# Let’s Frets! Mastering Guitar Playing with Capacitive Sensing and Visual Guidance

Karola Marky
Technical University of Darmstadt, Germany, University of Glasgow, Scotland
marky@tk.tu-darmstadt.de

Andreas Weiß
Music School Schallkultur, Kaiserslautern, Germany
andreas.weiss@musikschule-schallkultur.de

Florian Müller, Martin Schmitz
Technical University of Darmstadt, Germany

Max Mühlhäuser, and Thomas Kosch
Technical University of Darmstadt, Germany

**Figure 1: We present *Let’s Frets*, a modular guitar learning concept with three feedback modules: (1) visual indicators, (2) finger position capturing, and (3) a combination of both modules.**

## ABSTRACT

Mastering the guitar requires regular exercise to develop new skills and maintain existing abilities. We present *Let’s Frets* - a modular guitar support system that provides visual guidance through LEDs that are integrated into a capacitive fretboard to support the practice of chords, scales, melodies, and exercises. Additional feedback is provided through a 3D-printed fretboard that senses the finger positions through capacitive sensing. We envision *Let’s Frets* as an integrated guitar support system that raises the awareness of guitarists about their playing styles, their training progress, the composition of new pieces, and facilitating remote collaborations between teachers as well as guitar students. This interactivity demonstrates *Let’s Frets* with an augmented fretboard and supporting software that runs on a mobile device.

## CCS CONCEPTS

• **Human-centered computing** → *Collaborative and social computing systems and tools*; **Systems and tools for interaction design**.



*CHI ’21 Extended Abstracts, May 8–13, 2021, Yokohama, Japan*



ACM ISBN 978-1-4503-8095-9/21/05…$15.00
https://doi.org/10.1145/3411763.3451536

## KEYWORDS

musical instruments, support setup, capacitive sensing

**ACM Reference Format:**

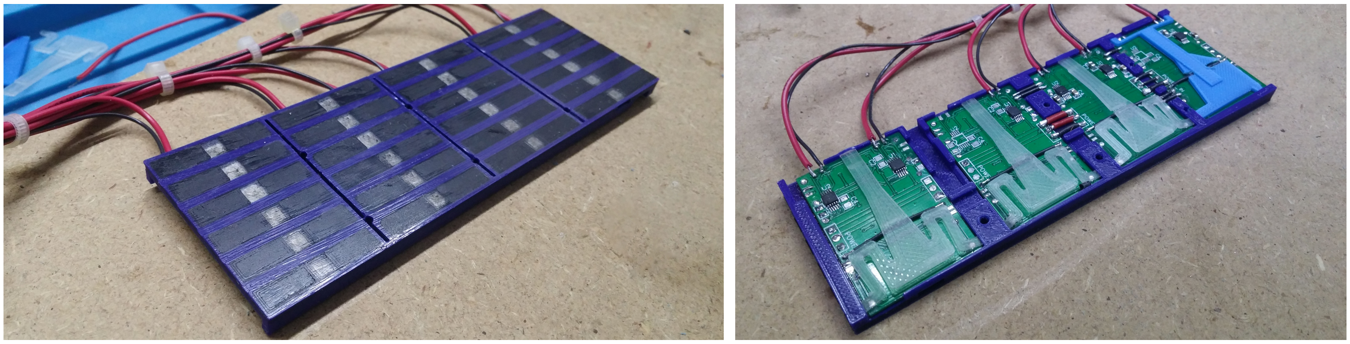
Karola Marky, Andreas Weiß, Florian Müller, Martin Schmitz, and Max Mühlhäuser, and Thomas Kosch. 2021. Let’s Frets! Mastering Guitar Playing with Capacitive Sensing and Visual Guidance. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI ’21 Extended Abstracts), May 8–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3411763.3451536

## 1 INTRODUCTION

Guitars are popular musical instruments that represent an essential part of many music bands. Prospective guitarists need regular practice sessions with professional teachers to master the guitar. Even experienced guitarists require regular exercise to maintain their skills [1, 5]. Such skills include a sense of rhythm and the agility to playing different techniques, such as strumming or vibrato.

Based on a limited number of allocated teaching sessions, beginners This could result in erroneous playing habits that may become difficult to break and might even lead to health issues (e.g., “Repetitive Strain Injury” syndrome [11]).

In this context, assistive systems have been proposed to provide autonomous practice sessions for guitar students by teaching aids. For example, projections on the guitar have been used to visually depict the next strings to be pressed [6, 7]. Further support can be provided through in-situ assistance with mixed reality [8, 10], or the actuation of the current playing style through implicit gestures and physiological measures [2, 3, 14]. Each of the proposed solutions



**(a) Front of the capacitive fretboard.** **(b) Back of the capacitive fretboard.**

**Figure 2: Front- and backside of the capacitive fretboard including wiring.**

delivers individual benefits. However, projection-based solutions require a complicated setup that needs to track the guitar. The previously mentioned solutions require either the guitar or the user to be prepared, hence increasing the overall effort before practicing.

This demonstration presents *Let's Frets* – a modular guitar support system that combines visual indicators, feedback about finger positions on the fretboard, and a dedicated configuration app on a mobile device (see Figure 1). Capturing the finger positions is realized via capacitive sensing through the fretboard to not change the guitar haptics. Feedback and guidance are provided through built-in LEDs and a mobile device app that visualizes the finger positions captured by the capacitive fretboard. We envision *Let's Frets* as a continuous assistive system for beginners as well as advanced guitar players. We discuss a variety of use cases, including collaborative and remote learning.

## 2 CONCEPT AND CAPABILITIES

*Let's Frets* provides two main functionalities to support guitar players: 1) visual guidance and 2) capturing of finger positions on the touched fret that is visualized using a smartphone app.

Chords, individual tones, and sequences thereof can be visualized using built-in LEDs (see Figure 3a). This can be used for learning new finger positions on the fretboard and the practice of sequences, such as chord progressions or scales. The mobile device app can be used to configure exercises and displays chords and melodies in traditional music notation for the guitar (see Figure 3d). Hence, the guitarist can also use the app to practice sight-reading, which is playing based on music notation. We use the traditional musical notation for the app since it has been demonstrated to be beneficial [4]. Furthermore, the app allows guitarists to load additional exercises. Therefore, exercises developed by teachers, a guitar community, or the student can be composed and practiced.

Touched frets are captured by the fretboard's capacitive sensors (see Figure 3b) and visualized on a mobile device screen. The visualization can be an overlay of the music depiction, such that the guitarist can easily spot mistakes. The capturing functionality from the fretboard can furthermore be used to transform newly composed pieces into music notation. Sensing and visual guidance can also be used in combination (see Figure 3c). Based on a programmed exercise, the guidance LEDs can depict the target finger positions. Once the fingers are placed correctly, the app can automatically switch to the next chord.

## 3 *LET'S FRETS* IMPLEMENTATION

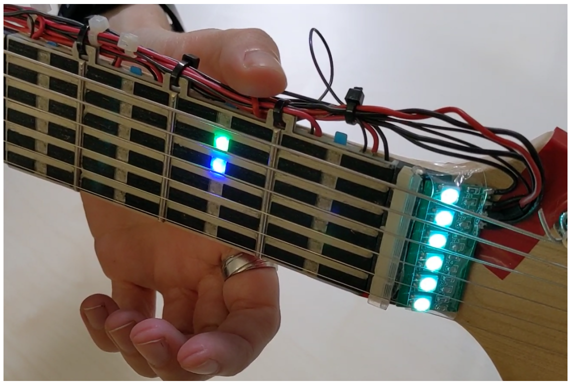
An electronic guitar serves as the basis for the smart guitar support system. We modified the guitar neck by removing the fretboard from the first four frets and replaced it with our developed components.

To realize the capturing of finger positions by capacitive sensing, we designed 3D-printed touch sensors (cf. [12, 13]). The sensors are printed with Proto-Pasta carbon-doped PLA and separated by regular PLA. Each fret is equipped with six of these sensors – one for each guitar string (see Figure 2a). For measuring the capacitance, each fret has a FDC1004Q 4-Channel touch controller chip[1] below the sensor (see Figure 2b). The measured capacitance is sent to the onboard controller. The connection between the touch controller chips and the on-board controller is realized by wires on top of the guitar neck. However, these wires can also be hidden in the guitar neck below the touch controller chips.

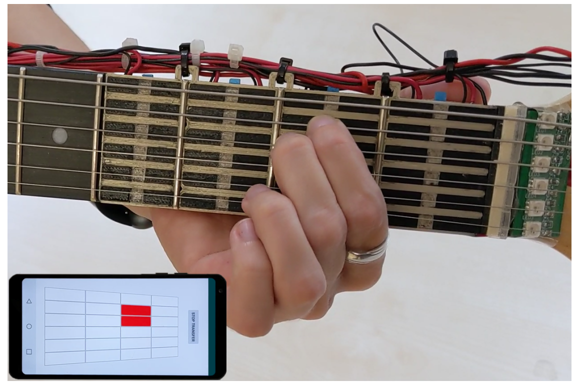
As an onboard controller, we used a Raspberry Pi that communicates with the mobile app via Bluetooth. The on-board controller is placed on the guitar body in the lower part, such that it does not affect playing. A small onboard controller, such as a Raspberry Pi Zero, can even be integrated into the guitar body. For further implementation details, the 3D models, and the source code of *Let's Frets* the reader is referred to our online repository [2]. Using the touch sensors detailed above, we can capture three types of finger positions:

(1) Touches of individual frets and their corresponding strings. This represents the playing of tones or chords and progressions thereof without specific playing techniques.
(2) Vertical shifts in the direction of another string. This can either be the result of a mistake because the guitarist touches the fret too high or too low or be part of a playing technique, such as bending or vibrato. The app can determine whether it is a playing technique or a mistake based on the chosen exercise.

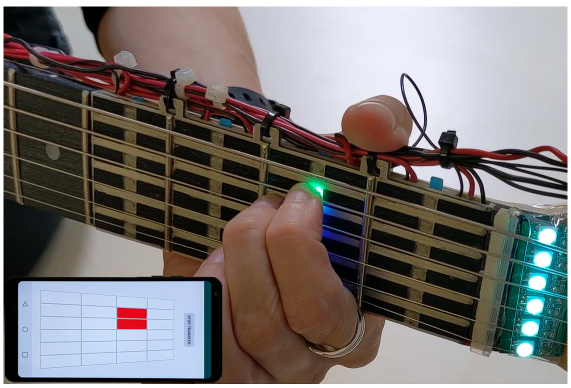
[1] www.ti.com/lit/ds/snoscz4/snoscz4.pdf - last access 2021-01-11
[2] www.github.com/Pinyto/lets-frets - last access 2021-01-11



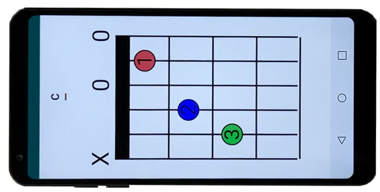
**(a) LEDs indicate which strings should be pressed.**



**(b) The touched fret is visualized.**



**(c) Combination of LEDs and capacitive sensing.**



**(d) Display of fretboard charts.**

**Figure 3: Feedback and guidance modules.**

(3) Horizontal shifts towards other frets. Such shifts can either be the result of a mistake by touching two frets at the same time or be part of a playing technique, such as sliding. Again, the app can determine whether it is a playing technique or a mistake based on the chosen exercise.

For visual guidance, we integrated RGB-LEDs into the fretboard (see Figure 3a). For this, we left space in the Proto-Pasta carbon-doped PLA to place the RGB-LED. To realize a smooth surface, the RGB-LEDs are covered with a transparent layer of PLA and are placed in the center of each fret (see Figure 2a). We placed a separate set of LEDs above the nut to indicate the strings that the guitarist should strum. Using the app, individual colors can be assigned to each finger to assign specific fingers to positions or to communicate specific playing styles, such as bending, hammer-on, pull-off, or vibrato.

## 4 OUTLOOK

We demonstrated *Let's Frets*, an assistive system that supports guitarists via integrated capacitive sensing and visual guidance. *Let's Frets* does not change the overall form of the guitar and maintains the original shape, hence acting as a learning or support tool when necessary.

### 4.1 Enhancing Solo Practice Sessions

There are several use cases in which *Let's Frets* can provide beneficial functionality. First, we consider solo practice sessions. During these sessions, guitarists practice alone to develop new skills. This has already been investigated in a user study with 24 participants demonstrating the usability of *Let's Frets* for practicing simple chords [9]. *Let's Frets* can provide exercises for these sessions, guide the guitarists through them, and offer feedback about finger positions. The exercises can be composed by a teacher or by the students themselves. Besides traditional exercises, such as sight-reading, we envision exercises based on gamification. For instance, students could play a chosen song or exercise while sensing technology is used to calculate a score based on their speed and accuracy. Furthermore, this functionality could be leveraged as a learning diary, such that guitarists can track their current skills and progress.

### 4.2 Composition Support

When composing a new piece of music, musicians either need to record it or make breaks for written down their newly composed music. The sensing technology could be used to automatically transform played music into traditional music notations, such as guitar tabs. In this use case, sensing technology is even superior to audio analysis because not each tone has a unique position on the guitar. A guitar with 25 frets has 150 possible finger positions. However, it can only produce 45 unique tones. However, music notation by a guitar tab requires information about the finger position, which cannot be determined for each tone by audio analysis.

### 4.3 Remote Collaboration

Further, we envision *Let's Frets* as remote learning tool. For example, guitar students and a teacher can remotely collaborate to mediate progress and experience over distances. This can be accomplished by setting the next melody or chord remotely by the teacher. At the same time, the teacher can observe the student's playing and provide advice. The guidance and sensing technology from *Let's Frets* likely reduces the cognitive load of both – teachers and students – because perceptual mappings based on a camera picture are not required in the remote setting. Guitar practice, composing, and collaborative music-making can therefore be achieved over distances, and *Let's Frets* can be seen as an add-on to video calling technology.

### 4.4 Detecting New Gestures

The capacitive sensing modalities of *Let's Frets* are not limited to detecting finger positions. We envision additional interaction scenarios and playing styles using the capacitive sensing capabilities of *Let's Frets*. For example, different gestures on the fretboard (i.e., similar to the swipe gestures on the smartphone) can be recognized. Such gestures can be given by sliding between frets. Further, the pitch, amplitude, or frequency of sounds could be changed by conducting additional gestures on the fretboard. We will investigate if such gestures are suitable for guitarists and how such gestures can be implemented to provide additional methods for an expressive playing style.

## 5 CONCLUSION

This demonstration presented *Let's Frets*, a guitar support system. *Let's Frets* provides 1) visual guidance, 2) finger position capturing, and 3) the combination of both to support guitarists. This functionality can be leveraged to support guitar learning, teaching, the composition of new pieces, solo practice, and remote collaboration with guitar teachers and other musicians. We will investigate how capacitive sensing technologies can be used to capture novel playing style techniques in future work. We are confident that *Let's Frets* paves the way for interactive assistance, which is directly integrated into the guitar to augment the overall playing progress.

## ACKNOWLEDGMENTS

This research work has been funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 326979514/3DIA).

## REFERENCES

[1] Anders Ericsson, Ralf T. Krampe, and Clemens Tesch-Römer. 1993. The Role of Deliberate Practice in the Acquisition of Expert Performance. *Psychological Review* 100, 3 (1993), 363. https://doi.org/10.1037//0033-295X.100.3.363

[2] Jakob Karolus, Annika Kilian, Thomas Kosch, Albrecht Schmidt, and Paweł W. Wozniak. 2020. Hit the Thumb Jack! Using Electromyography to Augment the Piano Keyboard. In *Proceedings of the ACM Designing Interactive Systems Conference (DIS '20)*. ACM, New York, NY, USA, 429–440. https://doi.org/10.1145/3357236.3395500

[3] Jakob Karolus, Hendrik Schuff, Thomas Kosch, Paweł W. Wozniak, and Albrecht Schmidt. 2018. EMGuitar: Assisting Guitar Playing with Electromyography. In *Proceedings of the Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 651–655. https://doi.org/10.1145/3196709.3196803

[4] Joseph R. Keebler, Travis J. Wiltshire, Dustin C. Smith, and Stephen M. Fiore. 2013. Picking Up STEAM: Educational Implications for Teaching With an Augmented Reality Guitar Learning System. In *Proceedings of the International Conference on Virtual, Augmented and Mixed Reality (VAMR)*. Springer, Cham, Switzerland, 170–178. https://doi.org/10.1007/978-3-642-39420-1_19

[5] Ralf T. Krampe and Karl A. Ericsson. 1995. *Deliberate Practice and Elite Musical Performance*. Cambridge University Press, Cambridge, United Kingdom, 84–102. https://doi.org/10.1017/CBO9780511552366.005

[6] Markus Löchtefeld, Sven Gehring, Ralf Jung, and Antonio Krüger. 2011. guitAR: Supporting Guitar Learning Through Mobile Projection. In *Extended Abstracts of the CHI Human Factors in Computing Systems (CHI EA '11)*. ACM, New York, NY, USA, 1447–1452. https://doi.org/10.1145/1979742.1979789

[7] Markus Löchtefeld, Sven Gehring, Ralf Jung, and Antonio Krüger. 2011. Using Mobile Projection to Support Guitar Learning. In *Proceedings of the International Symposium on Smart Graphics*. Springer, Cham, Switzerland, 103–114. https://doi.org/10.1007/978-3-642-22571-0_9

[8] Karola Marky, Andreas Weiß, and Thomas Kosch. 2019. Supporting Musical Practice Sessions Through HMD-Based Augmented Reality. In *Mensch und Computer 2019-Workshopband*. Gesellschaft für Informatik e.V., Bonn, Germany, 1–5.

[9] Karola Marky, Andreas Weiß, Andrii Matviienko, Florian Brandherm, Sebastian Wolf, Martin Schmitz, Florian Krell, Florian Müller, Max Mühlhäuser, and Thomas Kosch. 2021. Let's Frets! Assisting Guitar Students During Practice via Capacitive Sensing. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. ACM, New York, NY, USA. https://doi.org/10.1145/3411764.3445595

[10] Yoichi Motokawa and Hideo Saito. 2006. Support system for guitar playing using augmented reality display. In *2006 IEEE/ACM International Symposium on Mixed and Augmented Reality*. 243–244. https://doi.org/10.1109/ISMAR.2006.297825

[11] Boni Rietveld. 2013. Dancers' and Musicians' Injuries. *Clinical Rheumatology* 32, 4 (01 Apr 2013), 425–434. https://doi.org/10.1007/s10067-013-2184-8

[12] Valkyrie Savage, Ryan Schmidt, Tovi Grossman, George Fitzmaurice, and Björn Hartmann. 2014. A Series of Tubes: Adding Interactivity to 3D Prints Using Internal Pipes. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology (UIST '14)*. ACM, New York, New York, USA, 3–12. https://doi.org/10.1145/2642918.2647374

[13] Martin Schmitz, Mohammadreza Khalilbeigi, Matthias Balwierz, Roman Lissermann, Max Mühlhäuser, and Jürgen Steimle. 2015. Capricate: A Fabrication Pipeline to Design and 3D Print Capacitive Touch Sensors for Interactive Objects. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15)*. ACM, New York, New York, USA, 253–258. https://doi.org/10.1145/2807442.2807503

[14] Beste F. Yuksel, Kurt B. Oleson, Lane Harrison, Evan M. Peck, Daniel Afergan, Remco Chang, and Robert J. K. Jacob. 2016. Learn Piano with BACh: An Adaptive Learning Interface That Adjusts Task Difficulty Based on Brain State. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. ACM, New York, NY, USA, 5372–5384. https://doi.org/10.1145/2858036.2858388