A LIDAR-BASED NAVIGATION SYSTEM FOR THE VISUALLY IMPAIRED

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ABSTRACT

A common issue faced by people who are visually impaired is the difficulty of navigating and traveling through unfamiliar outdoor and indoor environments. The current state-of-the-art solutions to this problem consist of very expensive guide dogs and simple canes for obstacle detection. The team sought to develop a LIDAR-based navigation system with binaural auditory feedback that would allow the blind to navigate in unfamiliar environments and perform basic obstacle avoidance. Though basic auditory feedback relating to environmental obstacles was developed, further work is necessary to fine-tune the system and to determine the practicality of the device.

INTRODUCTION

People who are visually impaired face two major obstacles to leading fully independent lives: the ability to consume mass media and the ability to safely navigate unfamiliar environments. Electronic reading materials and various other text to speech technologies have significantly improved the ability of visually impaired people to consume the majority of mass media. Engineers, however, have largely failed to develop user-friendly and effective technologies for assisting in navigation. The team sought to develop a LIDAR-based navigation system with auditory feedback that would allow the blind to navigate in unfamiliar environments and perform basic obstacle avoidance. The system need be cost-effective compared to that of a guide dog and practically effective compared to that of a cane or previously developed technological solutions.

EQUIPMENT

Due to the generosity of the Missouri S&T Mars Rover Design Team and SICK AG, we were allowed access to a state-of-the-art SICK Tim551 2D Laser Scanner (Figure 1) for the development of this project. A basic Linux system was used for executing code and for performing audio manipulation and generation. The message-handling service, as well as the LIDAR sensor drivers, were provided by ROS and the ROS community.

Figure 1 – SICK Tim551 2D Laser Scanner.

SYSTEM ARCHITECTURE

The system is basically structured as in Figure 2. Data regarding the direction and distance of obstacles detected by the LIDAR is read from the LIDAR. The audio processing software (detailed in Section III) produces the binaural audio feedback signal relating environmental obstacle location to the user. The resulting signal contains ”direction” and distance (loudness) components and is passed to the Linux audio driver for audio generation. Finally, the audio signal is output to the user.

Figure 2 – System Overview.

The system is written in the Robot Operating System (ROS) and is architected as in Figure 3. A sick tim551 205001 node acts as a client and listens to incoming data from the LIDAR. It publishes this data to the scan topic. A generate audio node subscribes to this data and performs the audio processing algorithms on the data. The generated audio signal is published to an audio topic. A play audio node subscribes to this topic and outputs to the user the audio feedback signal.

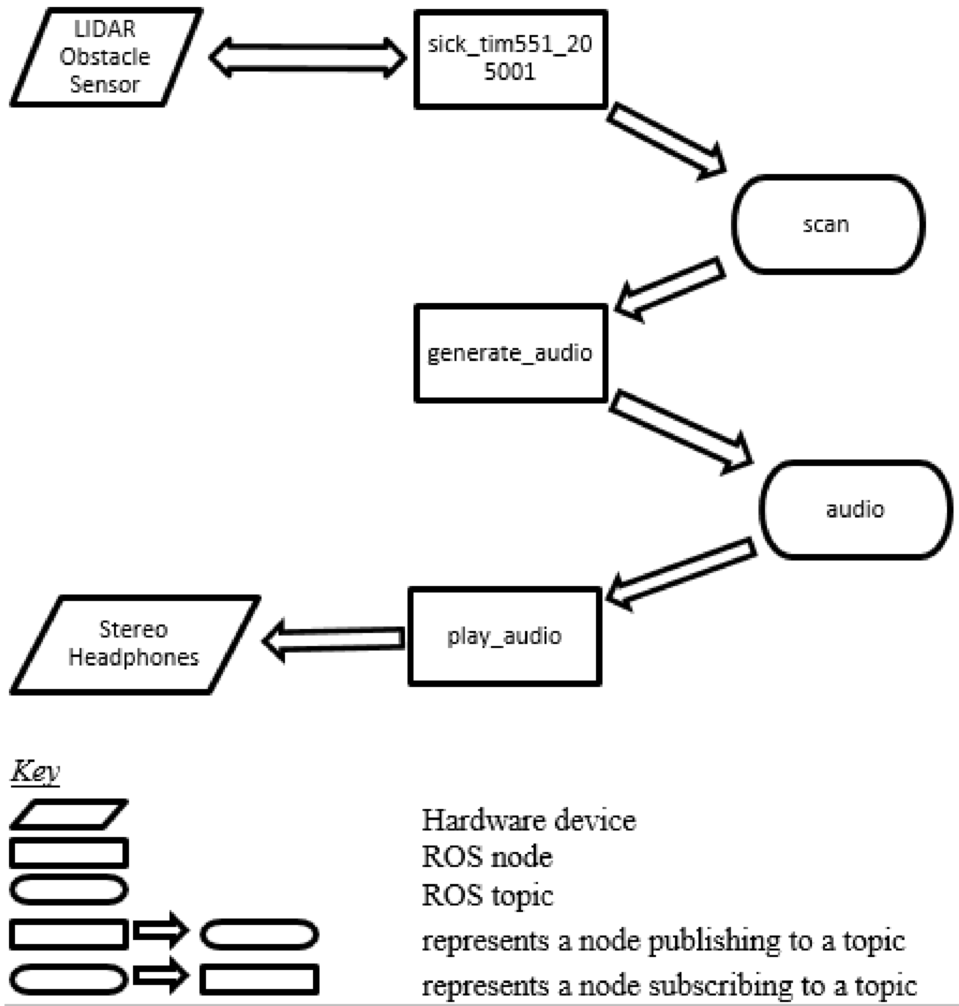

Figure 3 – ROS Architecture.

AUDIO PROCESSING

The audio processing software begins by converting the polar-coordinated obstacle data from the LIDAR to rectangular coordinates for manipulation by the audio processing algorithms. It then performs a Head-Related Transfer Function (HRTF) on the data to produce a Head-Related Impulse Response (HRIR) of the obstacle data (Figure 4). This gives a base signal for each ear detailing how a reference audio signal would be proportioned to give the illusion of a sound coming from a distance. The ratio of the gains of each audio signal determines the sound's direction and the magnitude of the gains determines the sound's loudness, and therefore, distance. This feedback signal is convolved with a reference signal and passed to the Linux audio generation drivers for outputting to the user's headphones.

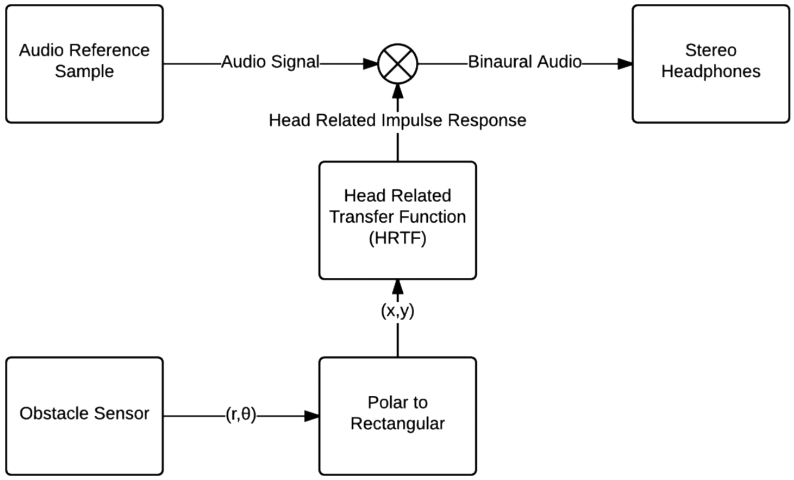

Figure 4 – Audio Processing Block Diagram.

In order to test our algorithm, it was developed and simulated in Simulink. The first iteration of the design utilized audio panning to demonstrate the ability to generate spatial audio by varying the loudness of two audio channels. Each channel of signal was multiplied by a constant gain (a base DC bias) and then an additional time-varying gain was applied to each channel based on the object's position relative to the user. Objects' rotation about the user was correlated to a different gain applied to each channel, while distance was related to an equal gain (or attenuation) applied to both channels.

At this stage the LIDAR data input had not be included in the simulation so a simple user interface was included to demonstrate these concepts. By varying a slider from 0 to 1, we can adjust our Gain to produce a feedback signal that sounds further or closer to the user, respectively. By varying a knob from -1 to 1, we can vary the perceived direction from the left-hand side to the right-hand side, respectively, with 0 associated with a sound, which comes from directly in front of the user.

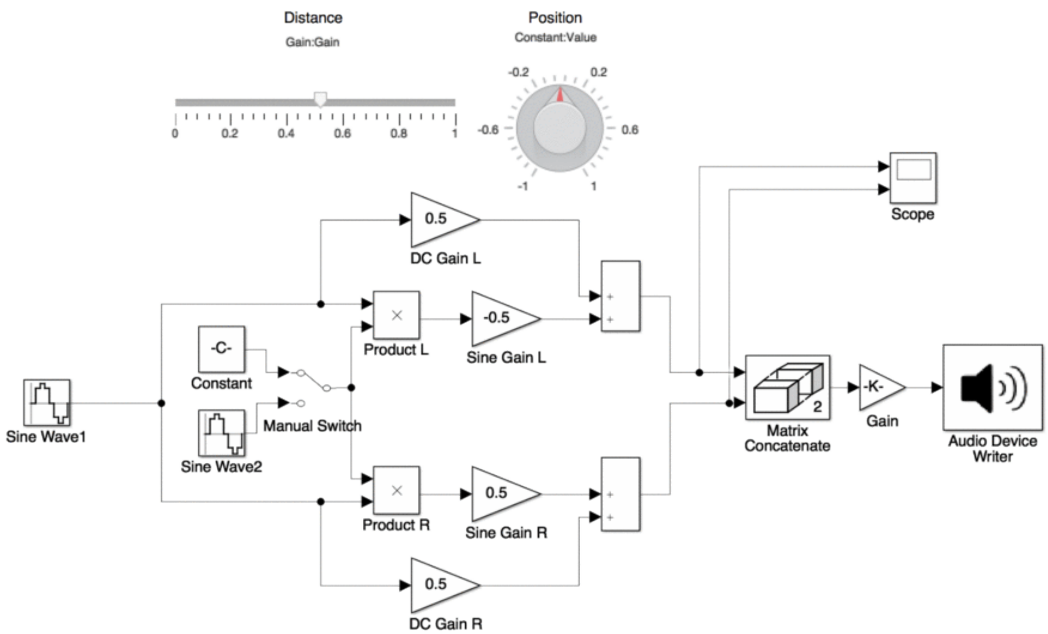

Figure 5 – Audio Generation MATLAB Simulation.

ROS NODES

For the final design three ROS nodes were developed using MATLAB/Simulink: a LIDAR simulator, an audio generator, and an audio I/O node. An additional ROS node was included from the open source community that was designed to interface with the actual LIDAR hardware over USB or Ethernet and publish data to the ”scan” topic.

The LIDAR simulator node (figure 6) was a publisher that published to the ”scan” topic. Algorithms were developed in Simulink, which simulated the output of the LIDAR sensor based on the position and size of an obstacle specified by the user. The node was used to preliminary software tests.

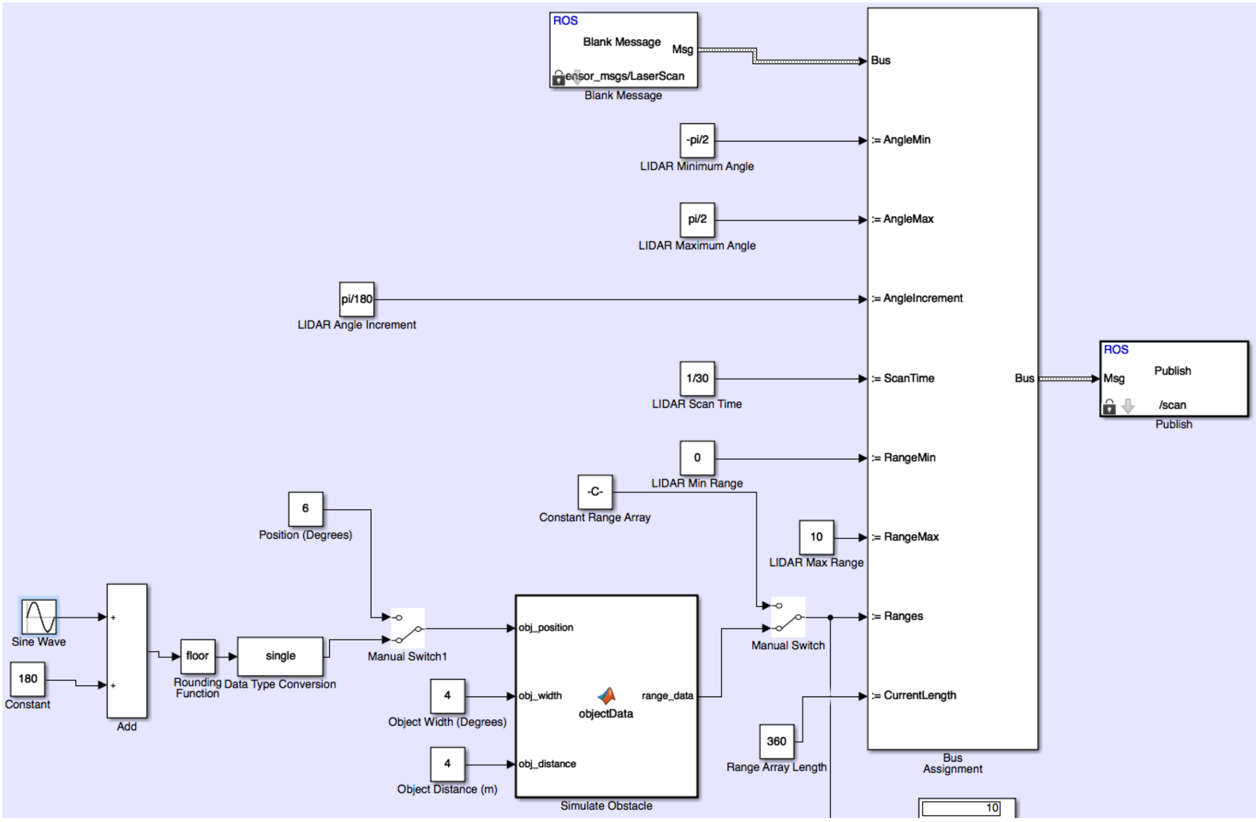

Figure 6 – LIDAR Simulator ROS Node.

The second node, the audio generation node, subscribed to the ”scan” topic, generated the binaural audio tone, and published the streaming audio data to an ”audio” topic. Initial iterations of the audio generation node utilized the audio panning algorithm described previously; however, it is intended for future iterations of the design to utilize a look-up table to apply a head-related transfer function to a reference tone via convolution to generate the binaural audio.

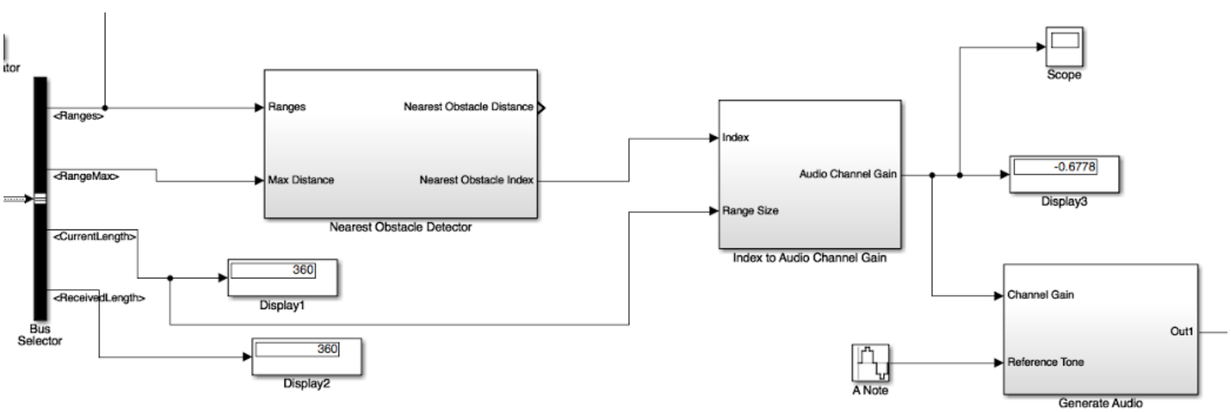

Figure 7 – Binaural Audio Generation ROS Node.

The final node in the data processing chain, the play audio node, subscribes to the ”audio” topic and outputs audio to the system’s audio hardware using the appropriate operating system level interface, in this case the Linux ALSA drivers.

RESULTS

By streaming data from a 2D LIDAR scanner into a audio processing algorithm and through to a pair of stereo headphones, the user was able to easily distinguish the direction from which a sound pertaining to an obstacle came from, as well as its relative distance from the user.

Though simple verification of the system came from the team’s personal experiences, it is expected that practical navigation and fine-tuning of the system require significant training on the part of the user. This is in conjunction with continuous feedback to and development among the development team.

FUTURE WORK

Besides the consistent need to continually fine-tune the LIDAR sensor technology and audio processing algorithms, there are several aspects of the project that would make it far more practical in modern society. First and foremost, the system must be ported to a portable Linux platform, such as a Raspberry Pi, and be packaged in a small and lightweight unit. This unit would also require a portable power supply. Secondly, based on previous research, navigation tools for the visually impaired are heavily criticized by their audiences due to their obvious and obstructive appearance, so a physically appealing unit and wearable LIDAR sensor must be integrated into the system. Lastly, other performance enhancing features, such as 3D audio scanning and higher scan rates are desired. It is also desired to experiment with other ways of communicating the distance and direction of an object to the user via audio, such as using frequency to communicate distance instead of loudness. Modifications such as these may make the system more intuitive or easier to learn.

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