The eDobro: An Implementation of Design Strategies Intended to Diversify and Expand the Use of Computer Music Controllers

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ABSTRACT
This paper discusses the importance of designing computer music controllers that appeal to a wide range of potential users. Design guidelines are proposed with this in mind. An emphasis is placed on the importance of designing controllers that are easy to learn and that allow musicians to immediately capitalize on skills that they already possess, while at the same time allowing them to gain significantly increased levels of control and flexibility as they become proficient. The eDobro, a slide/fretless guitar-based controller, is proposed as a sample implementation of these principles. The eDobro uses long sensor strips to determine the position and pressure of the fingers and thumb of the left hand. It also uses FSRs to sense the pressure exerted by the fingers and thumb of the right hand.

KEYWORDS
Hyperinstrument, gestural control, slide guitar, fretless guitar, fretless bass, eDobro, design guidelines, music

INTRODUCTION
Many controllers have been designed in recent years that hold a great deal of potential for musical expression. Unfortunately, many of them have only been used by a limited number of performers in a limited number of performances. Although it is sometimes useful to specifically design a controller for a particular performer or piece, the importance of having controllers used in a broader context should not be overlooked. An important challenge in the field of gestural control is to design controllers that appeal to a wide range of performers beyond the small circle of people already in the field, while at the same time managing not to sacrifice the flexibility and originality that distinguish many recent controllers from the traditional or commercial alternatives.

Increased interest in controllers from a broad user base will provide designers with opportunities to receive diverse feedback that will enable them to refine and enhance their controllers. Greater distribution will also increase the level of funding that is available to design new controllers. Most importantly, increasing the range and number of users will help fulfill the most basic reason for designing controllers: the production of interesting music. Once a controller becomes widely accepted, sophisticated performance practices and a body of work will hopefully be developed specifically for it. These developments will very likely lead to improvements over what could have been done with the controller if its use had remained limited to only a few people.

Ideally, a controller should appeal to both new and accomplished musicians when they first come into contact with it. The controller should also allow users of all types to gain increasing amounts of control over the sound that is produced as they gain experience. It is also important that the controller allow musicians to control the parameters of sound to a greater degree and/or with more ease than existing instruments. With these and more general considerations in mind, the following guidelines are proposed for designing controllers with a broad appeal:

- Accomplished musicians should be able to apply skills that they already possess so that they can learn to use the controller quickly, as they will likely be unwilling to invest large amounts of time in learning an unknown instrument.
- Users with little musical experience should receive enough immediate gratification from the controller that they will be motivated to pursue it further.
- The controller should encourage experimentation.
- The controller should impose enough direction on users that they do not spend too much time playing rather than refining specific gestural skills.
- Users should only be able to control a limited number of synthesis parameters directly, as attempts to precisely control too many parameters at once can lead to cognitive overload. Careful coupling of control parameters can help to alleviate this problem.[1]
- The controller should be sensitive to non-obvious performance gestures so that performers who have

[1] [5], [7] and [8] provide further information relating to this.

achieved a high level of proficiency may eventually take advantage of this data.[2]

- It should be possible to control parameters over a wide range of values and with a high degree of accuracy. The controller should be sensitive to nuance.
- The latency between performance gesture and sound production should be imperceptible.[3]
- The controller should feel natural, and a moderate amount of experience should allow users to play it without consciously thinking about gestures or individual parameters.
- The controller should provide users with sensory feedback beyond the sound produced (e.g. haptic feedback).
- Although the controller should be easy to learn and use, it should also require users to exert some effort when playing, as many artists feel that this is an important factor in expressive performances.[4]
- Practice with the controller should lead to increased control over the sound produced. This implies a high level of consistency and at least partially deterministic mapping strategies.
- There must not be a low ceiling of control beyond which users cannot progress.
- Once proficiency is attained, a variety of mapping strategies and ways of physically manipulating the controller should become available to users. Mappings should not deviate from one another so much that they necessitate a serious time investment to learn, but there should be enough flexibility so that experienced users can tailor the controller to their needs.

These guidelines can sometimes conflict with one another. Each designer must find the appropriate balance for each particular controller. The eDobro is presented as an attempt to achieve such a balance.

Since designing a controller that could be quickly adopted by skilled musicians was considered a priority, it was decided to build a controller based on an existing instrument. This allows musicians familiar with the original instrument to play the controller effectively as if it were the original instrument almost immediately. Users can then gradually learn to use its more sophisticated and original capabilities over time. An additional advantage of using an existing interface as a base is that such interfaces have been proven to be effective, whereas entirely new interfaces carry the risk of having serious unforeseen usability problems.

The particular model of the slide/fretless guitar was chosen for the eDobro partly because the author has some performance experience with this instrument and partly because no other attempts, to the best of the author's knowledge, have been made to use it as the inspiration for an electronic controller. In addition, the model of the slide guitar offers a simple yet versatile interface that can easily be expanded on without compromising the original control paradigm.

Since the standard guitar is an extremely popular instrument, it was decided to design a mapping that quantizes the sensor strips into fret spaces in addition to a continuous slide guitar mapping. A mapping using lower pitches was also implemented in order to simulate a bass guitar. These alternatives greatly expand the potential user base of the eDobro, as performers who only play standard guitar or bass will also be able to immediately apply their knowledge to the eDobro.

In order to place the eDobro in context, a review was conducted of recent existing string-based controllers.

EXISTING STRING-BASED CONTROLLERS

Although a number of MIDI guitars were available commercially in the 1980s, these have now been abandoned for the most part in favour of traditional guitars fitted with MIDI pickups. The exception to this is the Starr Labs Ztar [1] [20]. The fingerboard of the Ztar is equipped with a pressure sensitive button for each fret on each string. The body of the Ztar comes in two main configurations: either a set of strings or a set of pressure-sensitive bars that are controlled by the right hand.

The discrete nature of the Ztar fingerboard buttons makes it incompatible with the model of a slide guitar, as it does not allow slides or microtonal playing without the use of additional controllers outside of the guitar control paradigm. The idea of a pressure sensitive fingerboard, however, is interesting, as pressure provides another dimension of control without necessitating any dramatically new kinds of gestures.

A number of controllers have also been designed based on violins and cellos. Recent examples include the BoSSA [14], the SuperPolm [6] and the Marching Cello [12]. The most common approach with these controllers has been to use a large number of sensors in order to obtain many streams of data. Examples of the kinds of information measured include position and orientation of the bow, position and orientation of the instrument body, fingerboard data and bridge data. This approach does allow access to many parameters and offers a high level of customizability, but it can have the consequence of overwhelming performers

[2] See [17] for more information on non-obvious performance gestures.

[3] [18] provides some rough guidelines relating to this.

[4] See [9] and [13] for a review of information relating to this.

with too many parameters to control at once. New users may also end up spending too much time experimenting with different control parameters rather than gaining skill with the instrument by focusing on a particular control paradigm. The decision was therefore made to strictly limit the number of sensors and data streams used in the eDobro.

Many of the existing string-based controllers use fingerboards that require different fingerings than those of their traditional ancestors. Some only have one string-like sensor on the fingerboard and others have separate string-like sensors positioned next to each other vertically as well as horizontally. Since it is essential that performers using the eDobro be able to use the same fingerings that they would use with acoustic or electric guitars, these options were rejected for the eDobro.

PHYSICAL DESIGN

The eDobro consists of a fingerboard connected to a small control panel. The eDobro can be held vertically on one's lap like a standard guitar, between one's legs like a cello or horizontally on one's lap like a laptop guitar.

The front of the fingerboard is designed to be mounted with five long strips[5] that sense pressure and position. The back of the fingerboard is mounted with a similar strip to track thumb position and pressure.

The bottom of the control panel is equipped with four small pressure sensitive buttons, one for each finger. An additional pressure sensitive button is mounted on a thumb rest. These sensors can be used to initiate notes with the right hand in a way similar to some aspects of traditional fingerstyle technique. There are also five switches on the control panel that can be used to switch between different mapping modes.

It was decided to use five strings instead of the standard six because of the width of the sensor strips. Six sensors would have caused the distance between the highest string and the lowest string to be too great to span comfortably with one's fingers. Although the use of five strings is an unfortunate compromise, many slide players do not use all six strings in every piece, and the pitches of each sensor can be adjusted using software if necessary. This approach offers the limited advantage of keeping a correspondence between the number of strings and the number of fingers of the right hand, so that each right-hand finger can control a single string without ever needing to move out of position.

This fingerboard design allows users to use precisely the same fingering patterns that they would for a standard guitar, with the exception of the missing string. A user can bar a single finger over multiple strings to play bar chords or simulate a slide. The eDobro also makes several new techniques available if desired. For example, rather than being limited to a single slide, users can use different fingers on different strings in order to simulate the effect of using multiple slides in different positions simultaneously.

The eDobro is also easier for musically inexperienced users to learn than the traditional guitar. Simply pressing on a sensor with the left hand and then touching the corresponding sensor with the right hand will result in a clear note. This provides a level of immediate gratification not offered by most traditional instruments. The elimination of unwanted artifacts like string noise also makes the eDobro easier to play than traditional guitars.

Although left-hand thumb and pressure related data are not part of the traditional slide guitar control paradigm, introducing these dimensions of control only requires a refinement of existing left hand technique, and does not require any new types of gestures. This is consistent with the goals of minimizing the effort needed for slide guitar players to adopt the instrument initially, while at the same time giving them additional control parameters that they can incorporate into their playing as they gain experience with the eDobro.

Right-hand playing technique is where the eDobro deviates the most from the slide guitar control paradigm. Although the eDobro does allow users to retain many aspects of traditional fingerstyle technique, it does not allow the use of a pick as an alternative to fingerstyle playing, it does not allow users to rapidly pluck the same string with multiple fingers, it does not permit as much thumb mobility and it does not provide as much control over articulation.

The eDobro approach to the right hand does offer a number of benefits to compensate for its weaknesses, however. Users are able to use the right hand to continuously modify a parameter for each string using aftertouch, a possibility that is not available with traditional guitars. It is also easier to mute a string, since a user only needs to remove his/her finger from a sensor to stop the corresponding string from sounding. Users can also initiate and control notes with much less finger movement, since the need for finger repositioning after each plucking motion is eliminated. This allows for easier and faster playing than is possible using traditional fingerstyle techniques.

MAPPING STRATEGIES

One of the benefits of electronic instruments is the virtually limitless variety of mappings that can be devised. In keeping with the design goals of the eDobro, how-

[5] For ease of communication, the term "string" will be used in the remainder of this paper to refer to the fingerboard sensor strips.

ever, a limited number of straightforward mappings have been used here. Once a user has gained expertise with the eDobro, of course, s/he is free to employ whatever mappings are desired.

A progression of increasingly sophisticated mappings has been devised. The goal of this is to facilitate a gradual adaptation from standard guitar techniques to more sophisticated techniques unique to the eDobro. This approach also allows beginner-level users to gradually build proficiency with the eDobro by mastering different aspects of the interface one by one, rather than being forced to contend with all aspects of the controller at once. Of course, new users do have the option of starting with more sophisticated mappings if it is their preference to become familiar with all control dimensions of the eDobro from the beginning.

The mappings, in order from simplest to most complex, are as follows:

- Left-hand thumb position and pressure are ignored, as is right-hand aftertouch. Right-hand pressure beyond a threshold initiates a note and sets its velocity. How long the left hand remains on a sounding string determines the duration of each note. Left-hand finger position determines the pitch of each string. Each sensor strip is divided into quantized regions. This mapping simulates a basic fretted guitar.
- Same as above, but sudden strong left-hand pressure on a string initiates a new note with a pitch determined by position and a velocity determined by pressure. No right-hand activity is involved in this gesture. This simulates hammer-ons.
- Same as above, but pitch data from the fingerboard is continuous rather than quantized. This mapping simulates a slide guitar and allows microtonal playing.
- Same as above, but removing a finger entirely from a right-hand sensor has the effect of muting the corresponding string, regardless of left-hand activity.
- Same as above, but pressure on the left-hand thumb sensor beyond a threshold allows the user to bend all sounding pitches, including open strings, by changing thumb position. This simulates a whammy bar.
- Same as above, but right-hand pressure controls loudness of notes even after they have been initiated.
- Same as above, but resolution of slides is determined by left-hand pressure on strings. This allows fine microtonal control, very wide slides or anything in between, depending on the needs of the moment.

This progressive approach to mapping allows users to start with a simple instrument and gradually add new levels of control as they gain proficiency. By the end of this progression, users will have access to several types of control that are not available on traditional slide guitars. The aftertouch loudness control can greatly enhance expressivity and the variable pitch resolution can facilitate fingering and increase both expressivity and ease of playing. The end result is a complete instrument that is fully playable with no further mapping modifications. Musicians can continue to gain proficiency with this mapping by learning to refine their technique, just as they would with any traditional instrument.

Users also have the option of changing the tuning of each string. This is a major advantage over traditional guitars, since many slide guitarists utilize different tunings and are forced to either use several different guitars or spend a significant amount of time retuning them. The tuning of all strings can also be changed in parallel, which allows users to simulate a capo without needing to surrender the use of any portion of the fingerboard. Lowering the pitch of all strings has the effect of allowing one to play the eDobro as if it were a fretless bass guitar. It is also possible to alter the pitch change per unit length of the sensor strips, as some performers may prefer finer control than others.

Some users may wish to develop alternative or expanded mappings once they have become proficient with the eDobro. Since the main motivation for emphasizing a particular mapping strategy was to facilitate learning and create a standardized way of playing, users who have already mastered the basic mapping are welcome to find an alternative approach that meets their particular needs. Flexibility and customizability are, after all, desirable controller characteristics for expert users.

Those who wish to develop their own mappings should keep in mind that left-hand thumb position and pressure are coupled with left-hand finger position and pressure. The thumb should therefore not play too critical a role. Threshold-based thumb mappings are probably the best option. Aside from this warning, users are encouraged to use their imagination. Left-hand thumb pressure and position, left-hand finger pressure and right-hand aftertouch are all parameters not present in traditional guitars that can be mapped in a wide variety of ways. Adventurous users may even wish to use different mapping strategies for different strings. Some possible ideas are:

- Define presets so that exceeding thresholds will trigger automatic harmonizations or other macros.
- Use a control parameter to pre-set the duration of notes so that users will be free to initiate new notes

on a string while other notes are still sounding on it. This would enable users to escape the limitation on the number of simultaneously sounding notes enforced by the finite number of strings and could greatly facilitate fingering.

- Allow an aspect of timbre to be continuously controlled. Effects similar to those of a wah wah pedal could be achieved, for example, either for all strings together or for individual strings.

An alternative approach to the eDobro is to hold the controller between one's legs and play the fingerboard with both hands. Under this setting, fingerboard pressure initiates notes and controls loudness continuously. Pitch is still determined by finger position, and notes end when fingers are removed from strings. The thumb sensor acts as a sixth string. This is an entirely different control paradigm from that of the guitar, and users are encouraged to experiment with it and see where it leads. With some experience, this approach could enable very fast playing. This mapping is not the main focus of the eDobro, but is suggested both as a curiosity with potential for future development and as an alternative kind of playing that can be inserted at key points into performances that otherwise use the standard mapping. This is in some ways analogous to using the guitar technique of tapping.

DETAILS OF THE PROTOTYPE

Due to financial limitations, the prototype that was actually constructed was only equipped with one string. Although this did limit the playability of the prototype, it did not affect the testing of the eDobro's mapping strategies, since each string is independent and effectively identical aside from its starting pitch.

The fingerboard sensor strip consists of an Infusion Systems SlideLong mounted on top of an Infusion Systems TouchStrip [19]. The left-hand thumb position/pressure sensor was developed at for Suguru Goto's SuperPolm MIDI violin [6]. The right-hand FSRs were also obtained from IRCAM.

The signals from all sensors are sent to an Infusionsystems I-Cube, which converts them to MIDI messages and sends them to a Macintosh computer. Cycling '74 Max/MSP was used to implement all mappings.

MIDI is used to control all synthesis. Despite its limitations, MIDI is by far the most widely used standard, and it was felt that using MIDI with the eDobro is consistent with the goal of appealing to a wide range of potential users. There is nothing to say, however, that users cannot remap the output of the eDobro to control synthesis in other ways if they wish.

FUTURE DEVELOPMENT

The following is a list of ideas for improvements that could be made to the eDobro in the future if more time and funding become available:

- Construct a more ergonomically comfortable and aesthetically appealing body.
- Find or develop thinner sensor strips so that more strips can be mounted on the fingerboard.
- Find or develop sensor strips that can output multiple positions and pressures at once so that more than one note at a time can be played on a single strip.
- Design an alternative eDobro that uses strings instead of FSRs for right-hand control, similar to the approach used by the Ztar [20]. This would sacrifice the aftertouch and ease of muting of the FSRs, but would provide more control over articulation and would be closer to the basic control paradigm of a guitar.
- Add a foot pedal to give an additional global dimension of control. Many guitarists are already familiar with pedals, so this would be consistent with the basic guitar control paradigm.
- Add accelerometers to the body of the instrument to detect subtle performance gestures by expert users.
- Fit the eDobro with a self-contained processing unit and acoustic diffuser, similar to that used in the BoSSA. [14] This would give the eDobro a physical presence as a complete integrated instrument rather than just a controller.
- Develop alternative mapping strategies, with a focus on mappings that could be adopted with relative ease by performers already proficient with the basic eDobro mappings.

CONCLUSION

In order to expand the user base of electronic music controllers, it is necessary to design controllers that are easy to learn and that allow musicians to apply skills that they already possess. It is also important that controllers help users to develop their performance skills in a focused fashion that eventually enables them to control sound with a high level of precision, ease and range. Controllers should also allow users a reasonable degree of flexibility in terms of control gestures and mapping once they have achieved some expertise. This necessitates finding a balance between customizability and versatility on one hand and learnability and usability on the other. The eDobro is presented as a sample attempt to balance these considerations.

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REFERENCES

[1] BeauSoleil, B. 2001. "Starr Labs Ztar Z1 and Z1-S: Is the Ultimate MIDI Controller a Guitar?" *Electronic Musician,* 17(11): 178-183.

[2] Bongers, B. 2000. "Physical Interfaces in the Electronic Arts. Interaction Theory and Interfacing Techniques for Real-Time Performance." In M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music.* IRCAM - Centre Pompidou.

[3] Colbeck, J. 1996. "Alternate Controllers: Beyond Black and White." *Music & Computers,* 2(2): 57-64.

[4] Cook, P. 2001. "Principles for Designing Computer Music Controllers." Presented at the 2001 New Interfaces for Musical Expression Conference, Seattle.

[5] Garnett, G. E. and C. Goudeseune. 1999. "Performance Factors in Control of High-Dimensional Spaces." Presented at the 1999 International Computer Music Conference, Beijing.

[6] Goto, S. 2000. "The Aesthetics and Technological Aspects of Virtual Musical Instruments: The Case of the SuperPolm MIDI Violin." *Leonardo Music Journal,* 9: 115-120.

[7] Hunt, A. and R. Kirk. 2000. "Mapping Strategies for Musical Performance." In M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music.* IRCAM - Centre Pompidou.

[8] Hunt, A. et al. 2000. "Towards a Model for Instrumental Mapping in Expert Musical Interaction." Presented at the 2000 International Computer Music Conference, Berlin.

[9] Mulder, A. G. E. 2000. "Towards a Choice of Gestural Constraints for Instrumental Performers." In M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music.* IRCAM - Centre Pompidou.

[10] Orio, N. et al. 2001. "Input Devices for Musical Expression: Borrowing Tools from HCI." Presented at the 2001 New Interfaces for Musical Expression Conference, Seattle.

[11] Paradiso, J. 1997. "Electronic Music: New Ways to Play." *IEEE Spectrum Magazine,* 34(12): 18-30.

[12] Schoner, Bernd. 2000. "Probabilistic Characterization and Synthesis of Complex Driven Systems." PhD Thesis, M.I.T. Available on-line at <web.media.mit.edu/~schoner/PhD/>.

[13] Tanaka, A. 2000. "Musical Performance Practice on Sensor-Based Instruments." In M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music.* IRCAM - Centre Pompidou.

[14] Trueman, D. and P. R. Cook. 1999. "BoSSA: The Deconstructed Violin Reconstructed." Presented at the 1999 International Computer Music Conference, Beijing.

[15] Vertegaal, R. et al. 1996. "Toward a Musician's Cockpit: Transducers, Feedback and Musical Function." Presented at the 1996 International Computer Music Conference, Hong Kong.

[16] Wanderley, M. M. 2001. "Gestural Control of Music." Presented at the 2001 International Workshop on Human Supervision and Control in Engineering and Music, Kassel, Germany.

[17] Wanderley, M. M. 2001. "Quantitative Analysis of Non-Obvious Performer Gesturses." Presented at the 2001 International Gesture Workshop, London.

[18] Wessel, D. and M. Wright. 2001. "Problems and Prospects for Intimate Musical Control of Computers." Presented at the 2001 New Interfaces for Musical Expression Conference, Seattle.

[19] ----. Infusion Systems Homepage. Available on-line at <www.infusionsystems.com>.

[20] ----. Starr Labs Homepage. Available on-line at <www.starrlabs.com>.