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ImaginationTOOLS^{TM}. A 3D environment for learning and playing music

E. Bilotta[1], P. Pantano[2], F. Bertacchini[3], L. Gabriele[3], G. Longo[3], V. Mazzeo[3], A. C. Rizzuti[3], A. Talarico[3], G. Tocci[3], S. Vena[3]

[1]Department of Linguistics, University of Calabria, Rende, Italy
[2]Department of Mathematics, University of Calabria, Rende, Italy
[3]Longo & Longo s.a.s., Rende, Italy

Abstract

In this paper, we present ImaginationTOOLS, a software which uses mathematical models to generate, analyse and synthesize sound and music. User learns in an imaginary 3D-city basic concepts on mathematical models and music by interacting with pedagogical agents; composes in a laboratory room using a manipulatory agent-like interface; listens to music in an immersive room and creates interactive music with ad-hoc designed instruments and performs and shares music on the net. It represents a real advancement on the existing similar scientifically-oriented products available on the market and it is considered a fusion of different music and multimedia technologies, with a strong developmental trend into physical interaction design. It is the first software using 3D interaction in a 3D environment to produce sound and music, extending the potential of musicians by experimenting in the psycho-acoustical domain of sound and overcoming the problems of musical education, with simple interface.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; Audio input/output; H.5.2 User Interfaces;User-centered design; H.5.5 Sound and Music ComputingModeling; Signal analysis, synthesis, and processing; I.3.7 Computer Graphics; Three-Dimensional Graphics and Realism

1. Introduction

The field of research that deals about the process of generating or composing music with the aid of computers is Computer Music and has been linked to technological creativity and innovation from the first experiments with electronic instruments at the beginning of the 20th century [Bus62]. It also refers both to the study of how technologies can improve musical cognitive processes (from composing, to performing to listening), modelling the generation algorithms on the obtained results by studies on psychological performances with humans and on defining which are the design principles in building up augmented software/hardware environments that can be used by musicians in order to extend their potential.

The consequence is that Computer Music is changing the process of music making. There is a lot of effort in creating new ways of composing by using score processing as in FINALE, software packages based on LabVIEW-like interface, from MAX/MSP to other programming environments such as the Audicle [WMC06], interfaces for musical expressions (www.viktoria.se/fal/events/mobilemusic/2005.html), from the work of Machover [Mac06] BrainOPERA at the MIT Media Lab, to the React-Table [JKGB05], which is a state of the art of the Tangible User Interface (TUI) [UI01]. But in the list are not mentioned improvements and applications in the use of music on mobile devices such as mobile phones (music on demand) and i-Pods (www.viktoria.se/fal/events/mobilemusic/2005.html) and in the realization of complex multimedia network architectures in order to create wide-band communication infrastructures, capable of supporting "Distributed Immersive Performance" [CZS*04, CZS*05] for musical interaction at distance. These studies have given life to a new generation of musical activities, hardware, architectural components and software packages (from composing to performing by using physically real embodied intelligent objects) which have widened the musician's creativity, deepening the

musical knowledge of a community of users overcoming physical barriers and extending human capabilities as well. There is another great wave of changes in Computer Music, the use of the contemporary models of Science such as Chaos [Tru90, Bid92], Fractals [Deg05], Dynamical Systems [Pre88]; [BGP05], Artificial Life [BP01, BP02] Evolutionary computation (http://evonet.lri.fr//eurogp2006). The aim is focused on linking researchers who are developing musical artificial life systems to share their ideas and experience, and to help establish this topic as a promising application of the methods, technologies and application of the Science of Complexity and of Artificial Life.

Music researchers, in addition to traditional historical and theoretical issues, have long sought answers to questions regarding the nature of music itself, its biological basis and its function and significance in human society and culture, and its evolution. The use of Artificial Life models for creating music is one of the most stimulating and significant areas in computer science today. Artificial Life models offer creative methods of solving problems in this domain, using mechanisms derived from natural evolution, cellular automata, evolutionary computation and so on. The term Artificial Life designates the research into human-made systems that exhibit some fundamental properties of natural life [Lan86]. The comprehension of essential properties of life proposes some questions inherent to biological phenomena and to complex systems. Music is a complex phenomenon, because it emerges from the interaction of cognitive, biological and cultural processes. The emergent properties of a melody are set to a more complex level than constituent elements. In spite of several studies in this sector, many characteristics of the nature of this complexity are still unknown.

The scientific questions that artificial life proposes in the study of music concern: the creative process of musical composition and production, the issue of origin and evolution, the dynamics of formation and diffusion of musical culture in a social context, the emergent behaviour and -if any- the functional meaning. Regardless of this great number of researchers working in many directions - musical programming languages and hardware/software applications- there still exist many musicians who are completely unaware of technology matters, due to many problems, but principally for the lack of what Norman calls emotional design [Nor04]. According to him, it is impossible to design a software or any other object without a deep knowledge of the people who will use it. Furthermore, it is possible to design smart things or "Things That Make Us Smart" [Nor93], giving to the object we are designing the characteristic of emotions, which are a fruitful mix of "heart and mind".

ImaginationTOOLS wants to grasp this design approach, trying to create a metaphor in which the user is immersed in an emotional environment, with a rich quantity of objects, places and activities, the City of Imagination. In this city it will be possible to fill the gap existing between computer musical technologies and non-skilled musicians in these matters, with the aim of recreating a quick hands-on educational path for these topics, with a self-confident approach and an easy to learn method. Furthermore, this project seeks to exploit the new technological and scientific progress for creating music, sound and advanced tools, coming back to the idea of the Renaissance scientists who were tool inventors and scientists at the same time.

The paper is organized as follows: after the introduction, section 2 deals about the goal of the software; section 3 reports on the environments and the activities the user can do in the environment, while section 4 illustrates some of the Computer Graphics issues we have faced and solved for creating the 3D places, by using Chua's attractors as building blocks. Finally, the conclusions and future work close this presentation.

2. Goals of ImaginationTOOLS

The main aim of this project is to build up technological scenario in which to do experiments on modelling user composing, performing, listening to music and building sound behaviour while he/she is interacting with agents (spheres of different colour and dimensions) that embody continuous dynamical systems such as Chua's attractors and all its generalizations.

The project will also implement new technologies that consist in collections of physical devices (microcircuits, wireless devices, ubiquitous computing, small robots provided with a specific cognitive architecture, etc.) that interact with an external environment and communicate both among themselves and with human users, by using particular artificial languages developed from Chaos Theory [BP06].

The project topics are the following:

1. To plan and develop a virtual reality based scenario which will allow to the activation of the musical modelling processes in a technologically advanced experimental context.
2. Investigation of the mathematical models, the computer graphics tools, the virtual and augmented technologies, the manipulatory behaviour suitable in order to implement graphical virtual environments where users can interact in many and different non conventional ways with these dynamical systems.
3. Implementation of different interaction modalities in order to produce music and sound from these systems.
4. Creation of new tools for music and sound making, both simulated and physical.
5. Music and sound composing, performing and listening.
6. Music and visualization systems.
7. Experiments on cognitive processes related to the creation of music and sound and to the auditory perception.
8. Study of the usability of the system and of the user behaviour.

3. Landscapes from the City of Imagination

3.1. The Edutainment Environment

ImaginationTOOLS represents a new philosophy of emergent musical software which present a beautiful city (Figure 1, 2) made up of Chua's attractors.

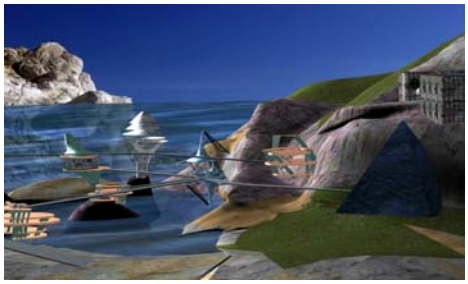

Figure 1: *'The software environment'.*

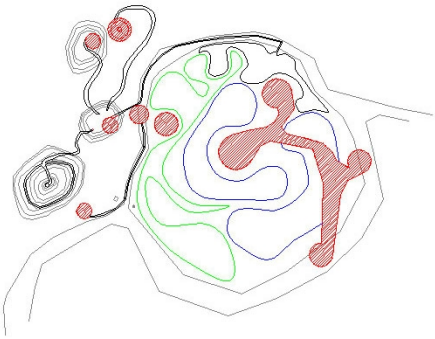

Figure 2: *'A plan of the software environment: in red colour are represented the buildings; in green colour the areas used for the vegetation; in blue colour the aquariums; in black colour the footbridges that will link the different buildings.'*

This environment is immersive. The user arrives by flying and landing near the Museum entrance. From the sky, the user can see a very nice place on the sea, with some buildings which seem to be hanging from a rock. In front of this place, a sky-line made of Chua's attractors closes the view on the explorable world. The museum, is a building made by Chua's attractor, after a process of complexity reduction especially of the external texture of this object) and has been organized as a real immersive museum where it is possible to visit a collection of Chua's attractors and to listen to music and sound they produce and to visit an artistic gallery of the same topic. In this place it is possible to manipulate patterns coming from Chua's dynamical systems and to discovery the fractal nature of these objects. Furthermore, the user can create his/her graphical and sonorous or musical exhibition and allow other users to enjoy it. In the City of Imagination, the user is free to learn, by interacting with pedagogical agents which occupy some edutainment places, where, for example, it is possible to study pattern formation in chaotic systems, deployed as a virtual exhibition in a museum (Figure 3).

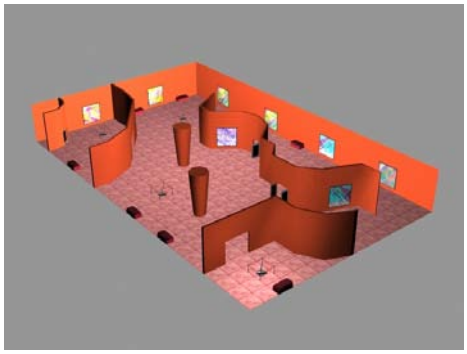

Figure 3: *'In this figure you can admire the museum structure.'*

These agents help him/her to understand concepts about scientific models and music by using hands-on activities. Furthermore, the agents guide the user in the city tour. Two prototypes are ready, one realized in JAVA, the other in C++. We remind to section 4 for explanation of Computer Graphics Issues.

3.2. The Lab

In the Lab (Figure 4), the user can construct sound and music regardless of his/her competencies, by using direct manipulation of objects.

Figure 4: *'In this figure you can admire the laboratory environment'*

These objects, called tools, are spheres of different colours and belong to three different categories according to their functions (input, process, output, link), and, using some simple rules, can be joined together by using cylinders in order to create a network of musical elements, which can be played together (Figure 5).

The metaphor that has been drawn is based on the

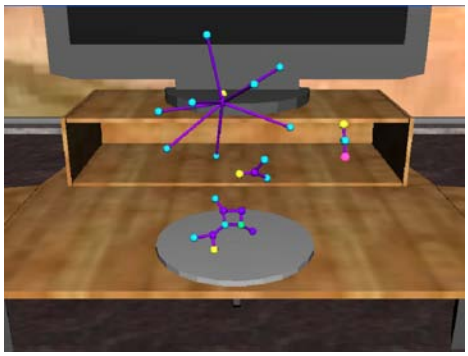

Figure 5: *'In this figure you can admire a network of musical elements.'*

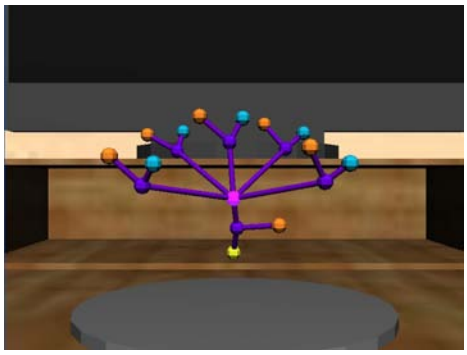

Figure 7: *'Musical agents linked in a network.'*

Physics particle-springs model, where the spheres are positive charged particles and cylinders have a behaviour like springs. Two spheres can be connected toghether only by means of a cylinder. The pattern the user creates can be manipulated both using direct interaction with the 3D objects or by the scripting box. The user can have two different manipulation modalities: in a synchronous way, which allows the realization of a pattern and then to listen to how and what it sounds like, or in an asynchronous way, which allows the user to get direct auditory feedback, in order to satisfy his/her musical requirements. The tools are organized and managed by a plug-in engine structured on three levels, graphic, interactive and audio (Figure 6).

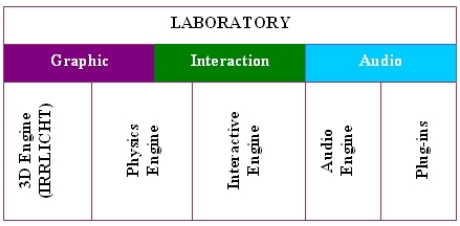

Figure 6: *'Laboratory's implementation layers.'*

The audio engine is a particular self-contained and self-organized library that maintains memory of all the Tools present in the lab and manages the audio output resulting from their connections. The graphical engine that has been used is the same as the Museum's C++ version and it improves the user's interaction with the object from a physical point of view. The virtual worlds of musical agents linked in a network allow to the evolution of musical pieces, with the possibility to create also physical autonomous agents, with the same characteristics contained in the simulation (Figure 7). These applications represent a valid research tool for the comprehension of several issues related to the realization of a compositive grammar, that is the identification of many sets of predefined structures or patterns, which the users knows (since they are in the library of the software), which speed up the creative musical process, as we do normally when we speak a natural language and instead of casual sound, we emit a set of formalized sounds, called phonemes, and structures by means of a grammar. Furthermore, in the lab, it is possible to model the behaviour of autonomous agents generating melodies, that simulate the evolution of musical material with genetic transmission and interaction with behaviour rules.

3.3. The Virtual Immersive Room

The Immersive Virtual Reality (IVR) of the City of Imagination foresees the use of advanced technologies, including computers and various multimedia components, in order to produce a simulated environment which is perceived as analogous to real world objects and events. With the aid of specially designed transducers and sensors, users interact with displayed images, moving and manipulating virtual objects, and performing other actions in a way that engenders a feeling of actual presence (immersion) in the simulated environment.

IVR allows users to experience and interact with a life-like model or environment, in a safe way and at convenient times, while providing a degree of control of the simulated events, not possible in the real-life situation. Promising applications are those related to visualization and representation, distance communication and education, hands-on training, and orientation and navigation. In this place, it will be possible to access a room in which many psycho-acoustical experiments will be carried out, from the sensation of being immersed in a multidimensional sound environment, where one Chua's attractor, embodied in a pattern the user has previously selected is diffused in the room by using an emergent organization of sound paths, and filling the virtual room with different sound spatial organizations.

The other activity the user can do is to select, from a list of sound patterns, two or three multidimensional sound organizations coming from different Chua's attractors in order to

explore the creation of complex sonorous scenes, which have never been heard. While the user is listening to these sound scenes, he/she can access multimedia contents related to the same Chua's attractors, following different morphogenesis processes which can happen in the space of all Chua's dynamical systems.

3.4. The Computer Supported Collaborative Music (CSCM)

This place in the system explores one of the most challenging of the networked media technologies: creating a seamless environment for remote and synchronous musical collaboration. Participants in the performance are situated at remote locations, both in the imagination city or outside in other places, and the interaction occurs synchronously.

So, the goal of this environment is to allow musicians to collaborate synchronously over distance. The communication architecture can be multi-user. In other words, many people, connected to the net can work in the CSCM, creating a collaborative composition synchronously. Groups of users who stay in the CSCM can create artificial musical universes, or record and retrieve musical pieces, in an environment in which they share compositions and make experiments on the emergence of musical structures. Furthermore, a "jam session system" in which each player is independent and can interplay with all other players will be developed. The CSCM enables computer players to listen to other computer players' performances as well as human performances and to interact with each other. Moreover, all players can communicate not only by listening to other players' performances but also by seeing each other's bodies and gestures. These computer players will be implemented as separate processes on several distributed workstations. Providing a platform for the exploration of collective creativity for both emergent and established artists from a diverse array of geographical locations and social contexts.

4. Computer Graphics Issues

From the graphical point of view, the metaphor of the interface is the City of Imagination, that is realized as a 3D virtual place, inside which many interactive edutainment focal spots allow users to learn mathematical and musical concepts, to have fun by listening to multidimensional sound organizations in an immersive 3D room and to share collaborative advanced activities related to music making on the net. Furthermore, all the buildings of the imaginary city are made with strange attractors, coming from a generalization of Chua's dynamical systems, and giving the idea of self-contained structures which fit well with new architectural design theories.

The object of the environment, the Tools of the lab, the agents in the Edutainment place and every object of the system have been modelled with 3D STUDIO MAX and some CAD packages, allowing the ImaginationTOOLS team to focus efforts on developing a clean, efficient design instead of spending a large portion of its time engaged in drafting. JAVA 3D and C++ are the programming languages that have been used for the algorithmic side of the City. On the other hand, the realization of the buildings in the setting of the City of Imagination, which come from Chua's attractors has been very difficult and time consuming. First of all because chaotic attractors are complex objects which present many representation problems from the graphical point of view [BPS06]. Second, because, when imported in a 3d software, they are rendered with millions of polygons, making intractable the management of these systems. So we had to find a way to reduce polygons and optimize 3D models and physical appearance before inserting the buildings in the environment. The other problem is that the surface of these attractors is non-linear. We have run many commercial reduction algorithms but they change the appearance of the attractors, losing the beauty of these 3D patterns. The graphic designer of the team made this reduction without automatic algorithms limiting the number of polygons in the 3D graphic object by using visual feedback during the process, and altering the number of polygons in the 3D graphic object in real time based on his personal vision, so controlling and optimising the results. This method allowed us also to cut the surface of the objects, and to map it on the reduced patterns, obtaining the quality and appearance of the originals. Other issues regard the creation of interactive educational points, agent navigation and behaviour control and user-agent interaction. In particular, the interaction and navigation issues, for example collision detection, and object manipulation wew obtained by Inrilicht (modified and recompiled to gooal our needs) in the C++ version, by implementing a simple 3D engine in the java 3D version.

5. Conlusions

The desire of the team is to let ImaginationTOOLS be a science-oriented but at the same time an appealing product, different from others today available on the market. In the City of Imagination the user can relax and learn difficult concepts and methods, can make music with the most surprising activities and the most advanced media technologies, obtaining sound and music which satisfy his/her aesthetical ideas and creativity. To achieve this goal, the team uses the Human Computer Approach to design, which mixes creativity and efficient methods and above all tries to look at real user requirements. From its birth [CMN83], Human Computer Interaction (HCI) "attracts innovation and creativity because of its multi-disciplinary nature, in computing and IT research and development. For the last 25 years, it inspired new solutions, specially, for the benefit of the user as a human being, making the user the focal point which technology should serve rather than the other way round" [Gha05].

The website of ImaginationTOOLS is available at the following address http://www.imaginationtools.it

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