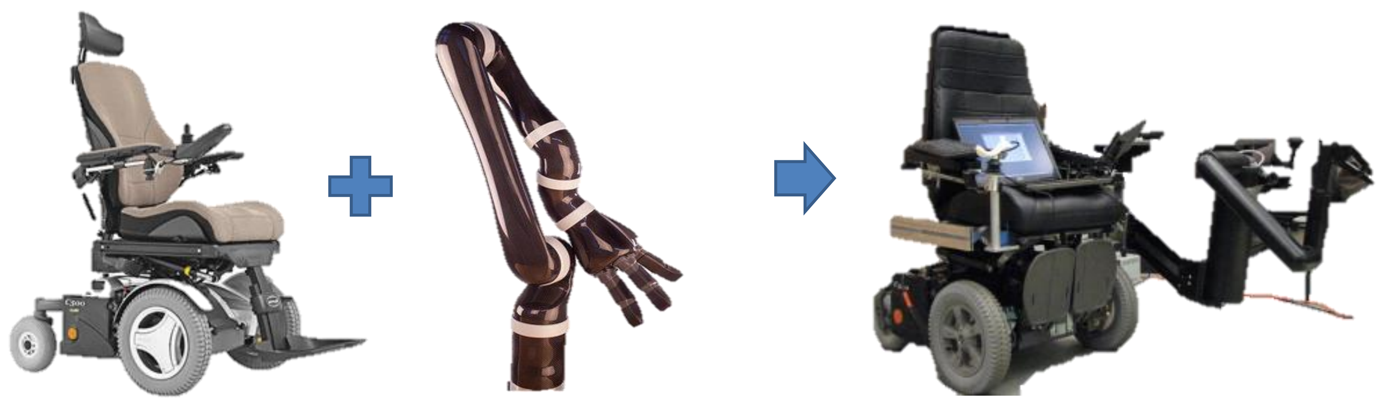
The design, development, and testing of the Personal Mobility and Manipulation Appliance (PerMMA) a robotic wheelchair system for people with disabilities

Elaine Houston[1], Jorge Candiotti[1], Chengshiu Chung[1], Hongwu Wang[1], Garrett Grindle[1]
[1]Department of Rehabilitation and Science Technology, University of Pittsburgh

Introduction

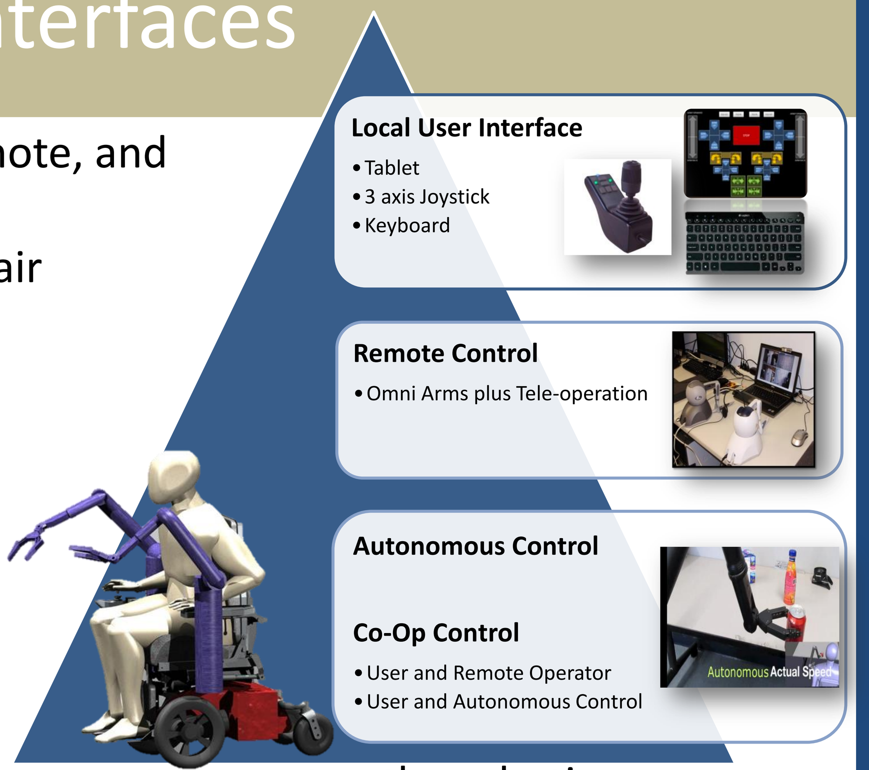
Background: For many people with disabilities, essential tasks such as dressing, preparing food, shopping, or taking medications require the assistance of a caregiver. For those who have concomitant mobility impairments, the use of a device that provides independent mobility and assistance with personal tasks could have a large impact on activity, participation, and quality of life, and may reduce reliance on caregivers [1]. Technology which aids in these tasks must allow the user to independently control mobility and manipulation, and work within an unstructured environment [2].



Motivation: Almost 16 million people have difficulty with lifting grocery bags, and 7 million have problems grasping a drinking glass [3]. Robotic systems have emerged as a rehabilitation engineering solution to ameliorate disabling conditions. A symbiotic system, at core, melds robotics with its traditional approach to developing autonomous systems with user operated quality of life technologies (QoLT). These systems create a symbiosis of human and technology maximizing the use of the abilities of the person and the capabilities of technology in natural environments. The Personal Mobility and Manipulation Appliance (PerMMA) was created to provide increased functional independence and spontaneity in both mobility and manipulation to persons with significant disabilities. This powered mobility device is equipped with Manus arms to assist the user in daily tasks[8].

User Interfaces

- PerMMA can be operated in local, remote, and autonomous control modes.
- **The first interface** allows the wheelchair user to use a keyboard, touch screen interface or a 3 axis joystick based on a user's dexterity and diagnosis.
- **The second interface** consists of two Phantom Omni (Sensable) haptic robots, a PC laptop, and custom software that allows PerMMA to transmit inputs and receive feedback via the Internet.

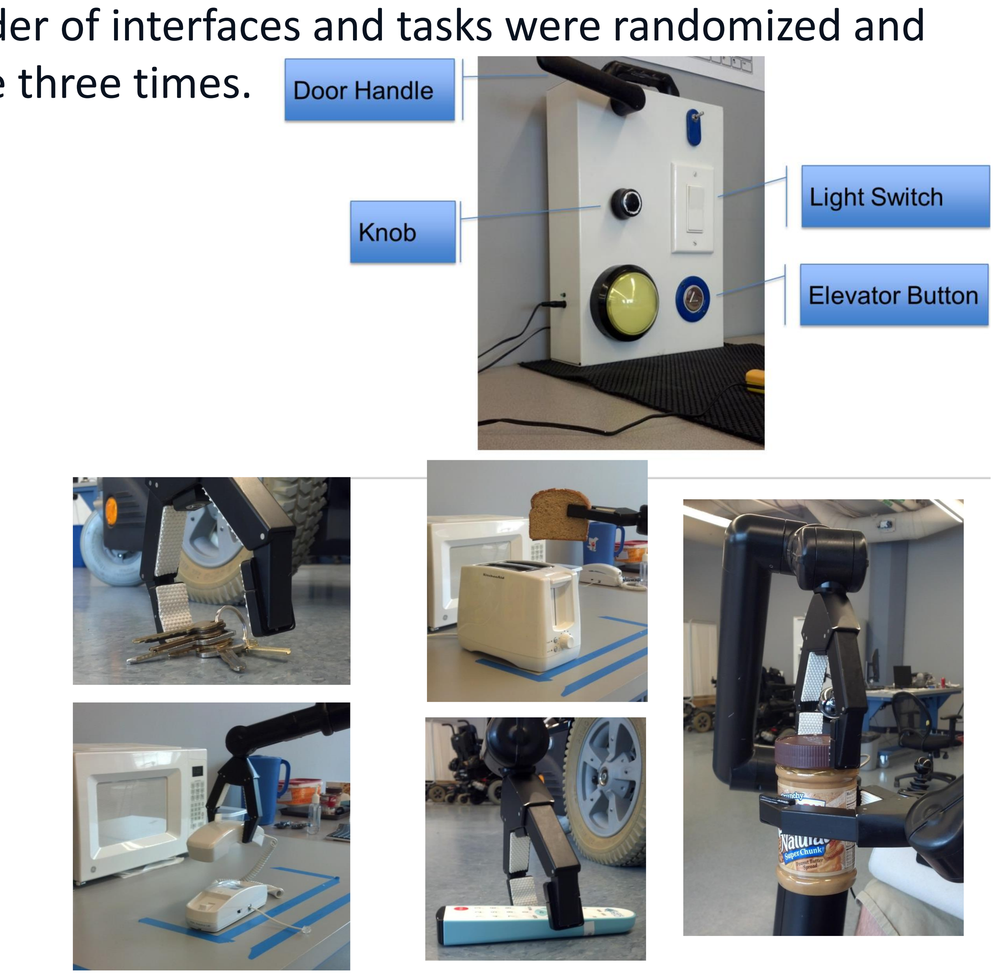


- When the haptic robots are moved by a remote operator, the robotic arms attached to PerMMA move in concert. The interfaces can be used simultaneously, with the local user taking priority in case of conflicting input.
- **The third interface** is an autonomous mode preferred for wheelchair users who have limited dexterity to perform fine activities. In this mode, the robotic arm uses visual feedback to detect the object that the user needs in order to retrieve the object towards the user.

Methods

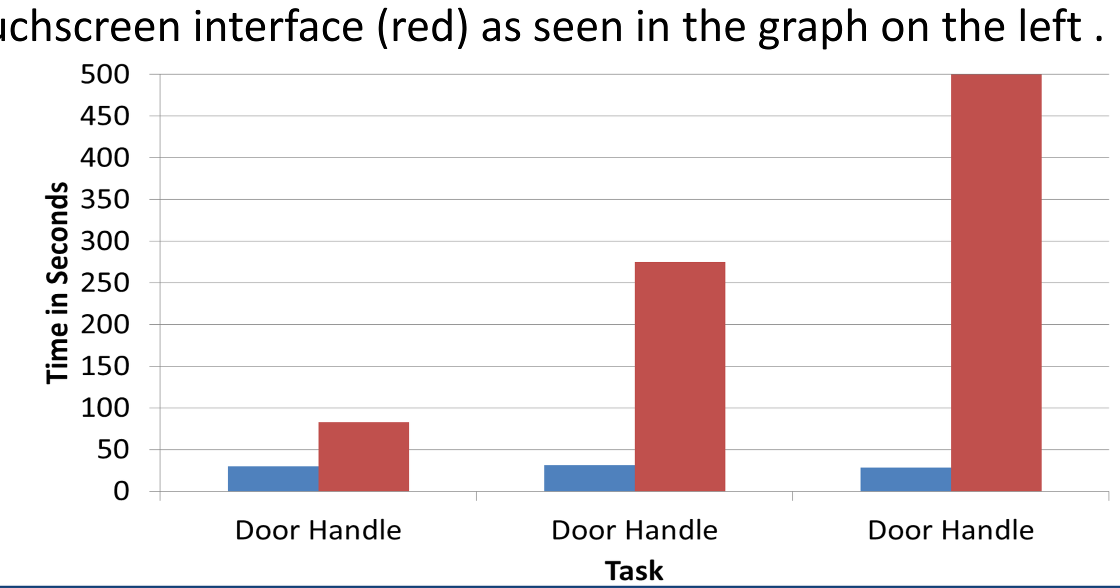
- **Sample:** Subjects with disabilities who have limited movement in upper extremities
- **Goals:** Examine how users are able to use different interfaces (touch screen and voice control) and how their disability might impact interface needs
- **Outcome Measurement Tools:** This study uses ETS Paper folding test and Cube Comparison Test, an upper extremity (UE) exam, and a modified version of the PST QoLT Battery. Tasks to be examined in visit two include picking up dropped remote and keys, placing a container in microwave and closing door, retrieving can off high shelf, among other ADLs. Outcome measures collected include time, key presses/voice commands, and PASS-R.
- **Protocol:** Each participant was asked to complete a training protocol that included performing different activities from a Task Box using the different interfaces of the robotic arm. Each participant performed this action three times in a randomized order while using the touch screen, then repeated in a different order with voice control. Order of interfaces and tasks were randomized and repeated with each interface three times.

Strength		
	Right	Left
Biceps (C5)		
Wrist Extension (C6)		
Triceps (C7)		
Finger Flexors (C8)		
Intrinsics (T1)		
Range of Motion		
Shoulder Flexion (0-180)		
Shoulder Abduction (0-180)		
Shoulder Internal Rotation (0-70)		
Shoulder External Rotation (0-90)		
Elbow Flexion-Extension (0-150)		
Wrist Flexion (0-80)		
Wrist Extension (0-70)		
Finger Flexion (MP, DIP 0-90; PIP 0-100)		
Spasticity/ Modified Ashworth Scale		
Elbow Flexion-Extension		
Wrist Flexion-Extension		
Hand Dominance		



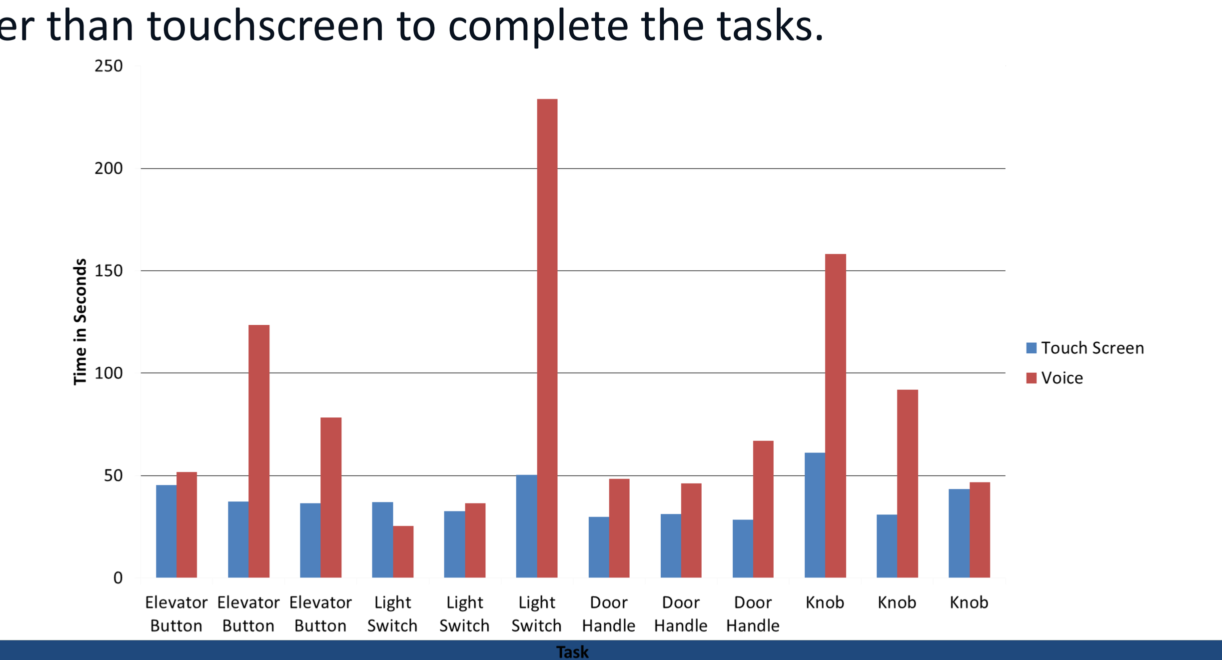
Results

- Before testing users on PerMMA we collected a series of data on both the visuospatial reasoning of the individual as well as the physical function of their upper extremities. Then using PerMMA we asked the individual to complete a series of tasks using various interfaces, on the instrumented ADL task board we created.
- Some of the preliminary results we collected so far show the differences in task completion time between a user who readily understands and is able to use PerMMA (blue) and a user who has a difficult time grasping how to use a touchscreen interface (red) as seen in the graph on the left .



Results

- In the graph below you can see the differences in task completion time between using the touchscreen interface as shown in blue and voice control interface shown in red, for an expert user. Most trials voice control took longer than touchscreen to complete the tasks.



Conclusion

- These preliminary results show the importance of matching the interfaces to the users as well as figuring out what factors play a role in being an expert or poor user.
- Increase Dexterity and mobility
- Improve performance in Activities of Daily Living,
- Enhance independency,
- Involvement with community.
- improve quality of life

References

[1] H. Hoenig, D. H. Taylor, and F. A. Sloan, B. Does assistive technology substitute for personal assistance among the disabled elderly? [Amer. Public Health Assoc., vol. 93, pp. 330–337, 2003.]
[2] R. G. Platts and M. H. Fraser, B. Assistive technology in the rehabilitation of patients with high spinal cord lesions, [Paraplegia, vol. 31, no. 5, pp. 280–287, May 1993.]
[3] J. M. McNeil, B Americans with disabilities: 2005, household economic studies, [Current Population Reports, 2008, pp. 70–117.]
[4] G. G. Grindle, H. Wang, B. A. Salatin, J. J. Vazquez, and R. A. Cooper, B Design and development of the personal mobility and manipulation appliance. [Assistive Technol., vol. 23, no. 2, pp. 81–92, 2011, DOI: 10.1080/10400435.2011.567374]

Acknowledgments

- Thanks to colleagues and collaborators who have contributed to the development of the PerMMA project, most importantly the end users and caregivers who have contributed their time.
- Especial thanks to the shop staff C. Blauch, B. Brewer, Z. Mason, M. McCartney, C. Atkeson, M. Hebert, S. Sinervasa, R. Schulz, K. Seelman, and B. Gebrosky.

QoLT Center