Abstract

Current audio solutions for PCs provide sound panning only in a planar configuration. Therefore, drivers for these sound cards do not support non-planar configurations. Systems that are developed for 3D spatial audio are geared for the professional user market and are very expensive. Our work explains how to use inexpensive consumer-level hardware and open-source software for Linux to build a true 3D spatial audio system.

Introduction

- **Typical speaker configurations:** 4.1, 5.1, and 7.1
- **It is not possible to have sound emitted from above or below the listener, it is only possible to simulate this effect**
- **True 3D spatial audio allows sound sources to clearly be heard in all directions**
- **Therefore, a sound source from the upper left can be differentiated from a source from the lower left**

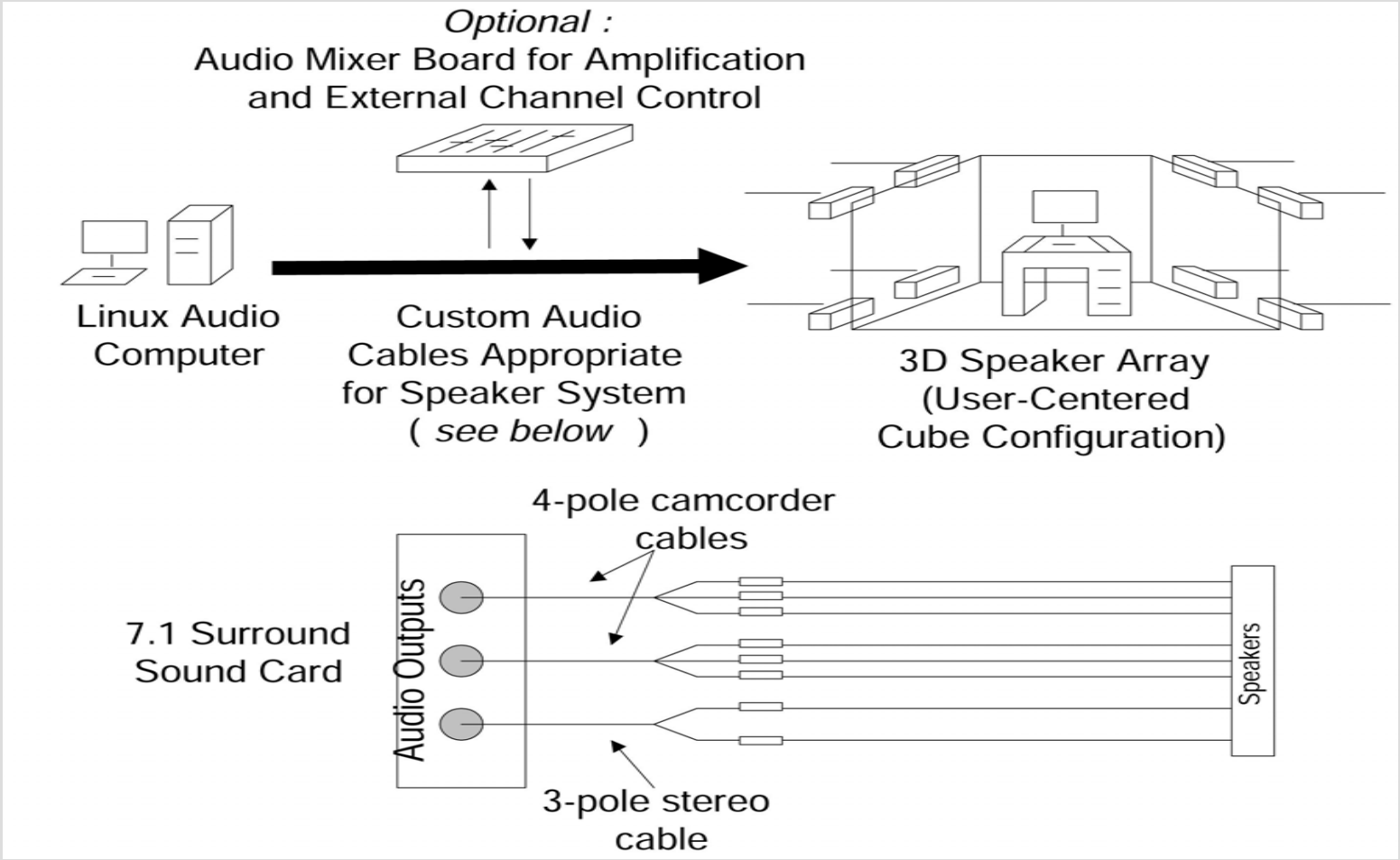
Background

- **High-cost hardware packages available for high acoustic quality:**
  - RME Hammerfall
    - High-end sound card
  - M-Audio Delta
    - High-end sound card
  - Lake Audio
    - Full sound system (software, speakers, etc.)
- **Mustajuuri**
  - 3D spatial audio API built upon ALSA drivers
  - Developed by Tommi Ilmonen at Helsinki University of Technology (HUT)
  - Implements Vector Base Amplitude Panning (VBAP) as the underlying 3D spatial audio model

Hardware Selection

- **Used eight speakers in a cubic configuration**
  - Each speaker at a vertex of the cube
- **Requires a sound card capable of producing eight-channel audio**
  - Such as Creative Labs Audigy 2 ZS card
- **Ideally, speakers should be able to amplify line-level inputs or separate amplifiers should be used between sound card and speakers**
  - However, this can be done in software, albeit at a lesser quality

Hardware Setup



Software Selection

- **Primary development under Linux**
- **ALSA driver provides audio and MIDI functionality to Linux OS**
- **Mustajuuri API provides the features needed for 3D positional sound system and is easy to extend**

Software Setup

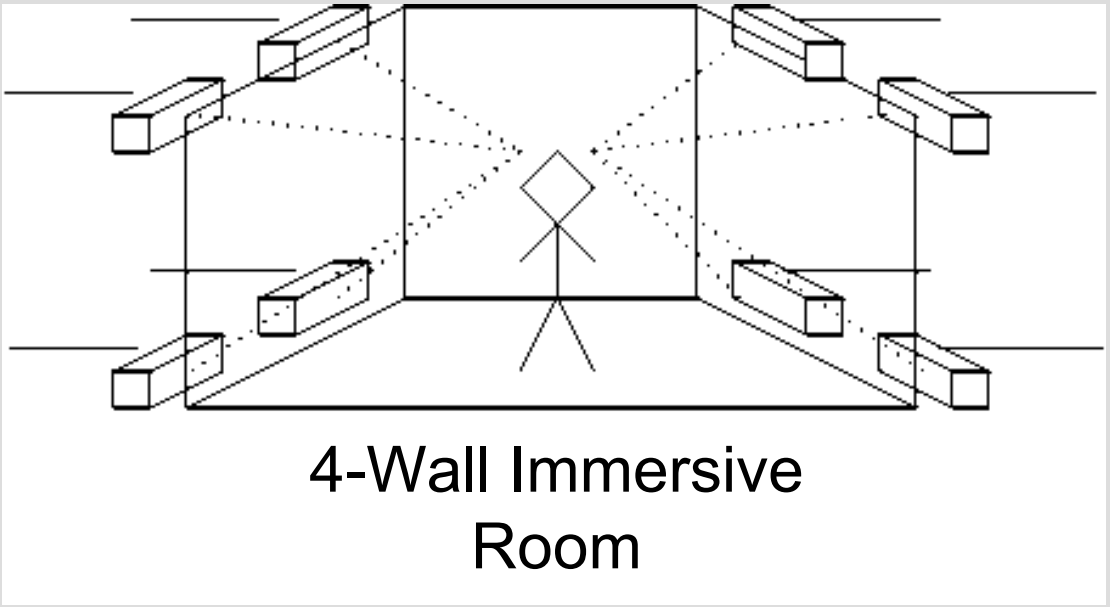
- **Task 1 – Configuring ALSA:**
  - Necessary to define an “asymmetric” device
    - Number of input and output channels is not necessarily the same
  - An environment variable must be set to allow Mustajuuri to talk to the audio card through ALSA

- **Task 2 – Configuring Mustajuuri Mixer Panel**
  - Configure a mixer-board style GUI
  - GUI has two mixer strips

Software Setup

- **Task 3 – Specifying Speaker Placement**
  - Set up the configuration file to specify azimuth and elevation angles for each speaker relative to position of listener
- **Task 4 – Configuring Sound File Loader**
  - Set up configuration file to specify all sound files possibly used by Mustajuuri
- **Task 5 – Configuring Mustajuuri for Remote Control**
  - Set up Mustajuuri to listen for control commands over a network
- **Task 6 – Interfacing with Mustajuuri API**
  - In order to control Mustajuuri from an application, it is necessary to add code included with Mustajuuri API into the application

Hardware Testing and Calibration



4-Wall Immersive Room

- **Tested hardware by integrating system with a 4-wall immersive virtual reality room**
- **Speakers were arranged in cube array and placed in the corners of the immersive room**

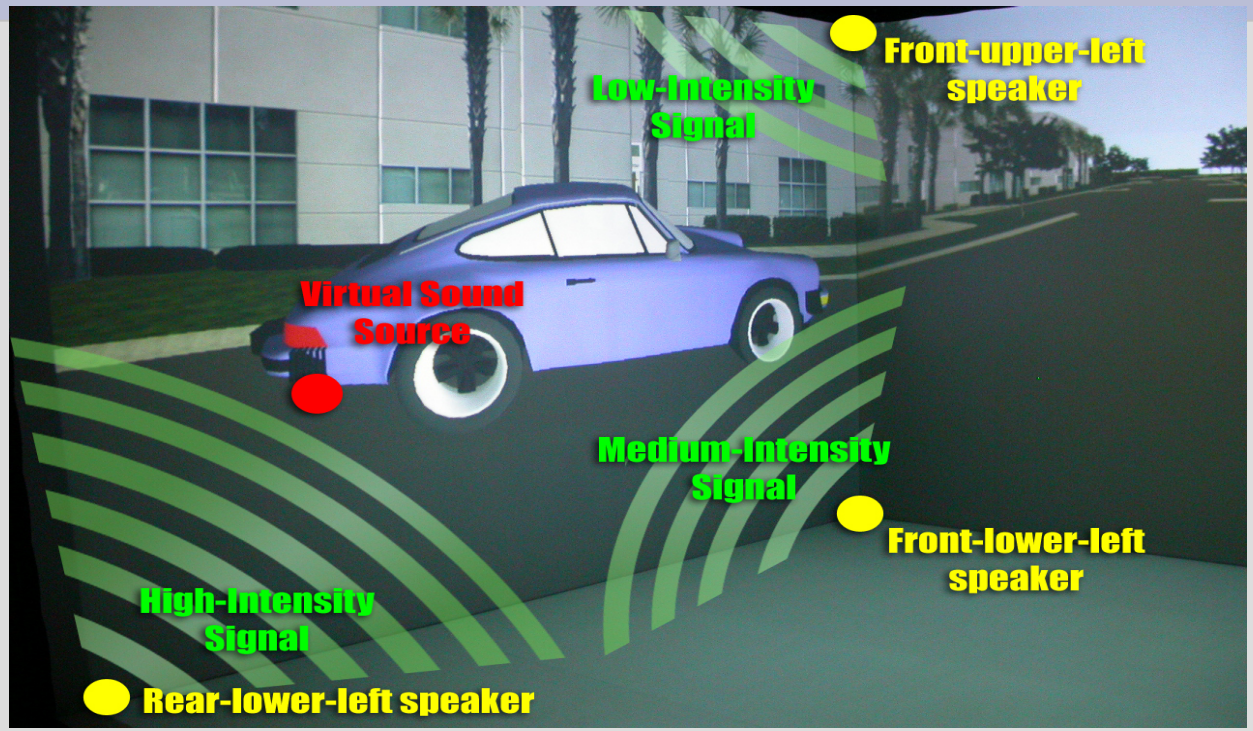
Software Testing

- **Integrated sound in an existing simulation platform operating on a Linux visualization cluster**
- **Tested the sound system by attaching audio effects to animated objects in our scenarios**

System Validation

- **Evaluated how the new sound system configuration compared with previous planar configurations**
  - Used unbiased test subjects
  - Switched between each configuration and rated audio quality of each system
  - Every test subject preferred the sound from the new, non-planar system
- **Evaluated how well the listener is able to localize the source of the audio using the 8-speaker configuration**
  - Presented subjects with several sounds, played one at a time, originating from different positions around the immersive room
  - Subjects were able to localize the direction of the sound source correctly in all three dimensions.

Conclusions and Future Work



- **Future:**
  - Directional Sound Cones
  - Additional Environmental Reverberation Effects
  - Enhanced Sound Attenuation Model