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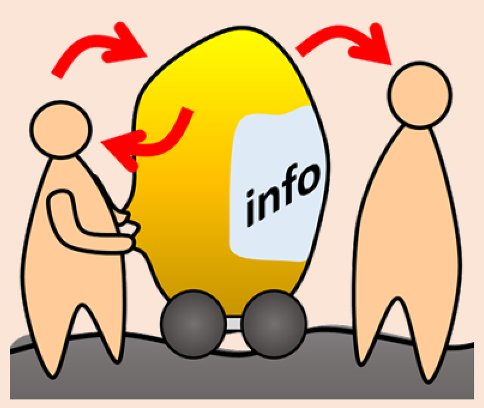
Collective Embodied Intelligence Lab

Human-Robot Swarms

1. Human Robot Swarms

Many experts envision situations where a group of non-expert humans must collaborate with robots, thus forming an ad-hoc human-robot swarm to accomplish a global, high-level task. An example is efficient building evacuation in emergencies. In this broad scope, our project is to design a custom robotic rover with the following features :

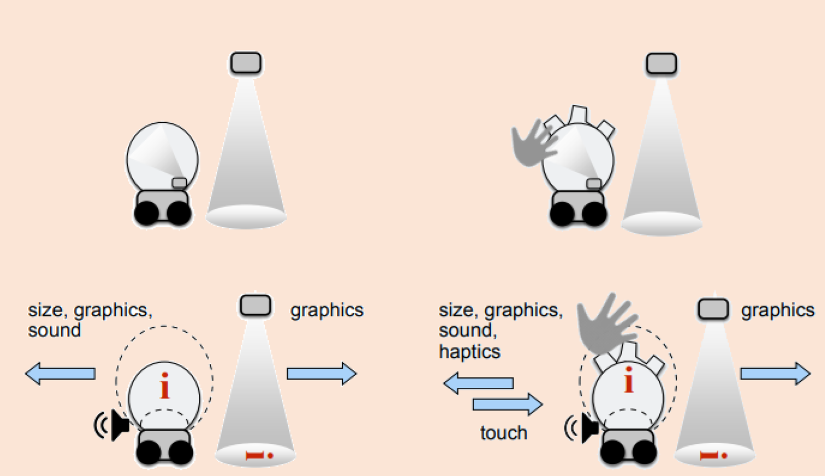
- **Small scale** to allow navigation in close confines
- **Low cost** to promote mass production
- **Light weight** to permit easy manual transport
- **Differential drive and collision avoidance**
- **Wireless** communication for remote control
- **Modular software architecture** to permit easy integration of future functionalities
- **Visual, auditory, and tangible interface** for user interaction, in the form of an inflatable bladder that permits the robots to convey or receive information from non-expert users (see figure to the right)



2. Stages : Iterative Prototyping

Rapid Prototyping
For our first version of the rover, we...

- selected and tested the electrical components including chassis, motors, sensors, batteries, RGB and RGB-D cameras, speakers, projectors, Bluetooth remote control, and more.
- and wrote software infrastructure for low-level control, as well as graphics projection onto the bladder, text-to-speech, image capturing and face detection, and automatic wireless connection through a Raspberry Pi node.



Iterative Development
For our second version of the rover, we...

- formally designed the system architecture first and then integrated everything (Sec. 3)
- added functionalities including bladder touch detection, and a protocol design for better user control
- designed 3D printed parts for improved mounting of motors, projectors, cameras, and bladder
- designed PCBs for better power routing
- switched to Agile/Scrum development to improve our team dynamics and throughput

In collaboration with Prof. Kress-Gazit, the robot can now be controlled in a motion capture space

4. Results & Future Scope

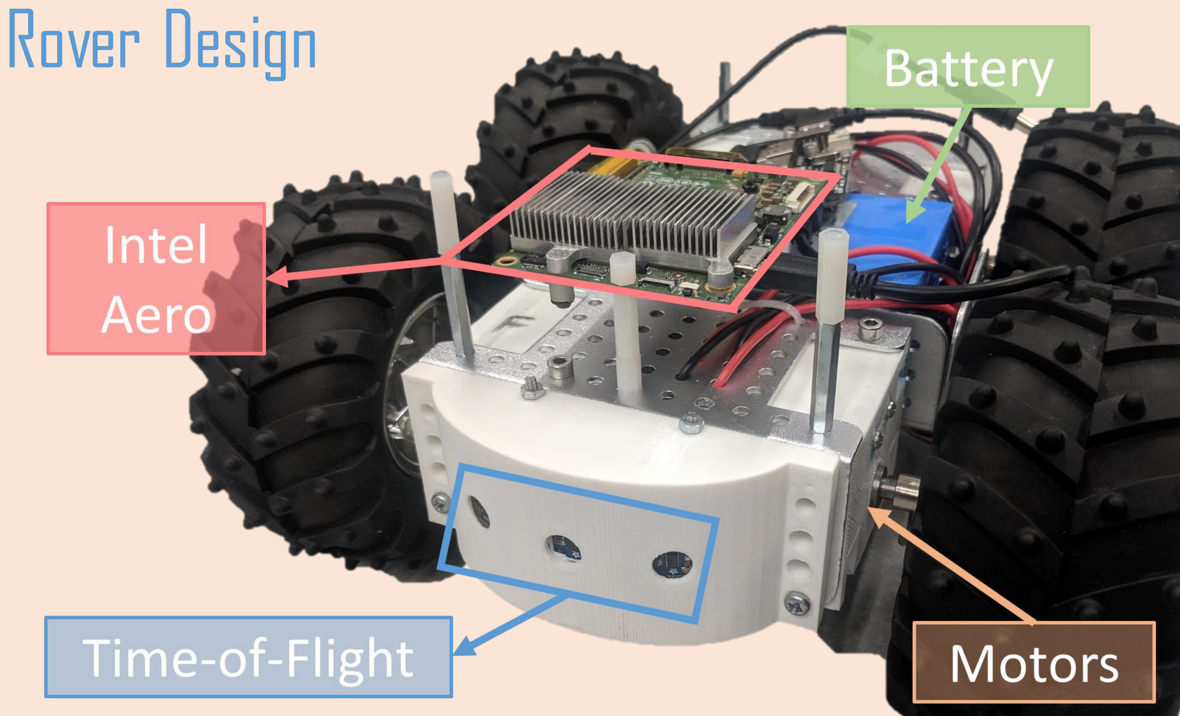
In this project, we successfully designed an inexpensive (<$2.5K), light weight (<2kg) wirelessly controlled rover, capable of relatively fast motion (~7km/hr), obstacle avoidance, projection of information onto an inflatable bladder, and auditory text-to-speech.

This summer the rover will be used in human robot experiments, showing how robots can guide participants through a complex scenario. In the future, this robot will use the internal RGB-D cameras to detect information passed from the user to the robot through physical interaction with the bladder.

3. System Design

A. Mechanical

Rover Design

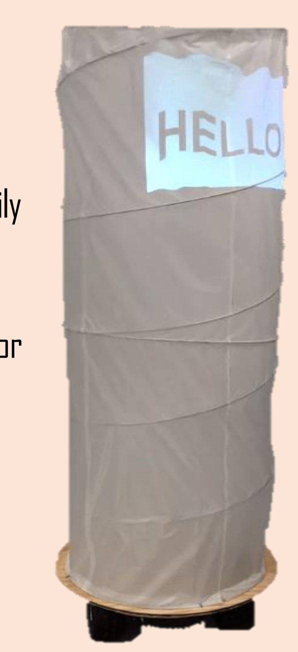


(Not shown: Projector, internal and external cameras, speakers, motor drivers, base plate, pumps, bladder.)

What is inside?

Our Rover has an embedded controller based on the Intel® Aero Compute Board, alongside the Intel® Aero Vision accessory kit. It is driven using low-torque brushed motors. Collision detection is done using three time-of-flight sensors on the front and rear. There are air pumps to inflate and deflate the bladder. It is Wi-fi enabled to receive commands from a remote operator. User interaction is done using internal speakers or by projecting images on the bladder. User feedback, like gestures, are captured using the real sense depth camera mounted on the rover.

Inflatable Bladder

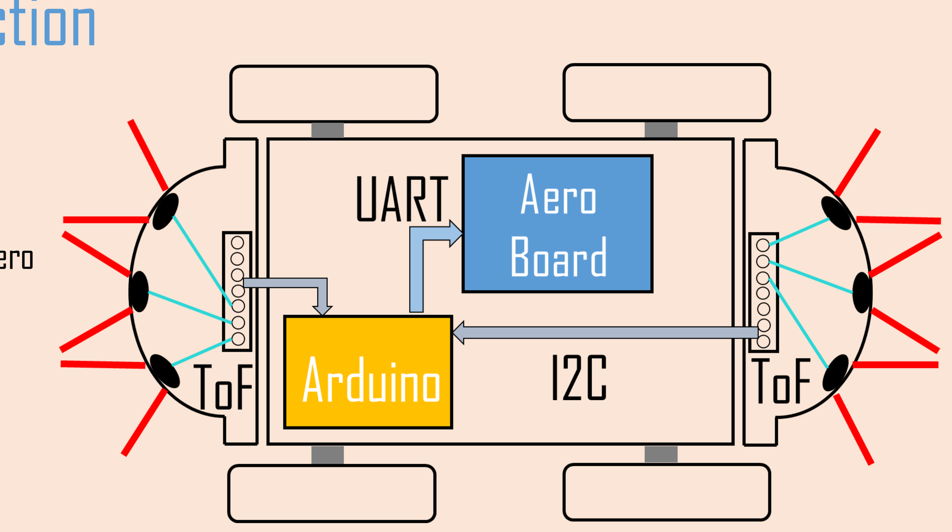


The bladder is composed of light-weight, rip-stop nylon that is easily penetrated with the light from the projector.
We tested several designs for structural integrity:

- Metal spirals (from laundry hampers) with motors and pulleys for 'deflation'
- Origami-like folding of the bladder to support repeatable in/deflation
- Air-filled channels on the perimeter, made of welded PTE
- Internal tendons and wires support the bladder during motion

Collision Detection

- Arduino control
- Time-of-flight sensors
- UART connection to Aero board

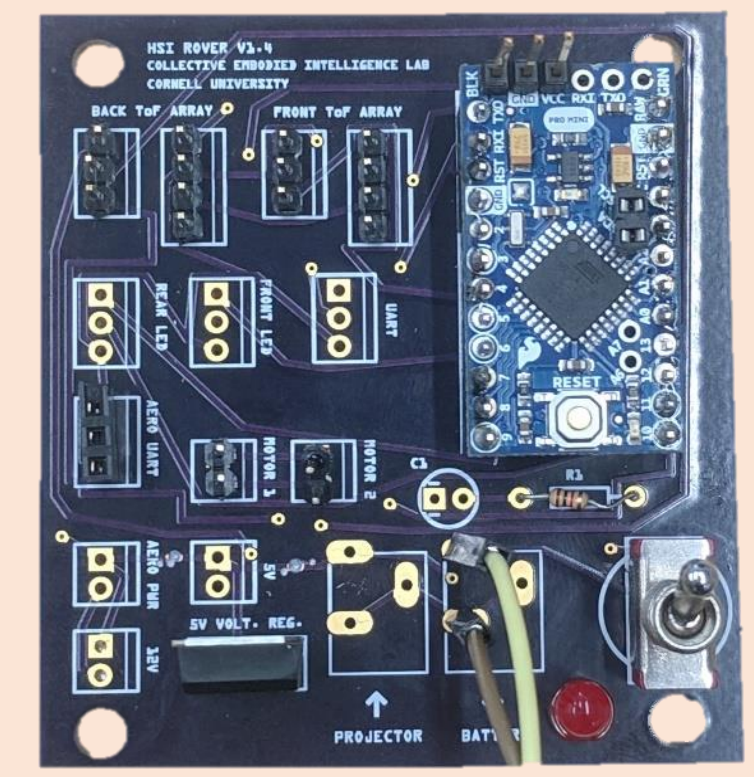


B. Electrical

Custom-Designed PCB

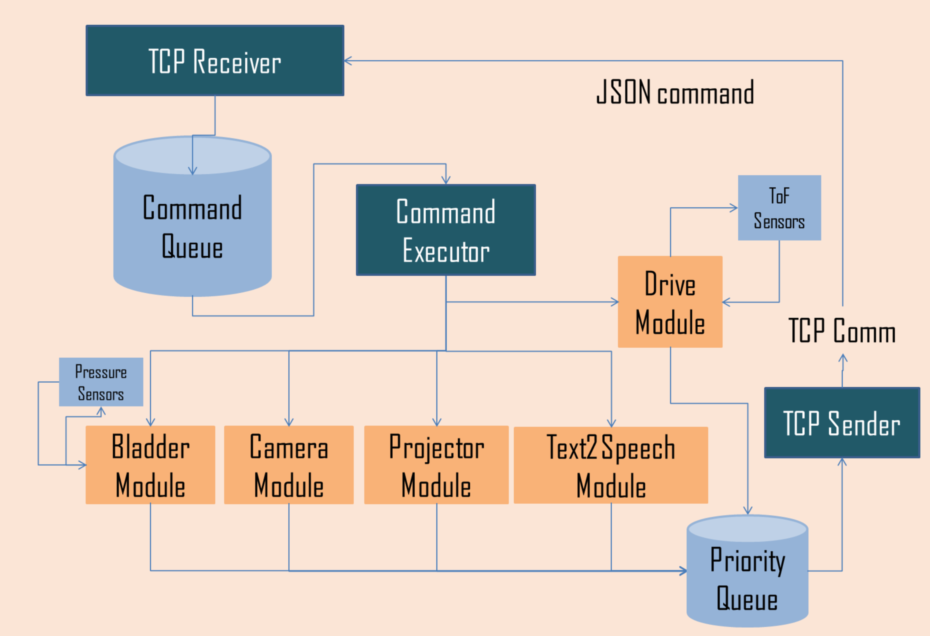
We designed a custom PCB to integrate of all the electrical components, and to distribute power all over the rover.

Components include UART, time-of-flight sensor connections, battery, projector, an additional microcontroller (Arduino), motor drivers and connections.



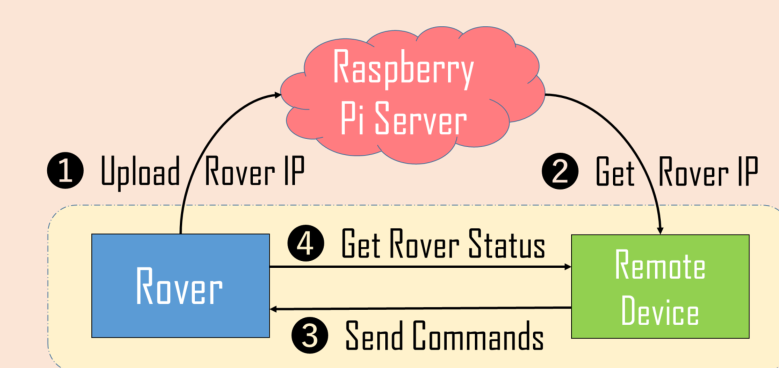
C. Software

Scalable, Modular, and Testable



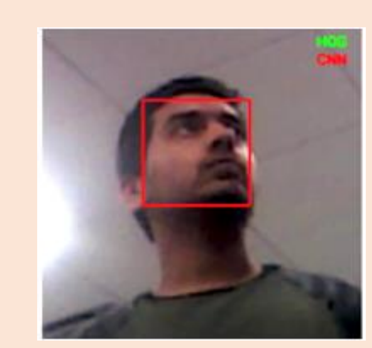
The rover software is designed to take a variety of inputs from the remote operator. We have also designed a custom and generic protocol for rover control, and a comprehensive user manual.

Wireless Control



- Customized protocol
- Wi-Fi enabled communication with the rover
- Face detection (frontal and non-frontal view), enhanced to work at steep angles to accommodate the camera mounted at the base of the rover
- Text-to-speech
- RGB-D camera for detection of user feedback on the bladder

Face Detection



Text-to-Speech

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