Tracking Head Movement

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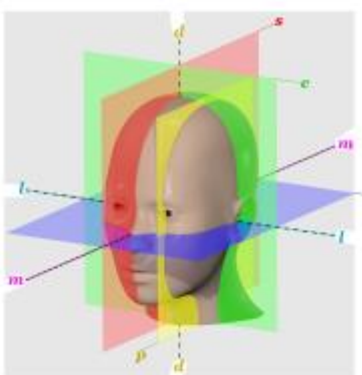
Introduction

Our project is an immersive and interactive music format. As the user turns their head, the sounds that they are being played through their headphones change.

To create this experience, we need to accurately and quickly determine the orientation of the user's head in three dimensional space.

Head Movement

The head moves in order to position sensory organs (such as the eyes or ears) in ways so that they can collect better data. Because of this, head movement plays a large role in the way that humans are able to localize sound.



"Human head anatomical planes letter annotations" is a work used under the public domain.

For example, if a person hears a loud sound to their left, they might they might rotate their head to the left in order to allow both eyes and ears to have maximized access to potential events in that region in the future.

Strategies

IMU Method

A common tool in head tracking implementations is the IMU (inertial measurement unit). IMU's generally contain an accelerometer, a gyroscope, and a compass. The data from all three sensors can be combined to determine the position of the head.

It is important to realize that the IMU outputs data in discrete time at a given sampling rate. Because this technique involves performing calculations using rounded values, there will be a growing rate of error as time increases. This error is referred to as drift.

Ultrasonic Method

Another method for tracking head movement is referred to as ultrasonic head tracking. This method does require equipment to be attached to the head, but does not use any sensors directly on the head. Instead, it uses transmitters placed at strategic locations around the head. Also, a base station is positioned at a known location near the user.

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Each transmitter sends out a different tone, and the base station compares the phase difference between signals to determine the orientation of the user's head. This technique has the benefit of being cable free. Although a wireless system could be derived to make the IMU technique portable, the latency for an ultrasonic system should be much lower.

Optical Method

The above methods have all involved sensors physically attached to the head. In some applications, this is not a convenient option. A different solution for head tracking involves using a camera. By identifying certain key facial features, it is possible to track the location of those features within each frame captured by the camera.

The change in location of those features from frame to frame can then be easily mapped to orientation of the head. Creating a hybrid optical and IMU based system can be very effective for error reduction, but it will cause a significant increase in latency.

Latency

A low-latency system is important in the context of our project. If there is a significant amount of latency in the head tracking system, the user will easily notice the lag in audio output and most likely be unhappy with the experience.

"Headphones with glasses" is a work used under the public domain.

A study at the Air Force Research Laboratory concluded that users could detect latency in head tracking above 60 ms in virtual auditory environments.

It is important to note that the head tracking module is by no means the only source of latency. Any sort of audio or visual processing that is required to create sensory output must also be factored into latency calculations or measurements (2).

Improving Data Quality

More expensive sensors output cleaner data. One common approach for cutting costs in design is to use multiple cheap sensors and average outputs. Resetting these sensors frequently also causes their error to effectively be reset.

An additional approach is to collect a large amount of data with the sensor sitting still (so there is zero expected angular velocity) and determine a constant offset for drift correction that can be applied to the raw data during use.

While these systems can be relatively effective, they are somewhat unintelligent. A better approach is to use a Kalman filter. The Kalman filter combines the next expected value with the measured value to determine a more accurate final output.

Conclusion

In our project, it is convenient to mount an IMU on a pair of headphones for the user to wear. Our project requires only knowledge of the side-to-side rotation of the head, seeing as we are currently only creating a two-dimensional soundscape around the user.

Additionally, using an IMU makes it simple to calculate both pitch and roll as controlling parameters in the future. These parameters could easily be mapped to other audio effect parameters for the multi-track files, or could be used in an implementation of three dimensional spatialization.

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