Facilitated Instrument Learning Project Proposal

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1 Introduction

1.1 Objective

Problem Statement

Musicians spend a substantial amount of time learning the positions of chords and notes on new instruments they are interested in learning. Facilitated instrument learning will allow one to sing, hum, or play another instrument and the currently played notes will be mapped onto the new instrument in real time. This allows a beginner, with little musical background, to sing a melody they wish to play and learn it on a new instrument and also allows a professional, with an extensive background on musical theory and other instruments, to compose music on new instruments.

Proposed Solution

The proposed solution is for the acoustic input recorded into an analog MEMS microphone and the signal will go through an ADC. This will connect to a DSP chip which handles the frequency analysis. This will connect to a microprocessor which controls the LEDs on piano keys. The DSP chip filters noise, additional signals from the instrument, and harmonics to determine the current notes being played. The frequencies of the notes will correspond to positions on an instrument which can be indicated by LEDs.

1.2 Background

The software complexity will be within the pitch detection algorithm. Noise, additional harmonics, and overtones first come to mind when filtering. Then there are frequencies which come from striking strings and frequencies which come from resonances instrument bodies. The pitch detection algorithm will contain signal processing and machine learning algorithms such as autocorrelation and k clustering to accurately determine the fundamentals.

The hardware complexity of this project will be the system integration and programming the DSP chip's firmware.

There are other products in the market which help people earn instruments but they have different limitations which this project overcomes.

SCI V9000 KEY/NOTE VISUALIZER. This $2000 product is limited because notes must be pre-selected on the piano for students to learn from later. With the proposed project, users produce the melodies with their voice or an instrument and the notes on the destination instrument will be shown in real time.

Synthesia This piano learning subscription service is limited to select songs the company has pre-transcribed for its users, so customers are unable to write songs with melodies they have come up with.

1.3 High-level Requirements List

- Detect pitches accurately at least 80 percent of the time,
- Analyze up to three notes simultaneously when a chord is played.
- Handle at least two instruments, voice and guitar, to map the notes to the piano.

2 Design

2.1 Block Diagram

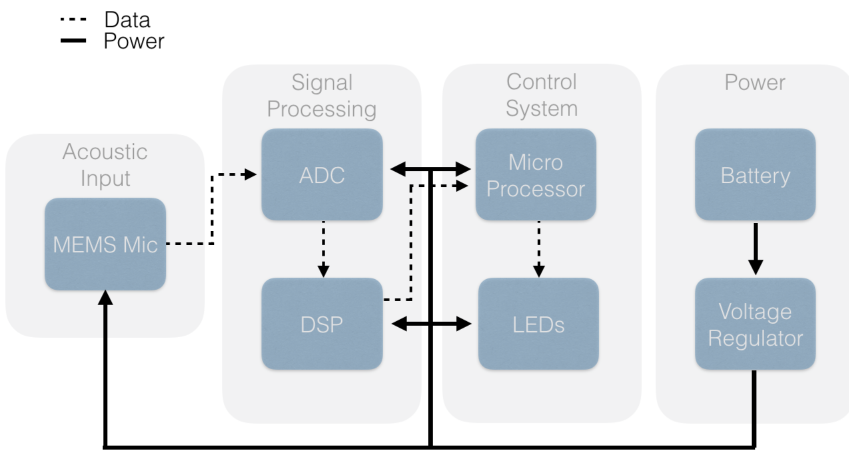

Figure 1: Project Block Diagram

2.2 Functional Overview

The Power module connects two 3.7V 18650 li-ion batteries to voltage regulators and a charging circuit. The voltage regulators step down to 5V and 3.3V, which will supply power to other components in our system. The batteries will be charged via USB to ensure wide compatibility with current chargers.

The Acoustic Input module takes the user's audio input, and sends the analog signal to the Signal Processing module. This module serves as the input module to our whole system.

The Signal Processing module takes the analog signal as an input, and outputs the frequencies of the signal by taking the fourier transform of the analog input data.

The Control System module contains the microprocessor and LEDs. The microprocessor will perform algorithm work on the frequency domain data. After determining the fundamental frequencies of the audio, the corresponding LEDs on the piano keys will turn on.

2.3 Block Requirements

Requirements	Verification
MEMS Mic $2.45V < V_{out} < 3V$	• attach a Ω resistor as load •
Voltage Regulator $V_{out} = 3.3 \pm 0.3V$	
Boost Converter $3.3 \pm 0.3V_{in}$ to $5.0 \pm 0.5V_{out}$	
Li-ion Battery $V_{out} = 3.6 \pm 0.6V$ $V_{in} = 5 \pm 0.3V$	
ADC Discretize analog signal 0-5 V to 2^{16} values	
DSP Output is within 5Hz of the actual waveform's frequencies	
MicroProcessor Analyzed notes are displayed on the correct LEDs	

2.4 Risk Analysis

The algorithm stored in the microprocessor in the control system module poses the greatest risk to the project. The algorithm's ability to simultaneously identify multiple fundamentals is more complex than detecting single pitches and will likely require the most time to develop. If a robust multiple pitch detection algorithm could not be developed, the customer will not be able to quickly map chords to the piano. However, single pitch detection is available for the user to play individual notes of the chord on the source instrument and know the positions on the piano.

3 Ethics and Safety

3.1 Ethics

To avoid IP infringement, we will be designing our own hardware module and software algorithms. If we come upon existing solutions that are available for us to use in our design, we will properly cite them.

This project doesn't illegally use other people's musical work, so there shouldn't be any issues related to copyright infringement

The project's use case is pretty limited for personal instrument learning, we don't think there will be misuses of our project.

3.2 Safety

Li-ion batteries can explode when they are overheated. To prevent that, we need to make sure to follow the instructions to connect the batteries.

References