Integrating Cumulative Context into Computer Games

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ABSTRACT
In this paper, we describe a cumulative context computer game, where accumulated contextual information of the players' activity levels, obtained through mobile sensors, is used to modify game state. Our implementation used a statistic-based, real-time version of the classic game of chess, where the statistics of the pieces depended on the activity of the users and the environment in which they performed the activity. Users found the game engaging and fun, and almost all of the participants altered their behaviors to enhance their performance in the game. This work provides a platform for further research into meaningful integration of cumulative context in games.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces *–interaction styles, theory and methods.*

General Terms
Design, Human Factors.

Keywords
Ubiquitous games, persuasive games, exertion interfaces, chess, sensors

1. INTRODUCTION
With the proliferation of the sensing, wireless access, and data storage capacity of mobile devices, there is an opportunity to gather contextual information. Accumulating user contextual information enables interesting context-aware game design opportunities in mobile and traditional console or computer gaming environments. There has been some recent research into incorporating context into game play; however, most of the examples are based on a user's location [1] or one aspect of their activity [7]. In our work, we are interested in whether we can design games that incorporate accumulated and generalized context [11]. We aim to create a method of sensing and capturing aspects of an individual's context and injecting this "personality" into a gaming environment, resulting in a game environment that responds to a player's context rather than players responding to preconceived gaming challenges.

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The goal of the present paper is to investigate how to effectively integrate accumulated context into play environments. We gathered sensor-based activity levels on eight users for one week, and used this information to scale their pieces' behavior in a real-time strategy game (RTChess). We have used the results of this exploratory study to formulate more focused questions for future work.

2. RELATED WORK
Integrating personal context into game environments has been explored in the domains of persuasive games, ubigames and exertion interfaces.

Based on the principles of persuasive technology [5], persuasive games are intended to alter people's behaviors in healthy ways through game play. Serious games can also educate people, and thus alter their behaviors through an increased awareness about relevant social and cultural issues [16].

Recently, games intended to increase physical activity have been created and evaluated. *Fish'n'Steps* is a social computer game that links a player's daily foot step count to the growth and activity of an animated virtual fish. A social element is introduced by including other players' fish, creating competition and collaboration [7]. In *Neat-o-games* [6], players' activity is monitored through an accelerometer, which controls an avatar in a virtual race. Each day a winner is declared, which provides that player with points to use on hints in individual mental games such as Sudoku. In the *Ubifit Garden* [4], players' physical activity - gathered through a combination of sensing and journaling - improves their virtual garden, showing their progress on a glanceable display.

Another line of research that combines physical activity with computing is exertion interfaces. Although these systems are not always designed from a persuasive perspective, the aim is to increase the physical activity requirements of computing. Exertion interface principles have been explored through games such as *Breakout for Two* [14], through everyday fitness applications such as *Jogging over a Distance* [15], and by incorporating activity into everyday computing tasks like the *StepUI* system for reading email [12] and the *SuperBreak* ergonomic break software [13].

Ubiquitous games (also called pervasive games or ubigames) are games that are no longer confined to the virtual domain, but integrate the physical and social aspects of the real world [9]. Using the principles of ubiquitous computing [17], ubigames offer opportunities for new game styles that adapt to a user's context, support natural interactions, or are persistent in real-time [3].

One popular class of ubigames is games that respond to a player's location [1][2]. Tabletop games that incorporate physical and digital elements have also been explored [8][10]. For an extensive survey of pervasive games, see [9].

3. EXPERIMENT

The study we conducted lasted six days and involved eight participants. During each day of the study, people met at 9:00 for one hour to play RTChess. Each participant was paired with a different teammate for each session. Teams participated in a daily round-robin tournament, playing each team once.

RealTime Chess (RTChess) is a real-time multiplayer video game, allowing 2-32 players to connect and play chess on their own computers. RTChess is not turn-based; instead, players move pieces as quickly as possible, requiring different strategies from traditional chess. We introduced a system of player statistics, similar to the ability scores in real-time strategy games, to RTChess. The statistics system is composed of six values that affect a player's attack power, defense, and piece speed for pawns and major pieces. In our implementation, the ratio of an attacker's power and the defender's defense is scaled into a weighted percent chance that the defender will survive. Piece speed scales the RTChess time delay between movement steps. Both attack power and piece speed statistics are player-specific, but the defense statistics are averaged over the team.

After each session, the participants were interviewed and audio taped for about 5 minutes as a group about the game's learning curve, the strategies they employed, the previous day's activities, and whether they coordinated their actions outside the game with their partner. On the last day of the study, we carried out an extended group interview (30 minutes), and users completed an online survey.

Participants wore a small mote or data logger (MicaZ 310, Crossbow Technologies Inc.) on their ankle from 10:00 to 15:00 for the first five days of the study. The mote collected a single record every 10 seconds, and every 10 minutes a 10 second burst of data was collected at 21 Hz. The motes collected acceleration, temperature and ambient light information.

We gradually introduced participants to the statistics used in the game and the corresponding sensor mote mappings, allowing players to view their statistics and the group average. The information provided to players is summarized in Table 2.

Table 2. Conditions used during morning sessions.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Equal stats	Different preset stats	Individual stats, *unknown* mappings		Individual stats, *known* mappings	

We adopted a simple normalization scheme, where data from the first day was used as a baseline case, and the activity of subsequent days was multiplied by hand-tuned factors determined from the first day's data. However, in practice, as the players began to comprehend the mappings, it was necessary to rescale the thresholds and scaling factors to keep the participants with the highest activity from saturating the statistics scores.

We recruited 8 male participants, aged 19 to 34 (mean of 23), from a local university. Participants were paid for their involvement in the study. All participants indicated that they used computers for more than two hours a day, played video games weekly, and had some past experience playing chess. Two people reported they had previous experience with RTChess.

3.1 Mapping Mote Data to RTChess

We used algorithms which required periodic motion of the leg so that vehicular transport or leaning would not impact the result. We biased the analysis to reduce the impact of repeated short duration activities, such as shifting in the seat without moving. Light and temperature biased the motion input towards one statistic or another. Table 1 summarizes the mappings between sensors and statistics.

Table 1. Overview of sensor mappings.

	Sustained motion	Motion outdoors	Motion indoors
Low vigor	Pawn speed	Pawn attack	Pawn defense
High vigor	Major speed	Major attack	Major defense

Activity was determined by departure from the norm of activity on a given accelerometer, characterized by a high standard deviation of the signal in a given time window. Activity vigor was determined as the integral distribution of the Fast Fourier Transform of the burst signal between zero and 1 Hz. Indoor and outdoor motion was inferred through thresholding the ambient light and temperature. A weighted average of 70% from the newest and 30% from the historical values were used to generate the day's statistics.

Data integrity was usually reliable during the study, but on a few occasions, data was lost for some participants. We addressed these problems by filling in the missing data using the general activity trends found in the data that we were able to recover.

4. RESULTS

In the next sections, we discuss several of the main observations from the study. We consider game strategy, the effect the mote settings had on game play, the behavioral changes that occurred as a result of participation in the game, and participants' opinions on different aspects of the game.

4.1 Game Strategies

All teams used strategies during the study. Initially, the strategies were simple, but their complexity increased as the study progressed. Participants indicated that usually one team member played offense, where they tried to capture the other team's king, and the other team member played defense. Teams established their strategies by discussion: "We would talk before the game began and work out specific moves. From there we would briefly speak to each other in between games, where we would switch pieces."

4.2 Effect of Player Statistics on Game Play

All players indicated that player statistics had a significant effect on the game, and that players with high scores had an advantage. One participant pointed out his preferred combination of attributes: "I found the best combination to be an above average speed with an average or above average attack power. Defensive power was useful as well, although not as important since defensive power was averaged with your partner." Team members who had high scores developed strategies for exploiting their advantage. One participant summarized his strategy: "The person with highest speed/attack would attack since it was an offensive stat combination. Defense was shared so it made more sense to have the player with weaker stats play defense. Personal play style also came into account. I prefer to play defense but would often get thrust into attacking based on stats."

4.3 Behavioral Changes

Most of the participants stated that they changed their behavior during the study (7/8, 87.5%). We asked people to describe how they adapted their behavior during post-session interviews and in the post-experiment questionnaire. Four participants indicated that they tried to spend more time outside, and two of them explicitly stated that they were interested in increasing their attack scores: "I walked around outside more once I was told this would improve my attack. I also played Frisbee for a short period of time one of the days to try and boost my stats." Only one participant felt that increasing his defense score was more important than the attack score, saying: "I wanted high defense first and speed second....Since I knew that light was a factor in trying to determine if I was indoors or out I tried to walk in the shade while outside or avoided going outside."

Most of the changes represented subtle but significant modifications to each person's daily activities. Five people said that when they needed to walk somewhere, they extended their walk by taking a longer route. For example, one person said: "In an average day when I come across stairs and an elevator, I take the elevator when it's available and stairs otherwise. The mote made me actively take the stairs all the time."

Three people increased their activity levels by introducing new activities. One person described how playing the game affected his decision making process: "If I was deciding whether I wanted to <walk to the coffee shop>, the mote would give me additional motivation to do so." In an amusing incident, three of the experimenters were walking back after lunch and saw one of the participants vigorously running back in forth in front of the Computer Science building while waiting for a friend.

In the post-study questionnaire, three people indicated that they worked with their teammates to adapt their daily routines, conflicting with daily interviews, where four people described how they cooperated with their teammates. The coordination was often very simple, where people encouraged each other to increase their activity. One pair described a more sophisticated strategy: "I went outside to build up attack, and [my partner] stayed inside and twitched his feet."

We asked participants whether they felt that the statistics used in the game accurately reflected their activities from the day before. They were asked about their level of agreement with the following statement: "The game settings accurately reflected my daily activities." Participants answered using a five-point Likert scale, and two people agreed with the statement, four were neutral, and two disagreed. During interviews, some people said that their statistics were often different than what they anticipated, either unexpectedly high or too low. We believe these discrepancies may be due to the way that we sampled data from the motes. Small changes in behavior, such as climbing stairs, might not significantly alter the overall measured daily activity.

We analyzed log data to objectively determine whether participants' activity levels increased during the study. The graph shown in Figure 3 plots their daily activity using the algorithm applied to regular 10-second samples. Data points with 0 activity represent hardware failure and a loss of data. With the exception of participant 32 who reported no change in activity, and participant 35 who started with a high level of activity, each participant's activity level was higher on the final day than at the beginning of the experiment. Participants 31, 33, and 36 have maximum activity at the end of the experiment. This subset of participants stated that they employed the 'twitch' strategy, where they bounced their feet while sitting at the desk to increase their statistics. Participant 37, who increased his overall activity level, saw a return for his efforts, but not to the same extent as those employing the "twitch" strategy. Participant 35 increased his perceived activity by choosing not to take the elevator; however, his overall activity dropped slightly, leading to a disconnect between his perceived and actual statistics.

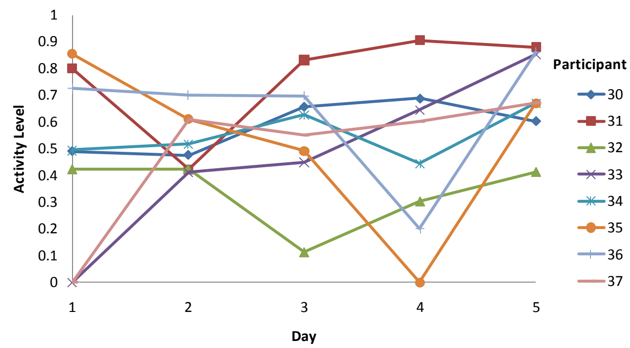

Figure 3. Activity level for each participant by study day.

4.4 Preferences

During the study, people played RTChess under four conditions as shown in Table 1. We asked participants to rate each condition according to how fun and how engaging they found it. They rated each using a five-point Likert scale, where a score of 1 was used for the lowest choice (i.e. not fun, not engaging), and a score of 5 was used for the highest choice (i.e. fun, engaging). The results are shown in Figure 4. On average, the equal setting received the highest fun rating, and the conditions that rely on mote data received the lowest scores. This trend is reversed in the scores that were given for engagement, where the mote conditions had the highest average scores.

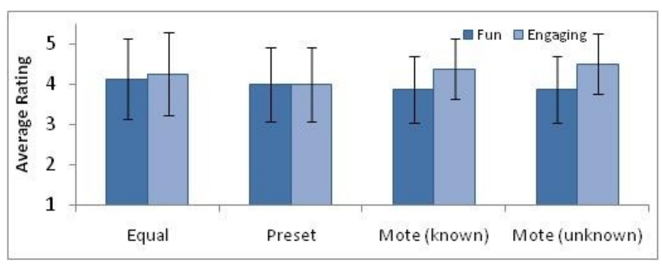

Figure 4. Likert scale ratings for each RTChess condition (higher is better). Error bars show standard deviation.

All eight participants indicated that they preferred the equal condition, where each player has the same attribute scores. Most people stated that they preferred to emphasize the strategic aspects of the game, and using variable statistics could make the teams unbalanced: "I found it frustrating when the opposing team had much higher stats, as there was not a whole lot I could do to counteract it in the extreme cases. The unequal modes were still fun, but…a higher degree of frustration overall. Also, when winning a game, it is not as satisfying, because the win is mostly attributed to having better stats, and not having better skill."

4.5 Performance Results

We examined log data to determine the impact that differences in team statistics had on wins and losses. We analyzed system logs from days 3-6, covering 24 unique matches with an average of 38 games per match. We plotted the dominant team's average percentage advantage in total statistics as well as the percentage of games that team won during the match. The graph is shown in Figure 5, with a best fit logarithmic curve. While there is an apparent trend between player statistics and winning percentage; below the 20% mark, the dominant team had a small advantage.

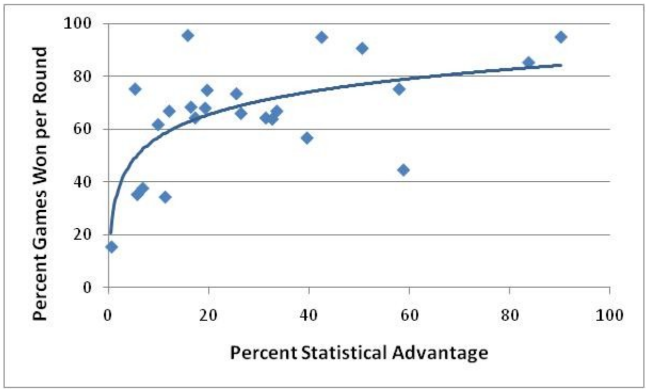

Figure 5. Percentages of games won in a round plotted against advantage in team statistics

4.6 Limitations and Future Work

This study was exploratory, and as such, leaves the door open for substantial future work. Our study switched the participants in each team every day to avoid and partially negate the impact of strong players being paired up at the beginning. However, it would be interesting to investigate how strategies both in the game and during the context collection might have evolved if the teams were left together through the entire course of the study.

Our study has illuminated several potential pitfalls, which should be avoided in future work. The choice of game and context should have a closer match, and not violate players' expectations about game play, or context mapping. Allowing users to obtain feedback on accumulated context might help illuminate the mappings and reduce confusion.

Because our study was short term, we cannot make claims about the long-term viability and engagement of cumulative context games, or how these games would impact the overall life-habits of the players, as we only collected data during working hours. We would also like to investigate applying this technology to other games, such as RPGs, where the context mapping of enhanced statistics is more plausible to the user.

5. CONCLUSIONS

In this paper, we present a study on the design and deployment of cumulative context games, where accumulated contextual information of the players, obtained through sensors, is used to modify the game state. Our implementation used a statistic-based real-time version of the classic game of chess, where the statistics of the pieces depended on the environment and activity of the users. Users found the game engaging and fun, and almost all of the participants changed their behavior to enhance their performance in the game. With the experience gained in this study, future work can focus on designing compelling cumulative context-aware computer games for the next generation of mobile and gaming devices.

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