NRI:INT: Ad-hoc collaborative human-robot swarms

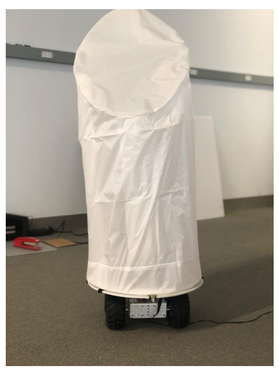
PI: Hadas Kress-Gazit, Co-PI: Guy Hoffman, Kirstin Petersen

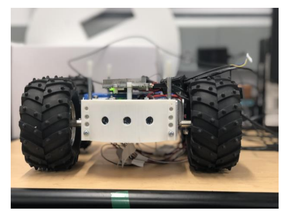
Cornell University

Goals

Build an autonomous human-robot swarm system with:

- Control synthesis for global task completion with local interactions
- Multi modal interactions with non-expert humans
- Safe, robust and cheap interaction-enabling hardware





Shadow Detection - interaction

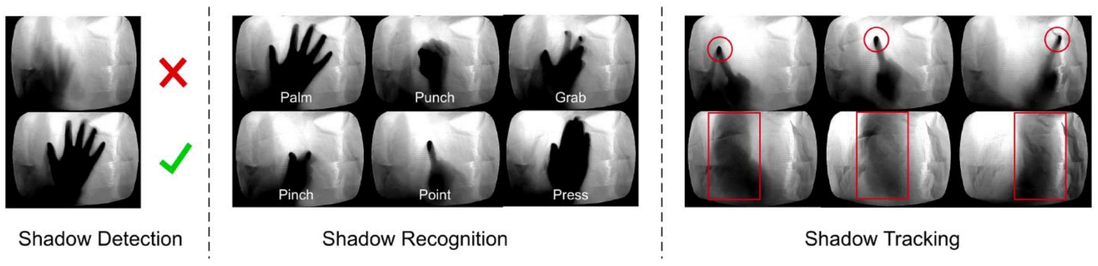


Fig. ShadowSense can (a) detect touch activities, (b) classify touch gestures, and (c) track touch positions

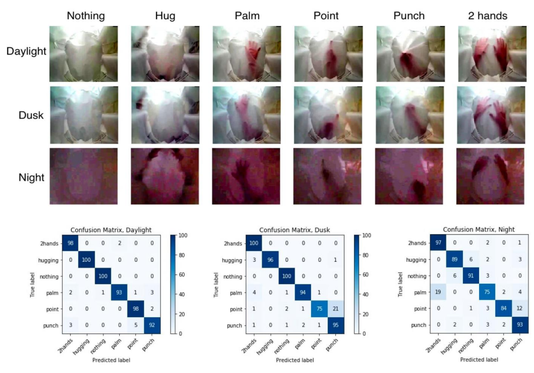


Fig. Confusion matrices for classification (in percentage), by lighting condition

Fig. Image samples from the training dataset. Each column represents one of the six interaction gestures. Each row displays one of the three lighting conditions under which images were collected.

Fig. Interaction examples using ShadowSense on an inflatable mobile robot. (a) When the robot detects a "poke", it turns around to face the human. (b) A "sliding" gesture instructs the robot to move closer. (c) A tap on the back sends it on its way.

We propose the use of image classification for human-robot tactile interaction. A camera positioned below a translucent robot skin captures shadows generated from human touch and infers social gestures from the captured images. We demonstrate the idea with an inflatable robot and an algorithm for recognizing touch gestures from shadows that uses Densely Connected Convolutional Networks. Experiments show that the system can distinguish between six touch gestures under three lighting conditions with 87.7 – 97.0% accuracy, depending on the lighting.

Experimenting with interaction modalities

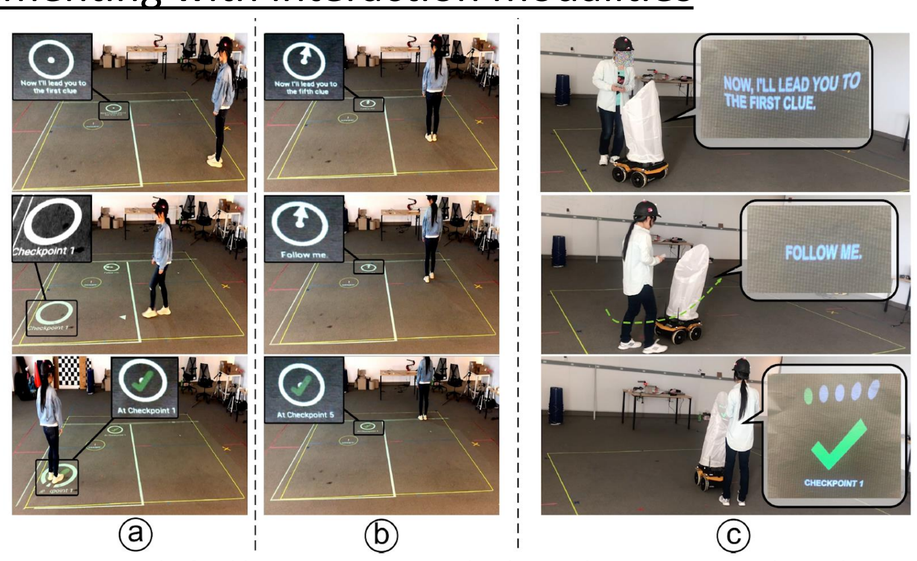


Fig. Experiment Overview. The fixed-location projection guides the user by projecting a marker at the waypoint if it's in the projection coverage (a), or an arrow pointing to its direction when off (b). The mobile display directly leads the user to the waypoint through movement (c).

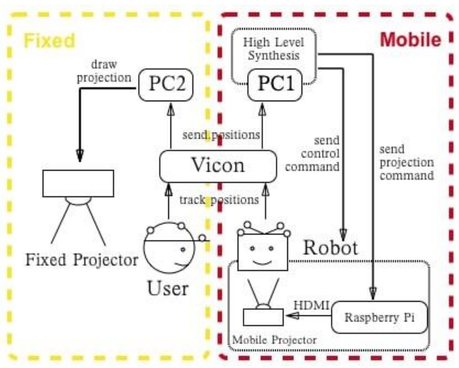


Fig. Diagram of the system showing the communications between the tracking system, the controllers, the robot, and the projectors.

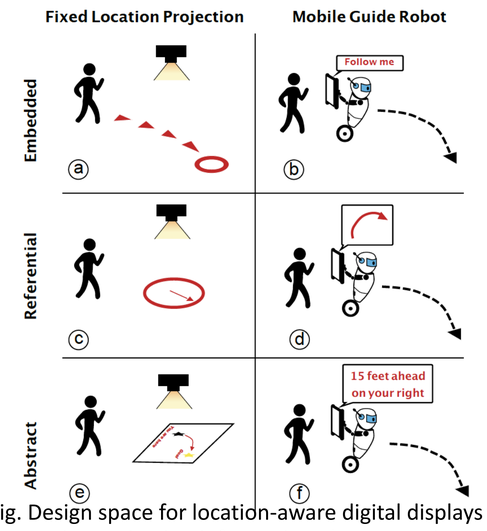


Fig. Design space for location-aware digital displays to provide users with navigation information along two dimensions: Fixed/Mobile and Embedded/Referential/Abstract.

We compare guide robots with dynamic projection signage as possible design solutions for leading people toward waypoints. We conceptualize the design space encompassing these two solutions and present an exploratory laboratory study (n=30) of the relative benefits and drawbacks of each. The study also presents participants with a combined robot-projection option. Participants are asked to follow navigation instructions, mark waypoints, and avoid restricted zones. From quantitative and qualitative data of participants' experiences, we find that projection signage is more efficient, accurate, and encourages active navigation. Guide robots, in contrast, are easier to use, can cover a larger space, reduce cognitive load and imbue a sense of safety.

Rover – Hardware Design

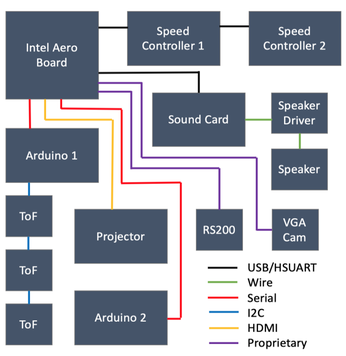


Fig. Hardware overview

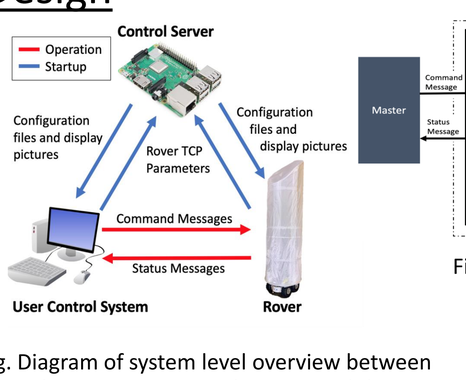


Fig. Diagram of system level overview between control server, user control system and the rover

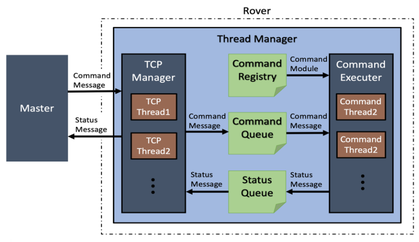


Fig. Software overview

Fig. Rover driving on different landforms.

We present a new mobile robot platform composed of a small rover base and a soft human-scale inflatable interface, capable of visual, tactile, and audible interaction. The inflatable interface allows the robot to maneuver discretely or in confined spaces when deflated yet grow to encourage interaction; it combines an internal projector, a camera, and speakers to emit and receive user information.

Social Impact

Deployment of low-cost robots that can safely interact with non-expert humans.

Robots may efficiently and safely manage large crowds in scenarios ranging from festivals and conventions to building evacuation.

Educational Impact

Material taught in several classes including Formal Methods in Robotics, Human Robot Interactions: Algorithms and Experiments.

The project broaden participation activities including lab tours and hour-long workshops as part of Cornell's Expanding Your Horizons yearly workshop for 7-9 grade girls.

Potential Impact

Deployment of small, robust, low-cost robots in disaster relief scenarios to team up with humans in large scale search or evacuation operations.

2019 NSF Cyber-Physical Systems Principal Investigators' Meeting

November 21-22, 2019 | Crystal City, Virginia

Award ID#: 1830471