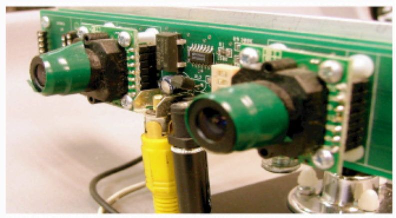
Assistive Robotics @ UMass Lowell

UMass Lowell Robotics Lab
Department of Computer Science
http://www.cs.uml.edu/robots



Vision-Based Interaction for Robot Arms and Wheelchairs in Human Environments

Assistive technology provides independence for people with disabilities. While assistive devices such as powered wheelchairs and menu-driven robot arms improve the quality of life for some, others are unable to effectively use these technologies due to their limited user-interaction methods. Addressing this issue, the UMass Lowell Robotics Lab is developing assistive robot technologies with more user-friendly interaction methods. We are currently designing a robot wheelchair and a robot arm that use artificial intelligence techniques, including computer vision and robot mapping. These systems will be able to work robustly any environment without reconfiguration. Unlike other robot technologies that must be operated at a distance, assistive robots work in the same space as their user, often with the user as a rider of the technology. Our systems are designed to take advantage of this collocation through the development of effective human-in-the-loop control.

UMass Lowell Robotics Lab

The Robotics Lab was founded by Dr. Holly Yanco in 2001. Research focuses on human-robot interaction (HRI), which includes interface design, robot autonomy, computer vision, and evaluation methods. Application domains include assistive technology (AT) and urban search and rescue (USAR). The Robotics Lab also has an active community partnerships program, working with K-12 students.

Research in the lab is funded by the National Science Foundation (IIS-0308186, IIS-0415224, IIS-0546309, IIS-0534364, SES-0623083, CNS-0540564) and the National Institute of Standards and Technology (70NANB3H1116). Dr. Yanco received an NSF Career Award in 2005.

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Assistive Robot Technology

Imagine you are going to a meeting in an building in which you have never been before. You enter the lobby and look for a building directory. You determine where you are going using the building directory or map. After proceeding to the elevator, you press the elevator call button, enter, and select the desired floor. Upon reaching your floor, you look for a sign indicating which rooms are to the left and which rooms are to the right. If there is a sign, you travel in the direction corresponding to the location of the room. If there is no sign, you monitor the progression of the office numbers. When you successfully reach your destination, you open the door and enter.

This process seems easy, almost intuitive in most buildings. However, to someone in a wheelchair with limited mobility, this scenario can be challenging.

The UMass Lowell Robotics Lab is drawing upon a decade of assistive technology experience to design robot wheelchairs that help users navigate easily and confidently in situations such as the above scenario. We are developing and testing new technologies in wheelchair navigation, human cue detection, and robot arm manipulation on a prototype robot wheelchair, Wheeley.

Automatic Map Annotation

Our daily environment is filled with human-designed cues that tell us where we are, what to do, and where to go. In indoor environments, there are many building codes dictating the location, size, color, and shape of human cues. Our map annotation system automatically annotates building cues on a map as our robot wheelchair navigates through the environment.

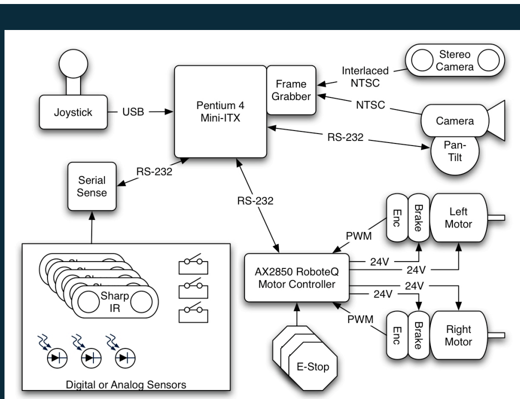
In this simulated example, optical character recognition detects the room number. Reading room numbers is a complex task because any number is just as likely to be followed by any of the ten digits and possibly a dash, punctuation or letters.

Someone using our robot wheelchair would find indoor environments much more accessible. The robot wheelchair build maps of new environments while reutilizing them later. For example, if the wheelchair occupant wanted to revisit a particular location later, he could activate the navigation system and proceed directly there automatically.

To allow the system to detect human cues, we are continuing the development of the Swarthmore Vision Module (SVM). SVM includes a text detector and basic optical character recognition (OCR) system. The text on the signs may be relevant to a robot's task. An example is navigating from one room to another in a numbered hallway. SVM is being expanded with more robust OCR and will include detection of other human cues such as doors, door handles, elevators, and elevator buttons.

Stereo Vision Simultaneous Localization and Mapping

Simultaneous localization and mapping (SLAM) has traditionally used active distance sensors, such as laser range finders and sonar. However, these sensors are not ideal for a robot wheelchair. Laser range finders are not eye safe and are expensive. Sonar sensors produce audible clicking noises.



Enabling Technology: Wheeley, A Robot Wheelchair System

Our wheelchair base is a Vector Mobility chassis. The motor controller has a RobotEQ AX2850 and optical encoders for closed-loop motor control. Two 12V batteries supply 24 volts to the entire system. A Pentium IV 2.8Ghz Mini-ITX computer running Debian Linux is mounted inside a custom Pelican case on the back of the wheelchair. The PC has a four-channel frame-grabber with a Canon VC-C50i pan-tilit-zoom color camera and Videre Design's STH-V1 stereo head. A 1-inch peg-hole Plexiglas grid mounted below the seat allows for quick prototyping of sensor configurations. Analog and digital sensors values are polled using a SerialSense, an interface board developed at the UMass Lowell Robotics Lab.

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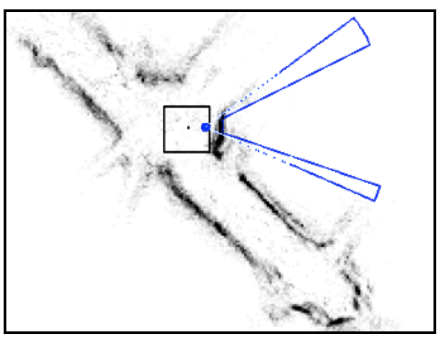
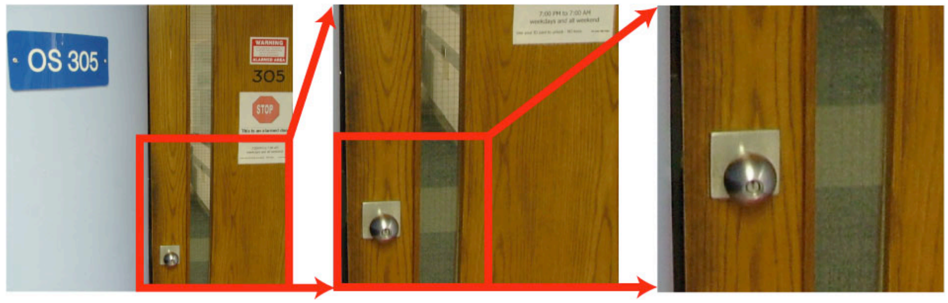
We are using stereo vision cameras as a solution to this problem. A passive camera will not be as disturbing as clicking noises to someone in a wheelchair nor pose the potential safety hazards of traditional range finders. In addition, camera technology is less expensive than active sensor alternatives.

To perform SLAM on our wheelchair, we are integrating a stereo vision library with pmap, a SLAM implementation. We generate 2D range data from the stereo camera and pass that information to the mapping software. This software runs in real-time and creates a map as the robot wheelchair travels in known and unknown environments.



An example of a map generated in real time using stereo vision based SLAM while navigating a hallway. This map can be used by the wheelchair occupant for assisted navigation.



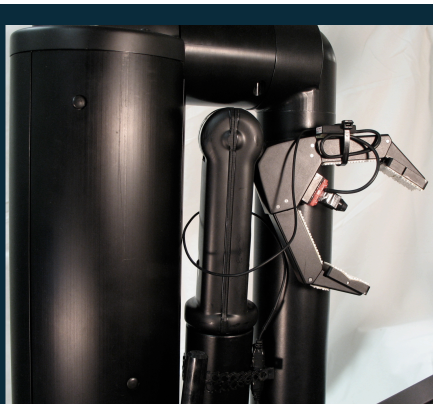
The user "zooms in" on the doorknob using progressive quartering. Identification of objects like this help the vision system target and manipulate the environment.

Visual Control of a Robot Arm

Activities of daily life, such as picking up a telephone or drinking a cup of coffee, are taken for granted by most people. Typically, people with severe physical handicaps have a dedicated caregiver to help them, but more independence may be desired in personal activities. Personal fixed-base robot arms can assist with daily activities, but most of these devices are engineered for specific environments. While they succeed at their predefined tasks, they fail in the real world.

The Exact Dynamics' Manus ARM functions in unstructured environments, but it is awkwardly controlled through a menu system using a keypad, a joystick or a single switch. These controls are not intuitive or natural because they require a high level of cognitive awareness. Also, the input devices may not correlate well to the user's physical abilities.

UMass Lowell Robotics Lab's research investigates visual control or a robot arm. We leverage all of the Manus ARM's benefits while eliminating its weaknesses. Our vision-based system draws inspiration from people's innate abilities to see and touch. Because the wheelchair occupant is collocated with the ARM, the occupant's view is the same as a camera mounted over the ARM's shoulder. The occupant "zooms in" on the desired object using progressive quartering. Our goal is to allow the occupant to acquire the object by unfolding the ARM, then reaching and grasping the object in a manner emulating human kinematics. This human-in-the-loop control will provide simpler and effective interaction.



Enabling Technology: Exact Dynamics' Manus ARM

The Manus Assistive Robotic Manipulator (ARM) is a wheelchair mounted robot arm. It has a two-fingered gripper end-effector and is a 6+2 degree of freedom unit with encoders and slip couplings on its joints. The ARM weighs 31.5 lbs and has a reach of 31.5 inches from the shoulder. The gripper has a clamping force of 4 lbs; the payload capacity at maximum stretch is 3.3 lbs. The ARM is controlled by accessing menus using a keypad, a joystick, or a single switch. Two different modes provide individual joint control or 3D translation. In addition to manual control, the ARM can be controlled by communication from a PC. The UMass Lowell Robotics Lab's ARM has been outfitted with a Canon VC-C50i pan-tilt-zoom color camera mounted over the shoulder and a small, color camera within the gripper.

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Our Collaborators

- **Crotched Mountain (David Kontak)**
- **University of Central Florida (Aman Behal)**
- **Exact Dynamics (GertWillem Romer)**
- **Swarthmore College (Bruce Maxwell)**
- **MobileRobots, formerly ActivMedia (Bill Kennedy)**

Related Links

- **UMass Lowell Robotics Lab**
  http://www.cs.uml.edu/robots
- **Exact Dynamics**
  http://exactdynamics.nl

Selected Publications

K. M. Tsui and H. A. Yanco. "Simplifying Wheelchair Mounted Robotic Arm Control with a Visual Interface." *AAAI Spring Symposium on Multidisciplinary Collaboration for Socially Assistive Robots*, March 2007.

K. M. Tsui and H. A. Yanco. "Human-in-the-Loop Control of an Assistive Robot Arm." *Proceedings of the Workshop on Manipulation for Human Environments, Robotics: Science and Systems Conference*, August 2006.

M. Desai and H. A. Yanco. "Blending Human and Robot Inputs for Sliding Scale Autonomy." *Proceedings of the 14th IEEE International Workshop on Robot and Human Interaction Communication*, August 2005.

M. Baker and H. A. Yanco. "Automated Street Crossing for Assistive Robots." *Proceedings of the International Conference on Rehabilitation Robotics*, June 2005.

M. Baker and H. A. Yanco. "Autonomy Mode Suggestions for Improving Human-Robot Interaction." *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2004.

H. A. Yanco and Jill Drury. "Classifying Human-Robot Interaction: An Updated Taxonomy," *Proceedings of the IEEE Conference on Systems, Man and Cybernetics*, October 2004.

H. A. Yanco. "Evaluating the Performance of Assistive Robotic Systems." *Proceedings of the Workshop on Performance Metrics for Intelligent Systems*, August 2002.

K. Haigh and H. A. Yanco. "Automation as Caregiver: A Survey of Issues and Technologies." *Proceedings of the AAAI-2001 Workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care*, August 2002.

H. A. Yanco. "Wheelsley, A Robotic Wheelchair System: Indoor Navigation and User Interface." In *Lecture Notes on Artificial Intelligence: Assistive Technology and Artificial Intelligence*, Springer-Verlag, 1998, pp. 256-268.

H. A. Yanco. "Development and Testing of a Robotic Wheelchair System for Outdoor Navigation." *Proceedings of the 2001 Conference of the Rehabilitation Engineering and Assistive Technology Society of North America*, RESNA Press, 2001.

H. A. Yanco. "Integrating Robotic Research for Assistive Technology Applications." *AAAI Spring Symposium on Integrating Robotic Research: Taking the Next Leap*, March 1998.

H. A. Yanco and J. Gips. "Driver Performance Using Single Switch Scanning with a Powered Wheelchair: Robotic Assisted Control Versus Traditional Control." *Proceedings of the Annual Conference of the Rehabilitation Engineering and Assistive Technology Society of North America*, RESNA Press, 1998.

H. A. Yanco and J. Gipps. "Preliminary Investigation of a Semi-Autonomous Robotic Wheelchair Directed Through Electrodes." *Proceedings of the Rehabilitation Engineering Society of North America Annual Conference*, RESNA Press, 1997, pp. 414-416.

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