Using Doppler Effect for Motion Sensing

CSE 570 – Wireless and Mobile Networks

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Introduction

The Doppler effect (or the Doppler shift) is the change in frequency or wavelength of a wave for an observer who is moving relative to the wave source. A common example of Doppler shift is the change of pitch heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. When it moves towards the observer, the sound waves are compressed, and so the frequency becomes higher, and when it moves away from the observer, the frequency becomes lower.

Statement of Problem

The use of motion sensing for personal devices is becoming increasingly popular. However, it is still costly to deploy robust motion sensors in mobile platforms. Recent advances in computer vision techniques have popularized motion sensing using the mobile device's camera. Unfortunately, vision-based gesture recognition techniques are generally brittle (e.g., sensitive to lighting conditions) and require quite a bit of processing power

Objective

Currently, the major use of microphones in a mobile device is to convert the sound waves into electrical signals, which can then be transmitted to recipient. It turns out, however, that with the addition of suitable software, microphones can detect more than mere audio signals. They can act as versatile sensors, capable of detecting motion, assessing the social environment and even tracking posture and gestures.

We propose using the microphone in mobile devices, to detect motion of moving source of sound, using Doppler effect. This method is chosen as it does not have the shortcomings similar to those mentioned for vision based system above. In addition, it offers several advantages:

1. It is self-contained and does not need any additional infrastructure support.
2. It applies completely unsupervised classification techniques and no prior training is needed for the system to operate.
3. It is accurate and robust, as it works with any android mobile devices.

The steps to detect motion using the sound from mic will be as follows:

1. **Pre-processing**: Before the captured sound can be used for motion detection, we first need to perform several pre-processing tasks, including segmenting the continuous stream of sound signal into smaller chunks (as android's MediaRecord module doesn't provide chunks of data), and conducting required processing on each chunk, such as discrete Fourier transform (DFT). These steps prepare the data for subsequent signal processing.

2. **Feature Extraction**: Next, we extract features specific to a particular use case. We will have to come up with an accurate feature extraction mechanism for each use case we implement. For example, to recognize hand gestures, we will have to come up with new features that are unique to hand movement sound signals and that facilitate accurate, timely, and unsupervised hand movement detection.

3. **Direction Estimation**: Our plan is to use Time Difference of Arrival (TDoA) of the sound signal as estimate of direction. By computing the cross-correlation function over signals from two channels, we can provide a coarse direction estimation of the sound source.

On completion of the basic motion sensing module, we plan to add some of the use cases from the exhaustive list below, for demonstration:

1. Recognizing the motion of a mobile source in the vicinity that makes loud noise.
2. Identifying the direction and velocity of the moving mobile source.
3. Identifying hand movements so as to create a hands-free scroll gesture

Project Timeline

Duration	Activity
Day 1 - 30	Implementing base motion detection module using Doppler effect in android using mic input
Day 31-45	Identifying the direction and velocity of the moving mobile source
Day 46-60	Identifying hand movements so as to create a hands free scroll gesture