

EXPLORING THE DESIGN SPACE OF HAND-CONTROLLED GUITAR EFFECTS FOR LIVE MUSIC

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ABSTRACT

Many new interfaces for musical expression are hand or gesture controlled. For guitarists especially, this opens new ways to control sound effects while playing live. At the same time it is a challenge regarding the conception and design of such hand-controlled effects as guitarists usually use both hands for playing. In this paper we elaborate this particular design space to support future development. For this purpose we analyse four different examples of controllers that already in use and one purpose-built prototype called “UniCoMP” (Universal Control for Musical Performances). For the latter we additionally present the results of an evaluation during a live concert. Our study illustrates that hand-controlled guitar effects are a powerful alternative for traditional foot-controlled devices keeping in mind important design issues.

1. INTRODUCTION

Musicians, and of particular concern here, guitarists, are increasingly engaged with multiple actions and devices in order to create entertaining stage performances. Playing an electronic guitar is usually done with both hands. Additionally musicians often use their feet to control devices on the floor for sound modulation. By stepping on different switches the guitarist activates or deactivates certain effects or chooses presets in multi-functional effect devices. Customisable foot interfaces also have been developed by commercial manufactures [1, 13].

While this opens a wide range of possibilities to change the sound in real-time during a performance, it also forces the guitarist to stay close to the effect device for operating purposes or return to it frequently after moving around on stage, limiting dramaturgical possibilities. Furthermore functionality is restricted to choosing among presets and not changing single parameters of effects in most cases. Sometimes boards have pedals to adjust particular parameters such as volume, sustain or to create the ‘wah-wah’ effect. Keith McMillen’s SoftStep [13] even allows expressive control with pressure sensitive buttons and is highly customizable regarding control messages. But most foot controlled interfaces are limited to simple push buttons and they do not allow any gestural or embodied effect control. Furthermore they are bound to a certain place on stage which limits the musician’s movement.

The approaches towards new guitar-related effects are manifold as well as specific aspects that have been investigated. There have been attempts addressing issues such as sonic aspects, real-time control and gestural expression. This was achieved either by enhancements (e.g. [4]), modifications (e.g. [12, 15]) or augmentation (e.g. [10, 17]). Michailidis and Berweck [14] proposed a technical solution which adds tactile feedback to foot pedals. Instruments other than guitars have also been developed for controlling sound differently [6, 16].

Existing studies by Birnbaum et al. [2] and Magnusson [11] focus on defining the dimension space for musical devices. While they analysed musical interfaces in general and present two different approaches, we specifically target hand-controlled guitar effects for live music, with the aim of exploring and describing the design space of sound manipulation for guitarists using hand-controlled interfaces in live music. Within this context we elaborate the aspects (or also called dimensions) that make hand-controlled guitar effects a powerful alternative for traditional foot-controlled devices. We emphasise advantages and disadvantages of such solutions and, in doing so, draw out key characteristics that can help frame the design space for such systems. With this paper we want to provide a new systematic approach to characterising the range of different guitar effects controlled by hand, gestures or embodiment.

In the following we start with the research approach and then go on to describe the different devices studied in this paper.

2. RESEARCH APPROACH

To explore the design space of hand-controlled guitar effects, we compare five devices: one we especially developed as a technology probe [8] and four existing examples using a non-foot solution for controlling guitar effects.

The four examples were chosen on the basis of their hand-control features and their specific design for guitarists. To ensure diversity of the design space we selected two examples from scientific research (multimodal guitar [10] and attached key pad [4]) and two commercial examples (Killswitch and built-in touch pad [12]), which are already used by popular artists.

Our technology probe, termed “UniCoMP” (Universal

Control for Musical Performances), provides a guitarist with an off-the-shelf smart phone and laptop for controlling and modulating the sound of the guitar and remotely playing additional instruments like a synthesizer by body movement or touch gestures.

For all examples, we analysed them in terms of their design, their features and their live usage. For the four existing solutions, we used existing literature, documentation and videos of performances. For the UniCoMP system we used an auto-ethnographic approach [3, 5], a video-analysis [7, 18], log data and interview data.

We proceed with the analysis of the four selected examples and the description and evaluation of our own technology probe UniCoMP.

3. REVIEW OF SELECTED EXAMPLES

As stated previously, we chose the following four examples because all of them were designed for guitarists to control effects by hand. Studying existing literature about each realisation helped us to understand the technical background and features as well as get the idea behind the modification or enhancements. Additionally we looked at publically available videos of artists performing with the instrument.

Table 1 shows a summary of the four reviewed examples. First, it illustrates the number of videos we analysed. The criteria for choosing a video were that the specific feature is used at least once during the performance and the video lasts at least one minute. Second, it points to the number of documents we found that describe the features or provide technical instructions. Here it was important to either use scientific publications or, if not available, other web resources describing clearly the functionality.

During the analysis of all videos and documents we focused on the way of playing, capabilities of sound modulation, design and construction issues.

Example	# of videos	# of documents
Killswitch	14	3
Built-in touch pad	11	3
Multimodal guitar	2	2
Attached key pad	10	1

Table 1. Summary of reviewed resources

3.1. Killswitch

The Killswitch is a simple push button or toggle switch to interrupt the tone of an electric guitar for the time the button is pushed (Figure 1, left). If it is triggered very quickly, interesting sounds can be achieved. It is not a standard feature of a guitar but can be self-made quite easily with cheap components and a little soldering [9].

Tom Morello (Figure 1, right), guitarist of the band “Rage Against The Machine”, is one popular artist who uses the Killswitch for his playing. In a live video from



Figure 1. Guitar with a push button Killswitch (left, © itsachen[9]), Tom Morello playing the Killswitch live (right, © Kevin Pletcher)

1996¹ of the band, the use of the Killswitch is clearly comprehensible. At 2:34 minutes into the video the characteristic staccato sound of the guitar starts according to the gesture of the player’s right hand.

The artist “Buckethead” has even two Killswitches on the customised guitar he plays in a performance from 2011². In this video at 1:18 he also lets the audience play live which indicates an intuitive usability, low learning effort and high traceability.

Usually a guitar is played with both hands playing the strings. One hand pushing them on the neck and one strumming them. However, in both performances the guitarists played with their left hand while controlling the Killswitch with the right one. It seems counter-intuitive but it works as both videos show - at least for certain parts of the songs.

3.2. Built-in touch pad

Guitars with a built-in touch pad [12] as shown in Figure 2 allow the guitarist to control the sound in various ways and very precisely through intuitive gestures. It is played directly on the guitar and controls external effect devices remotely via MIDI. For the audience the position of the touch pad on the front side of the guitar and the changing colours of the pad itself are both good aspects to indicate to viewers what is going on, when the sound changes obtrusively and unusually for a guitar.

Matthew Bellamy from the popular band “Muse” for instance uses the touch pad for a scratching sound right from the beginning in the video³ of a live performed song and later at 3:15 again for a solo.

With the touch pad he controls a Kaoss Pad⁴ remotely via MIDI to create unusual sound effects for the guitar directly on the instrument [15]. This allows a lot of freedom to move around which he does extensively as seen

¹<https://www.youtube.com/watch?v=j6w0tKz3uew> [last accessed 6th June 2013]

²<https://www.youtube.com/watch?v=9gpABEdbcqA> [last accessed 6th June 2013]

³<https://www.youtube.com/watch?v=P69dBo6ZuuQ> [last accessed 6th June 2013]

⁴<http://www.korg.com/Kaoss> [last accessed 6th June 2013]



Figure 2. Guitar with built-in touch pad. © Hugh Manson, Photo by Jas Morris



Figure 3. Otse Lähdeoja plays the multimodal guitar using its touch slider. © Otse Lähdeoja

in the live video at 0:35 when he walks to the amplifier at the back of the stage. During the solo he uses his left hand to produce chords and create a sound by pushing the strings. The other hand operates the touch pad to shape the sonorous sound.

3.3. Multimodal guitar

Lähdeoja developed the multimodal guitar [10] which is an augmented electric guitar. He equipped a standard Fender Stratocaster with several sensors and an additional piezoelectric pickup (Figure 3). All sensors register different hand-gestures and movements. For external sound and effect processing a computer uses the sensor data as well as sound analysis to modulate the actual sound of the guitar.

This allows a finger-controlled ‘wah-wah’ effect directly on the fret. Normally this is done with a foot controller. The piezoelectric pickup detects percussive attacks of the instrument made by hand to play additional pre-recorded sound samples. Furthermore palm pressure on the strings with the picking hand is sensor-detected to control an effect pedal’s on/off switch by hand. Finally a tilting movement of the guitar’s neck by hand or the whole torso creates a sustain effect to prolong the played tone.

Literature on the multimodal guitar [10, 17] suggests a lot of technical effort to build the features. Also the software for sound analysis and modulation written in Max/MSP is custom-made. An analysis of a video⁵ showing Lähdeoja

⁵<http://vimeo.com/35067635> [last accessed 6th June 2013]



Figure 4. Guitar with attached key pad. © Trond Engum

playing the multimodal guitar in a studio session, presenting all features separately, illustrates each augmentation in an understandable and audible manner.

3.4. Attached key pad controller

Engum attached a simple USB key pad onto a guitar to control a remote Digital Audio Workstation (DAW) in real-time on stage (Figure 4). This allows the guitarist to access the wide range of effects available in a DAW directly from the guitar. Usually this high number of effects in the DAW are not available in floor boards and limited to recording sessions in studio only.

According to literature [4] this way to control sound effects remotely is cheap and easy to realise. The fastening to mount the key pad on the guitar does not seem very robust, though. A video⁶ of a performance let the spectator clearly identify the key pad on the guitar’s body as shown in Figure 4. However, the video shows the guitarist using the key pad at 4:03 and it is not really traceable which influence it has on the sound.

3.5. Summary

The analysis of the four examples has shown a good playability and visibility of all features. The resulting effects could not have been achieved with foot-controlled devices at all or in the same way. In contrast all examples vary widely regarding design, construction and traceability. All aspects will be identified and discussed later after the description of our own prototype.

4. UNICOMP

We developed our own technology probe to further explore the design space of hand-controlled guitar effects. The “Universal Controller for Musical Performances” (UniCoMP) was designed as a simple, easy-to-use and flexible controlling system for musicians on stage. Inspired by the experience and characteristics of the previously described

⁶https://www.youtube.com/watch?v=1eMe_UKxu-s [last accessed 6th June 2013]



Figure 5. The display of the wrist mounted smart phone while playing the guitar. © Magdalena Schindler

examples, we combined different features such as remote effect control, gestural playing, high accessibility and low assembling costs in one framework.

4.1. Technical description

To implement UniCoMP we used common off-the-shelf devices and software for the purpose of versatility and minimisation of efforts. The basic idea of UniCoMP is to provide the guitarist with a smart phone which is connected through WiFi to a laptop. The laptop processes the control data and distributes MIDI messages to external effect devices. Hence, the guitarist can remotely control the laptop and in further consequence the guitar effect device or any other MIDI-compliant equipment.

As shown in Figure 5 and 6 the smart phone is designed to be mounted on the wrist of the right hand, comparable with a wristwatch, so as not to interfere with the guitar playing while also allowing easy access to the device. For our prototype, we used simple heavy-duty tape in combination with a hook and loop fastener to turn the smart phone into a wearable device.

The guitar itself is not modified at all. Thus, the performer can choose to use any guitar without additional configuration or effort. A common guitar effect floor board manages the sound modulation of the guitar. For our particular scenario as we will see later the guitarist is playing a stage piano throughout a performance. The sound for the stage piano is created through a software synthesizer on a laptop. Hence, the guitarist is able to control both the sound of the guitar and the synthesizer with the wrist mounted smart phone (Figure 5 and 6).

We used an Android-based smart phone which hosts the application TouchOSC⁷ and sends OSC messages over WiFi from the smart phone directly to the laptop. All OSC messages - precisely signals of sliders, buttons and accelerometer data - that are received by the laptop are first handled by Max/MSP which then creates MIDI messages

⁷<http://hexler.net/software/touchosc> [last accessed 6th June 2013]



Figure 6. Playing the piano while having remote control of various effects on stage. © Martin Leitner

for controlling and generating sound at (1) the digital audio workstation (DAW), (2) the software synthesizer or (3) at the guitar effect floor board.

The DAW does the central sound control. Its built-in sequencer has three main tasks in every song: (1) giving the beat to the musicians' in-ear monitoring, (2) playing pre-recorded samples, and (3) sending pre-defined MIDI messages to the guitar effect floor board. The software synthesizer listens to MIDI messages sent from the stage piano or the smart phone. The guitar effect floor board is either controlled by foot as usual to change presets or additionally through the smart phone which enables the control of various parameters directly at the device through MIDI messages.

As an example for the configuration we used in our performance, a screenshot of TouchOSC is shown in Figure 7, along with a description of the functionality of the buttons and sliders. The details of all functions and effects are beyond the scope of this paper and also not necessary to understand the general idea of UniCoMP. The interface can be customised according to the requirements of the songs for any particular performance. A more generic interface can also be created if needed. Optionally, any other app can be used to send OSC messages to the laptop.

To summarise, UniCoMP in our configuration can be used in various ways during a performance: (1) start and stop the DAW's sequencer for the playback of additional sounds and the metronome, (2) manipulate the software synthesizer's range wheel as the stage piano has none built-in, (3) as a standalone instrument playing a tone of the synthesizer and modify it by moving the smart phone accelerometer on the hand, (4) manipulate guitar effects remotely using the accelerometer while playing and (5) manipulate guitar effects remotely with sliders and buttons during a short break or while letting a tone fade away.

4.2. In-situ Study

To test UniCoMP in a real performance we conducted an in-situ pilot study. This happened during a public live

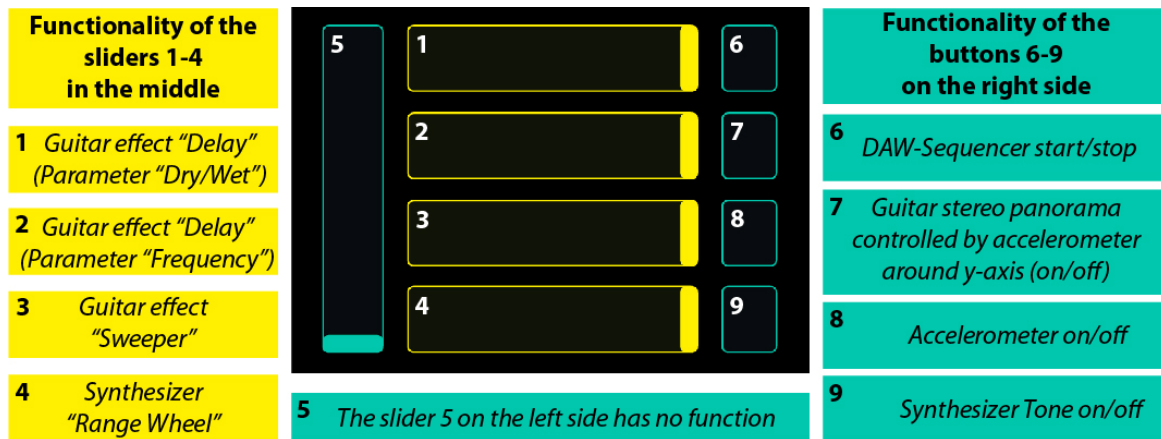


Figure 7. A screenshot of the UniCoMP TouchOSC interface in landscape format as seen by the guitarist, with the description of sliders and buttons

concert of the artist (first author), with another performer playing drums, in a club with approximately 80 spectators.

For the pilot study, we chose an auto-ethnographic approach [3], where the first author used the system during his live concert. The performance was video-recorded for later self-reflective evaluation. The main reason for choosing an auto-ethnographic approach is the system itself. Although easy to assemble and handle it is still a prototype and we wanted to test its stability in a live setting before giving it to other artists to use. Moreover the focus was on exploring the design space by testing UniCoMP's suitability and functionality during a performance rather than exploring particular experiences of different artists (this needs more objectivity and will be subject to later studies).

While the system was used for the whole concert, for the evaluation we focused on one song on which to conduct an in-depth video analysis [7, 18]. For this purpose the whole stage was video-recorded during the performance. The choice of the particular song was well-considered to test different types of uses of UniCoMP while the artist moved around stage.

The song starts with a pre-recorded spoken voice played by the sequencer running on the laptop while the guitarist paints on a scaffold. During the following major parts of the song until the end, the guitar and the synthesizer are played alternately. The performance of the song takes 5:12 minutes which corresponds to the length of the recorded video we used for the analysis.

We identified the major parts of the song, the corresponding location and movement of the guitarist and every use of the smart phone which was also logged in a log file on the laptop. In addition to the video-based analysis we used the personal experience of the first author as the guitarist to extract meaningful information about the application of UniCoMP.

After the concert we conducted a semi-structured interview with the drummer. The interview was audio-recorded and took about 28 minutes. The questions covered the

musician's instrumental practice and habits on stage, his experience with new musical instruments in general and with UniCoMP in particular, and finally his opinion of the performance with UniCoMP.

To complement our qualitative evaluation we also observed the spectators [18]. For this purpose we recruited some of the band's crew members to observe spectators randomly during the performance, particularly noting their reactions to the use of UniCoMP. We collated their observations via discussion after the performance.

4.3. Results

Overall, the experience of the performance was a positive one for the artist. The system was relatively stable and the artist was able to (mostly) focus on the actual performance of the song, rather than on the device itself. He could also move around on stage for dramaturgical effect and control devices remotely.

According to the song structure and identified on the video, UniCoMP was used four times during the whole song:

- 00:07, starting the sequencer remotely from the other side of the stage while painting at the scaffold.
- 01:43, adjusting a slider that was manipulated accidentally sometime before.
- 02:39, after playing the synthesizer on the stage piano starting to play the synthesizer remotely with the smart phone while moving to the other side of the stage.
- 04:44, directly after playing the guitar, starting to play the synthesizer remotely on the left side of the stage and start to modulate the sound by moving the hand.

While three occurrences were intentional according to musical interpretation and dramaturgy, one usage of UniCoMP (at 01:43) was not supposed to happen from a per-

formance perspective but was needed to correct the misaligned slider.

A thematic analysis of the transcribed interview with the drummer has shown a clear theme in his experience with UniCoMP. He did not really perceive the usage of UniCoMP intentionally apart from a couple of times when it was used to control the synthesizer with the accelerometer through expansive gestures. He rather stated: “For me it is just another instrument the guitarist uses on stage and I merely care about the sound, not how he plays it.”

The audience perceived UniCoMP more consciously compared to the drummer but it seems that they could not really figure out what was happening. Two spectators for example were observed saying to their neighbors: “What is this thing on his wrist?” In general our observers could identify numerous impacts among the audience throughout the whole show from positive to negative. For example at the end of the song when the guitarist controlled the synthesizer remotely by moving his hand for several seconds, one observer noted a comment from an audience member: “Oh, it is going to be experimental.” Another stated: “Cool!”

5. DISCUSSION

In total we have analysed five approaches towards hand-controlled guitar effects. Two of them have underlying scientific projects, another two are commercial devices, all four are used by professional artists, and finally one, UniCoMP, was especially designed for this study to further explore the dimensions of the design space. Through this exploration we can identify seven important key aspects that have to be considered when designing and characterising hand-controlled guitar effects. We can represent these as a dimension space, similar to the approaches taken in Birnbaum [2] and Magnusson [11].

Figure 8 illustrates each example in a separate plot. We rate each dimension from low (center) to high (outside) in each graph to create characterising shapes. These plots are not meant to provide an absolute rating but they allow an easy comparison and relative grading within the defined space [11]. We go on to discuss this design space in more detail.

As a main **motivation** behind all approaches we can assume that hand-controlled guitar effects seem to be motivated by the chance to create effects that cannot be realised with usual pedal-controlled floor boards or only to a limited extent. The Killswitch, the built-in touch pad, the attached key pad and UniCoMP give the guitarist freedom to move around the stage according to dramaturgy rather than following given technical and spatial constraints. For instance the use of UniCoMP in our particular performance shows the advantage of controlling devices or playing instruments remotely. It would not have been possible otherwise due to timing constraints to physically move to a separate controller or instrument. The touch pad on the guitar and the sensors of the multimodal guitar allow the guitarists a much more intuitive

control of effects than would be possible with a pedal. The Killswitch effect per se could also be realised with a simple pedal instead of an extra integrated push button to obtain the same effect. But it is much easier to play a push button really quickly with a finger. This brings us to the first identified aspect.

The **playability** describes how well an effect can be played or controlled and basically addresses the fine motor skills of the human hand. Whether it is the quick tapping of the Killswitch, the subtle movements on the touch pad or the ability to play a sound and control an effect at the same time as it is possible with the finger-controlled ‘wah-wah’ of the multimodal guitar. They all allow meticulous playability to a high extent. The attached key pad’s purpose is more the selection of sound effects than dedicated manipulation of parameters and playing. The accelerometer of UniCoMP’s smart phone allows the guitarist an embodied and intuitive gesture controlled sound manipulation. This noticeable modulation leads us directly to the next issue.

The **transparency** of hand-controlled effects allows the audience and of course also other musicians on stage to follow and track the sound effect at the same spot where the sound is generated - directly at the instrument. This traceability makes hand-controlled effects more visible and graspable especially for unfamiliar and unusual effects. The gestures on the touch pad are viewable as well as understandable for the spectators watching the guitarist playing, and so are the tilting movements of the multimodal guitar or the arm moving gestures with UniCoMP. Even the use of the Killswitch and the key pad can be recognized although both are less traceable. However, the mentioned variety and the uncommon effect control possibilities reveal another aspect.

The **versatility** is highly dependent on the general concept. For instance the Killswitch is a simple modification with a certain purpose and constrained features which makes it less versatile, likewise the multimodal guitar which has several sensors for specially defined purposes. The situation is different with the built-in touch pad and the key pad. Both have pre-defined limited controlling possibilities but reveal their power and universality when mapped to effect devices to control particular parameter of effects in real-time. UniCoMP goes one step further with an adjustable touch screen interface to meet special requirements in particular performances. Although primarily intended for guitarists, other instrumentalists may also benefit from its features as it is not directly connected to the guitar and allows a customised mapping of control commands. This high adaptability of course brings us to the next consideration.

The **learning effort** of hand-controlled guitar effects can be very divergent while most pedal effects do not have many possibilities to control certain parameters in real-time. It is similar with the built-in touch pad and the Killswitch. They both create pre-defined effects which are controllable intuitively with an assumingly flat learning curve. With the multimodal guitar it seems to be similar

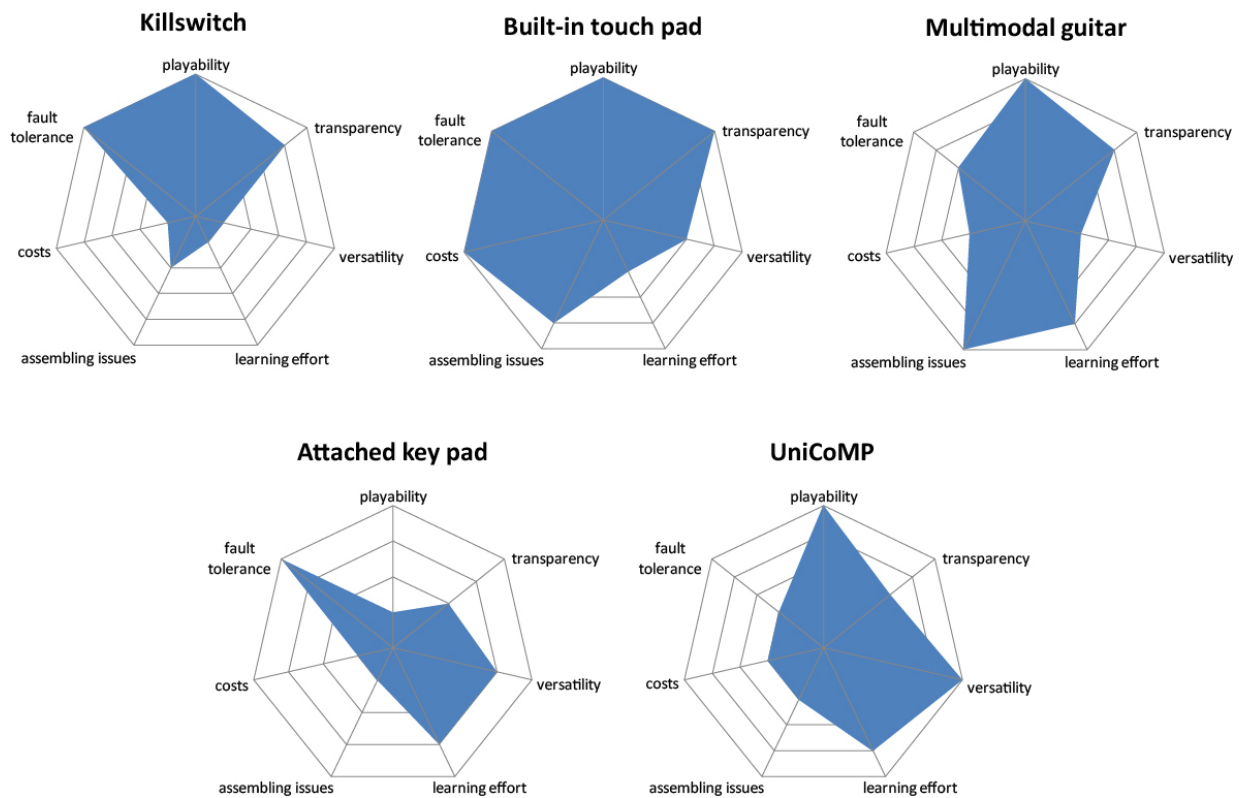


Figure 8. Plots describing each example within the elaborated dimension space

regarding functionality but with a much higher learning effort to get the most out of all effects through a specific combination of all features. With the key pad and UniCoMP the learning effort depends mostly on the individual configuration of the controller. They both allow a very flexible application which has to be well trained if used live on stage. Time which is an important factor for the learning effort, is also relevant for the next aspect.

Assembling issues address the effort which is needed for technical realisation. From our selected examples the key pad and UniCoMP are easy to connect without any special knowledge as long as the devices and the software are available. The built-in touch pad and the Killswitch are both stationary parts of the instrument. It takes a certain modification of the guitar for realisation which is less effort for the Killswitch compared to the built-in touch pad. Furthermore it is remarkable that the Killswitch is the only effect that works without any additional external device such as a computer for sound processing. For the multimodal guitar it can be assumed that it needs the highest effort regarding technical knowledge, components and implementation. Along with that we focus on financial criteria.

The **costs** for hand-controlled effects seem to correlate to some extent with versatility or assembling issues. For this reason we bring up this aspect separately. The Killswitch within our selection is definitely the cheapest one aside from a little working time. Furthermore we can assume that the multimodal guitar uses mostly sensors which are readily available and affordable nowadays. The

attached key pad or UniCoMP use everyday off-the-shelf components only which makes them readily available and cost-efficient keeping in mind their versatility. To buy a guitar with a built-in touch pad one has to pay a relatively high price. But compared to the other more prototype solutions, the price seems to be justified as it has proved to be suitable and robust enough for stage. This leads to a final aspect.

Fault tolerance is very important especially for live musicians. Unlike in recording sessions on stage there are no retakes, overdubs or post-processing. Every effect has to work properly in real-time. The built-in touch pad and the Killswitch are permanent features of the guitar and both robust against external impact. The other examples seem to be less fault tolerant according to their prototype-like assembling. The key pad is attached with a fastening which can get loose while moving around the stage. Beside that it should be robust regarding handling, though. The additional wires of the multimodal guitar as seen in Figure 3 and the various sticky-taped sensors are indicative of a careful handling. As experienced when evaluating UniCoMP the accidentally manipulated touch screen slider of the wrist-mounted smart phone bears a certain uncontrollable risk. Even if the artist can immediately react and correct the problem, it can still influence playing or even force the guitarist to stop playing.

To summarise, we have identified and discussed seven aspects that can be used to characterise the design space for hand-controlled guitar effects on the basis of five examples.

6. CONCLUSION

To elaborate the design space of hand-controlled guitar effects for live music, we reviewed four existing examples and one purpose-built technology probe. We identified the following key aspects: playability, transparency, versatility, learning effort, assembling issues, costs and fault tolerance.

Our findings indicate that hand-controlled guitar effects show up as a suitable alternative or rather addition to foot-controlled pedals. The real power of all the reviewed examples lies in a high accessibility regarding playability or versatility. The experiences here suggest that controlling features directly on the guitar might be a good option for sound manipulation purposes while playing the instrument.

The analysed examples imply that a conventional performance can be enriched by providing tools that enhance the playing of the original instrument and add new possibilities to play it and additional instruments. Furthermore hand-controlled guitar effects can fill the gap between usual floor board effects and more embodied and gesture controlled sound manipulation. Instead of interfering with the normal playing, they enrich creative possibilities if designed in a well-considered way.

Above that, we presented our own technology probe UniCoMP that allows high flexibility regarding control of sound effects, freedom of action on stage and finally versatility of an easy-to-use system. However, during evaluation we could also identify a certain susceptibility to unexpected errors that distract the musician and, in the worst case, cause unwanted sound manipulation. This points to the need for future work to make UniCoMP more fail-safe.

Additional evaluation of UniCoMP has shown that the other musician's perception of the interface was quite different to the one of the audience. While the drummer cared about the sound mostly the audience primarily perceives the visual aspects. This might be relevant for other hand-controlled guitar effects and indicates the need of further evaluation to better understand the issues from different perspectives.

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