Personal Radar

ELECOMP Capstone Design Project 2017-2018

Sponsoring Company:

Bose Corporation
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Company Overview:

Bose Corporation was founded in 1964 by Dr. Amar G. Bose, then a professor of electrical engineering at the Massachusetts Institute of Technology. Today, the company is driven by its founding principles, investing in long-term research with one fundamental goal: to develop new technologies with real customer benefits. Bose innovations have spanned decades and industries, creating and transforming categories in audio and beyond. Bose products for the home, in the car, on the go and in public spaces have become iconic, changing the way people listen to music.

Bose Corporation is privately held. The company's spirit of invention, passion for excellence, and commitment to extraordinary experiences can be found around the world -- everywhere Bose does business.

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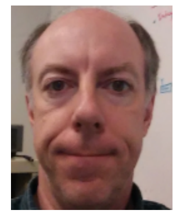

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Project Motivation:

Technology has given us a world full of distractions. From cell-phone texters who walk into lamp posts to music lovers isolated by their headphones, most people could use help getting back in touch with the world around them. Technology is a big part of the problem. Can it be part of the solution?

Recent advances in radar such as Google Soli and its widespread use for automotive driver assistance have resulted in smaller, lower power and cheaper systems. This project will investigate whether the technology has developed to the point where a personal, wearable radar could warn the user when they need to pay more attention to their environment.

Anticipated Best Outcome:

The team builds a battery powered, self-contained (i.e. all the processing done on the device) portable personal radar system and that is able to warn a distracted walker when they're in danger of running into something.

Project Details:

Infineon Technologies makes a complete compact radar system on their Distance2Go board: https://www.infineon.com/dgdl/Infineon-Distance2Go+Development+Kit-PB-v01_00-EN.pdf?fileId=5546d4625debb399015e0951648d40f3

We will use this board to learn the principles of radar and to gain an understanding of whether the technology is ready for a wearable personal radar. This will also be the first exposure to radar for the Bose engineers - we'll all learn together.

The primary use case we'll investigate is using radar for a personal collision avoidance system. The wearer is walking and focussed on their cell phone. The system warns them about possible collisions.

Below is a proposed set of steps for the project. However as we learn about the system we'll modify the approach.

First we'll gain an understanding of how the radar system behaves when operated in Frequency Modulation Continuous Wave mode (FMCW) and about the Infineon system in particular. The FMWC mode allows measurement of both distance and mode will let us measure both the radial distance and radial speed of a reflector. We'll use Matlab to analyze the data.
The team will answer questions like the following.

- What are the minimum and maximum distances and velocities that can be detected?
- How small of a change in distance and velocity can we measure?
- What is the smallest object that can be detected?
- What is the angular field of view of the Infineon's system?
- Is there a difference between a tall, thin object and a square one with the same cross section?
- The experimental results should agree with the model equations for the radar system.

The radar board has a 32-bit microprocessor for controlling the radar system. In this early phase the team will experiment with Infineon's software to explore what can easily be adjusted on the radar. Infineon provides an Eclipse-based development environment (www.infineon.com/dave) that uses a debug probe called XMC Link for flashing and debugging C and C++ code.

The next step will be to design a prototype for a portable system to take live data with a walker. One important choice is the computer that will connect to the radar board and do the data analysis. Choices (in order of most to least product-like) range from an ARM Cortex-M board, an Android Things board, an Android phone a Windows laptop or tablet. The choice will take into account the programming strengths of the team.

Once the portable system has been built the team will can investigate using the radar system for collision avoidance. Here are some of the questions to explore.

- Can we use the signal from the single-antenna Infineon board to tell the difference between an obstacle directly on the path and one just off to the side?
- Can we measure the speed and bounce of the walker? This would indicate that the person is walking as opposed to riding.
- Can the system detect when the cell phone is being held in reading position?
- Will long hair draping over the sensor affect the readings?
- Will the system work for a runner - higher speeds?
- Can the team develop an algorithm for warning the user in real time about potential collisions?
- What would be good audio feedback that would warn the user but not interrupt them?
- For data collection and for demonstration can we collect a video along with the radar data?
- An important consideration for a battery device will be minimizing power consumption. How can the radar be run in the most power efficient manner, and how much power does that take? Infineon has a nice app note on this. *Using BGT24MTR11 in Low Power Applications*, AN341.

Hardware

Infineon's board provides a complete radar system. There is no hardware work for this project. However, there will be some embedded programming work.

Project Tasks

Part 1: Come up to speed.

- Use radar theory and Matlab or Python with Jupyter notebooks to understand radar operation.
- Create (or find) a computer program for generating model radar data corresponding to our radar system.
- Do the tasks in the Infineon document titled "Quick Start Guide Distance2Go Module".
- Take initial data from the radar system and compare it to the model.
- Understand how varying the radar's parameters affects the signal. Parameters include power, frequency and width of sweep and waveform for the frequency sweep.

Part 2: Portable device for data collection

- What are the safe power levels for a 24 GHz radar system worn on the body?
- Put together the portable device.
- Save radar scan data for processing off-line. How this will be done is TBD. It depends on the portable computer.

Part 3: Analyze data

- What features could be used for a collision-avoidance system? Is the feature extraction simple enough to run on the radar board's microprocessor?
- Can the system recognize when a phone is in position for looking at the screen?
- Can the system recognize when the user is walking and how fast they're walking?
- Can the system tell the difference between an obstacle that the walker will hit and an obstacle off to the side?
- Can the system recognize a low barrier such as a fire hydrant?
- Can the system recognize a high barrier such as a low beam?

Part 4: Stand-alone portable collision-avoidance device

- Using what has been learned in part 3, make a portable device that warns the wearer of upcoming obstacles.
- Is audio a good channel for a collision warning?
- Document when the system works and when it doesn't.

Part 5: Other Radar Investigations

- Can the on-body radar system be used for measuring pulse rate and breathing?
- Can a single-antenna system recognize an object as a person (as opposed to an inanimate object or a small animal) in the range of 1-6 meters?

Composition of Team:

4 Computer Engineering/Electrical Engineering students, who will combine to cover the skills areas listed below.

Skills Required:

- C/C++ development on the Distance2Go's ARM Cortex-M processor.
- Java or Kotlin programming on Android (if we can use an Android of Things device).
- C/C++ or Python programming on a Windows machine (if we use a portable Windows machine).
- Matlab programming for data analysis.
- Physics knowledge to build and use a model of the radar system.

Anticipated Best Outcome's Impact on Company's Business:

Bose will understand how radar systems could be used in future products.

One possible product is a radar system for the blind. Here's a link to an article about a similar system:

https://phys.org/news/2017-01-wearable-sensor-device-visually-impaired.html

The article mentions that users were not satisfied with the vibration feedback of the device. Perhaps audio feedback from headphones would work better.

Broader Implications of the Best Outcome on the Company's Industry:

Radar is just one wearable sensor, but it does have unique advantages. The goal of all the sensors is to help the product adapt to the user and to enhance and extend their awareness of the world.