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Wheelchair Navigation: Automatically Adapting to Evolving Environments

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Abstract. Power wheelchairs can increase independence by supporting the mobility of their users. However, severe disabilities of users can render controlling the wheelchair difficult, if not impossible, especially over longer periods of time. This paper describes a proposal for research into techniques that would improve the experience and quality of life of wheelchair users by reducing the cognitive burden introduced by repetitive and complicated navigation tasks and manoeuvres. This will be achieved by sharing the control between the user and an autonomous controller. A number of techniques will be used to achieve this aim. Simultaneous Localisation and Mapping (SLAM) and topological mapping will be used for navigation between rooms while Computer Vision techniques will allow the (semi) automatic recognition of places in the user's home, based on the detection and categorisation of objects. Finally, medium to high level automation will be provided. This includes automatic and transparent assistance with tasks such as navigating through doorways but also autonomous navigation to specific locations using high level constructs ("take me to the kitchen table").

Keywords: Wheelchair · Computer Vision · SLAM · Shared Control · Middleware.

1 Introduction

A power wheelchair is an option available to users with a mobility impairment. An abundance of wheelchair interfaces exist to control the power wheelchair to cater for a variety of disabilities. The joystick is most commonly fitted to power wheelchairs. Clinicians found that 40% of power wheelchair users considered it difficult or impossible to manoeuvre within tight spaces such as offices or doorways [1]. These issues arise when the wheelchair user has more severe disabilities.

Several factors impede on a wheelchair user's participation in day-to-day life [2]. Major factors include inaccessible locations and uneven surfaces, which are challenging to navigate for the healthiest of wheelchair users.

2 Background and Motivation

During the last two decades many research projects have created and developed prototype "smart wheelchairs" [3]. Although prototypes have been developed, there are no commercially available wheelchairs that offer "smart features" that aid navigation and obstacle avoidance. Past research shows that the smart wheelchairs previously developed focused on a few areas, described below.

2.1 Shared Control and User Intentions

Not all users possess the ability to accurately control their wheelchair to perform common manoeuvres, such as following a corridor or navigating through a doorway. A smart wheelchair known as 'Sharioto' [4] provides a working example of human computer interaction or *shared control*, where the user dictates their intentions to the autonomous controller on-board the wheelchair via their preferred interface. Once the wheelchair recognises what the user's intentions are, it takes perceptions from sensors into account to decide how it should traverse to the goal.

One of the most important aspects of shared control is switching between different modes of operation; the 'Sharioto' wheelchair requires the user to make the high-level planning, while utilising LIDAR and Sonar sensors for obstacle avoidance and a behaviour based framework to act upon common wheelchair manoeuvres, such as docking at a table or navigating a doorway.

2.2 Global Navigation

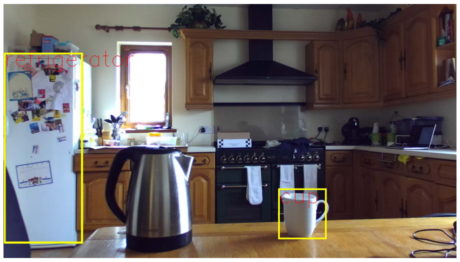
Simultaneous Localisation and Mapping is a well-defined method of localising a robot while navigating in the environment. Many existing software frameworks exist to perform SLAM and path planning. A "smart wheelchair" developed in California [6] utilises the Robotic Operating System (ROS) to unite SLAM and shared control. They use a deliberative control system that enables the wheelchair to navigate its environment, based on an occupancy grid populated by on-board LIDAR data. Given the improvements and developments in the field of computer vision, using low cost cameras and sophisticated algorithms has achieved a viable solution to aid in the wheelchair navigation process. Using an omnidirectional camera that provides a panoramic view of the environment, objects can be detected. In [7], a prototype smart wheelchair uses an omnidirectional camera to capture images at regular intervals. Localisation can be achieved using epipolar geometry, the captured images and odometry data (including speed and distance travelled). Another example of vision-based navigation is shown in [8], where a Microsoft Kinect is used to calculate distances between the wheelchair and obstacles. This enables the wheelchair to determine safe docking locations.

3 Proposed system

We describe in this section the novel aspects of the proposed system.

3.1 Object Segmentation and Recognition

Many algorithms allow for object detection using deep neural networks, pre-trained on large datasets of annotated objects in images. We aim to automatically detect the type of room the wheelchair is in by performing object recognition. Because every home is different, we propose to complement the database of objects by allowing the automatic detection of new objects and asking the user what these



(a) Object detection using MobileNetV2

(b) Depth map from a stereo camera

(c) Segmented objects from depth map

Fig. 1. Example of object detection

are. This is done using stereo cameras to perform depth segmentation on objects unrecognised by the wheelchair. In Figure 1(a) we show a mug and refrigerator as recognised objects, and a kettle in the foreground as an unrecognised object, using the MobileNetV2 architecture and OpenCV. MobileNetV2 is used due to its accuracy and efficiency, valuable for running on small, energy efficient, embedded computers on board wheelchairs. Figure 1(b) shows the first step of the segmentation process; a depth map is generated from stereo cameras. This enables the objects (e.g. kettle and mug) at the forefront of the image to be segmented using the OpenCV vision library. Figure 1(c) shows that once the image has been segmented, the user can be asked to provide a label for the unrecognised object (kettle) and the deep neural network would be further trained using the Tensorflow software.

We aim to assist the identification of unknown objects by analysing the context of the environment using other identifiable items; for example, if a refrigerator and an oven are detected, the scene is likely to be a kitchen. This can help narrow down the detected object as one normally found in a kitchen, such as a kettle. The user then confirms what the object is, resulting in the development and customisation of the wheelchair for the user.

The system will be evaluated by comparing the confidence level in detecting new objects compared to objects the system was originally trained for (using the COCO dataset).

3.2 Localisation and Path Planning

For the wheelchair to traverse to its desired location, the tools associated with ROS, such as Cartographer for mapping and Wavefront for path planning, provide a viable solution to performing global navigation. ROS is a widely used framework, where libraries and drivers for a variety of sensors exist. ROS is also compatible with the Gazebo simulator, enabling us to test the wheelchair extensively before trialling the wheelchair with users. We aim to predict the type of location (i.e. kitchen or bedroom) based on the categorisation of the detected objects within the environment. This might require confirmation from the user in case of ambiguity. The wheelchair can then adapt its behaviour, for example, by reducing its speed and docking at a table in the kitchen. Secondly the wheelchair will build a topological map of the home that will allow high-level planning and navigation, recording the important locations as nodes and the type of control along the edges linking the nodes.

The system will be evaluated using a number of scenarios, first in simulation, then using tame testers and finally selected real users. Feedback will be collected to gather evidence about the performance, specifically about incorrect behaviours, such as avoiding the object the chair is supposed to dock to.

4 Conclusions

We have described in this paper a proposal for a system that will provide power wheelchair users more autonomy while keeping them involved in the control of the wheelchair as much as possible.

The system will automatically learn a map of the home of the user, involving the user in the process by asking the user to confirm or correct choices made by the system ("I can see a kettle and a refrigerator, are we in the kitchen?"). This will be based on automatically recognising objects as well as detecting unrecognised ones, again asking the user what these might be, therefore progressively adapting to the environment of the user.

Although only a proposal at this stage, our informal tests and evaluations of existing technologies allow us to believe that such a system can be researched and developed.

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