

Obstacle Avoidance Wheelchair System

Submission to CanestaVision™ Competition: Phase II

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Abstract

We present a collision avoidance system for powered wheelchairs used by people with cognitive disabilities. Such systems increase mobility and feelings of independence, thereby enabling reversal of some symptoms of depression and cognitive impairment and improvement of quality of life. Canesta electronic perception technology allows the wheelchair to “see” obstacles, avoid collisions, and suggest alternatives to users. The Canesta sensors are ideal, as they combine accuracy with efficiency in the distance range necessary for collision avoidance.

1 Motivation

High quality of life is of the utmost importance and mobility is a key component of a positive quality of life. Unfortunately, many older adults face various impairments and disabilities that result in their mobility being compromised. Furthermore, many of these people require a powered wheelchair because they lack the strength to manually propel themselves. However, powered wheelchairs are not appropriate for older adults with a cognitive impairment, such as Alzheimer’s disease, as they do not have the cognitive capacity required to effectively and safely manoeuvre the wheelchair. In addition, their sometimes aggressive and unpredictable behaviour makes wheelchair use unsafe for both themselves and others sharing the environment. If we can provide these users with some level of independence, irrespective of ability, without placing the person or others at unreasonable risk, then it may be possible to reverse some symptoms of depression and cognitive impairment and improve quality of life. The goal of this project is the novel application of Canesta’s 3D sensor system to adapt a powered

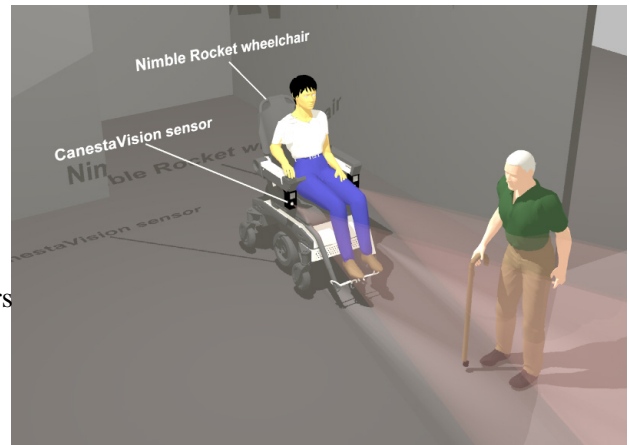


Figure 1: Nimble Rocket™ wheelchair with Canesta 3D perception sensors.

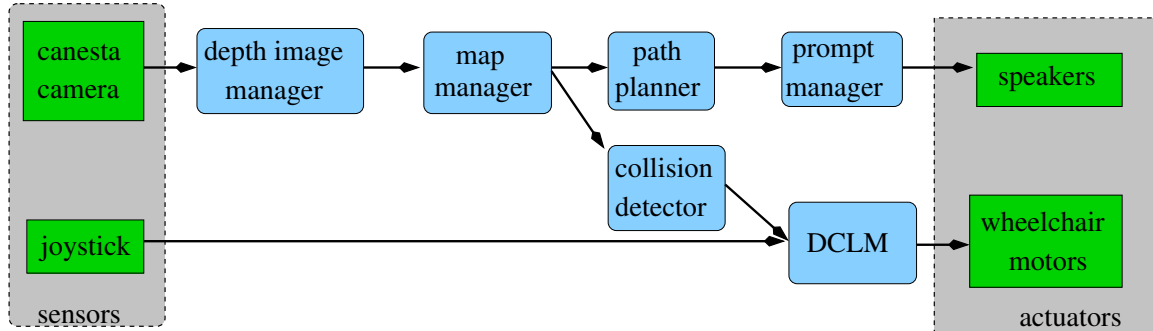


Figure 2: Schematic of the system including five major components.

wheelchair, specifically, the Nimble RocketTM so that it can be driven safely by users with cognitive and other complex impairments. The Canesta sensor is an ideal choice for this application. For example, its advantages over a laser range sensor are its 3D and imaging capabilities, smaller footprint, and low power requirements. Figure 1 shows an artist’s rendition of the Canesta sensor mounted on the wheelchair.

2 System Overview and Results

An overview of the system is shown in Figure 2. The input layer is the *depth image manager*, which takes output from the Canesta sensor and produces a 64×64 depth image, in which each pixel gives the depth of that location. This depth image is then passed to the *map manager*, which constructs an occupancy grid map. We describe occupancy grids at the end of this section. The occupancy grid is then input to the *collision detector* and to the *path planner*. The *collision detector* estimates if there is a collision imminent by comparing the distance to the closest object in the map to a pre-defined threshold. If an object is too close, then a signal is sent to the *Directional Control Logic Module* (DCLM)¹. The DCLM acts as a filter for the control signals from the joystick to the motors, only allowing those through that will not lead to a collision. The collision detector sends the direction of the hazardous direction to the DCLM, thereby restricting the motion of the wheelchair in that direction. The *path planner* computes the best direction around the obstacle from the occupancy grid using the *direction of greatest freedom* (DGF). The DGF is the direction around the obstacle with the largest number of unoccupied grid cell. The DGF is then sent to the *prompt manager*, which selects an audio prompt to play, suggesting a possible alternative action for the wheelchair user.

An occupancy grid is a method for robotic mapping which represents obstacles in the world using a 2D map of *cells*. Each cell has a value from 0 (known obstacle) to 256 (free space) with 128 representing unknown or unexplored. The *map manager* constructs a local occupancy grid from a range image in three stages. First, the depth image (Figure 3(b)) is projected to the floor, where the closest depth in each column is used, as shown in Figure 3(c). Given the known camera geometry, the resulting 1D array of depths can be mapped into the 2D horizontal plane by ray tracing, Figure 3(d). The occupancy grid cell values, $G(i)$ for each cell i , are then updated using the method of [ML98], by adding a constant $+K$ if the cell is in the occupied region of a radial map, and by $-K$ if its in the clear region. The constant K controls how quickly the map evolves over time and responds to changes.

Figure 4 shows an example as the wheelchair approaches a large obstacle.

¹Designed & developed by Gerald Griggs, Centre for Studies in Aging, Sunnybrook & Women’s College, Toronto, Canada

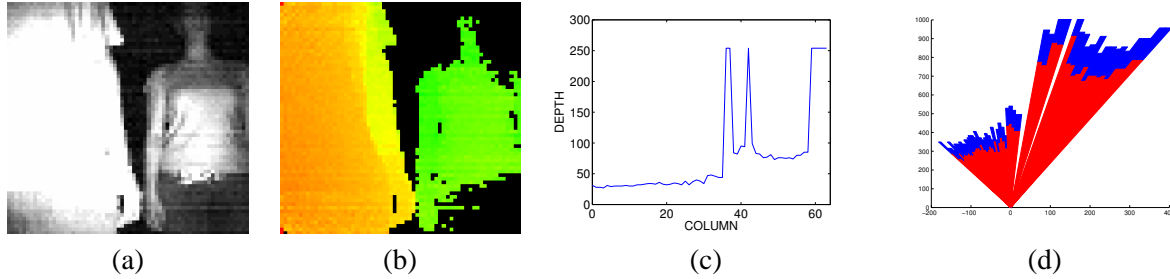


Figure 3: Constructing a map from a depth image. An image (a), its depth image (b), is projected onto the ground (c). Rays are then computed from the sensor position to give the radial map (d).

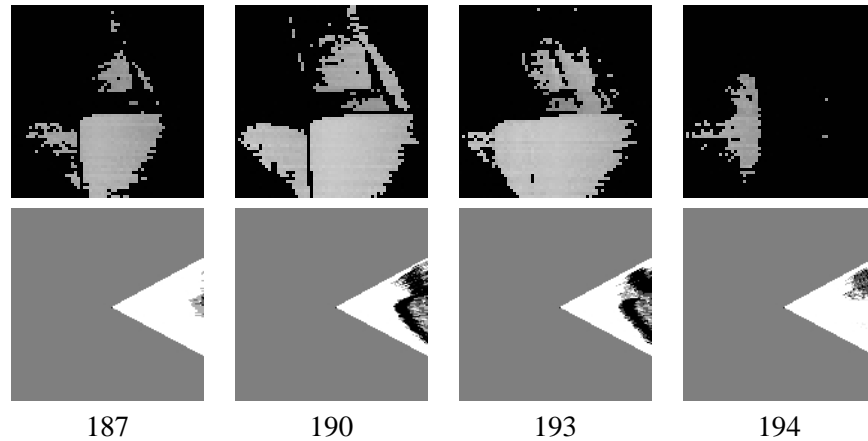


Figure 4: Example of avoiding a collision with a chair. Depth images(top row) and corresponding occupancy grids (bottom row). The wheelchair approaches (frame 187), stops (190), a prompt is issued, suggesting a right turn, which the user takes, and the obstacle moves to the left (frames 193-194).

3 Conclusion and Future Work

We have presented a method for wheelchair obstacle avoidance using the Canesta 3D sensor. The wheelchair stops before collisions, and suggests alternatives for mobility. The Canesta sensor's speed and accuracy make it ideal. This system has great potential to improve health and independence in an increasingly elderly population. Future work can include allowing more range to see obstacles to the sides and back. This involves using odometry to sew occupancy grids into a global map of the environment, allowing for more intelligent path planning. A pan-tilt unit could also be used for active sensing.

References

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