The *Lightwork* Performance:

Algorithmically Mediated Interaction for Virtual Environments

ABSTRACT

This is a brief description of the performance piece *Lightwork*, an interactive work combining algorithmically generated virtual worlds and electroaccoustice music. The algorithms for world construction, viewpoint control and sound diffusion are described, together with the broader implications of our work, in particular for concepts and techniques for Human Computer Interaction.

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The *Lightwork* Performance: Algorithmically Mediated Interaction for Virtual Environments

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Introduction

In this paper, we describe the human-computer interaction concepts we have built into an improvisatory performance art work called *Lightwork.* This—a 15 minute long piece combining electroacoustic music with the real-time construction and navigation of back-projected virtual environments (VEs)—has combined artistic, social and computer science skills, building on our experience of VEs and studies of them [1, 2]. Multi-disciplinary design of this sort is typical of work at the Centre for User-Oriented IT-Design (CID) at the Royal Institute of Technology (KTH) in Stockholm, and of the eRENA European Community project which *Lightwork* contributes to and is supported by.

Central to our interest in developing technologies for performance art is that this provides one of the most testing contexts for computer system development. Naturally, the highest standards are to be met for visual and sonic design but also reliable real-time system-performance is essential to an effective piece. The 'users' of such technology—the performers themselves and their audience—are also highly critical and demanding people, who are unlikely to be reticent if the interaction experience is unsatisfactory. From an HCI standpoint, all these features present challenges often met in only diluted form when research results are publicly appraised in a 'demo' format.

Just as HCI can benefit from performance art as a rigorous 'target domain', so—reciprocally—can performance and installation art profit from innovative interaction concepts. The prevalence of so much 'push-button' interaction in CD-ROM art, for example, suggests to us that new interaction principles should be of interest to both HCI and art communities. Indeed, a core principle of our work is that interaction design can be an aesthetic matter and that techniques should be developed for their aesthetic value as well as for technical feasibility.

Perhaps this is most strongly felt in artistic applications of VR research. Many familiar VR interaction concepts and devices are not well suited for performance art applications. Performances tend to require a large public display interacted with by means of gestures which are themselves public to the audience. This means that both 'immersive' and 'desktop' VR techniques and devices are rarely appropriate—besides head-mounted displays and other VR accoutrements are rather clichéed in a performance art context. Finally, some of the debated interaction issues in VR are even more strongly experienced in performance contexts. For example, overshooting

one's destination while navigating and getting 'lost in cyberspace' would be disastrous for all concerned.

Accordingly, the rest of this short paper concentrates on the design concepts in *Lightwork* and finishes with brief notes of the potential general import of our approach. Aesthetic appraisal will be more strongly in focus in other papers.

Lightwork

Algorithmically Mediated Interaction

Lightwork is concerned with the construction of a series of visual and sonic VEs *as* the performance. While the process of VE construction has been a theme of interactive art before (e.g. in Bill Seaman's 1996-1997 piece *The World Generator*), to our knowledge, the notion of 'performing virtual worlds' is innovatory here. However, familiar techniques for VE construction hardly make for apt performance gestures. It is not engaging to watch someone edit VRML files or interact with a 3D modeller no matter how flamboyant their gestures are! Thus, in *Lightwork*, performers manipulate VE interaction *algorithms.* They do not directly manipulate VE content. Rather, interaction is *mediated* by algorithms, some *constructing* VE content, others governing the *animation* of virtual objects, yet others controlling the *navigation* of the viewpoint around the VE. As such, *Lightwork* is an exploration of *algorithmically mediated interaction*. Again, algorithms have been used to generate VEs in installations (e.g. Marcos Novak's 1995 *transTerraFirma*) but not yet, to our knowledge, applied in real-time in artistic performances.

VE Construction and Animation Algorithms

A *Lightwork* VE is composed of several elements which can change independently with new material being created and deleted 'on the fly'. With the exception of the VE's background (which is a series of images which change about every 80 seconds), each element is algorithmically generated, and—in the case of animated elements—has algorithmically controlled behaviour. For each algorithm, its parameters correspond to perceptually obvious features of the material generated by it. For example, 'enclosures' which tend to surround the viewpoint can be generated by a chamber generation algorithm called `chamgen`. `chamgen` will create VE content resembling a room with various objects protruding from its walls. A performer can influence the size and regularity (e.g. the range of rotations and stretches) of the protuberances but the precise values which enter the VE world model are calculated algorithmically by sampling from probability distributions. Two other algorithms are available for other kinds of enclosures (e.g. a 'cave' environment with more smoothly contoured walls).

Various 'forms' can be placed within enclosures. `scaffolder` creates strongly angular forms by aggregating 'pipes' onto each other. The overall size of the form and the parameters influencing how the aggregation takes place can be influenced in performance. `formModulator` takes a sphere and distorts it non-linearly to generate complex 3D shapes. The size of the form and degree of distortion are parametrised by performer gesture. `plenumbulator` fills up the enclosure with image and text material according to a constrained random distribution where the amount and density of material are the main parameters. Finally, `THALES` creates a set of objects which orbit each other in a nested manner (orbits within orbits)—here the main parameters fix the distribution of orbit radii and cycle times.

Navigation, Viewpoint and Sonic Control

In *Lightwork* the back-projection is given by the view along a path which is computed in real-time by means of a selection from two algorithms. One employs a modulated sinusoidal function which generates periodic orbits. The function has been selected so that circular, elliptic and a family of 'looped' paths (e.g. figures of eight and three and four-leaf 'clovers') can be generated by different settings for it. The notional 'radius' of the path, speed along it, and its 'loopiness' can be influenced in performance. It is through these features (rather than, say, pointing in a desired direction) that movement is controlled—hopefully an easier task to manage in performance and well suited to exploring enclosed VEs. Another algorithm is available to approach/retreat from the centre of the VE.

Whatever function is selected for viewpoint control, this also influences the diffusion of some parts of *Lightwork's* specially composed electroaccoustic music through a four speaker sound system. Sound sources are associated with static objects in the VE and the navigation function is used to compute their relative location in the soundspace.

Performing The Interactive Narrative Machine

Lightwork is realised by two performers. One performer, S, improvises a response to the projected VE by processing and mixing sonic elements further to those whose spatialisation is given by the viewpoint function just described. An interaction device comprising two joysticks and a pair of pressure sensitive gloves is under development for S, but at the time of writing, conventional MIDI-faders have been used. The other performer, V, interacts with the algorithms which generate visual VE content by playing an electronic wind instrument—the Yamaha WX-11—and using footswitches to trigger VE modification and select the algorithm to be used. By using a musical instrument to determine VE interaction and a device usually employed for VEs (joysticks) to control music, we reverse conventional associations. The intention here is to explore the boundaries of what is 'intuitive' in gestural control and to open up possibilities for synaesthesia as the basis for interaction [3].

V's playing is analysed by a program called 'The Interactive Narrative Machine' (INM) which converts the WX-11's MIDI data stream into parameter values. The INM works with three 'time windows' which can compute level and variability statistics for the last 20, 100 and 500 notes. Three attributes of V's playing can be reported on: pitch, loudness (MIDI-velocity) and timings between notes. Selections from all these statistics are mapped onto the VE algorithms. For example, short-term (20 note window) timing values are used to control navigation (faster playing causes speeding up, syncopation yields 'loopiness' in the path). Some forecasting is employed to adjust for the 'inertia' which would occur in basing current values only past activity. Other mappings involve 'narrative rules' which define how past performance statistics get further transformed to generate future values. For example, one rule might specify that long-term loudness statistics define the size and regularity of `chamgen`'s protruding objects, such that if V has been playing loudly, the next chamber will contain small objects. In this way, the performer can *systematically* respond to existing and *predictably* generate new material. Playing loudly to big objects and quietly to small ones leads to an alternation between small and large protuberances. In this way, the INM enables the temporal unfolding of *Lightwork* to be improvised through performer activity within the piece itself—*narrative from within*.

Technical Implementation Details

The algorithms for construction, animation and navigation are run as an application within the DIVE [4] VR system (see also `http://www.sics.se/dive/`) on an SGI Octane. The INM has been authored in Opcode's MAX environment which gives language-level support for handling MIDI data. Two Apple Power Macintoshes are used for sound processing and running the INM. Communication between machines is quite lightweight as, for example, parameters are passed to algorithms only intermittently. RS232 serial and MIDI communications have sufficed to date.

Conclusion

Our work is 'late breaking' in that *Lightwork* was performed in its first version on 16th December 1997 in Stockholm with the first two authors as respectively V and S. Accordingly, we are only beginning 'user-evaluation' of our work and have concentrated here on the interaction *concepts* which *Lightwork* embodies. Most important in this is the principle of *algorithmically mediated interaction*, which is intended as an alternative to *direct manipulation* (DM) for the construction, animation and navigation of VEs. Our experience is that real-time interaction with algorithms works well provided that (1) algorithms are selected so their parameters have obvious *perceptual effects* for the features that performers will respond to (something which is not be true for many graphical algorithms studied in the literature on fractals, for example) and (2) performer activity can have a *loosely coupled* relationship to parameter values so that performers do not feel themselves in a 'straitjacket' where the slightest infelicity could have disastrous effects (the INM achieves this (i) by basing its results on *sets of gestures* so that 'errors' can be compensated for within the time window, and (ii) leaving several of the calculated statistics *unmapped* to algorithm-parameters—in the short term time window, for example, pitch and loudness have no effect). In these ways, we are exploring interaction techniques which can give performers control, do not overly restrict their latitude for action, allow error correction, and still enable computations in complex virtual worlds—a combination of features rarely considered possible in current debates on, for example, DM *versus* software agents [5].

References

1. Bowers, J. et al. Talk and embodiment in collaborative virtual environments. Proceedings of CHI’96. 1996.
2. Jää-Aro, K.-M. & Snowdon, D. Retaining body language in subjective virtual environments using artifact-centred coordinate systems. Proceedings of HICSS 30. 1997.
3. Smets, G. et al. Form giving: expressing the non-obvious. Proceedings of CHI’94. 1994.
4. Hagsand, O. Interactive multiuser VEs in the DIVE system. IEEE Multimedia, 3 (1), 30-39. 1996.
5. Bradshaw, J. (ed) Software agents. MIT Press. 1997.