TGarden: Wearable Instruments and Augmented Physicality

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ABSTRACT

This report details work on the interdisciplinary media project TGarden. The authors discuss the challenges encountered while developing a responsive musical environment for the general public involving wearable, sensor-integrated clothing as the central interface and input device. The project's dramaturgical and technical/implementation background are detailed to provide a framework for the creation of a responsive hardware and software system that reinforces a tangible relationship between the participant's improvised movement and musical response. Finally, the authors take into consideration testing scenarios gathered from public prototypes in two European locales in 2001 to evaluate user experience of the system.

Keywords

Gesture, interaction, embodied action, enaction, physical model, responsive environment, interactive musical systems, affordance, interface, phenomenology, energy, kinetics, time constant, induced ballistics, wearable computing, accelerometer, audience participation, dynamical system, dynamic compliance, effort, wearable instrument, augmented physicality.

1. INTRODUCTION

We report on work done for TGarden, an experimental responsive media environment where small groups of participants from the general public can control and play with real time generated sound and image through improvised movement and gesture. Development on Phase 1 of the project took place during 2000-2001 with support from the Daniel Langlois Foundation and was shown as a work in progress at the Ars Electronica Festival and at V2/Las Palmas in Rotterdam for the European Cultural Capital of the Year in the fall of 2001 [6].

Our focus in this report lies on issues arising in the process of designing a physically responsive musical system activated by the motion and gestures of non-experts, where no predetermined, a priori representation of gesture can be said to exist.

While so-called "audience participation" installations are beginning to take these issues into account, there has still been little work to date, at either the conceptual or technical-implementation levels on how to build a responsive system that is physically engaging *and* learnable within a short period of time *and* musically rich and coherent for the casual, non-expert participant [9].

While literature in the field of gesture-activated musical interaction is well established and voluminous, most of this work has focused on systems designed for trained and expert performers, dancers and musicians, where issues of musical (and movement) nuance, control and expression are assumed from the start. Furthermore, much of this literature assumes traditional performer/spectator relationships, where the behavior of an interactive system is experienced passively by a viewer/listener at a distance.

The work described here focuses less on the specifics of the hardware and software layers in TGarden but rather suggests a novel approach to the total design of a responsive musical system. This system is architected to create a coherent and felt resonance between multiple layers: a participant's improvised movement, sensor input, software and the resulting musical response.

2. PROJECT BACKGROUND

TGarden is a responsive environment where visitors can shape media around them through improvised gesture, play and social interaction. The project investigates how people individually and collectively interact with and make sense of a responsive media space by articulating their knowledge non-verbally. More specifically, the project examines the process of meaning making as a complex relationship between the production of gesture and movement and the resulting audio/visual responses that ensue from solo as well as group motion and action.

The TGarden setting consists of a series of private dressing rooms leading to a physically demarcated, curtained off performance space for between two to five visitors over a defined time cycle. The performance area is a large (approximately 12 x 14 m) environment, with real time generated video projected onto floor of the room and multi-channel sound, the number of speakers determined by the number of participants. Besides a number of oversized balloon-like balls that help to catalyze participant's movement and spatial exploration, the performance space is empty. Participants are informed of the time frame set for their play period before they enter the event.

Outside of the actual participants, there are no spectators allowed to watch from the sidelines.

After making a reservation for a specified time slot, visitors arrive at the space and are presented with an array of specially designed garments to choose and subsequently change into. Each of the garments is designed with unusual materials (plastic tubing, Styrofoam balls, springs and wire) and appears at first to be more sculptural than wearable. Additionally, the exaggerated weight, scale and dimension of the garments acts to augment and shift a participant's normal, everyday way of moving.

Figure 1. TGarden costumes, Ars Electronica festival 2001.

Loosely attached to some of the garments and woven into others are several ADXL202 2G accelerometers that can measure the degree of acceleration-from small arm gestures to larger, full body movements-of each participant.

Continuous data streams from the accelerometers are transmitted from each of the individual participants by way of a wearable, commercial COMPAQ iPAQ handheld computer running LINUX and sent, via 802.11b to a central dynamics system that forms the core of the TGarden system architecture. This dynamics model, written as a custom C extension to the Max programming environment, models the states of the players and of the entire TGarden performance space as a set of continuous dynamical physical systems.

While a technical description of the system is beyond the scope of this report, the software looks at overall energy input from the multiple data streams, interprets data from the sensors and analyzes what is happening in the environment overall, subsequently sending commands to the sound and video systems based on its judgment. The dynamics system contains the microscopic logic of how the environment responds to visitors' actions, both immediately as well as over time. The different sound and image systems modify their own internal states on the basis of the dynamic system's hints and also on the basis of the continuous output from the sensors themselves [5].

From a user perspective, TGarden is conceived to be an emotionally engaging event, aiming to create a tangibly experienced dynamic between the environment's physical and computational layers. Metaphoric but highly physical notions of digging, excavating, camouflaging, unearthing, marking and skrying form a dramaturgical context for the overall design of the media layers, from music and image to architectural space, "props" and garments.

Furthermore, TGarden is grounded in an explicitly phenomenological approach that sees the production of human agency and meaning making as a process of embodied action, made explicit or *enacted* through improvised, "on the fly" gestures and movements that spontaneously arise from the participants' interaction with each other as well as the proximal environment itself [7].

While the process of participants' improvising or "performing" for each other without a pre-determined script is constrained by the specific "framing" of the event (set length of time of engagement, numbers of simultaneous participants, architectural configuration of the space, ritual of dressing and undressing, the exaggerated bodies of the costumes themselves), TGarden's constraints are most tactilely conveyed through the wearable interface of the garments themselves. Here, the garments function as both an *affordance*-where the participant's gestures and movements are shaped, limited and expanded by the inherent physical attributes and properties of the textiles-and, simultaneously as a wearable *instrument*. Indeed, much of the design of responsiveness in TGarden is based on the vision of a first encounter with a musical instrument. As every novice discovers, a new instrument has constraints where "not everything is possible" as he/she quickly learns to grasp at the instrument's physical affordances to enable the production of sound. It is this approach that places TGarden in a long lineage of gesture-based instrument design that explicitly takes the creation of tactile affordances into account [2].

Figure 2. TGarden group interaction, Rotterdam 2001.

3. RESPONSIVITY

Given the explicit dramaturgical and interface context of TGarden, we were faced with devising a responsive musical system in hardware/software which could accommodate a wide range of movement possibilities from non-trained participants, while conveying an integrated relationship between music, image, garments and social interaction itself.

3.1 From sensing to music

In designing a musical software layer, we began with the understanding that participants interact with music in the TGarden world not as an extraneous object which a person is coached into accepting or "learning," but rather through processes of dancing and "marking" - dancing, in that music arises from a moving body and marking, in that the relation to music is rather than mere triggering, one of inflecting and shaping sonic material whatever its provenance. Joel Ryan's comment that "the physicality of the performance interface gives definition to the (musical) modeling process itself," suggests that there must be an equal physicality between the interface (i.e., sensors) and the software layer [1,3].

In choosing body-mounted sensors as the system's sole input devices, we looked for technologies that were sensitive to the widest possible range of bodily movement. While a host of sensors systems, from the BioMuse that monitors electrical charges in the muscular system, to bend sensors that measure relative position of limbs are available, these systems were passed over due to the amount of control required on the part of the participant and their relatively limited dynamic range [8].

The use of accelerometers to measure degrees of bodily force is a technique that has been previously deployed for responsive musical systems. Indeed, as Sawada, Onoe, and Hashimoto incisively point out in their article "Acceleration

sensor as an input device for musical environment," "although most of the reported works to introduce body movement into musical performance treat the shape or position of the body, the most important emotional information in human gestures seems to appear in the forces applied to the body" [4].

Because TGarden participants experience the garments as an instrument/interface, however, we felt the need for an augmented physicality in the software layers of the system. In other words, TGarden instruments begin with accelerometer data, but the responsiveness of the system is built on simulated physical behavior.

Figure 3. TGarden Rotterdam 2001.

In the TGarden instruments, players connect to higher-level musical parameters like pitch and beat not directly but via an additional layer of simulated physics written in SuperCollider. This physics, by adding elastic couplings and phantom masses, induces distinctive ballistic behavior in the response of the system. A player listening to the sonic feedback of his/her movement, while perhaps not being able to decode their relation to some intricately woven algorithm or mapping, easily comes to identify wobbles and bounces, recoils and lags as their own; as their personal marking of the sound. This is clearly related to our encounters with real instruments. At any one time in the TGarden system, there are several physical models in action simultaneously, some based on simulated kinetics, some on energy. Each has a set of time constants that can be tuned to bring players closer to the musical time of a phase of their physical play within the environment. This characterization in terms of time constants is perhaps the most direct link between TGarden's system design and its compositional thinking. Though we use a variety of musical sound generating methods, all share this augmented physicality.

The system and player are in a dynamic compliance that varies as the play evolves from state to state. The energy of the players is the primary input that drives the large-scale behavior of the environment. This includes the density and angular momentum of groups and the averaged energies of individuals at several time scales. A great deal of effort has been put into recovering the reduced physicality of a simple, sensor-based interface through a simulated physics, not to create phantom instruments, but because we believe that embodiment and immediacy is as much the medium of music as intentions drawn from musical experience. This is central to reinforcing TGarden's overall dramaturgy of "felt" physicality. In addition to giving us a way of achieving musical coherence, we found that providing the players with an exaggerated body by drawing attention to ballistics helped overcome resistance to enthusiastic physical exploration and play.

4. USER TESTING/USABILITY

During TGarden's public showings at the Ars Electronica festival in Linz and in Rotterdam in the Fall of 2001, the development/production team conducted extensive user testing and usability studies of the prototype system. In over 250 videotaped user interviews, participants were asked to evaluate the quality of their experience based on a series of questions asked by team members. The wide range of ages, body types and overall responses to the experience suggest that our early attempts at engendering a dynamic coupling between garments, participant movement and musical response were partially successful, if not sometimes too complex for the general audience.

4.1 System response

In general, participants focused primarily on (1) the immediacy of the feedback between gesture and sound as well as (2) the ability to sonically distinguish one participant from another. Indeed, the ability or inability to "parse" out individual sonic agency and distinguish "who was who" was a clear issue for the majority of visitors. The degree of this concern, however, varied widely among participants. Some groups sorted agency-feedback issues out in a round robin manner, letting each individual participant "solo" their own movement and the resulting sounds before beginning any group-related play. Individuals who detailed less successful experiences sometimes failed to acknowledge the necessity of concentration and listening to what other participants were doing.

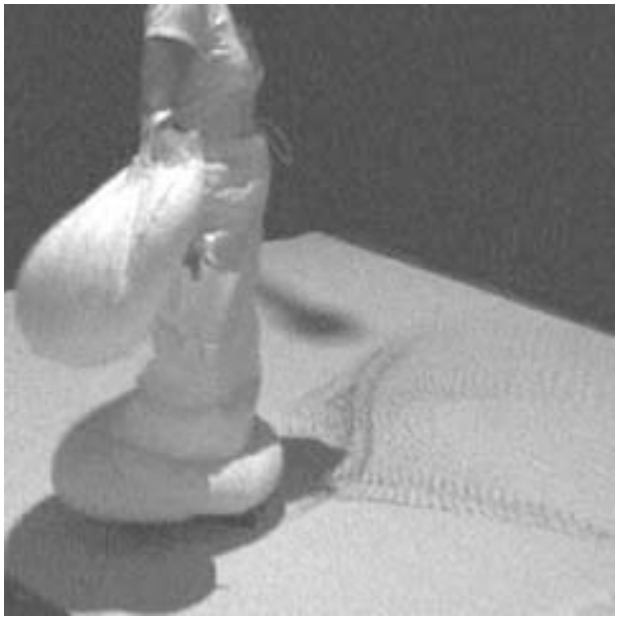

Figure 4. TGarden participant, Ars Electronica festival, 2001

While many users commented positively on both the richness and experiential quality of the timbral palette (finding a clear relationship between music, garments, images and the total theatricality of the event) some complained that the sonic complexity of the synthesis models overwhelmed their ability to make sense of the response characteristics. Further, some users grew tired of the system's inability to rapidly change musical/sonic material or to easily find the energy thresholds to make the musical system vary past its initial conditions. This comment, although perceptive, was expected based on lack of adequate

time in the software development period, resulting in a limited sonic palette.

4.2 Temporal engagement

Time clearly emerged as a critical issue in both sets of prototypes, demonstrating that the amount of time spent inside the environment had a crucial impact on the overall user experience. Some users, perhaps conditioned by other interactive experiences expected an immediate "return" on their time investment, wanting to discover all of the system's response "tricks" almost immediately. Some participants revealed a clear sense of frustration with an experience that required so much time commitment overall. The number of simultaneous visitors within the environment also clearly impacted how long participants were willing to remain in the performance space. While system problems during the rehearsal period in Linz forced the team to cut back on the number of simultaneous participants, visitors in Rotterdam were able to interact with up to six other players. Groups in Rotterdam occasionally remained inside the main room for more than 45 minutes, finding it hard to leave. Some users commented on a complete loss of any sense of time whatsoever, particularly since they were faced with so much perceptual overload between the garments, media and social interaction.

4.3 Sensing: physicality and robustness

The use of accelerometers was confirmed to be an appropriate choice yet also revealed unexpected usability and robustness issues. What was immediately apparent was that user experienced hinged on the degree of willingness to explore multiple movement and gesture possibilities as well as different attitudes to bodily acceleration and force. Many visitors quickly discovered the clothing/sensor relationship, playfully exploring a wide variety of movements and gestures to see what the system was capable of. Despite being informed beforehand, some visitors were confused by the idea of a strictly body-based interface, instead moving about the performance space in search of static, environmental sensing. Other users were confused, in general, about what movements to make. Visitors who remained stationary and reserved in their movement exploration were naturally disappointed by the lack of response and mentioned that they quickly grew tired of the experience.

Still other participants remarked on the physical difficulty of setting the system in motion, some even complaining of physical exhaustion during the experience. While such observations certainly reinforce Joel Ryan's comment in his article "Effort and Expression" that "in designing a new instrument, it might be just as interesting to make playing it as difficult as possible," it is clear that TGarden assumes (perhaps too much) an inherent willingness on the part of the participants to explore potential extremes of bodily physicality without knowing a priori what results will occur [3].

Finally, while the integration of accelerometers and the induced ballistics of the costumes worked to a degree, the extraordinary and unexpected abuse wrought by the participants resulted in frequent accelerometer and connector breakage as well as some sensors coming loose from their costumed housing/material. This resulted in the impossible situation of some users trying to excite the system to no avail due to the loss of appropriate axis calibration of the accelerometers. While team members were on hand to handle such breakages, it is clear that abuse from a general audience must seriously be taken into account in the next phase of clothing and sensor design and integration.

5. CONCLUSION

We have briefly described work done on TGarden, an interdisciplinary responsive environment for the general public. It should now be evident that the complexity of designing interfaces and musical responsivity which is both intuitive and experientially felt for non-expert users is a daunting task that challenges conventions in the field of gesture-based musical interaction. The success and feedback of the public prototypes in Linz and Rotterdam clearly point the way for further exploration into new kinds of body-based responsive musical environments for the general public as well as providing critical lessons for our ongoing research into these areas. This information is invaluable as we begin work on Phase 3 of the project under the support of the Rockefeller and LEF Foundations, for public showing in North America in late 2004.

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