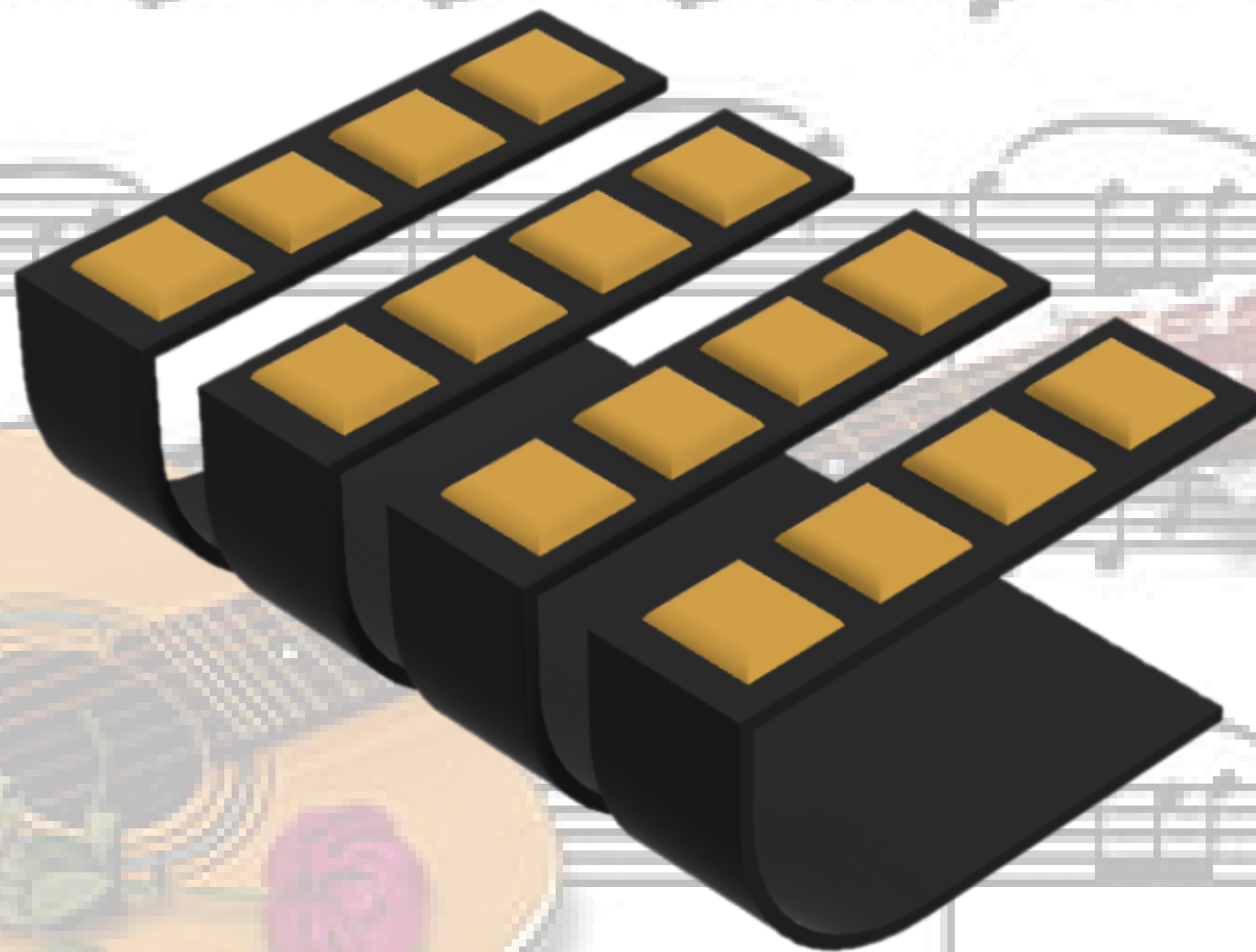


The FretFriend

MSc Final Project

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Introduction

This design journal is a summary of the work carried out during an individual project looking to enhance the learning of a dexterous skill online. It was originally a general skill learning project but after the initial research carried out was too general to take positive steps in any direction, the scope of the project was narrowed down to learning a stringed instrument. Due to personal preference, the instrument chosen was the ukulele.

The Coronavirus pandemic was both a curse and a blessing for this project in a sense as some music shops and teachers decided to start offering lessons online. I spoke to a couple of tutors during the course of the project and they have said that the lessons have been worthwhile for people in general but also those who cannot get to a shop for traditional lessons. For this reason, online lessons may stay commonplace once the crisis is over.

At the outset, the project started by looking at reading the user's hand movements and either giving them direct feedback or passing this information to a teacher or mentor who would give the user feedback and advice to hone their skills. This idea of monitoring the hands was abandoned when I realised that limitations between camera abilities in capturing movement and the expense that other options would most likely accrue to a consumer.

The following pages outline the design choices made to create my final product, the FretFriend.



Research

The initial direction that the project took before the scope was narrowed was looking at sensor gloves which would analyse the user's hand gestures. The data collected from the gloves could be passed onto a mentor who could inform the user how to improve their skills. The main issue found through researching a similar glove showcased in 2019 was that the glove could capture a the movement of the hand perfectly but it could only capture the hand's movement in relation to the wrist. This means that it can't be used on it's own to tell if the user has correct handling as the mentor would not see what or how they are holding or interacting with a required tool.

I had questions prepared for the tutor and he explained a couple of issues that he had noticed since starting the sessions. The one he mentioned which fitted with my original project outline was that he found it difficult when he could not see the student's fretboard due to them moving the instrument in and out of frame during the lesson. I decided that this was a problem worth tackling as a solution to this problem could also fulfil my original intention of giving a student feedback without a tutor.

Throughout the course of the project, I kept taking online lessons with the tutors at Duke of Uke, London.

Moving on to the ukulele, after purchasing my own instrument and looking at books for kindle and courses available online through websites like Udemy, I realised how hard it is to be self-critical when I didn't have a professional player to interact with. After browsing a little more online, I found a ukulele shop in London who had started doing taster sessions and batches of lessons through Zoom meetings. I signed up for a taster session and spoke to the tutor at the end of the lesson.

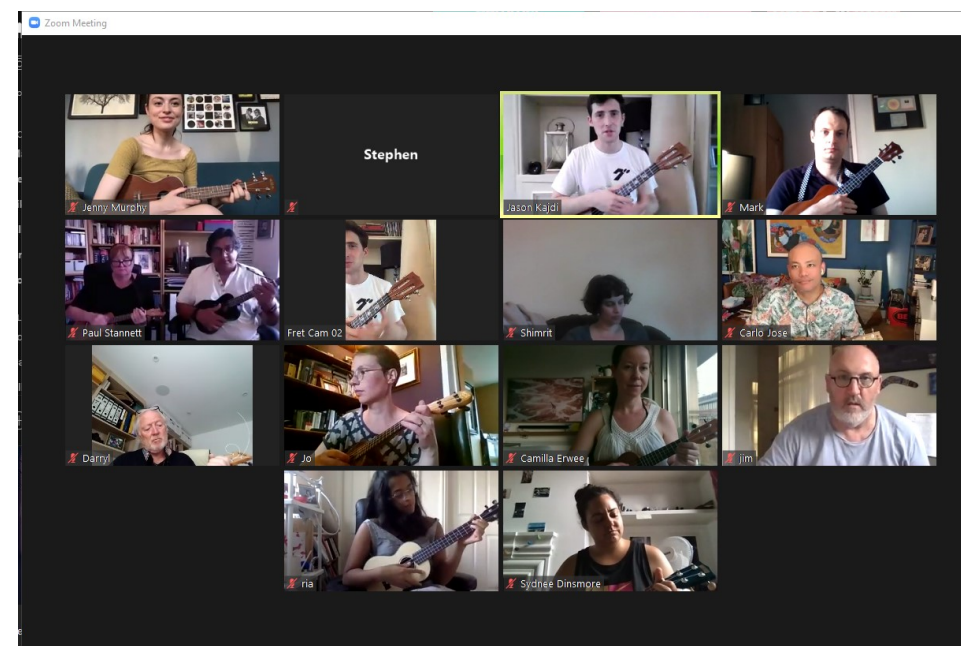
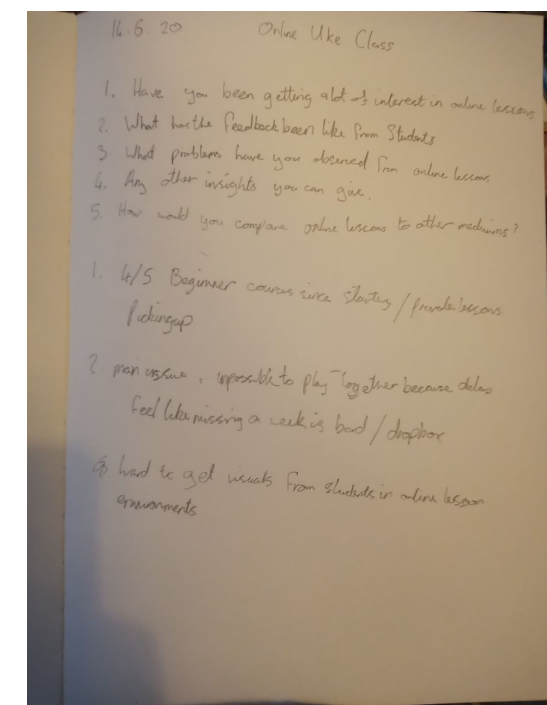


Photo of a ukulele class over Zoom



Photo of hand measurement gloves developed by ETH Zurich and New York University 2019

<https://techxplare.com/news/2019-07-stretch-sensing-glove-captures-interactive-poses.html>



Notes taken from a Conversation with a Ukulele Teacher on 14.6.2020

Earlier Directions

Starting on the more focussed problem, I was looking for a way to make the fretboard more visible for a teacher on a zoom call. A couple of directions were explored at this point but the most notable was a mount for the ukulele which can hold a mobile phone to be used as a second camera constantly showing the fretboard. Different issues were brought up for why this would not work:

- The phone could be in use for the zoom call in the first place
- A badly finished attachment could damage the instrument (like I managed to do when using an existing phone stand to illustrate the idea)
- A camera would struggle to see what the fingers are actually doing from a top view as they can cross over or the rest of their hand could obstruct the view.

The last objection was the most important factor when deciding this was not a worthwhile direction. What's the point in designing something to hold a camera when the camera could not see what is to be monitored.

Another solution being considered at the same time was a colour-coded overlay for the fretboard to make the user's hand positioning more apparent. This could help a user on their own by colour coding chord notations in music they are learning to match their overlay so they can see what buttons need pressed for each chord by colour. More issues were brought up when this was presented in my interim presentation:

- If this is on the fretboard, the student is not able to get a feel for the strings so they could end up practically at square one when they remove it.
- The overlay would still be obscured to a teacher or camera so would not solve that problem.
- The overlay could interfere with the strings on the instrument.

Although these objections all made sense, there seemed like something could be done with a button array if it was used differently for monitoring. This idea was how my final design came about from this early concept.

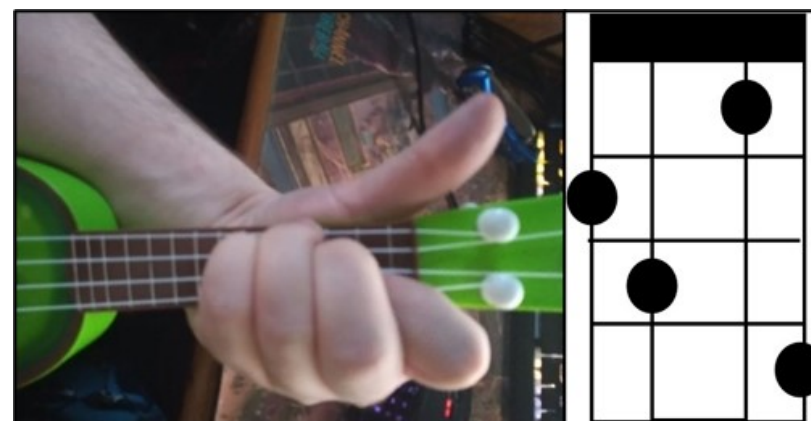
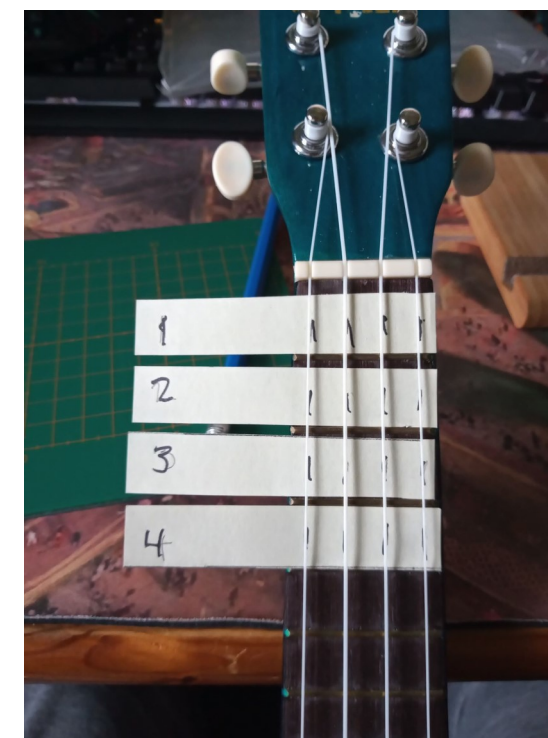
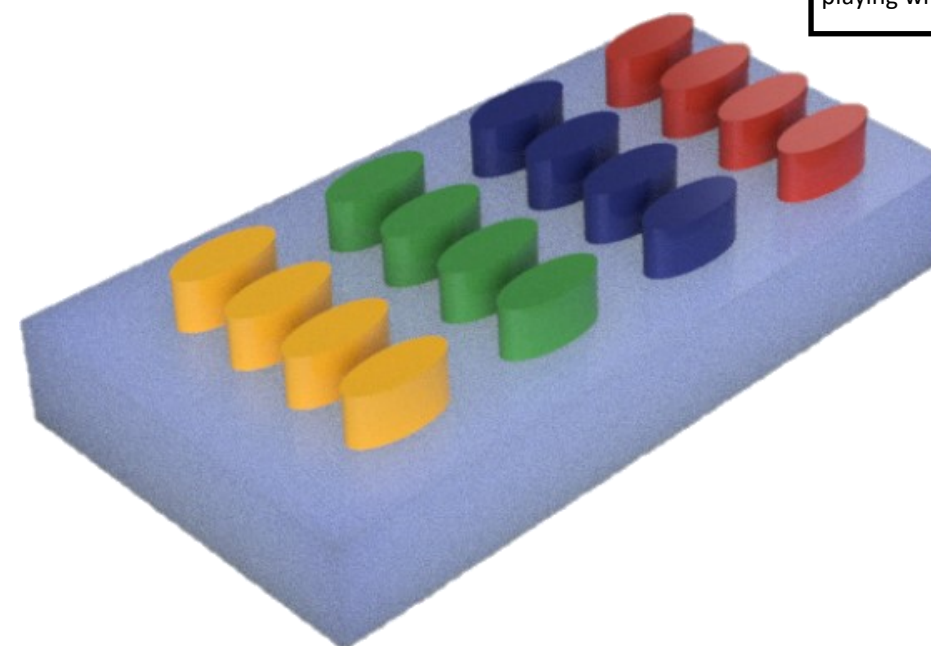


Illustration of a hand pressing strings from above to show a camera's ability to analyse a hand



Post-it tabs on the first 4 frets of a ukulele to try playing with something under strings



Visual of the colour-coded overlay concept

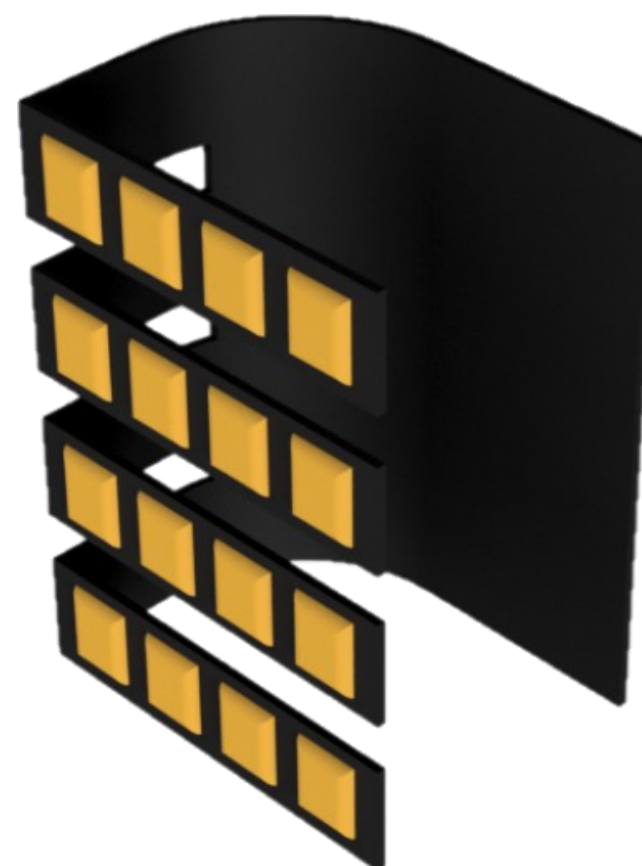
Final Concept

The final design I am presenting was more of an underlay than an overlay. This device would be slid between the strings of the ukulele and the fretboard and contain a 1x4 button array for each of the first four frets. When the strings are pressed by the user to form a chord, they will also be pressing down on the buttons which pass this information to a microcontroller to identify the combination as a specific chord or random jumble of notes and feed this information as a visual to another device. This visual will be useful for both a learner on their own or in a teacher and student situation, both of which will be explained on the next couple of pages of this journal.

The FretFriend would connect to other devices via Bluetooth so an adapter may be needed by a user wishing to use it with their computer. Another thing I considered for connectivity was a custom screen that would be designed specifically for the Fret-Friend. This screen would be pre-loaded with the chord images it would display and be a generally self contained unit which can be charged up and taken wherever the user needs. This would allow the musician to practice transitions wherever they go, potentially without needing the instrument if they take just the FretFriend with them.

When handling the ukulele, the neck of the instrument rests on the player's non-dominant hand while the other hand is used to strum and pluck the strings at the body. This means that the other side of the neck is empty so the FretFriend was designed to slide onto the fretboard from there. Looking at the instrument front on, the FretFriend would slide onto the neck from the left-hand side with a right-handed user and the opposite way around for a leftie. This would mean that the buttons would be rotated 180° about the centre of the device so it would need programmed to run with the buttons inverted for a left-handed user.

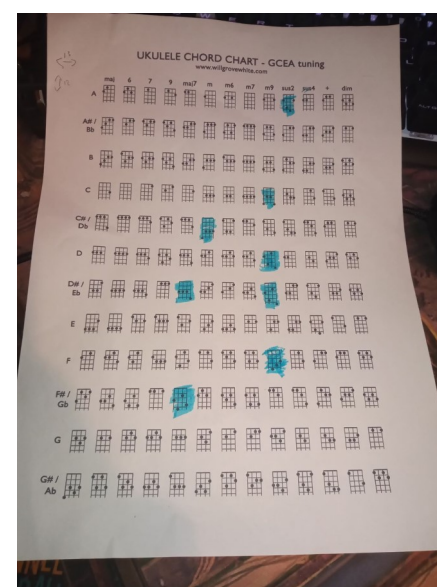
The FretFriend has been designed to have four "fingers" with buttons on them instead of a flat plate containing all 16. This is due to a flat plate interfering with the bars on the fretboard which would stop sound coming from the instrument when it is strummed. There are only four fingers as I found a chord sheet for a ukulele with GCEA tuning and out of the 156 chords shown, only eight used frets 5 or 6 so I decided it would not be worth adding the extra buttons for those obscure chords.



Rendering of the FretFriend device



Rendering of a screen to work with the FretFriend



The chords for a GCEA tuned ukulele highlighting those which use frets 5 and 6



Plastic prototype on a ukulele fretboard

Use Cases

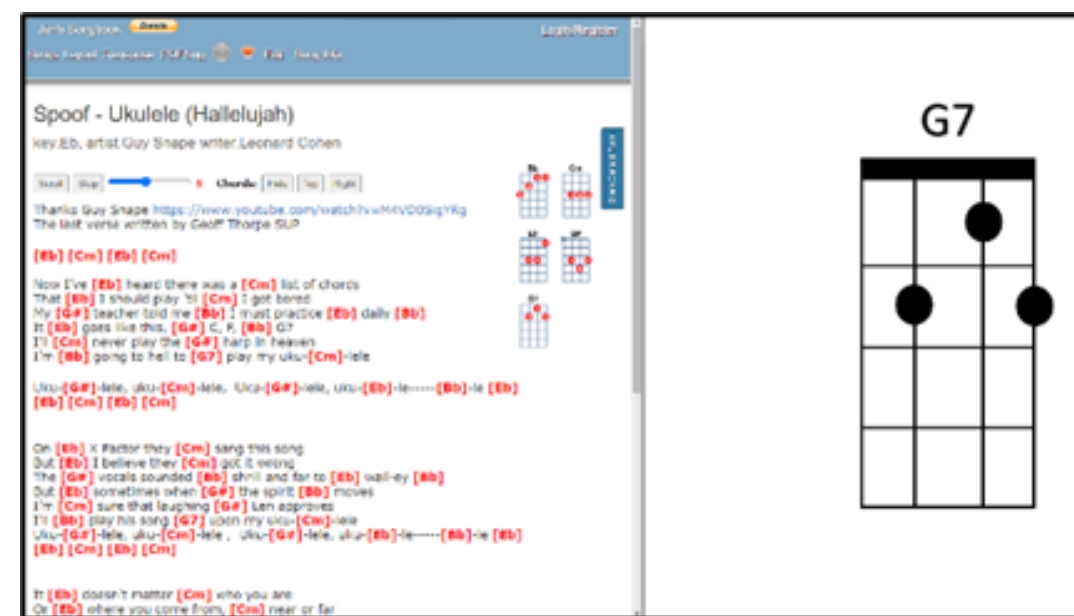
There are multiple situations that the FretFriend can be used in to help the student, two relevant for learning from home are described on this page and another for group lessons on the following one

During a group lesson video call, or even a one-to-one session with a tutor, the student can connect their FretFriend to the device they are using for the call. They would then use an application which would take the video from their camera and add a layer on top of it with their fretboard. This fretboard would update when the student presses their finger down or lifts it from a string and update in real time. This video would be used for the call so the tutor can easily see as each student finds the next chord in the song being practiced and identify if there is somebody struggling and offer advice without anybody being too embarrassed to ask for it.



Mock-up of a student's video in a video call using the FretFriend

When a learner decided to start practicing a song on their own, they can connect their FretFriend to a screen and sit with it alongside the song sheet they are consulting. This would allow the student to read the music while keeping an eye on what chord they are playing without looking at their fretboard. Doing this would allow them to make sure they are performing well and build up confidence in their ability to find play a chord without looking. A big part of the ukulele is singing while you play and constantly checking the fretboard can disrupt your flow so having a diagram off to the side means they can keep an eye on it while not interrupting their singing.



Mock-up of a user's screen with a song and the FretFriend computer application

Use Cases Continued

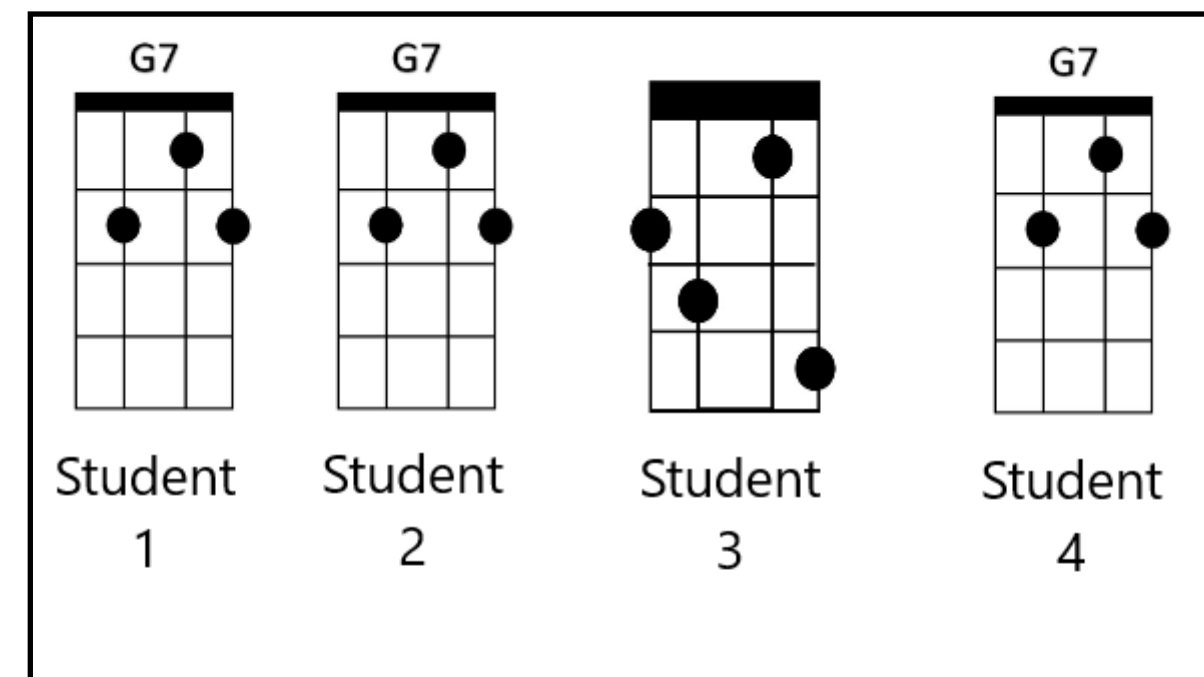
During an in-person group lesson, each student can arrive with their FretFriend already on their instrument and connect them to a tablet or computer that the tutor brings to the lesson. After connecting, the lesson can continue as normal but with the tutor able to see what each person is doing by glancing to the screen. This can be used in a similar way to an online lesson where the teacher can do impromptu drills to help struggling students or keep an eye on a particular student that they can tell is needing individual help.



A group music lesson

A one-to-one lesson could also use this feature of the FretFriend but the tutor does not have to divide attention as much in this scenario so it may not be needed.

One last situation was mentioned before, practicing without your instrument. A budding musician could take their FretFriend with them on public transport and fiddle about with it connected to their phone. While connected to the phone in this manner, the mobile app connected to the device could have an option to play the chord being held down, helping the musician recognise chords being played by ear. It could also have a drill function where it shows a chord diagram or name and you have to press the combination as quickly as possible, adding a game element to your practice.



Mock-up of a tutor's screen with multiple FretFriend users in a lesson

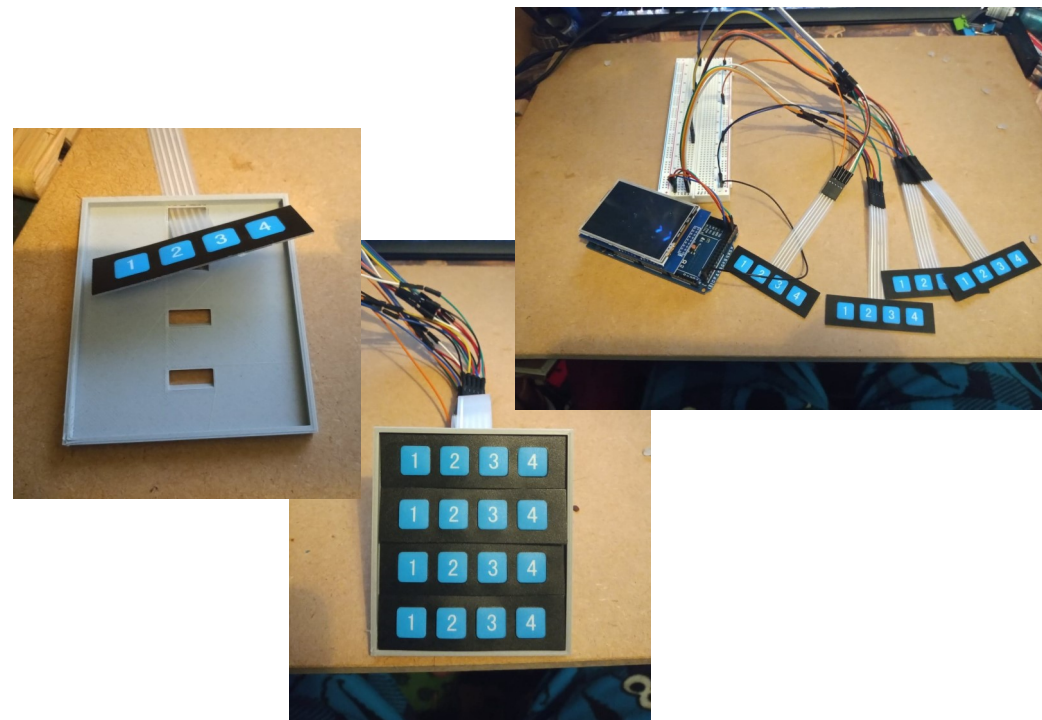
Prototyping

Once the concept which would later become the FretFriend was decided upon, I started work on a couple of prototypes for it.

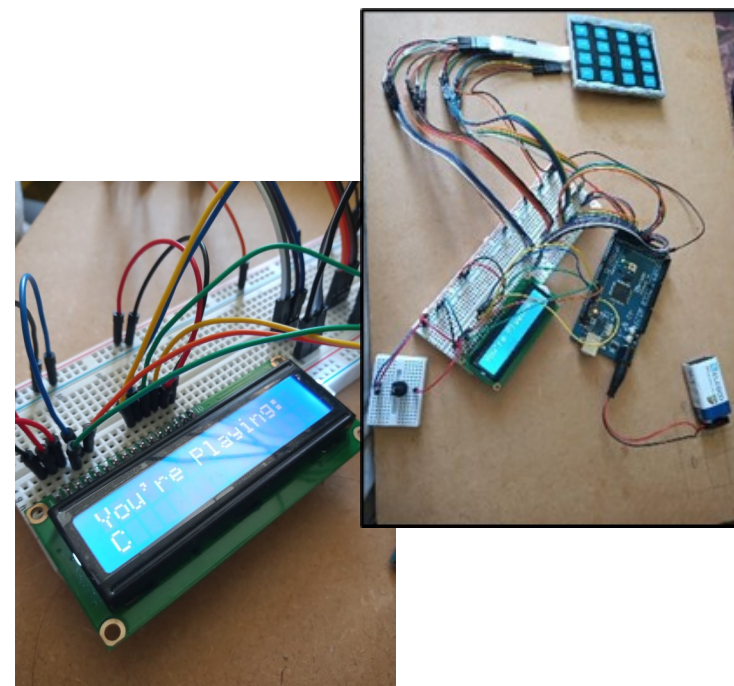
One part of my prototyping was developing an electronic-based one using an Arduino Mega2560. I started by getting the buttons wired up and checking that each was connected properly. The wiring for the buttons were different from the guide I found online so I had to swap wires around on the breadboard until each was connected to the right pin. With the amount of cables around, it was difficult to keep the buttons the right way around so I ended up designing and 3D printing a frame which would hold them in place.

The next step with the electronics was getting them to produce an output which did not require the computer to be connected to the board. I started by trying to program an LCD display which would show images of the chords being played by different button combinations but the Arduino sketch was not liking this. As I uploaded the sketch to the board, it kept producing errors with the libraries needed to run the screen so I was forced to abandon it. I ended up using a LCD1602 screen which can only produce normal text and symbols and got it to work for some of the chord combinations I programmed.

The other prototype I made was a physical form one. I measured different dimensions from my ukulele and created a CAD model of the device. From this model, I was able to 3D print a physical copy to try slide onto my instrument. I had some trouble getting the buttons under the top fret but they had been put onto the model the way they were to make them more noticeable, actual buttons would not be that thick in practice. Even with the buttons being a little thick, the instrument could still play all noted from the top 4 frets, with the exception of the top right one, which was due to the thick buttons and the fact that the plastic had bent up a little during printing.



Early stages of the electronic prototype sorting the buttons



The electronic prototype once the LCD1602 screen was installed and working



The 3D printed physical prototype both on and off a fretboard

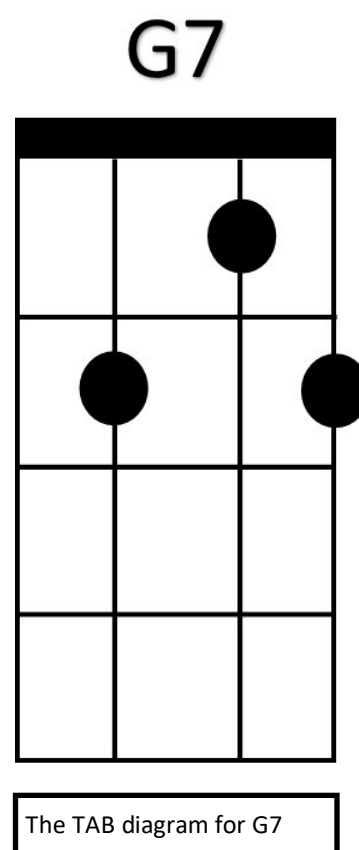
Feedback Display

Before now, I have mentioned different methods of getting feedback from the FretFriend but only gone in depth for a video lesson as to how this would be carried out. The thing to note first is that ukulele chords are shown as a graphic called a TAB which consists of a grid with a spot on the vertical lines to signify where a finger should be pressing down. All of the feedback methods I have considered, it would be such a graphic shown to the learner (and tutors).

The FretFriend would require its own software on the two main app stores for it to be used on a mobile phone. This software would allow the phone to interpret the data being sent from the microcontroller in the FretFriend and produce a TAB of the notes being pressed down. This software also has the potential to add little speed testing games for the user to try and beat their times while they practice their chord transitions.

Likewise, a software would need to be developed for PC to allow the device to work with it. Another consideration is the need for a USB Bluetooth adaptor, one could be packaged with the FretFriend but it is also something which can be found easily enough online.

Lastly is the screen I mentioned earlier specifically for the FretFriend. This is a simple touchscreen display which displays the TAB but additional functionality could also be added such as a tuner and metronome, two tools which are handy with any stringed instrument. Since it would have a microphone to be able to function as a tuner, this screen could also run strumming practice drills where it shows a pattern of strums to be played by the user and listens for how accurately it gets played.



Blown-up version of prototype screen



Rendering of the FretFriend Official screen

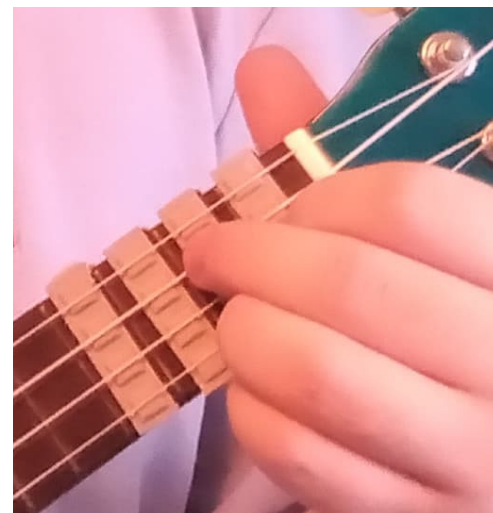
Materials

When making the physical prototype, PLA was used on a 3D printer. As a material and manufacturing method for the final product, this would not be the chosen combination. What would be more likely is injection moulding a plastic such as ABS due to its good resistance to chemicals and heat. This means that the oils and chemicals from the user's skin should not degrade the product through its lifespan.

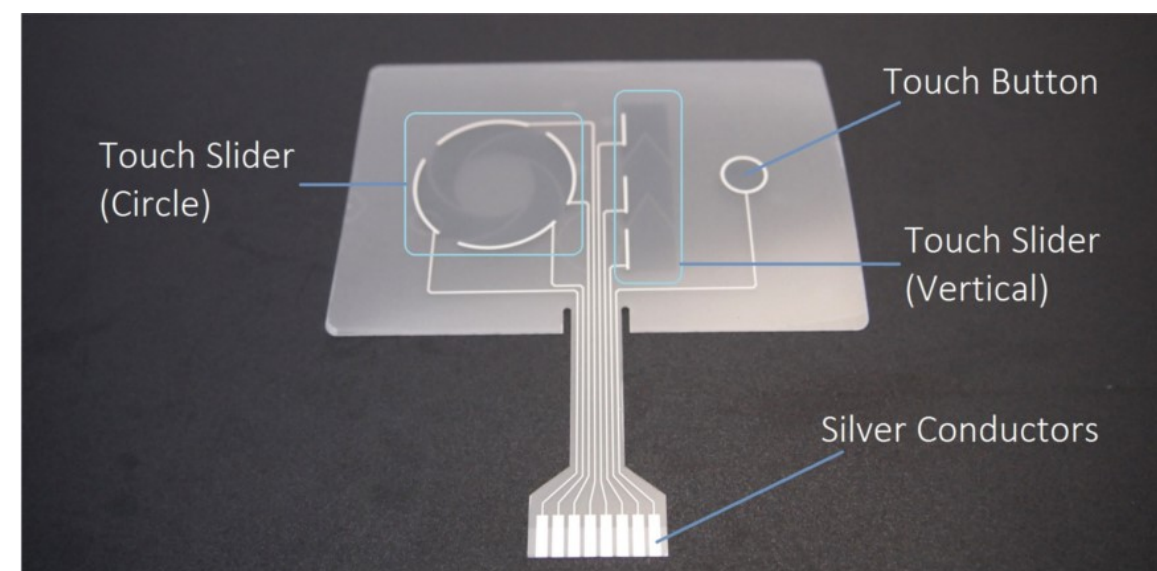
Thin touch switches can be easily found online which would work well for the buttons however they do not necessarily have much resistance of their own. For this reason, a thin silicon film can be used to cover the switches from above, thereby protecting the switches from excessive wear and tear from the ukulele strings being pressed down on them.



Close-ups of the physical prototype after breaking while being removed from the ukulele



Close-up of the physical prototype on a ukulele

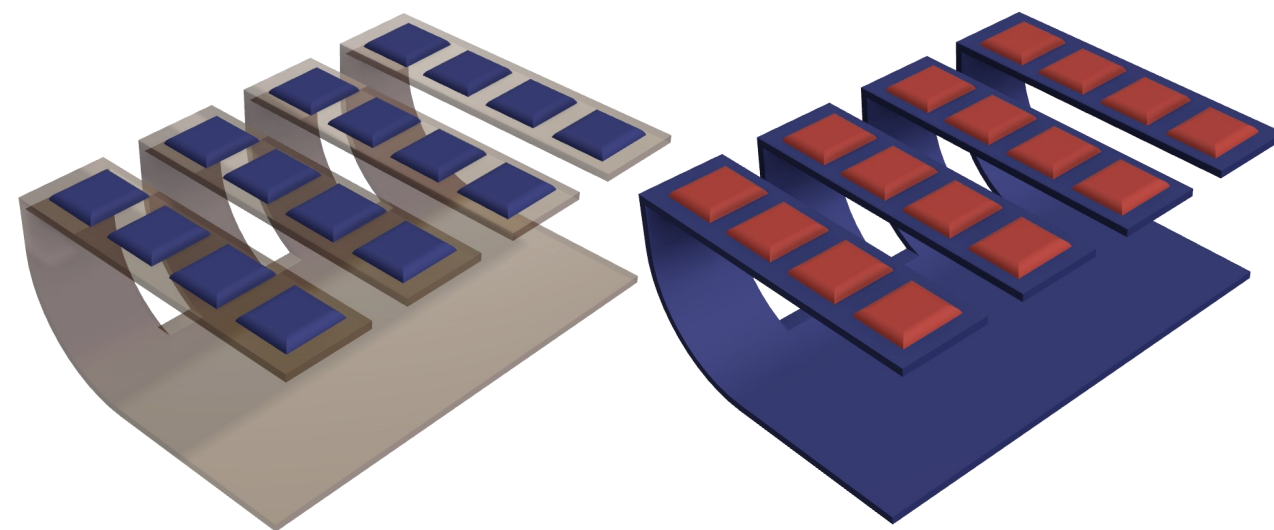


Display of thin touch sensor versatility from COCHIEF INDUSTRIAL CO., LTD
https://www.cochief.com/en/category/Flexible-Touch-Switch-Film/E01_TK-Touch-Switch.html

Further Development

Because of how the FretFriend has been designed, it would be easy enough to customise and alter it to suit a person's preferences. The plastic body could be a range of colours so the musician can match theirs to their instrument. The other main adaptation I have considered is widening it slightly to house more buttons. Adding the extra buttons would allow the FretFriend to work for other instruments, in particular acoustic and electric guitars.

One point worth noting is that the model I designed was based on my soprano ukulele. There are three bigger sizes of ukulele so they would need to be measured to make FretFriends for them too.



Different colour options for the FretFriend



FretFriend guitar edition