EMPOWER: Enhanced Movement and Physical-Augmentation through Web-Enabled Robots

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Introduction

Robotic technology has the ability to unlock the productivity and grant greater purpose to mentally capable, but physically disabled, users. Towards this end, current commodity robots, such as robotics telepresence systems and quadrotor helicopters (Figure 1), provide platforms to enrich the lives the physically disabled. If these platforms can be made usable and globally accessible, physically disabled users can enjoy a higher quality of life and engagement with the world, essentially by removing physical and geographic barriers through networked robot embodiment.

According to the 2012 US Census figures (http://www.census.gov/prod/2012pubs/p70-131.pdf), approximately 30.6 million individuals ages 15 years and older (12.6 % of the population) have upper and lower body limitations, requiring assistive devices such as canes and wheelchairs. These physical limitations can be due to illness, genetics, or injury incurred through accidents or military service. Physical therapy and nursing care costs can become expensive and quality of life may be diminished due to reduced mobility, which serves as a barrier to potentially meaningful employment, physical recreation, and a number of common fulfilling activities.

Figure 1: Henry Evans (quadriplegic), flying a quadrotor helicopter using our web-browser interface.

Robotics is now at a stage to improve the lives of physically disabled individuals. This work describes the application of our work robotics-centered network communications to enable physically disabled users across the world to access and teleoperate quadrotor helicopters through common web browsers. The browser provides a distinctly advantageous computational platform given is ubiquity across society, interoperability with common assistive interface devices, and flexibility for designing graphical user interfaces to increase the ability to interact and communicate with the world in a more facile and meaningful manner. With the long-term goal of enabling the disabled to meaningful engage in the human-robot workforce, we have regularly made our quad rotors available to a global community of disabled users for web-based control. We believe this model of globally-accessible low-cost time sharing of robots is critical for broader participation in human-robot interaction in common human environments.

Communications for Web-enabled Robots

The technology for our EMPOWER research is founded on the research for viable web-accessible robot control over the past five years by Prof. Jenkins and his group at Brown. This work includes the rosbridge protocol and rosjs JavaScript library, which allow any robot running the Robot Operating System (ROS) to be controlled from any web browser or networked embedded system. (Crick et al. 2011) These tools are at the core of the open-source Robot Web Tools organization (http://robotwebtools.org), with usage and contributions from a wide variety of groups across academic, public, and industrial sectors. Our goal for Robot Web Tools is to broaden human-robot interaction by lowering the barriers of entry into robotics and reach more users through front-end robot web interfaces, while allowing maximal utilization of back-end robot capabilities (such as in ROS (Quigley et al. 2009)). Our previous work explored this aim through developing time-sharing through remote robotic labs, such as the PR2 Remote Lab (http://pr2-remotelab.com) (Osentoski et al. 2012), which allowed many remote users to access a small number of PR2 robots. Similar related work by Toris et al. in the RobotsFor.Me project (http://robotsfor.me) (Toris, Kent, and Chernova 2014), used rosbridge/rosjs to evaluate remote user performance for mobile manipulation tasks. rosbridge has also been used in assistive robotics applications (Chen et al. 2013) towards enable quadriplegics to perform basic activities of daily living through web interfaces. In each of these cases, the use of rosbridge enables interoperability through a clear open network protocol, and the integration with ROS (as one possible back-end) means that the system can be used on a wide variety of robot platforms, including simulated robots for high demand training.

Figure 2: Front end. Video feed as well as button controls shown on screen in web-browser interface.

The pipeline for communication between the robot platform and the web-browser includes: robot platform, device drivers, robot middleware, rosbridge, and the web-browser (Alexander et al. 2012).

Rosbridge allows non-ROS clients to work with ROS processes. Rosbridge allows for publishing and subscribing of ROS topic messages to be passed in JSON-formatted messages over TCP sockets and websockets. The rosbridge protocol allows for platform independence; publishing and subscribing can be achieved between any combination of clients and servers. Furthermore, any websocket-supported language can be used to write the rosbridge client.

We also run mjpeg_server for the video, each frame of a video stream is separately compressed as a JPEG image. The mjpeg_server subscribes to requested image topics and publishes the requested topics as mjpeg streams via http.

Initial Results

The potential of EMPOWER can best be illustrated through the on-going projects between Brown University and Robots for Humanity.

Over the past year, we have also been collaborating with Mr. Stuart Turner, a quadriplegic in Manchester, England. He has assisted us in determining international lag times and providing us with usability feedback on our drone interfaces using the Robot Management System (RMS). He enjoys flying the AR.Drone: around the lab, through an obstacle course we setup in the lab, and around the campus. He expressed excitement with the toggle cam button which allowed him to "look down on the world for the first time in 10 years".

Through our web-enabled AR.Drone (running ROS), Mr. Evans has been able to engage in the world from his home in California, where he remotely pilots AR.Drones and the Beam located in Providence, RI. The live video feed from the embedded cameras in the drone provide Mr. Evans a vehicle to explore and interact with the world far beyond the confines of his bed. Additionally, language capabilities such as "Yes" and "No" have been programmed into the web interface to allow Mr. Evans to communicate with others with a simple click of "yes" and "no" buttons, which stimulate the drone to make "yes" or "no" motions. Mr. Evans and Prof. Jenkins demonstrated the potential for this work in a recently well-received TEDxMidAtlantic talk (http://www.ted.com/talks/henry_evans_and_chad_jenkins_meet_the_robots_for_humanity) in Washington D.C.

These pilot experiments led to several preliminary insights into human-robot interaction for the physically disabled. Using only our stock web control demo, we were pleasantly surprised by the immense sense of enjoyment, mobility, and independence reported by our users. However, the user-experience came with some tradeoffs. The video feed needed to be significantly throttled and compressed for transport over HTTP. The image blurring and latency created by the drone's highly dynamic motion created challenges for remote operation, resulting in inconsistent piloting, instabilities in flight motion, quadrotor helicopter crashes, and limited flight durations from increased power consumption. We posit the piloting experience can be improved with power-aware shared autonomy to assist the user in navigating through the environment within the energy constraints of quadrotor helicopter systems.

References

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