Electronic Music and Gesture

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The history of electronic music is increasingly attracting interest, as shown by a number of recent texts published in various journals from popular *Keyboards Magazine* to scholarly *Leonardo Music Journal, Organised Sound* and *Computer Music Journal*, among many others. Various bodies are involved in this movement, in Europe as well as in North America. Museums, professional associations, academic institutions, as well as individuals, feel the need to study and document the past of our music. Collections of musical instruments have been gathered and many items are on display in museums around the world. The voice of pioneers is recorded in various publications so that first-hand documentation can be made available for further research.

After over a century of technical experiments and musical realizations, the evolution of electronic music can been determined to have been through specific stages[1]. These periods begin with innovations in music - making devices and are conditionned by technological breakthrough. This table does not take a chronological order into account, as it merely serves as a categorization of the main periods.

Period	Characteristics
I	Invention of new electric and electronic instruments
II	Laboratories
III	Synthesizers and studios on stage
IV	Computer-based instrumentation

Invention of new electric and electronic instruments

In the first historical period, technology was adapted to the creation of musical instruments. This movement started in the XIXth century with several major innovations: the Babbage Analytical Engine (1833), telephone microphone (1860), telephone transmission (1876), phonograph recording (1877), wireless telegraphy (1895), magnetic recording (1898). This list could be carried on for many inventions deserve to be mentioned, but our purpose is to discuss the relationship of these inventions with instrumental gesture.

It may be observed that there were several motivations for using electricity in inventing new musical instruments. Let's examine some of the oldest applications of this sort. What electronic technology brought to music is a new way of sound production. Instead of a being the result of a mechanical movement, such as a string being bowed or plucked, acoustical waves are directly sculpted by electricity. Depending on the specification of the electronic circuit used, a wide variety in the signal was rendered possible. Many inventions started in response to the desire to experiment with these technological offerings. For instance, many early electronic instruments were based on the heterodyne effect, a technology applied in radio and which can be found in the theremin (1920) and the ondes Martenot (1928).

1. M. Battier. 1993. "Computer Music Enters the Museum. Recents Developments in Paris." In *Proceedings of the International Computer Music Conference*, San Francisco: International Computer Music Association, pp. 328-330.

There was one aspect of the electronic technology that had a strong impact on gestural control: the ability to produce one or several tones at once. The heterodyne effect used in the thereminvox and the ondes Martenot induces monophonic sound generation. With only one sound at a time, gestural control can take advantage of musical effects such as portamento and glissando and, more generally, a specific type of pitch articulation.

Furthermore, there were the question of microtonal scales, which had already a strong influence at the beginning of the XXth century. In 1913, Ferruccio Busoni wrote :

> "The question of notation seems to me subordinate. On the other hand, the question is important and imperious, how and on what these tones are to be produced. Fortunately, while busied on this essay, I received from America direct and authentic intelligence which solves the problem in a simple manner. I refer to an invention by Dr. Thaddeus Cahill[2]. He has constructed a comprehensive apparatus which makes it possible to transform an electric current into a fixed and mathematically exact number of vibrations. As pitch depends on the number of vibrations, and the apparatus may be 'set' on any number desired, the infinite gradation of the octave may be accomplished by merely moving a lever corresponding to the pointer of a quadrant."[3]

When Edgard Varèse, in 1907, met Busoni at the beginning of his stay in Berlin, they discussed the matter. Later, Varèse gave an account of their encounter and related their discussion of this topic: "He was very much interested in the electrical instruments we began to hear about and I remember particularly one he had read in an American magazine, called the Dynamophone, invented by Dr. Thaddeus Cahill[4]". However, Varèse adds: "which I later saw demonstrated in New York and was disappointed." Why didihe give such a judgement? I can only speculate that two aspects could have brought him to this conclusion: one may have to do with the rigidity of the Dynamophone's timbre, as can be understood from the schematics of the tone generation specifications of the two instruments built by Cahill, but the other may be due to the simple gestural control, which is no different from a simple organ, and, thus, does not match the formidable complexity offered by the electrical sound production.

Instruments based on heterodyned radio-frequency oscillators appeared in the 1920s by taking advantage of the newest radio technology. The thereminvox, realized in 1920, was one of the first electronic instruments and is still in use today, as a musical instrument or as a non-contact controller [Editors' note: see the article by Chadabe in this volume]. The thereminvox, born "aetherphone", came into existence as a laboratory device made to measure gas density variation. As a sonification equipment, its frequency would vary according to the modification of density. A cellist himself, Leon Termen (or Theremin) was a young scientist in a Physical Institute in Russia. At about the same time, Jörg Mager invented the elektrophon (1921), also based on heterodyned frequency oscillators. However, Mager's motivation to invent an instrument were turned towards the exploration of micro-intervals. An organist by training, he studied electronics in order to build new instruments capable of producing microtonal scales.

The thereminvox, or "theremin", as it is usually called, presents unique performance features, as it is a early example of a non contact controller-based musical instrument. Despite Varèse's efforts, who asked L. Termen to build a couple of keyboard theremins for the performance of *Ecuatorial* in 1934, a request which was denied by the inventor, but since then, several keyboards versions of the theremin have been built, such as the Clavivox of Raymond Scott, later to be used as a synthesis engine component of his Electronium.

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2. In a footnote, Busoni adds: "'New Music for an Old World.' Dr. Thaddeus Cahill's Dynamophone, an extraordinary electrical invention for producing scientifically perfect music. Article in *McClure's Magazine* for July, 1906, by Ray Stannard Baker. Readers interested in the details of this invention are referred to the abovementionned magazine article."
3. F. Busoni, *A New Esthetic of Music* (1911), reprint in *Three Classics in the Aesthetics of Music*, New York: Dover Pub-lications, 1962, pp. 94-95. Busoni refers to an article published in *McClure's Magazine*.
4. L. Varèse, Varèse: *A Looking-Glass diary*. New York: Norton & Company, 1972, p. 50.

Fig. 1. Left and right: Leon Termen performing with his instrument, with typical hand and arms gestures. Center: another right hand position, usually adopted for frequency vibrato.

These two pictures, taken from pamphlets, emphasize the non-contact aspect of the instrument.

Zenaide Hanenfeldt

Presenting the

RCA - Theremin

Ether Wave Music Instrument

Dematerialized Music Produced Solely by Delicate Movements of the Hands and Fingers in the Air, without Any Actual Contact with the Instrument

D. A. R. MEMORIAL CONTINENTAL HALL
Saturday, February 15, at 8:45

Tickets May Be Secured in Advance by Mailing Orders to
Madame M. M. Hanenfeldt
1801 Columbia Road
Washington, D. C.

Fig. 2. Left: pamphlet for a concert by Zenaide Hanenfeldt. Right: a duo advertised in an early R.A. Moog Theremin's catalog.

These two picture above show different examples of the unique posture position taken while performing the instrument. On the right is a picture taken from an early R.A. Moog Theremin's catalog. On the left is a pamphlet for a concert given by Zenaide Hanenfeldt on the RCA thereminvox in February 1930, a former L. Termen's student, which announces "Dematerialized Music, Produced Solely by Delicate Movements of the Hands and Fingers in the Air, without Any Actual Contact with the Instrument." A music critic, after attending this concert in which a piece by Schillinger was played, quoting a reaction from someone in the public, reported: "The fact remains that, to the merely musical and unscientific mind, it is a wonder and a mystery that by making motions of the hands and fingers through the air, in the neighborhood of an apparatus consisting, to the eye, of a box on legs, a rod, and a loud speaker, a man can draw music apparently from atmosphere." For "those to whom this newest addition to mechanical inventions and to the ranks of music is still a mystery", as said another newspaper review of this concert, Z. Hanenfeldt gave a short lecture and "explained the mechanics of the Theremin instrument, or rather the means by which this music is brought from the air."

The picture below (left), also taken from a R.A. Moog same catalog, explains: "This is the position the performer assumes when playing the Theremin. Notice that the performer is not in physical contact with any part of the instrument.

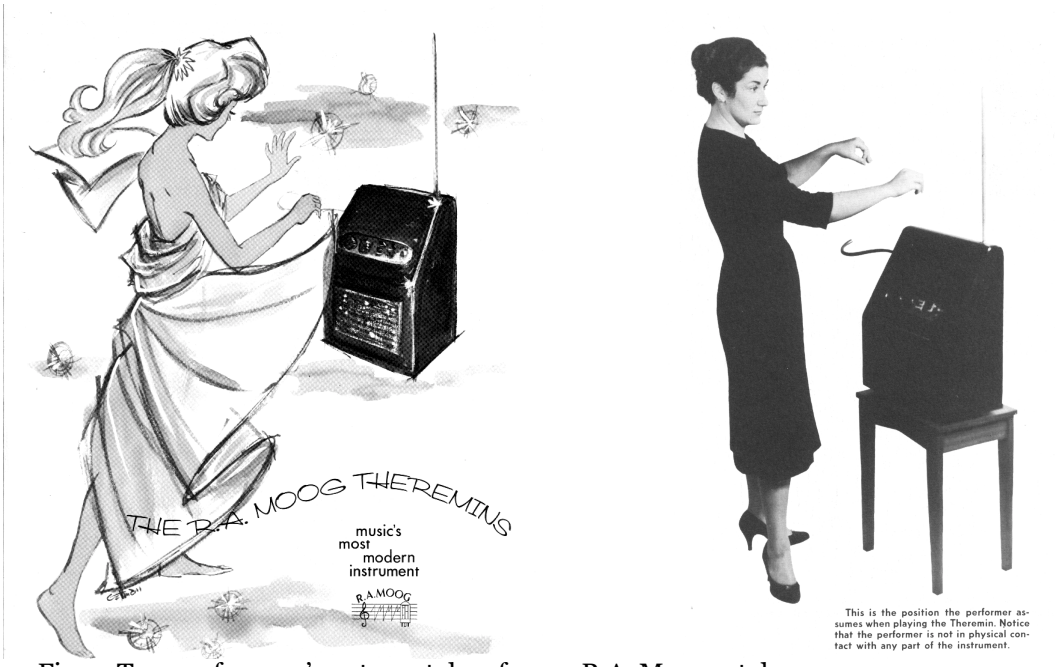

Fig. 3. Two performers' postures taken from a R.A. Moog catalog.

As early as 1929, one year after Theremin's arrival in the United States, Joseph Schillinger, then a young Russian immigrate and assistant to Leon Termen in New York City, composed his *First Aerphonic Suite for thereminvox and orchestra*, which was first performed in Cleveland on the 28th of November that year, with Leon Theremin playing. Several other composers turned to the thereminvox, but the instrument was plagued by a lack of competent performers. Several virtuosos, Clara Rockmore, for whom, in 1945, Anis Fuleihan composed his *Concerto for Theremin and Orchestra*, Lucy Bigelow Rosen, and, more recently, Lydia Kavina, made tremendous efforts to encourage composers to write for this instrument. Nevertheless, the repertoire of concert pieces remains rather limited to this day, and the venturesome Termen made successful forays in film and popular music.

At the same time, an instrument using similar technology appeared: the ondes Martenot. It was first presented in the spring of 1928 at the Paris Opera house, only a few months after the memorable Termen's concert and lecture in the same theatre. Maurice Martenot was rather disappointed not to have been the first to unveil an electronic instrument to the public, but the ondes were just not ready until then and, according to Laurendeau [1990], Termen's show helped Martenot to focus on the completion of his own instrument. The first 1928 model had a unique gestural control feature: a ring made of celluloid was attached to long string whose other end served as a frequency control device. This end was metalised and, following the gesture, varied the capacitance of a heterodyned sound-producing device. The ring was placed on the right hand, and the left hand was free to manipulate additional controls: amplitude, which could translate into legato or staccato articulations, and, to some extent, some tone control. It may be observed that, in choosing this particular of pitch control, which he called "remote playing", Martenot had probably been influenced by Termen's instrument. This model was marketed by Gaveau. Soon after, he invented a keyboard for playing pitches in a more flexible manner, but he devised a keyboard with mobile keys. The lateral movement was used to produce a pitch vibrato, a device later popularized by the Jenny's ondioline. A rather unique application of the instrument's possibilities was the realization of a prototype for Rabindranath Tagore, whose patent was made by Martenot and musicologist Alain Daniélou in 1938. The instrument had a 5-octave range and could produce microtonal intervals with 1/12th tones. It can now be seen at the Museum of Music in Paris.

Another feature which may have contributed to the success of the ondes is its timbre control. In the beginning, Martenot used two grand pianos as resonators. He later turned to metallic gongs which would be excited by the ondes's loudspeakers, and devised a number of resonating devices, including springs, of various shapes and materials. A control device on the instrument enabled the performer to choose a loudspeaker. These festural control possibilities provided instrumentalists with enough degrees of liberty to be able perform music, and attract composers. Over six hundreds works have been composed for the ondes.

Instruments using similar approach, gestural and technical, were realized during the 1930s. One striking example was la croix sonore (1934) by the mystical composer N. Oboukhov, an instrument shaped as a cross.

The trautonium introduced another approach, with a complex wave produced by a neon tube oscillator. The performer could set and modify the timbre during the performance using knobs, using a type of substractive synthesis in which the balance of the harmonic spectrum can be continuously altered. The trautonium is one of the first instruments where tone control can be achieved by turning knobs while playing, a typical situation for the 1960s and 1970s analog synthesizers. The pitch control was made by applying a pressure on the metallic rail that ran alongside the cabinet.

Eventually, the instrument grew as the large mixtur trautonium, conceived and used by Berlin film composer Oskar Sala[5]. Later, a special type of hardware contacts were introduced in the mixtur trautonium as shown here:

Fig. 4. Playing pitches on the mixtur trautonium.

Well preserved trautoniums can be seen at the Berlin Instruments museum as well as in the Deutsches Museum in Munich. The trautonium lives through the music that has been written for it and has been preserved through the work of Oskar Sala. In 1932, the trautonium was commercialized by the Telefunken Company firm in Germany.

Laboratories

By mid XXth-century, a new music began to be realized in Radio studios. It relied on the use of laboratory test equipment and radio recording, electrical and electronic devices. Studios appeared also in universities, with the work of Vladimir Ussachevsky and Otto Luening and technology research centers such as Philips, where Edgar Varèse composed his *Poème électronique* for the Brussels World fair in 1958.

Because music was to be made out of machines, new compositional strategies had to be defined, and they had an impact on gesture. Sometimes, they derived from gestures made to control an apparatus. When, in 1948, radio sound engineer Pierre Schaeffer created intriguing new sounds, he was using two technologies: the recording mixer with its sound level potentiometers, and the phonograph, which was the recording device used by all radios at this time. The potentiometers allowed him to mask sections of a sound, such as the attack: Schaeffer noticed that, deprived of the attack portion, some sound would lose their identity and become unrecognizable. Their were no longer contingent to their cause and would yield interesting results. The phonograph manipulation enabled other types of sound manipulation: playback speed change, retrograde, and, by removing the pick up, selecting bits of a sound being reproduced. Thus, the musique concrète set of instrumental gestures was indeed very limited, but it is with these that a new type of music was born.

5. Sala's music can be heard on the sound track of Hitchcock's *The Birds* movie. A CD where he performs works for trautonium by Hindemith and himself has been released.

However, electronic music developed also through another approach, which was based on sound synthesis. It started in Cologne in 1951 and eventually led to the creation of a laboratory where special equipment would enable the composition of new sounds. This equipment merely consisted of a couple of electronic instruments as sound source and miscelleanous devices such as tape recorders, filters, reverberation and mixing consoles. With them, all the ingredients were gathered for this new musical genre: music composed on magnetic tape. In the beginning, composers tried to imagine sine waves combination and sat down at their desk to compose a score, later to be realized. This led to electronic works by Karlheinz Stockhausen and, later, Franco Evangelisti, G.M. Koenig and Boguslav Schäffer. Several of these composers soon went back to experimenting with the equipment by cutting and splicing tapes and turning the knobs of the frequency generators and filters. This experimental approach was fundamental for the Studio di Fonologia Musicale of Milan, set up in 1955 by Luciano Berio and Bruno Maderna, a trend that had ben first experimented by John Cage with the Project for Music for Magnetic Tape, established in New York City in 1951 and by O. Luening and V. Ussachevsky in 1951 at Columbia University.

In this special kind of laboratory, the electronic music studio, the vocabulary of instrumental gestures was hampered by the fact that most devices had been collected among radio and test equipment and were not designed to work together in this sort of interaction that is required by the creation of sounds in real-time. As a response to this problem, several semi-automated studios began to appear in the late fifties. The most well known was the Siemens Studio, in which sound producing and processing devices and recording machines were synchronized by a paper tape. This studio can now be seen at the Deutsches Museum in Munich. Similar answers were developed in Belgium and in The Netherlands. However, we will not describe them as they move away from the real-time interaction situation linked to instrumental gesture.

Let's merely evoke the RCA Electronic Music Synthesizers (1952-1955 and, for the mark II, 1958) designed by Harry Olson and Herbert Belar at the RCA laboratories in New Jersey. The music machine was conceived as a complete performance and recording system. A large paper ribbon was punched to encode pitches and various sound processing settings, and, once played through the reading mechanism, would automatically control the synthesizer. At the other end, a phonograph would record the result. This was a case of a completely automated electronic music studio. While built to produce popular music and, in effect, replace live performers by a machine, which the powerful American musicians union did not allow, it was through the placement of the device in the hands of composers, through its installation in New York's especially created Columbia-Princeton Electronic Music Studio in 1959, and particularly the works of Milton Babbitt, helped the instrument to be preserved.

Synthesizers and studios on stage

Modern electronic technology, and, specifically, the transistor, led to the development of analog modular synthesizers. It may be interesting to note that the first synthesizers were commissioned by electronic music studios.

Robert Moog's first synthesizer, conceived in 1964, was a response to the needs of a composer, Herbert Deutsch, an instructor at Hofstra University who had composed several electronic music tapes[6] and who met R. Moog in 1963 at a music teachers convention where the inventor was demonstrating his theremin kits. It is through their collaboration that prototypes were realized one year later, but it is through Moog's technical dexterity that the modules were methodically conceived with two goals in mind: "composing electronic music directly on recording tape", but also "testing configurations for new electronic musical instruments for live ('real time') performance."[7]

In California, the composers who created the San Francisco Tape Music Center, Pauline Oliveros, Ramon Sender and Morton Subotnick wanted better equipment for sound synthesis and it is through their relationship with Don Buchla, a musician himself, that a modular system was conceived. The first modules were labelled "San Francisco Tape Music Center" and were then sold as "Modular Electronic Music systems". Audio signals were carried from one module to another through patch cords with miniature phone plugs; control voltages and timing pulses were given separate types of cords with banana plugs. While building a sound synthesis and processing device for this studio, Don Buchla conceived a couple of

6. See: H. Deutsch. 1966. "A Seminar in Electronic Music Composition", *Journal of the Audio Engineering Society*, 14(1): 30-31.

7. R. Moog. 1965. "Voltage-Controlled Electronic Music Modules." *Journal of the Audio Engineering Society*, 13(3): 200.

unique gestural control systems. The first major control invention was a sequencer with eight steps, each one generating three voltages, named a "Sequential Voltage Source". A controllable clock set the scanning speed through the eight steps. The second Buchla's contribution was a keyboard in the form of a ribbon controller, labelled a "Touch Controlled Voltage Source". Each key would generate two preset voltages but the device was also sensitive to finger pressure, and each key activation would send a pulse to serve as trigger.

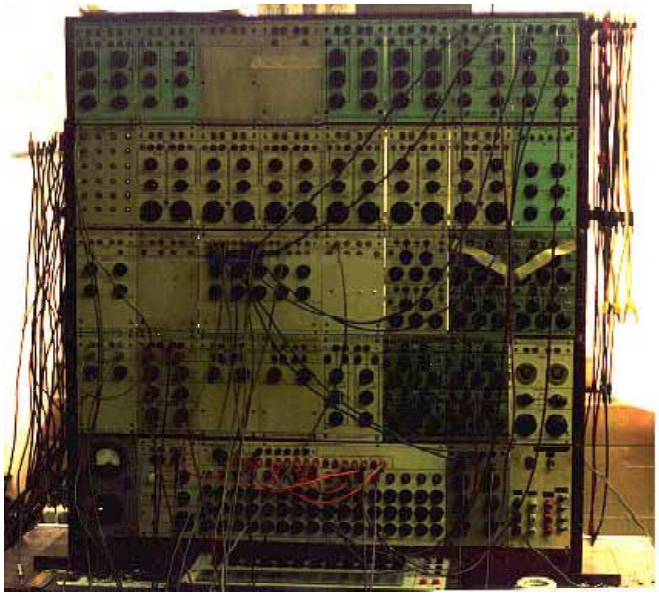

Fig. 5. A large Buchla 100 with patchcords.

The sequencer built by Buchla had an advantage over other types of sequencing devices in existence during thattime, such as the Polynome or the Coordinome, invented by Emmanuel Ghent in the early 60's to serve as "polytempo cueing device"[8]: it was interactive: one could speed up or slow down the clock speed scanning through the steps during the performance.

Another type of interactive sequencer had been devised by Raymond Scott as the central device of his first electronium[9] . In his Manhattan Research lab, Scott had been experimenting with sequencers since 1960 and had built several prototypes. It was by meeting R. Moog, then involved in manufacturing theremins, that he was able to build a solid-sate sequencer. Moog designed a four-state device which was used to sequence through eight-note chords. According to a Scott's pamphlet, the device could automatically harmonize a melody, provide a rhythm accompaniment and even invent "new rhythms, new harmonies, new ideas for melodies". Since Scott's electronium was primarily conceived as a composing machine which could, once programmed, execute a performance of a piece, the sequencer was placed under the control of the composer. In this sense, it is a particular case of gestural control device. The musician described his device in 1970: "The Raymond Scott electronium is not a synthesizer – there is no keyboard – and it cannot be used for the performance of existing music. The instrument is designed solely for the simultaneous composition-performance of musical works." The label under which Scott worked evolved to show this artistic trend. His Manhattan Research corporation advertised "Electronic Music and Musique Concrète". Ten years later, when he relocated near Hollywood and set up his activity under the name of the Raymond Scott Laboratories, he claimed "Instantaneous Music Composition Performance Machines". From his past as a band leader and instrumentalist, Scott retained a sense of gestural control even in his most advanced inventions.

In 1965, when the Italian engineer Paolo Ketoff was commissioned to build a synthesizer for the electronic music studio of the American Academy in Rome, he designed a combination of sound generators, modulator units for the processing of amplitude, and filters. These devices were gathered in three independent units, turning the instrument, called a synket, into a three independent voices synthesizer. He was requested later to add a keyboard, which he did: since three sets of identical modules were built into

8. See J. Chadabe. *Electric Sound*, p. 159.
9. About the Electronium, see the site dedicated to the work of Raymond Scott: http://Raymond-Scott.com. See also the articles by Irwin Chusid in the reference section at the end of this article.

the small frame of the instrument, Ketoff conceived a multiple system with three keyboards. Each miniature keyboard could control a bank of modules. This was used by John Eaton in 1965 for one of the first live synthesizer piece, *Songs for R.P.B.*, for soprano and synket.

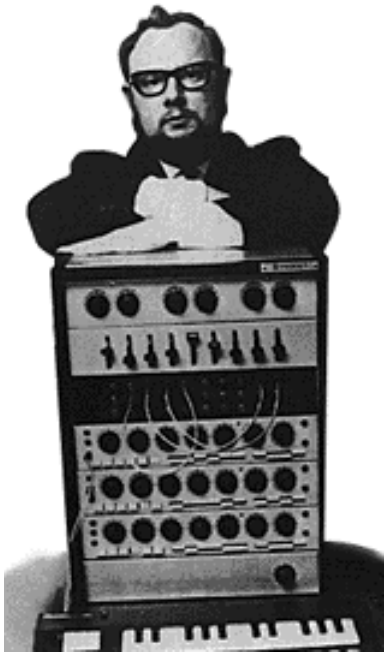

Fig. 6. Left: an early photograph of the keyboard Synket with John Eaton. Right: view of the three keyboards.

When Peter Zinovieff created the VCS-3, whose name is probably an acronym for "voltage-controlled synthesizer – 3 [oscillators]", through his London firm, EMS, he had some sort of computer control, à la GROOVE (see below) in mind. This explains the lack of a control keyboard. Despite the fact that, to keep the product's price affordable, low-quality components were used which in consequence would induce constant frequency drifts, the VCS-3, firstly commercialized as "Putney", the name of the London neighborhood where Zinovieff's shop was located, became an instant success. It was soon used by pop artists who performed with this synthesizer on stage, usually with its small monophonic control keyboard, the DK2, and by contemporary music composers. The latter used the instrument in their electronic music studios but also in concert situations. Many European compositions have been performed live, using the EMS instrument. In most cases, the performer processed the sound of an instrument through the various modules (ring modulator, reverberation, filter and envelope) while turning the settings knobs or inserting or removing the little pins which patched the modules together. A small sister of the VCS3, the Synthi A, housed in an elegant plastic suitcase, featured a tiny capacitive touch sensitive keyboard and a sequencer.

In this situation, the performer's gestures were similar to a composer's while working in a studio: turning potentiometers to alter settings and changing the patch that linked various modules together. Dexterity was difficult, as only two knobs could be manipulated at once, but not entirely impossible. A compromise had to be made. The answer came with hybrid synthesis, a set-up in which a micro-computer generates control voltages through a digital-to-analog converter.

Fig. 7. A 1970 VCS-3 Putney. Although a small keyboard could be attached to it, it was often played by turning knobs.

Computer-based instrumentation

The introduction of computer-based instrumentation took place during the 1970s. The first MUSIC program written in assembly language by Max Mathews (1957), which ran on a gigantic IBM 704, paved the way for direct digital sound synthesis. With MUSIC III (1960), the representation and simulation of instrumental gesture became an issue, but the nature of the medium, not involving actual physical gesture, falls outside of the scope of this article.

The first musical systems were based on the use of digital computers and between 1957 and the end of the 1960's did not consider an instrumental approach, there are notable exceptions. One stands out: the GROOVE system designed by Max Mathews and Richard Moore at the Bell Laboratories in 1967. The acronym of "Generated Real-Time Operations on Voltage-Controlled Equipment", the GROOVE had been assembled from various analog devices: Arp and Waveteck oscillators, Moog voltage-controlled amplifiers and filters, and so on. All these modules were placed under the control of a Honeywell DDP 224 minicomputer with a random-access memory of 32K 24-bit words. The system was programmed to produce instrument-like tones: flute, oboe, brass, percussion and string quartet instruments. Interaction occurred while a performer was played with gestural control devices, such as a keyboard, a joystick and sets of knobs, which were sampled by an analog-to- digital converter at a variable rate, typically of 50 to 100 Hz. Since the music was encoded in the computer and sequenced, the perfomer was seen more like a conductor. Later, M. Mathews has developed other systems based on a similr musical paradigm.

Other hybrid systems which followed did not adopt a similar, performance-oriented approach, but were rather composition systems sometimes allowing some degrees of interaction during the performance of a piece. Due to the advent of microprocessor technology, digital synthesizers were developed in the mid-seventies, paving the way for a modern technology that would allow the development of computer-driven interactive and real-time systems.

The next section presents a list of museums and Web sites related to historical electronic music instruments.

List of museums

This list is composed of museums that have a collection of electric and electronic musical instruments. The museums are listed in alphabetical order.

Audio Playground Synthesizer Museum

The Audio Playground Synthesizer Museum located in Orlando, Florida (USA), states: "The museum's mission is to preserve the history of the achievements in electronic instruments as they are realized as well as the accomplishments of the past." Their Web site has a number of interesting pages, including pictures and specifications, at http://www.keyboardmuseum.org/play.html. It is also a place to look for antique manuals.

Deutsches Museum

The Deutsches Museum in Munich (Germany) has an interesting collection of electric and electronical music instruments, including the sole model of Fonosynth by Paolo Ketoff and Gino Marinuzzi, the whole Siemens studio (1958-1960), and other instruments. A links takes you directly to a selective presentation of their electronical music instruments:

http://www.deutsches-museum.de/ausstell/dauer/musik/musik7.htm.

Haags Gemeentemuseum

In the Netherlands, the Haags Gemeentemuseum (The Hague) has a large section devoted to well preserved electric and electronic musical instruments and is active in locating and collecting rare pieces.

http://www.hgm.denhaag.nl/.

Henry Ford Museum

The Henry Ford Museum in Dearborn, Michigan (USA) hosts the first commercial Moog modular synthesizer that had been sold in 1965 to choregrapher/musician Alwin Nikolais.

http://www.hfmgv.org/.

ICOM

members of the International Council of Museums (ICOM)
http://www.music.ed.ac.uk/euchmi/cimcim/iwm.html.

Musée des arts et métiers

The Musée des arts et métiers in Paris is famous for its mechanical instruments collection.

http://www.cnam.fr/museum/.

Musée de la musique

The Musée de la musique in the Cité de la Musique in Paris, has a very good collection of historical instrumental landmarks, including a 1929 RCA theremin, with its vintage external speaker, various ondes Martenot, and hosts more recent devices such a 1965 Moog synthesizer previously owned by Eric Siday and the first UPIC conceived by Iannis Xenakis. As in many museums, not all instruments are on display.

http://www.cite-musique.fr/francais/musee/ (in French)
http://www.cite-musique.fr/anglais/musee/ (in English)

New England Synthesizer Museum

The New England Synthesizer Museum is located in Nashua, New Hampshire, has a limited Web site, hosted by Virtual Synthesizer Museum (see below).

http://www.synthmuseum.com/nesm/index.html.

Smithsonian

Some rare electric and electronic devices made in the USA have been collected by the National Museum of American History, a Smithsonian Institution, in Washington DC. It is there that one of the strangest electronic instrument is kept: a Rhythmicon, originally conceived by Henry Cowell and built by Leon Termen at his New York studio. A Web site for the music collections of the Smithsonian can be found at:

http://www.si.edu/resource/faq/nmah/music.htm.

Stearns Collection of Musical Instruments

The very first commercial model, commissioned in 1965 by choreographer and composer Alwin Nikolais, is part of the collection of this museum located in Michigan.

http://www.sils.umich.edu/CHICO/Stearns/StearnsHP/stearns.html.

Web sites devoted to Electronic Instruments

Despite their names, most of these sites offer more than archival documentation on analog synthesizers. They often include information on The sites are presented in alphabetical order, notwithstanding the size of their collection.

Brûn OnLine

In the Netherlands, Jeroen Bruintjes has painstakingly gathered a large number of Web sites links of electronic instruments. Each instrument is associated with one link.

http://users.bart.nl/~brun/index2.htm.

Drum Machine Museum

The Drum Machine Museum was opened in1999

http://www.drummachine.com/index.html.

Electronic Musical Instruments Museum

The Electronic Musical Instruments Museum has pictures of synthesizers manufactured from 1977 to 1991.

http://naoki.hirotaka.co.jp.

Caution: the main page is in Japanese. Set your browser's characters set accordingly. In doubt, jump directly to this page: http://naoki.hirotaka.co.jp/77/77.htm, and move tour way around.

EMIS Synthesizer Museum

The EMIS Synthesizer Museum, located in Bristol (UK) has a collection of synthesizers and electronic music devices. Its web site presents several of them.

http://dspace.dial.pipex.com/emis/museum/museumhome.htm.

Harmony Central

The Keyboard/Synth Database gathered by Harmony Central has a large collection of reviews on electronic instruments.

http://www.harmony-central.com/Synth/Data/.

Melmusic's Vintage Articles page

This Australian site offers many magazine articles, converted into HTML, about electronic musical instruments.

http://www.melmusic.com.au/articles/articles.html.

Music machines

Music machines is a good starting point for finding links related to electronic musical instruments, mostly synthesizers from the 1970's and 1980's:

http://machines.hyperreal.org/.

Museum of synthesizer technology

The Museum of synthesizer technology, opened in 1994, is, as stated in its name, devoted to electronic synthesizers from the mid sixties.

http://www.analogsynths.com/museum/home.html.

Official Analogue Synth FAQ

The Official Analogue Synth FAQ/Info File is a meta site of atchives Web links, resources addresses and mailing lists.

http://pages.pomona.edu/~jmaxwell/faq.html.

Its sister page has some music devices links.

http://pages.pomona.edu/~jmaxwell/mmachines.html.

120 Years of Electronic Music

An interesting source of documents (iconography and some explanations) can be found at a Web site called "120 Years of Electronic Music – Electronic Musical Instrument 1870 - 1990". Each instrument is presented in a separate page and the collection is slowly growing.

http://www.obsolete.com/120_years/.

Sound and Vision

Sound and Vision, in Japan, offers a page of pictures, video clips and audio examples of various historical synthesizers and processing devices.

http://www.cavestudio.com/S+V/musicsynthesizers.html.

Synth Site

Another comprehensive resource Web site can be found at Synth Site:

http://www.sonicstate.com/synth/index.cfm.

Synthesizer Network

Based in Sweden, the Synthesizer Network has a sleek Web site with some interesting documentation on audio processors, vocoders,converters and synthesizers:

http://www.analogue.org/network/frames24.htm.

Synthesizer Picture Archive

The Synthesizer Picture Archive has, indeed, pictures and not much else, but its collection is fairly large.

http://www.code404.com/synths/.

Synthfool

Synthfool is another rich site for information about analog synthesizers, which has been rapidly expanding.

http://www.synthfool.com/.

Synthzone

Synthzone can serve as a switchboard to look for pages on specific instruments.

http://www.synthzone.com/.

Terrey Collection

The Terrey Collection of vintage synthesizers site is fairly large. Pictures of instruments are presented on specific pages on the Old Tech Web site.

http://www.oldtech.com/synth/index.html.

Vintage Synth

Another expanding site is Vintage Synth. As of this writing, they claim to provide some sort of documentation for over 370 popular vintage and retro-vintage synthesizers.

http://www.vintagesynth.com/.

Virtual Synthesizer Museum

The Virtual Synthesizer Museum is, despite its name, a brick-and-mortar museum in Watertown, Massachusetts (USA), and, as such, is rather known as "Synthmusem". While its premises can be visited, it offers a large selection of pictures on its Web site.

http://www.synthmuseum.com/.

Auction sites

A British company, Vemia, organises an auction of vintage electric musical instruments on the Web at http://www.vemia.co.uk.

List of some institutions

This list of institutions involved in the study and preservation of electronic musical instruments represents only a selection and is by no means comprehensive. This list is maintained and updated on a website: http://www.ircam.fr/forumnet/.

Electronic Music Foundation

One if the goal of Electronic Music Foundation is to preserve and document landmakrs of the electronic music history. A museum is considered as the means to present the collections to the public.

IDEAMA

Over the 1980s, a consortium composed of researchers from CCRMA at Stanford University, with Max Mathews and Marcia Bauman, and from ZKM in Germany, with Thomas Gerwin and Johannes Goebel, instigated a large-scale project aimed at gathering a selection of electronic music, the International Digital Electroacoustic Music Archive. In association with studios and research centers from around the world, a repertoire of works up to 1970 was put together and led to a collection which was made available through CDRs.

Audities Foundation

The Audities Foundation, which recently moved to Canada, collects and restores Mellotrons, Chamberlains and synthesizers. As stated on their Web page, their mission "is the preservation of electronic musical instruments and the documentation associated with them for use in museums, recording studios, modern instrument research and new music works. The instrument collection comprises over 150 instruments and spans the last 70 years of instrument development." The have an important archive of Buchla equipment technical documentation as well as some for the Moog synthesizers.

http://www.audities.org/.

References

Arveiller, Jacques, Marc Battier, and Giuseppe Englert. 1976. *A computer Music Repertory*. Paris, Como (Italy): I quaderni dell'autunno musicale 4 and *Artinfo/musinfo* 23-24-25, Groupe art et informatique de Vincennes, 128 p.

Battier, Marc. 1993. "Computer Music Enters the Museum. Recent Developments in Paris." In *Proceedings of the International Computer Music Conference*, San Francisco: International Computer Music Association, pp. 328-330.

———. 1999. "L'approche gestuelle dans l'histoire de la musique électronique. Etude de cas: le theremin." In *Les nouveaux gestes de la musique*, Hugues Genevoix and Raphaël de Vivo (eds), Marseille: Editions Parenthèses, pp. 139-150.

———. 1999. "La musique électronique au regard de la mécanisation". In *Musiques du XX^{e} siècle, Conférences et séminaires*, Paris: Université de Paris-Sorbonne, Observatoire Musical Français, pp. 143-156.

———. 1999. "Les polarités de la lutherie électronique. Instrument, machine, représentation." In *Méthodes nouvelles, musiques nouvelles. Musicologie et création*, Màrta Grabòcz (ed.), Strasbourg, Presses Universitaires de Strasbourg, pp. 307-318.

——— (ed.). 1999. Aesthetics of Live Electronic Music, Contemporary Music Review 18(3), 136 p.

Brand, Stewart. 1987. *The Media Lab. Inventing the Future at MIT*. New York, Vicking Penguin, 285 p.

Busoni, Ferruccio. 1911. *A New Esthectic of Music*. Reprint in *Three Classics in the Aesthetics of Music*, New York: Dover Publications, 1962, pp. 94-95.

Buxton, William (ed.). 1977. *Computer Music 1976/1977: a directory to current work*. Ottawa, the Canadian Commission for Unesco and Toronto, Structured Sound Synthesis project, Computer Systems Research Group, 239 p.

Chadabe Joel. 1997. *Electric Sound, the Past and Promise of Electronic Music*. Upper Saddle River, NJ:Prentice Hall.

Chusid, Irwin. 1993. "Raymond Scott's Push Button Musical Universe." Mix, Oct., 126-129.

———, and David Garland. 1994. "Reckless Nights and Turkish Twilights: the Genius of Raymond Scott." Naras Journal 5(1): 69-79.

Clara Rockmore. 1998. Asheville: Big Briar, VHS video tape, 58 minutes.

Davies, Hugh. 1979. "A history of recorded sound." In *Poésie sonore internationale*, Henri Chopin (ed.), Paris: Jean-Michel Place, p. 13-40.

———. 1984. Electronic musical instruments. Various entries in *The New Grove Dictionary of Musical Instruments*, Stanly Sadie, ed. London: Macmillan Press.

Laurendeau, Jean. 1990. *Maurice Martenot, luthier de l'électronique*. Montréal: Louise Courteau (Canada) and Croissy-Beaubourg: Dervy-Livres (France) , 313 p.

Martin, Steven. 1995. *Theremin. An Electronic Odyssey*. Los Angeles: Orion Home Video 5080, VHS video tape, 84 minutes.

Mathews, Max and F. Richard Moore. 1970. "GROOVE - a Program to Compose, Store, and Edit Functions of Time", *Communications of the ACM* 13 (12): 715-721.

———, F. Richard Moore and Jean-Claude Risset. 1974. "Computers and Future music", *Science* 183: 263-268.

———. "The Conductor Program and Mechanical Baton". In *Current Directions in Computer Music Research*. Max Mathews et John Pierce (eds.), Cambridge, Mass.: The MIT Press, p. 263-289.

Moog, Robert. 1965. "Voltage-Controlled Electronic Music Modules." *Journal of the Audio Engineering Society*, 13(3): 200-206.

Olsen, William. 1995. *Mastering the Theremin*. Asheville: Big Briar and Little Big Farms, VHS video tape, 45 minutes.

Pousseur, Henri. 1970. *Fragments théoriques I sur la musique expérimentale*. Bruxelles: Editions de l'Institut de Sociologie, Université Libre de Bruxelles.

Reichadt, Jasia. 1968. *Cybernetic Serendipity. The Computer and the Arts*. A *Studio International* special issue, London: Studio International, 101 p.

Risset, Jean-Claude. 1999. "Nouveaux gestes musicaux: quelques points de repère historiques." In *Les nouveaux gestes de la musique*, Hugues Genevoix and Raphaël de Vivo (eds), Marseille: Editions Parenthèses and GMEM, pp. 19-33.

Schaeffner, André. 1968. *Origine des instruments de musique. Introduction ethnologique à l'histoire de la musique instrumentale*. Paris: Mouton Editeur. [reprint].

Varèse, Louise. 1972. *Varèse: A Looking-Glass diary*. New York: Norton & Company.

Vinet, Hugues and François Delalande (eds.). 1999. *Interfaces homme-machine et création musicale*. Paris: Hermes Science Publications, 236 p.

Wanderley, M., and P. Depalle. 1999. "Contrôle gestuel de la synthèse sonore." In H. Vinet and F. Delalande, eds. *Interfaces homme-machine et création musicale*. Paris: Hermès Science Publications, pp. 145-163.

Weidenaar, Reynold. 1995. *Magic from the Telharmonium*. Metuchen (New Jersey): The Scarerow Press.

Young, Gayle. 1989. *The Sackbut Blues. Hugh Le Caine. Pioneer in Electronic Music*. Ottawa: National Museum of Science and Technology.

