BioSonics: Sensual Explorations of a Complex System

Daniel Bisig
Artificial Intelligence Laboratory
University of Zurich
Andreasstrasse 15
8050, Zurich Switzerland
+41 1 635 4577
dbisig@ifi.unizh.ch

ABSTRACT

Complex systems abound in nature and are becoming increasingly important in artificial systems. The understanding and controlling of such systems is a major challenge. This paper tries to take a fresh approach to these issues by describing an interactive art project that involves cross-modal interaction with a complex system. By combining sound and vision, the temporal and spatial dynamics of the system are conveyed simultaneously. Users can influence its dynamics in real time by using acoustics. Preliminary experiments with this system show that the combination of sound and vision can help users to obtain an intuitive understanding of the system's behavior. In addition, usability profits from the fact that the same modality is employed for both interaction and feedback.

Categories and Subject Descriptors

J.5 [**Computer Applications**]: Arts and Humanities – *Fine Arts.*

I.3.6 [**Computing Methodologies**]: Computer Graphics – Methodology and Techniques – *Interaction Techniques.*

General Terms

Algorithms, Experimentation.

Keywords

Complex systems, art and entertainment, cross-modal interaction, direct interaction, interactive visualization.

1. INTRODUCTION

The field of complex system research plays an important role in many scientific disciplines. In addition, its impact on application oriented areas such as engineering, entertainment and art is growing. In these areas, issues concerning interactivity play an important role. HCI research in this field concentrates mainly on the interaction of expert users with reliability, performance, and safety critical systems such as in air traffic or processing plant control. In this paper, we would like to look at interactive complex systems in entertainment and art which pose very different demands on software and interface design. Here, issues such as user motivation, engagement, intuition, and entertainment predominate.

Several examples of interactive complex systems exist in entertainment. These include computer games such as Lemmings [1] and SimCity [2] or mass scenes [3] and procedural textures [4] in computer graphics to name just a few. Interest in interaction with complex systems has already some tradition in the field of generative art. Most of these artworks allow users to explore various system configurations through interaction. Artworks in which the system itself has a certain autonomy whose mutual interaction with a user leads to the continuous emergence of new patterns are still relatively scarce. Examples of such systems include installations in which users influence the evolution of artificial organisms [6][7][8][9][10] or participate in social interactions among artificial organisms [11].

In general, complex systems have a great appeal for entertainment and art since they possess the capability to constantly change, adapt and evolve [12].

The fact that interactive complex systems tend to respond to user input in non-trivial and surprising ways renders these systems both attractive and problematic at the same time. Interaction tends to quickly become frustrating and boring for an inexperienced user if no causality between input and feedback seems to exist. Therefore, it is essential to implement user interfaces that focus on intuitive interaction with appropriate feedback. The system BioSonics which we present in this paper is an attempt to implement such a system.

2. CONCEPT

BioSonics implements a multi-modal interface to a autonomous complex system which provides feedback of both, its spatial and temporal dynamics. Contrary to artworks such as [7][10] users affect directly the behavior of the system rather than the environment in which the system acts. In BioSonics, the complex system consists of a simulated growth process. Biological growth represents a complex system whose adaptivity and pattern formation capabilities are particularly impressive [13]. BioSonics simulates growth by combining simple artificial chemistry [14] with a mass-spring structure. The interactive aspect of BioSonics is implemented as a cross-modal interactive visualization by combining various concepts such as direct manipulation [15], multimodal interaction [16], dynamic visualization, and computational steering [17]. The emerging spatial structure is visible as 2D graphics. The chemical processes guiding growth generate acoustic output. In this way, the feedback of the program relies on two modalities that complement each other: vision excels at discriminating spatial details while audition is particularly good in the detection of temporal patterns. Since both modalities are used simultaneously, cross-modal integration eases the detection of complex patterns [18] and may therefore help in understanding the system. Interaction with the system happens in real time and relies both on input via the keyboard and a microphone. The fact that users can directly influence the dynamics of the complex system by relying on the same modality for feedback and interaction clearly distinguishes BioSonics from similar art installation such as

[6][7][8][9][10][11]. We believe that this form of interaction can increase both the intuitivity and immersiveness of the user's engagement with a complex system.

3. IMPLEMENTATION

The implementation of BioSonics involves the following main aspects: growth simulation, visual and acoustic feedback, and interaction.

3.1 Growth Simulation

An artificial organism grows due to the interaction of an underlying chemical system with a body structure that is implemented as a mass-spring system. As such, it consists of a number of discrete particles whose connectivity is maintained by attached springs. Changes in the structure of the mass-spring model are generated by the underlying chemical system. This system consists of six different types of abstract chemicals. Each structural element acts as a chemical compartment storing its own concentrations of these chemicals. Chemicals can be exchanged between neighboring compartments by diffusion. Reactions within these compartments can occur between chemicals as well as between structural components and chemicals. By this way the structure and the chemicals form a reaction network. Possible reactions include: hetero- and autocatalytic chemical reactions, creation and deletion of structural elements, consumption of chemicals in order to sustain structural elements, modification of structural parameters, and fusion of structural elements due to proximity. The simulation of the mass-spring system and the reaction kinetics proceed by using a simple Eulerian integration scheme.

3.2 Visual Feedback

An essential aspect of BioSonics is its multi-modal feedback. The growing mass-spring structure is graphically depicted by using simple 2D shapes such as rectangles for masspoints and lines for springs (see figure 1, top graph). Users can use the keyboard to navigate within the structure (moving the structure on the screen and zooming into and out of the structure). This gives the user the possibility to look either at structural details or observe the entire structure at once. Navigation within the structure is tightly coupled to both sonification and interaction.

3.3 Acoustic Feedback

In BioSonics, the dynamics of the complex system itself is rendered perceivable by having the chemical system produce sound. Each chemical plays a particular sound sample whose amplitude depends on its associated concentration. All chemicals that belong to currently visible structural elements play their corresponding sounds. The overall sound output of the system is therefore a mixture of all the concurrently playing chemical sound samples. The further a visible element is offset from the screen center the more the amplitudes of its chemical sounds are attenuated. Thus, an acoustic focal point is created at the center of the screen. Depending on how much of the structure is visible within this focal point the user hears the acoustic output of all the chemical processes within the entire structure or the output of those within one single structural element only. By moving the structure on the screen different structural regions pass through the focal point thus rendering chemicals in different parts of the organism audible.

3.4 Interactivity

The second essential aspect of BioSonics is a simple form of real time direct manipulation. This is achieved by relying on acoustics as the modality for both data representation and interaction. Therefore, the system implements a unique form of the direct manipulation concept [15]. In the current setup, a microphone picks up all the sounds provided by the user. These detected sounds are compared to the sounds that are associated with the various chemicals based on their frequency spectra. If the similarity is sufficiently high a certain amount of the corresponding chemical is fed into the system (see figure 1 bottom graph). Chemicals are only fed into those structural parts of the organism that are located within the acoustic focal point. Depending on the visual magnification of the structure the new chemical is either fed into many structural elements or will affect only a single element. This allows the user to interact both on a global level with the system or decide to apply changes at a very detailed level.

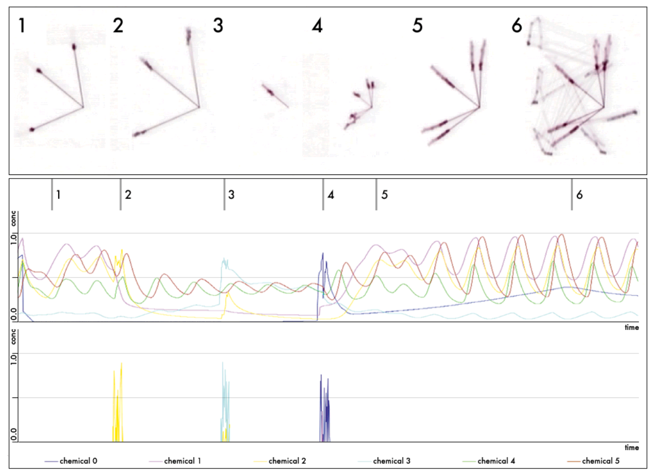

Figure 1. Time sequence depicting the graphical representation of the growing structure (top graph), the spatially averaged chemical concentrations (middle graph), and the interactively produced chemical concentrations (bottom graph). Numbers indicate corresponding positions in simulation time. Time runs from left to right.

4. RESULTS AND DISCUSSION

The project BioSonics is ongoing research in regard with both, its actual implementation and the analysis of the user's experience. So far, informal feedback has been collected from various users interacting with the system described in this paper or with a slightly different system that was exhibited in a museum context. None of the users knew the system in advance or had any background in the field of complex systems. This preliminary evaluation focused on the following aspects: the ability of the system to catch a users interest, whether this interest is maintained by providing an engaging interaction, and the amount of intuitive understanding the users acquired by simply interacting with the system.

Initial interest was generated through the changing feedback of the system and the fact that these changes were not immediate. This interest was further supported by the perceived degree of synchronization between acoustic and visual output. The fact that synchronization was neither total nor totally absent, mediated the impression that both outputs are coupled by a non-trivial algorithm. Interactivity played an important role in generating continued interest. It became quickly obvious that different users interacted in very different ways with the system. Some users were happy to expose the entire organism to very noisy sounds which usually resulted in large bursts of growth. In order to cause smaller and more diverse changes in the growth process users had to produce strongly pitched sounds. In this case the sound input matched only one or two chemicals which were consequently infused into the organism. Users that interacted in this way quickly realized that they could recreate structural changes they had previously observed by mimicking the acoustic feedback the system provided. This type of interaction was therefore a prerequisite to create a longer lasting interest in the system and to promote an intuitive understanding of the system's behavior.

5. CONCLUSIONS AND OUTLOOK

Due to the preliminary nature of both the system's implementation and the user evaluation we are not yet able to present definite results. However, based on our experience so far we believe that our approach to the creation of an interactive complex system for art and entertainment purposes is very promising. Users can interact in a playful and exploratory way with a complex system without being confused and put off by its potentially unpredictable and baffling properties. We believe that the necessary prerequisites to create such a rewarding interactive experience are both an intuitive and direct form of interaction as well as adequate forms of multi-modal system feedback. On the other hand, the system depends on a high degree of willingness from the side of the user to fine-tune his input and to carefully observe the resulting feedback. Further work on this project clearly involves the undertaking of a well-founded user evaluation. This will include surveys of user experiences in various setups such museums, public spaces, and conferences. In addition, we plan to implement a more intuitive and direct user interface for navigation within the growing organism. Finally, we would like to improve the growth algorithm by refining the underlying chemical system in such a way that both a superficial and a deeply engaged exploratory interaction can be interesting and rewarding to the user.

6. ACKNOWLEDGMENTS

The interesting discussions with Dale Thomas on technical and conceptual topics pertaining to this work are highly appreciated. In addition, I would like to thank Pamela Ravasio for her very helpful criticism throughout the writing of this paper.

This research is part of a project entitled "Embodied Artificial Intelligence" that is funded by the Swiss National Science Foundation.

7. REFERENCES

[1] SONY, "Lemmings", 1998, http://www.us.playstation.com/games/slus-00760.asp

[2] Electronic Arts, "SimCity 4", 2003, http://simcity.ea.com

[3] Massive Limited, "MASSIVE", 2002, http://www.massivesoftware.com

[4] Fleischer, K. The Biological Simulator Behind "Cellular Texture Generation". Siggraph Course Notes, 1997.

[5] Milicevic, M. The Impact of Fractals, Chaos and Complexity on Computer Music Composition. In Proceedings International Computer Music Association (San Francisco, 1996), 473-476.

[6] Sommerer, C., and Mignonneau, L. A-Volve, 1994.

[7] Sommerer, C., and Mignonneau, L. Phototropy, 1995.

[8] Sommerer, C., and Mignonneau, L. Life Spacies I & II, 1999.

[9] Sommerer, C., and Mignonneau, L. PICO_SCAN, 2000.

[10] Plancton Art Studio, Relationi Emergenti, 2000.

[11] Rinaldo, K., Autopoiesis, 2001.

[12] Sommerer, C., and Mignonneau, L. Modeling Complex Systems for Interactive Art. In Applied Complexity - From Neural Nets to Managed Landscapes (Institute for Crop & Food Research, Christchurch, New Zealand, 2000), 25-38.

[13] Turing, A. The Chemical Basis of Morphogenesis. Philosophical Transactions of the Royal Society (London, 1952), 237, 37-72.

[14] Dittrich, P., Ziegler, J., and Banzhaf, W. Artificial Chemistries A Review. Artificial Life, 2001, 7(3), 225-275.

[15] Shneiderman B., Direct Manipulation for Comprehensible, Predictable and Controllable User Interfaces. In Proceedings of International Conference on Intelligent User Interfaces (Orlando, FL. 1997).

[16] Waibel, A., Vo, M. T., Duchnowski, P., and Manke, S. Multimodal interfaces. Artificial Intelligence Review, Special Volume on Integration of Natural Language and Vision Processing, 1995, 10(3-4), 299-319.

[17] Mulder, J., van Wijk, J., and van Liere, R. A Survey of Computational Steering Environments. Future Generation Computer Systems, 1999, 15(2), 91-102.

[18] Bernstein, L. and Benoit, C. For Speech Perception By Humans or Machines, Three Senses Are Better Than One. In Proceedings of the International Conference on Spoken Language Processing, 1996, 3, 1477-1480.

Columns on Last Page Should Be Made As Close As Possible to Equal Length

IUI'04, *JAN. 13–16, 2004, MADEIRA, FUNCHAL, PORTUGAL.*

ACM 1-58113-815-6/04/0001.