

From One to Many: My Personal Quest for Meaningful Mobile Manipulation



Charlie Kemp

<https://charliekemp.com>

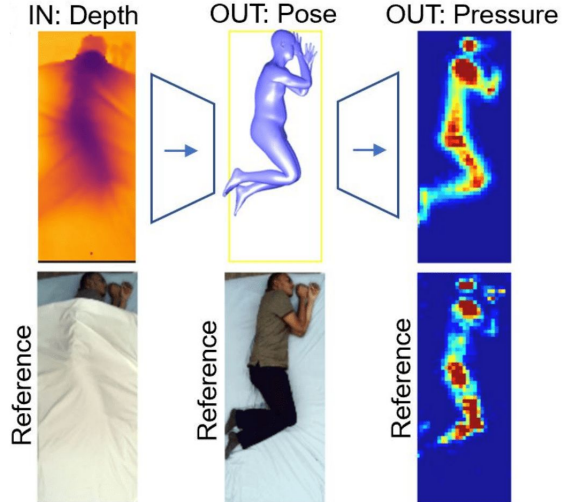
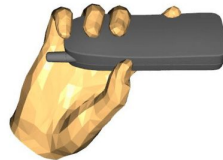
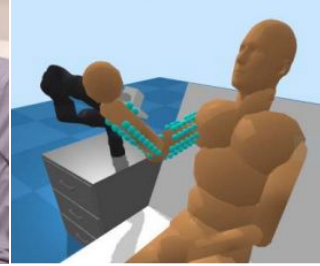
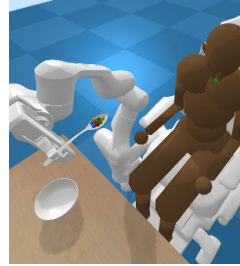
*Associate Professor, Department of Biomedical Engineering
Adjunct, School of Interactive Computing
Adjunct, School of Electrical and Computer Engineering
Georgia Tech*

Conflict of Interest Statement

Prof. 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.

The Healthcare Robotics Lab

<http://healthcare-robotics.com>



My Plan Today

- Introduce myself
- Explain why I left to cofound Hello Robot
- Tell Stretch's academic backstory



*The Stretch RE1
from Hello Robot*

A Brief Timeline

1997-2005 : Earned my degrees at MIT in EECS

2006 : Joined Georgia Tech

2007 : Board of Regents approved Robotics PhD

2017 : Leave of absence to cofound Hello Robot



Charlie's Time at Georgia Tech

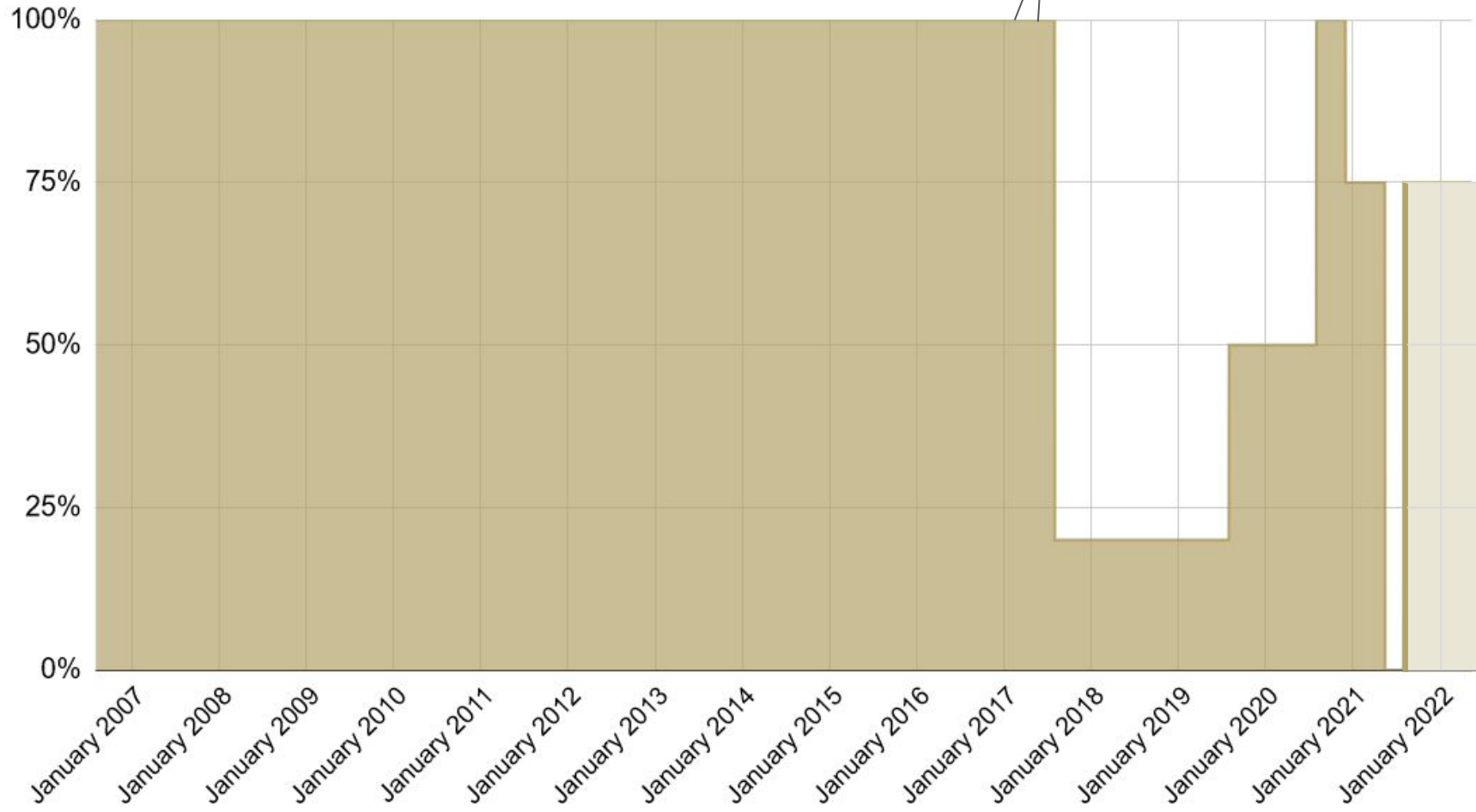




Photo Credit: Peter Menzel/Science Source
from <https://robots.ieee.org/robots/cog/>

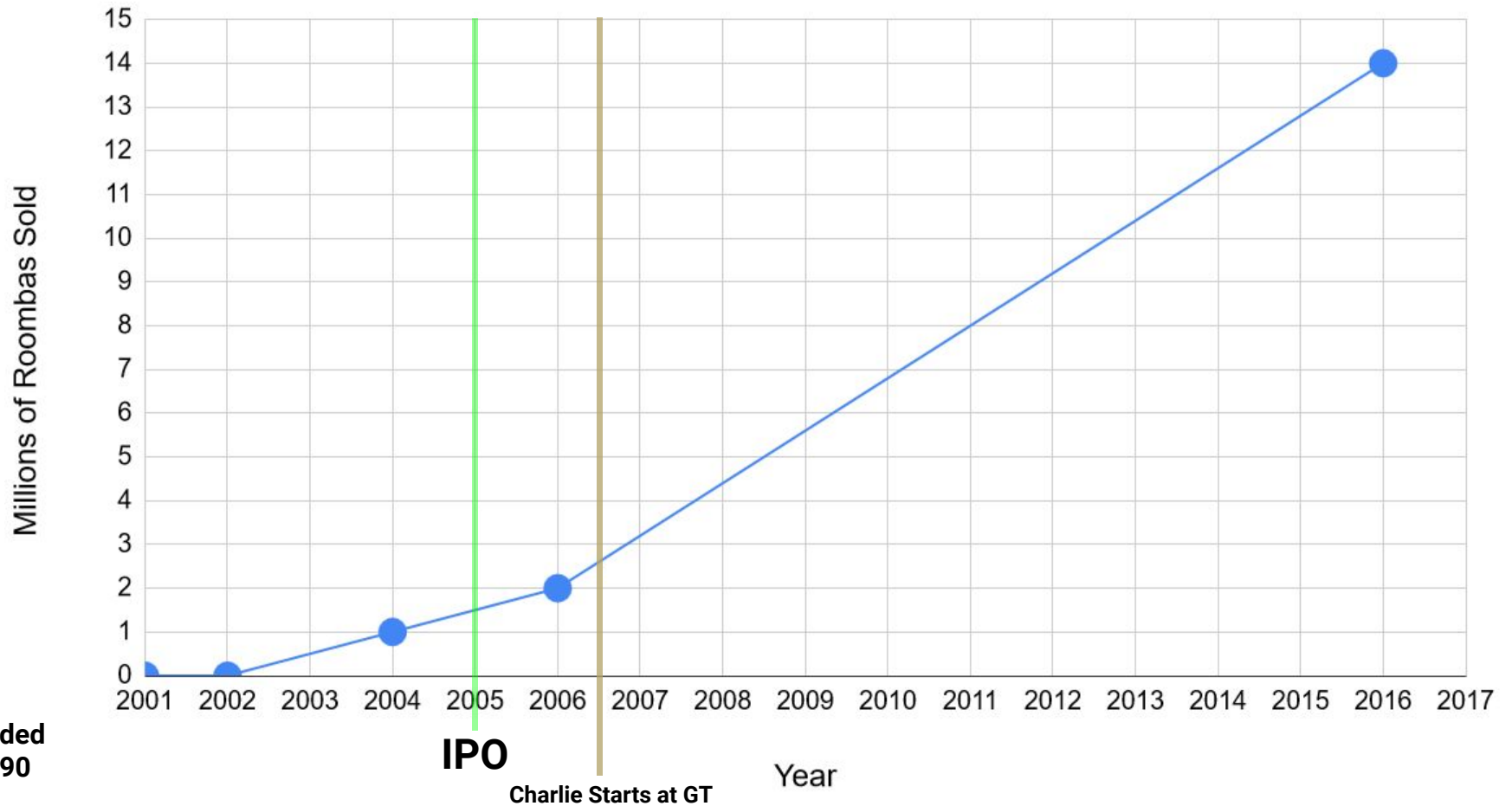
[Building Brains for Bodies](#), Rodney A. Brooks and Lynn Andrea Stein, MIT AI Lab Memo 1439, August 1993.

Photo Credit: Larry D. Moore, [CC BY-SA 3.0](https://commons.wikimedia.org/wiki/File:Larry_D._Moore_-_iRobot_Roomba_2002.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



An Intellectual Victory

- No mapping
- No planning
- No learning
- Hand-engineered behavior-based system



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



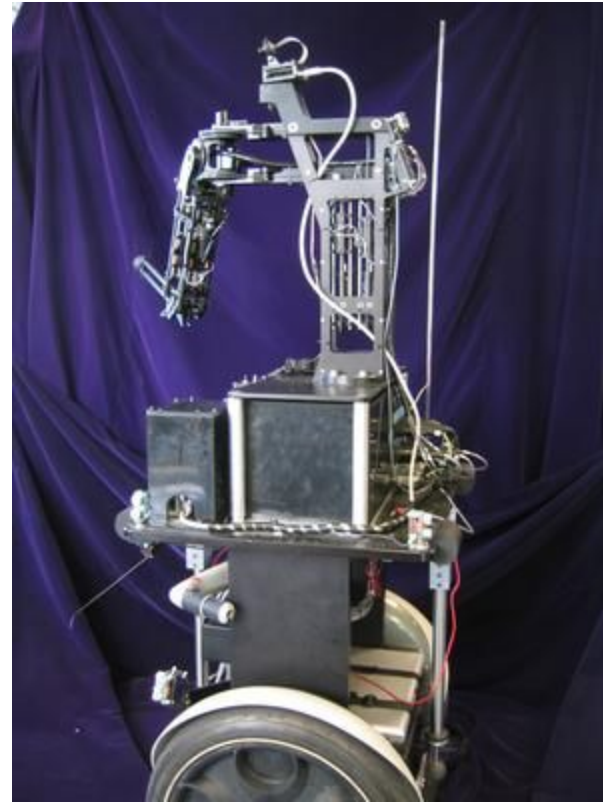
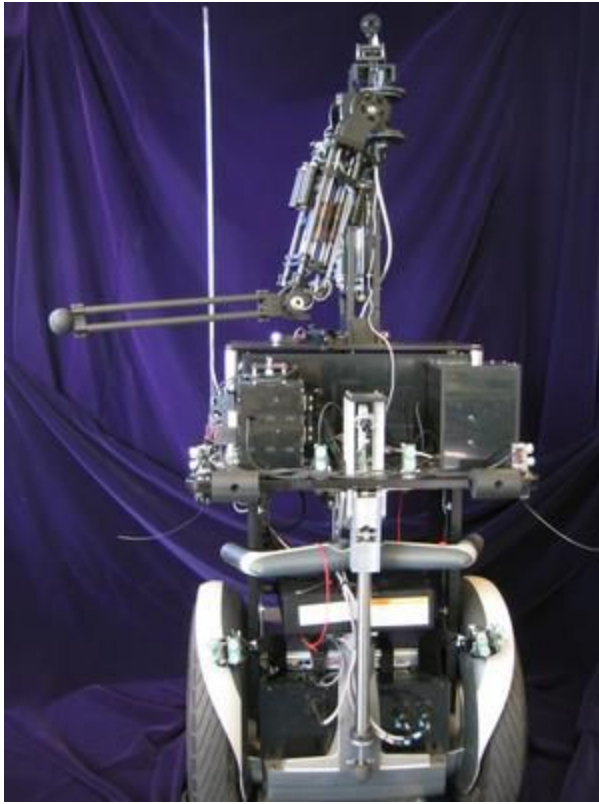
Photo Credit:
Andreas Dantz
Roomba, first attempt
Taken on April 14, 2013
<https://www.flickr.com/photos/szene/8649326807/in/pool-roomba/>

What is the Roomba of mobile manipulation?

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

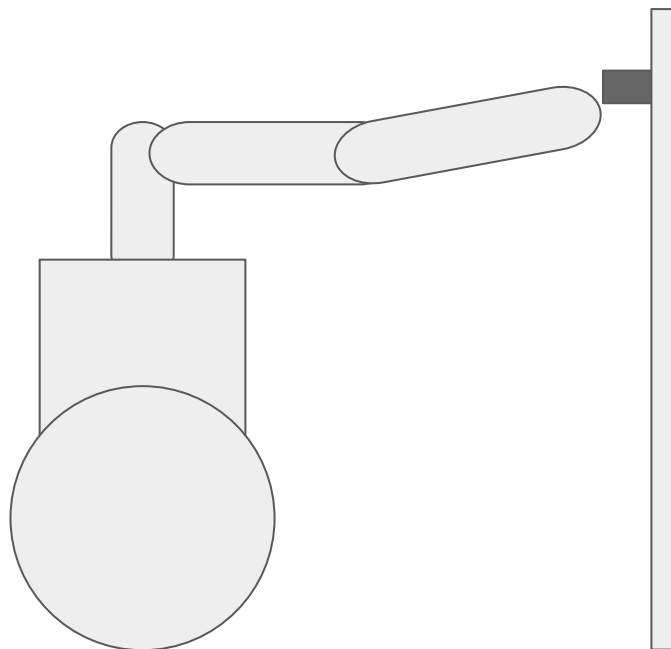
- Flat smooth surfaces
- Visible from human head height
- Reachable by human arms
- Children, older adults, and pets



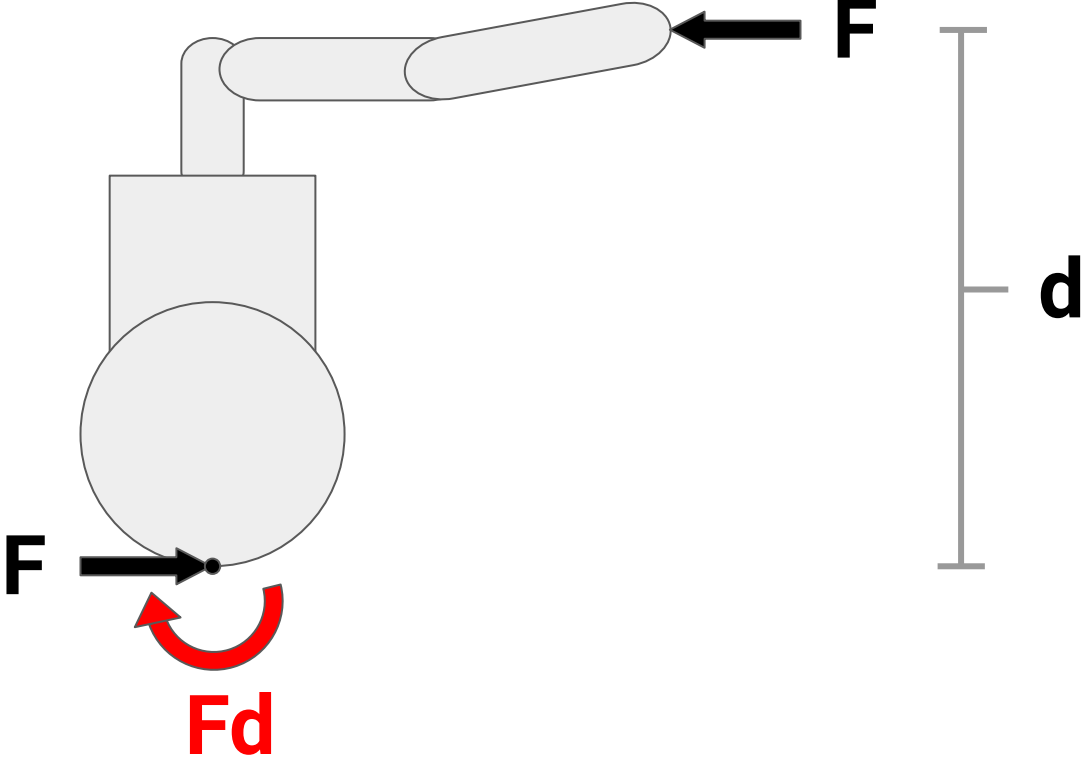


[Sensing and Manipulating Built-for-Human Environments](#), **Rodney A. Brooks**, Lijin Aryananda, **Aaron Edsinger**, Paul M. Fitzpatrick, **Charles C. Kemp**, Una-May O'Reilly, Eduardo Torres-Jara, Paulina Varshavskaya and Jeff Weber. International Journal of Humanoid Robotics, Vol 1, Number 1, pages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

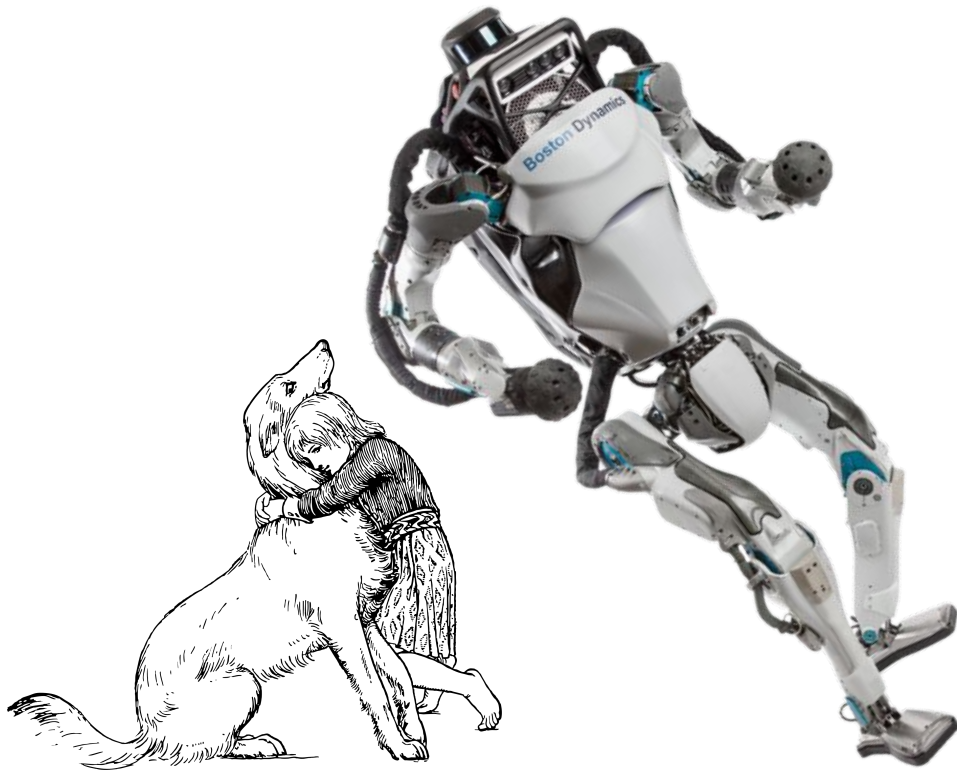
Momentary Problem when Balancing on Wheels



Momentary Problem when Balancing on Wheels



It Just Takes One Fall





4632B/8803 : Advanced Intelligent Robotics – Mobile Manipulation (spring 2007) with Prof. Henrik Christensen



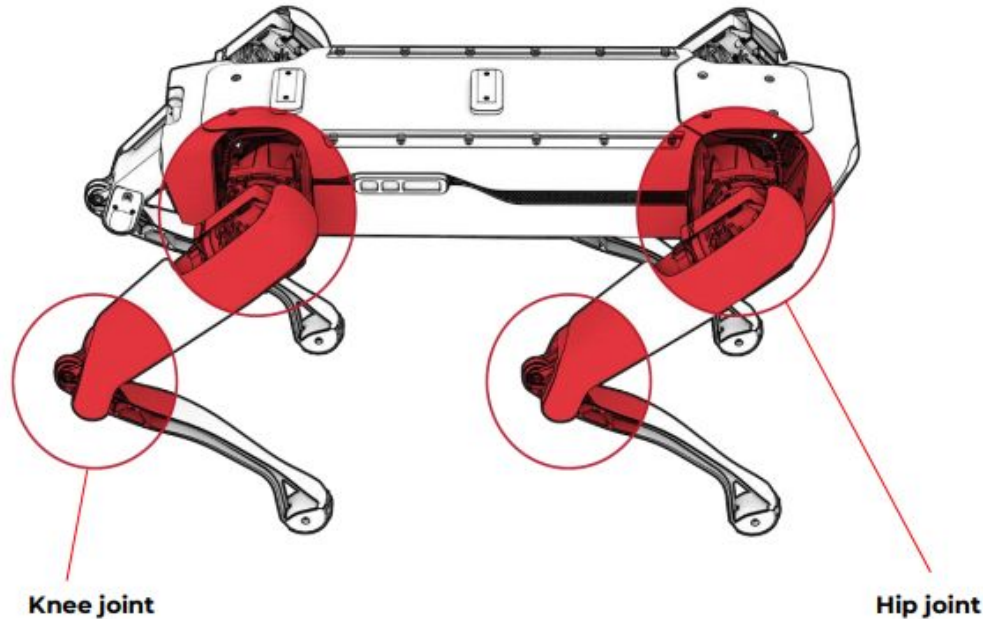
[Mobile manipulation: a challenge in integration](#), Cressel Anderson, Ben Axelrod, J Philip Case, Jaeil Choi, Martin Engel, Gaurav Gupta, Florian Hecht, John Hutchinson, Niyant Krishnamurthi, Jinhon Lee, Hai Dai Nguyen, Richard Roberts, John G Rogers, Alexander JB Trevor, Henrik I Christensen, Charles Kemp, SPIE Proceedings Vol. 6962: Unmanned Systems Technology X, 2008.

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 Initial Answer (EL-E)

- 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

THE NEW YORK TIMES, SUNDAY, MARCH 18, 2006

BRIGHT IDEAS

NOVELTIES
LONG ASSURES

An Assistant Who May Need the Occasional Battery

PROFESSOR ED E. ASSURE has a new assistant. It's a robot named E-1, a sleek, silver, humanoid figure that looks like a futuristic version of a Star Wars droid. The robot is designed to assist Assure in his research on the development of a new type of battery. The robot is named E-1 because it is the first of a series of robots that Assure plans to build. The robot is designed to be able to perform a wide range of tasks, from simple tasks like carrying a tray to more complex tasks like operating a microscope. Assure says that the robot is designed to be able to learn from its environment and to be able to adapt to new situations. The robot is also designed to be able to communicate with Assure and to be able to report back on its progress. Assure says that the robot is designed to be able to work in a laboratory setting and to be able to handle delicate equipment. The robot is also designed to be able to work in a cleanroom environment. Assure says that the robot is designed to be able to work in a variety of environments and to be able to handle a wide range of tasks. The robot is also designed to be able to work in a laboratory setting and to be able to handle delicate equipment. The robot is also designed to be able to work in a cleanroom environment. Assure says that the robot is designed to be able to work in a variety of environments and to be able to handle a wide range of tasks.



The robot E-1, designed by Ed Assure, is shown here in a laboratory setting.

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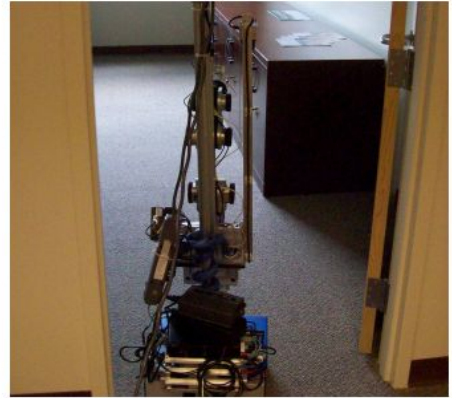
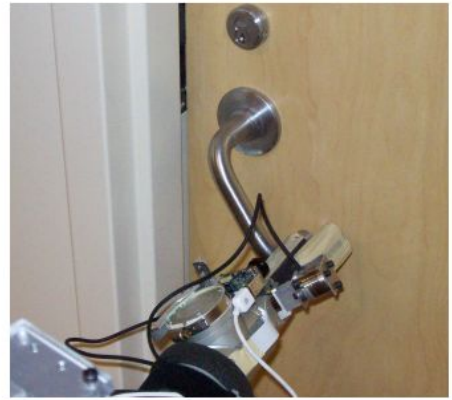
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[Behaviors for Robust Door Opening and Doorway Traversal with a Force-Sensing Mobile Manipulator](#), Advait Jain and Charles C. Kemp, RSS Manipulation Workshop: Intelligence in Human Environments, 2008.



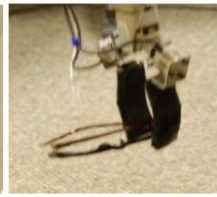
1) TV remote



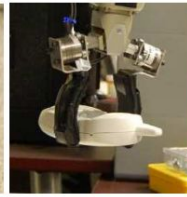
2) Pill



3) Pill bottle



4) Glasses



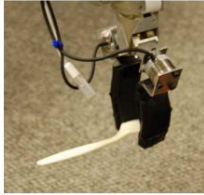
5) Cordless phone



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



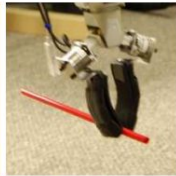
17) Book



18) Dollar bill



19) Mail



20) Straw



21) Keys



22) Table knife



23) Slipper



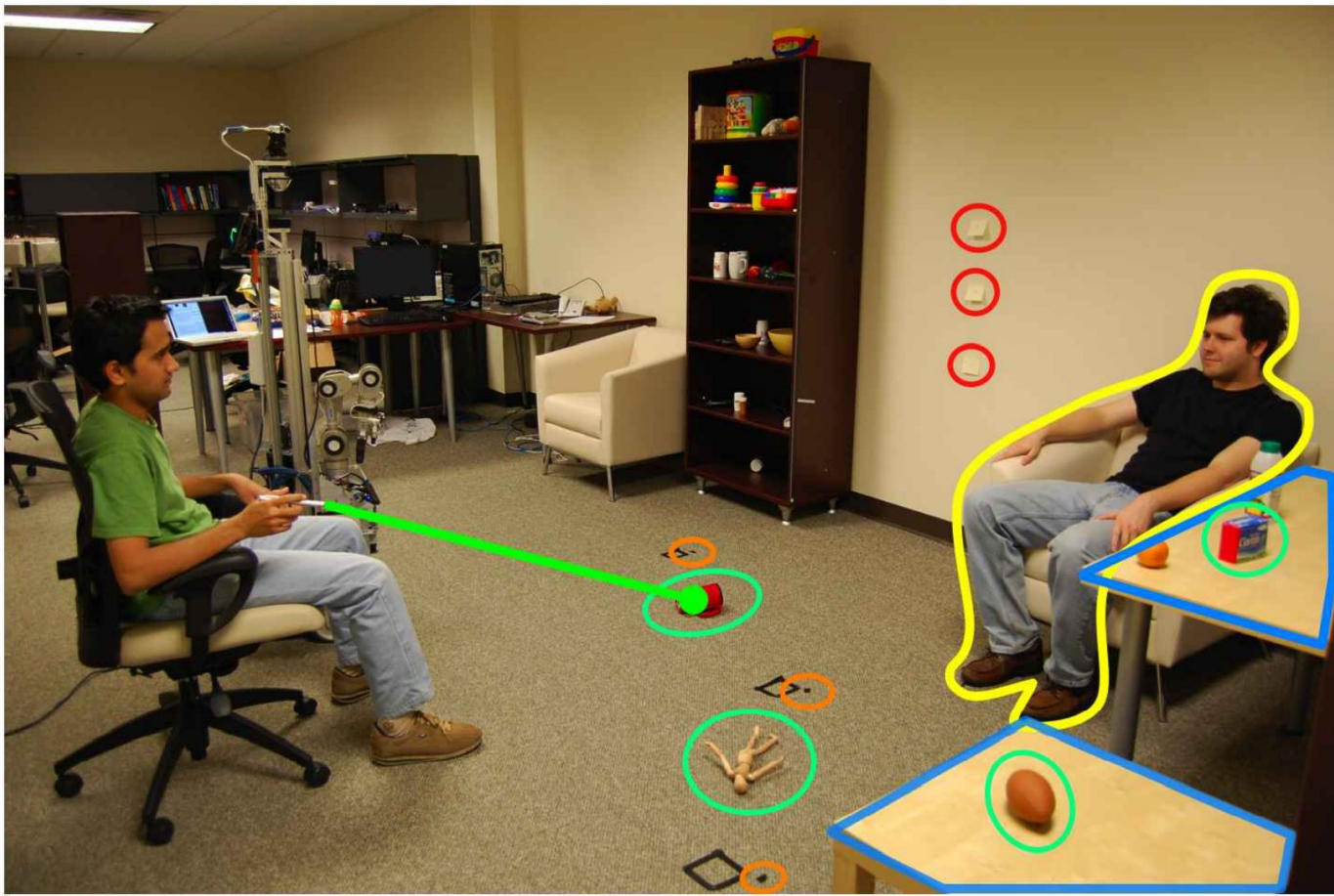
24) Pencil



25) Medicine box



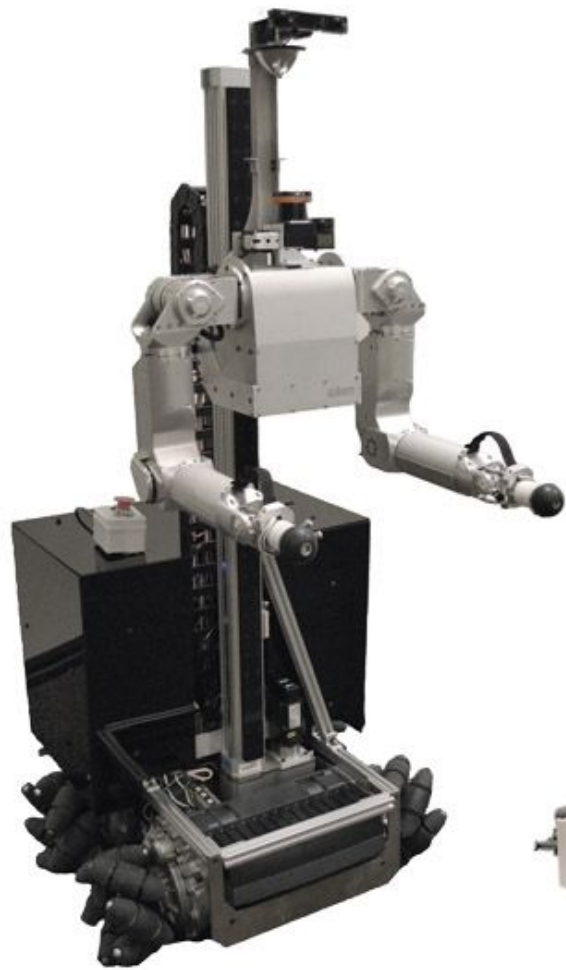
[PPS-Tags: Physical Perceptual and Semantic Tags for Autonomous Mobile Manipulation](#), Hai Nguyen, Travis Deyle, Matt Reynolds, and Charles C. Kemp, IROS 2009 workshop: Semantic Perception for Mobile Manipulation, 2009.



[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







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

Mobile Manipulators Provide Meaningful Assistance



<http://healthcare-robotics.com>

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)

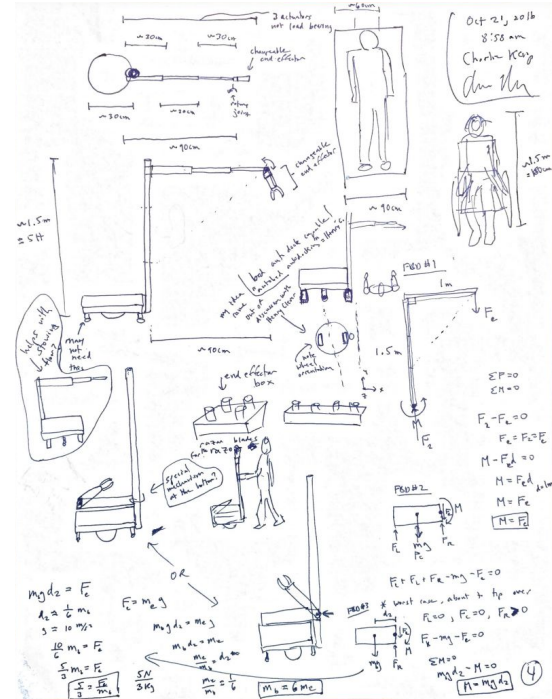


Toyota HSR
Cost: not commercially available
Footprint Width: 43cm (17")
Weight: 37 kg (82 lb)

Frustration Leads to Invention

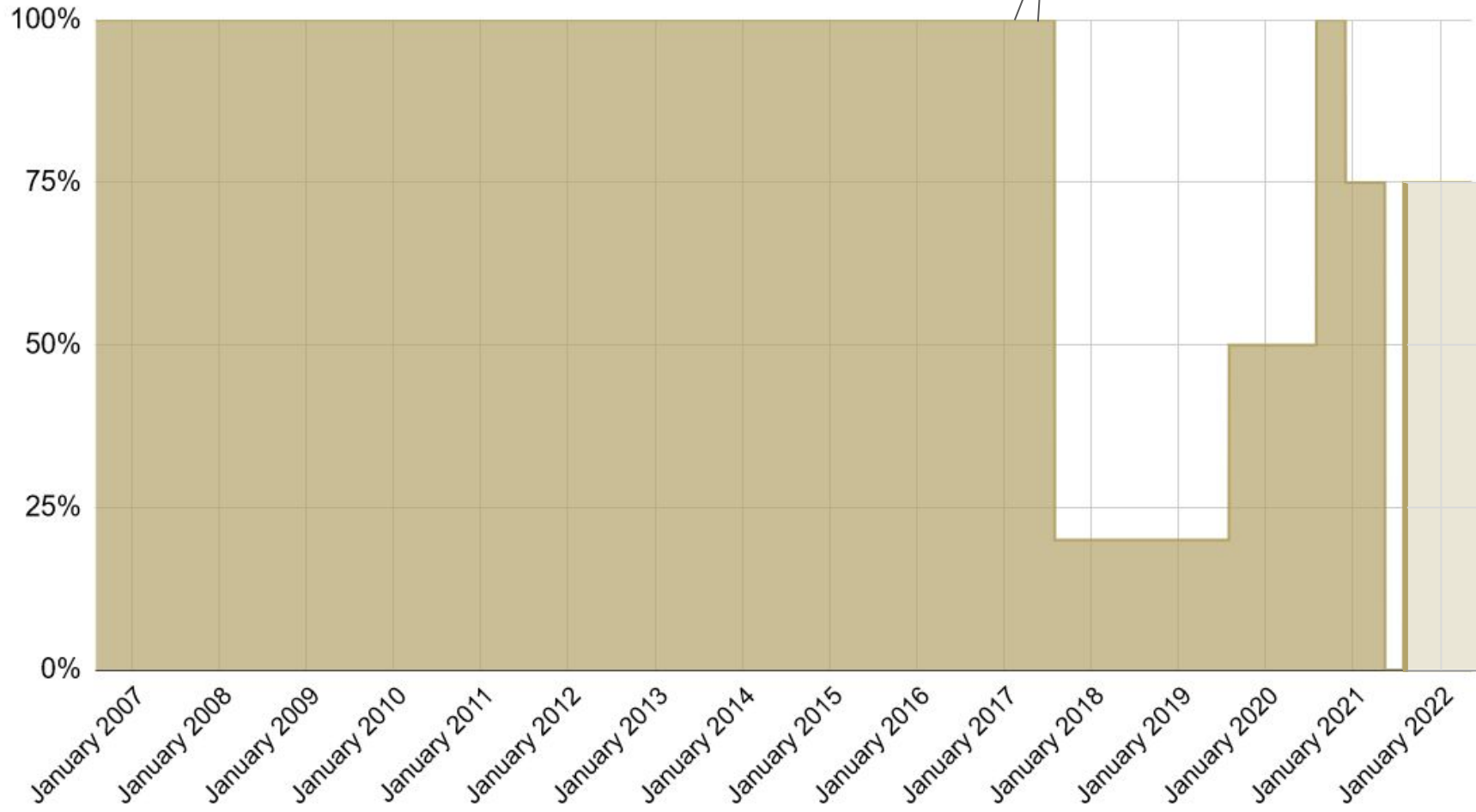
Minimize the actuator requirements while maximizing the capabilities.

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

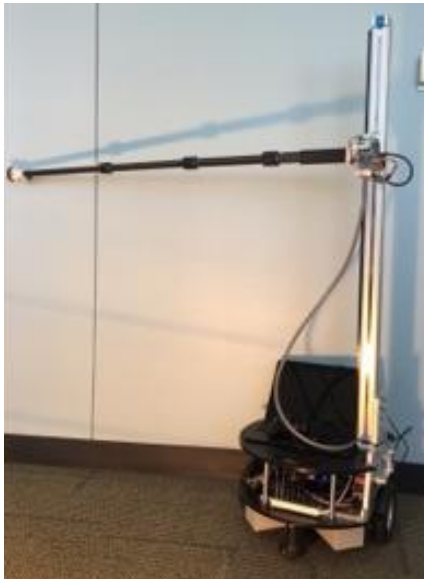




Charlie's Time at Georgia Tech



Georgia Tech's Prototype
March 2017



Hello Robot's Product
July 2020



2016

2017

2018

2019

2020



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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Tech



01:30

Research robot helps with housework and other news



Cornell University



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