NRI: FND: COLLAB: An Open-Source Robotic Leg Platform that Lowers the Barrier for Advanced Prosthetics Research

Elliott J Rouse
(UM/Lead PI)

Robert Gregg
(UTD [now UM] PI)

Hartmut Geyer
(CMU PI)

Levi Hargrove
(AbilityLab Co-I)

2021 NRI & FRR Principal Investigators' Meeting
March 10-12, 2021

Contact Email: ejrouse@umich.edu | Website: www.opensourceleg.com

Award Numbers 1734586, 1949346, and 1734559

Elliott J Rouse (UM/Lead PI), Robert Gregg (UTD [now UM] PI)
Hartmut Geyer (CMU PI), Levi Hargrove (AbilityLab Co-I)

- Control is one of the greatest barriers for robotic legs

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- Control is one of the greatest barriers for robotic legs
- Many researchers – developing different robotic leg platforms

Gregg *et al.*
U-M

Goldfarb *et al.*
Vanderbilt

Ames *et al.*
CalTech

Rouse/Herr *et al.*
MIT

Geyer *et al.*
CMU

Lenzi *et al.*
U Utah

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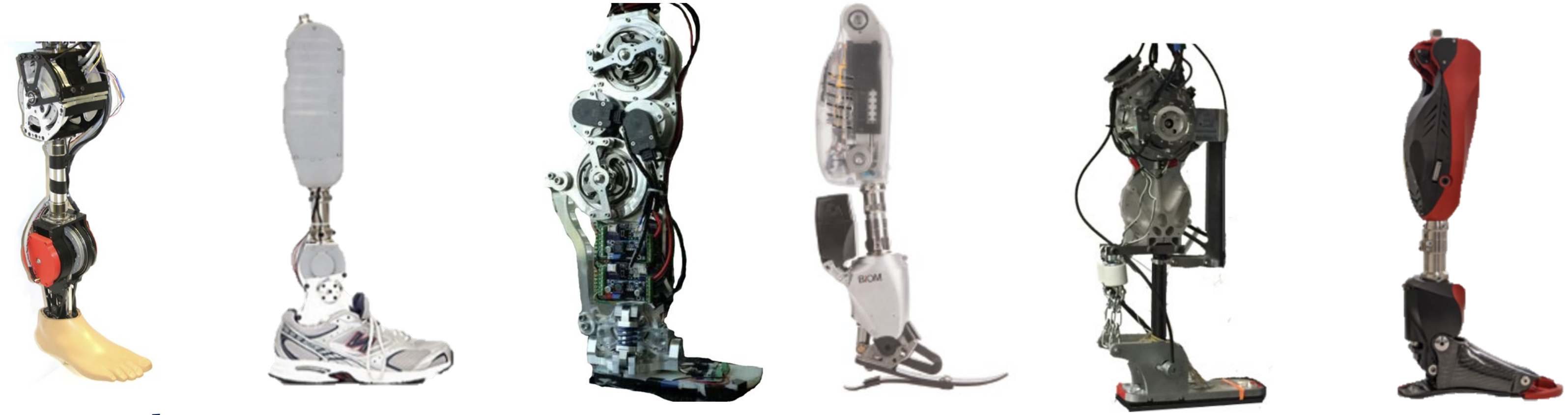
- Many researchers – developing different robotic leg platforms



Gregg *et al.* U-M | Goldfarb *et al.* Vanderbilt | Ames *et al.* CalTech | Rouse/Herr *et al.* MIT | Geyer *et al.* CMU | Lenzi *et al.* U Utah

- Hinders comparisons and is very inefficient for the field

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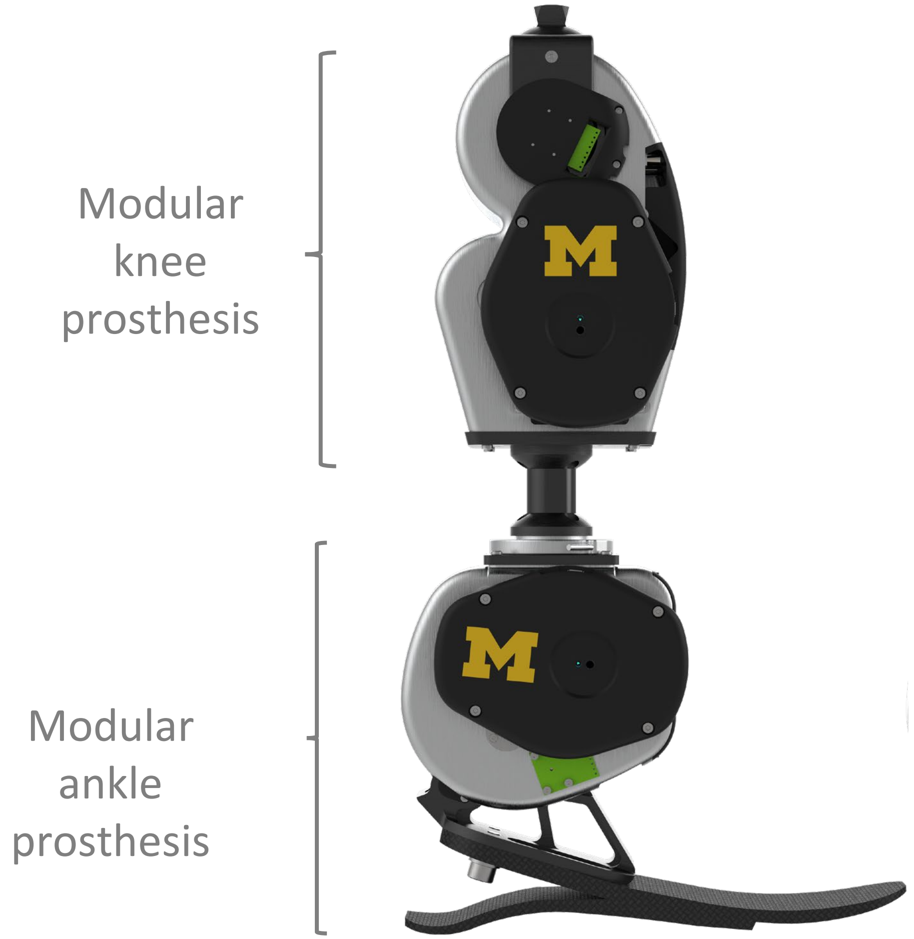
Open-Source Robotic Leg

- Modular 2-DOF system



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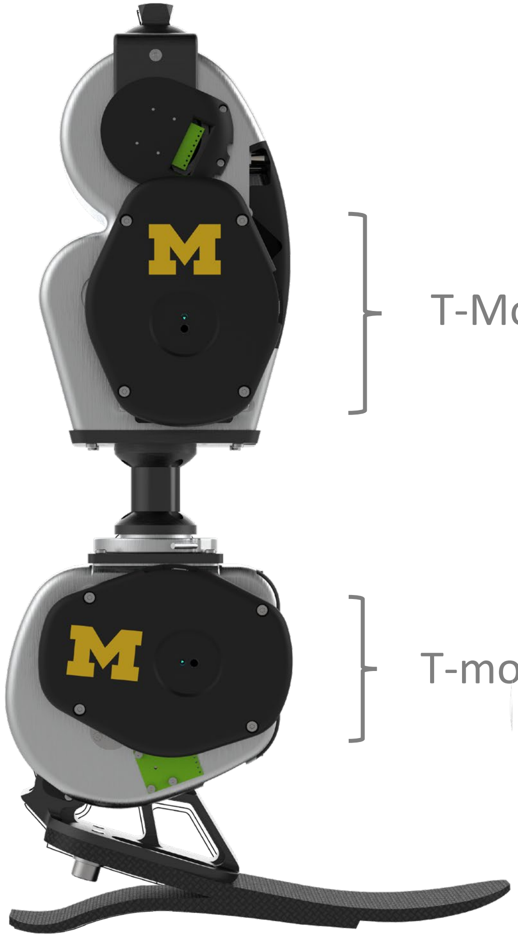
Open-Source Robotic Leg

- Modular 2-DOF system
- Drone technology
- Quiet, efficient, low cost



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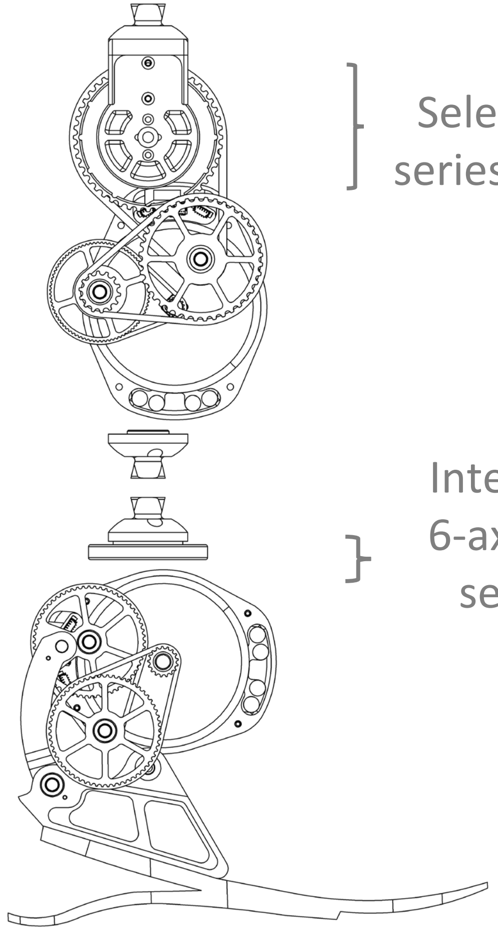
Open-Source Robotic Leg

- Modular 2-DOF system
- Drone technology
- Quiet, efficient, low cost
- Integrated sensing
- Fully self-contained
- Series-elastic actuator



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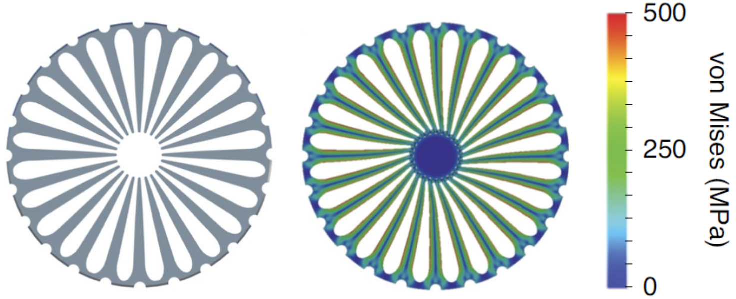
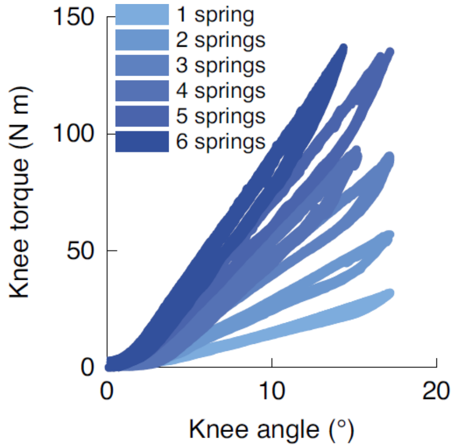
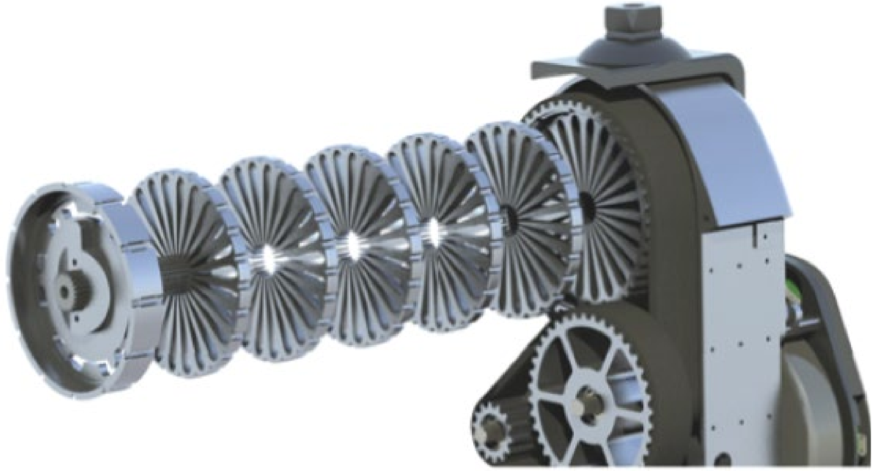
Open-Source Robotic Leg

- SEAs have benefits and drawbacks
- Design capable of working in both configs
- Adjustable series stiffness during assembly
- New NRI focused on torque control with PIs Rombokas and Gregg







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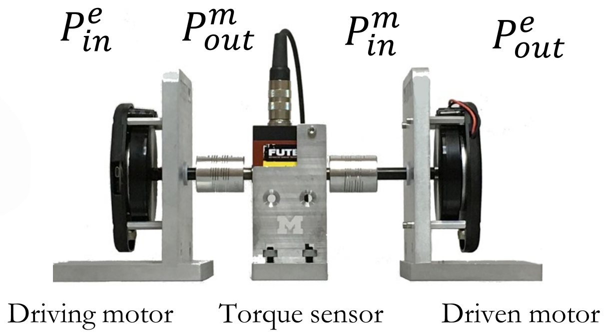
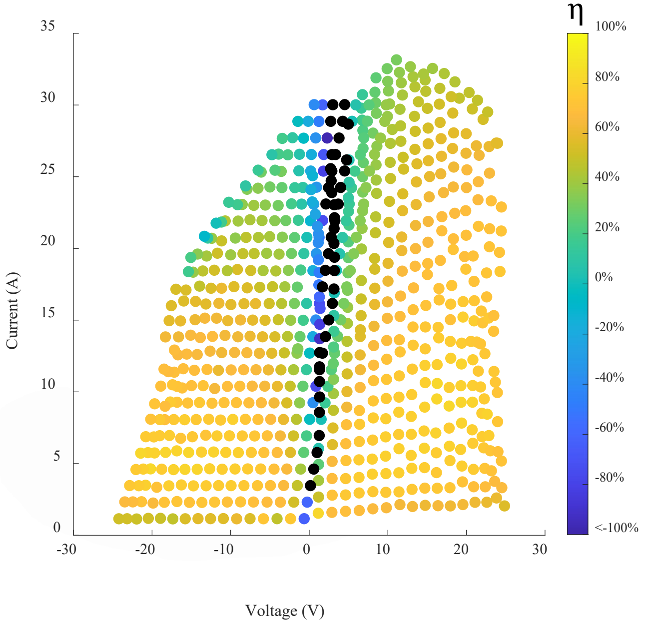
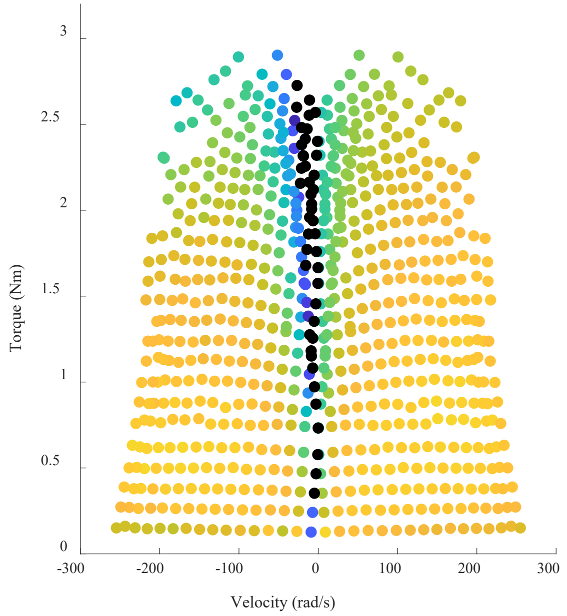
BLDC Motor Characterization

- ‘Drone style’ motors are relatively new
- Specs are difficult to find / drone application specific
- We characterized the U8 KV100 motor
    - Motor parameters / efficiency







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U H Lee, C W Pan and E J Rouse, Empirical Characterization of a High-performance Exterior-rotor Type Brushless DC Motor and Drive, IROS 2019

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BLDC Motor Characterization

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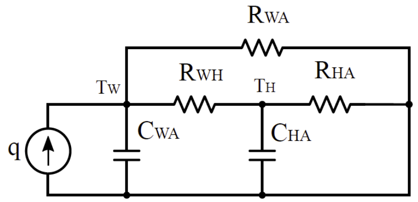
- We characterized the U8 KV100 motor
  - Motor parameters / efficiency
  - Thermal modeling
  - Closed loop control



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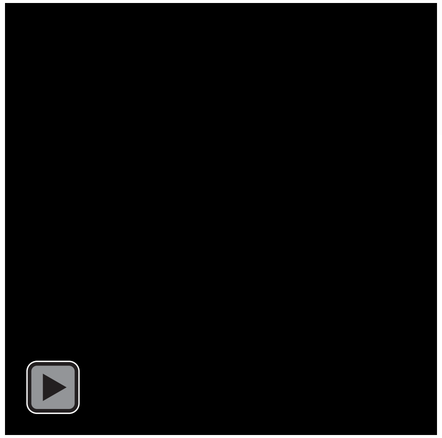
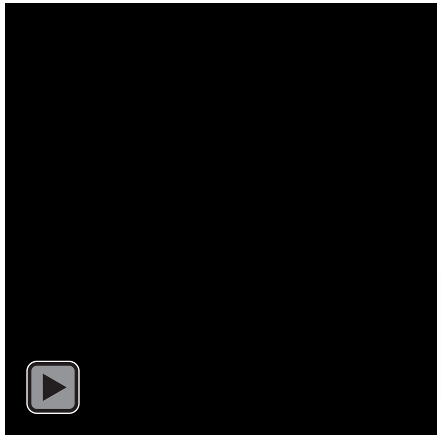
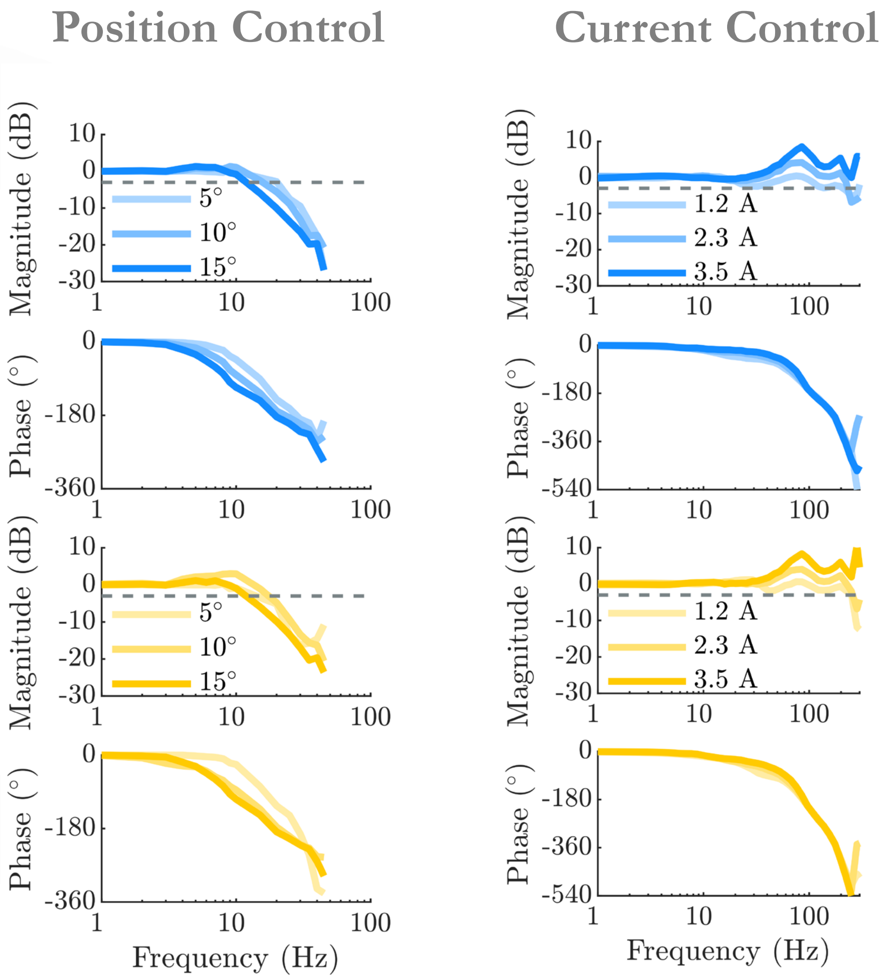
OSL Control

- Closed loop control performance
- Position, current, impedance, torque controllers developed
- Position controller: bandwidth 10 – 20 Hz
- Current controller: bandwidth > 200 Hz
- Torque controller (load cell)







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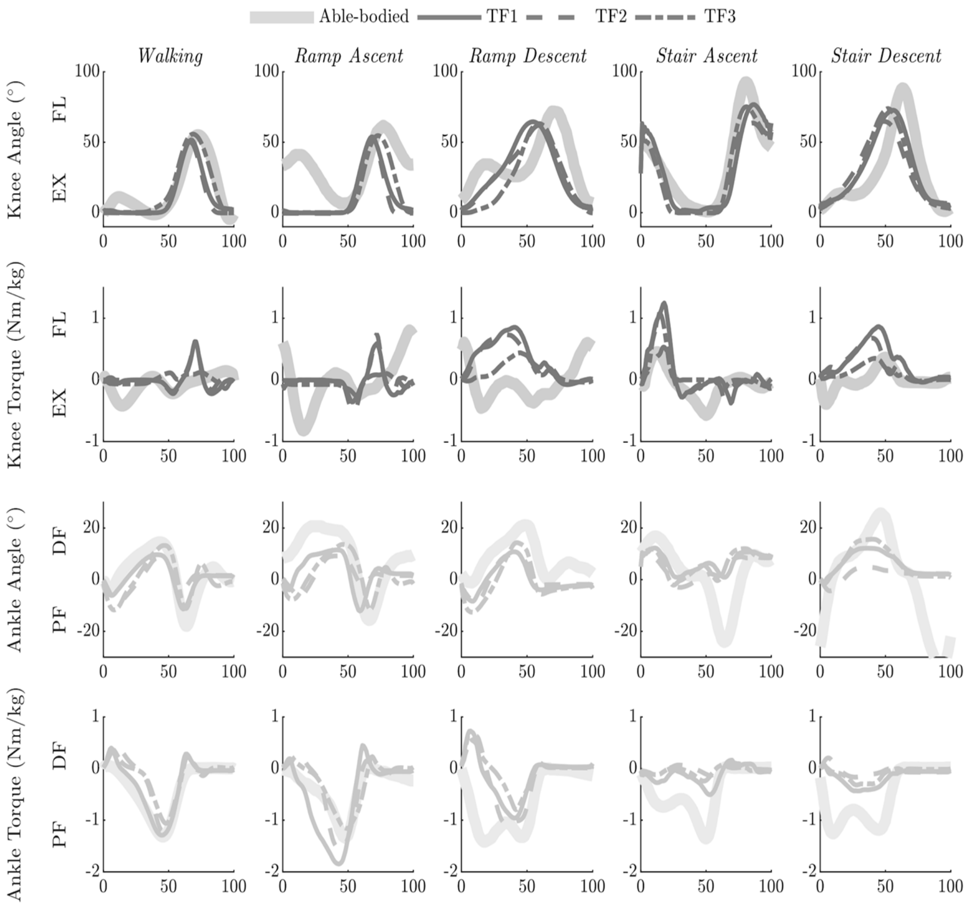
Human Subject Experiments

- Testing with three below-knee people w/ amputation (Hargrove)
- Kinetic / kinematic profiles shown across activities



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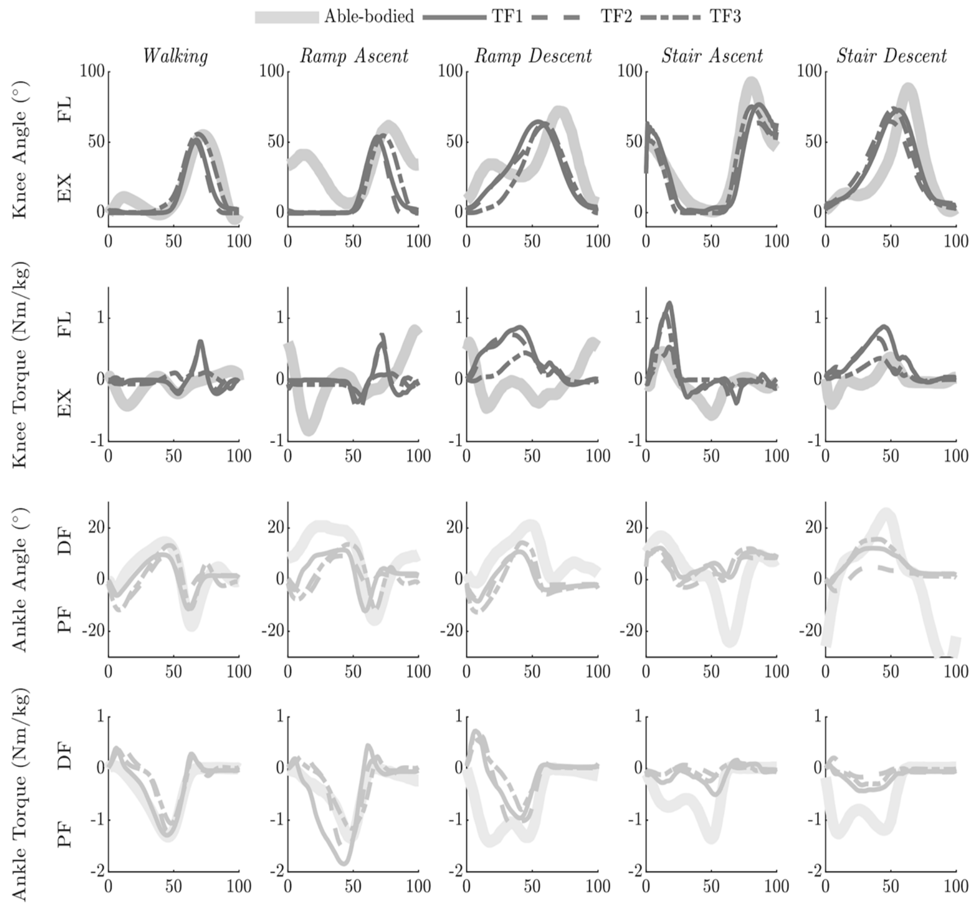
- Kinetic / kinematic profiles shown across activities
- Provide control parameters needed to replicate results
- Unable to compare implemented control strategies due to COVID



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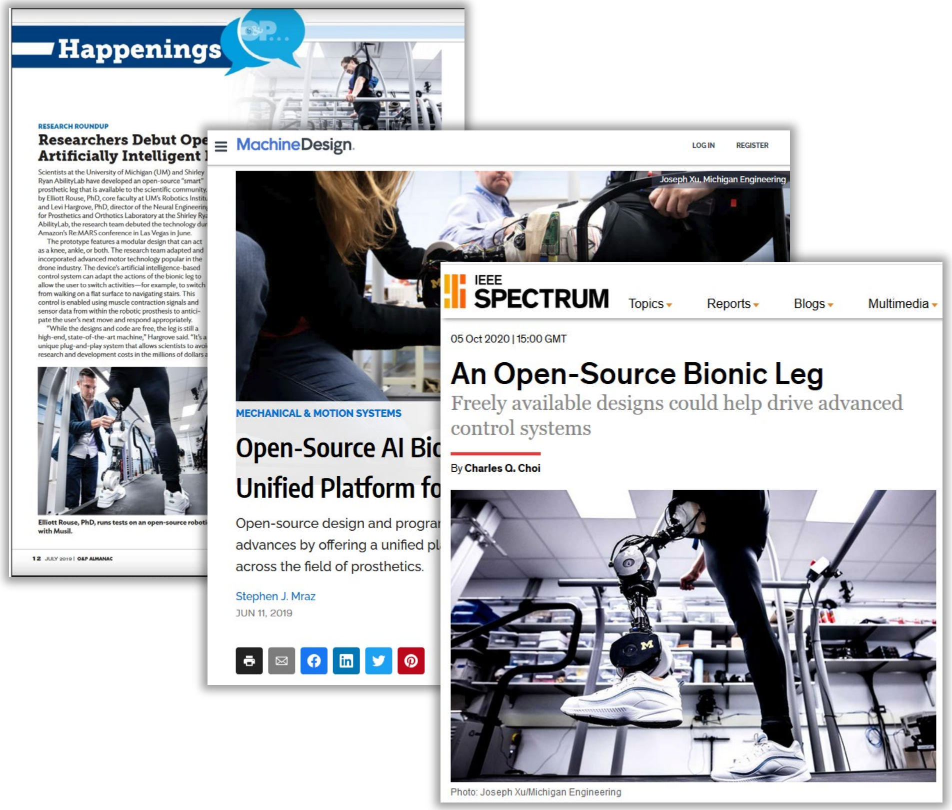
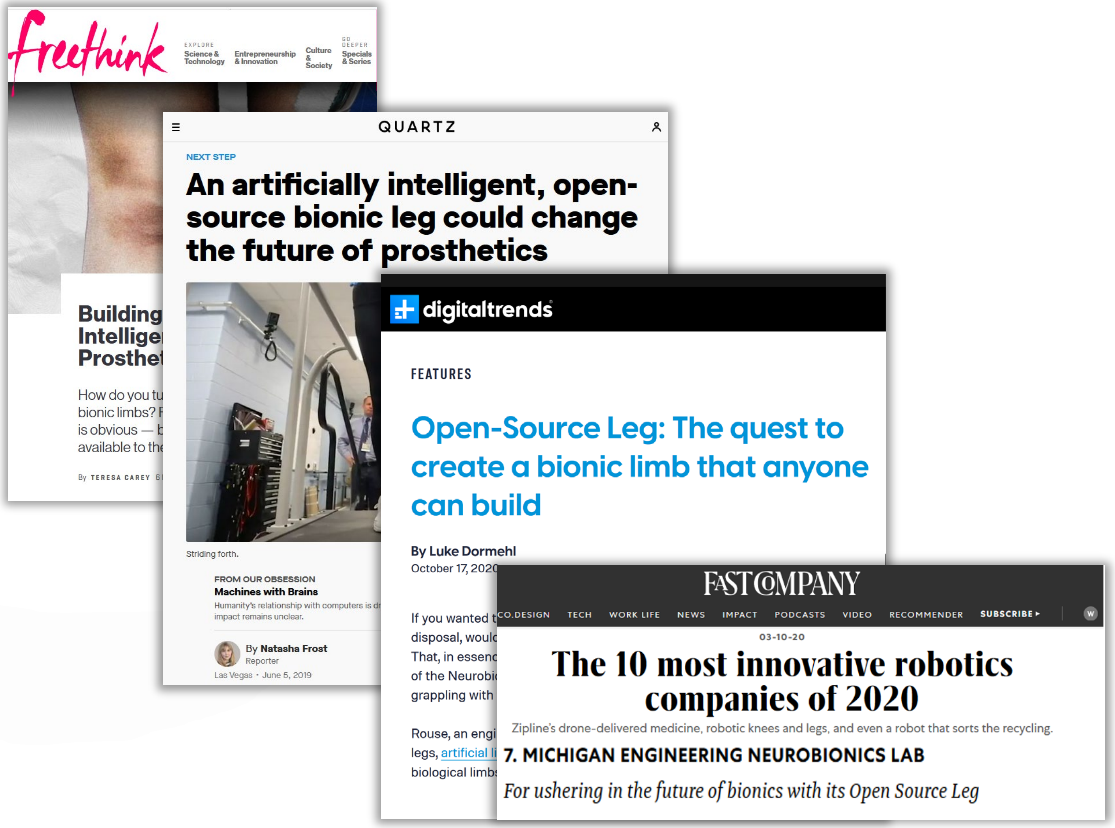
Broader Impacts

Dissemination trade magazines



Dissemination in popular media



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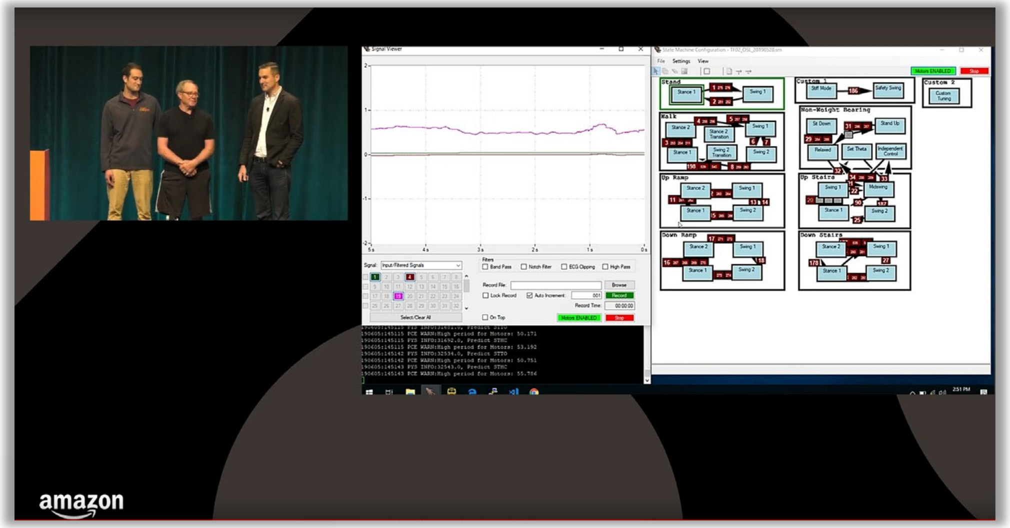
Broader Impacts

- Invited to present at Amazon's 2019 re:MARS conference
- On stage demonstration

amazon re:MARS



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Broader Impacts

- Invited to present at Amazon's 2019 re:MARS conference
- On stage demonstration
- The project was featured on a new television series
- Crash Test World with Kari Byron (Mythbusters)
- Created educational modules in conjunction with the show
- Soon to be hosted on Project Explorer

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Broader Impacts

- Finally, created educational materials to foster STEM interest in grade school students
- Includes presentation for teachers and an activity sheet for students
- Released last month (open access)
- Please let me know if you know teachers / students who may be interested!

futurum
Inspiring the next generation

HOW CAN ROBOTS HELP US WALK?

PROSTHETIC LEGS HAVE ENABLED THOUSANDS OF PEOPLE WITH A DISABILITY WALK, BUT ARTIFICIAL LIMBS CAN BE STIFF AND UNCOMFORTABLE TO USE. DR ELLIOTT ROUSE, OF THE UNIVERSITY OF MICHIGAN, IS USING ROBOTICS TO HELP US UNDERSTAND HOW PEOPLE WALK AND DEVELOP NEW PROSTHESES THAT CAN REACT AND ADAPT TO OUR MOTION

ELLIOTT'S TOP TIPS FOR STUDENTS

01 Think about the types of problems you like to solve and start there. Search for broad opportunities that overlap with those types of challenges and begin looking. Take the next step and perform as strongly as you can. Then use that experience to level up.

02 Don't be afraid to change your path as you learn about your passions. In fact, this often leads to cross disciplinary skillsets that you can leverage throughout your career. I began as an autoracing mechanic, and am now a professor studying bionic systems, but I still use my 'hands on' mechanical skills everyday.

03 When working in school or in the workplace, be sure you convert your effort into tangible results. This is important for showing productivity, and demonstrating your abilities when you want to take your next step.

04 Don't put too much pressure on yourself – start with an idea you really care about and see where it takes you!

TALK LIKE A BIOMEDICAL ENGINEER

PROSTHESIS – an artificial body part

AMPUTATION – removal of a limb

BIONICS – the science of using ideas from biological systems to solve engineering problems. Bionic parts are artificial body parts that combine electronic and mechanical devices

BIOMECHANICS – the study of how living systems move and function

EXOSKELETON – in robotics, an exoskeleton is a wearable electromechanical device. They are often used to enhance performance, such as to help someone lift objects heavier than they normally could

LOCOMOTION – motions such as walking, running or climbing stairs

Robots make our lives easier in so many ways. For instance, they help us build cars, explore dangerous environments, and can even help us move our bodies. Iron Man might be a fictitious character, but bionic limbs that can adapt to different types of movement in the human body are an exciting new reality.

Dr Elliott Rouse is an assistant professor at the Neurobionics Lab in the University of Michigan in the US. He is also a biomedical and mechanical engineer whose pioneering research aims to help people with a disability and/or amputation. His Neurobionics Lab is devoted to overcoming many of the problems with conventional protheses and exoskeletons by understanding more about how we move and developing robotics technologies that leverage this.

WHAT ARE THE PROBLEMS WITH PROTHESES?

Take a conventional prosthetic leg, for example. Leg prostheses have enabled many people who have lost part or all of their leg to regain the ability to walk without any need for crutches. Conventional prosthetic feet are usually made from carbon composite springs that store and return energy to push the wearer forward while walking. They are shaped like feet but are typically very stiff. This stiffness cannot be changed, which can be fine for walking but can make it more difficult if the wearer wants to do different kinds of activities, like moving from walking to running, or ascending and descending stairs.

When we walk, we burn energy from food to fuel the movement of our bodies. How much energy is needed to make a step depends on how efficient that conversion process is. If a protheses is poorly designed for a particular type of movement, the storage and return of energy in the carbon composite springs will also be poor, making the movement more tiring, in addition to more unstable and asymmetric.

WHAT DOES THE BIONIC LEG DO?

To solve these problems, Elliott and his team have developed an 'open source bionic leg'. This is a protheses that can be used as a bionic knee or ankle joint, or both. It is freely available to the research community, i.e., open source. Unlike a normal protheses, Elliott's bionic leg is fully robotic and can be controlled using a small computer. Not only that but sensors in the leg give information about the forces at work, which scientists can use to understand how the joint behaves during different types of movement, and develop mathematical instructions called 'control systems' that tell the leg how to move.

Excitingly, many different research groups and students around the world have been involved in this project. Students from Georgia Tech, USA, and India have been writing new software to learn more from the data collected from the bionic leg. The leg has also been designed to be low-cost, compact and easy to manufacture, meaning it is easier for innovators to use it as a test device to trial their ideas.

Elliott has been using this bionic leg to better understand how humans walk and as a test system for designing new bionic protheses. Although many of us do not think about it when we walk, walking is a complicated movement and understanding the biomechanics of this process has challenged researchers for years. Through his research, Elliott realised that there is a longstanding misconception about how joint stiffness changes during walking.

WHAT ARE THE NEW DESIGNS?

Based on this new knowledge, Elliott and his team have developed a new type of ankle-foot protheses called the VSPA foot that can vary its stiffness from step to step. VSPA stands for variable stiffness prosthetic ankle-foot and walking with this VSPA foot should feel much more natural for the wearer when compared to conventional foot prostheses. Licensed by WillowWood, a major prostheses manufacturer in the US, it also heralds the development of more advanced protheses that can respond to changes in movement, just like our bodies do. These new protheses are much more flexible and efficient in terms of energy use, as well. Elliott is now working with a company to commercialise the VSPA foot and make it available to more people who need protheses.

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Thank you to the NSF, NRI, students, and collaborators that made this project possible!

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