Figure 1: Block diagram

The dynamic audio system can be simplified as five measure blocks, each serving its own application in order to provide a dynamic surround pocket over the listener's head,

0.1 Depth estimation unit

Depth estimation unit includes stereo vision assembly of two web cams with similar (known or unknown) focal length (In our case 18 cm).
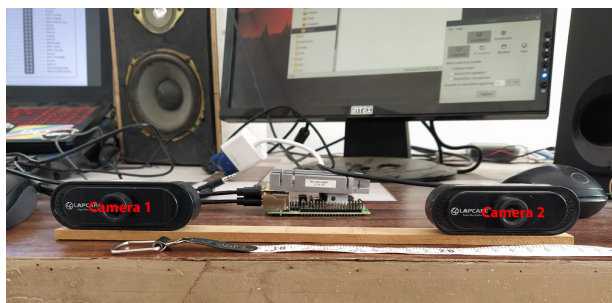

Figure 2: Assembly of the depth estimation unit

The cameras are placed at some known distance x from each other (24 cm) and computer vision (opencv) and geometrical equations have been implemented to measure the depth, deviation and height of an object from a reference point, where the reference point is the center of the stereo vision system.

0.2 Micro-processor

The Microprocessor acts as middleware between DAC and the hardware to control speakers. In this project we are using raspberry pi 4B (Quad core Cortex-A72 64-bit @ 1.5 GHz clock) as our microprocessor. Webcams are connected through USB 2.0 of RPi.

First we find depth, deviation and height of the listener's face from the reference point using OpenCV's frontal face Harr cascades classifier followed by open source AA symmetry algorithm of geometry, where OpenCV also helps to classify between listener and other objects.

The above process provides us three real-time variables,

1. Depth of the listener's face from the reference point.

2. Deviation of the listener's face from center of the axis.

3. Height of the center point of listener's face from the origin (reference point).

Further using this real-time variables, and some constants (room dimensions and speaker positioning), using custom designed geometrical algorithm we can calculate the panning, tilting angles and depth of the listener from each speaker.

Using panning and tilting angles we can rotate the servos to the required angles to direct the sound field towards the listener. And using depth we can adjust the sound levels of the speakers by controlling input voltage of amplifiers digitally.

0.3 Mechanical Unit

As discussed in the methodology, the speakers propagates sound in elliptical. Hence we need to align the major axis of the sound field towards the listener.

The mechanical unit is consisting of two servo motors for each speaker (channel), one for panning and the second for tilting,

Servos are connected to hardware PWM pins of the RPi and controlled in real time using feedback of the angle algorithm.

0.4 Audio Processing Unit

Usually, a surround sound system contains two or more speakers to generate a sound effect of moving objects from one place to another.

Even if we direct the speakers towards the listener's direction, it is necessary to adjust each speaker's sound levels according to the depth of the listener from each speaker.

The audio processor unit assembles with 4 class AB audio amplifiers driven by two 2-channel digital potentiometers for controlling each speaker's sound levels to adjust the sound pocket over the listener's head (ears).

0.4.1 Audio amplifier

An audio amplifier is a circuitry designed to increase the applied signal's magnitude to power a low resistance load (speakers).

Sound signals are applied to the non-inverting terminal of an amplifier through a voltage divider circuitry (potentiometer). This voltage divider adjusts the input signal's voltage levels, resulting in a change in volume levels at the output. This change is inversely proportional to the resistance at the wiper terminal of the voltage divider.

For this application, we are using LM386N-1 as our amplifier.

0.4.2 Digital potentiometer

Digital potentiometers mimic the analog functions of a mechanical potentiometer where microcontrollers or microprocessors control the resistance.

As we discussed, to adjust the audio amplifier's sound output, we adjust the input voltage given to the non-inverting terminal of the amplifier. Hence, we supply the audio signal to the amplifier through a digital potentiometer to increase and decrease input voltage and, hence, the speaker digitally using a microcontroller or a microprocessor.

For this application, we are using SPI-compatible MCP42010 Digital POT.

0.5 Speakers

Speakers serve the four channelled dynamically adjusted surround sound to the listener. Usually, they are mounted on four corners of the room, either at the listener's ear levels or near the ceiling.