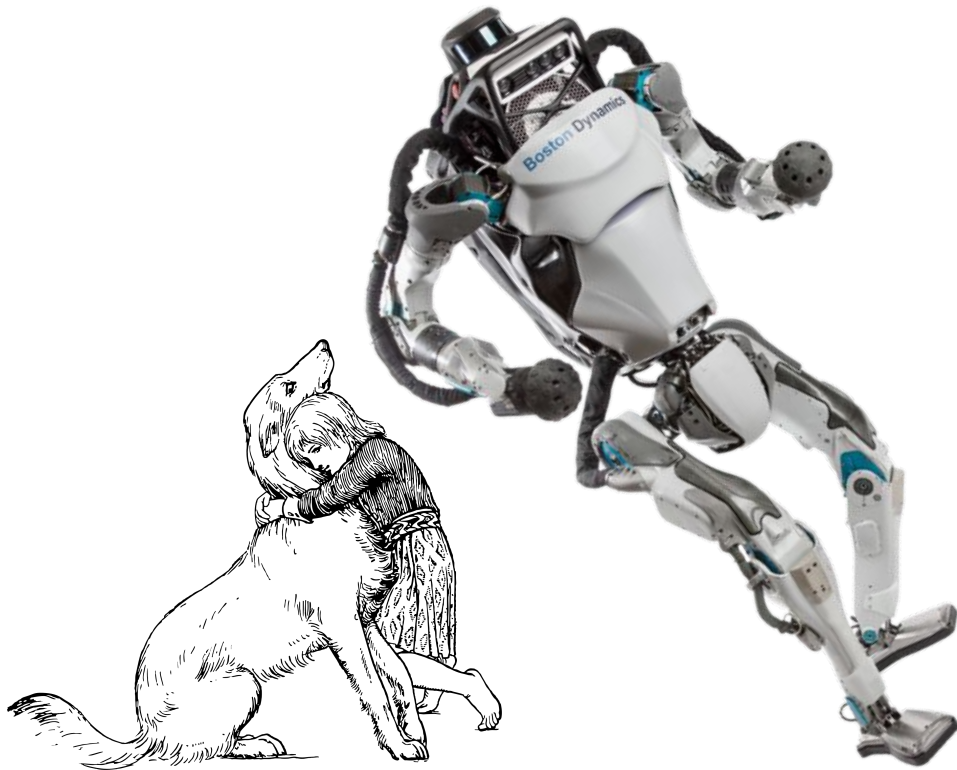
- Flat smooth surfaces
- Visible from human head height
- Reachable by human arms
- Children, older adults, and pets





[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.

It Just Takes One Fall



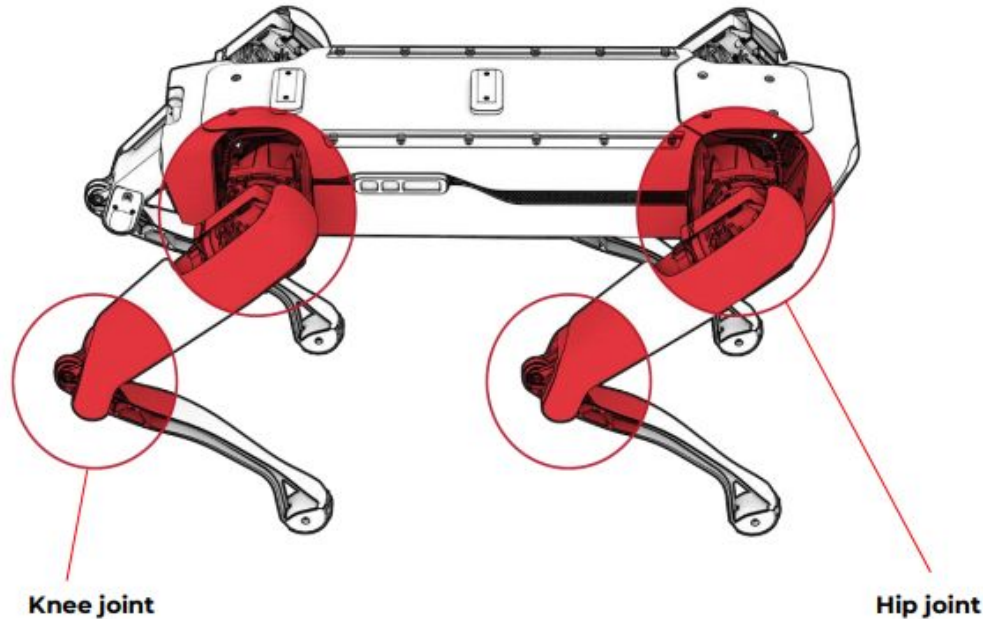


What about quadrupeds?



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.

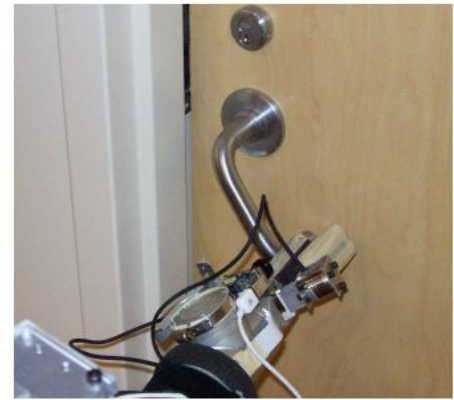
Always keep a separation distance of 2 m

What is the Roomba of mobile manipulation?

My Lab's Initial Answer (EL-E)

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





[Behaviors for Robust Door Opening and Doorway Traversal with a Force-Sensing Mobile Manipulator](#), Advait Jain and Charles C. Kemp, RSS Manipulation Workshop: Intelligence in Human Environments, 2008.



1) TV remote

2) Pill

3) Pill bottle

4) Glasses

5) Cordless phone

6) Toothbrush



7) Plastic fork

8) Plastic spoon

9) Bottle

10) Toothpaste

11) Cup

12) Plate



13) Bowl

14) Soap

15) Cellphone

16) Hand towel

17) Book

18) Dollar bill



19) Mail

20) Straw

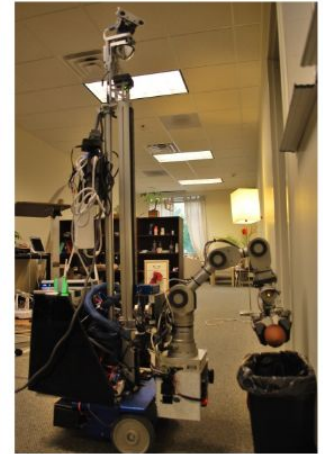
21) Keys

22) Table knife

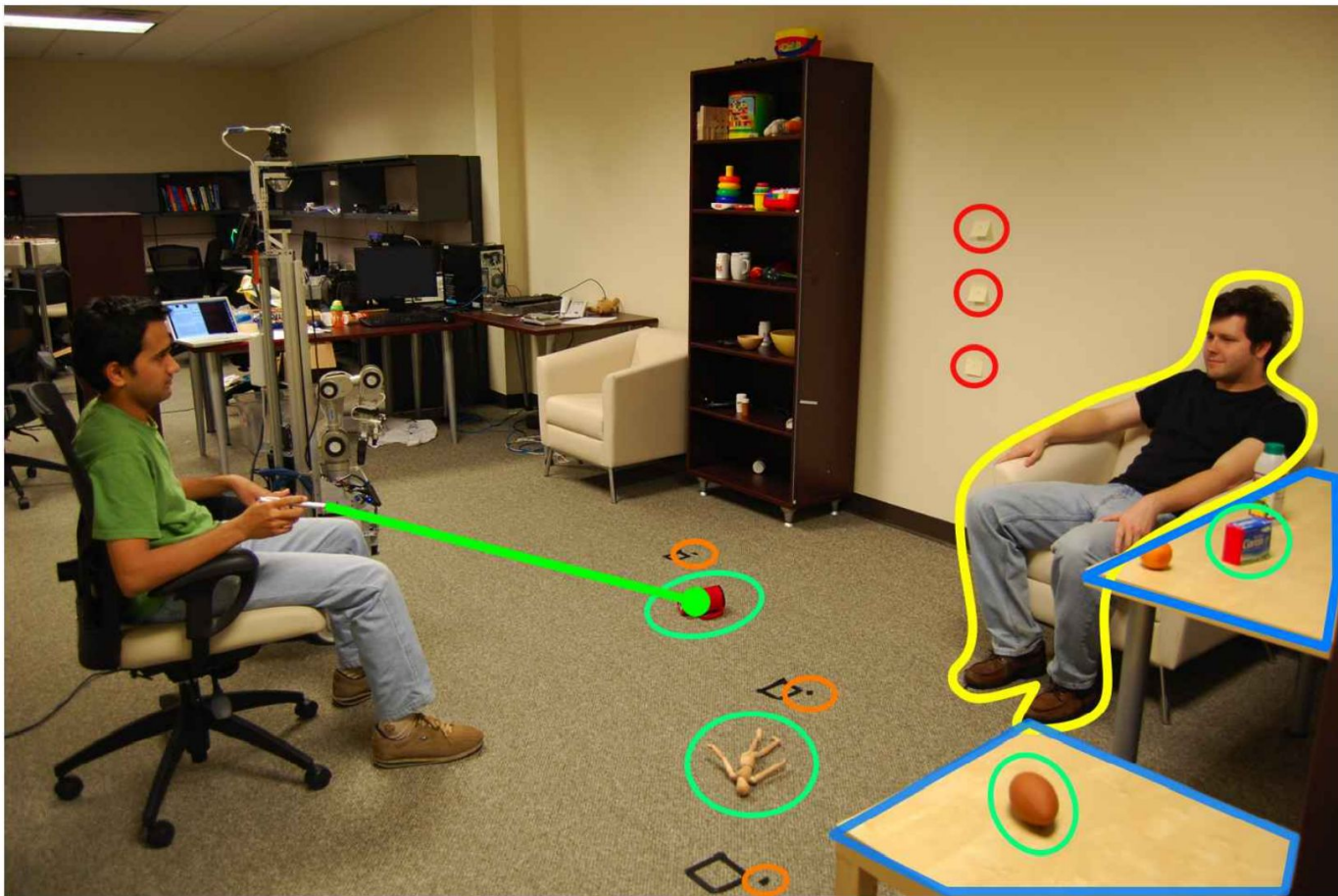
23) Slipper

24) Pencil

25) Medicine box



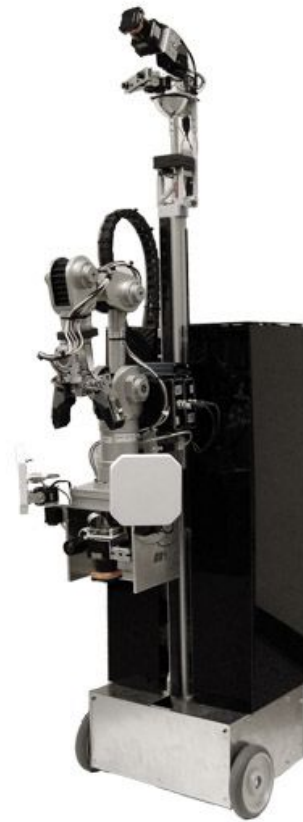
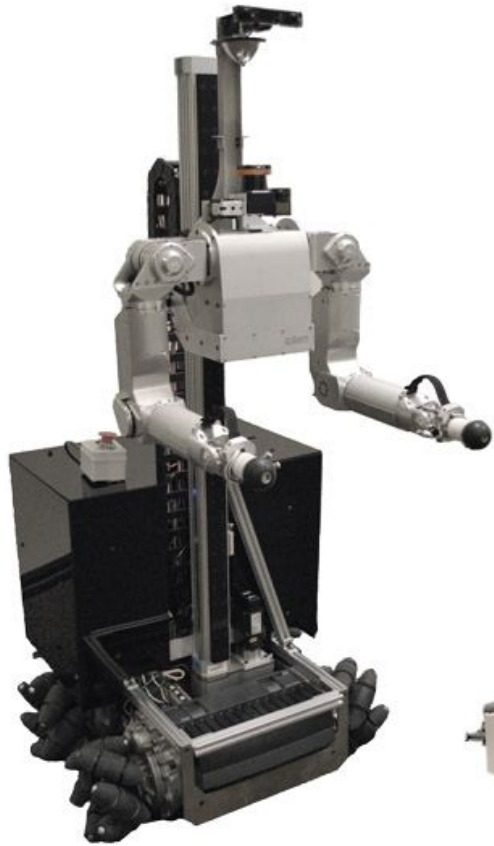
[PPS-Tags: Physical Perceptual and Semantic Tags for Autonomous Mobile Manipulation](#), Hai Nguyen, Travis Deyle, Matt Reynolds, and Charles C. Kemp, IROS 2009 workshop: Semantic Perception for Mobile Manipulation, 2009.



[A Clickable World: Behavior Selection Through Pointing and Context for Mobile Manipulation](#), Hai Nguyen, Advait Jain, Cressel Anderson, and Charles C. Kemp, IEEE/RJS International Conference on Intelligent Robots and Systems (IROS), 2008.

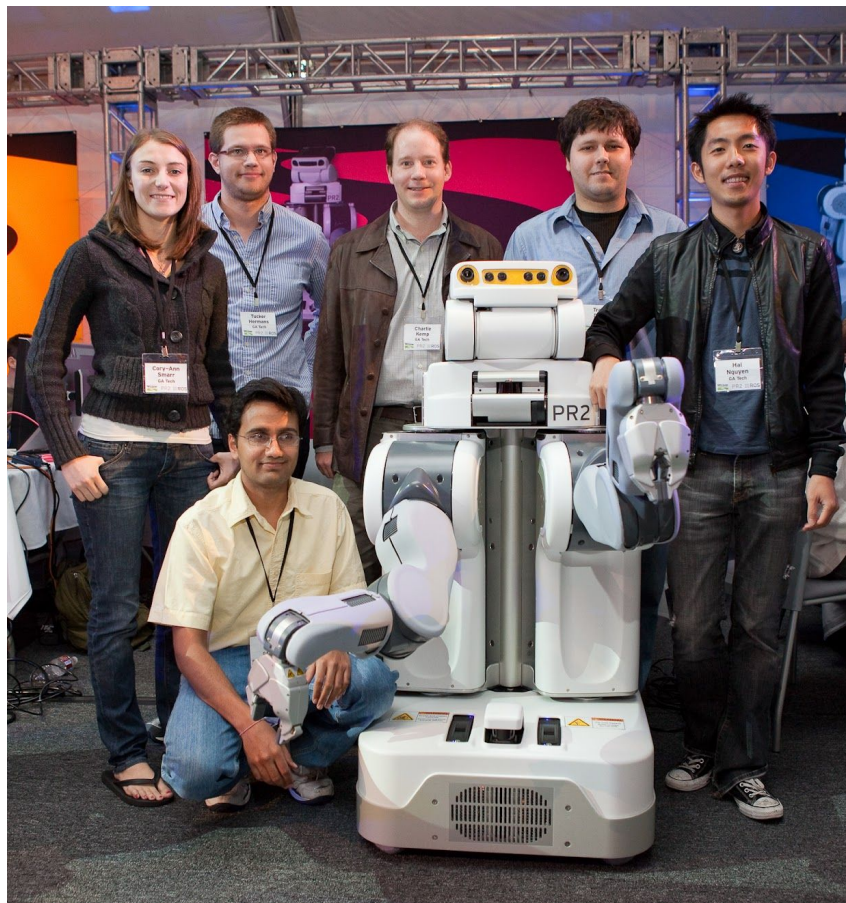


[Hand It Over or Set It Down: A User Study of Object Delivery with an Assistive Mobile Manipulator](#), Young Sang Choi, Tiffany L. Chen, Advait Jain, Cressel Anderson, Jonathan D. Glass, and Charles C. Kemp, IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2009.



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.



Photo from <https://www.flickr.com/photos/willowaraae/4648144203/>

Mobile Manipulators Can Provide Meaningful Assistance



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

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



Fetch
Cost: ~\$100,000
Footprint Width: 51cm (20")
Weight: 113 kg (250 lb)



PAL Tiago
Cost: \$58,485 (base model)
Footprint Width: 54cm (21")
Weight: 70 kg (154 lb)

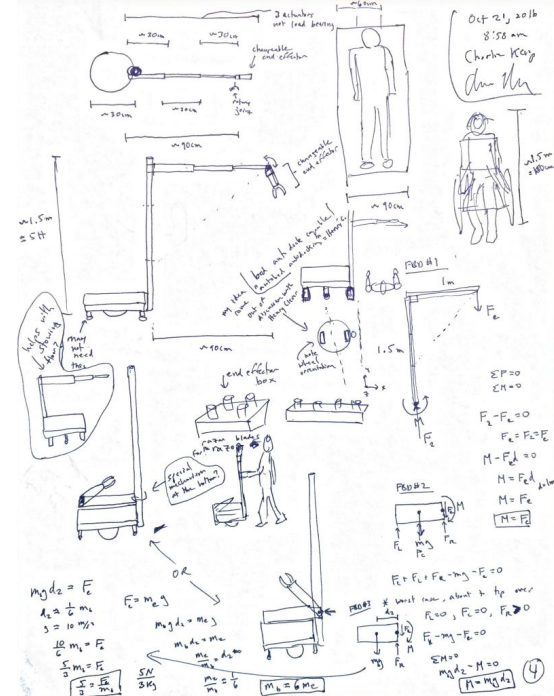


Toyota HSR
Cost: not commercially available
Footprint Width: 43cm (17")
Weight: 37 kg (82 lb)

Frustration Leads to Invention

Minimize the actuator requirements while maximizing the capabilities.

- **affordable**
- compact
- lightweight
- humancentric
- capable



My Initial Georgia Tech Notes
October 2016

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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July 2020

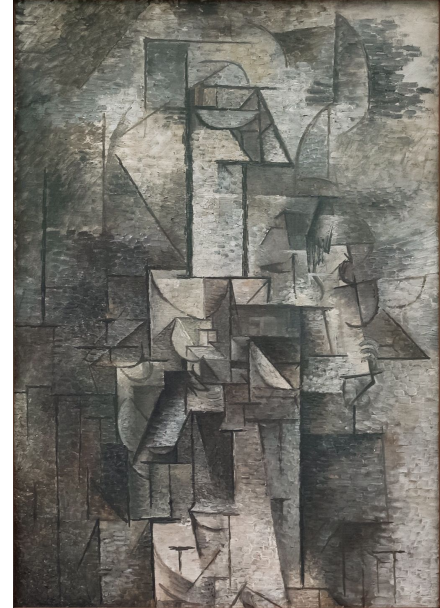
**3 years
8 versions
tested in Charlie's home**

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Robotic Cubism

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

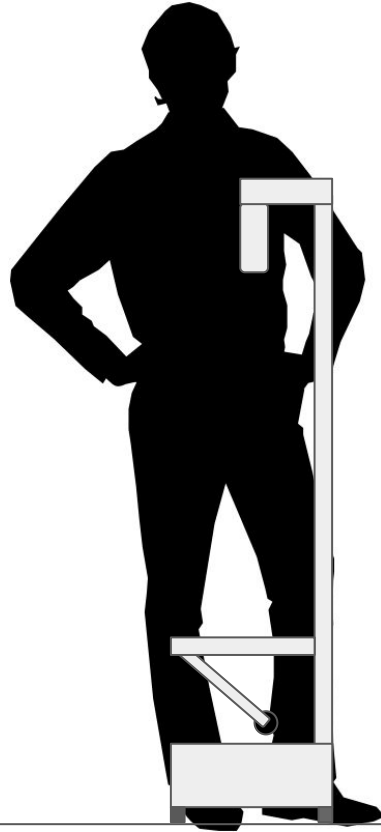
[La Femme au Violon - Pablo Picasso. 1911](#)



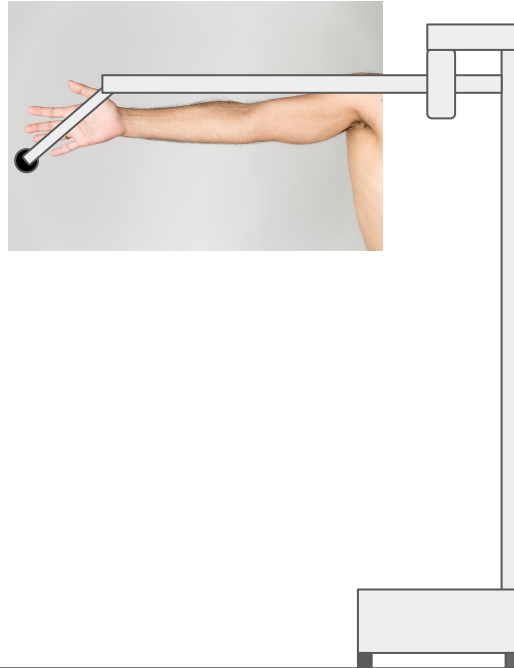
“In Cubist artwork, objects are analyzed, broken up and reassembled in an abstracted form”

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

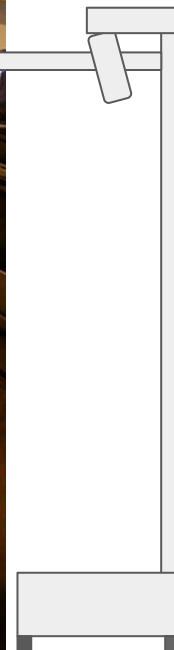
< 50th Percentile Hip Width



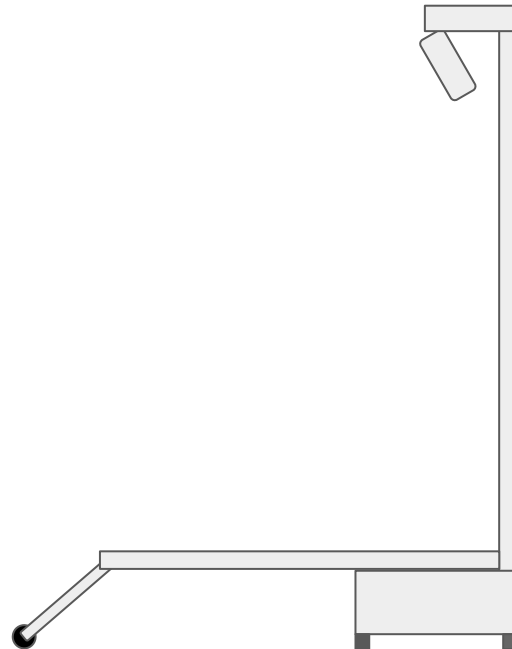
50th Percentile Arm Length



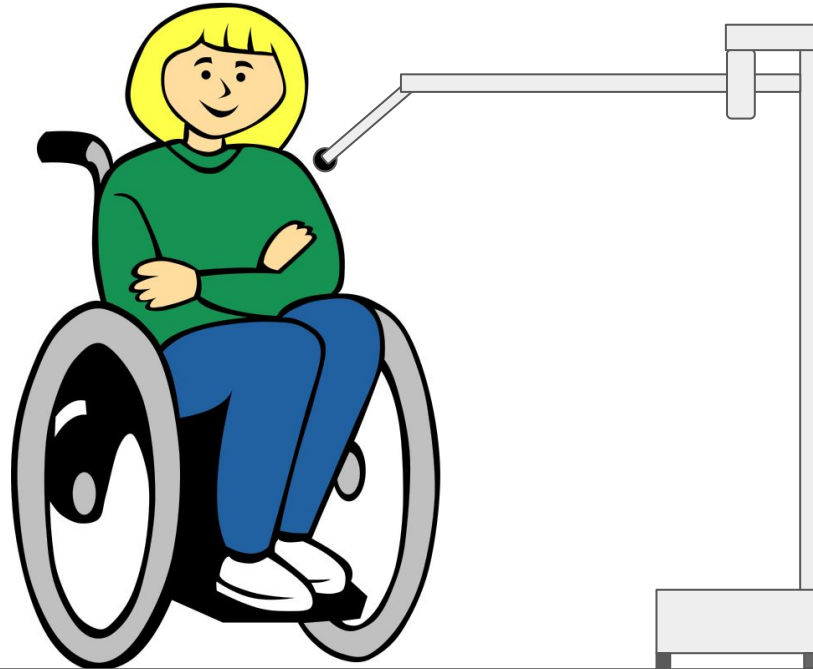
Reaches 36" Countertops



Reaches the Floor



95th Percentile Shoulder Height for Wheelchair Users



23 kg (51 lb)



Successful Launch in July 2020

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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](#)



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01:30

Research robot helps with housework and other news



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