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Semi-Autonomous Mobility verses Semi-Mobile Autonomy

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Abstract

Robotic wheelchairs are an excellent example of tight coupling between the desires of the operator and the automated navigation system of a robot. One of the primary challenges of such a system is to have the chair follow the navigational desires of the operator while maintaining safety. Often, in crowded situations, the automated system will halt movement, or redirect the chair against the operator's desires. In these cases the operator usually has to execute a manual override – temporarily disabling the automated safety features of the robot. This paper explores two alternatives. The first is an autonomy dial, where the operator can move along a spectrum of manual to autonomously guided movement. The second is a system for autonomously deciding when to switch to manual control i.e., having the autonomous system recognize when it is stuck and needs assistance.

Introduction

The TinMan (KIPR 99, Miller 95) robotic wheelchair consists of a standard power wheelchair (a Vector Velocity) with a modified control system and an array of sensors. The primary sensors on our test robot include an array of ten IR proximity sensors, an instrumented front bumper, and two drive wheel encoders. The control interface consists of a standard wheelchair joystick, and a control paddle which has two programmable buttons and a frob knob. All the controls and sensors feed into the TinMan supplementary controller which then generates commands for a standard PG-8 wheelchair controller.

Robotic mobility aides, such as the TinMan semi-autonomous wheelchair, can allow a quadriplegic or other person with a severe mobility disability to move autonomously about the world (Yanco 98). Obstacle avoidance, route following, and docking are all features that have been put into these experimental systems. However, these systems cannot be treated as standard autonomous or semi-autonomous robots.

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The operator of a robotic wheelchair has mobility wants and desires that must be satisfied if the robot is to be of any benefit. A robotic chair is required because the operator is not capable of operating the interface to a standard power wheelchair. The robotic wheelchair allows driving directions to be given at a much lower bandwidth than is usually required. The robot takes high-level directional instructions and does the fine level of navigation (obstacle avoidance, docking, etc) autonomously.

There can sometimes exist a conflict between the autonomous navigation system of the robot and the even more autonomous operator (Simpson 96). On most of these devices it is often difficult for the operator to move next to an object without first disabling features of the robot navigation system (e.g., obstacle avoidance). These overrides act as a digital scheme for adjusting the level of autonomy in the system. Certain capabilities are successively disabled until the chair is an intellectual vegetable whose every movement is controlled by the operator.

In such a manual mode, the system, including the operator, is at risk. The reason for using a system such as TinMan is because the operator's sensory abilities and/or fine motor control abilities are limited. Going into a manual mode, even for limited periods is inefficient and potentially dangerous.

Switching Modes

For the TinMan system, the standard method of switching modes is to press a specific combination of buttons on the control paddle while moving the joystick. Such a command is beyond the capabilities of many of the eventual target users for this system. In addition to the physical difficulties in performing the maneuver for some users, there is a considerable possibility for confusion and accident. The only high speed collisions that have occurred with the TinMan system (known to the author) have occurred when an operator switched to manual mode to get out of a tight situation, and then neglected to reengage the obstacle avoidance system – but thought that it was operational. They then proceeded to head off at high speed with complete (but unfounded) confidence that the system would guide them around the approaching pillar.

In an attempt to minimize these accidents, we tried introducing a spectrum of autonomous-manual modes that were adjusted (pseudo)-continuously by the frob knob. In normal semi-autonomous mode the robot would head off in the direction initially selected by the operator. If an approaching obstacle were detected, the robot would autonomously adjust its course to avoid it. If the operator input a new directional command, it would be followed unless an obstacle avoidance maneuver was invoked. The clear hierarchy of commanding the chair was (from the bottom up):

1. autonomously following the set direction
2. operator input
3. obstacle avoidance
4. operator stop command

The frob knob allowed this hierarchy to be muddied. In particular, it allowed the positions of the middle two levels to be merged and even switched. At one end of the knob the hierarchy is as shown above, at the other end it is reversed. In between both commands are weighted according to the knob position and the chair is moved along the resulting vector.

This was at best a mixed success. The weighted mode was sometimes useful in tight corridors, or for nudging the chair through a narrow doorway. The autonomous system would line up the chair, but it would stop just before the doorway. With the knob set just shy of the standard hierarchy, the chair would start moving forward slowly if the joystick was pushed most of the way forward. Once it started into the doorway it was fine.

Unfortunately, the results were not as positive in areas with several distinct obstacles. In particular, it was quite possible to head straight into something (albeit at low speed) because the chair had decided to go left and the operator right.

Another fault with this approach is that different situations seemed to work best with different settings. Typically, the tighter the environment, the more manual control input was desired (at least by our able-bodied testers). Since the knob was being adjusted fairly often, the system was failing as a method of reducing operator bandwidth.

Autonomously Switching to Manual

The protocols from these tests did yield some interesting results. One was that when the chair was set with the traditional hierarchy, and got stalled in a narrow doorway, the user would push forward on the joystick, for an extended period, with ever increasing force, until giving up and adjusting the knob.

In tight situations, when the chair would get itself stalled in what it thought was a box, where the only perceived open area (if any) was a radical departure from the previous direction, then the user behaved differently. In most of those cases, the user started maneuvering the joystick almost randomly, searching for some direction which would cause the chair to move and get out of its “box”.

We believe that these situations can be recognized. The combination of the sensor readings and the joystick patterns yield a very discernible pattern. Our current work involves having the TinMan controller recognize when the chair is stuck, and what strategy the operator is attempting to use unstuck it. The controller will then temporarily reverse levels two and three of the hierarchy until the sensors indicate that the chair is beyond that tight situation. It will then autonomously revert back to semi-autonomous mode.

We hope to have results from these new tests in the near future.

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