Autonomous Wheelchair with Monocular Visual Odometry

ELECTRICAL & COMPUTER ENGINEERING

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CYBERWORKS ROBOTICS

Problem Statement

Common paths and doorways are daily challenges for powered wheelchair users

- Many users operate the wheelchair with single switch inputs, making precise motion difficult
- We have developed an autonomous control system for powered wheelchairs to enhance user driving capabilities

System Requirements

- Inexpensive onboard processor and webcam
- Accurate monocular visual odometry
- Safe Control of Powered Wheelchair

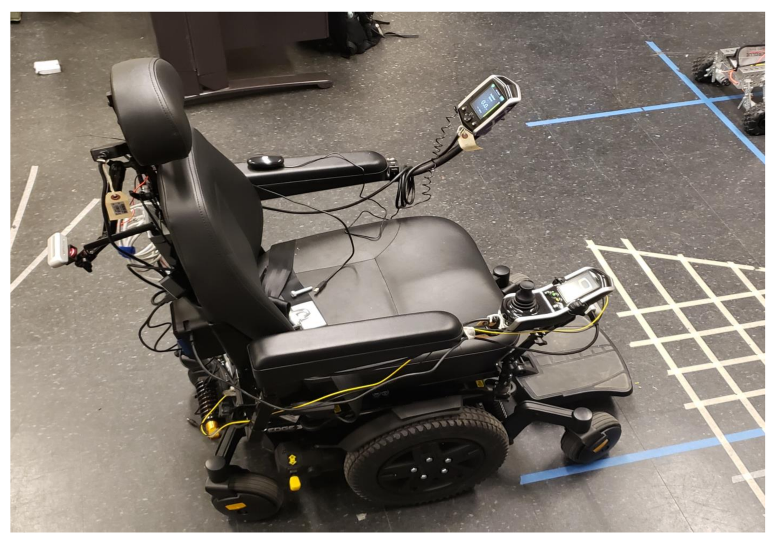
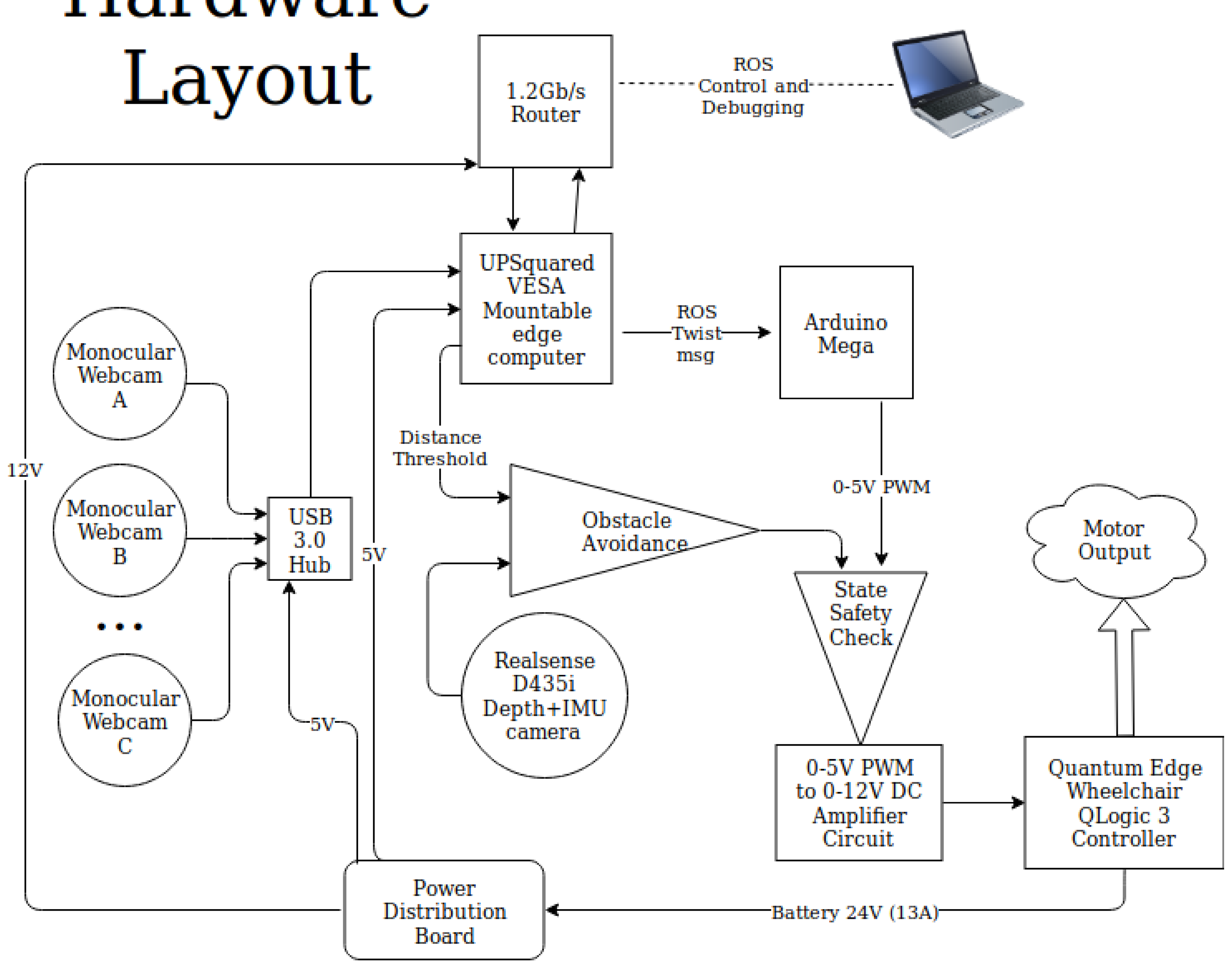


Figure 1: Pride Mobility Quantum Edge Wheelchair

System Data Flow

- Data shared among ROS devices on network
- User drives robot in teach pass and robot records waypoints
- Robot autonomously navigates path in repeat pass with added active safety checks

Hardware Layout



SLAM Limitations

- Computationally expensive; requires expensive hardware for real-time performance

Limitations of Traditional Approaches

- Odometry from wheel encoders prone to noise
- LIDAR's and 3D depth cameras are expensive

Monocular Odometry

Autonomous Robotics need robust odometry to repeat trajectories through space

- Detect and track feature points between images
- Use ground planar model assumption to calculate the three-dimensional coordinates of the tracked image features
- Solve perspective-n-point problem to obtain frame to frame pose change estimate
- The pose changes are combined for final odometry result

Ground Planar Model

- Use trigonometry and camera to ground transformation to calculate 3D position of any point on the ground plane

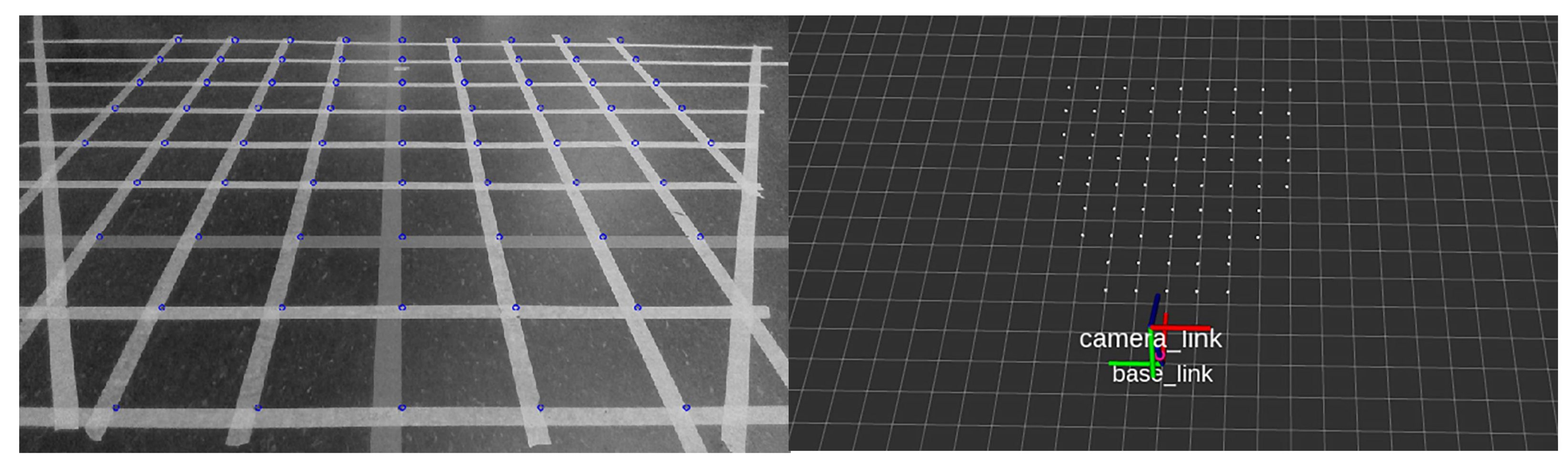


Figure 2: The small blue dots at each grid intersection in the left image are features on the ground plane. The right image shows the same features converted to 3D space using the ground plane model assumption and then visualized in RVIZ

Teach and Repeat

Teach Pass

- Collect 3D coordinates of waypoints for every change in distance and/or angle and store waypoints in a file
- Autonomous control of a powered wheelchair that can repeat a previously taught path

Repeat Pass

- Load path waypoints from a file
- Use monocular pose estimation to choose waypoint and estimate path error
- Use PID or Lyapunov controller to minimize error and converge to waypoint
- Repeat until end of path reached

Figure 3: PID controller following high resolution path waypoints from teach pass with high degree of accuracy. Note that grid lines are 0.6 m.

Experimental Results

Monocular Odometry

- We have not been able to test with ground truth but have tested returning to the starting position and response to a 90 degree turn in a hallway, using the wheelchair

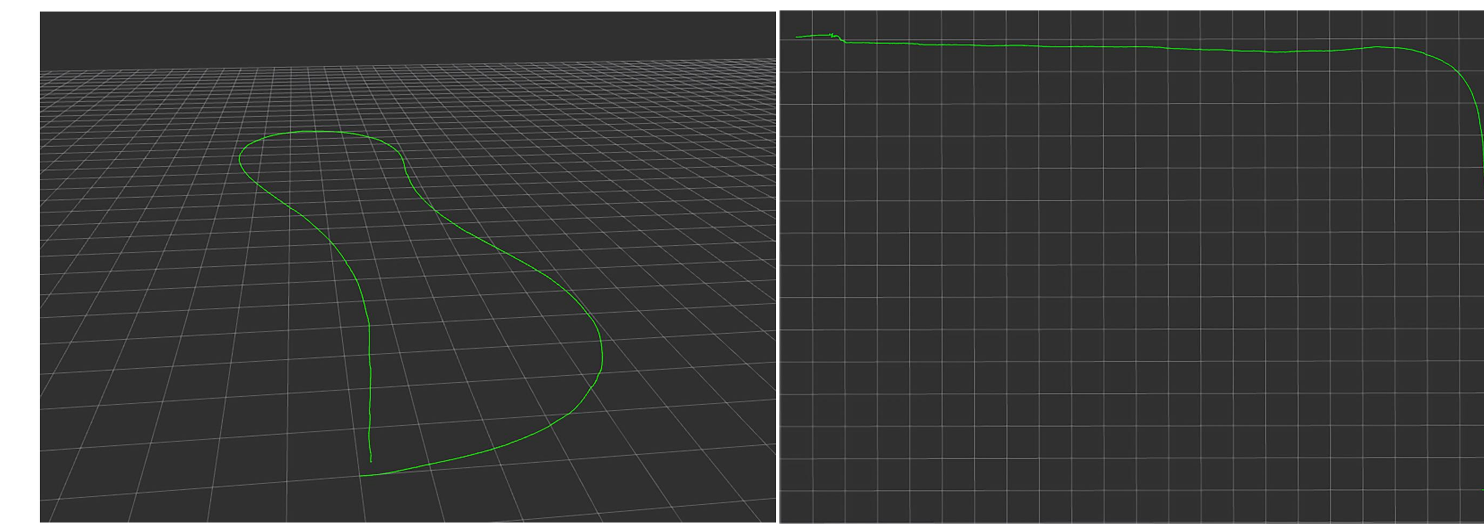


Figure 4: Both images are results from monocular odometry taken from the wheelchair. In the left image the wheelchair returned to the starting position and in the right, it performed a 90 degree turn in a hallway. The grid lines are 0.6 m

Teach & Repeat

- Accurately captures teach pass path in high resolution
- Controllers can follow paths accurately

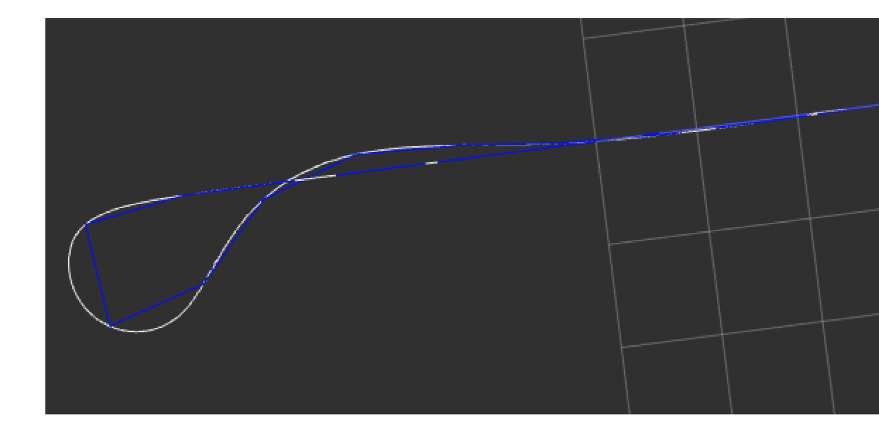


Figure 5: PID controller following teach path

Future Work

Teach and Repeat

- Improve teach and repeat to follow paths on kilometer scale
- Implement capability to record multiple teach and repeat paths

Computer Vision

- Use bundle adjustment or extended Kalman filter for improved odometry estimates
- Incorporate one 3D depth camera for point cloud recording and matching for improved localization
- Create neural network to estimate 3D points of non-planar features from 2D image
- Research other methods for improved localization

Navigation and Controls

- Potentially implement algorithm based on Difference Image Correspondence Hierarchy (DICH) for greater controller robustness against noise
- Implement MPC controller for obstacle avoidance capabilities and improved path tracking