Live Algorithms for Music research network – Final Report March 2007

Overview
The vision for this network is the development of an artificial music collaborator. This machine partner would take part in musical performance just as a human might; adapting sensitively to change, making creative contributions, and developing musical ideas suggested by others. Such a system would be running what we call a "live algorithm". However, we can only glimpse at how this might be achieved.

The aim of the network has been to form an interdisciplinary community to identify the theoretical and practical issues implicit in this vision. The community has been nurtured through a series of research workshops (W1-5), project groups (P1-7), annual meetings (AM1-3) and concerts. In all we heard 40 presentations and 27 performances of live algorithm-inspired music.

At the time of writing (29th March 2007) the Live Algorithms for Music research network (LAM) has 150 members, many of whom joined when attending a LAM event (having become aware of the network through the network's promotional activities or other channels). The membership is diverse; practising musicians (electronic and instrumental), composers, artists, software engineers are represented, and from academia, researchers in computer science, cognitive science, robotics and mathematicians play an active role in LAM. Although primarily UK-based, there are members from other European countries, Australia and USA.

Interdisciplinarity has been nurtured in two ways. First, by bringing together people who might not normally meet in such a context. As well as providing a platform for the cross-fertilisation of ideas., this encourages the identification and development of new subject domains. At the first workshop we heard presentations from an artist, a roboticist, two musicians, a social psychologist, an engineer, a music theoretician, a computer scientist and a composer. This mix of interests and expertise was evident in each meeting, and in the constitution of the project teams. Second, interdisciplinarity has been fostered by providing a critical and reflective forum for researchers who are already working across subject domains. LAM members who are professed computer musicians, for instance, are well versed in specific cutting edge technology (Max/MSP, pd, SuperCollider,...) and are active performers. LAM has given defined a rigorous intersection for several interdisciplinary domains, uniting them with a vision of what computer music could become; more than a tool or a digital instrument, the live algorithm would be a creative force in its own right. As well as inviting established figures LAM has also actively encouraged participation from research students and young researchers, who are well represented in LAM presentation and performance sessions.

LAM has benefited from visits by world leaders in improvised and computer music. Arguably the immediate precedent for Live Algorithms research is the pioneering Voyager system of George Lewis (Columbia University, USA). Professor Lewis gave the plenary talk at our final meeting, hosted a workshop on voyager and performed with software developed by the LAM project teams. Al Biles (Rochester Inst. Technology, USA) presented and performed the GenJam system at the second meeting. A third proto-live algorithm, Francois Pachet's Continuator, was also represented at a LAM workshop. At the first meeting, Robert Rowe (then at NYU), who has written extensively on interactive computer music delivered a keynote address via the MARCEL. Evan Parker, George Lewis and John Tilbury, acknowledged internationally as leading exponents of improvised music were also special guests at LAM concerts. A public concert at the last annual meeting featured duets between George Lewis, Evan Parker and live algorithm software developed by the project teams. This concert was awarded a "Critic's Choice" award by Time Out magazine and was featured in a leader article in Society for the Promotion of New Music's New Notes magazine, and was attended by over 100 people, including many members of the public. The function and characteristics of the algorithms were explained in an accompanying booklet.

In our original proposal we had planned for an initial year of networking activity and discussion followed by a year of intense project work and outreach. On the whole this plan has been implemented. Between December 2004 and December 2005 we held two conferences and two workshops and ran two mini-projects. The website, mailing list and wiki were established during this period to facilitate communication. Additionally, two mini-projects investigated key issues of the LAM agenda. Early in 2006 we placed a call on the mailing list for project ideas. Three proposals for the development of software systems were subsequently sponsored. A discussion-based project resulted in a grant proposal (details online in the Je-

S system, about to be submitted).

LAM has established close links with international conferences NIME and ISMIR and with the leading international research centre, IRCAM. These links were fostered during the second year when there were numerous inter-site meetings as the project teams developed their ideas. LAM held its third workshop at IRCAM, Paris in June 2006. This event, which was attended by participants in the NIME 2007 conference and the IRCAM 'Improvisation with Computers' workshop, served to disseminate the LAM goals to a wider audience of academics and musicians.

This report continues with details of LAM events and closes with a statement of the novel research domains uncovered during the last two years, and how LAM will continue to operate.

P1 Conscious Algorithms Prof. O. Holland (Dept Computer Science, Essex), T. Blackwell.

Instigated after Prof. Holland's talk at W1, this project investigated connections between machine consciousness research and live algorithms. Two half day meetings were held in the summer of 2005, with feedback to the network at W2. This topic is important for live algorithms research because it addresses important contentions: are they (the live algorithms) alive? Are they conscious? Does this matter? Up until this point the prevailing view of the network had been that a purely dynamical system (i.e. without learning, memory, critical judgement and intentionality) might suffice. Particularly salient is the idea of embodiment of the algorithm into a human-like, robotic form, so that intentionality can be communicated by actual movement (e.g. the pause before a down-beat). This might also help the audience understand the relationship between the algorithm and the performers, an idea also taken up by project P2.

P2 Codification of Performance N. Hyde (Kreutzer Qtte, Royal Academy of Music), R. Redgate (Goldsmiths), C. Redgate (oboist), P. Healey (Interaction, Media and Communication Group, QML), M. Young, I. Stonehouse (EMS, Goldsmiths)

This project explored a central question identified by network members at the 1/2 day meeting 5 July 2005 - if an artificial improviser is to communicate/interact in a manner analogous to human-human musical interactions, how can the latter be better understood? More specifically, to what extent can aural and visual communicative strategies be discerned and distinguished when an ensemble is improvising collectively? The meeting concluded with a proposal for an experiment to be reported back to the network.

The experiment comprised two parts: 1. three volunteer musicians were recorded/video-ed improvising without prior discussion or preparation under various conditions of constraint. These constraints entailed isolation of each player from another, either aurally and visually, allowing only specific routes of potential communication (e.g. sonic communication between players A and B only, or no visual communication etc.). In part 2 the recorded material was presented to a discussion group at the following LAM workshop, who completed a questionnaire based on their observation of the material. The aim was to ascertain how far the observers could identify evident communicative strategies, expressed in call/response, instigations of behaviour etc. The questionnaire responses demonstrated that particular forms of adaptive coding in musical interaction were evident, and this encouraging response suggests that computer systems might in future learn/adapt their own codes for interaction. Future AHRC proposals are mooted to develop this project further.

P3 Interactive Non-Linear Media Prof. E. Miranda (Plymouth), Prof. A. Adamatzky (University of West of England), B. de Lacy Costello (UWE), T. Blackwell, M. Young

This discussion-based project ran throughout 2006. There were three 1 day meetings at Plymouth and Bristol and further discussions at the Unconventional Computation Conference, York. Classical computation is based on the paradigms of Turing Machines, von Neumann architectures and the digital computer. Unconventional computation (UC) seeks to widen computational possibilities by taking the computation outside the machine and into the real world, thereby harnessing the immense parallelism and non-algorithmic openness of physical systems. UC is particularly apt for many situations (including interactive music making) that are characterised by fuzzy, ill-defined, inputs and outputs, a constant throughput of streams of information and the lack of definitive answers. With these ideas in mind, two key workers in UC were invited to join LAM and contribute to a grant proposal aligned along the question of how people might interact with such unusual computational devices.

P4 Framework for sonification and visualisation of multiagent systems

Prof M. d'Inverno (Centre for Agent Technology, Westminster), F. Olofsson (independent software engineer)

Multiagent systems are a very general framework for patterning algorithms. In terms of a theoretical model for live algorithms research, introduced by Blackwell and Young and presented at AM1, a patterning algorithm f represents an 'ideas' engine (ref [1] in Other Outputs). Organisation – spatial and/or temporal – of states of f are interpreted as musical or sonic parameters, thereby giving the system a structured, idiosyncratic and ultimately algorithmic musical identity. Suitable f's include neural networks, swarming and particle systems and genetic algorithms. Multiagent systems interpolate between dynamical systems with simple entities and systems with more complex individuals interacting with a non-trivial environment.

 The system developed by this project team – 'RedUniverse' - allows fast prototyping of different scenarios of agent behaviours and environmental properties. The sounds an agent outputs is a function of its internal state and that of the external environment. One of the main objectives that drives the development of this framework is to create interesting musical structures by 'hijacking' what is hopefully emerging from within the system as a whole. There is also a visualiser to help users, audiences and developers to be able to help interpret the behaviours of the agents and how sounds are being developed. The RedUniverse toolkit is written in SuperCollider, a popular development language for live electronics. RedUniverse was demonstrated at W5 and is available for use by the SuperCollider community, and others, by download from http://quarks.svn.sourceforge.net/viewvc/quarks/redUniverse/

P5 Frank: Co-evolution framework for music improvisation D. Morelli (independent software engineer), D. Plans Casal (PhD student, Dept. Music UEA)

 This project is inspired by Todd and Werner's work on coevolution and algorithmic music composition. Their methods used co-evolution algorithms to simulate musical criticism through sexual selection. However, they lacked an important feature of any musical system or activity: contextual memory (a past). The aim of this project is to improve on existing methods by building a musical context: a lexical representation of features extracted from musical input (using MPEG7 techniques as exemplified by Casey's Soundspotter). The system is able to answer questions such as "What usually follows this musical gesture?" by building a database of acoustic lexemes. Frank creates contextually aware responses to live performances using a cultural memory (archived material of past performances) and co-evolution. The system, which is quasi-autonomous, performed with George Lewis and Evan Parker at AM3, and was presented at W5. The software, which is written in PureData (another much used environment for computer music development) is freely available for download from http://mp7c.svn.sourceforge.net/viewvc/mp7c/branches/GA/soundspotter/. Frank has also performed at Shunt Vaults, Joiner Street, London (9th Nov. 2006) and Ray's Jazz cafe, Foyles bookshop, Charing Cross Road, London (June 2006). The system, and its role within LAM, has been presented at Brunel University Drama and Music departments.

P6 Behavioural objects for musical composition and performance O. Bown (PhD student, Computing Goldsmiths), A. Eldridge (PhD student, Evo. and Adaptive Sys Group, Sussex)

The behavioural objects (BO) project aims the application of ideas from contemporary behavioural robotics to interactive music systems. Within the framework for live algorithms (P7), this project focuses predominantly on creating f's. The project has focused on methods for designing responsive pattern generators using Continuous Time Recurrent Neural Networks (CTRNNs). The implication is that an evolved CTRNN network can produce complex internal patterns of activity and respond to its environment with a form of dynamic memory. In a musical setting, artificial evolution can similarly be used to create networks which respond to an acoustic environment produced by an instrumentalist's improvisations. The project has looked for simply evolving behaviour that demonstrates a combination of reactive and generative capacities. It has been difficult to find the correct balance between the responsive and the generative. Often generative processes dominate, requiring the performer to trust that the algorithm is interacting with him. This very issue was an outcome of the musician's workshop (W4). The project team met with Dr. E. Di Paolo (Sussex) a leading researcher in evolutionary robotics and a draft grant proposal has been drawn up.

There have been talks on BO by the project team at an Interactive Mind and Art(efacts) network meeting in Brighton, at Dorkbot, London (a public meeting of electronic artists, musicians and technologists) and at the Music Department, Edinbugh University. The software has also performed at numerous public

events in Australia (Lan Franchis memorial discotheque, Sydney), Hungary (Artpool gallery, Budapest), The Netherlands (Lantaren Venster, Rotterdam) and numerous venues in the UK including the Huddersfield Contemporary Music Festival. Behavioural Objects performed with George Lewis and Evan Parker at AM3 and was demonstrated at W5. The Java-Max/MSP CTRNN object is downloadable from http://doc.gold.ac.uk/~map01ob/

P7 Framework for Live Algorithms T. Blackwell, M. Young
This project has investigated a modular framework for live algorithms based on our previous work on a biological metaphor for improvisation. One idea is to use a version of stigmergy, the mechanism used by social insects for communication by environmental modification, to enable interaction between a human musician and a computer. The idea is that the sonic environment is mapped into the system by a function P. The simulation f encounters these environmental changes and states of the system are subsequently rendered back as sound by a module, Q. This PQf framework formed a common language for our inter-disciplinary discussions. More recent work has incorporated neural networks into the scheme.
Presentations *Live Algorithms in Music,* Music Dept., U of British Columbia Jan 2006. *Live Algorithms, composing or not*? Music Dept. UEA, Oct 2006. *The Live Algorithms for Music Research Network* at Foundation for Art and Creative Technology, Liverpool, Nov 4, 2005. *Stigmergy and self-organisation in musical improvisation* at School of Computing, Communications and Electronics, University of Plymouth, Jan 27th, 2006. *Swarming and Music* at Music, Informatics and Cognition seminar, Edinburgh University, May 9th 2006
Music Performances of Swarm Music and Swarm Granulator at LAM concerts. Neural network driven live algorithms (MY) *Pianoprosthesis* K. Ryder, piano CNMAT, Berklee & Mills College. 2007. *Argrophylax* for oboe and electronics C. Redgate (oboe). British Music Information Centre "Cutting Edge" series and at RADAR 4, XX1 Festival de México, Mexico City, 2005. *Argrophylax* released on CD Oboe+: Berio and Beyond. Oboe Classics series. *Ebbs- for violin, cello and interactive electronics*. S. Prenn, M Weston. W. Kamermuziek, N. Muziekgebouw aan't IJ, Amsterdam. 2006.
Publications [1] Blackwell T.M. and Young M. *Live Algorithms*. Society for the Study of Artificial Intelligence and Simulation of Behaviour Quarterly 122: 7 (2005). [2] T. Blackwell: *Swarming and Music.* In Miranda E. and Biles A. (eds.): Evolutionary Computer Music. Springer Verlag 2007. [3] *Swarm Granulation* In Machado P and Romero J. (eds.): The Art of Artificial Evolution: A Handbook. Springer Verlag 2007 (Forthcoming). [4] Young M: *Au(or)a: Exploring Attributes of a Live Algorithm,* International Electroacoustic Music Studies Conference 2007.

AM 1 13-15 Dec 2004
Keynote R Rowe (New York University) M*achine Musicianship*
Presentations T. Blackwell, M. Young *Live Algorithms* E. Miranda *Music as Emergent Behaviour: A Discussion on the Activities of the Plymouth Group* P. Rebelo (SARC, Belfast) *Research Culture at SARC* G. Wiggins (Goldsmiths) *Computational Creativity* J. Bello (QMUL) *Introduction to the Centre for Digital Music* N. Schnell (IRCAM, Paris) *ATR Group at IRCAM* J. Impett, J. Bowers (UEA) *Redefining a Live Algorithm* K. Ng (Leeds) *Interactive Multimedia*
Performances J. Bowers *For al-Khwarizmi* J. Impett (meta-trumpet), S. Lexer (piano, electronics) and J. Tilbury (piano) *acoustic and electronic improvisations* P. Archbold (Kingston), C. Redgate (oboe) *a little night music* E. Miranda *Robotaphitecos* O. Bown (laptop) and T. Arthurs (trumpet) *duet* T. Blackwell *Swarm Music* M. Young, C. Redgate (oboe) *Argrophylax*

AM 2 19-20 Dec 2005
Keynote Al Biles (Rochester Institute of Technology, New York) *Improvising with Evolutionary Computation: Lessons from the GenJam Project*
Presentations D. Plans Casals *Frank: an Open Source framework for evolutionary music composition* Joao Martins (Plymouth) *Evolution of Rhythms in Artificial Worlds* A. Renaud, P. Rebello (Sonic Arts Research Centre Queens University of Belfast) *Distributed Cues in Networked Improvisation* T. Davis, P. Rebello (SARC, Belfast) *Emergence in Sound* C. McClelland, M. Alcorn (SARC, Belfast) *Escore* L. Harrald (Elder School of Music, Adelaide University, Australia) *The Prisoner's Dilemma* A. Eldridge, O. Bown *Live (Dynamical Systems) Algorithms for Musical Instruments* David Muth (Ravensbourne College) *Sodaconductor*
Performances R. Herrema *Habitation* T. Gardner *Lipsync1 (cello and live electronics)* E. Lyon *Stem Cells* M. Bille (independent singer), T. Blackwell & M. Young *Swarm Granulator* M. Casey, C. Redgate, S.

Lexer, T. Chrysakis, O. Bown i*mprovisations*

AM 3 18-19 Dec 2006, Goldsmiths
Keynote Prof. George Lewis, Columbia University
Presentations Tim Blackwell & Michael Young *LAM Projects: Report.* William Hsu (San Fransisco State Uni.) *Modeling Mood and Interaction in Automatic Improvisation.* Tim Sayer *Expanding The Territory: Prosthetic Mental Functioning In Man Machine Interaction.* Diemo Schwarz (IRCAM, Paris) *Real Time Corpus-Based Concatenative Synthesis System and Performance.* Nick Collins *Autonomous Interactive Music Systems* Tom Davis *Environmental Context in Live Algorithms, 'Excuse Me'*
Performances George Lewis, Evan Parker, with *Voyager*, the LAM projects, and other live algorithms. William Hsu and John Butcher *improvisation.* Sebastian Lexer, Thanos Chrysakis, Dario Bernal Villegas *Audio crossings* Nick Collins *Drumtrack.* Mike Casey, David Gorton (Royal Academy of Music), Chris Redgate *Erinnerungsspiel.* Diemo Schwarz, Sam Britton *Rien de Tout. Andrew* Robertson, Real-time *Beat Tracker.* Michael Young, Roger Redgate *Aur(or)a.* Matt Lewis and Hilary Jeffery *Videoscores for Tromboscillator*

W1 Goldsmiths, April 2005
Presentations O. Holland (Essex) *Machine Consciousness and Creativity* P. Brown (School of History of Art, Film and Visual Media, Birkbeck College) *Robotic Art* T.Blackwell and M.Young *A Framework for Live Algorithms* E. Miranda and B. Boskamp (St Andrews) *Generative Grammars* M. Casey *Audio Similarity* C. and R. Redgate *Textural Improvisation: Practitioners' View* N. Bryan-Kinns and P. Healey (QMUL) *Digital Reciprocity*

W2 15 Sept 2005 in association with ISMIR 2005 http://ismir2005.ismir.net/program.html
Keynote J. McCormack (Monash University, Australia) *Practical strategies and ideas for how generative techniques can be used in artworks/live algorithms*
Presentations F. Pachet (Sony CLS) *Research at CLS including Ringomatic: A Real-Time Interactive Drummer* R. Dannenburg (School of Computer Science and School of Art, Carnegie Mellon University) *Music Understanding for Interactive Music Performance* A. Brown and R. Wooler (Queensland Institute of Technology) *Generative Scores, Impromptu, a live programming environment, generative dance music* C. Raphael (School of Informatics, Indiana University) *Music Plus One* N. Collins (Cambridge) *Machine Enhanced Improvisation* O. Holland and T. Blackwell *Conscious Algorithms* M Young, C Redgate, R. Redgate, P. Healey *Codification of performance (including experimental results)*
Performances A. Eldridge *fond punctions* C. Redgate (oboe) and R. Redgate (violin*) improvisation without electronics* J. Lely and S. Lexer *improvisation with electronics* N. Collins (with C. Raphael on oboe*) Concerto for Accompaniment* N. Collins, F.Olofsson *audiovisual capture experiment* M. Casey (trombone), Roger Dannenburg (tpt) *Sueme No. 1*

W3 4 June 2006 in association with NIME 2006 and IRCAM, Paris
LAM co-hosted, with the ATR Group at IRCAM, a one-day workshop *Improvisation with Computers* http://recherche.ircam.fr/equipes/temps-reel/nime06/workshops.htm
Presentations T. Blackwell and Michael Young *What is a Live Algorithm?* E. Miranda and Marcelo Gimenes *BCI got Rhythm - Improvisation for Two Pianos and Brain-Computer Music Interface.* A. Eldridge, O. Bown, S. Lexer *Behavioural Objects for Interactive and Generative Music* D. Plans-Casal, D. Morelli *Give Frank a brain: improvisation for piano using co-evolution and MPEG7 techniques*

W4 7 November 2006 Behavioural Objects: Musician's Workshop
Six improvisors were invited to a workshop on the newly developed behavioural objects: C. Redgate (Oboe), Adem (songwriter), M.Grierson (film maker), M. Yee-King (Drums), J. Black (guitar)

W5 19 Dec 2006 Software workshop
Featuring live algorithm software from: T. Blackwell, O. Bown, D. Plans Casal, A. Eldridge, O. Hancock, G. Lewis, F.Olofsson, D. Morelli, D. Schwarz, M. Young. The systems heard just the previous night in concert were explained in some detail to the network in a workshop and poster session.

Summary

The diverse range of backgrounds found within the LAM network and the contributors to the projects, workshops, meetings and concerts is evidence that a vibrant new research community is coalescing around the LAM agenda. A unique and exciting feature of our interdisciplinary methodology has been the feedback between performance, theoretical analysis and software design. The rigours of the concert environment is an excellent experimental test-bed of live algorithms; how well the musicians interact with the machines, how creative the machines might have been, whether these relationships are communicated to the audience, and whether the software is robustly engineered. Musical performances provide opportunity for the dissemination of materials, allow network members/audiences to critically evaluated the efficacy and originality of "live algorithmic" systems, and allow experienced musicians to explore and interact with such systems (with which they may or may not be familiar in advance). These activities, as practice-based research, are integral and necessary component of the network's research.

The network closes its EPSRC funded period with some planned outreach tasks still in progress, due to finish in May. We have obtained a quote from an web design firm to rework our existing site (www.livealgorithms.org). LAM now has a large archive of concert material, video footage of experiments, presentations and other documents, and we intend to develop the website to facilitate the dissemination of this material, and to allow for future expansion of this resource. In particular we wish to provide a portal for software distribution and host the proposed Journal of Live Algorithms (see below). A recording of the final concert with George Lewis, Evan Parker and our live algorithms has now been mastered to a red book standard. In line with our original plan we aim to release a cd of this event with an accompanying explanatory booklet. We are also in discussion with Columbia University on an idea to found an online journal for live algorithms research (JLA). The concept is to broaden the theory and application of computer autonomy to other performance art forms. The editorial panel would be found within the LAM network, and through our contacts at Columbia.

LAM now has a considerable momentum and the 2007 meeting is already being planned. This will be funded by a small participation fee and with the assistance of the society for Artificial Intelligence and Simulation of Behaviour who are keen to incorporate LAM within their own public understanding of science initiative.

We have delineated a research domain which encompasses music computing (signal processing, music informatics, sound synthesis), natural computation (the search for novel patterning algorithms from artificial life, neural networks, genetic algorithms etc.), unconventional computation (novel hardware-software hybrids, often involving parallel processing), machine consciousness (in order to impart intentionality and critical judgement), machine learning (so that the LA might learn from past musical encounters), performance and interpretation studies (so that the relationship between human performers in an improvised setting can be better understood, and then generalised) and human computer interaction (to facilitate non-aural communication between performers and the LA, and between the audience and the LA). The explorations of the project teams have defined these interdisciplinary research topics:

Embodiment of the algorithm (P1) Robotics, computer science, neuroscience, choreography, performance art
Codifying strategies for interactions between musicians (P2) Improvised and classical music, performers, musicology, linguistics, music psychology, software design
Interacting with non-linear media (P3, P7) Generative composition (esp. generative), Composition for bespoke instruments, musical instrument design, computer science, chemistry, electronics, engineering
Sonification and Visualisation (P4) AI, animation design, HCI, computer music (esp. sound synthesis)
Biological models of improvised behaviour (P5, P7) Music informatics, biology, evolutionary science, software design, digital signal processing
Neuro-computer music (P3, P6, P7) Neuroscience, neural networks, natural computation, sound synthesis, audio analysis

"LAM is an international force" George Lewis, plenary talk, LAM annual meeting 2006