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Technology White Paper

Strum Pad and String-Array MIDI Technologies for Electronic Musical Instruments

Abstract

This whitepaper describes systems and methods as specified in U.S. Pre-Grant Patent Application 2004/0069129 and related issued and pending patents for expanding and generalizing essential concepts characterizing an autoharp ("chorded zither"), Omnichord / Q-chord[*1], *and related instruments, making the associated functionalities available to other contexts and as an accessory to other instruments.*

Underlying the technologies is the abstraction of a non-keyboard linear array of note-triggering elements working together with a "chord" control interface that determines the pitches that may be sounded. The linear array of sound producing elements may include touch-switch array strumpad technologies, adapted arrays of vibrating elements (such as strings or tynes) with activated trigger circuits, or adapted touchpad technologies. Any of these may be used to generate note events with the specific notes determined according to an active mapping selected or specified by a chord control interface. The chord control interface may comprise buttons, foot switches, a music keyboard, pitch conversion, incoming MIDI control signals, etc.

Further information regarding reference designs for the controller can be provided under negotiable terms. Financial or in-kind proceeds from such arrangements are used to fund academic research at New Renaissance Institute®.

1. [*] Omnichord, Q-chord, and strumpads are products and technologies of Suzuki Corporation.

1 Introduction

This whitepaper describes systems and methods for expanding and generalizing many functional aspects of the autoharp (or "chorded zither"), Omnichord / Q-chord*[2], as well as making adaptations of these functionalities beneficially available in other contexts and as an accessory to other musical instruments. These technologies are described in U.S. Pre-Grant Patent Application 2004/0069129, "Strumpad and String Array Processing for Musical Instruments" and other related patent applications. The technologies range from the simple to the more complex, and may be drawn from to form a variety of products of widely varying cost and sophistication.

Underlying these technologies is a common abstraction of a linear array of note-event triggering elements and a chord control interface which selects or provides an active mapping that determines the pitches that may be sounded.

The linear array of note-event triggering elements may include, for example:

- a strumpad (i.e., linearly arranged touch switches arrays)
- an array of other actuators
- an array of vibrating elements (for example, strings, tynes, etc.)
- a suitably adapted touchpad
- combinations of these.

Multiple instances of these may themselves be assembled in large arrays.

The chord control interface may comprise one or more of the following:

- an array of buttons, levers, foot switches, etc., with either fixed interpretation, a dynamically assignable interpretation, or a plurality of interpretations which may be recalled under stored program control.
- keys depressed on a music keyboard
- notes recognized by pitch conversion
- incoming MIDI control signals,
- combinations of two or more of these

Overall, U.S. Pre-Grant Patent Application 2004/0069129 and related issued and pending patents provide a generalized adaptation of the autoharp, rhythm-bar, and Suzuki strumpad-based instruments :

- a more generalized strum-pad element with the following attributes:
  - low activation-pressure proximate switches
  - linear spatial arrangement (although others are useful)
  - no hard-wired note repeats (these may be rendered, if needed, in software)

2. * Omnichord, Q-chord, and strumpads are products and technologies of Suzuki Corporation.

  - visual and/or small tactile markings to the player
  - compact physical size
- simultaneous multiple switch activation without perceivable interaction
- generalized note event information that can be assigned interpretation under program control
- more generalized strum-pad interpretation software and hardware with the following stored program attributes and assignments which can be rapidly altered during playing:
  - assignment to selected melodic notes, percussive events, lighting or special effect events, etc.
  - arpeggio pattern select
  - note-repeats added as desired and in the manner desired
- issuance of note, outgoing program change, and/or other control signals at the initial activation of each stored program (to sound a background chord, activate lights, etc.) with or without activity on the strum-pad
- selection and rapid change of specific programmable attributes and assignments via button or foot-switch control.

Further information regarding reference designs for the controller can be provided under negotiable terms. All financial or in-kind proceeds from such arrangements are used to fund academic research at New Renaissance Institute®.

1.1 Acoustic Autoharp and its Mutable String Arrays

A contemporary autoharp, depicted in the example of Figure 1a, incorporates a plurality of strings, tuned to selected notes in a chromatic scale, which are selectively damped by mechanical damping bars with cut-outs in the damping material that allow only selected strings to sound. A player of the autoharp selects and depresses a chosen chord button, which in turn actively positions a damper bar associated with the chosen chord, and strums a portion or all of the strings, and only the undamped strings, namely those associated with the voicing of the chord, sound.

The long history of the autoharp includes some mysteries [2] and numerous patents [21]-[26]. Many of the patents use chromatic keyboards rather than chord buttons. Although the autoharp is currently regarded as a lower folk or beginning instructional instrument, the basic arrangement of the autoharp can give rise to a powerfully flexible instrument.

1.2 History of Electronic Strumpads of Organs, Omnichord, and Q-Chord

A few early music synthesizers replaced a conventional keyboard with a low-activation pressure membrane touch switch array laid out to resemble a keyboard. One could freely tap or easily drag fingers over the membrane switch array without the overhead and potential injury involved in more deeply operative conventional keyboards. Because of the lack of conventional keyboard action and applicable technique, such keyboards rapidly lost their appeal.

The early Hammond S-6 organs featured a rhythm bar which could be used in conjunction with chord buttons [3]. In the late 1960's, some home models of deluxe organs featured a metallic strum-type controller on the edge of one of the keyboards used to render "chime" tones arpeggiating the notes of a chord held down on that keyboard.

More recently, the Suzuki "Omnichord" and subsequent Q-Chord" products [4-5], designed in keeping with the techniques and functionalities of an autoharp, provided a low-activation pressure membrane switch array, called a "strum-pad," laid out to mimic the strummed-string array of an autoharp. An example of a strumpad is illustrated in Figure 1b. As a selected chord button is activated various notes associated with the chord are assigned to the various membrane switches so that a finger sweeping over the strum-pad produces an arpeggiated chord in a way suggestive of strumming a traditional autoharp. The Omnichord strum-pads are hard-wired to repeat notes multiple times and the note assignment software permits only fixed chord selections with preassigned arpeggio note sequences.

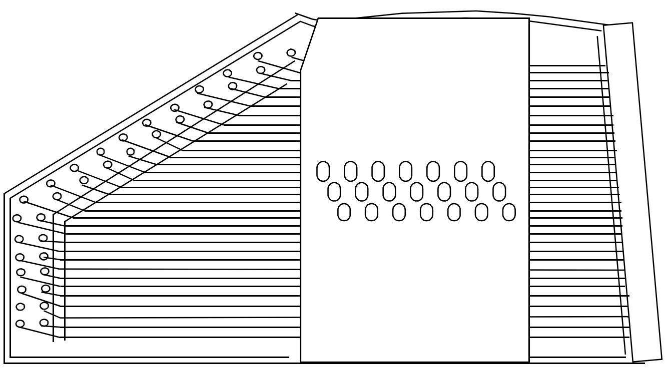


Figure 1a

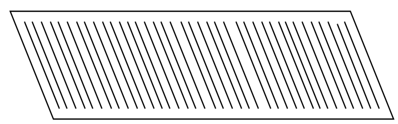


Figure 1b

1.3 Abstraction of Autoharp and String Array Concepts

Figure 2 illustrates how the functional aspects of the autoharp (and the more recent Omnichord / Q-chord) may be adapted, expanded and generalized to other contexts and employed as an accessory to other musical instruments as described in U.S. Pre-Grant Patent Application 2004/0069129. At the top of the diagram, the autoharp is decomposed into two principal aspects: a linear array of sounding strings and the selection of which pitches are allowed to sound according to a selected chord. These are then abstracted to the functional level of the interface to the musician: the linear array of sounding strings is abstracted as a more general linear array of note-triggering elements, and the selection of which pitches are allowed to sound according to a selected chord is abstracted as a more general chord control interface. Additionally, strumpads may be employed outside the notion of chords and instead used to render note sequences as may be employed in South Asian raags, Western serial compositions, hip-hop sound collage, etc.

The linear array of note-triggering elements covers two principle categories: touch-driven electronic strumpads and arrays of vibrating elements. The strumpads may be implemented with touch switches or emulated by spatially quantizing the contact location on a higher resolution touchpad. The first of these in turn covers additional categories: simple touch switch strumpads alone, or touch switch strumpads coupled with pressure and velocity sensing to provide additional control parameters. Similarly, emulated touchpads may be limited only to spatial quantization, or may include measurement of additional parameters as taught in the companion U.S. Patent 6,570,078 [9] or via other methods [10]-[11].

In the classical autoharp, mechanical dampers are used to prevent the pitch vibration of strings tuned to pitches other than those associated with a chosen associated chord. In the Omnichord and Q-chord, buttons are used to assign which note-event pitches are assigned to specific touchpad locations. In Figure 2, the abstracted chord control interface accepts the output of actuators or input signals and responsively selects a specific collection of permissible note-event pitches associated with a chosen chord. The chord control interface may comprise one or more of a wide range of actuator or input signal arrangements:

- Buttons, levers, footswitches or other actuators may be used to select the chosen chord used to specify pitches assigned to specific touchpad locations;
- A pitch detector, responsive to the pitch of a musical signal (such as a voice, vibrating string, etc.), may be used (in isolation or in conjuction with other input information) to specify pitches assigned to specific touchpad locations;
- An incoming control signal may be used to select the chosen chord used to specify pitches assigned to specific touchpad locations;
- A keyboard may be used to specify pitches assigned to specific touchpad locations;

The stimulus from these in turn may recall stored editable assignments, activate fixed pitch assignments, or be interpreted to produce the specific pitches to be employed, etc. Additionally, previously sounding notes may be optionally (or selectively) silenced, and note events of an associated chord may be issued. This is illustrated in Figure 3. In the case of using melodic keyboards as the chord control interface, the keys of the melodic keyboard may include sensors to provide additional control parameters as described in companion U.S. Pre-Grant Patent Application 2004/0074379 [8], companion U.S. Patent 6,570,078 [9] or via other methods [10]-[11].

2 Note Event Triggering Technologies

In this section, various applicable note-event triggering technologies provided for in U.S. Pre-Grant Patent Application 2004/0069129 (and set out in Figure 2) are considered in more detail. Strumpads and their emulations are considered immediately below. This is followed by discussion of vibrating element arrays.

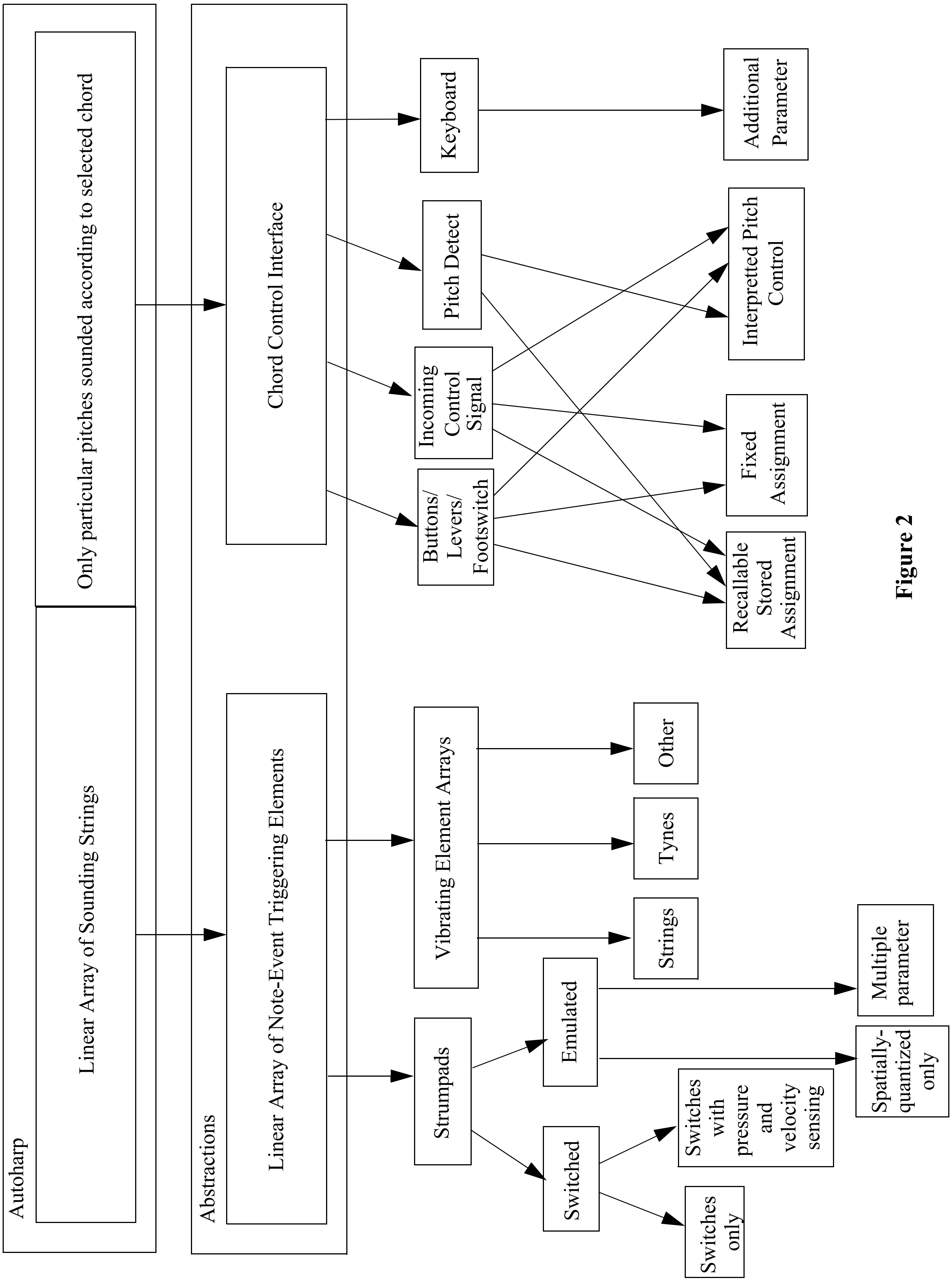

Autoharp
Only particular pitches sounded according to selected chord
Linear Array of Sounding Strings
Abstractions
Chord Control Interface
Linear Array of Note-Event Triggering Elements
Keyboard
Pitch Detect
Incoming Control Signal
Buttons/ Levers/ Footswitch
Additional Parameter
Interpretted Pitch Control
Fixed Assignment
Recallable Stored Assignment
Vibrating Element Arrays
Other
Tynes
Strings
Strumpads
Emulated
Switched
Multiple parameter
Spatially-quantized only
Switches with pressure and velocity sensing
Switches only

Figure 2

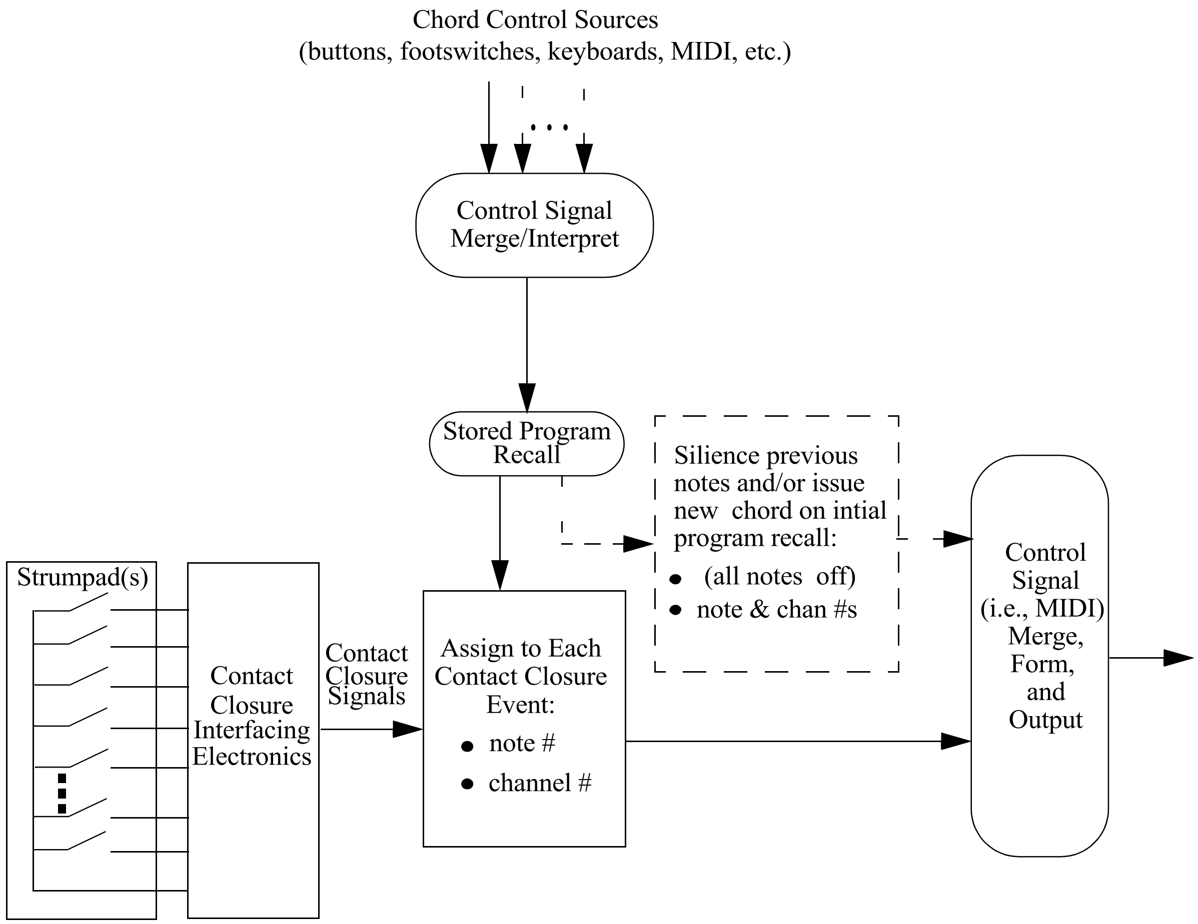


Figure 3

2.1 Touch-Activated Strumpad Technologies

Strumpads (which may be viewed as abstractions of string arrays) can be used to generate MIDI note events according to the active mapping by a chord control interface. Strumpads may be implemented with touch-switches (capacitive, resistive deformable membrane contact, etc.) or may be emulated using touchpad technologies [9] by spatially-quantizing regions of touch along one spatial direction of position sensing.

The strumpad elements and strumpad emulations covered in U.S. Pre-Grant Patent Application 2004/0069129 provide the following generalized adaptations of the autoharp string, rhythm-bar surface, and Suzuki strumpad element ideas:

- low activation-pressure proximate switches or spatially-quantized touchpad areas;
- linear spatial arrangement (although other spatial arrangements may be useful);
- no hard-wired note repeats (may be rendered in software as needed);
- visual and/or small tactile markings to the player;

- compact physical size
- inclusion of appropriate sensors and signal processing so as to produce additional control signals responsive to other aspects of touch;
- sharing scanning electronics over a plurality of touch-switch strumpads, or over at least one keyboard and at least one strumpad.

These attributes may be used individually or, more valuably, in combination. Ideally the resulting strumpad elements are physically small enough to be built into or placed as an attachable accessory onto a wide range of other instruments. Arrays of individual strumpads may also be advantageously created, supporting a number of functional needs and unique capabilities. A few of these topics are considered in more detail in the three subsections below.

2.1.1 Providing An Application Of Addition Touch-Controlled Parameters: Rich Control Of Sound Production Parameters and Multichannel Strumpads

In addition to sending note events for specific selected pitches, a touchpad may be adapted or implemented in such a way as to produce additional control signals responsive to other aspects of how the strumpad elements or strumpad emulation is touched.

For example, by placing a velocity sensor (such as a piezo element) and/or pressure-sensor under a touch-switch strumpad element, and feeding the resulting signal(s) to the MIDI keyboard interface as would be done in a conventional MIDI keyboard realizing these features with such sensors, it is possible to responsively product additional control signals such as note-velocity, key-pressure, after-touch, channel-pressure, and general continuous controller outputs. Alternatively, it is possible to supplement, or replace altogether, each individual touch-switch with a corresponding individual pressure-sensor, thus creating a linear pressure-sensor array. Such a linear pressure-sensor array can also be used to implement note-velocity, key-pressure, after-touch, channel-pressure, and general continuous controller outputs.

If a touchpad is used to emulate a strumpad, one direction within the touchpad plane is quantized into distinct trigger regions for strumpad emulation. The other direction or other apects of touch may be ignored, interpreted for the control other control parameters, or also quantized into distinct trigger regions for strumpad emulation. As illustrated in Figure 4, the left-right position of a finger contact with the touchpad may be quantized into some number (for example, 30-45) of discrete steps. Alternatively, the forward-back position may be used instead. Additionally, both the left-right position and forward-back position of a finger contact with the touchpad may be simultaneously used to emulate two independent strumpads. Dependent on the type of touchpad technology used (null-contact alone, null-contact with pressure and/or velocity sensors, pressure sensor arrays, etc.) other touchpad measurements (forward-back position, downward pressure, etc.) may be used to control other sound production parameters (such as timbre, envelope generation parameters, stereo pan, etc.) or parameters relating to other performance systems such as lighting, video, etc. Employing, for example, the touchpad technologies described in U.S. Patent 6,570,078 [9],

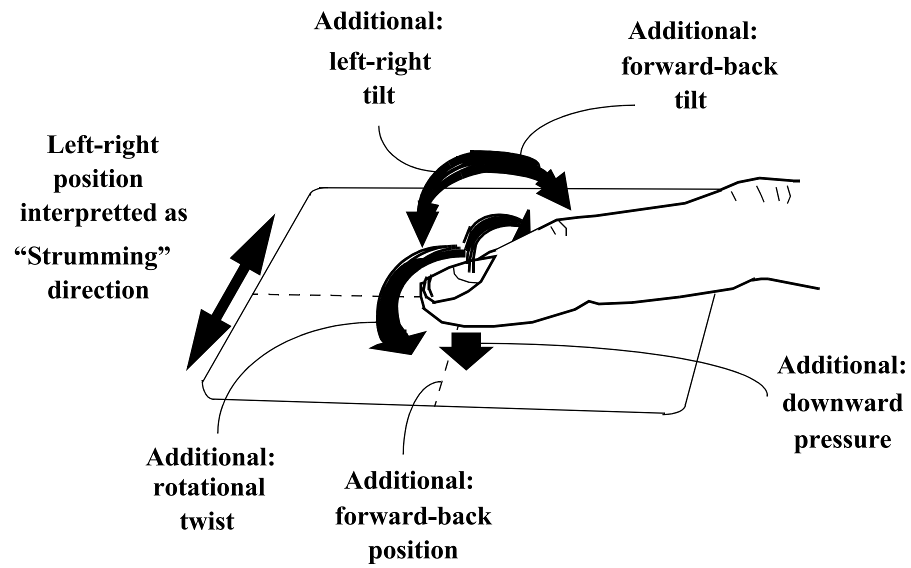


Figure 4

independent control of up to five additional parameters is possible. Figure 4 illustrates an example of five such additional parameters, although other measurements may be used.

It is especially noted that any of the parameters other than left-right position and forward-back position of a finger contact (for example, left-right and forward-back finger tilt/roll) may also be simultaneously used to emulate additional independent strumpads, providing a spectacular multichannel meta-strumpad easily controlled by the slight touch of one or more fingertips. As an example, each of the left-right finger contact position, forward-back finger contact position, left-right finger tilt/roll, and forward-back finger tilt/roll may control an independent strumpad emulation (giving a total of four strumpads controlled by a single fingertip). The overall pressure may additionally be used to control volume, MIDI note velocity, envelope parameters, stereo pan, etc. of one or more of the touchpad-controlled sounds, may be used to control the number of independent strumpad emulations sounding, etc.

2.1.2 Shared Scanning Arrangements

In arrangements with multiple strumpads, one or more associated switch-closure keyboards [8], superimposed keyboards [8], or related input devices, switch-closure scanning arrangements can be shared. For example, a common microprocessor could be used to generate a common multiplexing address for a group of contacts or sensors across several keyboards and the status of individual contacts would then be serially polled or transferred in parallel. Figure 5 illustrates an example of how a switch-closure scanning arrangement may be shared so as to support a plurality of any of keyboards, strum-pad, buttons, switches, etc., as covered by U.S. Pre-Grant Patent Application 2004/0069129.

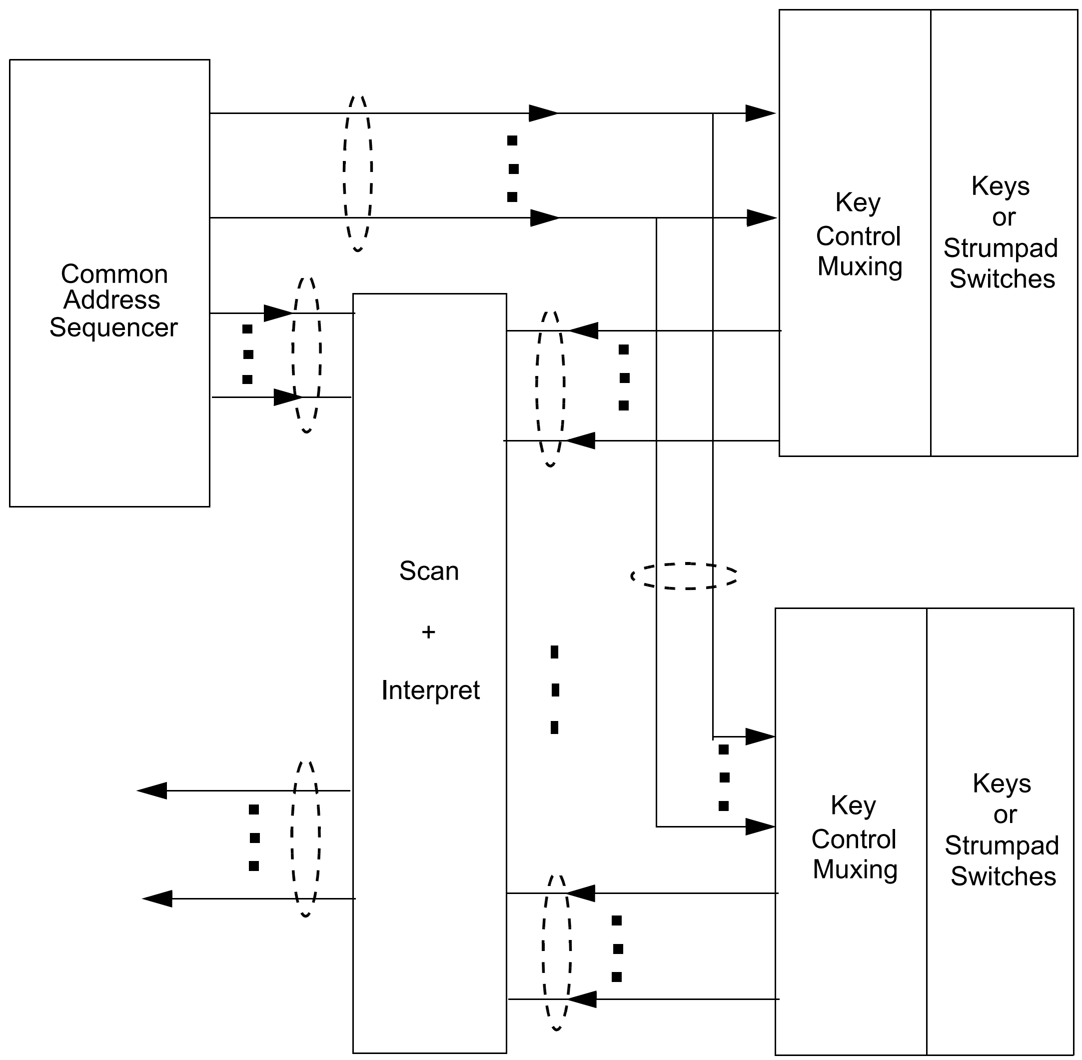


Figure 5

2.1.3 Small and Large Arrays of Strumpad Sensors

Two or more strumpads may be advantageously grouped in an array or be otherwise associated with one another on the same instrument or add-on module. There are several reasons why multiple strumpads may be useful.

- As a first example, two or more strumpads may be sequentially positioned so as to create a longer strumpad, as shown in Figure 6a.
- As a second example, two or more strumpads may be organized in tiers, such as in the case of traditional organ manuals as illustrated in Figure 6b. Each strumpad in such an associated group of strumpads may be assigned differing notes (corresponding to differing chord inversions or entirely different chords), various repeated note patterns, differing timbres, additional functions (such as lighting control, percussion sounds, etc), differing stereo pan settings, etc.

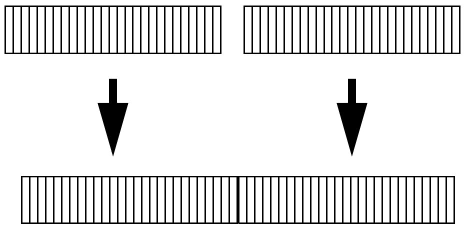


Figure 6a

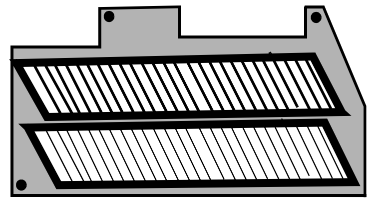


Figure 6b

- As a third example, large arrays of strumpads may be used to provide fast access to a wide range of differing timbres, differing repeated note patterns, differing stereo pan settings, percussion sounds, additional functions such as lighting control, etc. Figure 7a illustrates a large strumpad array employing a linear array of 12 strumpads. These may be oriented in various directions, allowing for left-right operation, forward-back operation, etc. The individual strumpads may also be arranged in other types of arrays (rectagular, triangular, etc.). Additionally, with sufficient numbers of strumpads, one or more of the strumpads may have a fixed note assignment which does not require a chord control interface. Figure 7b and Figure 7c illustrate examples of such sufficiently sized strumpad arrays. For example Figure 7b, with 24 strumpads, provides a strumpad for both every major and minor chord associated with the diatonic scale. In such an arrangement, the chords may be advantageously sequenced according to the circle of fifths and associated relative minors. Figure 7c, with 36 strumpads, supports additional chords such as sus4, varous choices of 7ths, 9ths, etc. Also, such large arrays of strumpads may be very useful in microtone tuning, particularly those with large numbers of notes (such as 24 pitch-per-octave Turkish quarternote scale, the 43 pitch-per-octave scale of Harry Partch, etc.) where the keyboard arrangements are difficult to chord. Additionally, such large arrays of strumpads may be quite usefully employed outside the notion of chords and instead to hold pallets of note sequences as may be employed in South Asian raags, Western serial compositions, hip-hop sound collage, etc.

- As a fourth example, multiple parallel strumpads may be provided for multi-location access as is employed in the autoharp depicted in Figure 8a (to be discussed in Section 5.1) or the keyboard configuration depicted in Figure 8b. These arrangements allow the same strumpad functionality to be accessed by either of two spatially non-collocated hands, or from a variety of hand positions imposed in the course of simultaneously playing another instrument.

Figure 7a

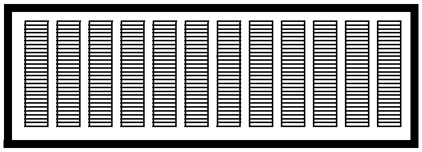


Figure 7b

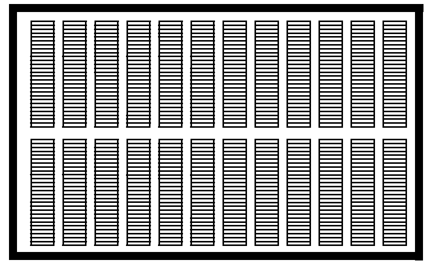
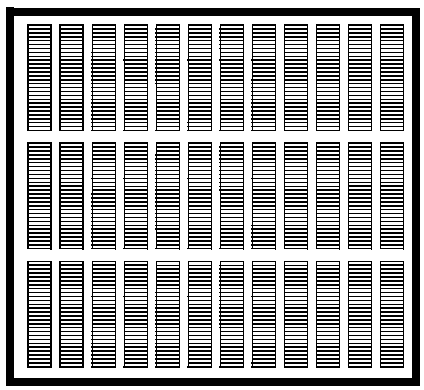


Figure 7c



2.1.4 Use of Traditional MIDI Keyboard Interface Systems

U.S. Pre-Grant Patent Application 2004/0069129 provides methods for realizing a flexible generalized strumpad element and associated stored program control utilizing traditional MIDI keyboard interface systems and MIDI processing. As illustrated in Figure 9, the strum-pad switches can be electrically wired to a simple conventional MIDI keyboard interface so that each consecutive switch triggers a consecutive MIDI note event. The note event stream is then directed to a MIDI message processor which can, under program control, reassign each incoming note event a potentially new MIDI note number and MIDI channel, or perhaps a null operation to create inactive zones. From here, individual MIDI channels can be directed to a variety of destinations: various synthesizer voice channels, lighting systems, special effect systems, etc. Additional control possibilities can be further realized by translating note events into other types of MIDI events, (as described later,) or into non-MIDI control signals.

2.2 Emulating Strumpads with Arrays of Vibrating Elements

The point of departure for the contact-closure strumpad was the abstraction and emulation of string arrays. Once this is established, associated note event control structures and systems are defined around the types of control signals produced by the strumpads. As just seen, the user interface aspect of contact-closure strumpads can itself be abstracted and em-

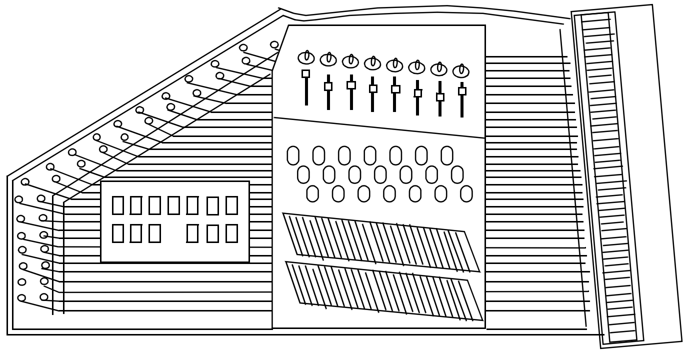


Figure 8a

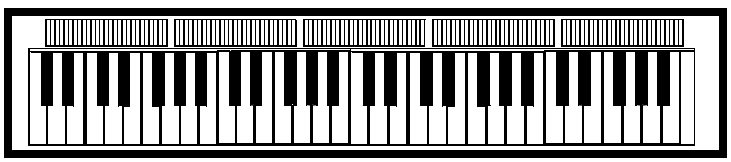


Figure 8b

ulated (via null-contact and pressure sensor array touch pads, as was just discussed) and the resulting emulation can employ the same associated note event control structures and systems used originally to support contact-closure strumpads. Thus, however ironic, it becomes natural to extend the abstractions and emulations of contact-closure strumpads back to arrays of vibrating elements such as strings, tynes, membranes, plates, etc., so that they too may employ the same associated note event control structures and systems.

Figure 10 illustrates a general exemplary approach to accomplish this. Vibrating elements stimulate transducers which produce electrical signals that are applied to not only audio mixing and/or signal processing but also to individual amplitude detectors. The individual vibrating elements may be adapted to include individual vibration sensing transducers (pickups) for each string. These pickups may be any of electromagnetic, piezo, optical, etc. in their operation. The resulting amplitude detection signals are directed to level threshold detectors which provide binary signals indicating whether the vibration amplitude of each individual vibrating element is sufficiently large to be interpretted as actively vibrating. The latter arrangements may be configured with hysteresis to limit sporadtic triggering and/or recognize the duration of sustained uninterrupted vibration. These may also be configured to produce only initial triggering signals. The resulting binary signals emulate a contact-closure strumpad. The amplitude detection may be further processed so as to generate additional amplitude-tracking control signals, potentially using the amplitude of the pluck to set note velocity and potentially tracking the ongoing string amplitude and harmonic structure variations as provided for in pending U.S. patent applications (see for example U.S. Pre-Grant Patent Application 2004/0069128 [20].

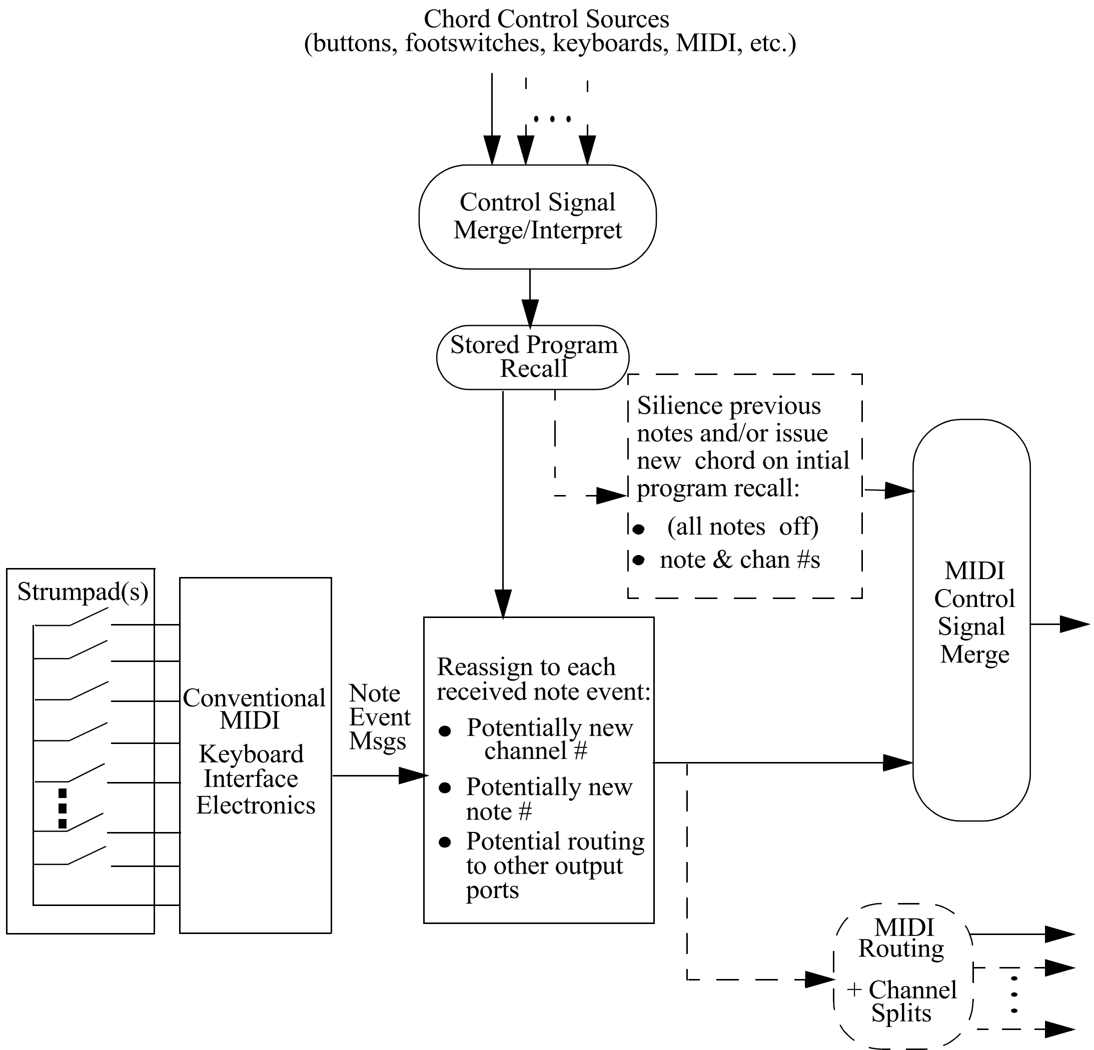


Figure 9

2.2.1 String Array Technologies

Although the arrangements of Figure 10 and much of the subsequent discussion may apply to arbitrary kinds of vibrating elements, the subsquent sections specifically address string array technologies due to their additional adaptations to autoharps and resonant sympathetic strings employed in various traditional instruments.

2.2.1.1 Mechanical String Dampers: Chord Buttons and Keyboards

In the the modern autoharp, a mechanical chord damper bar arrangement is used to select which notes are allowed to sound and damp the vibration of the remaining strings with a vibration-damping materal such as rigid felt.

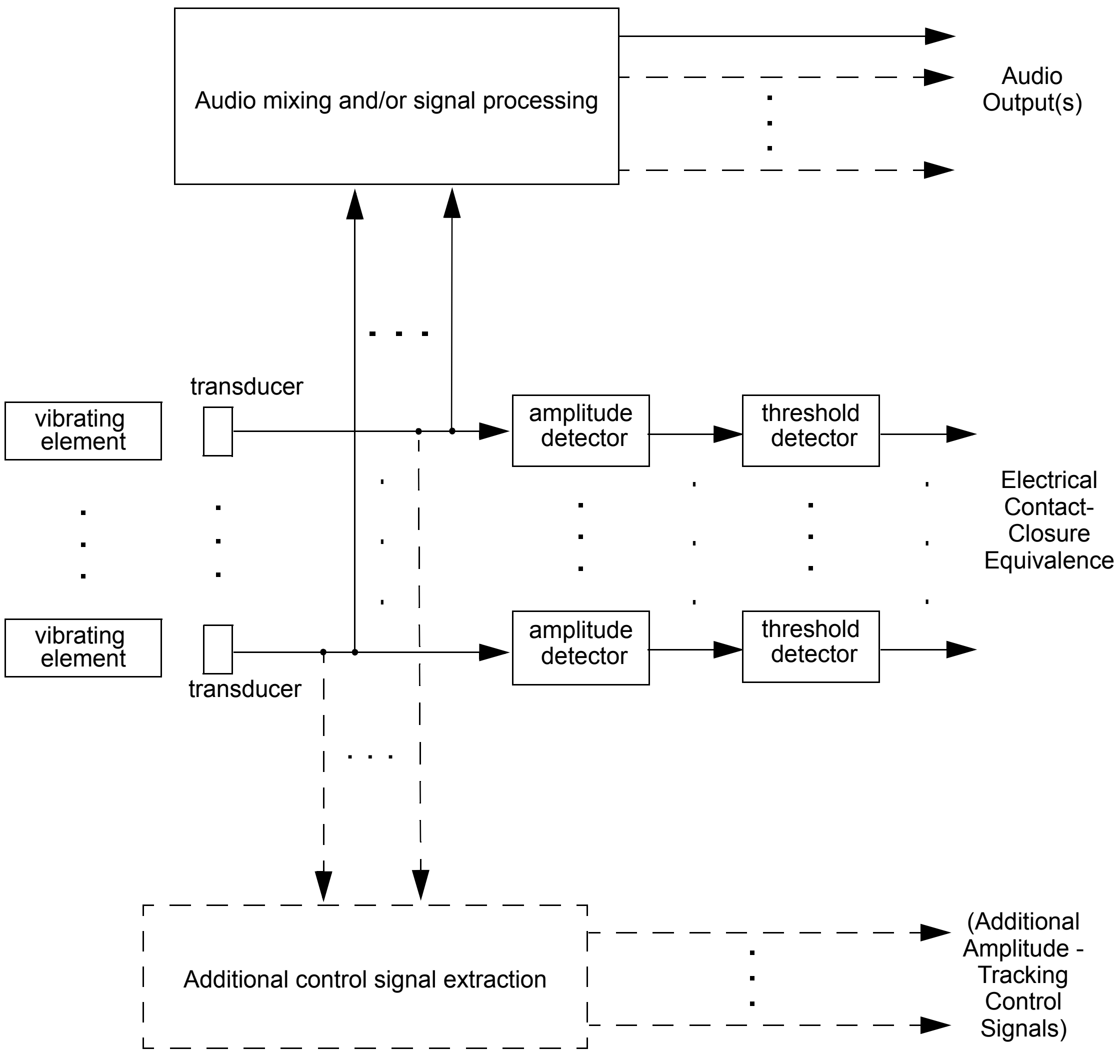


Figure 10

Alternatively, a 12-note chromatic keyboard or similar arrangement may be used for selecting which chromatic notes are allowed to sound. The earliest patents of the autoharp [22]-[26] employ chromatic keyboard-operated dampers rather than chord button-operated dampers. This requires damper bars to normally damp selected strings and let those wanted strings sound only when a key or button is depressed (rather than damping only unwanted strings when a key or button is depressed). In this way more arbitrary chords can be selected, chords can be dynamically changed at a resolution down to one pitch at a time, etc.

In whatever way the strings are mechanically damped, the mechanical buttons or keys may be fitted with electrical contacts, buttons, or sensors so as to generate corresponding electrical control signals. These may be used to electronically select which strings are allowed to produce recognized note-event control signals, as well as to issue associated chord note events or other control signals. The aforementioned electronic selection of strings may also involve selection of which strings are to produce audio signals so as to reduce some of the noise created when damped strings are strummed.

2.2.1.2 Replacing String Dampers with Electronic Attenuation and/or Pitch Shifting

With a separate pickup provided for each string, mechanical string damping may be replaced with electronic amplitude control and/or electronic pitch shifting. The output signal amplitude and/or pitch of each string may be determined by the chord control interface, incoming control signals, etc. Many variations of this are possible. In one approach, only some strings are selected for audio sounding and strumpad emulation, and others are disabled under the control of the chord control interface. The chord control interface may recall a stored program contaning this information, or may control the affairs of each string directly. As a simple example of the later, all strings of various octaves of the same pitch are gated on and off by the depression of the key on the keyboard associated with that note.

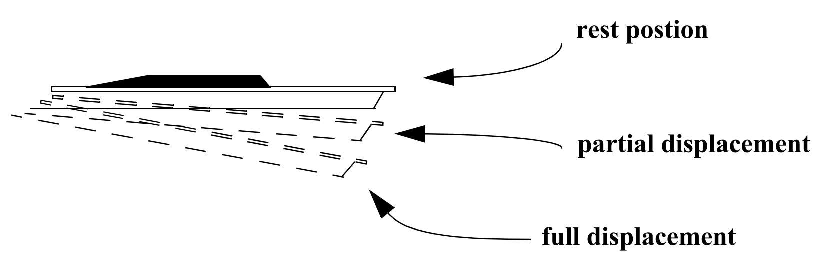


Figure 11

In an enhancement, each keyboard key or chord button of a physical chord control interface may be fitted with a depression-depth or total pressure sensor so that the overall displacement can be measured. (Figure 11 illustrates this for a pivoted keyboard key.) The resulting sensor signal may be used as a volume control for the relative volume of all notes associated with that physical keyboard key or chord button. The volume control may affect the note-on velocity value, or cause generation of a continuous controller message.

If a key or chord button further has two-dimensional touch sensing, as with a null/contact touch-pad on the key or chord button [9]-[10], additional parameters may be controlled by the fingers actuating the key or chord button. These additional parameters may be used to control sound production parameters, lighting, or for additional strumpad emulation as described earlier.

In another type of implementation, each string in the string array is always active, but the pitch of audio signal is shifted under the control of the chord control interface. In this situation, the pitch of the issued note events is adjusted to match that associated with the selected notes provided by the chord control interface.

2.2.1.3 Multichannel Signal Processing and Generalized Interface

Individual audio signals from each vibrating element may be handled by multi-channel signal processing (for example, treating the strings with differing degrees of equalization, chorus, reverb, pitch shift, dynamic filter sweeps, etc., and/or providing separate noise gates, compression, limiting, amplitude control, etc.) as described in [6] and carried by a multichannel electronic music instrument interface [7]. The multichannel signal processing system may also provide the functions described above, and associated with Figure 10. An example of such a multichannel signal processing system is depicted in Figure 12.

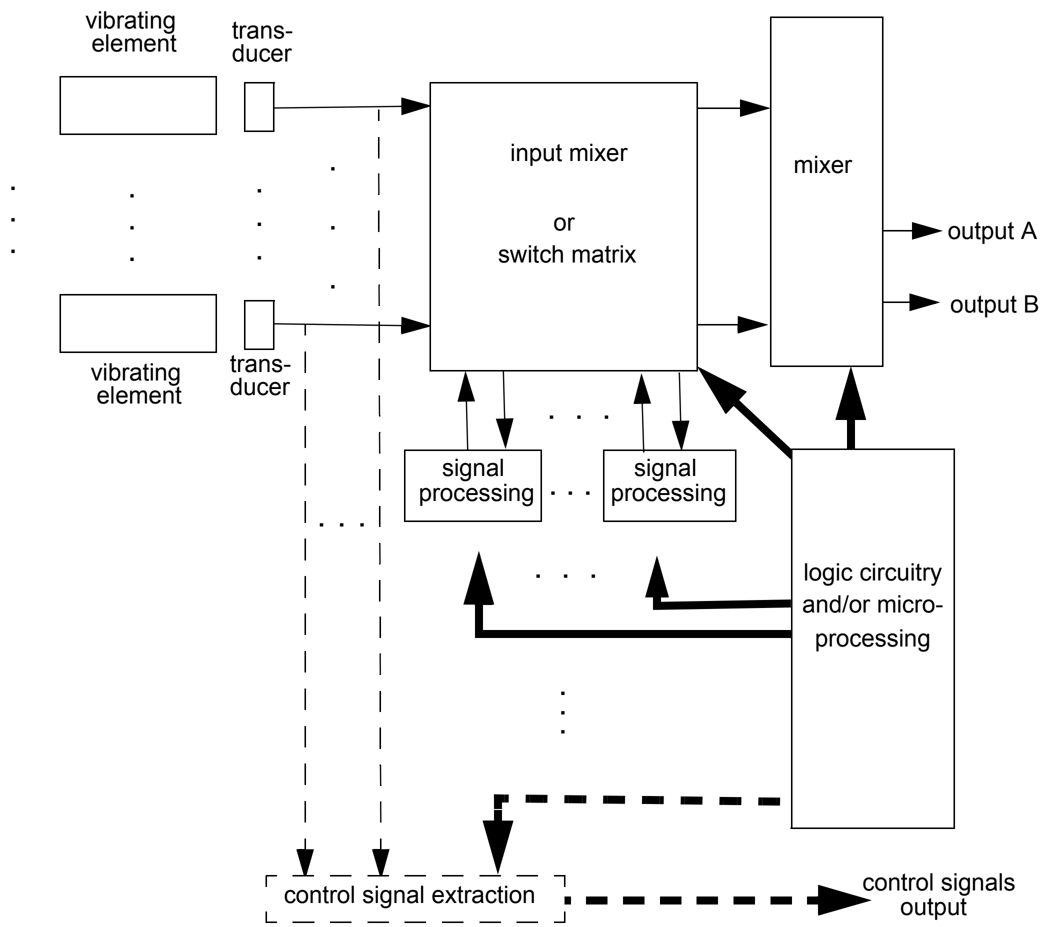


Figure 12

3 Chord Control Interfaces

In this section, the chord control interfaces introduced in Figure 2 are considered. Examplary general features include:

- simultaneous multiple switch activation without perceivable interaction
- generalized note event information that can be assigned interpretation under program control

- more generalized strumpad interpretation software and hardware with the following stored program attributes and assignments which can be rapidly altered during playing:
    - assignment to selected melodic notes, percussive events, lighting or special effect events, etc.
    - arpeggio pattern select
    - note-repeats added as desired and in the manner desired
- issuance of note, outgoing program change, and/or other control signals at the initial activation of each stored program (to sound a background chord, activate lights, etc.) with or without activity on the strum-pad
- selection and rapid change of specific programmable attributes and assignments via button, foot-switch control, or other control signal source.

The chord control interface may be in general configured to accept input from one or more of the following input sources:

- buttons
- footswitches
- derived from keyboard
- derived from pitch detection (for example, guitar MIDI)
- incoming MIDI control signals

These chord control interface arrangements are now considered in further detail.

3.1 Control by Button and Foot-Switch Control

The method for implementing a chord control interface that is most directly associated with the contemporary autoharp is that of chord buttons. Figure 12a shows a strumpad module comprising a number of electronic chord control buttons. The hybrid autoharp arrangement of Figure 8a shows a number of electronic chord control buttons attached to the mechanical chord control buttons of a traditional autoharp. In the later arrangement, either the strings or the strumpads may be used to trigger note events determined by the chord control control interface.

Alternatively, or in addition, footswitches may be used as part of or the entirety of the chord control interface. In one arrangement, footswitches may select the assignments made to the electronic chord control buttons of Figure 13a or other similar systems. In another arrangement, footswitches may duplicate the selections of these chord buttons, or serve to select the chords employed in the configurations of Figures 6b, 7a-7c, 8b, or other similar systems. In either of the above arrangements, the footswitches may generate special control signals or simply provide MIDI program change or MIDI note event messages to a MIDI-controlled chord control interface implementation (see section 3.5). Such an approach allows some footswitches to control other systems.

Figure 13b shows an arrangement of twelve footswitches. Two of the 5e may be used to scroll up or down among settings for the other ten footswitches as is common in commercial MIDI floor controllers. Alternatively, two or more of the footswitches may be used to make hierarchically determined selections as covered in U.S. Patent 6,689,947 [14]. Figure 13c illustrates an arrangement of twenty-four footswitches, in keeping with the 15-21 chord buttons found on modern autoharps. Arrangements with larger numbers of footswitches are considered in U.S. Patent 6,689,947 [14].

Figure 13a

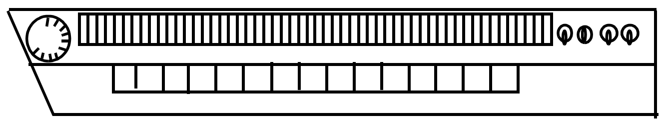


Figure 13b

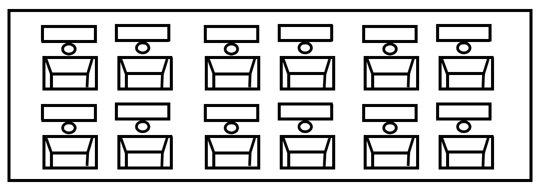
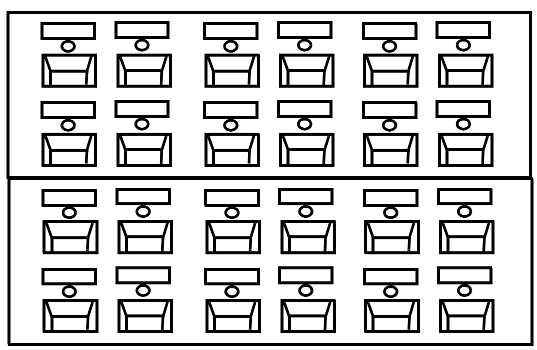


Figure 13c



3.2 Control by Keyboard

As indicated earlier, a chromatic keyboard may be used as the chord control interface. In one implementation, both issued chord notes, and the notes assigned to actual or emulated strumpad contact-closure events, may be directly determined by the keyboard. In another implementation, specific combinations of keyboard notes may trigger the recall of a stored program in the arrangements of Figures 3 or 9. In either of these arrangements, the keyboard may generate special control signals or simply provide MIDI note event messages to a MIDI-controlled chord control interface implementation (see section 3.5). Such an approach allows the same keyboard to also control synthesizers and other systems.

Listed below are some examples of various settings and instruments where keyboards may be used as chord control interfaces for associated strumpads:

- In the keyboard arrangement of Figure 8a, note assignments to the strumpads may be made responsive to chords most recently held, or scales most recently recognized.
- In the autoharp arrangement of Figure 14, the keyboard both controls mechanical dampers as in the early autoharp patents [22]-[26], as well as the chord control interfaces for associated strumpads.

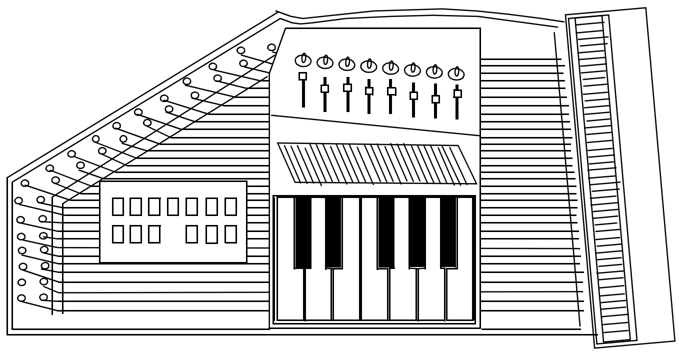


Figure 14

- In the advanced electronic guitar arrangement of Figure 15, one of the two-tiered miniature keyboards may be used to control note assignments to the strumpads responsive to chords held, most recently held, or scales most recently recognized.
- In the advanced sitar arrangement of Figure 16, the miniature keyboard may be used to control note assignments to the strumpads responsive to chords held, most recently held, or scales most recently recognized. (Use of the strumpad in the context of the traditions of South Asian stringed instruments is discussed in more detail later.)

3.3 Control by Pitch-Detect

By employing standard guitar-controlled synthesizer and pitch-to-MIDI technologies, the pitches of individual strings of a stringed instrument may be used to identify notes actively or most recently played. Other pitch-to-MIDI and related technology directed towards the human voice, wind instruments, etc. may also be employed to identify notes actively or most recently played. After this identification is done, the chord control interface technology described above in the context of keyboards may be applied directly. Listed below are some examples of various settings and instruments where keyboards may be used as chord control interfaces for associated strumpads:

- In the advanced electronic guitar arrangement of Figure 15, notes played on the guitar strings may be used to control note assignments to the strumpads responsive to chords held, most recently held, or scales most recently recognized.
- Similarly, the two-tired strumpad module of Figure 6b may be applied to a conventional electric guitar in place of, or attached to, the guitar pickguard as

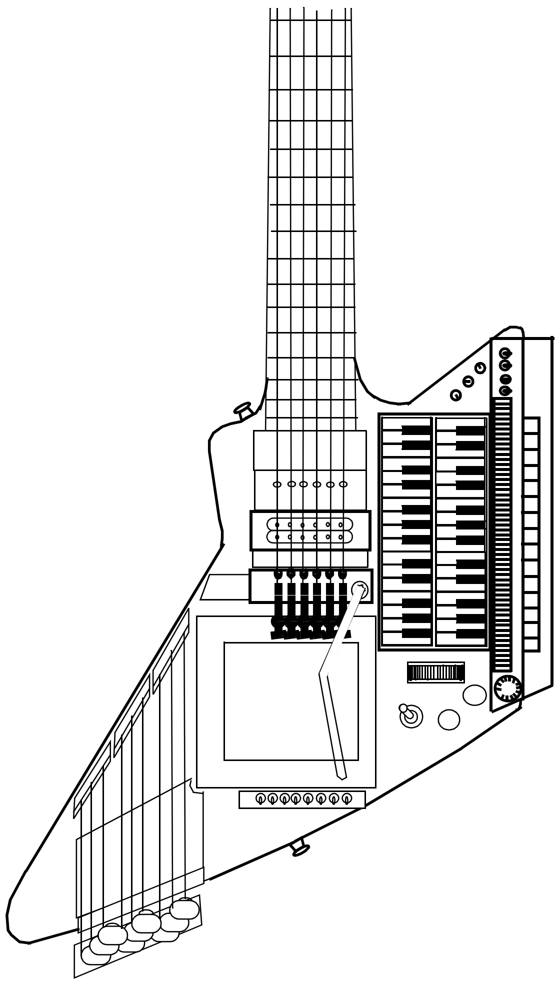


Figure 15

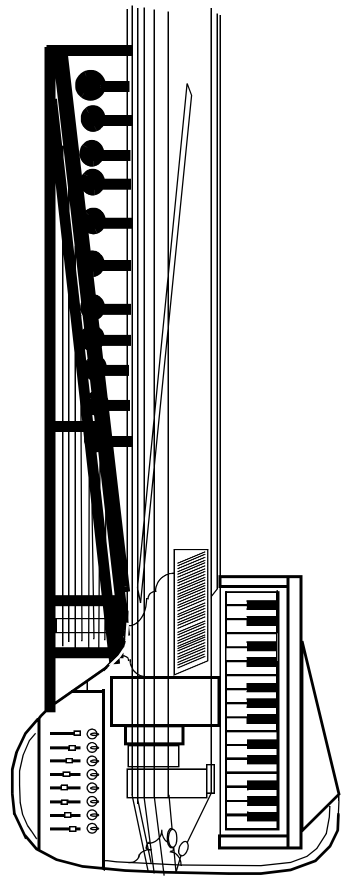


Figure 16

shown in Figure 17. Notes played on the guitar strings may be used to control note assignments to the strumpads responsive to chords held, most recently held, or scales most recently recognized.

3.4 Control by Incoming Control Signals

As discussed earlier in the context of Figure 3, Figure 9, and elsewhere, incoming MIDI control signals such as MIDI program change and MIDI note events may be used as input to a chord control interface. In the case of incoming MIDI program change messages, stored programs as employed in Figures 3 and 9 may be directly recalled. In the case of incoming MIDI note events, there are at least two approaches:

- specific combinations of incoming MIDI note events may trigger the recall of a stored program in the arrangements of Figures 3 or 9.

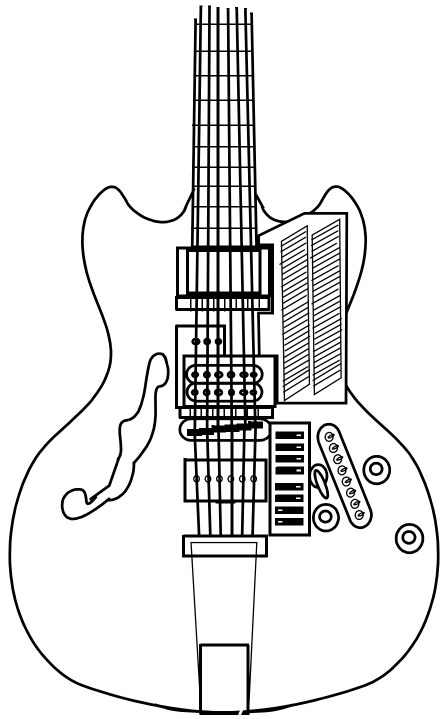


Figure 17

- notes assigned to actual or emulated strumpad contact-closure events may be directly determined by the incoming MIDI note events.

4 Example Add-On Strumpad Modules

In addition to instruments built around strumpad technologies or which build in strumpad technologies as an accessory, U.S. Pre-Grant Patent Application 2004/0069129 also provides for add-on modules for attachment to guitars, keyboards, and a wide variety of other existing instruments. In any of these, free fingers can then, while playing the guitar as normal, "strum" or tap arpeggios, trigger percussion devices, trigger lighting or special effect events, etc.

As shown earlier, the two-tired strumpad module of Figure 6b may be applied to a conventional electric guitar in place of, or attached to, the guitar pickguard as shown in Figure 17. Figures 18a and 18b show, respectively, a flat-mount and inclined strumpad element which may connect to a support electronics and connector module such as that depicted in Figure 18c. Alternatively, the support electronics may be miniaturized (using for example surface-mount components) and entirely included within the housing of the strumpad elements of Figures 6b, 18a and 18b, in which case a power and connector mounting function may be

Figure 18a

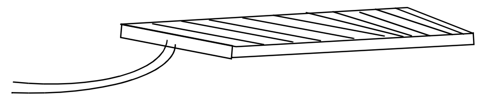


Figure 18b

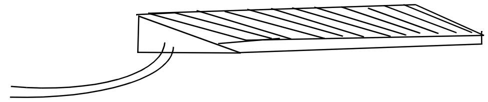
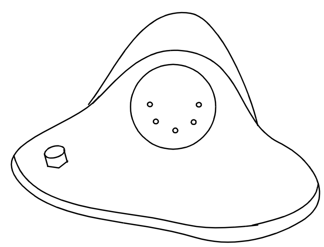


Figure 18c



all that is required of the module depicted in Figure 18c. These may produce a fixed assignment of MIDI note events, or accept incoming MIDI control signals as a chord control interface. In the case that the modules of Figures 6b, 18a and 18b produce a fixed assignment of MIDI note events, external MIDI processing may be used to impliment the mapping functions depicted in Figure 9. Any of these arrangements may be used in conjunction with foot-switches, finger-activated buttons, or pitch detection to select stored program interpretations or note event mappings. In the case where the entire MIDI interface may be built into an electronic instrument such as an electric guitar, electric violin etc., or otherwise itself provides MIDI output (as in the case of a MIDI keyboard instrument or controller), the keyboard and/or pitch-detection chord controller configurations described earlier may be applied.

Add-on modules may also include an internal chord controlled interface. An example of this was described earlier in the context of Figure 13a. Additionally, modules could be custom designed for specific instruments such as the autoharp, permitting adaptations such as that depicted in Figure 8a. Here, a conventional autoharp with the usual arrangement of strings and damper-bar activating chord buttons may be fitted with a long strum-pad adjacent to the traditional strumming area, one or more shorter strum-pads near the chord button area, a plurality of slider controls and control switches and control buttons for stored program recall, operational mode control, or other features.

Add-on modules may also be parts of a more complex add-on module, such as the keyboard, strumpad, and chord-button block depicted in Figure 15 as attached to a Gibson Explorer™ style electric guitar, or the simpler keyboard and strumpad block for attachment to a sitar or other South Asian stringed instrument as depicted in Figure 16.

5 Further Applications of Strumpad Technologies

In this section, some previous and additional examples are considered from this perspective in further detail. As mentioned earlier, strumpad technology may be built into an instrument.

5.1 Example Chord Button Controlled Enhanced Autoharp Implementations

Figure 8a depicts an autoharp to be supplemented with sliders, switches and buttons for issuing control signals. In particular, a select group of buttons or contacts can be operated by, or in conjunction with, the mechanical damper bars. This group of buttons or contacts may be used to control at least one of the following: issued note control signals for sound, lighting, and/or special effects, note assignments to one or more strum-pads, and/or the amplification of individual strings.

The individual strings of the autoharp are provided with an individual pickup for each string. In addition, it may include one or more of the following:

- a common pickup for the entire group of strings
- a plurality of smaller pickups associated with sub-groups of strings, or

These pickups may be any of electromagnetic, piezo, optical, etc. in their operation. In cases where a plurality of pickups is employed, signals from groups of strings or individual strings may be handled by multi-channel signal processing as described earlier (for example, treating the strings with differing degrees of equalization, chorus, reverb, pitch shift, dynamic filter sweeps, etc., and/or providing separate noise gates, compression, limiting, amplitude control, etc.).

Strum-pads are provided for use in conjunction with strumming the strings or in conjunction with operating the mechanical chord dampers. A long strum-pad may be provided adjacent to the traditional strumming area, and one or more shorter strum-pads may be provided near the chord button area. Also potentially provided are a plurality of slider controls and control switches and control buttons for stored program recall, operational mode control, or other features. Stored program recall may be used to determine control signal assignments, strum-pad voicings, etc. as well as operational features such as muting or sustaining of strum-pad notes, whether notes issued at the pressing of a chord damper bar are released when the damper bar is released, or instead only when a new bar is activated, etc. These control features may also be controlled remotely, for example, with a foot controller, and/or implemented remotely in separate signal routing, processing, and sound synthesis entities.

Additionally, the plucking of a particular string may be used to trigger a synthesizer note, lighting, or special effect event, potentially using the amplitude of the pluck to set note velocity, and potentially tracking the ongoing string amplitude and even harmonic structure variations, as provided for in the invention and described later.

Figure 14 shows how the autoharp arrangement of Figure 8a can be adjusted to replace the chord button array and associated strum-pads with a keyboard and one or more strum-pads positioned over the keyboard. Various aspects of keyboard control, key-travel detection, and touchpad-enhanced key surfaces described earlier may also be included.

5.2 Pedal Steel Guitar Applications

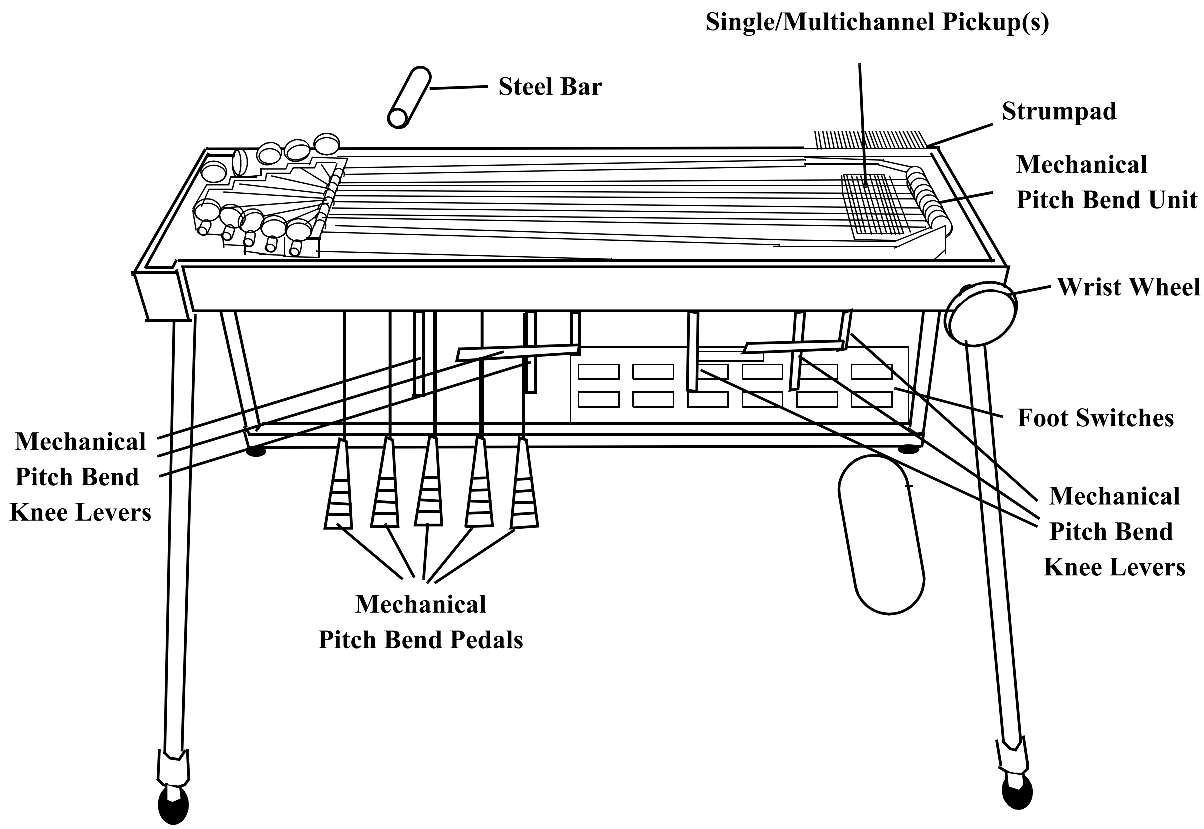


Figure 19

Figure 19 shows how a strumpad may be added near the picking area of a pedal steel guitar as provided for in U.S. Pre-Grant Patent Application 2004/0069129 [1] and U.S. Patent 6,852,919 [27]. The strumpad dected may be indeed built in or be introduced via an add-on module. The chord control interface may comprise use of the depicted floor controller and/or pitch-detection of the strings.

5.3 Sitar and Other South Asian Instrument Applications

Figure 16 illustrates a sitar with a strumpad, keyboard, and other electronics and enhancements as covered in by U.S. Pre-Grant Patent Application 2004/0069129 [1] and U.S. Pre-Grant Patent Application 2004/0099131 [12]. Alternatively, the sitar may be fitted with the modules of Figures 18a or 18b (and Figure 18c), thus resulting in a simpler result like that of Figure 20 (note sitar frets not shown).

In South Asian classical music traditions, the many sympathetic strings located along the long face performance surface of the neck under the curved frets fretted strings are tuned to the scale used in the raag (raga), ghazal, or other musical piece. At the opening and in other parts of the performance of the piece, these sympathetic strings are picked or strummed, providing a first natural application for a strumpad located as shown in Figures 16 and 20. Additionally, in the exposition of the raag, segments of the scale and certain note phrases intrinsic to the raag are stylistically rendered in an improvisitory or semi-inprovisational fashion. This provides a second natural application for a strumpad located as shown in Figures 16 and 20. Further, in the traditions an additional drone string instrument (ie.g, the tanpura) is slowly sequentially strummed by an additional performer. The drone strings are configured to produce a very long-duration sustained buzzing tone which needs only occassional stoking and is quite forgiving as to inconsistant timing. This offers a third natural application for a strumpad located as shown in Figures 16 and 20, employing the strumpad to trigger sampled or synthesized drone sounds of this type. Among these applications, there may well be application for two, three, or more strumpads to be added to the instrument. In the tradition, the raags are well-defined and thus may be pre-programmed into the strumpad system. The scales and phases associated with a raag may also be entered by keyboard, such as the keyboard depicted in Figure 16 (which may also be used for a harmonium or smooth bowed-string sound as employed in ghazals) or a remote MIDI keyboard for the simplified arrangement depicted in Figure 20.

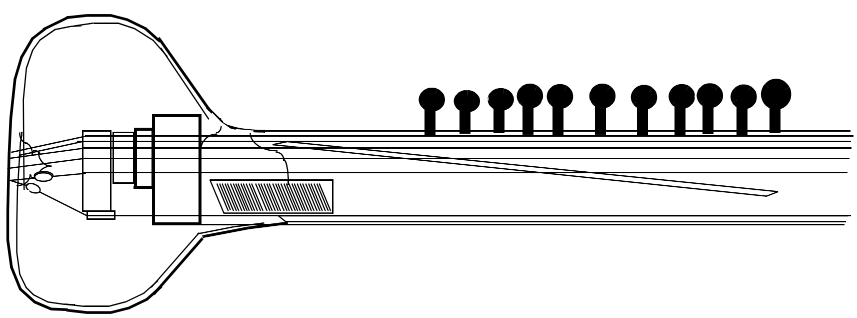


Figure 20

In a similar way, the strumpad technology described also serves as a valuable accessory to other traditional South Asian melodic instruments, including the sarod, saringi, veena, dilruba, esraj, tanpura, santoor, harmonium, bulbbul tarang, seni rabab, etc.

5.4 East Asian Instrument Applications

Strumpad technology may also be applied to a number of East Asian instruments as provided for in U.S. Pre-Grant Patent Application 2004/0069129 [1], U.S. Pre-Grant Patent

Application 2004/0069127 [13], and related pending patents [6]-[7]. Some East Asian music traditions provide a natural application for a strumpad technologies and their emulations with string arrays:

- Strings of the Japanese koto, Chinese sheng, and Chinese pipa may be arpeggiated while melodies are played on other strings or by other instruments.
- Some or all strings of the Japanese koto and Chinese sheng (gu-zheng) may be sequentially strummed in the sequence of ascending and/or descending scale.
- The Chinese pipa tradition employs many percusive and multi-timbral sound production techniques, typically involving motions and tappings of the string-plucking hand.

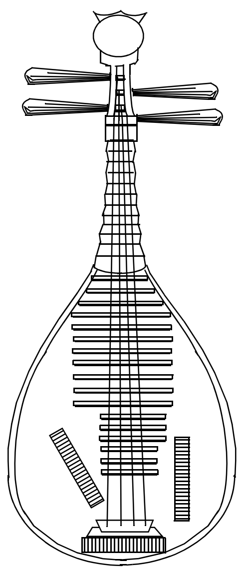


Figure 21a

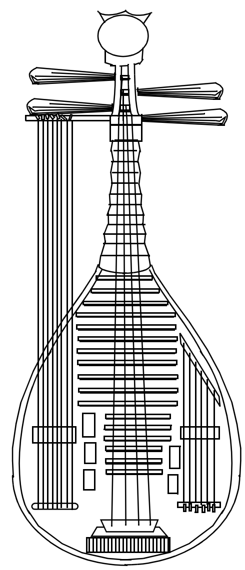


Figure 21b

Figure 21a illustrates three possible strumpad locations for the Chinese pipa, assuming the traditional playing position with the neck pointing essentially upright. The vertically-oriented strumpad may be operated by the fingertips of the string-plucking hand. The horizontally-oriented strumpad may be operated by the fingertip of the small end-finger of the string-plucking hand. The strumpad with slanted orientation may be operated by the thumb of the string-plucking hand, and may be additionally curved to more readily capture the natural arching sweep of the thumb. Any one or more of these strumpad locations, as well as others, may be used.

Figure 21b shows an electronic pipa fitted with a number of additional tunable fixed-vibrating-length strings, as well as one horizontally-oriented strumpad as described above. Here the additional fixed-vibrating-length strings may be used for both amplified sound, and as triggering elements in a strumpad emulation.

Figure 21b shows an electronic koto fitted with a long strumpad along the bridge where string plucking takes place. This location easily facilitates operation with either hand in the rending of note arpeggitions, sequentially strummed scale segments, or melodic phrases, as may find value in contemporary koto performance.

In a similar way, the strumpad technology described also serves as a valuable accessory to other traditional East Asian melodic instruments, including the Chinese yang-chin and gu-qin, bowed Chinese erhu, and large families of equally rich related instruments from Korea, Viet Nam, Thailand, Cambodia, and other East Asian countries.

5.5 Traditional African Instrument Applications

Strumpad technology may also be applied to a number of traditional African instruments as described in U.S. Pre-Grant Patent Application 2004/0069129 [1], U.S. Pre-Grant Patent Application 2004/0069126 [6], and U.S. Pre-Grant Patent Application 2004/0065187 [7] ,with additional patents planned.

Figure 24 shows an exemplary traditional African kalimba, here fitted with four strumpads. The kalimba comprises a number of vibrating tynes. If the kalimba bridge is adapted to support a separate vibration sensing transducer for each string, the resulting signals may be used for both amplified sound, and as triggering elements in a strumpad emulation.

Figure 25a shows a line drawing of a traditional African Kora (which may be found in the public domain as www.coraconnection.com/images/transkora3.gif), while Figures 25b-25c shows Robert Grawi's electronic adaptation called the "gravichord" (see U.S. Patent 4,481,856 [16], where base instrument diagram is published for public use, as well as the associated article [17]), here shown fitted with a strumpad on either side of the strings. One or more strumpads may be located in other positions on the gravichord as well. Further, if the gravichord bridge is adapted to support a separate vibration sensing transducer for each string, the resulting signals may be used for both amplified sound and as triggering elements in a strumpad emulation.

The traditional African kalimba, traditional African kora, and intended tuning of the gravichord each employ alternating-side tuning systems such as the one depicted in Figure 26. This is in contrast to the linearly ascending pitch tuning arrangements found in many stringed instruments. One result of the tuning is that linear struming of, for example, the kora (or gravichord) strings produces a pleasant melodic quality which is lucidly used both as ornimentation and melody component in associated musical traditions. By introducing strumpads as shown in Figures 25b-25c, not only may other timbres and melodic voices be introduced, but opportunities for access to the same or opposite alternating scale segments may be readily provided. The strumpads also provide opportunities for melodic phrases as may find value in contemporary performance.

Figure 27 illustrates a traditional African mbira, also shown fitted with four strumpads. Like the kalimba, the mbira comprises a number of vibrating tynes. Unlike the kalimba, the mbira typically does not employ the tuning of Figure 26, but rather one involving three rough partitions of pitch into three registers (see for example [18], its Figure 5 on p.55].

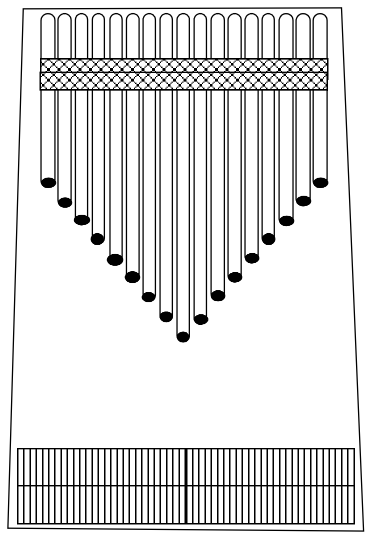


Figure 24

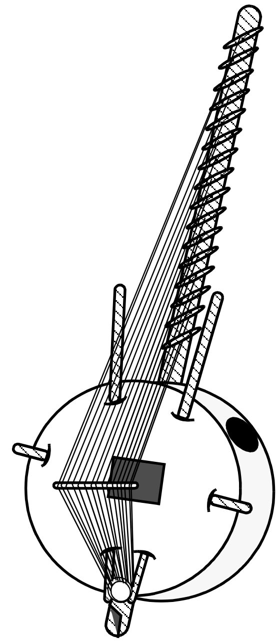


Figure 25a

Thus, by introducing strumpads as shown in Figure 27, not only may other timbres and melodic voices be introduced, but opportunities for access to the same or opposite alternating scale segments may be readily provided. The strumpads also provide opportunities for melodic phrases as may find value in contemporary performance. As with the kalimba, if the mbira bridge is adapted to support a separate vibration sensing transducer for each string, the resulting signals may be used for both amplified sound and as triggering elements in a strumpad emulation.

5.6 Wind Instrument Applications

U.S. Pre-Grant Patent Application 2004/0069129 [1] provides for strumpads to be attached to, or incorporated into, electronic or acoustic wind intruments. Figure 28a illustrates two locations where strumpads may be located on a Western flute for thump operation. Other arrangements are also possible for these and a wide variety of other wind instruments.

5.7 Percussion Instrument Applications

Strumpads to can be attached to, or incorporated into, electronic or acoustic percussion instruments. These may include unpitched percussion instruments, such as hand drums, stick-striken drums, etc. as well as pitched percussion instruments, such as bell trees, xylophones, mirimba, orchestra bells, chimes, triangles, etc, The strumpads may be operated by hand,

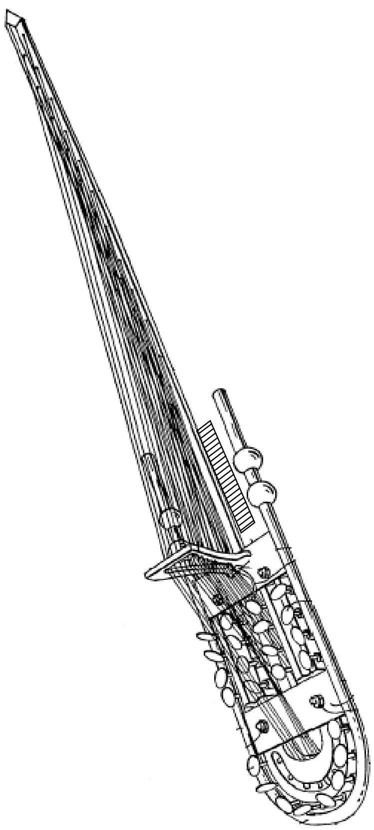


Figure 25b

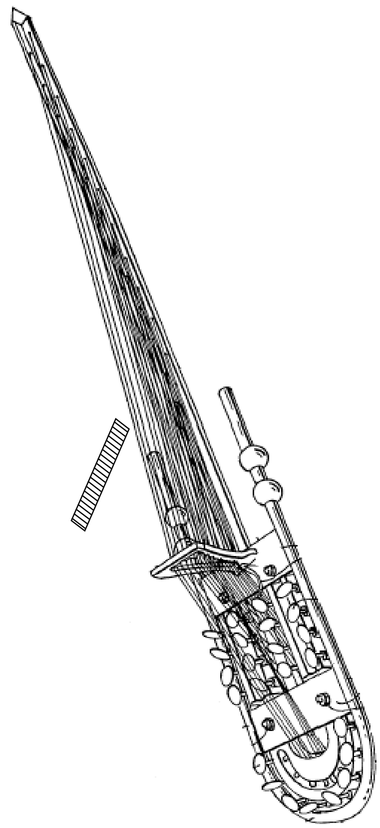


Figure 25c

stick or mallet. Additionally, a percussion instrument stick or mallet itself may be fitted with a strumpad. Figure 29 depicts an example where a strumpad is provided on a portion of the handle of a percussion instrument mallet. Other arrangements are also possible for mallets, sticks, and a wide variety of percussion instruments.

6 Licensing

This document has sought to explain and illustrate the concept of the strumpad and related technologies covered by issued and pending New Renaissance Institute®. patents, as well as demonstrate the potential scope and areas of application. Further information regarding reference designs for these technologies can be provided under negotiable terms. All financial or in-kind proceeds from such arrangements are used to fund academic research at New Renaissance Institute®. For further information, please contact New Renaissance Institute® at inquiries@newrenaissanceinstitute.com.

Figure 26

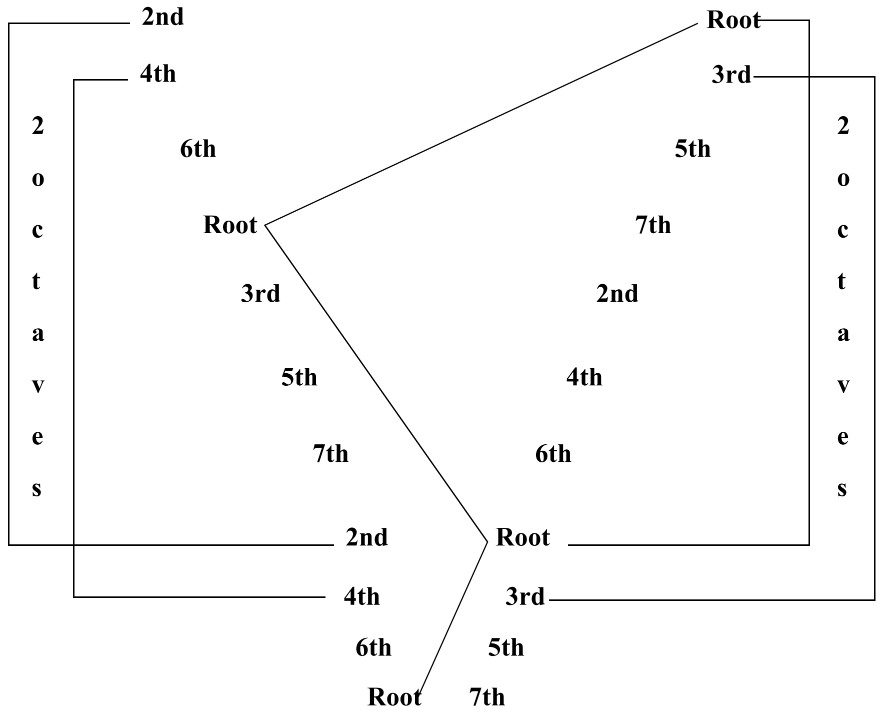
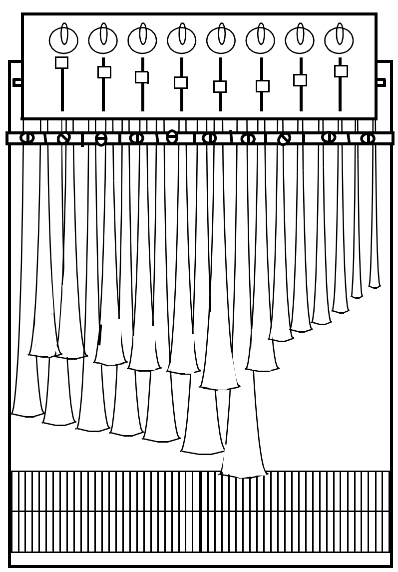


Figure 27



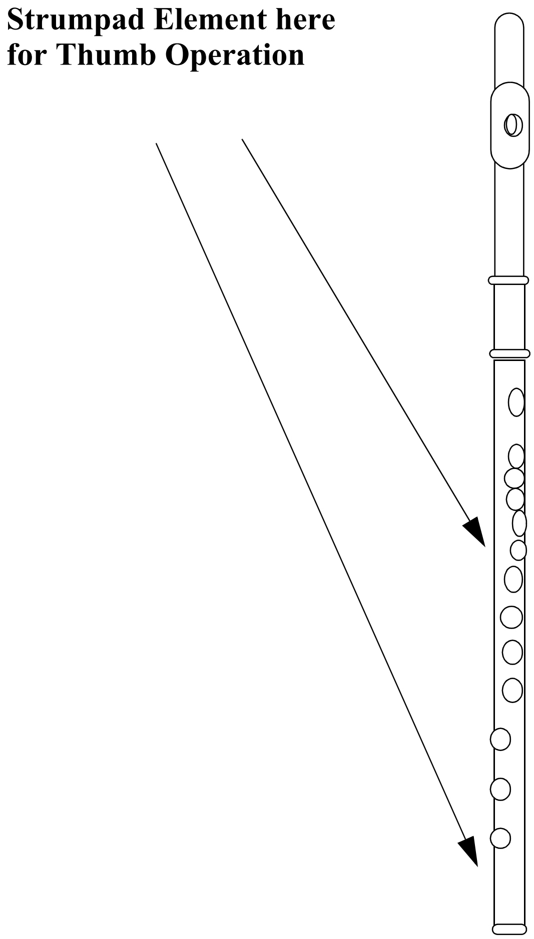


Figure 28a

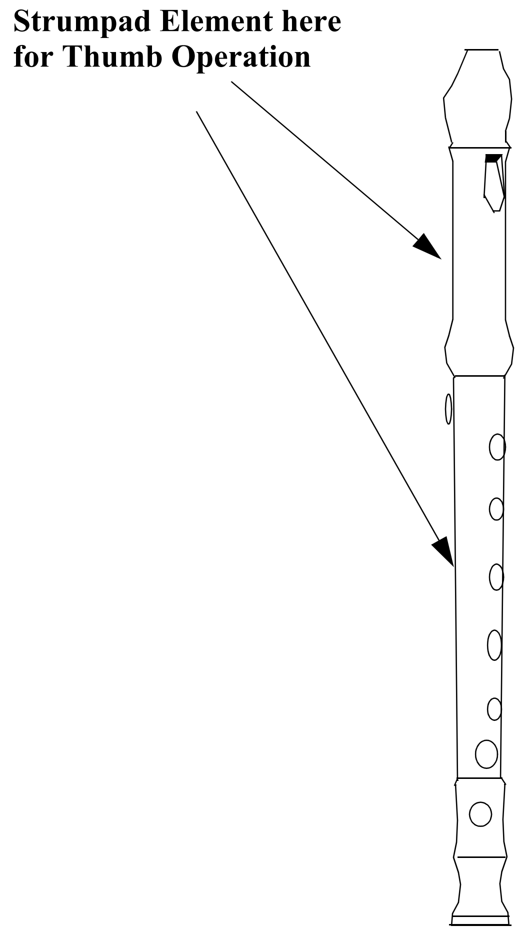


Figure 28b

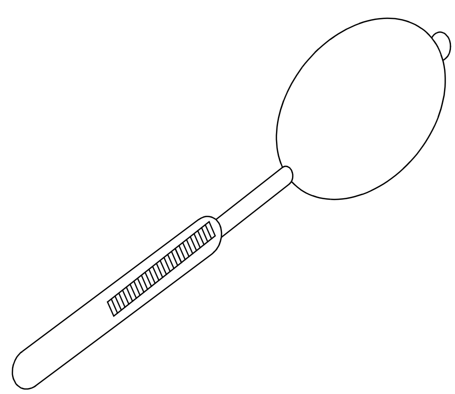


Figure 29

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[15]U.S. Pre-Grant Patent Application US 2005/00126378, "Modular Structures Facilitating Field-Customized Floor Controllers," June 16, 2005.

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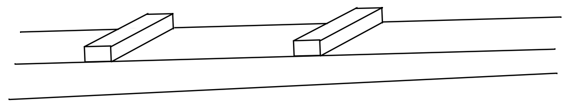
Figure 14f



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