'GXtar', an interface using guitar techniques

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ABSTRACT
In this paper we describe a new guitar-like musical controller. The 'GXtar' is an instrument which takes as a starting point a guitar but his role is to bring different and new musical possibilities while preserving the spirit and techniques of guitar. Therefore, it was conceived and carried out starting from the body of an electric guitar. The fingerboard of this guitar was equipped with two lines of sensors: linear position sensors, and tactile pressure sensors. These two lines of sensors are used as two virtual strings. Their two ends are the bridge and the nut of the guitar. The design of the instrument is made in a way that the position of a finger, on one of these virtual strings, corresponds to the note, which would have been played on a real and vibrating string. On the soundboard of the guitar, a controller, with 3 degrees of freedom, allows to drive other synthesis parameters. We then describe how this interface is integrated in a musical audio system and serves as a musical instrument.

Keywords
Guitar, alternate controller, sensors, synthesizer, multidimensional control.

1. INTRODUCTION
When the design of an electronic instrument is inspired by the one of an acoustic instrument, then the performer can use instrumental techniques and motor behaviors, which he has developed by a long practice time.

Thus, the performer will be able to transpose his skills to other applications. Indeed, he will have access to new sonorities, new possibilities of gestural control of the sound materials without having to learn completely new instrumental techniques.

2. RELATED PREVIOUS WORKS
2.1 Guitar-like controller
2.1.1 MIDI systems for guitar

Some systems use electromagnetic microphone to measure the vibration of the strings (independently for each strings) [6]. Then, by analysis of the signal (usually pitch tracking and energy envelope following) and interpretation of these features, MIDI message are generated. The commercial systems available generally don't consider the spectrum characteristics of the string vibration. Recently, C. Traube and P. Depalle have proposed other useful features extractions to qualify the plucking style [2]. This is certainly a good approach to capture standard guitar playing. Our approach is different, in the way that we want to build a new controller inspired by a guitar but which has his own identity.

2.1.2 The Ztar series
The Ztar series [4] are guitar-like MIDI controllers that are deeply related to the controller described here. But some characteristics of them, for example the discrete fingerboard, in our point of view, limit their expressive possibilities. The GXtar follows the philosophy of the Ztar series, but we tried to bring new ideas, such as continuous pitch control and aftertouch, and technological and technologic solutions to create a new more expressive instrument.

2.2 Other string-like controllers
Several efforts have been made to design violin-like controllers [1] [4]. Obviously, both from the technologic point of view and from the gesture approach, there are many common points between new violin-like new instruments and guitare-like new instruments. Probably, the 'Superpolm' [4] is the more related to the GXtar. But, in our approach we have tried to put more effort on some aspects in order to design a controller with more similarities with the acoustic instrument concerning position of the non-preferred hand fingers and pitch control.

2.3 Touch sensors and fingerboard
To measure pressure and displacement of fingers on a fingerboard, FSR (Force Sensing Resistors) sensors offer interesting possibilities to measure both pressure and position on a fingerboard. Other technologies as, for example, optic fiber networks can be good solutions too [5]. They have been used successfully in related applications, but are difficult to be adapted to the geometry of the guitar neck and are much more expensive. 'Old school' magnetic strips can also be useful but can only measure position and not pressure. It's generally the same for electric current voltage division. FSR are generally not expensive and can provide both position and pressure measurements. Even if some sensor manufactures offer to build 'made to measure' sensors it's generally hard to find ready to use sensors with an adapted size. That's the reason why some concessions have been made in this project compared to the initial project, i.e., a 6 strings instrument.

3. DESIGN OF THE GXTAR

Usually, in the acoustic guitar play, the non-preferred hand acts as selecting notes and the preferred hand acts as playing them by plucking the string. Other techniques like Hammer-on, Pulling-off and glissando are generally not considered in the design of electronic guitar-like controllers. The invention of the electric guitar associated to the evolution of amplification system and audio effects has allowed guitarist to invent and/or develop new playing techniques. One of this techniques is the 'tapping', where both the preferred hand and the non-preferred hand are involved in the excitation of the string, selecting the note and producing the vibration at the same time by tapping on the fingerboard. The concept of the GXtar uses this idea by allowing the non-preferred hand to select and play notes when the other hand acts on spectral continuous parameters. Glissando and other techniques previously cited are also considered in the Xtar.

3.1 Body of the controller

Figure 1 Global view of the board

The physical 'support' used is the body of a real electric guitar. It is a 'solid body' (i.e. without resonating chamber) guitar (imitation of a model Gibson SG) being previously equipped with brass strings. Before modification, the sound was generated by an electronic analog circuit. The frets were removed in order to be able to stick sensors on the fingerboard. Indeed, the new instrument is a fretless string instrument (fig 1). The sensors being of a width larger than usual spacing between strings in standard guitars, it was not possible to provide 6 virtual strings but only 2. Although it would be interesting to have 6 strings available the instrument with 2 strings remains interesting. In fact, some musicians need just two strings to produce fantastic music (as for example the bass player of the legendary rock band 'Morphine'). And this observation has been the origin of our hypothesis, which gives a musical interest to a couple of strings. The sensors having a dimension slightly longer than their zone of effective measurement, the nut was removed, so that measurement can be effective from the first millimeters of the fingerboard. We then add a new nut to support strings used as guide as it will be explain in a next part of this paper.

3.2 FSR for the non preferred hand

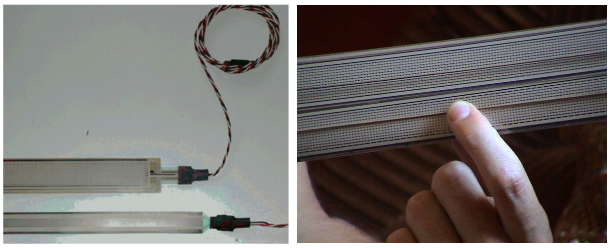

Figure 2. Position and tactile pressure FSR sensors / Playing on the fingerboard

For the non-preferred hand, tactile position and pressure sensors equip the fingerboard. The sensors used represent two virtual strings side by side (fig 2). The position of the fingers on these strings, and the pressure exerted by the fingers on the neck, are measured by superimposed different sensors. These sensors are FSR sensors. We decided to preserve the relation present on the acoustic or electric string instruments between the position of a finger on a string and the pitch of the played note. As on the acoustic instrument, the relationship between lengths of vibrating string fundamental frequencies of vibration corresponding is preserved. To obtain the played frequency, it is thus necessary to know the length of string between the finger position and the bridge. On our support, a string from the nut to the bridge measures 62 cm, but our sensor makes it possible to measure only one 39 cm length zone. Nevertheless 39 centimeters are sufficient to practically cover the totality of the neck, i.e. the equivalent of an octave on a single string.

To play a note using the fingerboard and to define a velocity for this note we use the principle of double threshold applied on the pressure. This principle is generally used to position to derivate velocity, as for example, in the legendary 'Radio Baton'. Previous experiences with other sensors using only the Max/MSP external library or other third party externals to implement this were not satisfying. A new external, called 'whack' (as the double threshold implementation was called in the documentation of the 'Radio Baton') has been implemented using the Max/MSP external SDK.

3.3 3D joystick for the preferred hand

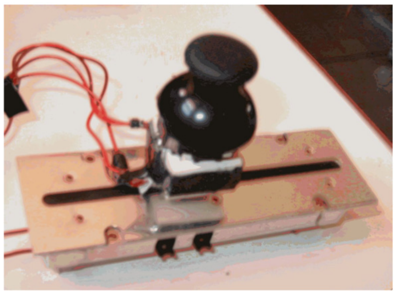

Figure 3. The 3 degree of freedom controller composed of a mini joystick and a slider

The control mainly assigned with the preferred hand is a control with 3 degrees of freedom. Two degrees come from a mini-joystick, the third comes from a rectilinear potentiometer which is used as rail of displacement for the joystick. The choice of a mini-joystick rather than of a joystick of higher size is justified by the idea to use only the grip made of the thumb and the index to handle it, whereas the palm of the hand and the other fingers handle and move the support of this mini-joystick. We chose to use a rectilinear potentiometer usually called a slider, and to superimpose a joystick on top of it. Thereby, the joystick was fixed on the moving part of a slider. The two devices associated in this way offer the control of 3 parameters simultaneously (fig 3).

Displacement along the rectilinear potentiometer reminds the displacement of the plucking position on the strings. The effect on an acoustic or electric guitar is strongly correlated to a comb filter effect. Finally, after different experiments, we selected a slider with an adequate length in order to reinforce this metaphor and the relation with the standard guitar playing techniques. The distance from the bridge is then correlated to the sound characteristics as it used to be for plucking in an acoustic or electric guitar. One can then use the possibility to get a different sound by choosing a different distance from the bridge for plucking.

3.4 Special plectrum

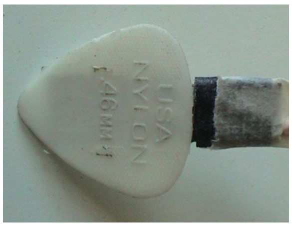

Figure 4. The plectrum-like controller: the sensor is between two glued thin plectra (0.46 mm)

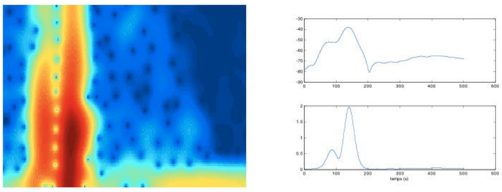

Figure 5. The left: a time-frequency analysis of a plectrum signal; right: two spectral lines

We also studied the design and use of a new control tool: a special plectrum. It is composed of a piezo film sensor fixed between two thin plectra with glue (fig 4). The idea is to extract instrumental gesture from the analysis of the 'plucking' signal coming from the sensor. Indeed, the signal coming from this new plectrum contains several cues about the performer intention and expression. Both the plectrum grasping and the impact with the string can provide interesting sources of control. This work has been carried out for specific initial condition: the case where plectrum and string are in contact before the acquisition and when the string is not already in vibration. First we made a real time asynchronous analysis; we detected time increase, maximum range and number of oscillations. In a second part, we tried to improve the result with the RMS (Root Mean Square) energy. A mapping combination of the features from oscillation and RMS measurement appears interesting to obtain an efficient control parameter. However this method was not fully satisfactory by looking only in the time domain. A time-frequency analysis has been done with this objective. The time-frequency analysis reveals an interesting element: we observe the appearance of a second spectral line (frequency of oscillation) with an intensification of playing (fig 5). A strong grasping of the plectrum can be detected with this direct consequence. This result is an example of relation between the intention and the signal measured from the plectrum. An advanced and systematic (all cases) analysis with a series of experimentation made in goods conditions should made this augmented plectrum a critic interface for the extraction some guitarist gestures.

3.5 Gesture guidance

Figure 6. The head of the Xtar. One can see the two lines of sensors and the new nut supporting the guiding strings

The guitar offers to the guitarist many reference marks helping him to play on it. One finds of course visual marks but also tactile marks. Apart from its acoustic role, the string is a physical interface between the sound and the musician. It presents:

- A role of guide for the fingers of the non-preferred hand
- A dynamic reaction due to its tension (a force feedback)

One can emit the hypothesis that the friction of the finger on the string during a glissando is quantifiable by the musician and brings additional information to him. In the first version of our prototype, the contact of the fingers with the fingerboard was done without intermediary mean. The fingers were thus in direct contact with sensors stuck on the plane surface of the fingerboard. The instrument was playable, functioned correctly, but was rather not very stimulant to play. Indeed the epistemic role [8] of the string seems essential in order to take advantage of the guitarist knowledge. It appears like the minimum to exploit the motor behaviors. That's the reason why strings, without acoustic role, were thus installed like simple guides. Not only the instrument became more pleasant to play, but moreover control became more precise. It seems that a major explanation is that the tension of the string also provides a force feedback perpendicularly to the fingerboard, which is the source of a control loop (action/perception) more efficient in this case. Technically another explanation of this fact can be that the size of the contact point on the sensor is smaller, and so it improves the precision of the gesture measurement.

3.6 Sound synthesis

For this realization, a MIDI software synthesizer was used to generate the sound (fig 7). MIDI codes were generated starting from the mapping, were made in Max/MSP, between the data measured by the sensors and the control parameters of the MIDI synthesizer. That made it possible to focus only on the design and the part of the mapping dedicated to the interpretation of the gestures. Obviously certain gaps of the MIDI protocol have been problematic. We solved these problems in different ways. One of them was to use in parallel two instance of the software synthesizer. The major problem was to be able to send a continuous control of pitch for the two strings. Indeed, with MIDI it means that each string has to be on a different MIDI channel if possible or connected to different synthesizers.

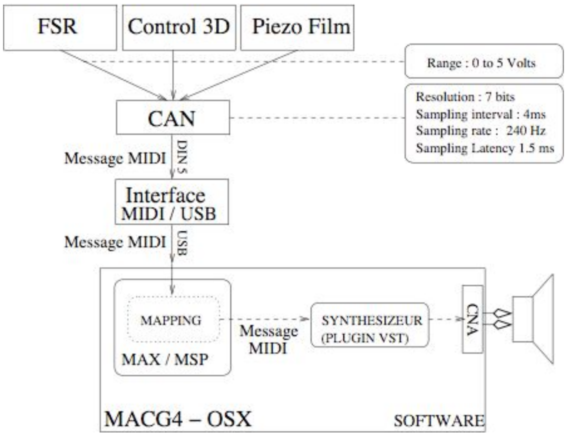

Figure7. Global Organization of the GXtar

4. MUSICAL USE OF THE GXTAR

4.1 Playing techniques

The GXtar allows 3 major playing configurations. First, one can exploit the 'tapping' technique with the 2 hands. Using only the fingerboard one can play in a percussive or rhythmic way, fast articulated phrases as in the tradition of the 'tapping'. The second configuration is to use only one hand for tapping and to use the other for spectral modulation with the 3 DOF controller (filtering, navigation in timbre space, other modulation). The performer can in this case sculpt the sound material. The third major configuration is to use a playing technique similar to the conventional guitar playing: selecting the pitch on the fingerboard and exciting the string with the plectrum. But several other hybrid configurations can be possible. It is, in fact an interesting field of exploration.

4.2 Comparison with related instruments

The first obvious improvement concerns the fact that guitar playing techniques related to modulation of pitch has been conserved in the design of this instrument (Hammer-on, pulling-off, glissando). At the same time the use of the tapping technique associated to the one of the 3 degrees of freedom controller allows new musical possibilities. Even if it's not so usual in guitar instrument (a little more or bass guitar) the use of fretless style is also an interesting possibility, in particular for non-tempered music.

4.3 Other sensors possibilities

A new generation of sensors, or a new strategy to use existing sensors could improve considerably the design of such instrument, especially concerning the fingerboard. The issue could be the same as other multi-point pressure sensitive control surfaces, or one could have a new approach specific to guitar or other related instrument. In this case FSR technology could just be used with a different geometry.

4.4 Learning, skills and training

Nevertheless, the efforts of training are undoubtedly still necessary to fully reach the new possibilities that the instrument offers. These efforts required, which are less important than in the case of the training of a completely new instrument, can be justified partly by a new organization of the motor tasks.

5. Conclusion

The new instrument presented in this paper is not an imitative instrument, e.g., it's not supposed to imitate a conventional instrument. It's even not exactly an equipped instrument, e.g. a conventional instrument equipped with sensors to bring new possibilities while preserving the usual playing and sound generation (acoustic or electric). It's more an instrument with a design inspired by a conventional instrument, which can, in a way be considered as a subgroup of alternate instrument. The role of this new instrument is to give new possibilities in electronic music to performers who have already developed skills in guitar playing. The FSR technology gives satisfying results for this kind of application and could probably bring more possibilities with more adapted size. The new organization of motor tasks seems also pleasant and adequate, but of course learning and practice certainly improve the musical use.

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