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

- Stretch Design
- Stretch Community
- Collaboration with Prof. Rogers
- Live Demo
- Pitch Competition
Stretch Research Edition

“Beautifully Simple, Clever Robot Design”
- IEEE Spectrum

Hardware & Software Platform
- $19,950 for a complete mobile cobot
- Lightweight (51lb)
- Slender & Compact
- Contact Sensitive
- Open Source Code
- Python & ROS
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, Blaine Matulevich

Mobile manipulators for indoor human environments can serve as versatile devices that perform a variety of tasks, yet adoption of this technology has been limited. Reducing size, weight, and cost could facilitate adoption, but risks restricting capabilities. We present a novel design that reduces size, weight, and cost, while still performing a variety of tasks. The core design consists of a two-wheeled differential-drive mobile base, a lift, and a telescoping arm configured to achieve Cartesian motion at the end of the arm. Design extensions include a 1 degree-of-freedom (DOF) wrist to stow a tool, a 2-DOF dexterous wrist to pitch and roll a tool, and a compliant gripper. We justify our design with mathematical models of static stability that relate the robot's size and weight to its workspace, payload, and applied forces. We also provide empirical support by teleoperating and autonomously controlling a commercial robot based on our design (the Stretch RE1 from Hello Robot Inc.) to perform tasks in real homes.

The first Roomba from 2002. 
Almost 20 years ago!
Founded in 1990. Charlie Starts at GT during 2005 and 2006. IPO occurred in 2007. The number of Roombas sold increased significantly post-IPO.
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
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?
My Lab’s Initial Answer (EL-E)

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

Mobile Manipulators Can Provide Meaningful Assistance

research from the Healthcare Robotics Lab (healthcare-robotics.com) at Georgia Tech
<table>
<thead>
<tr>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Georgia Tech’s Prototype March 2017" /></td>
<td><img src="image2.png" alt="Hello Robot’s Product - A Robot for Research July 2020" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

*Georgia Tech’s Prototype March 2017*

*Hello Robot’s Product - A Robot for Research July 2020*
3 years
8 versions
tested in Charlie’s home
Small, Lightweight, Affordable & Capable

● Static stability constrains capabilities
  ○ narrower, taller, longer, lighter ⇒ lower payloads & forces

● Degrees of Freedom
  ○ 4 DOF: minimal proximal actuation for Cartesian end-of-arm motion and base mobility
  ○ + 1 DOF wrist for stowing tools & planar dexterity
  ○ + 2 DOF optional wrist accessory for additional dexterity

● Dimensions matched to human environments
  ○ The human form deconstructed and reassembled
    (robotic cubism)

“In Cubist artwork, objects are analyzed, broken up and reassembled in an abstracted form” [https://en.wikipedia.org/wiki/Cubism](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)
Tipping from Payload

\[ m g \]

\[ (m + m_p) g \]

\[ d \]

\[ d_{ra} \]
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)
Community is our Priority
Successful Launch in July 2020
Our North Star

Robots that improve life for everyone.

It will take time.

We can’t do it alone.

Let’s build the future together
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
Human Fusions at ANA Avatar XPRIZE Semifinals

Prof. Veronica Santos from UCLA

http://humanfusions.org/ana-avatar-xprize.html
Megan Boivin, PhD
Droidlet from Facebook

https://ai.facebook.com/blog/droidlet-a-one-stop-shop-for-modularly-building-intelligent-agents
21 people, including 3 people with disabilities, remotely operated Stretch
Other 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
Collaboration with Prof. Wendy Rogers
Timeline of our Collaboration

2010: Profs. Rogers & Kemp begin collaborating

2020, April: Prof. Rogers buys early robot (first 10)

2020, April: Start of regular meetings

2021, Sept: NIH awards SBIR
Occupational Therapy Doctoral Project

Vy Nguyen

Henry & Jane Evans

Hello Robot

Harshal Mahajan, Travis Kadyk, Wendy Rogers, Megan Bayles

Blaine Matulevich, Charlie Kemp, Elliston Franks, Binit Shah

UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN

Pacific University Oregon

Maya Cakmak, Kavi Dey, Tapo Bhattacharjee
Stretch provides meaningful assistance
Stretch provides meaningful assistance
Live Demo of the Stretch RE1
TechSAge presents

Seeking creative solutions to support people aging with disabilities

STRETCH ROBOT PITCH COMPETITION
in collaboration with Hello Robot and P&G

Open to all majors (undergrad & grad) at the University of Illinois Urbana-Champaign

- Cash prizes & more!
- Submission Requirements: 2 page proposal & pitch video (< 3 minutes)
- Deadline: November 19, 2021
- Contact us: techsage@illinois.edu
- For complete details, visit: https://rebrand.ly/stretch-robot-comp

Stretch Robot Pitch Competition!
(Encouraging an Inclusive Future)

rebrand.ly/stretch-robot-comp
Stretch in the McKechnie Family LIFE

rebrand.ly/stretch-robot-comp
Questions?

Learn more at hello-robot.com
Extra Slides
\[ m_{\text{payload}} = m_r \frac{c}{t + \frac{2lD}{w}} \]

\[ F_{\text{pull/push}} = m_r g \frac{cw}{2hl} \]

\[ F_{\text{pull/push}} = \frac{23.68Nm}{h} \]

\[ m_{\text{payload}} = \frac{1}{0.0014 + 0.414D} \text{ kg} \]

\[ m_{\text{payload}} = 3.47 \text{ kg} \]
Hello Robot: Democratizing Mobile Manipulation

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 growing community of researchers to explore the future of mobile manipulation. In this talk, we will present the Stretch RE1 and the growing community and ecosystem around it. We will present our exciting collaboration with Professor Wendy Roger’s lab and provide a live demonstration of Stretch. Finally, we will be announcing the Stretch Robot Pitch Competition -- a collaboration with TechSage and Proctor and Gamble -- where students have the opportunity to generate novel design concepts for Stretch that address the needs of individuals aging with disabilities at home.