Notes

Introduction

1 There is a certain pressure to define and delimit electronic music, which we will sidestep. Electronic music has sometimes been technically differentiated from any music that might utilise electricity (in one sense, the brains of acoustic violinists use electricity!); for instance, the Wikipedia entry on electronic music founds its definition on the restriction of the IEEE standards body definition of 'electronic' (as referring to low-power components like transistors and integrated circuits). Whilst the main focus of our investigations in this book will refer to electronic circuits, and especially those modern-day hyper-miniaturised computer chips, we shall not refrain from discussing any electromagnetic and electromechanical technologies, especially where related to the history of electronic music, but also in contemporary work.

2 In one inspiring example of custom electrification and amplification, the ensemble Konono no.1 feature hand-built microphones salvaged from old car parts, and distorting sound systems incorporated into the essential fabric of their music (Congatronics, Crammed Discs).

3 In this book we will often emphasise such real-world examples, on one hand to support the ideas discussed, and on the other to serve as searchable topics for the Google/Wiki/YouTube/MySpace-friendly generation.

4 A large number of artists proudly declare that they bought the first or second Synclavier or Fairlight in the country . . .

5 This is especially true of the categorisation of electronica in the United States; elsewhere, it can connote a wider spirit of experimentation more readily.

6 At the time of writing, they both live in Germany, after all!

7 In another angle to such debate, fine artists who work with sound have entered into, well, not exactly competition, but correspondence and engagement with many of the same areas that musicians have explored. As we have discussed already, the music conservatoire education is not a necessary prerequisite for work in electronic music. It is often around the arena of electronic music where much of the sound art crossover takes place. Our own approach to this is pragmatic – everyone should learn about everyone else's work and background. It is now entirely normal practice that sound installations are cited as examples of work as well as tape pieces and live performances.

8 Further chronologies are provided in Cox and Warner (2004) and Shapiro (2000), or online, for example, http://eamusic.dartmouth.edu/~wowem/electronmedia/music/eamhistory.html

1 The origins of electronic music

1 This quotation has been cited by numerous musicologists over the years, including many of those listed in the bibliography.

2 First documented by Bartolome Ramos in 1482.

3 Recounted in Iamblichus (250–330 AD), *Life of Pythagoras*, chapter XXVIII: 'Organization Of The Pythagorean School'. Translated by Guthrie, K. S. in Fideler, D. (ed.) (1987) *The Pythagorean Sourcebook and Library*. Grand Rapids: Phanes Press.

4 For a good account of these questions in relation to electronic music, see Sethares (2005).

5 This piece was subsequently orchestrated by Beethoven for double woodwind (plus contrabassoon), four horns, six trumpets, three trombones, string section and large percussion section, including muskets and artillery alongside the usual timpani, drums and cymbals. The piece depicts a battle.

6 Franklin invented a *glass armonica*, in which revolving glass bowls pass through water and are then made to ring by gentle finger pressure on the rim.

7 The same book describes credit cards and shopping malls.

8 Had Cahill taken advantage of Lee De Forest's 'Audion' triode valve amplifier, invented in 1906, he could have achieved a reduction in size!

9 Buffet, *Musique d'aujourd'hui*, reprinted in the multi-volume work Slatkin, L. (ed.) (1971) *Les soirées de Paris*, vol. II. Geneva: Slatkin reprints, pp. 181–3.

10 The most celebrated example of a sound poem remains the *Ursonate* (1922–32) of Kurt Schwitters, a work which continues to influence contemporary sound poets such as Henri Chopin and Bob Cobbing.

11 Ball, H. (1927) 'Die Flucht aus der Zeit'. Reproduced in Elderfield, J. (ed.), Raimes, A.

(trans.) (1974) *Flight out of Time = A Oada Diary*. New York. The Viking Press, Inc. p. 70.
12 Specifically the Battle of Adrianopoli, 1912, in which Marinetti fought.
13 From Kostelanetz, R. (1970) *John Cage, An Anthology*. New York: Da Capo Press.

2 Electronic music and the studio

1 Gluck, B. 2006. Interview with the author. 19 November. Mr Gluck is one of the Executive Editors of the EMF, a web-based virtual museum documenting the history of electronic music.
2 Badagnani, D. 2006. E-mail correspondence with the author. 28 October. Mr Badagnani is the chief biographer for Halim El-Dabh.
3 Mathews, M. 2006. Interview with author. 8 September, San Francisco, CA. Max Mathews is one of the pioneers of computer music.
4 Hwang, S. 2006. E-mail correspondence with the author translated by Seong-Ah Shin. 9 October. Mr Hwang is the founder of the Korean Electro-acoustic Music Society.
5 Gluck, B. 2006. Interview with the author. 19 November.
6 Truax, B. 2006. Interview with the author. 4 December. Vancouver, BC. Mr Truax is an Associate Composer of the Canadian Music Centre and a founding member of the Canadian Electroacoustic Community.
7 Berg, P. 2006. Interview with the author. 20 September, Amsterdam, The Netherlands. Mr Berg teaches at the Institute of Sonology.
8 Dubois, R. 2006. Interview with the author. 6 October. New York, NY. Mr Dubois teaches interactive sound and video performance at Columbia's Computer Music Center and at the Interactive Telecommunications Program at New York University.
9 Oliveros, P. 2006. Instant messaging interview with the author. 11 September. Pauline Oliveros is the founder of Deep Listening.
10 Mathews, M. 2006. Interview with author. 8 September, San Francisco, CA.
11 Rai, T. 2006. E-mail correspondence with the author. 26 September. Mr Rai teaches computer music at the Kunitachi College of Music in Tokyo.
12 Mathews, M. 2006. Interview with author. 8 September, San Francisco, CA.
13 Wessel, D. 2006. Interview with the author. 26 September, Berkeley, CA. Mr Wessel is the director of CNMAT, the Center for New Music and Technology.
14 Sigal, R. Instant messaging interview with the author. 11 September. Mr Sigal is the director of CMAS, the Center for Music and Sonic Arts in Mexico.
15 Puckette, M. 2006. E-mail correspondence with the author. 26 September. Mr Puckette is the associate director of the Center for Research in Computing and the Arts.
16 Wessel, D. 2006. Interview with the author. 26 September, Berkeley, CA.
17 Sigal, R. Instant messaging interview with the author. 11 September.
18 Oliveros, P. 2006. Instant messaging interview with the author. 11 September.
19 Lippit, T. 2006. Interview with the author. 22 October, The Hague, Netherlands. Mr Lippit is a hardware developer at STEIM, the Studio for Electro-Instrumental Music.
20 Voudouris, D. 2006. E-mail correspondence with the author. 19 September. Mr Voudouris is the founder of UNYAZI, the first electronic music festival and symposium on the African continent in 2005.
21 Dubois, R. 2006. Interview with the author. 6 October. New York, NY.
22 Andrews, R. 2006. Interview with the author. 26 September, Berkeley CA. Mr Andrews is the Associate Director of the UC Berkeley Center for New Music.
23 Berg, P. 2006. Interview with the author. 20 September, Amsterdam, The Netherlands.
24 Oliveros, P. 2006. Instant messaging interview with the author. 11 September.
25 Berg, P. 2006. Interview with the author. 20 September, Amsterdam, The Netherlands.
26 Voudouris, D. 2006. E-mail correspondence with the author. 19 September.
27 Voudouris, D. 2006. E-mail correspondence with the author. 19 September.
28 Helmuth, M. 2006. E-mail correspondence with the author. 2 October. Dr Helmuth is the director of (ccm)2, the College-Conservatory of Music Center for Computer Music at the University of Cincinnati.
29 Sigal, R. Instant messaging interview with the author. 11 September.
30 Berg, P. 2006. Interview with the author. 20 September, Amsterdam, The Netherlands.
31 Chowning, J. 2006. Interview with the author. 3 September, Sausalito, CA. Mr Chowning was the director of CCRMA, the Center for Computer Research and Musical Acoustics at Stanford University.
32 Campion, E. 2006. Interview with the author. 26 September, Berkeley, CA. Dr Campoin is Co-Director at CNMAT, the Center for New Music and Audio Technologies.
33 Chowning, J. 2006. Interview with the author. 3 September, Sausalito, CA.
34 Hwang, S. 2006. E-mail correspondence with the author translated by Seong-Ah Shin. 9 October.

35 Shin, S. E-mail correspondence with the author. 9 October. Dr Shin teaches at the Baekseok University as a full-time lecturer and Korea National University of Arts, Seoul City University, Chugye University for the Arts in Korea.
36 Helmuth, M. 2006. E-mail correspondence with the author. 2 October.
37 Mathews, M. 2006. Interview with author. 8 September, San Francisco, CA.
38 Garton, B. 2006. E-mail correspondence with the author. 19 September. Dr Garton serves as the Director of the Computer Music Center at Columbia University.
39 Barnhart, M. 2006. E-mail correspondence with the author. 12 December. Mr Barnhart teaches electronic music at Shawnee State University.
40 Dubois, R. 2006. Interview with the author. 6 October. New York, NY.

3 Live electronic music

1 Unanticipated problems arose as telephone usage surged: crosstalk between adjacent cables caused the high-voltage signals of the Telharmonium to interfere with telephone conversations. Cahill tried alternative strategies, such as installing the instrument in a concert hall and broadcasting its sounds using nascent radio technology, but by 1914 his company was bankrupt.
2 Although it is worth noting that Robert Moog got his start by designing and selling Theremin kits while still in high school.
3 In fact in 1930, German film director Walter Ruttman used film soundtrack to create *Wochende* ('Weekend') a collage of environmental sound generally accepted to be the first work of *recorded* electronic music.
4 Private conversation between John Cage and the author, February 1974.
5 Which included over the years John D. S. Adams, Nicolas Collins, Paul De Marinis, John Driscoll, Phil Edelstein, Linda Fisher, D'Arcy Philip Gray, Ralph Jones, Martin Kalve, Ron Kuivila, and Matt Rogalsky.
6 At Mills these included Kenneth Atchley, Ben Azarm, John Bischoff, Chris Brown, Laetitia de Compiegne, Scot Gresham-Lancaster, Frankie Mann, Tim Perkis, Brian Reinbolt and Mark Trayle; at Wesleyan University, Ron Kuivila and Nicolas Collins; at California Institute of The Arts, Rich Gold.
7 The concept of integrating the player's skin in the circuitry would later figure prominently in the Circuit Bending scene.
8 It should be noted that some of the essential concepts of interactive computer music can be traced back to the compositions of Christian Wolff from the 1960s, such as *For 1, 2 or 3 People* (1960), in which acoustic players are asked to co-ordinate their playing by following rules very similar to the binary logical operations of computers.
9 This field was eventually institutionalised in the annual NIME (New Interfaces for Musical Expression) conferences, which began in 2001. See http://www.nime.org
10 'The Adventures of Grandmaster Flash on the Wheels of Steel', recorded in 1981 with The Furious Five, was the first record to feature these techniques, previously heard only in club settings.
11 I've yet to find a primary source for this possible urban legend. See:

Will Hoover, 'CD generation spins LP revival; loyalty of fans helps vinyl recordings defy predictions of their demise', *Honolulu Advertiser*, 6 March 2000. http://the.honoluluadvertiser.com/2000/Mar/06/islandlife1.html
Rajan Datar 'More Club. Club Class!', BBC News, *The Money Programme*, 8 March 2001. http://news.bbc.co.uk/1/hi/events/the_money_programme/1208710.
'DJ Interview: Jam Master Jay', *The Loop – Scratch Newsletter*, 1(1), August 2002. http://www.scratch.com/theloop/news/newsletter.html
Virgil Moorefield (2001) 'From the Illusion of Reality to the Reality of Illusion: the Changing Role of the Producer in the Pop Recording Studio', Ph.D. dissertation, Department of Music, Princeton University. Chapter 3, pp. 11–12. http://www.virgilmoorefield.com/prodtext.html

12 In the 1990s German Electronica groups Oval and Microstoria rediscovered the CD glitch, and adopted it as a signature element in their music, which in turn influenced the emerging genres of 'Glitch' and 'Micro-house'.
13 http://www.windworld.com
14 See for example Reed Ghazala's web site at http://www.anti-theory.com
15 Personal e-mail correspondence, April 2005. Britain's particularly vibrant bending scene has roots in the popularity of toys as affordable, alternative noisemakers among improvising musicians, such as Steve Beresford, in the 1970s.
16 Personal e-mail correspondence, April 2005.

4 A history of programming and music

1 Let us dispel one notion at the outset. Many artists are content to work with computer software that is essentially designed for them, providing a certain rather rigid interface, but

one that can be quickly navigated after a short learning curve. There is no intention herein to disparage such creation – wonderful *breakcore* and *8-bit* pieces have been made with tracker programs, sequencers are a staple of electronic dance music (good and bad) and some electroacoustic composers craft fascinating works by essentially the manual use of a sound editor. But where the experimental composer wishes to face the responsibility of control over musical ideas, with novel nonlinear structures, customised interactions and nonstandard synthesis, they are often led to need the facility of programming.
2 http://sonic-arts.org/darreg/dar6.htm gives one contemporary report.
3 To those overly used to modern realtime interactive systems, the efforts of composers in the preparation of works without much feedback – Cage's months of tape splicing, Stockhausen's months of layering sine tones, or Babbitt's heroic fight with the RCA Mark II synthesiser – can seem awe-inspiring. Nevertheless, there are always new research directions to drive you through long projects of your own . . .
4 Which stands for '**M**INC **is n**ot **C**!', an example of the type of computer humour we prefer to relegate to an endnote.
5 James McCartney's own example patches for SuperCollider are themselves often held up as fascinating compositions. The Aphex Twin track *Bucephalus Bouncing Ball* (1997) was alleged to have reworked (and extended) one such compositional demonstration . . .
6 For more background see the TOPLAP homepage at http://www.toplap.org
7 This photo was taken at the Changing Grammars symposium on live coding in 2005: http://swiki.hfbk-hamburg.de:8888/MusicTechnology/609

5 Interactivity and live computer music
1 Raymond Scott's music can mostly be heard in many Warner Brothers animated cartoons. The melodies he wrote in the 1930s, for his jazz Quintette, were used in more than one hundred classic *Bugs Bunny* and *Daffy Duck* animated features, often orchestrated or adapted by Warner's Looney Tunes musical director, Carl Stalling.
2 For more detailed information on interactive music software during the 1980s the reader can refer to Yavelow (1986).
3 Available online at http://www.nime.org
4 *Misuse* should not be interpreted here with ideological, moral or aesthetical connotations. What we suggest is that only when a performer is capable of relating unwanted results (effects) with the actions taken (causes) will this performer be able to learn and effectively progress.

6 Algorithmic composition
1 These approaches are discussed thoroughly by Pearce *et al.* (2002) and Wooler *et al.* (2005).
2 'The revolution might almost be equated with an anthropological turning point because it introduces a further narcissistic insult (after Copernicus, Darwin, and Freud) – it wrests the initiative from nature and mankind and replaces it with an automatable inherent law of action. The illusion of sovereign action on the part of the individual and the romantic notion of anthropomorphic decidability are tempered as a result' (Weibel 2005, p. 1).
3 Johann Philipp Kirnberger, *Allezeit fertiger Polonoisen- und Menuettencomponist* (The always ready Polonaise and Menuet composer, 1757); Maximilian Stadler, *Table pour composer des menuets et des trios à l'infinie, avec deux dez à jouer, pour le forte-piano ou clavecin* (Tables from which one can toss off countless Menuets and Trios for the piano or cembalo, 1781); attributed to Joseph Haydn, *Gioco filarmonico o sia maniera facile per comporre un infinito numero de minuetti e trio anche senza sapere il contrapunto* (Musical game or easy method for composing an infinite number of Menuets and Trios, even without the knowledge of counterpoint, before 1790).
4 Random numbers achieved by throwing two dice are not equally distributed. The probability of getting the number 7 is six times higher than getting 2 or 11.
5 Markov chains are weighted chains of random number choices which can lead to the emergence of patterns and stable structures without fixing a specific route.
6 The arithmetical series of durations that was used by Boulez is characterised by its uneven proportions and the dominance of longer values. For the different time-based parameters (frequency, rhythmic durations, durations of formal sections), Stockhausen suggested the use of logarithmic scales where consecutive members of a series have the same proportional factor. Through this unifying organisational principle, non-related parameters like pitch, rhythm and form can be viewed as different manifestations of time in different temporal domains (micro-, meso- and macro-time) (Stockhausen 1957).
7 This is not achieved by an automatism; it is the result of compositional decisions (Ligeti 1958).
8 A flow chart and the entire FORTRAN code of the program 'Free Stochastic Music' can be found in Xenakis' book *Formalized Music* (1971), pp. 145–53.

9 This term was introduced by the physicist and information theorist Werner Meyer-Eppler who defines aleatoric processes as 'processes which have been fixed in their outline but the details of which are left to chance' (Meyer-Eppler 1955).
10 *Projekt 1 – Version 1* (1965–6) for small orchestra.
11 This was based on experiments in the electronic studio – a regular (= periodic) waveform would result in sound, whereas an irregular (= aperiodic) waveform produced noise.
12 Taken from Koenig (1997). The rhythmic values are shown as 'entry delays' (ED) which define the temporal distance between two adjacent rhythmical entry points.
13 Available on request from the author through his website http://www.koenigproject.nl
14 Quoted from Shachtman, N. 2001. 'New Eno Music Gets "Generative"', *Wired News*, 27 October 2001.
15 The Algorithmic Stream began in 1997 at Brown University and is today located at Emerson College.
http://pages.emerson.edu/faculty/m/maurice˙methot/stream/newstream.html
16 http://www.r4nd.org
17 This started in 1986 at IRCAM, Paris, when Miller Puckette was designing a control language named 'Patcher' for the 4X machine – a digital sound-processing workstation developed by Giuseppe Di Guigno, initially for Pierre Boulez's live-electronic oeuvre *Répons* (1981). In the beginning, Max could only process MIDI data and was used to control external hardware like synthesisers, MIDI instruments or FX devices. This changed in 1990 with the development of the 'IRCAM Signal Processing Workstation' (ISPW) – a realtime sound processing unit comprised of a NeXT computer with a customised, highly-expensive sound card which was only affordable by computer music centres. As computers became fast enough to process audio without external hardware, PD (1996) and MSP (1997) were released – both are based on the original Max paradigm, but are capable of realtime synthesis and signal processing.
18 Available as Open Source for Mac OS and Windows XP and also for PD from http://www.essl.at/works/rtc.html
19 A programming language for sound synthesis by Barry Vercoe *et al.* (MIT 1984). http://www.csounds.com
20 A realtime audio synthesis programming language by James McCartney (1996). http://www.audiosynth.com
21 A strongly timed, concurrent, and on-the-fly audio programming language (2002). http://chuck.cs.princeton.edu
22 A visual programming language from IRCAM based on CommonLisp by Gérard Assayag *et al.* (1995). http://recherche.ircam.fr/equipes/repmus/OpenMusic

7 Live audiovisuals

1 See http://rhythmiclight.com/archives/timeline.html, or Peacock (1988).
2 These included works by Karlheinz Stockhausen, Pauline Oliveros and Morton Subotnick.
3 Personal communication with Michael Scroggins, e-mails to Amy Alexander, 1–5 October 2006.
4 They were not alone in this role. For example, Light Sound Dimension, a San Francisco-based ensemble, included both audio and visual elements: light show performers as well as electronic musicians comprised the ensemble, which rehearsed and performed together as an integrated unit. Light Sound Dimension made its first performance in early 1967 at the San Francisco Museum of Modern Art, and by 1968 had established their own theatre, the Light Sound Dimension Theater (Ham 2002, pp. 2–3).
5 As per note 2.
6 See for example 'The World's Largest List of Psychedelic Lightshows' http://www.angelfire.com/psy/liquid_sound_designs/LiquidSoundDesigns_lightshows.html; and 'Pooter's Lightshow Index' http://www.pooterland.com/index2/lightshow_menu/lightshows/lightshows.html
7 http://www.audiovisualizers.com/toolshak/vsynths.htm
8 Developments in visual computer technology have tended to lag a little behind audio, due to the increased processing load. Whilst at first sight the reader might believe the 44,100 samples a second of audio to be the greater challenge, if we imagine visual data processed as frames of size 640 by 480 RGBA pixels at a ballpark of twenty-five frames per second, the processing load is 30,720,000 floats per second, a factor of 697 times more!
9 An example of such fashion shifts is the move from the nato.0+55 extensions for Max/MSP under Mac OS 9 to Cycling 74's own Jitter package in more recent times.
10 A basic premise of much audiovisual performance is that extra stimulation in a further modality heightens audience's experiences. Commentators on audiovisual media have appreciated the 'added value' (Chion 1994) communicated by correlated information from stimulating two senses simultaneously. Indeed, in some cases, reaction time to stimuli in coincident modalities is faster than to either sense alone (Welch and Warren 1986).

8 Network music

1 http://earlyradiohistory.us/1909musi.htm
2 Bowker, G. and Star, S. (1996) *How things (actor-net)work: Classification, magic and the ubiquity of standards*, at http://epl.scu.edu:16080/~gbowker/actnet.html
3 DeMarinis, P. (2006) *Firebirds and Tongues of Fire*, at www.uiowa.edu/~iareview/mainpages/new/feb06/demarinis.html
4 Warburton, D. (1998) *Luc Ferrari, Interview by Dan Warburton*, at http://paristransatlantic.com/magazine/interviews/ferrari.html
5 Hyde, A. and Harger, H. (1998) *Radio Astronomy*, at http://www.radio-astronomy.net
6 Due to its relationality, Peirce's semiotics (theory of signs) provides a good model for reasoning about causality and programming in terms of sign processes (Peirce 1958; Andersen 2006). The notion that a symbol stands in for something else is equivalent to Shannon's concept of the message representing a *choice* in the receiver (Shannon 1948).
7 For a general discussion of transmission protocols see Holzmann (1990).
8 The absence of a unified system of truth doesn't mean, however, the absence of structure, and the experiment can't abdicate responsibility for the event. The paradigm rather shifts in another direction: the explicit intervention by rules, such as programs or instructions, is intended to formulate a problem, rather than a solution.
9 See Baumgärtel (2005) on the exhibition *Les Immatériaux* (1985), curated by Jean-François Lyotard.
10 A peer-to-peer network structure, for instance, may be used for a monopolistic control scheme and a central server for a pluralistic conversation.
11 De Campo, personal communication, 2006.

9 Electronic music and the moving image

1 Interview with Eduard Artemiev speaking of film director Andrei Tarkovsky and the music for *Solaris* (1972) (Egorova 1988).
2 A more extended discussion of Schaeffer's four listening modes is found in chapter 13.
3 A further refinement of this is found in Nicholas Cook's explanation of his models of multimedia: conformance, complementation and contest (Cook 1998, pp. 98–106).
4 Electronic music has traditionally incorporated the manipulation of sound recordings and this practice is implied throughout the discussion.
5 Although Davies (2006) states that the 'synthetic high and low frequencies' were actually drawn onto the soundtrack.
6 A more complete account of the use of the Theremin in film is contained in Hayward (2004); Wierbicki (2005).
7 It certainly makes them precursors to circuit bending.
8 By disembodied I mean that the sounds themselves don't necessarily bear a signature of direct human physical effort.
9 Burtt's own account in the audio commentary at 1:15:11 of *Star Wars IV*, from the Trilogy Limited Edition DVD set.
10 A technique named after Jack Foley, Hollywood sound effects pioneer who first recorded sound effects live and in sync while watching the film, to enrich the sound of early talkies.
11 Whose name today is Wendy Carlos.
12 There is a noticeable difference between having an orchestra booked for a three-hour recording session, including a fifteen-minute coffee break, under the careful eye of the musicians' union representative, and being able to make a similar sound with samplers and synths in the privacy of a home studio.
13 This comment is meant to be more thought-provoking than provocative. Academia can offer a safe haven to experimentalists who push the boundaries outside the commercial world and this benefits everyone in the end. However it is salutary to think that we are never that independent of our audience's taste or of contemporary musical trends. In any case, there is also such a thing as successful experimentalism, as the work of electronica artists such as Aphex Twin or Squarepusher demonstrates. Overall, we may even artificially separate academics, independent artists and commercial interests too much.
14 Scott had been developing it since 1948 (Blom and Winner 2000).
15 Track 23 from CD1 of *Manhattan Research Inc.: Raymond Scott*. Holland: BASTA Audio/Visuals.
16 The creator and producer of the children's TV programme *The Muppet Show*.
17 SMPTE stands for 'Society of Motion Picture and Television Engineers'; it is also a complex synthesised audio signal which is used in film/TV to identify a location by hours, minutes, seconds and frames.
18 In the *Manhattan Research Inc.* CDs mentioned above.
19 Given that video games are a very fast expanding industry, even by the time this book reaches the shelves anything billed as 'new' here may already seem slightly obsolete.
20 The first 'Tennis' graphic game was invented earlier in 1966 by Ralph Baer, in the US.

21 Tracker software, which is much like a sequencer program, can be found easily on the internet. Some of the earliest trackers were *Scream Tracker* or *Impulse*. If you search for MODs on the internet you will find many different applications for handling/sequencing this type of file. In any case, MIDI technology eventually took over as the favoured soundtrack creation tool.
22 Manufactured by Taito in Japan and distributed by Midway in the US.
23 Even though for those of us who owned an Intellivision console this may not be novel information, I would strongly refer the reader to Collins (2004): she presents a thorough account which is very worthwhile reading.
24 You can play an online version and listen to the hallmark accelerating tune at http://www.spaceinvaders.de/
25 Created by Oliver Wittchow, who to my knowledge was the first to make a full musical instrument out of the gameboy.
26 Thus, the algorithmic composition might be viewed as a secondary consequence of game world state.
27 These techniques have been widely utilised and were certainly not invented for the Lara Croft games, although recent media coverage would seem to suggest otherwise. Countless papers on adaptive music (and algorithmic composition) serve as a basis for it, in fact. See chapter 6 for examples of generative music and references. Such techniques have been around for a while in the music industry – as well as in academia – and, for example, featured in the Yamaha PSR series keyboards in the late 1980s, for which I was one of several music programmers at Yamaha R&D, London. To make 'styles', we would create the musical sections as 'cells' so that we had one or more introductions and endings, different transitions, breaks, and different accompaniments for verses, bridges and choruses. We also programmed different layers of orchestration that would only appear in response to the performer's musical activity. For instance, if they were playing a solo over the verse section and played many notes, very fast, brass sections would start to riff or string sections would appear. A specific site on adaptive audio in games can be found at http://www.iasig.org/aan

10 Musical robots and listening machines

1 The interested reader might follow up links to a blog of robot developments at http://techdigest.tv/robots or find further information on Repliee Q2 at http://www.androidscience.org
2 Indeed, this is a reason that there is much current research into the neuroscience of music, as an insight into brain activity.
3 In fact, the first reference to the term I have found is the Interactive Music System developed at CERL by Hebel, Scaletti and colleagues around 1981 (Chadabe 1997, p. 266).
4 http://www.studio360.org/show082104.html
5 http://logosfoundation.org/instrum_gwr/automatons.html
6 http://www.lemurbots.org
7 http://www.ai.mit.edu/projects/humanoid-robotics-group/cog
8 Paralleling contentions in the philosophy of artificial intelligence are issues of physical embodiment; many experimental systems are entirely virtual but for microphone input and speaker output. When this is accomplished well, it has the virtue of being non-invasive to traditional instrumental practice, such that acoustic musicians can quickly engage with a system. The disadvantage is a disquiet about the grounding in the real world; musical robotics, however, is a field of endeavour that is forced to confront the physical world outside standard computer interfaces.
9 Subsymbolic representations may prove very important for the modelling of non-expert listeners and indeed, the state of many musical situations even for experts (Scheirer 1996; Martin *et al.* 1998); for instance, in ambiguous harmony, or the difficulty of extracting inner voices.
10 This also implies some loss of information, however (Honing 1993). Whilst training and categorical perception tend to make certain sound objects jump out at us, we must be cautious about claiming that machines turn all audio into a perfect score-like representation (e.g. MIDI-style notes) as a necessary precursor to any further operation. An intelligent signal-processing device might operate entirely on low-level features and never deal with any discrete event formulation.
11 http://www.infomus.dist.unige.it/EywMain.html
12 So there are some flaws in the argument that the detection and anticipation of events is intimately tied to the physical substruct; for example, there is no tactile feedback or image of the body in beat tracking. Further, whilst the authors have attempted to fashion analysis routines for Haile based on theories of the perception of rhythm (the system remaining chiefly concerned with interaction in the rhythmic domain), these remain unproven and insufficient as regards human abilities. This is not to disparage the project; such undertakings

founded in cognitive science are extremely valuable approaches.
13 The reader unfamiliar with Nancarrow's wonderful contribution to music is encouraged to seek out the studies for player-piano, the culmination of fifty years of punching piano rolls by hand. These take advantage of mechanical pianos to explore territories beyond the limits of human performance, chronologically far in advance of later computer-based experiments.
14 Though this involves production rule mechanisms analogous to generate and test in algorithmic composition, and more advanced learning and critical mechanisms are open areas of research.
15 We are far from a time when machines might request membership of the Musicians' Union, though I heartily encourage any prospective system-builders to submit joke applications to the union for publicity purposes.

11 Computer generation and manipulation of sounds

1 http.//www.music.princeton.edu/paul/radiohead.ml.html
2 Arguably to the point of overuse for certain basic granular techniques in much recent electroacoustic concert music!
3 Research is ongoing; in one recent development, the grains of sounds are analysed for their features and can be used to form large databases of sound material for compositional reuse. *Concatenative synthesis* (Schwarz 2004) is now a blossoming area of interest for researchers and composers, often bringing up issues of copyright anticipated by the manually constructed works of composers like Pierre Schaeffer or John Oswald.
4 http://www.iua.upf.edu/mtg/pages/home
5 Using results from recent research on speech sound by Gunnar Fant.
6 For example, unfortunately, both Modalys and Cordis-Anima have a rather limited number of users, which is probably due to the way the software packages can be obtained. Modalys needs to be purchased from IRCAM, while, at the time of writing, Cordis-Anima runs only on Silicon Graphics machines, and needs to be purchased from ACROE.

13 Trends in electroacoustic music

1 Oliveros, P. (last updated 2006). At http://www.deeplistening.org/pauline/
2 See Manning (1985), pp. 31–3 for a more detailed description in English.
3 The reader will find Smalley (1992) a useful elaboration.
4 The combination of two texts by Smalley (1986; 1997) provide the clearest description.
5 For further reading see Wishart (1996), pp. 239–315; Bosma (1996); Hettergott (1999).
6 In contrast to a spatial illusion which is normally revealed over shorter durations, the time it takes a listener to arrive at an understanding of a spatial allusion is tied to the sound type and the duration that is needed to reveal its identity.
7 To explore this answer I direct the reader to Francis Dhomont's article 'Acousmatic Update' (Dhomont 1995) which suggests that although the concert may be an impressive enlargement of an acousmatic work, the CD is an exact replica of the composer's (stereo) master, contrary to the reduction (recording) of an instrumental concert.
8 Ferrari, L. (1998) 'Luc Ferrari Interview by Dan Warburton', at http://www.paristransatlantic.com/magazine/interviews/ferrari.html
9 Gerzso (1984); Boulez (1988) are interesting reference texts which explain compositional and technical aspects of *Répons*.