MobIGames: Mobile Interaction Games with Wireless Devices

Yi Wang[1], Shyam Kapadia[2], Bhaskar Krishnamachari[1,2]
[1]Department of Electrical Engineering
[2]Department of Computer Science
University of Southern California
Los Angeles, CA 90089, USA
{wangyi, kapadia, bkrishna}@usc.edu

Abstract

We propose the development of a broad range of exciting mobile interaction games using intermittently-connected wireless devices. As a concrete example, we describe the implementation of a *random walk game*, in which players each attempt to hold on to an otherwise itinerant token for as long as possible by running to evade other players in an open field. Besides their clear entertainment value, we argue that quantifying key performance metrics in these kinds of games can also provide some fundamental insights into adversarial behavior in both human and robotic settings. To this end, we present preliminary quantitative results for the random walk game obtained through real play evaluation as well as simulations.

1 Introduction

We advocate the development and analysis of a large class of games involving the interaction of mobile players carrying wireless devices. These games involve a set of players moving around within some pre-defined area, each carrying a simple programmable embedded low-power wireless device (mote); players interact with each other through exchange of packets between their respective devices when they come within radio range of each other.

These mobile interaction games with intermittently-connected wireless devices are inspired by the many games involving chasing and sensing that many of us may recall playing when we were children ourselves [11]. Examples of such children's games include different variants of *tag* (such as *freeze tag*, in which a player goes around trying to "freeze" all others, while active players try to unfreeze any frozen players), variants of *hide-and-seek*, *ghost in the graveyard*, and even many ball games. These games can involve a dozen or more players, and can vary in complexity, requiring sophisticated strategies and collaborative team-play. A key element in these games is proximate physical or visual contact between participants to mark important events/transitions. This contact can be emulated in wireless games by the notion of packet exchange within the radio ranges; the notion of a minimum duration of contact can be programmed, and the corresponding game events can be visually communicated to the players by lighting LED's on the device.

The primary motivation for playing such games is leisure and entertainment. Playing variants of the classic children's games using wireless devices provides a key advantage — it allows for automated logging of game information. This, in turn, means that the performance of players in the game can be quantified. For instance playing the freeze-tag game with wireless devices will provide detailed statistics on different metrics of player performance, such as the following: the time till the k^{th} player was frozen; who took the longest time to freeze all others; which players were the most successful in evading freezing over multiple games; which players were the most successful in unfreezing, etc. Besides adding richness to the game experience, the ability to quantify player performance in games has another ancillary value. By helping to identify agile players, wireless mobile interaction games may be potentially useful for short-listing candidates during tryouts for team sports such as football, soccer, etc.

Beyond their clear entertainment value, we argue that quantifying key performance metrics in these kinds of games can also provide some fundamental insights into adversarial behavior in both human and robotic settings. In other words, these games can be considered a metaphor for interactions between humans and mobiles in a wide range of adversarial contexts.

As a case study, we have developed and implemented a *random walk* game on embedded wireless motes. As in the traditional random walk [1] protocols for wireless networking, there is a token that moves through the network from one node to a nearby node in a random fashion. The goal of the players in this game is to keep the token with them for as long as possible by evading other players, i.e. staying out of their radio range, while others chase them to try and grab the token. Thus, this game is closely related to the classic game of reverse tag (also known as man tag), in which players chase the "it" person to try to become "it" themselves. This game is inherently a metaphor for adversarial resource allocation — the token is a resource that all players wish to keep with themselves greedily to the maximum extent possible. One can imagine that such a scenario may be useful in understanding player behavior in a distributed robotic setting if the token were a physical object like an energy recharger or some other useful tool, or if it were a virtual token that allows them to have prioritized access to a bandwidth-constrained uplink communication channel. As a case study, to understand player behavior in this game, we present some preliminary results from real play evaluation as well as simulations, quantifying the mean token-holding time as a function of game parameters such as the number of players and the size of the playing field.

2 Implementation Results of Random Walk Game

We have implemented a version of the random walk game on telosb motes [8] and conducted a few test runs with students from our laboratory in a grass field of size, approximately, 45 m by 20 m. Initially, the clocks on all the motes are synchronized to keep track of the time since the start of the game. Only one copy of a special packet referred to as the random walk token is present in the

	N=4	N=6	N=8	N=10
Mean	13.0435	17.6471	6.9767	7.5000
Standard Deviation	6.6040	17.8782	5.8710	16.9642

Table 1: Mean and standard deviation for average token holding time per player (in seconds) with different number of players obtained from one sample run conducted using the mote implementation.

system at all times; the player holding the token is called the 'token-holder'. The goal of the game is to keep possession of the token for as long as possible. Players other than the token-holder will determine its identity and chase him in order to grab the token from him.

Some notable features of our implementation include: (a) dynamic neighbor discovery, (b) token forwarding with a 1-step memory, and (c) reliable token delivery via a 'three-way handshake' protocol similar to that used in TCP. In the discovery process, the token-holder periodically broadcasts beacons in its radio range. After receiving a beacon, each player within radio range of the token-holder sends a response packet signifying its presence. The token-holder collects all the replies and randomly selects one player as the next token-holder.

To ensure reliable delivery of the token to the chosen neighbor, we use a three-way exchange comprising transmissions of three packets in order: 1. SEND-TOKEN 2. ACCEPT-TOKEN 3. ACK-ACCEPT-TOKEN. Finally, to prevent frequent flip-flop of the token among players we maintain a brief history of the token exchange process. This ensures that the token does not jump back from the current token-holder to its immediate predecessor. Appropriate combinations of LEDs are switched ON/OFF to give players information about whether they are currently holding the token, whether they are receiving or sending packets etc. After a suitable duration of time, the game ends and the winner is the player that held the token for the longest duration. In our experiments, we set the total game time to 300 seconds.

Table 1 shows the mean and variance values for the random walk game obtained from our empirical study. For each value of N, the number of players, we show the output of a single run in terms of the average token holding time. Even though intuitively, one may expect the average token holding time to reduce with the increase in the number of players, we see that this is not strictly true. There are two reasons for this. First, the results presented are only for one sample run. We plan to conduct multiple runs as part of the on-going work. Second, the set of players was not homogeneous. For example, in the run with 6 and 10 players, one player managed to avoid the rest for a large amount of time owing to his superior physical prowess thereby resulting in a higher average token holding time. This observation is further strengthened by the higher standard deviation values for the 6 and 10 player cases. In general, heterogeneity in the player skills may impact the resulting behavior observed in these interaction games.

In order to perform a comprehensive evaluation of the random walk game as a function of the number of players, different field sizes and player strategies, we perform an extensive simulation study, the details of which are presented in the next section.

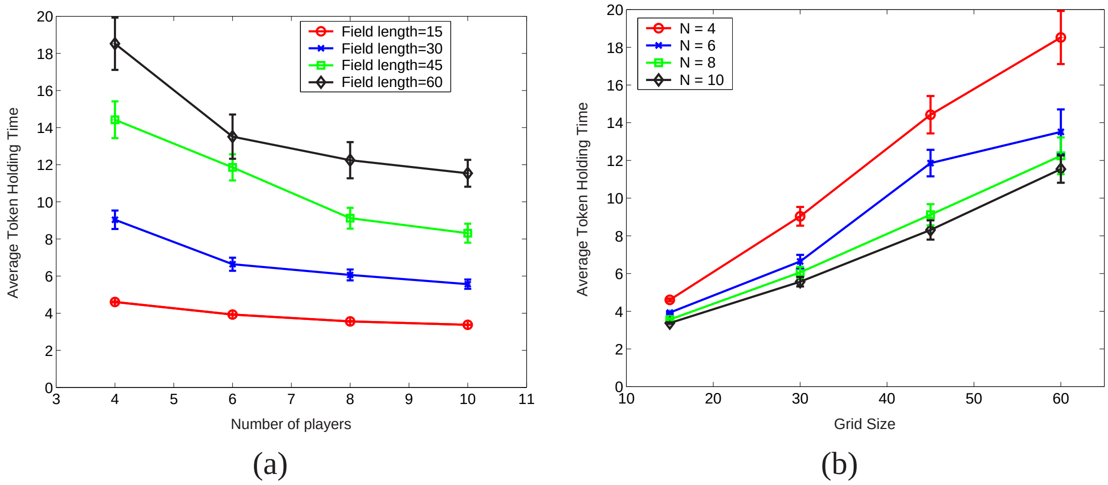

Figure 1: Average token holding time (in seconds) as a function of the number of players (Figure 1(a)) and different field sizes (Figure 1(b)).

3 Simulation Results of Random Walk Game

We now describe results obtained from a set of computer simulations of the random walk game. In these simulations, players are uniformly distributed in a square field. The strategy for the players other than the token-holder is the following: Chase the token-holder along the shortest path in order to grab the token from him. The strategy of the token-holder is to run away from the other players. Specifically, the token holder moves in the direction opposite to that of its nearest neighbor. Once the token-holder reaches the field boundary it is "reflected" back into the field.

We explored two scenarios: (a) players move with a constant speed of s m/s (b) speed of a player is a value uniformly distributed in the interval $[0 - s]$ m/s. The performance results regarding the token holding time per player were similar in both scenarios. Hence, here we present the results obtained in the case of constant player speeds. The speed of the players is set to 3 m/s. The radio range of the motes held by the players is assumed to be 3 m. This value is chosen in accordance with observations made from experiments conducted at lower power levels on telosb/micaz motes in an outdoor environment. The size of the square field (in square meters) is varied as $\{15 \times 15$, 30×30, 45×45 , 60×60 $\}$. The number of players in the game is varied as $\{$4, 6, 8, 10 $\}$. The game is played for a duration of 300 seconds. All presented results are averages over 100 simulations, each simulation run employs a different seed deciding the initial placement of the players and the identity of the token-holder. Also, all the time metrics are reported in seconds.

Figure 1 captures the average holding time per player as a function of two parameters, the number of players (N) and the size of the field (G). The error bars indicate the 95% confidence intervals. For a given field size, as the number of players increases, the probability that any player can hold the token for a longer duration reduces. Similarly, as shown in Figure 1(b), for a given number of players, increase in the field size enables a player to escape the others for a longer duration. This increases the average token holding time per player.

4 Related Work

Several gaming research directions have been pursued by the ubiquitous computing community [4, 3]. These games involve interactions between players and the physical environment. They involve equipping a PDA, a laptop computer or another computing platform with a wireless interface and in some cases a GPS to obtain location information. Closely related are some directions being actively pursued in the pervasive computing research [2, 7, 12, 5] where the virtual world simulated by computers is combined with the physical world in order to enhance player experience through augmented reality. In many cases, players are equipped with sophisticated equipment such as head-mounted displays, accurate location finders, joystick or play gun remote controllers, smart phones, etc. to interact with the gaming environment.

Wireless sensor motes have been employed relatively sparsely in gaming environments. One example is a game called Trove [10]. Implemented on mica2 motes, this is a variant of the popular treasure hunt game where the participants negotiate with each other in a closed environment such as a room to reach a hidden treasure. A base-station collects data readings from the motes periodically, typically light and temperature readings, to update a user interface which forms an integral part of the game in providing feedback to a player about the performance of the other players.

Another example is use of static sensor motes as resources such as virtual objects or characters in a physical environment in a game called 'Save the Princess' [9]. The authors propose a middleware architecture called TinyLIME for facilitating interactions between laptop computers held by players and the motes. Finally, researchers at Casino Labs [6] have devised some simple games where motes were handed to an audience during a presentation and either a pattern displayed on the screen was to be realized or a particular counting sequence was to be obtained. The players have a button for either toggling their mote LEDs or transmitting their current count value (where ON-OFF LEDs are interpreted as zeros and ones and then mapped into their integer equivalents between 0 to 7).

Our proposal is certainly complementary to these works but has some key differences in perspective. We advocate the implementation of a wide range of mobile interaction games (often variants of classic children's games) using mote-scale wireless devices. Going beyond the implementation, however, we also argue for quantitative performance evaluation of these games based on logged game statistics. Besides providing a richer gaming experience, analysis of these statistics can provide insights into adversarial behavior in a range of future human and robotic contexts.

5 Conclusions and Future Research Directions

We have presented a random walk game as a case study for the new class of mobile interaction games that we propose. This game, based on the classic game of reverse tag, is a metaphor for adversarial resource allocation. We have presented some preliminary quantitative evaluations of this game via real play as well as simulations. In ongoing work, we are developing suitable mathematical models that capture game metrics as a function of player strategies, number of players and the size of the field.

We are in the process of developing and analyzing other games on motes. These include an infection flooding game in which already infected players try to infect others. The infection flooding game offers a model to study epidemic viral spread in mobile robotic networks. The design and analysis of more sophisticated games that involve teamwork, such as a form of mote-based football that requires players within a team to pass a virtual packet "ball" amongst each other, presents another promising direction.

References

[1] D. Aldous and J. Fill. Reversible markov chains and random walks on graphs. Under preparation.

[2] S. Antifakos and B. Schiele. Bridging the gap between virtual and physical games using wearable sensors. In *ISWC*, pages 139–140, 2002.

[3] S. Bjrk, J. Falk, R. Hansson, and P. Ljungstrand. Pirates! - using the physical world as a game board. In *Interact, IFIP TC.13 Conference on Human-Computer Interaction*, July 2001.

[4] M. Chalmers, M. Bell, B. Brown, M. Hall, S. Sherwood, and P. Tennent. Gaming on the edge: Using seams in ubicomp games. In *ACM Advances in Computer Entertainment (ACE)*, 2005.

[5] A. Cheok, S. Fong, K. Goh, X. Yang, W. Liu, and F. Farzbiz. Human pacman: a sensing-based mobile entertainment system with ubiquitous computing and tangible interaction. In *NetGames '03: Proceedings of the 2nd workshop on Network and system support for games*, pages 106–117. ACM Press, 2003.

[6] M. Colagrosso. Casino lab games. http://ore.mines.edu/ mcolagro/article/casino-lab-games, April 2006.

[7] M. Flintham, S. Benford, R. Anastasi, T. Hemmings, A. Crabtree, C. Greenhalgh, N. Tandavanitj, M. Adams, and J. Row-Farr. Where on-line meets on the streets: experiences with mobile mixed reality games. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 569–576. ACM Press, 2003.

[8] moteiv. Telosb motes datasheet. http://www.moteiv.com/products/docs/telos-revb-datasheet.pdf.

[9] L. Mottola, A.L. Murphy, and G.P. Picco. Demonstrating Pervasive Game Development using Tiny Devices and the TinyLIME Middleware. In *5th Workshop on Network and System Support for Games(NetGames)*, Oct 2006.

[10] S. Mount, E. Gaura, M. Newman, A. Beresford, S. Dolan, and M. Allen. Trove: a Physical Game Running on an Ad-Hoc Wireless Sensor Network. In *Joint sOc-EUSAI*, pages 235–240, Oct 2005.

[11] G. Nieboer and L. Nieboer. Games kids play. http://www.gameskidsplay.net/.

[12] B. Thomas, B. Close, J. Donoghue, J. Squires, P. Bondi, and W. Piekarski. First person indoor/outdoor augmented reality application: Arquake. *Personal Ubiquitous Comput.*, 6(1):75–86, 2002.