Senior Design 22’-23’
Autonomous Guitar

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Team Sponsor
Self-sponsored

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1. Executive Summary

This document outlines the ideas, motivations, design considerations, and implementation details of ECE Group 30 / CS Group 42's Senior Design project. The goal is to build a fully functional autonomous self-playing guitar using a combination of both hardware and software. By nature, this is an interdisciplinary project. Our main objective is to be able to take any valid MIDI file and play those notes by fretting and strumming all 6 strings independently on an acoustic guitar (without self-interference). Specifications include being able to play all 29 valid notes between E2 and G#4, giving us a range of about 3.5 octaves.

We will accomplish this by using a custom algorithm written in Python to take MIDI data and convert it in realtime to playable notes on the guitar the exact start timing and duration of each note. This code will then run on a microprocessor that is connected to both the strumming motor assembly and fret motor assembly. The strumming assembly will consist of 6 motors positioned to pluck at each string. And the fret motor assembly will consist of solenoids positioned at fret locations 1-4 on each string. In total, giving us **30 unique playable combinations = 6 strings * (4 fret positions + 1 open string)** and totaling **29 unique notes** (B3 is repeated).

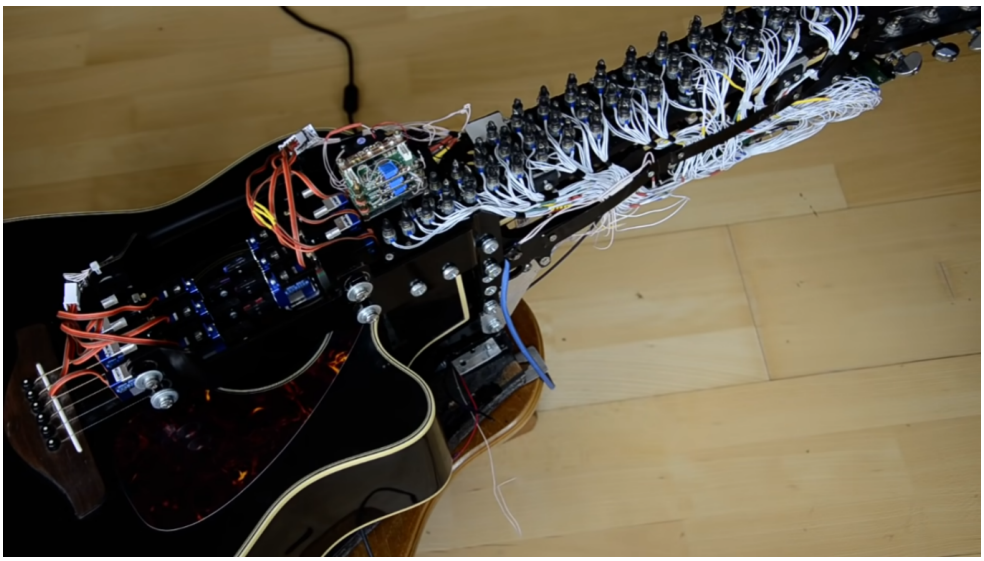
$$29 = 6 * (4 + 1) - 1$$

As this is a student-led and self-sponsored project, our budget is mostly limited to what we as students can afford: which we estimate will be around $200 across the 5 of us. There are little to no consumer products available at the moment which do this. However, there are a few hobbyists who have built similar machines as personal projects and posted videos of it on YouTube. Essentially, all projects of this nature are simply built for fun, entertainment, and as a personal challenge rather than for mass consumption. We will have the final design document report completed by the end of Senior Design 1: December 7th 2022. We would like to have our minimum viable product ready by halfway through Senior Design 2: February 24th 2023. And have the final product ready and presentable by one month before the end of Senior Design 2: March 24th 2023.

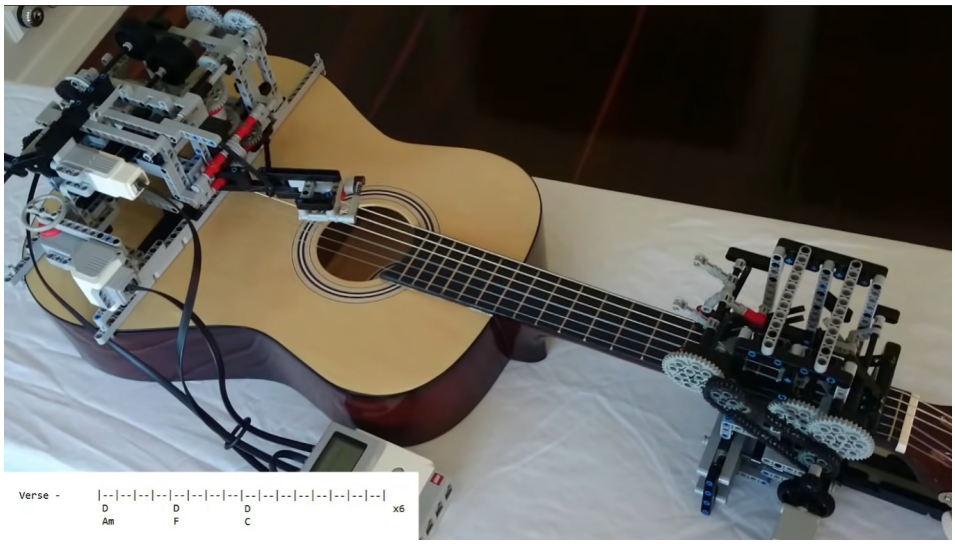
2. Project Overview

2.1 Project Description

The goal of this project is to create an autonomous self-playing guitar that is able to produce its own music. We have seen and taken inspiration from videos on YouTube of similar projects such as:



pirates of the Caribbean(guitar-robot)



Little Talks Guitar Cover by Lego Mindstorms EV3

The system would be able to take in MIDI files and play the notes on the guitar using separate mechanisms for strumming and pressing select strings against frets. It

would be lightweight and maintain the general form factor of the guitar (i.e, fits closely to the body).

The design should ideally be portable, and thus it would be powered by portable batteries. It should be responsive enough to accurately replicate the provided MIDI file compositions with comparable to - if not exceeding - the abilities of the average learnt guitar player.

Not only should this design be lightweight and portable, an issue with similar concepts is the price and size. They are typically not an attachment for a guitar and are more commonly an entire unit within the guitar. They are also extremely expensive with some models going for up to $1,100. Our goal for this project is to bring this idea to reality for significantly cheaper.

2.2 Student Motivations

Pedro Contipelli - My motivation for this project was that I wanted to bridge two very different fields that I am extremely passionate about: engineering and music. I felt this project would be the perfect choice for our team to put our knowledge and skills to the test, to create something that can be appreciated from both a scientific and human perspective.

Blake Cannoe - I used to play guitar in middle school. I thought this idea sounded like an interesting project.

Ethan Partidas - I want to do a project that has a large vertical scope, from the high-level software algorithm all the way down to the mechanical challenges of playing a guitar with motors.

Jonathan Catala - I am interested in this project due to the multidisciplinary nature of this project. It gives us the best look at an actual work project we could do. Due to this I believe this project will be beneficial to develop my engineering skills.

Kyle Walker - My dad played guitar throughout most of his life & also motivated me to become an engineer, so it seemed like a cool way to combine those two things.

3. Design Goals

Our ultimate goal for this project is to modify a guitar with electronics to be able to play itself. In pursuit of this we want our project to be:

1. Able to reliably play digital audio data
2. Portable
3. Lightweight
4. Within Budget (affordable)

3.1 Objectives

To realize the above goals, our project must:

1. Be built on an acoustic guitar
2. Be battery powered
3. Take MIDI file input over USB
4. Process MIDI files using a Microcontroller
5. Play a wide range of notes
6. Utilize servos for mechanical action (strumming and fretting)
7. Be able to strum all 6 strings either at once or independently
8. Be able to press frets to play individual notes
9. Use 3D Printed assembly parts

Table 1 below shows which objectives correlate to each goal organized by the index of each objective.

Goals	1	2	3	4	5	6	7	8	9
Plays Audio Data			✓	✓	✓	✓	✓	✓	
Lightweight	✓	✓							✓
Affordability	✓					✓			✓
Portability		✓							

Table 1

3.2 Specifications

The following Tables 2 and 3 outline the specifications and constraints of our project. On the following page is a figure detailing all notes between E2 and G#4.

Specification	**Measurement**
Minimum fretting force	3N
Maximum fretting force	5N
Electrical components weight	3 pounds
Battery weight	2 pounds
MIDI File Size	50 KB
Power consumed	< 9W
Playable notes	All notes between E2 and G#4 (see figure 1)
Maximum song length	3 Minutes
Battery Life	2 Hours

Table 2

Constraints & Standards
At Least 1 PCB required
MIDI Audio Storage Standard
Under $200
Algorithm written in python
Microprocessor code written in C
UART Communication protocol

Table 3

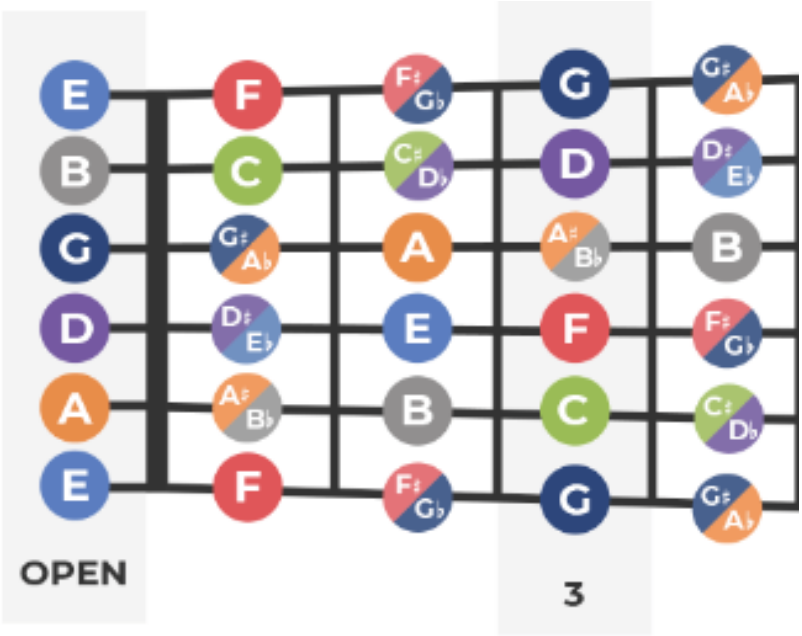


Figure 1

4. Division of Labor

Pedro Contipelli

- Reading MIDI data in Python
- Core algorithm for converting MIDI to guitar fret/strumming positions

Ethan Partidas & Blake Cannoe

- Microprocessor design
- Microprocessor code and interface

Jonathan Catala & Kyle Walker

- Setup, electronics, wiring, hardware, etc
- Planning schematic and board layout for PCB
- Ensuring DC to DC converter has correct power output
- Ensuring power is supplied to motors

5. Models

5.1 Block Diagram

Below (Figure 2) is the block diagram of what components we are planning to have in the guitar.

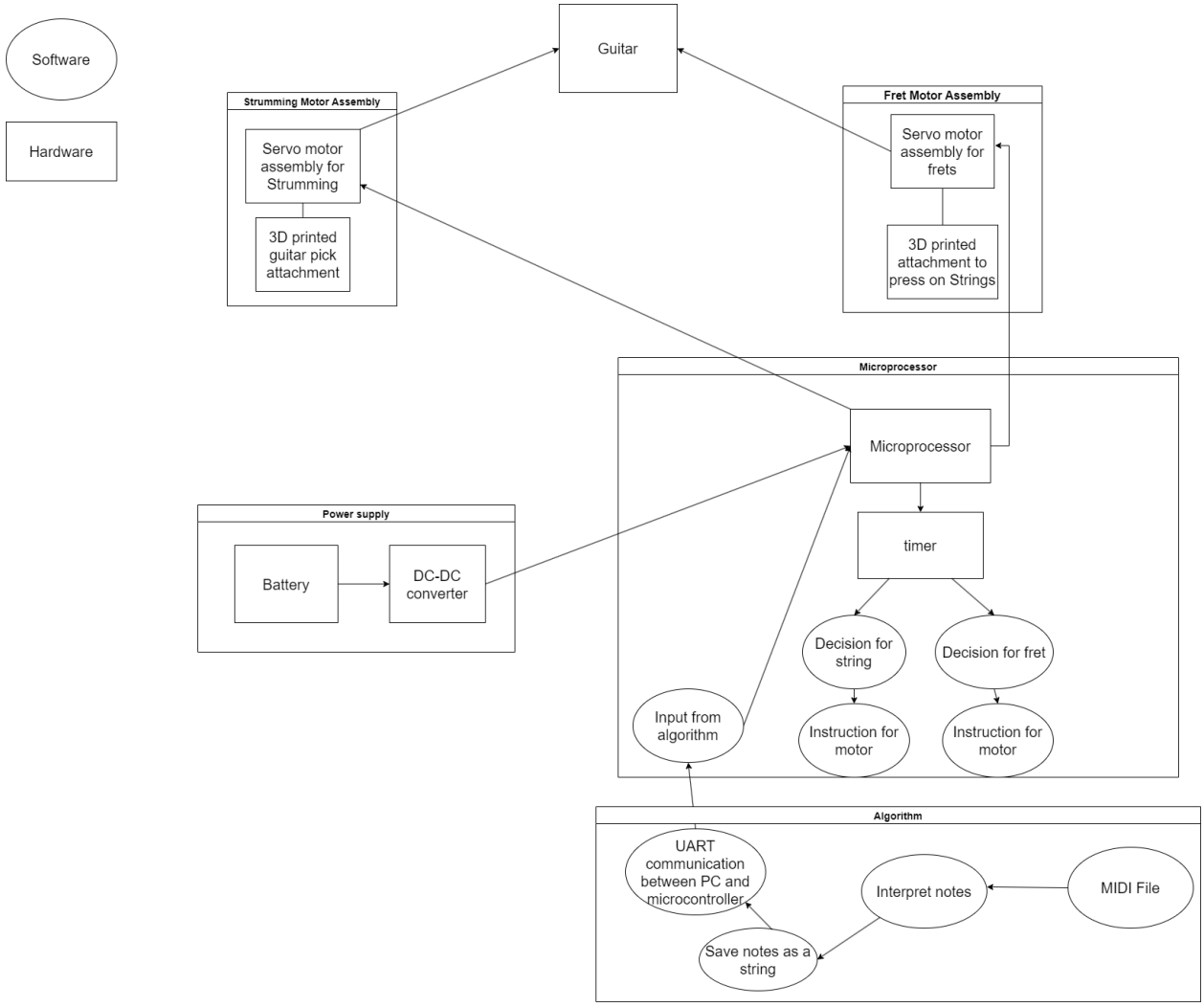


Figure 2

Hardware: Power Supply -> Microprocessor -> Motors -> Guitar

Software: MIDI interpreter -> Custom algorithm decides which strings/frets to play notes on

5.2 House of Quality

Figure 2 details the House of Quality model used to outline our project's specification requirements.

QFD: House of Quality C. Battles. (2011, May). QFD House of Quality Template. Schrodinger's Ghost.com [Online]. Available: http://www.schrodingersghost.com/?cat=54.

Project: Autonomous Guitar
Revision:
Date: 10/7/2022

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Correlations	
Positive	+
Negative	−
No Correlation	

		Column #	1	2	3	4	5	6	7	8	9
		Direction of Improvement	▼	▼	▼	▼	◇	▼	▲	▼	▼
	Weight	Customer Requirements (Explicit and Implicit) \ Engineering Requirements	MIDI file size	# of Fret motors	# of Strumming motors	Power Source	Output Power	# of microcontrollers	efficiency of code	timer speed	Cost
	8	Song Duration	●	○				●			●
	2	Sound Volume	▽	▽	●		●				
	4	Light Weight	▽	●	○	●		●			
		Song Complexity	●	●	●				●	●	
		Portable	▽	●	○						
		Low Power	○	●	●	●	●		●	●	
		Small install	▽	●	●						●
		accurate	○	○					●	●	
		Cost	●	●	●	●		●			●
		Target	>50 KB	> 29 motors	6 motors	Battery	> 9 Watt	>2	> 75%	1ms	>$200

Figure 3

6. Budget/Financing

Used Guitar: < $30
Microprocessor: $20
Misc. Electrical components: $5 to $10
Motors for frets and strumming: $60

Item	Quantity	Price
Used Guitar	1	< $30
Microprocessor	1	$20
Misc Electrical components	Unknown	< $5
Motors for Strings	6	$12
Motors for Frets	24	$48

Table 4

7. Competing products

Demin Vladimir's Guitar Robot	Plays the entire possible range of notes using many solenoids. Much more versatile, but also more costly.
TECHNICally Possible's Lego Mindstorms Guitar	Plays only chords using lego mindstorms. Not as versatile but much cheaper.

Table 5

8. Testing & Integration

9. Project Milestones

Senior Design 1	
Date	**Milestones**
10/7/22	(CS) TA Check-In & (CS) Assignment #3 & (ECE) D&C 2.0 Submission
10/14/22	Design Plans / 25-pages written
10/21/22	Dr. Leinecker Status Meeting Check-In / 40 pages written
10/28/22	50 pages of design document and finishing touches
11/4/22	(ECE) 60-page report submission
11/6/22	(CS) Assignment #4 Due: Individual Contributions to Design Doc
11/11/22	80 pages design document written
11/18/22	(ECE) 100-page report submission
11/25/22	Begin Design Implementation
12/2/22	Schematic complete and Documentation revision
12/6/22	All parts ordered
12/7/22	(CS) Final Design Document Due

Table 6

Senior Design 2	
Date	**Milestones**
1/13/23	MIDI File Research - (Pedro) Receive ordered parts - (ECE team)
1/20/23	MIDI File Reading Algorithm - (Pedro)
1/27/23	Core Note-playing Algorithm and Simulation - (Pedro) Single String strumming and fretting - (ECE team)
2/3/23	Finalization of algorithm and software tests - (Pedro) Strumming and Fret Assemblies hooked to microprocessor - (ECE team)
2/10/23	Project Prototype & Requirements Revision - (Whole team)
2/17/23	Software-Hardware Interface Connection - (Whole team)
2/24/23	Minimum Viable Product Finished - (Whole team)
3/3/23	Initial Presentation and Feedback - (Whole team)
3/10/23	Testing / Integration - (Whole Team)
3/17/23	Testing / Integration - (Whole Team)
3/24/23	Final Presentable Project Done
3/31/23	Stretch Goals / Buffer Time
4/7/23	Stretch Goals / Buffer Time
4/14/23	Stretch Goals / Buffer Time
4/21/23	Stretch Goals / Buffer Time

Table 7

10. References

1. https://yousician.com/blog/guitar-fretboard-learning-guide