CLAPPING MACHINE MUSIC VARIATIONS:  
a composition for acoustic/laptop ensemble

Daniel Trueman  
Princeton University  
Department of Music

ABSTRACT

Clapping Machine Music Variations is a new work for variable-sized chamber acoustic/laptop-ensemble, composed by the author for the new ensemble Sideband. Musical and technical motivations for the piece are described. In particular, the design of the laptop-based instruments and their relationships to the composition and performance of the work are explored. This paper is half of a Piece+Paper submission for ICMC.

1. INTRODUCTION AND MOTIVATIONS

At the core of Clapping Machine Music Variations is a pair of laptop-based Drum Machinists. Surrounding this duo is an assortment of other instruments, some clearly defined laptop-based instruments, others more variable and traditional in type. CMMV takes specific inspiration from works by Steve Reich, Györgi Ligeti and Björk. In particular, the drum-machine algorithm was initially designed to mimic certain rhythmic processes in the Ligeti Études pour Piano, processes which also coincidentally generate the rhythmic pattern for Reich's Clapping Music (this should come as no surprise, as both composers were deeply influenced by traditional African rhythms [1][2]); this algorithm is then used to generate variations on the original Clapping Music pattern, variations that are explored over the course of CMMV.

The somewhat open-form of CMMV results in performances that range from about 10 to 25 minutes, depending on the context and instrumentation. This instrumentation always includes at least two additional laptopists—the Silicon/Carbonists—and at least two additional Any Instrumentalists (these may also be laptopists, but will likely include traditional acoustic instrumentalists). The role of these instrumentalists is to variously articulate some of the contrapuntal writing that characterizes much of the piece and to bring to life the rhythmic patterns that define the variations. One particular kind of laptop-based instrument—the tether-controlled uBlotar—is also often used in this piece.

CMMV is the first piece composed for a new ensemble—Sideband—established to extend beyond some of the limitations of the Princeton Laptop Orchestra (PLOrk). A curricular initiative, PLOrk is dominated by new members each year; while several students return year after year, it is difficult to maintain a continuity of expertise and experience, or to benefit from repeated performances of specific repertoire and see how that repertoire develops. This becomes a significant compositional concern [3], and one of the aims of Sideband is to push the envelope of what is possible with laptop-based (or, more generally, computation-based) ensembles. Sideband members are professional-level performers, composers, and instrument builders—all with experience in PLOrk—and our aim is to maintain a stable membership so that our expertise can be refined and our repertoire can grow.

After a detailed description of the various instruments used in CMMV, I will explore how these instruments relate to the composition as a whole, its performance, and I will discuss future work for the composition and the instruments themselves.

2. INSTRUMENTATION

All of the instruments, including the laptop-based instruments, are intended to have an acoustic instrument-like presence. As has been documented elsewhere [4][5], this is aspired to through the use of hemispherical speakers placed locally with each (non-acoustic) performer. As with PLOrk, the aim is to create a social context for making music that is at once old fashioned and familiar, yet rife with new possibilities [6]. Depending on the performance space and acoustic instrumentation, any or all of these instruments might require reinforcement, in which case the laptop-based instruments are treated just like acoustic instruments and mic'ed accordingly.

2.1. the Drum Machinists

This instrument (written in ChucK [7]) was originally built for a laptop-percussion quartet—neither Anvil nor Pulley—commissioned by So Percussion. The drum machine algorithm is quite simple but yields remarkably complex, non-random results, in large part because it features feedback. In short:
1. Drum samples are fed (triggered by performer) into a delay line, which feeds its output back into itself, multiplied by a coefficient.
2. The length DL of the delay-line is always some integer multiple of a given fundamental pulse length FP, so DL = n\_int * FP.
3. After time DL passes, the delay length gets reset to some different multiple of the fundamental pulse, DL = n\_int * FP.
4. Step (3) iterates indefinitely.

Obviously, there are any number of ways that the multiples might be chosen. At the moment, the multiples move between performer-set minimum and maximum values, sometimes ascending (so, n=2, 3, 4, 2, 3, 4, ...), given 2 as a minimum and 4 as a maximum), descending (n = 4, 3, 2, 4, 3, 2, ...), or mirrored (4, 3, 2, 4, 3, 2, 4, ...). The performer can also choose to have it move through adjacent primes (7, 5, 3, 2, 3,...), adjacent Fibonacci numbers, or any precomposed sequence. So, parameters the performer might control include:

- fundamental pulse length
- maximum multiplier (n\_max)
- minimum multiplier (n\_min)
- counting method (integers, primes, etc. . . .)
- mirroring (on/off)
- feedback coefficient
- smooth time

The smooth time defines how quickly the delay length should be changed, and can yield interesting, pitched effects, depending on its value.

In addition to the array of drum samples that the performer can trigger, two of the drum pads are used to reset the delay-line time and set the counting point to either the minimum or maximum value. These "sync" buttons are crucial for control of the instrument and for syncing with other performers.

The behavior of this algorithm is often not intuitively predictable, but is highly consistent and performable. The original motivation for building the instrument was to explore rhythmic and metric patterns apparent in some of the Ligeti Études pour Piano, in particular #10 from book two—"Der Zauberlehrling"—which at one point features a rapidly expanding and contracting set of beat lengths, ll:4:3:2:3:ll. This is equivalent to setting the max/min values to 4 and 2, turning mirroring on, and counting by integers. See Figure 1 for an image of the waveform for this setting, when fed by a triangle sample.

The initial accent is followed by delayed subsegments of the original triangle strike, and a simple rhythmic pattern emerges: as the music notation indicates, the rhythmic pattern for Reich's Clapping Music. The clarity and stability is in part because the initial triangle hit is synchronized with the beginning of the pattern, achieved by striking the sync and triangle drum pads simultaneously; different timing relationships between the audio input and the delay pattern will generate less clear patterns, but usually patterns that bear some similarity to this one. It is possible, though tedious, to trace through the changes in delays and see how this pattern emerges; for instance, at the first moment the delay changes, to 3 * FP, the delay line is suddenly shortened, so it spits out the last 75% of the original triangle strike, as indicated by the boxed in waveform segments (note that the boxed in waveforms don't look identical, because they are summed with the tail of the original triangle strike, and the delayed sound is also attenuated, since the feedback coefficient is slightly less than 1).

In the particular configuration of the drum machine for CMMV, there are six percussion pads (kick, snare, open triangle, closed triangle, open hihat, closed hihat) and a parallel delay-line (with timing and length controlled in tandem with percussion delay-line, but with separate gain and smoothing controls) for bowed and struck vibraphone samples performed from a MIDI keyboard controller. This particular combination of sound samples with the drum machine architecture creates a sound world that is in some ways reminiscent of Björk's album Vespertine, sonically one of the inspirations for CMMV.

### 2.2. the Silicon/Carbonists

The Silicon/Carbon instrument (also written in ChucK) was originally built for a piece—Silicon/Carbon: an anti-Concerto Grosso—commissioned by the American Composers Orchestra for orchestra and laptop ripieno. A sample granulizer, Silicon/Carbon gives the performer control over a number of parameters for manipulating traditional orchestral instrument samples. It provides a
simple two-dimensional timbre space which enables the player to mix grains from four timbrally contrasting instrument groups while also manipulating a number of basic granular parameters. It is at its core a rhythmic instrument; when triggered, it generates a cluster of grains according to the performer-controlled parameters. The parameters the player can control are:

- timbre space X
- timbre space Y
- smoothness
- sample position
- accented/unaccented gain ratio
- overall gain

Smoothness is a meta-parameter that adjusts things like grain size, envelope, and separation to make a cluster of grains that is more or less "smooth." Sample position controls where within each sample to draw grains from, allowing exploration of attacks or tails of each sample.

For CMMV, the Silicon/Carbon triggering comes across the network (wirelessly, using direct sockets and Open Sound Control [8]) from the Drum Machinists. Each time the drum machine delay-time is reset, it sends an OSC message out to any computers listening, indicating that the delay-time has been changed, how much time until the next delay-time change, and how many subdivisions to articulate during that time. For example, if the fundamental pulse length FP is .2 seconds, and the delay-time has just changed to 4 * FP, then the drum machine will send out a message with two values: 0.8 and 4, indicating that the delay-time will change in 0.8 seconds, and that there should be four subdivisions of that time. Silicon/Carbon responds by immediately creating a cluster of grains (the "accented" cluster) followed by 3 more clusters (the "unaccented" clusters), evenly dividing the given delay-time. The Silicon/Carbon player can control the relative gains of the accented and unaccented clusters, thereby emphasizing strong beats or subdivisions as desired. The network triggering allows the instruments to remain synchronized, inviting the players to focus on texture and rhythmic interactions between the various instruments. When smoothness is high, any rhythmic articulations will be masked, leaving a smooth texture. Finally, if the Drum Machinist is playing pitched instruments (the vibraphone samples, in this case), the network message will also include pitch information, allowing the Silicon/Carbonist to either automatically follow those pitches, or respond indirectly in some way. Silicon/Carbon can play two pitches at a time, controlled by a simple mapping using the laptop keyboard [9].

A number of control mechanisms have been used with Silicon/Carbon, from the built-in accelerometer and trackpad on the MacBook to other external controllers. For CMMV, we use the Spacenavigator 3D-mouse from 3Dconnexion (for a nice example of the Spacenavigator in use, see Ted Coffey’s work [10]) mapped to the Silicon/Carbon parameters through use of the Wekinator [11]. The Spacenavigator provides six semi-independent control features with one hand. The Wekinator allows for rapid, playful generation of mappings via machine learning and neural networks. Rather than manually combining and filtering individual control features and then connecting them to synthesis parameters, we can provide the Wekinator with a few combinations of control feature and synthesis parameter sets (i.e., these set of control features from the Spacenavigator should make these sounds in Silicon/Carbon), from which it generates a neural network that invites the player to explore and in turn learn how to play the instrument. For CMMV, I created a variety of synthesis parameter sets that establish timbral and rhythmic extremes within Silicon/Carbon, and then created a "playalong" score from these sets so I could "perform" on the Spacenavigator while hearing the Wekinator automate the parameter changes [12]; simultaneously, the Wekinator collected my Spacenavigator gestural data, then trained a neural net that I was then able to literally perform with. This process is not only quick, but quite intuitive; rather than speculating about what kind of mappings I need to make, I simply define a few important desired nodes in the mapping and let the Wekinator figure out the rest; then, I can play with the instrument, add new nodes if desired, and retrain as needed.

Figure 2: example stage and network arrangement for CMMV. Drum Machinists 1 and 2 (DM1/2) send network messages (indicated by solid lines) to Silicon/Carbonists (SC1/2) and Any Instrumentalists (AI1/2) who are listening for them. As with the AIs, it would be possible to have additional pairs of SC players. DMs 1 and 2 synchronize with each other aurally and visually, not with the network.

CMMV requires at least two Silicon/Carbonists. Each pair divides, pairing up with opposite Drum Machinists, "listening" to their rhythmic and pitch data over the network (see Figure 2). Depending on the number of Any Instrumentalists, more than one pair of Silicon/Carbonists is possible.
2.3. the Any Instrumentalists

Around this core of four (or more) laptopists is an open set of other kinds of instrumentalists. Inspired by works like Terry Riley's *In C* and Louis Andriessen's *Worker's Union*, I was interested in creating a situation where an open number of instrumentalists and instruments (or instrument builders!) could join the piece. As with the Silicon/Carbonists, these instrumentalists should come in pairs, each taking one of the two Any Instrumentalist parts; like *Clapping Music*, CMMV is constructed in pairs of parts (see Figure 2). More details about the role of these players are provided later in this paper.

2.3.1. the Tethered-uBlotarists

I created a particular laptop-based instrument to take part as an Any Instrumentalist. This is optional, but the instrument provides particularly expressive ways, both sonically and physically, for laptop players to join the piece.

The uBlotar is a hybrid physical model of the flute and electric guitar. Originally created by Charlie Sullivan [13], the electric guitar physical model is topologically very similar to the flute model [14], and, at the suggestion of Perry Cook, I created a Max/MSP instrument that combines the two several years ago [15]. The uBlotar is a remarkably expressive instrument, but also very difficult to play; it has many parameters that need to be controlled simultaneously, and it is difficult to predict how it will respond to particular parameter sets, making it a special mapping challenge and an ideal candidate for the Wekinator. For CMMV, I chose to use a modified Mad Catz Real World Golf Game controller, inspired by Dan Overholt's work with Pendaphonics [16]; this controller, which we refer to as the tether, features two joy-sticks, each with an extendable stick via a nearly 3-meter long light "fishing" line. It requires a slight modification [17] which converts it into a standard HID device. The extendable nature of the joy-sticks invites a very physical type of play (for an example of the tethers in performance, see [18]).

Creating the Wekinator mapping for the tethered-uBlotar required many revisions. I found that I had to continually narrow the sonic range of my example uBlotar settings; otherwise, after training, the instrument was simply too wild to perform in the context of CMMV, for which I was interested in subtle, textural, microtonally sustained playing from the uBlotar, not wild, difficult to control noise (which I might very well want in another context). I also found that after my first "playalong" session, where I paired tether gestural data with the example uBlotar parameter sets, I had to add an additional training to teach the uBlotar to be quiet when the tethers were barely extended (while this example was included in the original "playalong," it needed reinforcing); this additional training had some wonderful unintended consequences—to be expected when working with neural networks—consequences that ended up being particularly inspiring. For instance, even though my additional training set focused on unextended tether gestures, the retraining also impacted the mappings when the tethers were fully extended, creating a space where the rhythmic qualities of the uBlotar vibrato could be performed, interacting with the rhythmic articulations of the other players. This became one of the most performable parts of the instrument within CMMV.

Like the Silicon/Carbonists, the tethered-uBlotarists can listen over the network for pitch information from the Drum Machinists, or ignore that information and decide themselves which pitches from the CMMV score to work with. Again, the role of the uBlotarists in CMMV will be discussed later in the next section.

3. COMPOSITION AND PERFORMANCE

Formally, CMMV consists of a series of seven variations. Each variation is in three parts. The first part consists of a slowly moving melodic passage. These melodic passages are implicitly contrapuntal; each note should be combined with its predecessor. This is easily accomplished with Silicon/Carbon, which by default only updates one of its pitches (the oldest) when given a new pitch (in order to play monophonically with Silicon/Carbon, a particular pitch has to be triggered twice), so simply playing through the melodic passages automatically generates the desired two-voice texture. In three of the variations, the melodic passages split into two, creating a four-voice texture. All of the instruments in CMMV articulate these voices; the Drum Machinists, through use of the vibraphone samples, play the melodic passages, splitting into two for the three variations that have two lines, and send their pitch material over the network for others to use as desired. The Silicon/Carbonists can either manually update their pitches, or follow their partner Drum Machinist via the network; the latter allows the player to focus more on other aspects of the textures, rather than having to count and use the somewhat awkward laptop-keyboard interface. The Any Instrumentalists also play this melodic material, some playing the main melodies, others playing the "delayed" melodies. However, Any Instrumentalists that aren't pitch oriented, or, like the uBlotar, are better suited to slow textural playing, can simply rest during these first parts.

At the beginning of each variation, the Drum
Machinists manually synchronize their machines with one another, resetting them to the default [4:3:2:3] pattern. The pulse of this pattern emerges quite quickly (as in Figure 1), and the rest of the ensemble uses it to synchronize with one another; in Figures 3 and 4, numbers below indicate how many beats each note should be held. The second part of each variation is where the Clapping Music variations begin to emerge and the Drum Machinists begin to move away from the initial [4:3:2:3] pattern. The sequence of pulse-length cycles is as follows:

1. [4:3:2:3]
2. [5:3:2:3]
3. [5:4:3:4]
4. [7:5:3:5]
5. [7:6:5:6]
6. [6:5]

These patterns were discovered through making small moves away from the [4:3:2:3] pattern with the drum machine, sometimes counting by integers, other times by primes. The resultant rhythmic patterns, akin to the original Clapping Music pattern, were transcribed and used as the basis for rhythmic cycles in the Any Instruments, and then finally for the clapping sections that close each variation.

During the middle parts, the Drum Machinists improvise, adding drum samples as desired, and manipulating the rhythmic cycles, eventually converging on the given cycle for that variation; they may converge separately from one another, resulting in Reich-like phasing composites. The Any Instrumentalists either articulate the specified rhythmic patterns, together or independently from one another, or simply expressively sustain individual pitches from part 1. This section is quite open, and depends on sensitive improvisation by the players. Even though the open instrumentation was inspired by In C and Worker's Union, these sections are quite different in that they invite more improvisation, especially from the Drum Machinists; what kinds of samples the Drum Machinists introduce into their delay-lines, and how they manipulate both the meters and the smoothing, can radically change both the metric feel and the overall texture. In addition, all the players have choices regarding pitch materials, and with Sideband, players are trusted to use their ears to make “good” choices, “good” being something we collaboratively try to agree on.

![Figure 4](image-url)

**Figure 4**: an excerpt from the Any Instrumentalist part. The top line functions the same way as with the Drum Machinist; depending on the instrument used, the register may have to be changed. The second part (middle line) indicates the rhythmic pattern the player should articulate (transcribed and transformed here from the [6:5] Drum Machinist pattern), using 1-2 notes from the first line; the player enters and stops freely for this section. The last line is the “clapping” pattern [6:5] that the player either claps or plays with their instrument.

One of the challenges and points of interest of these middle sections is how well everyone can entrain to the Drum Machinist's pulse; entrainment is one of the fundamental activities that we engage in when listening to much music [19], and CMMV in part endeavors to both frustrate and satisfy that activity. Some of the patterns (variations 5 [7:6:5:6] and 6 [6:5], in particular) are quite challenging in this regard, but the players are all supposed to entrain as best as possible. Sometimes the Drum Machinists have to briefly simplify their pattern to provide...
something easier to entrain to, before moving away again to the desired pattern.

However, some of the Any Instrumentalists might, during this section, simply ignore the pulses and contribute expressively sustained pitches (again, drawn from the first part of each variation); the tethered-uBlotar is designed to function this way—being rhythmically articulate is not one of its strengths!

At the end of these middle sections, one of the Drum Machinists counts off (vocally) a couple beats to cue the beginning of the third part. Here, everyone either claps the specified rhythm, or articulates the rhythm with their instrument in some way. After the bar of rest (though not silence, since many of the laptop instruments will still be making sound), one of the Drum Machinists cues the beginning of the next variation.

4. DISCUSSION AND FUTURE WORK

As of this writing, CMMV has yet to be performed. It has been rehearsed several times, and a recording of one of the rehearsals was used for submission to ICMC. CMMV is clearly a piece that will benefit from many performances, with various combinations of instrumentation. I am particularly interested in exploring various sizes of ensemble, from the minimum (6 players) to much larger: 15–25 players. The rhythmic challenges posed by the Drum Machine patterns can be quite formidable, and it is not clear how these challenges will scale from small to large ensemble sizes, both in terms of performability and textural result.

All of the instruments used in CMMV are ripe with potential for revision and improvement. For instance, the drum machine instrument has no GUI controls, and as a result minimal controls over some of its parameters; it would be useful to be able to type in and manipulate particular metric sequences. Multiple banks of different kinds of sound-samples would be enormously useful. There is no filtering or processing available yet, which would obviously create a whole new set of possibilities for the drum machine, not the least of which would be an inspiration for some kind of physical, gestural controller, in addition to the buttons and knobs on the standard keyboard controller. Finally, it would be interesting to be able to work with structures where the underlying sense of time is warped, along the lines of previous work like the Cyclotron [20], or certain types folk music (see, for instance, Johansson [21]).

The Silicon/Carbon instrument would also benefit from further palettes of instrument samples to granulize; it would be nice if the performer could define the 2-D timbral space on-the-fly, from a large array of given samples, or from samples created live. In addition, the granular controls themselves are rather primitive, with minimal envelope controls; enhancing these to better leverage all the capabilities of granular sampling and synthesis would be useful [22]. Other kinds of filtering and reverberation might also be useful. Finally, the mappings generated via the Wekinator are, at this point, first drafts (for both Silicon/Carbon and the tethered-uBlotar), and it is likely that in the future, performers themselves will work up their own Wekinator trainings that suit their own performance interests. Extending this idea, I hope CMMV, and in particular the Any Instruments role, will provide a context for instrument builders to put their trade to work and bring their new instruments, digital or otherwise, networked or not, and join in.

One of the compelling aspects of the Wekinator is that it facilitates instrument building that itself can be highly personalized and even done on-the-fly, in performance; one of our hopes for Sideband is that it provide a context for developing a new set of performance practices, some that focus on instrument building itself as a kind of performance practice. These performance practices will inevitably impact compositional practices as well. It has long been argued that instrument design has more deeply shaped compositional practices than we realize (see, for example, [23][24]). As performance practices become more fluidly intertwined with instrument building, our visions of what is possible and inspiring compositionally necessarily come along for the ride, and the lines between composition, performance, and instrument building become yet more obscured. CMMV is an example of this kind of piece; my compositional process was inspired by instruments that are still under construction' and the design of these instruments has been focused and guided by my compositional aims for CMMV and my experiences performing it.

5. REFERENCES


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1 Indeed, my compositional process was inspired even by instrument-building systems, or meta-instruments, like the Wekinator, that themselves are under construction.


[10] Coffey, T. Speech/voice processing interface: http://www.youtube.com/watch?v=Hk0LHHelx0


