A HISTORY OF SEQUENCERS: INTERFACES FOR ORGANIZING PATTERN-BASED MUSIC

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ABSTRACT

This paper presents a history of sequencers for musical performance and creation. A sequencer is a musical interface designed to record, edit and playback audio samples in pattern format for both music composition and performance. Sequencers have evolved over the years to take many forms including mechanical and analog sequencers, drum machines, software sequencers, robotic sequencers, grid-based sequencers and tangible sequencers. This vast array of sequencer types brings forth a number of technological approaches including hardware fabrication, software development, robotic design, embedded electronics and tangible interaction design.

1. INTRODUCTION

Throughout history, patterns have permeated music. From ancient chant to modern electronic music, a sense of rhythm and repetition appears in music of diverse genres. This notion of structure relates to various mathematical principles, ranging from the golden section[1] to the matrix, and their sonic applications have been manifold. The idea of a grid has been one of the most prevalent characteristics of music throughout the past few centuries. The reliance on a sonic grid with repeating rhythmic and melodic motives has become imbued into the human ear, and the sequencer in its many forms has become a popular interface for music creation and sound music computing.

In their most common modern form, sequencers play rigid patterns of notes using a grid of sixteen steps with each step corresponding to one-sixteenth of a measure. Patterns are then chained together to form longer rhythmic and/or melodic motives. Most commercial sequencers are monophonic and play one note or sample per step. However, many are capable of storing multiple samples, allowing for multi-timbral composition and playback.

The sequencer is a commonplace interface for popular electronic music composition and production. Its greatest benefit is its ability to rapidly construct pattern-based sequences that are tightly locked to a meter. Patterns can be layered to create multiple voices that play simultaneously.

In this paper, sequencers of every type are surveyed. Section 2 discusses mechanical sequencers. Section 3 discusses analog sequencers. Section 4 discusses drum machines. Section 5 discusses software sequencers. Section 6 discusses sound sculpture sequencers, while Section 7 discusses grid-based sequencers followed by Section 8, which discusses tangible sequencers.

2. MECHANICAL SEQUENCERS

Sequenced music appeared in history long before the advent of modern-day electronics. In fact, the earliest known sequencers are mechanical in nature. The following section explores two early mechanical sequencers, the music box and player piano, which have influenced the development of modern-day sequencers.

The music box (**Figure 1.** Music Box (a) and Weber Pianola Piano (b) can be considered one of the first sequencers and was popularized as a toy during the 18th century. The vibration of steel teeth cut into a comb produce sounds that occur with the revolution of a pin-studded cylinder underneath them. A full revolution completes the melodic pattern and results in a musical phrase [2].

The player piano is yet another form of mechanical sequencer that is powered by foot pedals or a hand-crank. Fourneaux invented the first player piano in 1863, which was then iterated on by other inventors including Edwin Scott Votey, who created the Pianola (**Figure 1.** Music Box (a) and Weber Pianola Piano (b)) in 1896, followed by Edwin Welte's loom-based player piano created in 1897. The melodic sequence is most commonly triggered by paper punch-cards that automatically operate the hammers on the piano [3].

(a) (b)

Figure 1. Music Box[1] (a) and Weber Pianola Piano[2] (b)

[1] http://upload.wikimedia.org/wikipedia/commons/7/79/Baud_museum_mg_8548.jpg
[2] http://www.pianola.org/history/history_playerpianos.cfm

3. ANALOG SEQUENCERS

Musical paradigms set forth by the player piano and music box made their way into future musical developments. Technological growth led composers and engineers to experiment with generating sound by way of electro-mechanical technology. Raymond Scott was one of the most notable composers to incorporate new technology in his work and the forefather of modern-day commercial sequencers.

In the mid-1940s, Raymond Scott created his “Wall of Sound” (**Figure 2**). It has been noted as one of the first and largest electro-mechanical sequencers spanning over thirty feet in length and stretched from his apartment floor to ceiling. The sequencer operated with mechanical relays that triggered solenoids, control switches and various tone circuits with sixteen individual oscillators. The sequencer could be manually adjusted by Scott to alter the sound patterns [4].

Scott’s work with sequencers led to the development of fully analog sequencers that utilize analog electronics. The RCA[3] Mark II Sound Synthesizer designed by Herbert Belar and Harry Olson at RCA was created in 1957 and installed at the Columbia-Princeton Electronic Music Center. The synthesizer was the first analog electronic sequencer and used paper tape to automate playback by sending instructions back to the synthesizer [5].

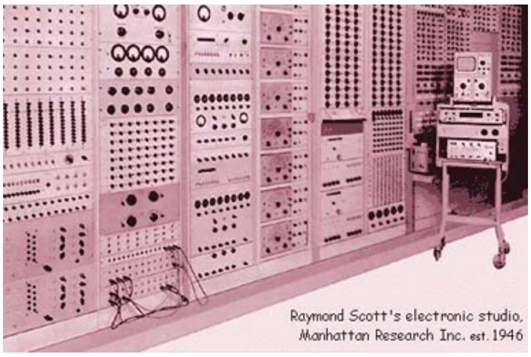


Figure 2. Raymond Scott's "Wall of Sound"[4]

As a student, Robert Moog took inspiration from Scott’s “Wall of Sound” to create his first analog sequencer, the Moog 960 in 1968. Moog created this particular sequencer as a module for his modular synthesizer. The 960 was one of the first analog step sequencers released for the commercial market. It contained three rows of eight value knobs and allowed for a three-value sequence of up to eight steps controlled by a clock. Each of the three banks could steer three different voltage-controlled oscillators (VCO), amplifiers (VCA) and filters (VCF) [4].

These early analog sequencers have affected electronic music production profoundly. Their developments led to the rise of a wide variety of electronic music. Many of the rudimentary sequencing implementations they utilized have served as paradigms for future electronic sequencers.

[3] http://www.rca.com/
[4] http://raymondscott.com/

4. DRUM MACHINES

This section explores the drum machine, a particular instance of a sequencer used to create percussive patterns. Since its inception, the drum machine has become a common interface for music creation and performance in electronic music.

The Rhythmicon is the earliest known drum machine invented by Léon Theremin in 1931. Having already established credibility and success with the creation of the theremin, Henry Cowell commissioned Theremin to build him a polymetrical instrument. The Rhythmicon was developed to produce up to sixteen different rhythms, each associated with a particular pitch (either individually or in combination). Despite its capabilities, the Rhythmicon was largely forgotten until the1960s [6].

Another instrumental drum machine was the Chamberlin Rhythmate created in 1957 by inventor Harry Chamberlin. This machine operated using fourteen tape loops. Each tape loop contained a sliding head, which enabled playback of different tracks on each piece of tape. The machine also contained volume, pitch and speed controls as well as a separate amplifier [7].

In 1959, Wurlitzer created the Sideman [8], which was the first commercial drum machine. It was electro-mechanical in nature and used a motor-driven wheel that would operate electrical contact points. These contact points could turn on up to twelve different preset rhythms, all of which contained ten drum sounds that were triggered using valve technology.

Shortly after the Wurlitzer Sideman, Ace Electronics began to prototype a new rhythm machine, the R1 Rhythm Ace, offering sixteen preset patterns that could be mixed together by pressing two buttons simultaneously allowing for over one hundred rhythm combinations. Ace changed the name to the FR-1 Rhythm Ace[5] (**Figure 3**) in 1967 when it was released for the commercial market.

Figure 3. Ace Electronics' FR-1 Rhythm Ace[5]

5. SOFTWARE SEQUENCERS

With technology’s exponential growth, software sequencers began to be developed. While the earliest software sequencers were used in conjunction with hardware synthesizers, modern software sequencers extend the physical metaphors set forth with analog sequencers described in Section 3. This section surveys early software

[5] http://www.soundonsound.com/sos/nov04/articles/roland.htm

sequencers to more contemporary ones included in many Digital Audio Workstations (DAWs).

The first software sequencer emerged as part of the ABLE computer created in 1975 by New England Digital. The computer contained a data processing unit developed for the Dartmouth Digital Synthesizer created two years prior. The ABLE computer served as the predecessor for the Synclavier I created in 1977, which was one of the earliest digital music workstations complete with a multi-track sequencer [9].

Three years later, the Page R was developed as part of the Fairlight CMI Series II synthesizer. This particular software-based sequencer combined sequencing with sample playback. It was commercially successful and its popularity led to the development of trackers.

In 1987, the first tracker software "Ultimate Soundtracker" was written by Karsten Obarski and released for the Commodore Amiga. The software supported only four channels of 8-bit samples and stepped through samples numerically using a vertical orientation. This structure became popular and led to the development of a slew of trackers including the OctaMED, ScreamTracker and others. The onset of computer games further popularized their use, as many game development companies leveraged tracker music for gameplay audio.

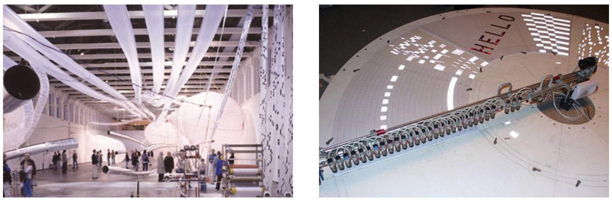
In the 1990s, DAWs such as Pro Tools[6], Logic[7], Digital Performer[8], Cakewalk[9] and many others began to hit the commercial market. Many of these DAWs dueled as production tools due to their MIDI capabilities and software instruments. As their companies developed the capabilities brought forth with MIDI, sequencing techniques became commonplace within most DAWs. Users now had the ability to loop patterns and build sequences directly with MIDI data. Ableton Live[10] further extended software sequencing with the creation of Session View, which allows users to play back loops in a non-linear fashion utilizing scenes and clips.

6. SOUND SCULPTURE SEQUENCERS

The sequencer has also made its way into more of a contemporary art context. The following section explores Tim Hawkinson's *Uberorgan* and Trimpin's *Sheng High*, two artistic works that explore sequencer functionality in more of an aesthetic installation setting. Both of these sound sculptures incorporate fundamental sequencer design tactics set forth by the music box and the player piano and extend them based on the artists' unique visions.

Tim Hawkinson's *Uberorgan* (**Figure 4** (a)), commissioned by MASS MoCA in 2000, was one of the largest indoor sound sculptures ever created. The installation consisted of thirteen large, inflated bags; twelve of them corresponded to the tones in the musical scale and one acted as a control that fed air into the other twelve by long tubular ducts. Each of the twelve bags contained a long nozzle with a cardboard horn on one end, which produced sound. Playback was triggered in a manner similar to a player piano, and in the center of the gallery was a continuous sheet of marked paper fed over a sensor. The sensor then read the sheet and triggered playback on the corresponding horn [10].

Trimpin's *Sheng High* (**Figure 4** (b)), installed in 2005, is a sound sculpture based on the original Chinese instrument the sheng. The sheng is a reed instrument that relies on air pressure to produce sound through bamboo pipes. The sheng predates both the pipe and mouth organs. In *Sheng High*, Trimpin uses a similar concept to the sheng's playback; however, instead of a human player, he uses water pressure to push air in and out of the bamboo pipe in order to activate the reed. In the installation, thirty bamboo pipes are precisely tuned and each one hangs from a tripod to be centered in a vessel of water. By raising or lowering the pipe into water, air is pushed over the reed and produces sound. A wall scanner equipped with infrared sensors, one for each pipe, serves as the main sequencer clock. Trimpin uses recycled CDs to act as a visual notation system. Patterns created by the CDs are used to trigger the various pipes, since their reflections signal the infrared sensors and scanning device. As a result, the installation acts as a robotic sequencer, allowing visitors to witness a dialogue between the visual and aural patterns created by the sculpture [11].



(a) (b)

Figure 4. Tim Hawkinson's Uberorgan at MASS MoCA[10] (a) and Trimpin's Sheng High[11] (b)

7. GRID-BASED SEQUENCERS

The development of the MIDI specification in 1983 brought forth a great shift in musical devices. Now musicians and engineers had the ability to network devices together and use hardware controllers to trigger software audio samples. Synthesizers, samplers and sequencers begin to use MIDI to communicate with each other in addition to software. With the ubiquity of MIDI and the establishment of Open Sound Control (OSC)[12], these devices and their use began to rise.

The gradual progression of these devices led to a more recent movement known as "controllerism"[12]. Coined by Matt Moldover in 2007, controllerism can be thought of as the practice of using software controllers (commonly using MIDI and/or OSC) to create and modify music. This section will explore the Monome family of grid-based controllers, which serves as one of the key developments in this movement.

Brian Crabtree created the original Monome in 2005 at the California Institute of the Arts. The Monome is char-

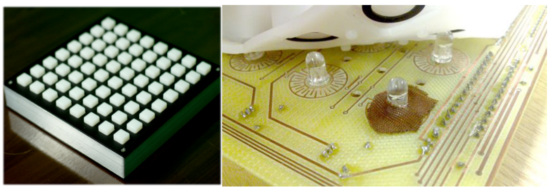
[6] http://www.avid.com/US/products/family/pro-tools
[7] http://www.apple.com/logicpro/
[8] http://www.motu.com/products/software/dp/
[9] http://www.cakewalk.com/
[10] https://www.ableton.com/

[11] http://www.artelectronicmedia.com/artwork/sheng-high
[12] http://www.controllerism.com/

acterized by a minimal design and takes shape as a box with a grid of LED back-lit buttons. The box is simply an interface for software-based audio and must be connected to a computer. The most common Monome controllers range from 64 to 256 buttons [13].

Custom software, such as MLR, dictates how the Monome is used. The function of each button is completely customizable based on the software, which communicates over OSC messages. Sequencing audio is a very common application of the Monome based on the layout of its controls. The MLR software in particular allows for sample manipulation and sequencing through the interface.

Since its inception, the Monome has contributed to a movement of grid-based controllers. Many commercial products have evolved as a result of its creation. Notable controllers following the Monome include the Novation Launchpad released as well as the Akai APC40 both released in 2009. The development of the Monome also brought forth an array of open-source projects including the Arduinome (**Figure 5** (a)), Chronome(**Figure 5** (b)) and the Lumi [14].



(a) (b)

Figure 5. Arduinome [13] (a) and Conductive Fabrics for Pressure Buttons on Chronome[14] (b)

8. TANGIBLE SEQUENCERS

The following section explores the development of tangible sequencers. A brief history of interaction design and its child discipline of tangible interaction design are discussed followed by two subsets of tangible sequencers: multi-touch tangible sequencers and computer vision tangible sequencers.

The principles of interaction design have played a large part in the future development of musical hardware including sequencers. Bill Moggridge and Bill Verplank first coined the term "interaction design" in the 1980s, and since its inception there have been many branches, all of which encompass the design of digital devices for human use.

Goal-oriented design is one of the primary methodologies surrounding interaction design. This facet of design is concerned with the creation of systems and devices that satisfy particular goals of its intended users. When viewed in a musical controller context, goal-oriented design can be seen as a musician's ability to easily create, edit and playback musical compositions and sequences. These design principles led to various branches of interaction design in order to make products more intuitive and easier to use [15].

Popularized by Hiroshi Ishii and his Tangible Media Group (TMG) at the MIT Media Lab, tangible user interfaces are those that allow a user to interact with digital information through physical controls. These interfaces seek to establish a metaphor between the physical world and the digital world; thus transforming intangible information into tangible, concrete objects [16].

8.1 Touch Display Tangible Sequencers

Beginning in the early 21st century, touch surfaces began to become prevalent in many technology-based research endeavors. Musical instruments and systems were no exception, and multi-touch sequencers emerged out of many music technologists' research. Notable touch display sequencers include the reacTable, scoreTable (created with reacTable technology), Lemur, ZooZBeat, Gliss and the SmartFiducial.

The reacTable (**Figure 6** (a)), created in 2003, uses a tabletop tangible user interface for musical creation. The instrument has the ability to be collaborative and is versatile as a kind of tangible modular synthesizer [17]. The scoreTable, developed shortly after the initial reacTable, uses the same physical elements of the reacTable; however, its software is set up to retain basic sequencing functionality in that asynchronous interaction is combined with real-time performance [18].

The LEMUR (**Figure 6** (b)) created by JazzMutant[13] in 2004 is a modular touch display audio and multimedia controller. The controller has a plethora of sonic and visual capabilities including synthesizers, virtual instruments, lights and audio sequencers. The controller makes use of a multi-touch sensor on top of a 12" TFT display. The LEMUR predated many smartphone sequencer applications and incorporated multi-touch sequencing combined with visual feedback.

Shortly after the LEMUR, smartphones and tablets with touch-screens began to imbue the consumer electronic marketplace. This shift in computing led to a number of new musical interfaces including sequencers, as most platforms created application marketplaces to distribute these applications. Many musical sequencers have been developed for smartphones and tablets that incorporate multi-touch interaction including the Korg iElectribe[14], Figure[15], iMaschine[16], NodeBeat[17], and a number of others.

ZooZBeat is a gesture-based mobile music studio presented at NIME in 2009, which uses not only multi-touch, but also the full gestural capabilities provided in most modern smartphones including accelerometer data. The interface makes use of a looping sequencer that is forgiving of user error from gestural input, allowing for constant real-time editing. The interface was designed to encourage immediate engagement and self-expression for novice players as well as room for growth and improvement in more advanced players [19].

Gliss is an iOS-based sequencer that allows for sequencing of up to five separate instruments. The interface takes inspiration from Xenakis' UPIC (Unite Polyagogique Informatique du CeMaMu) system, and allows

[13] http://www.jazzmutant.com/lemur_overview.php
[14] http://www.korg.com/ielectribe
[15] http://www.propellerheads.se/products/figure/
[16] http://www.native-instruments.com/
[17] http://nodebeat.com/

users to create sequences by drawing on the screen in real-time. Another feature is the ability to randomize the playhead from that of the drawings, or allow for gestural control of the playhead using the iPhone's accelerometer [20].

The SmartFiducial is a wireless tangible user interface that makes use of multi-touch and multi-modal features [21]. The interface incorporates both infrared proximity sensing and resistive-based force-sensors as controls for the interface and its included software Turbine. This sequencer makes use of sixteen nodes that can be dragged to affect pitch. Z-depth sensing adds further sonic control by morphing among wavetable single-cycle waveforms. Furthermore, these sonic manipulations are reflected with visual feedback in the software.

(a) (b)

Figure 6. The reacTable [17] (a) and the LEMUR[13] (b)

8.2 Computer Vision Tangible Sequencers

Many tangible sequencers make use of computer vision to aide human interaction. A variety of research projects have been conducted to address new tactics for musical control. Four notable tangible interfaces that use computer vision include the Music Table, d-Touch Sequencer, spinCycle, Bubblegum Sequencer and the Tactus.

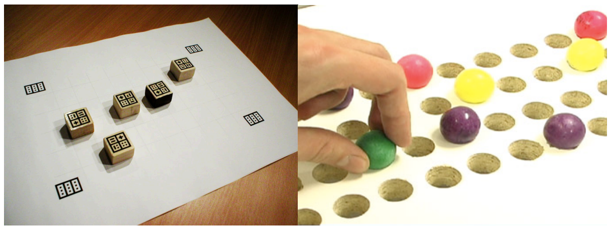
The Music Table is one of the first tangible sequencers to use computer vision for tracking of steps. Basic use involves arranging cards on a tabletop that are then detected by an overhead camera. The camera allows the computer to track position and movement in order to affect sonic parameters as well as provide visual feedback [22].

The d-Touch sequencer (**Figure 7** (a)) uses a similar paradigm to that of the Music Table. The crux of interaction involves positioning a set of blocks on a flat surface that are then tracked with a camera connected to a computer. In order to convey both user feedback and camera tracking, the playing surface and blocks are marked with printed pieces of paper that contain graphic symbols. Four markers are placed on the corners of the surface in order to calibrate the playing area, while one marker is attached to each block to track in real time. The position of a block is then mapped to software parameters, which triggers audio playback [23].

Another sequencer that utilizes computer vision tactics is spinCycle. The crux of the interface is a turntable and camera that use color tracking to denote different audio samples and instruments. Tokens take the shape of translucent colored discs positioned on a larger rotating disc. The camera acts similarly to a turntable needle and follows the rotation of the disc in order to map visual input to audio output. A computer next to the interface shows a visual representation of the camera's input, which provides additional feedback to the audience [24].

The Bubblegum Sequencer (**Figure 7** (b)) is a sequencer that uses physical mapping to correspond to sample playback. The physical interface contains a 4 x 16 array of holes, and the physical objects are gumballs comprised of five different colors, which correspond to different samples. Each of the sixteen columns represents one-sixteenth note, while the rows allow for multi-timbral playback by stacking gumballs together [25].

Using the Bubblegum Sequencer as inspiration, the Tactus is a tangible tabletop synthesizer and sequencer that was created at UC Berkeley. Its premise is similar in that it uses an optical camera coupled with Max/MSP/Jitter to detect patterns among tangible tokens. Yet, it extends the ideas set forth in the Bubblegum Sequencer by its ability to turn almost any matrix-like object into a step sequencer [26].



(a) (b)

Figure 7. The d-Touch Sequencer [23] (a) and The Bubblegum Sequencer [25] (b)

9. FUTURE DIRECTIONS

The sequencer has evolved drastically since the music box in the 18th Century[18]. Technology has progressed rapidly and musical devices and systems have progressed with them. It is interesting to note the transition to electronic music devices beginning with Raymond Scott's "Wall of Sound" into analog sequencers such as the RCA Mark II followed by the rise of software sequencers (**Figure 8**).

While the end of the 20th century saw a rise in digital devices and systems, the start of the 21st century has been marked by a desire for more intuitive interfaces and a return to tangible controls. The rise of mobile computing has also enabled anyone to make music. There are countless musical interfaces—everything from synthesizers to sequencers to mobile DAWs. While the smartphone and tablet market has brought forth a slew of musical applications, many of these interfaces serve as great complements to music composition and performance. As new technology is invented, sequencers will continue to play a large role in the evolution of the electronic artist, and as a community we will continue to find new ways of organizing and expressing sound and music.

[18] Go to http://en.wikipedia.org/wiki/Music_sequencer for a general overview of the history of sequencers.

SEQUENCER TIMELINE

YEAR	DEVELOPMENT
1700s	Music Box
1863	Player Piano
1896	Pianola
1897	Loom-based Player Piano
1931	Rhythmicon
1940s	Raymond Scott's "Wall of Sound"
1957	Chamberlin Rhythmate
1957	RCA Mark II Sound Synthesizer
1959	Wurlitzer Sideman
1967	R1 and FR-1 Rhythm Ace
1968	Moog 960
1975	ABLE Computer Software Sequencer
1977	Synclavier I
1980	Page R
1987	Ultimate Soundtracker
1990s	Popular DAW Sequencers
2000	Tim Hawkinson's Uberorgan
2003	reacTable
2003	d-Touch
2003	Music Table
2004	LEMUR
2005	Trimpin's Sheng High
2005	Monome
2008	Arduinome
2008	Bubblegum Sequencer
2008	iPhone App Store Release
2009	Tactus
2009	Akai APC40 & Novation Launchpad
2009	LUMI
2010	Chronome

Figure 8. Sequencer Timeline

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