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article

# Playing Electronics with Mallets Extending the Gestural Possibilities

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## Abstract

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The design of new instruments for real-time electronic performance usually takes one of two approaches: a controller either mimics the standard technique of an existing instrument, often dumbing down the interaction between the performer and the simulated instrument in the process, or a novel sensing technology is employed on its own merits in an alternative controller, requiring the invention and mastery of a unique playing technique. There is a middle ground. Elements of traditional instrumental technique that are normally taken for granted but not usually associated with broad musical expression can be captured and used as general controls.

Are there elements of traditional percussion keyboard technique that are easily captured and that can be comfortably used to control electronic synthesis? This paper examines the nexus between the sensing of instrumental gesture and the way gesture is mapped to MIDI synthesizers in common performance practice focusing on mallet percussion controllers. The current state of the art in mallet controllers is reviewed, and a new controller, the Marimba Lumina is described. The Marimba Lumina extends the performance capabilities of the mallet percussionist while preserving the traditional mallet keyboard technique, demanding very little in the way of new skills on the part of the player, but allowing normal playing movements to be used in novel ways.

## Introduction

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MIDI controllers that emulate the percussion mallet family (marimba, xylophone, vibraphone, glockenspiel) give a player the ability to access contemporary synthesis technology. However, the ability of these controllers to map performance gestures to sounds is limited. Traditionally, mallet controllers have offered little more than an array of triggers that produce velocity-sensitive note-ons when the bars are struck. The generation of the corresponding note-off is often left to the sound module, or is sometimes computed as a function of the note-on velocity. Such a constrained interface is adequate in many playing situations - most notably when a controller is used to replace an actual mallet instrument; but when a virtuoso approach is desired, with a high degree of musical expressivity, and especially when the synthesized sounds are not percussive at all, the limitations of simple note-on triggering are obvious.

These limitations are not a function of the instrument itself, rather they are consequences of the sensing technologies employed and the way in which the sensed data is mapped to musical parameters. It is possible to build a mallet controller that can sense a broader variety of gestures that are already a part of the physical act of playing a mallet instrument and are a conscious part of the player's technique. Moreover, these gestures can be mapped to control electronic synthesis in a comfortable, familiar, and satisfying way.

## Capturing Gesture: tracking versus triggering

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Musical controllers transduce what has been termed "instrumental gesture." These are the primary actions employed by a performer. Many schemes for categorizing instrumental gestures have been proposed (see Cadoz and Wanderley in this volume). It is important to note that no matter what the scheme, all gestures can be categorized as either discrete *events* (e.g., change in bow direction, striking a drum head, pressing a key) or continuous *signals* (e.g., bow/breath velocity, pitch modulation). In neurophysiological terms these actions are ballistic or coordinated (Goldstein, 1998).

Coordinated gestures create signals that must be *tracked*, while ballistic gestures accompany events that are *triggered*. It is important to note that in many cases an event need not be sensed directly, it can be derived from a signal. A stroke on a bar, for instance, can be detected by the location of a mallet passing through a plane some distance above the bar, or by the change in the sign of the velocity of a mallet.

The manner in which events and signals are triggered and tracked, the technology used, will directly affect the "feel" of a controller. Piezo-electric sensors, force-sensing resistors (FSRs), and light-beam tracking can each be used to detect a striking action, but to a player, each has a particular response, and the peculiarities of each mode of sensing may or may not be directly exploitable as a component of playing technique.

Finally, signals must be controllable. The player should be able to reproduce a time-series of values with a small amount of variation. The acceptable variance will be determined partly by the dynamic range of the physical gesture itself, and also by the scale of the musical parameters that the gesture will ultimately control.

## **MIDI Control 1: Mapping keyboard gestures to musical parameters**

The standard protocol for the control of synthesis modules, MIDI, has been widely adopted at the same time as it has been vilified for its shortcomings. As a practical matter, the creation of a new mallet controller should begin with the goal of utilizing as much of the resources that MIDI allows. An analysis of the use of MIDI in live performance, by keyboardists, reveals three prime dimensions of control:

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### Note gating

The ubiquitous note-on and note-off is the bane of MIDI control. While keyboardists take for granted the ability to control the ends of their notes, mallet players usually rely on the fixed envelope of the instrument itself (acoustic or sampled) to determine note duration. With sustainable sounds, the ability to precisely control the end of a note is an important musical resource. It is used for precise rendering of notes and rests, and for achieving legato/staccato articulation between a succession of notes.

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### Parameter modulation

MIDI parameters are usually modified by manipulating extra devices that are foreign to the native technique of the instrument: pitch wheels, mod wheels, ribbon controllers, foot pedals, breath controllers. These constrain the ability to use both hands and may also require the mastery of a completely new coordinated technique. Polyphonic keyboard aftertouch was a promising feature of the MIDI specification, but most performers find this mode of control very difficult to use. It is difficult to reproduce an exact pressure with a single finger and even harder to coordinate the pressure of many fingers simultaneously.

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### Multi-timbral performance

Contemporary keyboard players rarely limit themselves to a single MIDI timbre. In fact, to overcome the monotonous homogeneity of synthesized sound they often layer voices on top of each other, sometimes changing the balance in real-time via a foot pedal or by velocity-mapping. Quite often timbre assignments may change during the course of a single song. This can be done by using multiple keyboards, or foot switches, or also with a keyboard split. In a keyboard split, the keyboard is divided into non-overlapping zones, each range of notes is assigned a different timbre. Keyboard splits make a variety of timbres available quickly, but by segmenting the keyboard they also limit the range of notes available in each timbre.

## MIDI Control 2: Mapping percussive gestures to musical parameters, state of the art

Most MIDI mallet controllers are limited to triggered detection of strokes on bars. The instruments available today differ mainly in the types of playing surface and triggering sensors they employ rather than their performance features.

- The [XyloSynth](#) from Wernick is a controller that is built of wooden bars that are damped and do not sound. Strokes on the bars are detected by means of piezo-electric pickups installed on each bar. MIDI note-ons are generated, and note-offs are determined as a function of the note-on velocity. Performers choose this instrument because it has an excellent wooden "feel" that resembles playing a real marimba or xylophone and they can use their usual mallets. The XyloSynth does not offer additional controlling gestures apropos of mallet technique. On/off foot-switches may be attached to provide MIDI sustain and program change.
- [K&K Sound](#) makes an acoustic mallet pickup/amplification system that can be enhanced with the addition of a MIDI electronics package. MIDI note-ons are triggered whenever a bar is struck. Note-offs are detected from the decay of the acoustic signal of the bar itself, or as an option on a vibraphone, notes can be sustained when the sustain pedal is down and terminated together when the sustain pedal is released. In this sustaining mode, bars may only be struck once, they cannot be retriggered until the pedal is released. Players are attracted to this instrument because it is truly an extension of their acoustic one.
- [Alternate Mode](#) manufactures the Mallet Kat. This is a mallet controller that employs force sensing resistors (FSRs) under an array of rubber pads. Again, players can use their ordinary mallets. Many players enjoy the bouncy feel of the rubber playing surface. Because FSRs are used, a mallet can be held on the bar and pressed. This gesture can be used to implement a piano-like note-on/note-off gating technique rather than the typical mallet stroke. FSR pressure can also be used as an aftertouch controller, or to detect a damping stroke that terminates a note rather than starting a new one. The addition of this extra sensing mode is unique to the Mallet Kat, but it has problems. It is hard to control the pressure of the mallet on the bar accurately, so the aftertouch feature is difficult to use for subtle expressive effects. Furthermore, the FSR signal will always start at and return to zero. The mallet damping logic also requires careful calibration of multiple parameters. Some players also find that pressing a mallet into a bar is an uncomfortable gesture and over an extended period of time it can hurt their wrists. The Mallet Kat also provides inputs for foot pedals and foot switches that can be assigned to MIDI controllers, and there is an input for a breath controller. As with the extra wheels and

footgear on keyboards, these devices rely on auxiliary techniques not part of the normal mallet-playing art.

- The Mathews Radio baton, and the Buchla Lightning wands, while not mallet instruments per se, are notable for a unique feature they share. Both are played with two batons/wands, one in each hand, and each baton is sensed separately. The ability to recognize which stick is being used to strike an instrument can be an effective musical device. These instruments have other interesting features that are not within the scope of this paper.

## Mallet Moves Manqué — what's been missing?

The repertoire of instrumental gesture available on mallet instruments has not been exhausted. There are additional elements of mallet technique that can be sensed and intelligently used.

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### Choice of Mallet

Choosing which mallet to use to strike a note is similar to piano fingering, both facilitate execution. In mallet playing, the choice of mallet frequently involves additional musical considerations. Marimbists and vibraphonists commonly use four mallets, two in each hand. They are numbered 1,2,3,4 from left to right. Tone production across the range of an acoustic mallet instrument is not uniform. The lower bars are larger and often require softer, heavier mallets, while the higher bars are smaller and sound better when played with harder, lighter mallets. Some players will use a set of mallets of 2,3, or 4 different hardness. They will adjust their technique to use the softer mallets in the lower range of the instrument, and the harder ones in the upper range. This practice is very common in playing chorale-like literature. For rapid passages in different tessitures that require alternating sticking, a performer might use one pair of matched mallets 1/3, one in each hand, and another pair of different hardness for mallets 2/4. Sometimes, when playing a multiple percussion setup, one of the mallets may be a different type of stick or beater altogether, used to strike another instrument.

A well-trained mallet player has the option and the facility in many cases to select a particular mallet to sound a specific bar. A mallet controller that can sense which mallet is striking the bar can respond differently according to the mallet used.

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### Location of Mallet

Every mallet player must learn to strike the bars accurately. The best tonal response is obtained in the center or the extreme end of the bars. The nodal point, the part through which the bar is suspended, is usually avoided. Expert players select the location of a stroke to control the harmonic content of a note.

The vibist Gary Burton made popular the technique of bending vibe notes. He would place one hard mallet on a nodal point, pressing hard, and then strike the bar with a second mallet. By sliding the first mallet back and forth as the bar sounded, he could lower and raise its pitch.

Mallet players consciously control the playing location on the bars. Unlike pressure, mallet location is easily reproducible, comfortable, and can be coordinated between the hands. A mallet instrument that senses the location of a stroke on a bar can use the position as a synthesis parameter at note-on time. Furthermore, if the instrument tracks the mallet position as it remains on the bar, this signal can be used to modulate synthesis parameters continuously.

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### Stroke Type

Percussionists learn to produce sounds on mallet instruments with different types of strokes: starting from above, a quick down-up motion is performed. This full stroke contains a *downstroke*, which produces the tone, and an *upstroke*, the natural rebound. On vibes, *damping* strokes are used to stop notes. A mallet is pressed softly to a sounding bar and held for a moment. For a more dramatic effect *dead* strokes can be played: the mallet is brought down hard on the bar and held for a moment. The up stroke which naturally occurs whenever a bar is struck (what goes down must come up) is part of the technique - but on an acoustic instrument it does not produce any sound.

Triggers can not distinguish between the various stroke types, they only detect a downstroke. Damping and dead strokes are standard mallet techniques and any mallet controller should be able to recognize them and gate a note appropriately. If a controller could also sense the upstroke, the gesture could be used to trigger an event. This possibility suggests some interesting effects including a new kind of one handed-roll and the ability to sound different timbres on touching and releasing the same bar.

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### Monophonic/ Polyphonic Playing

When playing with four mallets, the instrument can be treated polyphonically or monophonically. Composers and improvisers are well aware of this and the best compositions and performances employ both modes.

A controller that can sense which type of passage is being performed could implement a zoning technique based on playing style rather than actual keyboard zone. Notes in monophonic passages can be played by one voice while the notes in a chord can be played on a different voice. This recognition technique also solves the classic problem of playing a monophonic voice with a polyphonic controller. Instead of squashing a group of notes in a chord, they are directed to a different channel capable of playing them polyphonically.

## Stroke Speed

One of the exciting aspects of mallet technique is watching the sticks fly during a rapid passage. Stroke speed is the inter-onset-interval, the time interval between successive non-simultaneous notes (this is not the velocity of the sticks through the air though the two are related). On wooden instruments rapidly alternating strokes (called rolls) are the only way to sustain a sound. Performers learn to control the speed of their rolls, usually alternating slower on lower bars and faster on higher ones. This affects tone quality and expression.

Stroke speed is certainly under the control of the player. A controller that can measure it can produce an additional continuous signal for general modulation purposes.

## The Marimba Lumina

The Marimba Lumina, made by Buchla and Associates, is a MIDI mallet controller that extends the gestural control of a mallet instrument in the ways described above.

The Marimba Lumina uses radio frequency sensing to continuously track the position of four mallets above an array of antennae etched onto a circuit board. The antennae are shaped like the bars representing 4-1/3 octaves of a mallet keyboard. Each mallet contains a different coil winding within. The mallets can be finished with wound yarn, or enclosed in a foam head. Some players prefer the normal yarn finish, but these mallets produce a considerable amount of contact noise. The foam mallets are more quiet and have a light bouncy feel. Mallets are tracked when they are in close proximity (less than 1 cm) to the bars and each mallet is tracked in three dimensions: bar number, height above the bar, longitudinal location along the bar. Two events are derived from the continuous tracking signals: a downstroke occurs when the mallet height above a bar stops decreasing, and an upstroke occurs after a downstroke is registered and the mallet is no longer detected over the bar. Downstrokes can also be classified as belonging to a chord or as single melodic downstroke.

The Marimba Lumina does not have any default playing behavior. It makes no assumptions about the effect of any particular gesture. Users can select one of the factory presets or configure it themselves. A program consists of a variable number of patches that specify the mapping between gestures and MIDI messages (e.g., note-ons and controller changes). The patching language is sufficiently general to emulate the common behavior of mallet instruments and to construct new modes of performance never before possible.

A patch is a pattern that is triggered by a striking gesture. Patches can be triggered by a downstroke, a melodic downstroke, or an upstroke. A patch can be triggered by one stroke type only, and the same triggering gesture may be used as the stimulus for a number of different patches. A patch can be constrained to match its triggering stroke on a specified mallet or any combination of the four mallets, and the stroke can also be limited to a single bar or a zone of contiguous bars.

Every time a patch is triggered it creates an object (either a note or a MIDI control). Information in the patch binds *other* gestures to the parameters of the object the patch creates. For a note, this means the gestures that can stop the note, for a control, the patch specifies the gesture that generates the signal attached to the control. The gestural bindings are dynamic and they apply only to the objects that created them and only as long as those objects exist (e.g., until note-off or until a controller is disconnected or attached to a different signal). The same triggering gesture may be repeated as the stimulus for a number of different patches.

There are other aspects of the Marimba Lumina's patching language that are not directly related to its mallet gesture capabilities. Patches can also be triggered by footswitches and external trigger inputs, and they may be set to trigger upon initialization when a new program is loaded. Besides notes and controllers, there are patch types for sending MIDI messages and performing system functions (such as channel mute and program selection). It is not the purpose of this article to describe the entire instrument and its programming scheme in detail, but rather to discuss some possible uses of its enhanced gestural abilities.

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### Note-gating

Since the Lumina detects downstrokes and upstrokes separately, it can use either type of stroke to trigger a note-on.

A note-on has a duration which is either infinite, a constant value, or a length proportional (or inversely proportional) to the initiating velocity, vertical position on the bar, or bar number.

Notes persist until their duration elapses, or until a gesture associated with one of several optional stopping modes is detected. The damping mode will issue a note-off for a sounding bar when a downstroke below a threshold velocity occurs. Damping also enables the dead stroke whereby a note will be stopped when the initiating downstroke remains on the bar. The toggle mode will issue a note-off when any downstroke occurs, it is a relaxed form of damping that will not cause a dead stroke. The release mode issues a note-off when an upstroke following the initiating downstroke occurs. Release is useful for emulating a piano keyboard action and for sustaining a tone while the mallet location on the bar changes to modulate it.

Since each mallet is detected separately, the same bar can support multiple note-ons with different behaviors assigned to different mallets.





Fig. 1. The author playing the Marimba Lumina.

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Parameter  
Modulation

Although the Lumina tracks the height of the mallet above the bars, this signal is only available close to the playing surface and is not useful as a general musical control. On the other hand, the vertical location along each bar is very easy to control and can be assigned to any MIDI continuous control. There are various ways in which the location can be mapped. Location can be sampled once, or it can be tracked relative to the bottom of the bars (0 at the bottom, 127 at the top), or relative to the center of instrument, so that the natural bars register 0-127 top-to-bottom while the accidentals register 0-127 bottom-to-top. Location can also be tracked as a delta signal: the value of the controller does not change when the mallet first meets a bar, subsequent movement varies the value of the attached controller by the amount of the offset from the initial location.

Mallet location can be used effectively to produce a tremolo or vibrato effect, by controlling volume or pitch bend, or to change filter or other effects parameters on-the-fly. When location and its inverse are mapped to two channels, location can be used to perform a cross-fade between two timbres.

The Lumina also provides a slewing signal for changing the value of a control at a constant rate. The slew up and slew down signals are gated by mallet location. When a mallet is in contact with a bar the slew signal is on, when the mallet leaves the bar, the slew signal is off.

Other signals can be attached to controls. Downstroke velocity can be used as well as mallet stroke speed. Both of these signals are effective for cross-fading between two timbres.

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### Multi-timbral performance

One of the most striking (excuse the pun) and easily grasped features of the Marimba Lumina is its ability to assign a separate voice to each mallet. A single bar can produce four different timbres when struck by each different mallet. The bars are large enough so that two mallets can comfortably activate a bar at the same time. One mallet may be held on the bar (perhaps in release mode, to sustain its voice) while a second mallet strikes the bar, sounding a different voice.

The Lumina can distinguish between single strokes played in monophonic succession and a group of notes in a chord (struck within a small interval of each other). Patches can cause monophonic strokes to play notes in one timbre, while notes in chords can be played on another. Thus, single note passages versus chords can be used as a zoning technique.

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### Discussion

The Marimba Lumina adapts well to a variety of playing styles. The specific gestural features selected will depend on the composition to be performed and the nature of the sounds assigned. Because the gestural vocabulary consists of familiar actions already associated with mallet technique, mallet players have no difficulty comprehending these new modes of expression, and audiences can readily understand that the moves the player is making are actually producing the sounds they are hearing. Persons who are familiar with a keyboard instrument can pick up a pair of mallets and successfully play the Marimba Lumina - as many pianists find they can also play a marimba or xylophone (to the chagrin of drummers who sometimes have less experience reading notes). As more gestural control is added, the instrument continues to challenge and reward advanced players who have more technical fluency with four-mallet technique and may encourage them to push the boundaries of their abilities even further.

A mallet does not necessarily have to be assigned every function possible. It need not even be used for playing notes at all; it could be reserved solely for controller modulation. Each bar of the Lumina is potentially four controllers (one for each mallet). We know how efficiently we can recognize and reach a specific key on a keyboard. Imagine fifty-two (times four) quickly accessible controllers. OK, perhaps an octave's worth would suffice. Using the Marimba Lumina as a hybrid instrument, capable of manipulating synthesis parameters while also being played at the same time, is an intriguing application. One can imagine a performance in the manner of a Guatemalan marimba band, where two, three, or four players perform on the same instrument. Some players control notes, while others are mixing and modulating synthesis parameters.

The Marimba Lumina does not exhaust the possibilities of mallet gestural expression, there are other areas that could be explored. Two-dimensional bar location might be useful on an instrument with fewer but larger bars (as in some of the larger Indonesian Gamelan instruments). Mallet players sometimes use their fingers to damp bars while they are holding mallets as well. Bars that could sense finger pressure separately from mallet contact may provide an extra dimension of control.

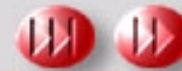
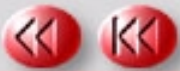
The ability to track the mallets in the air a considerable distance above the keyboard in the manner of a theremin or lightning wands would create a hybrid instrument, one with some fascinating challenges and opportunities.

## Conclusion

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Though the mallet instruments may appear to be too simple to consider as candidates for sophisticated music-making, there are a number of contemporary percussion soloists performing worldwide today who are regarded as first-rate musicians and the limitations of their chosen instrument have not impeded them from building successful careers. Clearly the instruments are capable of a high level of musical expressivity.

Mallet technique contains a vocabulary of gestures that are well known and map convincingly to musical control parameters. The sensing of additional features already inherent in the technique makes it possible to consider a mallet instrument seriously as a controller for real-time electronic performance. Such a controller has many benefits: It is recognizable on stage, comes with a repertoire of compositions that can be adapted for electronic performance and studied by composers desiring to learn the technical constraints of the instrument, is amenable to established notation systems, and most importantly, is played by a large population of well-trained and musically adventurous contemporary percussionists.



## References

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