The Lambent Reactive: Exploring the Audiovisual Kinesthetic Playform

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ABSTRACT
In this paper, design scenarios made possible by the use of an interactive illuminated floor as the basis of an audiovisual environment are presented. By interfacing a network of pressure sensitive, light-emitting tiles with a 5.1 channel speaker system and requisite audio software, many avenues for collaborative expression emerge, as do heretofore unexplored modes of multiplayer music and dance gaming. By giving users light and sound cues that both guide and respond to their movement, a rich environment is created that playfully integrates the auditory, the visual, and the kinesthetic into a unified interactive experience.

Author Keywords
Responsive Environments, Audiovisual Play, Kinetic Games, Movement Rich Game Play, Immersive Dance, Smart Floor

1: INTRODUCTION

The Lambent Reactive is a project that explores the interaction design factors involved in designing games and experiences for a multisensory immersive dance environment. Historically, luminous design has enhanced the immersion value of large group music and dance events, from the visual music displays of oil swirls and film strips at the psychedelic rock concerts of the 1960's to the disco light shows of the 1970's, all the way through the electrified neons of 1990's rave culture. These days, with the inclusion of interactive design elements such as pressure detection, position sensing, and adaptive displays, the possibilities for such audiovisual environments expand rapidly. Games designed for such systems have taken the party out of the club and moved it into the arcade and living room, bridging gaps between performance and recreation. Participants can play the part of both artist and audience, creating music and dancing to it as part of the same action. Players can take on both lead and backup roles, play by themselves or with others, and either collaboratively or competitively game. Using an 8' x 8' responsive floor provided by the Lightspace Corporation, a number of experiments were undertaken to push the limits of the confluence of interactive dance, music and gaming. Descriptions of these and future investigations are detailed below.

Figure 1: Lightspace Corporation's Interactive Floor

2: PRIOR ART

In previous and current research into reactive floors and responsive environments, attention has been paid to advanced position tracking, audio feedback, illuminated visuals, and interactivity. Joseph Paradiso's Responsive Environments group at MIT has addressed a number of these issues in the interfaces they have created, such as "Expressive Footware" [16], a sensor rich shoe that enables musical performance through the dance movements of a single wearer, "Magic Carpet" [15], an interactive rug that modulates parameters of a participatory soundscape with a user's steps and arm movements, and ZTiles [17], a network of sensate tiles that create an extensible perceptive floor space. Other non-visual interactive floors that have been created are the University of Limerick's "LiteFoot" project [9], aimed at recording traditional ethnic dances

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electronically, and Georgia Tech's "Smart Floor" [14], used to identify individual users by footstep patterns. Both Tobi Delbruck's "Ada" project, an illuminated reactive floor with behaviors modeled after a sentient organism [7], and the current iterations of software written for the Lightspace system [12] are excellent examples of tactile, luminous and programmable interactive environments. The collaboration of artist Toshio Iwai and the Klein Dytham architecture group on the Bloomberg ICE in Tokyo [3] is a beautiful example of how a responsive interior with visual cues can help to define a thought provoking and visually spectacular interactive space, and the installation done by the United Visual Artists in the London club Kabaret's Prophecy is a great example of the way an illuminated interactive environment can integrate into a club setting [20]. Electroland's Enteractive is another grid-based floor tile system, in which the interactions of an indoor illuminated grid are displayed on a matrix of neon squares mounted to the exterior of an office building in downtown Los Angeles [6]. In the games arena, the Nintendo Wii [21], with games like Wii Sports and Wario Ware, and Dance Dance Revolution [5] are wildly popular examples of the kinds of physical gaming that are gaining renown as both a social and an exercise phenomenon.

Each of the non-visual projects enables foot based musical performance, but none of them provide illuminated feedback or visual cues, important in the creation of spaces that can guide a user's movements, and necessary for crafting a meaningful gaming environment. In research done into illuminated surfaces, a parallel situation exists in that the work has included visual, gaming and kinetic aspects, but has never fully integrated musical elements into the space. The goal of this project was to explore the entertainment possibilities afforded when multiple discrete cognitive modalities were merged into a space. The hypothesis was that by synergistically combining all of these elements - audio, visual, kinesthetic, and game - into one immersive environment, the result would be a more highly rewarding and flow inducing state of play. [4]

3: SYSTEM DESCRIPTION

The hardware system for the Lambent Reactive consists of a grid of 36 networked 16"x16" square tiles fabricated by the Lightspace Corporation, a 5.1 channel Genelec sound system, and a computer simultaneously running Ableton Live, Native Instruments' Battery, and proprietary Lightspace software. Each tile of the reactive floor surface is composed of 16 individually addressable 4"x4" pixels, and is capable of transmitting pressure data from four sensors embedded in the intersections between the central and outer layers of pixels. In this way, individual position and pressure can be detected down to a resolution of two pixels, or 8", less than the length of all but a child's foot. The Lightspace software was retrofitted to convert each tile's sensor data into MIDI signals, which were routed to the audio software to trigger the sound sources.

Figure 2: Location of pressure sensors on floor tile

A timing system was also built on top of the Lightspace software to enable linear sequencing of visual and audio events, as well as rhythmic detection and recording of dance steps. To implement audience feedback in the Dance Off mode, a phone based Voice XML (VXML) system was programmed to take calls from audience members, read their DTMF keypad presses and tally the results in an online database that the Lambent Reactive accesses. Additionally, two Happ "Mega Button" pushbuttons were interfaced with the Lambent Reactive using the Arduino platform [1] to provide a more tactile audience feedback mechanism.

4: INTERACTION DESIGN

Multiplayer dance gaming, as evidenced by the popularity of arcade games like Dance Dance Revolution, has won support due to the positive social and physical interactions that it reinforces. Players who were not necessarily previously proficient in dance enjoy getting together and dancing in a structured environment, and not just for the competition alone [11]. Dancing is a freeing act, one that flows with music and causes transcendence and joyfulness for those involved in it, but one that can cause anxiety in more uncomfortable and timid participants. The idiom of dance gaming has combated this facet of amateur dancing with structures that allow any user to move on their feet and work up to more difficult challenges.

With this in mind, a group of low-level interaction modalities were defined for the Lambent Reactive, such as "repeat after me," "keep the rhythm," "cover the board," and "stand in a zone." These were then configured in various combinations to construct the higher-level playforms that were tested by players of this system. The final application designs encompassed both structured

system-based approaches and open-ended playground modes. It was instructive to explore the breadth of experience made possible by this system, as it brought to light some of the social factors exhibited by alternate styles of interaction. Users behave very differently when they are collaborating versus competing - likewise, when they are following guided steps versus inventing their own. By crafting varying experiences that would embody these opposing mechanics, a more detailed look at the interaction modes of multiplayer immersive dance and music gaming was made possible. In this paper, four interaction modes will be discussed: MetaSimon, Dance Off, Song Machine, and Freestyle.

4.1 MetaSimon

This playform was inspired by the 1970's puzzle game Simon, which used a four-button hand held board to play random sequences of lights and tones that players tried to memorize and repeat. The game would start with one tone, which would correspond to a lit button, and would build longer and longer patterns on top of that, as long as the player continued to input the correct sound combinations to the buttons [18].

Figure 3: Milton Bradley "Simon" Game, c. 1978

For MetaSimon, each button, instead of corresponding to a single tone, is represented by an area of nine tiles on the board - the play area of a single participant - eight of which emit tones. The center tile in each area is the designated null tile for players to stand on. Each player - up to four - stands on this center tile in one of these zones, and watches as the system plays a sound, accompanied by the illumination of a specific shape on the corresponding tile. When the system cues them to start, the player on whose area that audiovisual prompt occurred attempts to stomp on the tile that lit up. If they do so correctly, the system responds by playing the sound that already occurred, followed by a new tile/sound combination in a different location on the board, in any of the four quadrants. Each sound is spatially positioned to be heard as if it were coming from a specific player's area, to aid in memorization of the game patterns, and the quadrants have individual color schemes to provide differentiation between them. As long as players continue pressing the tiles in the correct order, MetaSimon will continue providing longer and longer sequences, up to a set number of steps that is a function of the number of participants playing the game.

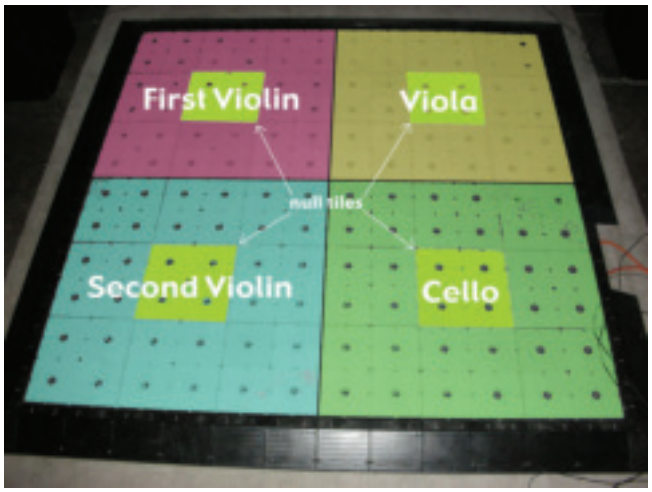

Figure 4: MetaSimon floor layout in String Quartet Mode

Success in a game of MetaSimon is attained by memorizing not only the pattern and location of the tiles in a player's individual zone, but also their temporal relation to the audio cues of the other players' movements. Each quadrant of the floor functions as both its own Simon board and as a button in the larger board, which fosters a collaborative game mechanic between players wherein they must depend on and encourage each other in order to progress farther in the game. In more advanced modes of MetaSimon, two or more sounds occur simultaneously on different sections of the board. This mode, unlike the standard mode, requires players to keep to a beat while stepping on their tiles, which adds difficulty but significantly increases the reward of hearing a successfully executed pattern. While the beat-based form makes the system much more complex, it serves to strengthen player relations and create an almost band-like dynamic between them. As well, the rhythmic aspect provides an additional mnemonic device to aid players in the recollection of their required steps. Further functionality of MetaSimon allows players to record their own patterns for others to play back during later game sessions, allowing a high degree of customizability and personalization.

4.2 Dance Off

Dance Off is a two player competitive activity in which each participant tries to one-up their opponent by executing complex and stylish dance moves to the beat of different pieces of music. One by one, each player trades off the roles of "attacker" and "defender" for eight measures of a song. The attacking player aggresses by pulling off a sequence of

steps, each of which triggers a white illuminated square that moves down the board to the other player's side, becoming more saturated and colorful as it travels. The square will become most colorful and stop traveling at the point when it is halfway across the board from where it was stepped on, after which it fades out and disappears. The speed of the square's travel is a function of the BPM of the song that the players have chosen to dance to. The defender's job is to step on all the squares sent out by the attacker at their most colorful point, thereby replicating the movements of the attacker, but in a manner that provides for strategy and creative interpretation. Feedback for correct steps is provided by explosions and horizontal lines spreading from the point of contact, the color and size of which is determined by the closeness of the step to the ideal timing. Points are assigned for hitting a square within a beat of its most colorful point, and are subtracted for letting a square die out without stepping on it at all. The score is depicted in "tug-of-war" style score bar on the side of the floor.

Scoring is also tallied by an "applause meter" mechanism, which consists of a system that allows audience members to vote for their favorite dancer by either pressing a large colored button placed by the side of the board, or by using a phone to call in to the VXML voting system. In this way, style and poise are integrated as game mechanics, making the play of the system more open ended and encouraging of creativity and improvisation, as dancing is in clubs and parties. In addition, the expressive and performative aspects of the play are emphasized in this mode, making it not only a recreational activity for players but also an interactive spectacle that anybody nearby, or even those watching remotely, can participate in.

The Dance Off references street and Freestyle dance culture in that it is a competitive dance forum that exists outside of the influence of traditional studio forms [19]. As in street dance, the audience witnessing the show largely determines the winner of the Dance Off. Much like breakdancers and Krumpers try to one-up each other by pulling off complex and difficult maneuvers, players of Dance Off try to make complex steps that will be difficult to replicate, while maintaining a sense of poise and style in their movements. Thus it is not only physical prowess, but also individuality and originality that will net a victory in the Dance Off.

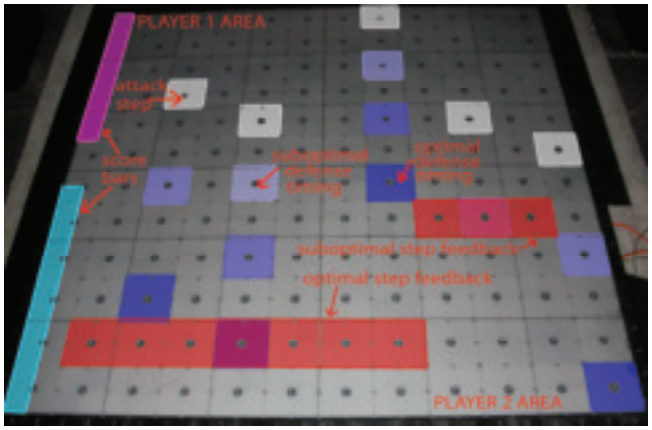

Figure 5: Sketch of step schema and board layout in Dance Off Mode

4.3 Song Machine

In Song Machine, the tiles are illuminated like a traditional 8-step sequencer, with squares of 3x3 pixels representing each step to comprise a total programming matrix of 64 buttons. Each row represents a different sound, and each column denotes one of the eight beats in the rhythm. Six of the rows are used for samples, and the bottom two are used for global controls. There are four different instrument "scenes" to sequence, each of which contains a different sound layout for the six rows. Players step on the buttons of the song machine to activate a certain sample at a specific place in the rhythm, as indicated by its horizontal position. As the beat plays, the activated instruments light up and play their sounds, thus visually representing the rhythmic pattern with moving spatial and temporal patterns of illumination. Users can affect the rhythm in real time by pressing each button on or off with a footstep, which results in the creation of a fully functioning, multiplayer, multisound, 8'x8' square drum machine. Rhythms can be started and stopped by stepping on the play and stop zones, and the current scene that is being sequenced can be cycled through by stepping on the scene up and scene down buttons. The music's rhythm speeds up and slows down in time to a player's footsteps as they step on the tap tempo zone. Song Machine is a collaborative musical experience that does not require proficiency to enjoy, just a rhythmic sensibility and a playful approach.

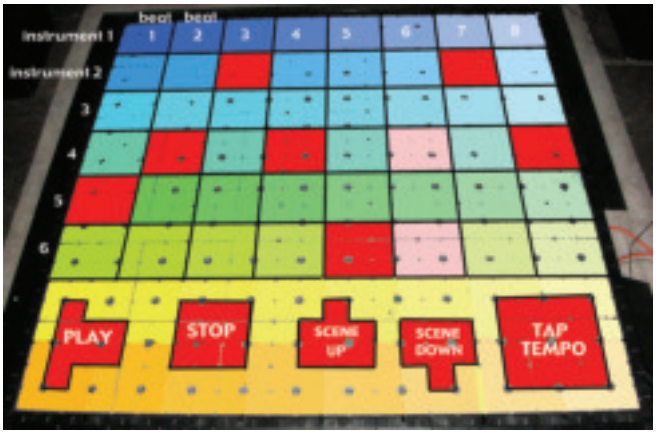

Figure 6: Song Machine floor layout with a sequenced pattern playing on beat six

4.4 Freestyle

Many of the various MetaSimon sound sets prove entertaining when presented to players for freestyle improvisation. Not entirely unlike a two dimensional and reprogrammable version of the FAO Schwarz Dance-On Piano [8], the freestyle mode functions equally well with a single player or with many. As a multiplayer instrument, it functions as a an accessible interface for collective musical expression that can provide even the most novice user with a satisfying creative and social experience [2]. The MetaSimon sound layouts are arranged so that no musical knowledge or skill is required to create basic melodies, which makes it an excellent interface for amateurs to playfully explore the act of musical composition in a social forum.

5: SOUND DESIGN

As the sound design of the Lambent Reactive is completely modular and programmable, multiple sound sets were created for MetaSimon to encourage different modes of play and expression. In the same way, multiple songs were chosen for Dance Off that the player can choose to compete to. The essential game mechanic does not change with the replacement of sound layouts, but the user experience differs wildly as the content of the audio landscape modulates. It was constantly a question in the design of the MetaSimon game modes whether it would be best for the system to choose the note patterns algorithmically or from pre-written scores. Some of the game modes function well stochastically, wherein the next sound to be played is chosen at random from any square on the board, whereas in other modes this approach did not produce any kind of meaningful result. It was advantageous to choose algorithmic patterning when possible, as this allowed for infinitely variable and replayable level design, but it was not feasible for all sound sets.

The color palette was also an important consideration for each sound set. As different sonorities evoke certain feelings or responses from listeners, it was necessary to design the board layouts to express this. Thus, on a preliminary level, sound sets like Dance Music and Rock Band contain more vibrant colors, due to the youth culture associated with them, whereas String Quartet and the Pythagorean Lambdoma are more subtle and muted. For Dance Off, the color set changes with the song chosen to dance to - a Dance Off to Michael Jackson's "Billie Jean" is much starker than one based around an emotive Chopin waltz. In further iterations, color schemes can be designed around certain social groups - for example, an 80's synth rock sound set could contain neon pink, black and white, to visually represent the pop culture trappings associated with this style.

5.1 2-D Tuning System

In an effort to define a tonal arrangement that would be sonically meaningful across the 36 tiles of the board, various 2-Dimensional tuning schemes were researched. The most successful result is described below.

5.1.1 Pythagorean Lambdoma

The Pythagorean Lambdoma is a tuning system originally developed by the Greek mathematician Pythagoras over 2500 years ago. Its harmonic resonances are alleged to provide feelings of wholeness and well being, and are used by some as musical therapy [10]. Its layout consists of a fundamental frequency, which is placed, in the upper left hand corner of the grid, for example 440 Hz (middle A). The next square to the right will be 2 times the original frequency, the square after that 3 times, and so on. In this size board the upper right square's frequency is 6 times that of the upper left (2640 Hz). In a likewise fashion, the square below the fundamental is one half its frequency, the one below that one third, and so on down to one sixth. Each square's frequency ratios are defined by its place in the matrix - the row number divided by the column number represents its relation to the fundamental frequency. This tuning scheme produces a range of tonalities that remain consonant with each other in almost any combination, making it an ideal layout for a multiplayer interactive instrument.

1:1 C	2:1 C	3:1 G	4:1 C	5:1 E	6:1 G
1:2 C	2:2 C	3:2 G	4:2 C	5:2 E	6:2 G
1:3 F	2:3 F	3:3 C	4:3 F	5:3 A	6:3 C
1:4 C	2:4 C	3:4 G	4:4 C	5:4 E	6:4 G
1:5 Ab	2:5 Ab	3:5 Eb	4:5 Ab	5:5 C	6:5 Eb
1:6 F	2:6 F	3:6 C	4:6 F	5:6 A	6:6 C

Figure 7: Lambdoma Matrix with C as fundamental

5.2 Dance Music

The percussive and non-melodic musical structure of electronic dance music is particularly well suited for both stochastic and programmed implementations on a 2-D game board. Many drum machines and samplers, such as the Akai MPC-2000 [13], already group sound triggers in a grid-based pattern, thus their structure naturally transitions to a mapping on the Lambent Reactive. Each quadrant of the board has a set of the core instruments in a techno track - bass, kick drum, snare, hi-hat, synth - but spatialized differently to provide sonic distinction among players. The sonic resemblance of the instruments creates a high level of difficulty for players, but makes the structure of the game extremely interesting, as each player contributes smaller rhythmic blocks to the creation of a large percussive structure. A player can concentrate on executing their own individual moves and also witness their sounds weaving together with those of the other players, as do musicians in polyrhythmic ensembles like those of the Batá players of Yorubá and Cuba.

5.3 Rock Band

To simulate the feeling of playing in a rock band, each quadrant of the board in this design mode represents a specific instrument - guitar, bass, drums and keyboard. Depending on the score of the song, the guitar and keyboard sections will have anywhere from three to five of the tiles representing chords, and the remaining tiles triggering individual notes. The tiles in the drum and bass sections each trigger individual samples in the case of the drum section, and notes in the case of the bass. The bass notes correspond to the chords played by the guitar and keyboard sections, so as to provide a template for the creation of typical rock and pop song structures. This sound layout only functions in the pre-programmed mode, but many popular songs can be mapped to it, making it both easier for players to remember the individual parts, and entertaining if they are already familiar with that particular song.

5.4 String Quartet

In this mode, each quadrant plays the sound of a single instrument of a string quartet - two violins, a viola and a cello. In a specific level design, either stochastic or scored, a player's area contains three tertian chords, with one square representing each of the three notes of the chord. In this way, either consonant or dissonant sonorities can arise, and arpeggiated harmonic structures can be played. The layout does not allow for the construction of complex classical pieces, but rather allows the user to playfully approach the music of a string quartet in a simple and accessible manner.

6: CONCLUSIONS AND FUTURE WORK

Future work with the Lambent Reactive will codify the interaction modalities and success metrics of designing for an audiovisual kinesthetic gameplay environment, and will explore the different play styles afforded by interfacing alternate technologies with this already established system. The addition of a Nintendo Wii controller or similar device will allow gestural input to define play modes, such as scrolling and panning through screens in a sound- based puzzle game, or the combination of swing-based attacking and step-based dodging to the Dance Off game. The addition of a wireless microphone opens possibilities of voice-based commands and "diva" style gameplay, in which the player is dancing and singing in the model of familiar rock and pop celebrities. Additionally, the further development of the mobile phone interface will allow remote players to both view and interact with the action occurring on the board, which will broaden the locative scope of the experience, and hopefully raise questions of situation, control and omniscience in the space of player interactions.

To conclude, the Lambent Reactive provides a highly immersive experience for its users, and allows for a plethora of innovative game forms to be written for it. As interfaces advance, a more holistic integration of multisensory experiences is seen as the path to more rewarding computer interaction. As evidenced by the popularity of both the Nintendo Wii and Dance Dance Revolution, the full use of one's body in controlling an interactive experience is showing itself to be what people are looking for in their play experiences. This project hopes to better define the methodology involved in creating physical game play by breaking down into its composite elements the nature of audiovisual and kinesthetic interaction design.

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