USE OF DISTANCE SENSORS FOR UAV OBSTACLE AVOIDANCE

THE EFFECT OF IMPLEMENTING AUTONOMOUS OBSTACLE AVOIDANCE FOR WHEELCHAIRS ON USERS

A Thesis Prospectus
In STS 4500
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In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Samir Chadha

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Technical Team Members
Patrick Hourican, Chase Moore, Sammy Nayhouse

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Catherine D. Baritaud, Department of Engineering and Society

Harry C. Powell, Department of Electrical and Computer Engineering

Autonomous obstacle avoidance is a technology that has the potential to be useful in various applications. These applications include but are not limited to helping to map out an area, path planning, and guidance for piloting a vehicle (Han et al., 2020). Two developing applications of autonomous object avoidance involve its deployment in taking over control from manned vehicles (Bareiss et al., 2017) and its deployment in assisting disabled individuals with movement (Joshi et al., 2020). Utilizing autonomous obstacle avoidance in these areas could not only make life for individuals using the technology easier in the case of assisting disabled individuals, but it can also prevent crashes in a cluttered environment that may otherwise be difficult for a human pilot to navigate (Lee et al., 2020).

My technical topic involves implementing autonomous obstacle avoidance for an unmanned aerial vehicle, or UAV for short, whereas my STS topic involves determining if the application of autonomous obstacle avoidance for wheelchairs would enhance the quality of life for individuals who use them. These topics are tightly coupled since they both are focused on autonomous obstacle avoidance, even if they are for different applications. For the technical project, Sammy Nayhouse, Patrick Hourican, Chase Moore and I will work under Bezzo Robotics with Nicola Bezzo, Pravardhan Nagireddy, Rahul Peddi, and Shije Gao as fellow research personnel and will be advised under Harry Powell. Everyone mentioned is from the Department of Electrical and Computer Engineering. The technical project has been carried out from September 28th and is expected to be completed on December 16th, 2022. Meanwhile, the research for my STS project will commence on December 17th and will conclude around the end of February.

One issue with piloting an aerial vehicle is that the space may be too complex for an ordinary pilot to navigate (Bareiss et al., 2017). Implementing autonomous control for a UAV would not only minimize this issue, but it could also be used to help with making a 3D map of an area (Salaskar et al., 2014) or to help a pilot perform other tasks that do not relate to navigating the vehicle, such as locating victims in a disaster (Bareiss et al., 2017).

The objective of this research project is to implement autonomous obstacle avoidance for a quadcopter that is being piloted by another human using 4 LiDAR sensors, with one sensor on the front, left, right, and back of the quadcopter. These sensors will read in data and, if an object is close enough to the quadcopter, the quadcopter will switch to unmanned control and will move out of an object's way. This would happen by having the quadcopter navigating to a waypoint that is beyond object on its original flight path as shown in Figure 1.

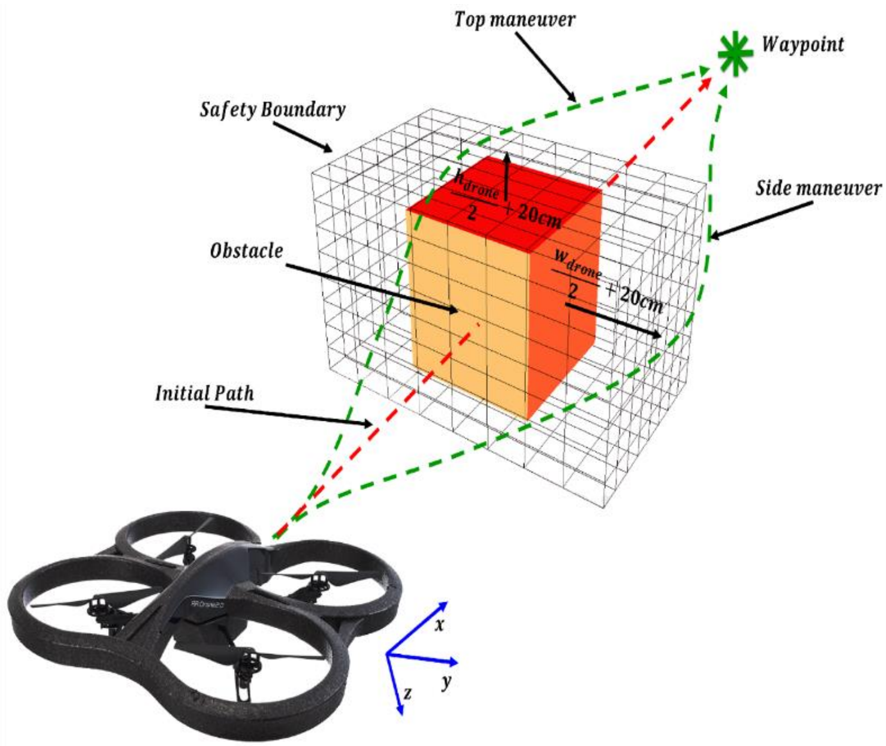

Figure 1: Quadcopter in UAV mode going to waypoint. It does this by navigating around the object to get to its destination (Bezzo, 2022).

Once the quadcopter is no longer close enough to an object, the quadcopter will switch from autonomous control to manned control and the pilot will regain control of the quadcopter.

In order to achieve this task, we will be using TerraRanger Evo 15m sensors, which can read data from up to 15 m in front and has a field of view of approximately 2^o (Fabre, R. H., 2021). There will be one sensor on each side of the quadcopter, excluding the top and bottom, with the front sensor being attached to a servo motor so its field of view will be extended while the servo motor is moving. For the autonomous obstacle avoidance algorithm, we will be using Robot-Operated-System, or ROS for short, which is an open-source software development fit that "offers a standard software platform to developers across industries that will carry them from research and prototyping all the way through to deployment and production." ("ROS: Why ROS", n.d.). These sensors will read in data about the surrounding environment, which will be communicated to a PCB on the quadcopter that will read the sensor data as well as supply power to the entire system, including the sensors and the motors. This PCB will communicate with our embedded microcontroller, a Jetson, that allows for the manual teleoperation of the quadcopter to be combined with the autonomous control by our obstacle avoidance algorithm. The Jetson, in turn, interacts with the main computer that will be able to visualize the data from the sensors. This process of communication is shown in Figure 2 below.

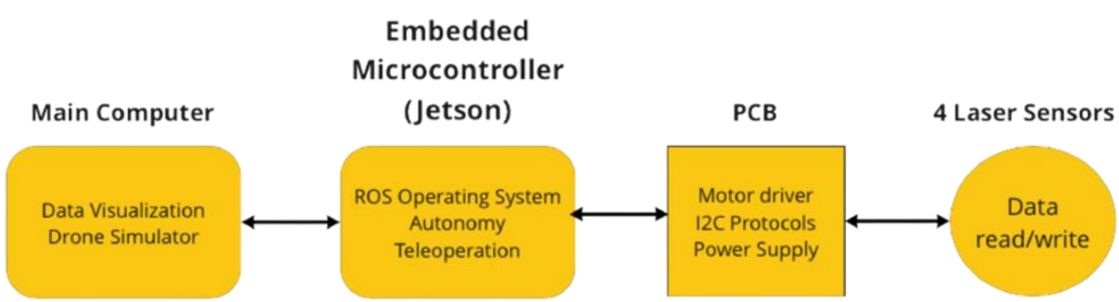

Figure 2: Communication within the quadcopter network (Nayhouse, 2022).

As for the autonomous obstacle avoidance, it starts in manual control since the quadcopter will be teleoperated by a human. Meanwhile, the LiDAR sensors will continuously observe the area in front of them and transmit that data to the Jetson. If one of the sensors detects that an object is too close to the quadcopter, autonomous control will be turned on and the quadcopter will navigate around the obstacle to a waypoint. Once the quadcopter reaches that waypoint, it will switch back to manned control. This behavior is illustrated in Figure 3 below.

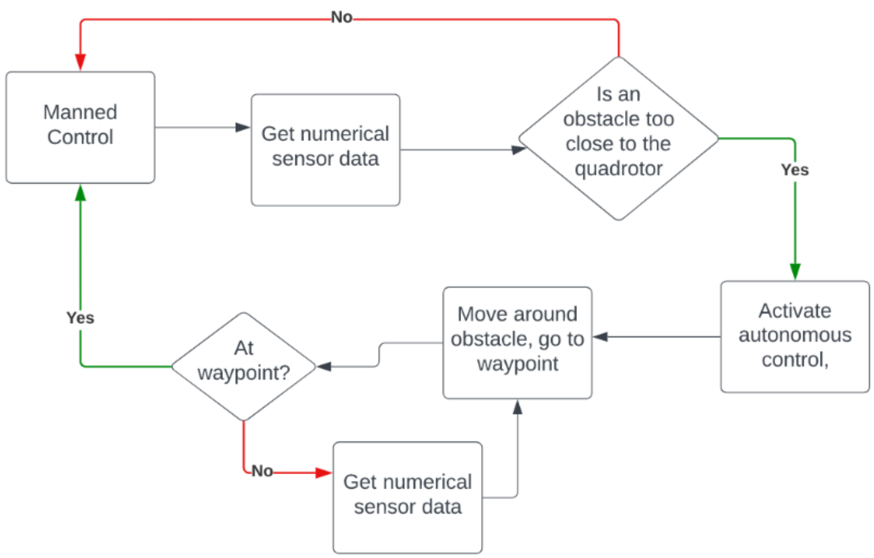

Figure 3: General behavior of autonomous obstacle avoidance. The switch to autonomous control happens when the quadcopter moves near an obstacle and the switch to manual control happens when the quadcopter gets close to a waypoint (Chadha, 2022).

In order to properly test the system, we will first simulate the quadcopter in Gazebo, which is a simulator that allows for testing our quadcopter "in realistic environments with high fidelity sensors streams" ("Gazebo", n.d.). This will first be done with the quadcopter being teleoperated by a human, then with just the autonomous obstacle avoidance. Once we test both components individually, we will integrate them to simulate our finished product. Once we have that simulation working, we will construct our quadcopter, attach all of the necessary equipment, and test it on an airfield to see if we have successfully implemented autonomous obstacle avoidance for a UAV.

In terms of other available resources, the project will have a designated computer provided by Bezzo Robotics along with Bezzo Lab itself in to work in if necessary. In Bezzo's lab, we will have access to a PlayStation controller that will be used to teleoperate the quadcopter and we will have access to a small quadcopter for reference, however we will not be allowed to fly it since we have not been trained to pilot the model. Once the quadcopter is ready to fly, we will have the ability to fly it on an airfield. As for funding, Bezzo Robotics gets $1 million in funding each year, which includes funding for our project. Once we finish the technical project, we hope to demo a quadcopter that is teleoperated by another human that will be able to avoid obstacles as it approaches them, even if it is intentionally directed by a pilot to said obstacle. Once the obstacle is avoided, the quadcopter should switch off autonomous control and allow for teleoperation by a pilot. We will also film the demo in order to display it for our final presentation on December 16th. The final technical paper will be a scholarly article.

THE EFFECT OF IMPLEMENTING AUTONOMOUS OBSTACLE AVOIDANCE FOR WHEELCHAIRS ON USERS

According to the Center for Disease Control and Prevention, 13.7% of American adults in 2019 had mobility issues, including serious issues with walking or climbing up stairs (Center for Disease Control and Prevention, 2019). Fortunately, technology has advanced to a point where we have fully autonomous object-recognition technology being developed (Joshi et al., 2020). This includes autonomous object avoidance, which could potentially help wheelchairs identify an obstacle in front of it and avoid it. This technology has already been explored, as researchers like Th. Rofer and A. Lankenau explored the operation of a semi-automatic wheelchair that can switch between autonomous and manual control (Röfer, Th., & Lankenau, A., 2000). Allowing for autonomous control for object avoidance has clear benefits, such as allowing one to navigate a tight space more easily along with one crashing into a wall with their wheelchair less often. One thing that needs to be considered, however is that there may be drawbacks to an autonomous obstacle avoidance system.

When considering if wheelchairs that automatically avoid objects benefit users, the benefits and drawbacks of the technology must be considered equally. The benefits of this technology have been explored in the past, including its potential use to allow for wheelchair control based on brain waves (Mueller, S et al., 2010) and its use in improving the efficiency of travel by wheelchair (Parikh, S. P. et al., 2007). The drawbacks are considered less in terms of determining if wheelchairs that automatically avoid objects benefit users but are still prevalent. One big example is how a wheelchair with autonomous obstacle avoidance handles moving around an obstacle on or near a paved road. In terms of the wheelchair operating on a paved road, researchers Shun Niijimaa, Yoko Sasaki and Hiroshi Mizoguchia found that wheelchairs with autonomous obstacle avoidance could learn to obey traffic signs and avoid pedestrians in Japan (Niijima, S. et al., 2019). One thing that is not considered in this study is the effect of motor vehicles on a wheelchair, which is more of a concern in an auto-centric country like the U.S. than Japan. Figure 4 on page 7 gives an illustration of the potential drawbacks of implementing autonomous obstacle avoidance for a wheelchair.

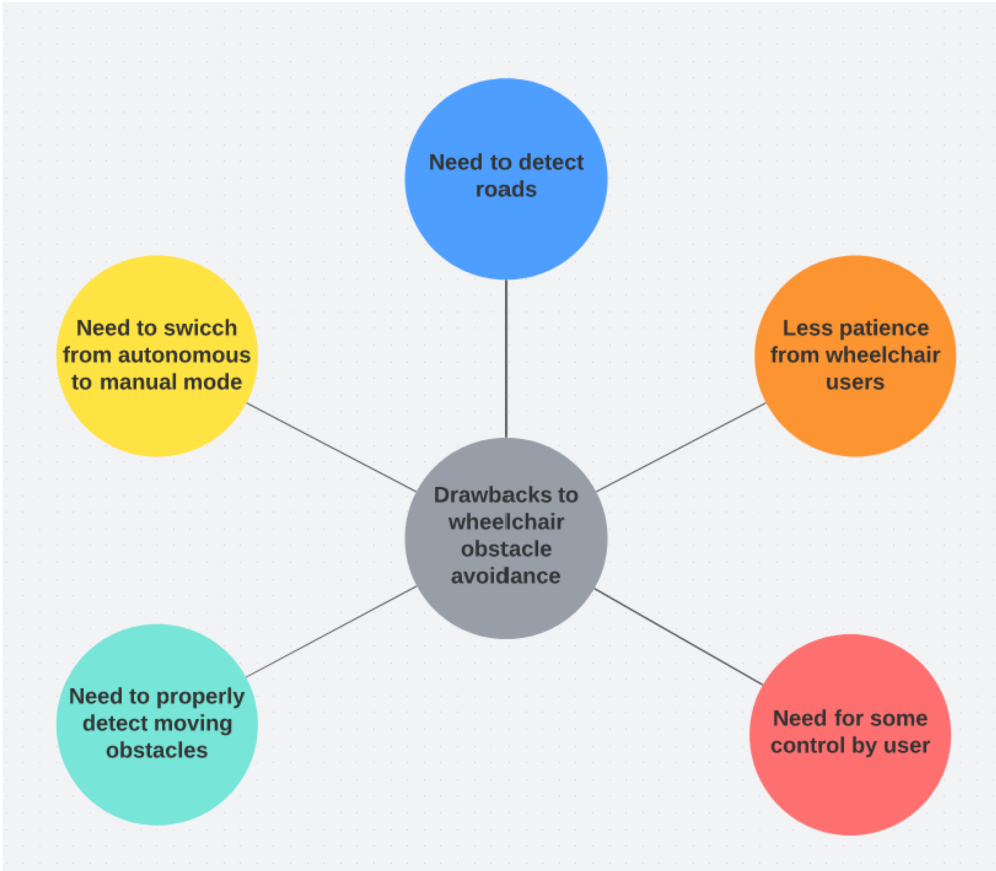

Figure 4: Illustration of the potential drawbacks for wheelchair obstacle avoidance. These include the need to switch from autonomous to manual mode (Röfer, Th., & Lankenau, A., 2000), the need to detect moving obstacles, the need for some user control, the need to detect roads, and the fact that users may have less patience with an autonomous wheelchair (Parikh, S. P. et al., 2007) (Chadha, 2022).

I will investigate how autonomous obstacle avoidance is implemented for wheelchairs and its effect on users to determine if the application of autonomous obstacle avoidance for wheelchairs would enhance the quality of life for individuals who use them. This will be done using the Social Construction of Technology (SCOT) framework pioneered by Trevor Pinch and Wiebe Bijker (Bijker et al., 1999). In this system, illustrated in Figure 5 on page 8 below, each party of interest will have a perspective on what an autonomous obstacle avoidance wheelchair would need and the engineer would need to consider all of their viewpoints.

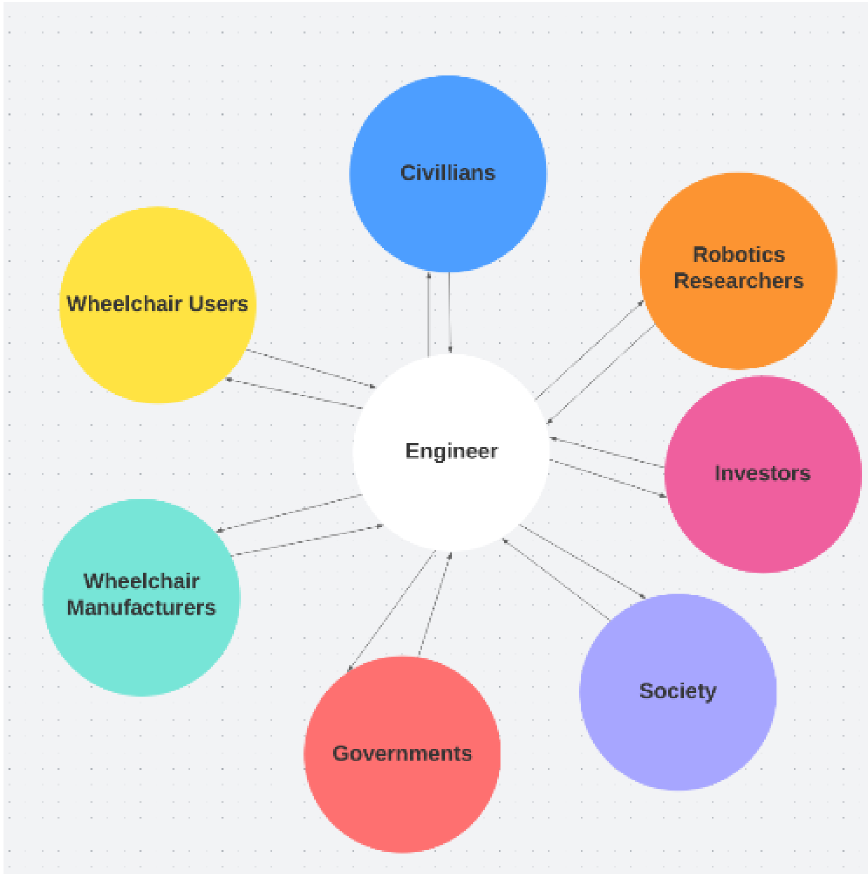

Figure 5: SCOT framework for a wheelchair that implements obstacle avoidance. The engineer is at the center of the model to act as a mediator between the various parties of interest (Chadha, 2022).

In turn, the engineer will do the best possible job at developing a final product that will satisfy stakeholders as much as possible. Understanding the relationships between the engineer and each of the relevant parties will allow one to explore if it is feasible to develop a wheelchair that implements autonomous obstacle avoidance and is beneficial to wheelchair users while simultaneously balancing the often competing interests of the stakeholders.

By the time I finish my STS research paper, I hope to have a definitive and educated response to determining if the application of autonomous obstacle avoidance for wheelchairs would enhance the quality of life for individuals who use them. The final STS paper will be a scholarly article.

USAGE OF AUTONOMOUS OBJECT AVOIDANCE

Autonomous object avoidance can be applied to a variety of vehicles, ranging from quadcopters to wheelchairs. Its use is even more varied, with it having the ability to help navigate a vehicle, to map out an area, or to let the controller of the vehicle to focus on tasks separate from controlling the vehicle. While this is a technology with the potential to greatly benefit society, it may also harm society depending on how negligent the individuals implementing the technology are. Autonomous object avoidance, like almost all technologies, is an example of how technology can greatly benefit society as long as it is pushed forward by the right people.

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