socio-ec(h)o: Ambient Intelligence and Gameplay

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ABSTRACT
This paper describes the preliminary research of an ambient intelligent system known as socio-ec(h)o. socio-ec(h)o explores the design and implementation of an ambient intelligent system for sensing and display, user modeling, and interaction models based on game structures. Our interaction model is based on a game structure including levels, body states, goals and game skills. Body states are the body movements and positions that players must discover in order to complete a level and in turn represent a learned game skill. The paper provides an overview of background concepts and related research. We describe the game structure and prototype of our environment. We discuss games research concepts we utilized and our approach to group user models based on Richard Bartle's game types. We explain the role of embodied cognition within our design and elaborate on what we chose to encode as embodied actions, cognition and communication. We describe how we utilized selective responses that were real-time, gradient, provided rewards and were unique to different group user models. We introduce our approach to designing ambient intelligent systems that is ecologically inspired. We stress the empirical nature of the design work and the role of participatory design in developing our system.

Keywords
Ambient intelligence, responsive environment, user model, physical play, puzzles, embodied, audio, motion-capture.

INTRODUCTION
This paper describes the preliminary research of an ambient intelligent system known as socio-ec(h)o. socio-ec(h)o explores the design and implementation of an ambient intelligent system for sensing and display, user modeling, and interaction models based on game structures. Ambient intelligence computing is the embedding of computer technologies and sensors in architectural environments that combined with artificial intelligence, respond to and *reason* about human actions and behaviours within the environment.

Ambient intelligent spaces lend themselves extremely well to physical and group play. In this paper we describe our design of an interaction model and supporting system based on physical play. The overall research goal of this project is to understand to what degree physical play and game structures such as puzzles can support groups of participants as they learn to manipulate an ambient intelligent space. Future evaluation of this project will allow us to more fully answer this

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question. To date we have designed and implemented the prototype and interaction model. We have incorporated formative feedback through a participatory design process. This approach allowed for the concurrent development of the concept, interaction model and prototype environment.

The paper provides an overview of background concepts and related research. We then describe the game structure and prototype of our environment, including a technical overview of the system. We discuss the utilized games research concepts and our approach to group user models based on Bartle's game types [2], and our ecologically inspired design approach to socio-ec(h)o. Lastly we conclude with a discussion of our work to date and future research.

BACKGROUND

Key contextual issues in socio-ec(h)o include related research in the area of play and ambient intelligent spaces, and literature linking play and learning.

Björk and his colleagues have observed progress toward fully ubiquitous computing games yet they identify the need to develop past end-user devices such as mobile phones, personal digital assistants and game consoles. Accordingly, we need to better understand how "computational services" augment games situated in real environments [3]. Recent projects have investigated the play space of responsive environments and tangible computing utilizing sensors, audio, and visual displays. For example, Andersen [1], and Ferris and Bannon [9] engage children in exploratory play and emergent learning through sensor-augmented objects and audio display. Andersen's work reveals how theatrical settings provide an *emotional framework* that scaffolds the qualitative experience of the interaction. Ferris and Bannon's work make clear that a combination of simple feedback and control lead children to widely explore and discover a responsive environment.

In the *Nautilus* project, Strömberg and her colleagues employ bodily and spatial user interfaces as a way of allowing players to use their natural body movements and to interact with each other in a group game within a virtual game space [17]. Strömberg observed in physical and team games such as soccer or dodge ball that players coordinate their physical movements and rely heavily on communication to be successful. In their findings, participants reported that controlling a game through one's body movement and position was "new and exhilarating." In addition, playing as a team in an interactive virtual space was found to be engaging, natural and fun.

In relation to the above research, socio-ec(h)o builds on the theatrical, simple and physical interaction models in order to develop a game structure approach that lies between exploratory play and a structured game for adults within an ambient intelligent environment. In addition, we extend the notion of a game structure to an interaction model for the environment rather than a virtual game space. We also build on the idea that action, play and learning are linked in such physically-based environments.

In respect to the links between action, play and learning there is a substantial amount of literature. Dewey argued for the *construction* of knowledge based on learning dependant on action [8]. Piaget, through his child development theory believes in the development of cognitive structures through action and spontaneous play [14]. According to Piaget, *constructivist* learning is rooted in experimentation, discovery and play among other factors. Papert extends Piaget's notions by investigating the knowledge-construction process that emerges from learners actually creating and designing physical objects [13]. Malone and Lepper consider games as intrinsic motivators for learning [11]. Subjective motivations like challenge, curiosity, control and fantasy may occur in any learning situation; other motivations like competition, cooperation and recognition are considered to be inter-subjective, relying on the presence of other players/learners. Design related theories have placed activity at the center of design action as in Nardi and O'Day's activity theory based information ecologies [12]. Schön argues that design is a series of actions involving experimentation and learning in the framing and re-framing of a design situation [16].

GAME STRUCTURE AND PROTOTYPE

Description and Scenario

The aim of our game is for a team of four players to progress through seven game levels. Each level is completed when the players achieve a certain combination of body movements and positions. At the beginning of each level, players are presented with a word puzzle as a clue in discovering the desired body states (see figure 1). The levels are represented by changes in the environment in light and audio. The levels are progressively more challenging in terms of body states and more complex in terms of the audio and visual ambient display. The physical environment currently consists of a circumscribed circular space (the area in which we can detect motion), surround sound audio, theatrical lighting, and two video projection surfaces.

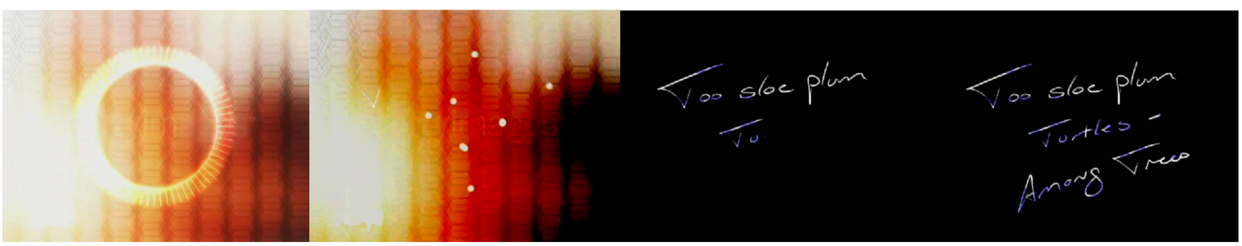

Figure 1. Depicted above are frames from a 33 second video introducing a level to players. The images at the beginning of the video provide a *sense* of the environmental change the players are trying to achieve for that level. This is followed by a *clue* in the form of a word puzzle aimed at helping players discover the desired body state. In this example, the puzzle is "Too sloe plum turtles – among trees."

Here is a short scenario of participants in the socio-ec(h)o environment:

> *Madison, Corey, Elias and Trevor have just completed the first level of socio-ec(h)o. They discovered that each of them had to be low to the ground, still, practically on all fours. Once they had done that, the space became bathed in warm yellow light and filled with a wellspring sound of resonating cymbals. Minutes earlier, the space was very dim – almost pitch black until their eyes adjusted. A quiet soundscape of "electronic crickets" enveloped them. They discussed and tried out many possibilities to solving the word puzzle: "Opposites: Lo and behold." They had circled the space in opposite directions. They stood in pairs on opposing sides of the space. At Corey's urging, the four grouped*

together on the edge of the space and systematically sent a player at a time to the opposite side in order to gauge any change in the environment. Nothing changed. Madison, without communicating to anyone realized the obvious clue of "Lo" or "low". While Corey was in mid-sentence thinking-out-loud about the puzzle with Trevor, and trying to direct the group into new body positions, Madison lowered herself to a crouching position. The space immediately glowed red and became brighter. The audio changed into a rising chorus of cymbals – not loud but progressively more pronounced. Corey and Trevor stopped talking and looked around at the changing space. Madison, after a pause began to say "Get down! Get down!" Elias stooped down immediately and the space became even brighter. Corey and Trevor dropped down in unison and the space soon became bathed in a warm yellow light like daylight. The audio reverberated in the space. A loud cheer of recognition came from the group, "Aaaaahhh! We got it!" Corey asked everyone to get up. As soon as they were all standing, the space became pitched black again. They dropped down again and the space was full of light. They had learned how to "create daylight" in the space. They had completed level one.

Soon after, a new word puzzle was presented to them in a short video projected on two scrims hanging from the ceiling: "The opposite of another word for hello but never settles." The lights have become very dim now and the audio has a slightly more menacing quality to it. Level two will clearly be more challenging…

Figure 2. Scenes from the final participatory design workshop in which the relationship between body states and word puzzles were explored. The system utilized is an early prototype with the substantive functions implemented. As players lower themselves, the environment becomes progressively darker and the ambient audio more pronounced. Note: the display response is not the same as depicted in the scenario. In this exercise, the goal was to create darkness rather than light.

We formalized our game structure into a schema of levels, body states and goals (see table 1). As earlier described, the game has seven levels. The body states are the body movements and positions that players must discover in order to complete a level. Goals are the change in environment players are aiming to achieve. The goals are implicit and not explicitly stated for the players. Each level has a beginning quality of light and audio. As the players progress toward achieving the right body state, the environment incrementally shifts toward the goal state of the environment. For example, as depicted in the scenario, when Madison lowered herself, the environment gradually shifted toward the goal of creating day. As each of the other three players followed Madison, the environment responded to movements of each player (see figure 2).

Table 1: This table describes the socio-ec(h)o game schema.

Theme	Levels	Body State	Goal	New Game Skill
Discovery of light	1	"high-low"	create day	body position
Day for night	2	"moving low"	create night	movement/duration
	3	"loosely moving"	create day	proximity
Rhizome	4	"dense center - scattered edge"	create spring	sequencing
	5	"this way slow – low to high"	create winter	sequencing/duration
Biota	6	"two low moving – two high"	create summer	composition
	7	"ringing around the rosie"	create fall	composition & location

In addition, the schema includes new game skills and themes. We assigned each level a generic skill in relation to each body state and level. Despite the specific body state, the generic skill acquired at each level is required in order to discover the more complex body states at higher levels. Themes allowed us to design an implied progressive narrative based on natural evolution. Again, the specific themes and even the narrative are not known to the participants, rather they provide an underlying structure for body states, goal states and game skill acquisition. We intend for the progressive narrative to provide a sense of coherency across the levels, and to loosely map increased challenge to the reward of a more complex display.

Technical Prototype

The technical system for socio-ec(h)o includes three key components, a sensing system, reasoning engine and display engine.

Sensing System

The sensing engine is comprised of a twelve-camera Vicon MX motion capture system (www.vicon.com) and a custom program written in Max/MSP. Each participant is differentiated by unique configuration of reflective markers worn on their backs. The system senses for discrete parameters such as velocity, position (x,y,z), orientation, proximity and movement. It measures across each unique player for participation and duration. Data is transmitted to the reasoning engine for high-level interpretation.

Reasoning Engine

The reasoning engine provides the intelligence for the system. It interprets the sensing data samples, identifies the level of body states completion, and manages the narrative flow of the socio-ec(h)o experience. The engine receives sensing data from the sensing system and interprets it in terms of high-level group behavior. For example the sensing system sends data on predefined parameters such as velocity and body positions and the reasoning engine synthesizes the parameters to determine if a given body state is achieved. The characteristics and their combination, and in some cases their sequence determine the 'intensity' of the state. Another factor influencing the state intensity is the group user model that is dependent on the combination of user types as identified by Bartle classifications (see the section below, "Description of Game Concepts and User Model"). The role of the engine is to manage the flow in the game by sequencing of the states and managing the timing of the state transitions. The reasoning engine is rule based and allows seamless modification and extension for other applications. The reasoning engine feeds it's output, state intensity and state transition to the display engine.

Display Engine

The display engine has two components, an audio and a lighting component. The audio display engine for socio-ec(h)o provides a sound ecology for each individual level of the system. It is custom software programmed in Max/MSP. We developed and structured the audio content on the principles of acoustic ecology and feedback-as-communication [18]. In addition, the audio display provides a gradient response to the participants, telling them how close they are to achieving their goal. The audio display system can alternate between stereo and multi-channel formats and localized and ubiquitous sound. The audio content follows the theme of evolution by utilizing sampled sound and several different sound processing techniques creating a shifting ambient soundscape that moves from simple, abstract sound to rich, environmental sound.

Lighting is manipulated with a DMX 512 controller via a Max/MSP patch. A small light grid and theatrical style lighting instruments and color scrollers are used. A lighting console was created to control multiple lights and color in concert through a cue list mechanism. Cues were written to simulate the various themes at each level.

Both the audio and the lighting systems take their cues from the reasoning engine, and respond to game aspects and configurations specified in the reasoning engine. Thus, the response of the display systems can potentially be used to provide feedback based on a variety of parameters such as how well participants are working together as a group.

Integration

The three components described above run on their own servers. The integration is achieved by lightweight communication protocol that is transferred over the User Datagram Protocol (UDP) communication channel. We consider uni-directional UDP communication appropriate for the real-time applications. Although the sensing system is capable of capturing data at the rate of 30 frames per second we are using slightly longer sampling rate of 200ms for data transferred between the servers. Considering the nature of the output (sound and video) this rate is sufficient for the required fine-grained response.

DESCRIPTION OF GAME CONCEPTS AND USER MODEL

We investigated the play and game aspects of socio-ec(h)o through short ethnography sessions, workshops among the researchers, and games research theory. We explored a range of game concepts including traditional game theory notions such as Nash's Equilibrium to contemporary games research [4, 5, 15]. Our aim was to encode a form of play for groups that lie between a structured game and open-ended play. Each level acted as a kind of group puzzle - that is, a game with a single solution or winning state [10]. The alignment of increasing difficulty of level solutions with the increasing skill of the participants as they proceed through the experience is consistent with Csikszentmihalyi's model for developing a state of flow [7].

In the end, we relied on our participatory design process to evolve our game structure. This was especially helpful since we were exploring social aspects of gaming such as communication, collaboration and shared cognition. In addition, our approach was highly physical which required an empirical approach to understanding our concepts. Theoretically, we utilized Bartle’s concepts of collaborative play in Multi-User Dungeons (MUDs) and MUD Object Orienteds (MOOs) to help us formulate a group user model to support the reasoning within our system [2]. Bartle identified four types of MUD player styles: *achievers*, *explorers*, *socializers*, and *killers*. *Achievers* seek in-game success, *explorers* satisfy their environmental curiosity, *socializers* value human interaction, and *killers* exercise their will at the expense of other players.

The group user model in socio-ec(h)o is constructed based on these Bartle’s types. The group user model is used in the interpretation of the individual actions in the environment and the level with which individual actions contribute towards an overall group activity. The display response in socio-ec(h)o is adjusted with respect to the group composition. We are currently investigating our hypothesis that by considering the Bartle types participants have a better experience and more quickly become *skilled* interactors.

AN ECOLOGICICAL AND PARTICIPATORY APPROACH

The key components of our ambient intelligent model are addressed as a systemic whole; they include interaction, reasoning, response and technology. For example, we investigated the balances between sensor technologies in relation to gesture, inference rules and display responses. Our design approach – inspired by an ecological frame – is centered on human activity and is participatory design driven, informed by observation and theory.

The concept of an *ambient intelligence ecology* emerged from findings in a previous research project known as ec(h)o. We discovered that ec(h)o had successfully balanced incongruent elements to form a dynamic and coherent system. Components such as interaction, reasoning, audio display and technology shaped the ambient intelligent environment around the purpose of a museum visit [20]. In ec(h)o we explicitly utilized an *information ecology* approach as an ethnographic analysis of the museum as well as a scaffold for our design decisions [19]. Nardi and O’Day describe an ecology to be a system of people, practices, values, and technologies in a local environment. They argue that the ecology metaphor shifts the focus to human activity rather than on technology [12].

The current research, socio-ec(h)o represents a preliminary exploration of the concept of an *ambient intelligent ecology*. The experimental nature of the project, its laboratory setting, and the fact that participants cannot be considered to be part of a relevant or definable ecology limit the degree to which this research fully explores the concept. Nevertheless, we feel this is a starting point in investigating an *ambient intelligent ecology* design approach. At this stage, we found the use of participatory design workshops to be a key component of an *ambient intelligent ecology* approach. The workshops simultaneously addressed issues of interaction, reasoning, response and technology. We ran five workshops that progressively explored open-ended concepts to more defined concepts. These workshops included investigations of the continuum between play and game, the physicality of our interaction model, the social aspect of play within our type of space, puzzles and narrative and finally the relationship between our body states and word puzzles. It was evident to us that we required an empirical and qualitative understanding of our concepts, interaction, technology use and prototyped environment *while* we were designing them.

DISCUSSION

In designing an interaction model and supporting system for play and learning of a complex system, many issues relate to the communication and action between participants and between the group of participants and the system.

Embodied cognition and communication

In our design, a successful participant experience relies on a tightly coupled system emerging from real-time, goal-directed interactions between participants, and between participants and the responsive environment. The nature of these interactions influences the challenge, enjoyment and success within the environment. Communication is key to solving the puzzles and coordinating actions. While the verbal discussion among participants is frequent and active, the physical nature of the interaction model and game structure emphasizes explicit embodied action, cognition and communication. Players actively *work out* the puzzle physically, as well as communicate actions and ideas physically. In many respects, the interaction model is founded on an embodied cognition view of interaction [6, 21]. Success in the game requires a quality of interaction in which mind, body, and environment mutually interact and influence one another positively.

From the perspectives of the design of the interaction model and system, we realized it was important to decide where not to specify interaction and system functionality. In many respects, we learned to *off-load* formalized interaction among participants to the situated dynamics of a group of people working toward a shared goal, i.e. people will communicate together in what ever form possible given the resources in the environment without the need of formalizing communication modes. In addition, the system does not need to encode or sense actions or behaviours that are not relevant to the desired body-state at a given level, i.e. no response from the system is a perceived response. We feel we supported an embodied and inter-subjective approach through limited means such as design constraints. For example, limiting sensing actions to whole body positions and movements rather then gestures, opened gestures up to unique, specific and complex communication between participants. Ignoring or not encoding large parts of the embodied action supported a wide range of exploration of body movements.

Selective Real-Time Response

We were however selective as to when and how the system did respond to participant's actions. The system responds when it appears that the group is on a trajectory toward the desired body state. The response is conceptually similar to someone telling another if they are close to a goal by stating if they are *cool, warm* or *hot.* Through our participatory design workshops we learned that four factors had to be met in our response in order to achieve this type of support through a changing environment. The response had to be in perceived real-time, the feedback is on a gradient related to the proximity to the goal, a reward is given for achieving a goal, and a response is mapped to the make-up of the group. The quality and nature of physical action requires an *accepted* real-time response. Given that we require a minimum duration before a body state is recognized, we had to find the threshold for what was understood as a required time to *hold* a position versus a perceived lag or failure of the system. A gradient response is critical in aiding players in understanding they are on the right track. The response is coordinated between the audio and the lighting. The nature of the gradient response is well illustrated in the scenario and figure 2 above. An audio reward is given once a state is completed. This is needed since the continuum of coordinated actions and durations is not explicit to the participants. Based on the different groups of players determined as a composite of Bartle types, we modified response and time. While we have yet to fully evaluate this approach, we anticipate a group of *achievers* will expect a different response or precision of action than a group of primarily *explorers*. With this in mind, we also provided a range of word puzzles of differing difficulty and challenge.

Empirical nature of designing ambient intelligent systems

An *ambient intelligent ecology*, as stated above, is an ongoing investigation of how we might define a design process specific to the challenges of ambient intelligence. Given the centrality of situated human activity and the need to develop an interaction model and system as a systemic whole – reducing the process or system to discrete elements is not a reasonable approach. While a theoretical approach to the design and system helps frame the problem and support design decisions, ultimately it is an empirical process such as ethnography or in this case, participatory design that yields useful qualitative and quantitative understanding of how to design the interaction model and system. The application that arises, such as socio-ec(h)o becomes a specific ecology of constraints, affordances and system functions, that is situated and relies on a unique dynamic of embodied action between people and environment.

FUTURE WORK & CONCLUSION

In this paper we have reviewed related research and have shown how our system builds on the theatrical, simple and physical interaction models in order to develop a game-based approach to ambient intelligence that relies on exploratory play with a conceptually structured interaction model. We discussed the links between play, learning and action that we extended into an embodied cognition approach. We provided a description of our game structure and prototype from conceptual and technical perspectives, and we discussed how we use Bartle's game types as the basis for our user types and group user model. We introduced our approach to designing ambient intelligent systems that is ecologically inspired. In our discussion, we explained the role of embodied cognition within our design, and elaborated on how we decided where and where not to formalize and encode embodied actions, cognition and communication. We detailed how the success of the experience relied on selective responses that were real-time, gradient, provided rewards and were unique to different group user models. Lastly, we stressed the empirical nature of the design work and the role of participatory design in developing our system.

Future work includes a series of evaluations of the system to better understand the influence of the game structured interaction model, the supporting user model, and the display. In particular, we aim to understand how our approach enables a better experience and more *skilled* interactors within an ambient intelligent environment.

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