MIGM: Mobile Interaction Games with Motes

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***Abstract*—We propose the development of a broad range of exciting mobile interaction games using intermittently-connected wireless devices such as motes. As a concrete application, 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 obtaining the clear entertainment value, we argue that quantifying and analyzing key performance metrics recorded during the game can not only help people to evaluate player ability, but also provide some insights into adversarial behavior in both human and robotic settings. To this end, we present preliminary quantitative results and analysis for the random walk game obtained through real play evaluation.**

I. Introduction and Related Work

The area of mobile interaction games with intermittently-connected wireless devices presents a novel and rich research direction. Their inspiration comes from games involving chasing and sensing that many of us may recall playing when we were children ourselves [8]. The games we developed involve a set of players moving around within some pre-defined area, each carrying a simple programmable embedded low-power wireless device (mote). Contact between players is emulated by the notion of packet exchange within radio range; and the corresponding game events can be visually communicated to the players by lighting LED's on the device. Motes also allow for automated logging of game information which, in turn, means that the performance of players in the game can be quantified. Besides adding richness to the game experience, the ability to quantify player performance may also be potentially useful in team sports such as football, soccer, etc, since there is no efficient way of recording fine-grained player interaction during the game and sometimes traditional observations will be biased because of the lack of accurate information.

Several gaming research directions have been pursued by the ubiquitous computing community [3], [2]. Each player carries a computing platform with a wireless interface such as a PDA or a laptop computer or sometimes a mote [7], [6]. The premise of these games relies on interactions between players and the physical environment. Closely related are some directions being actively pursued in the pervasive computing research [1], [4] where a virtual world simulated by computers is combined with the physical world in order to enhance player experience through augmented reality. Players are equipped with sophisticated equipment such as head-mounted displays, joystick, etc. to interact with the gaming environment.

Our proposal is certainly complementary to these works but has key differences in perspective. We advocate the implementation of a wide range of mobile interaction games using mote-scale wireless devices. Going beyond the implementation, however, we also emphasize on quantitative performance evaluation of these games based on logged game statistics.

As a case study, we have developed an application called *random walk game* on embedded wireless motes. Initially, one player is given a unique 'token'. When other players are in radio-range of this current token holder, the token is released to one of them chosen uniformly at random. The goal of the players is to hold on to the token for as long as possible. Hence, the current token holder tries to evade other players, i.e. by staying out of their radio range. The other players in turn try to chase the current token holder to grab the token. Inherently, this game is a metaphor for adversarial resource allocation — the token symbolizes a resource that all players greedily wish to keep with themselves for as long as possible. The analysis of 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 a virtual tag that allows them to have prioritized access to a bandwidth-constrained uplink communication channel.

To better look at the outcome of this game, we present some preliminary results from real play, quantifying the total token holding time for each player as well as the mean and variance of the time interval between subsequent token transfers.

II. Application and Preliminary Results

We have implemented a version of the random walk game on Telosb motes [5] as a concrete application and conducted a few games with students from our laboratory in a grass field of size $40m \times 25m$. Recall that the goal of the game is to keep possession of the token for as long as possible[1]. Here, the token is a unique special packet that jumps between the motes carried by the players.

Some notable features of our implementation include: (a) dynamic neighbor discovery, (b) reliable token delivery via 'three-way handshake' and (c) token forwarding with one-step memory (by not allowing token transmission to one's immediate predecessor to avoid frequent token flip-flops).

[1] In this study, we explicitly told players not to prevent token transfers by shielding the chip antenna. However, exploring different facets of individual player behavior represents a promising future research direction.

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Details of the above features are available in [9]. Appropriate combinations of LEDs are switched ON/OFF to give players information about whether they are currently holding the token, whether they are in range of the current token holder 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, four sets of games were played with number of players $N = \{10, 8, 6, 4\}$ in order and the game duration was set to approximately 5 minutes.

Table I shows the *total token holding time* as well as the averages across different games and players. We observe that player 3 shows the highest average token holding time: the overall 'winner' over all games even though individually it is the clear winner only in the game with $N = 8$ players. However, player 4 depicts a more consistent performance across all games as indicated by the low standard deviation in its token holding time. Incidentally, it ranks 4^{th} in terms of the average token holding time. A rather interesting observation is that player 5 shows increasing performance as indicated by an increasing trend in its token holding time (recall that the game with $N = 10$ was played first). This may be an indication that this player is a 'fast' learner and is able to adapt to the game and improve his performance over time. The above kinds of analysis enable building a clear picture of players physical/mental abilities especially when their performance is evaluated over a large set of games. Since traditional methods lack the ability of recording player interaction and quantifying detailed performance during game, we also provide a way to help the experts evaluating player abilities in competitive team sports/try outs. For example, in a quick try out, a soccer coach may draft a more consistent player over another, who is only enthusiastic for a short period.

Table II shows the mean and standard deviation values of the *time interval between subsequent token transfers*. This analysis serves as a metaphor of how long a human or a robot can manage a unique resource before it is taken away in an adversarial context. Even though intuitively, one may expect the average value 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 for each N. We plan to conduct multiple runs as part of the on-going work. Secondly, the set of players are not 'homogeneous'. For example, in the run with $N = 6$ players, one player managed to avoid the rest for a relatively large amount of time thereby resulting in a higher average token holding time. This observation is further strengthened by the higher standard deviation values for the $N = 6$ and $N = 10$ cases. In general, different results may be caused by heterogeneity in player skills/strategies, which provides another interesting research direction.

In order to make statistically significant observations for the random walk game, simulations have also been conducted which can be subsequently evaluated for further insights [9].

	N=4	N=6	N=8	N=10	Mean	STDV
Player1	50.69	16.51	12.58	6.92	21.68	19.74
Player2	34.16	13.88	7.73	19.17	18.74	11.30
Player3	13.48	21.05	73.23	27.26	33.76	26.91
Player4	30.42	18.46	25.45	24.10	24.61	4.92
Player5		56.63	23.86	7.32	29.27	25.10
Player6		17.59	4.65	30.88	17.71	13.12
Player7			24.70	40.13	32.42	10.91
Player8			11.98	8.02	10.00	2.80
Player9				15.88	15.88	N/A
Player10				19.42	19.42	N/A

TABLE I
TOTAL TOKEN HOLDING TIME(SECONDS) FOR EACH PLAYER.

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

TABLE II
MEAN AND STANDARD DEVIATION FOR AVERAGE SINGLE TOKEN HOLDING TIME (SECONDS) WITH DIFFERENT N.

III. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

We have presented a random walk game as an application for our proposed novel class of mobile interaction games. Besides good entertainment value, this game also serves as a metaphor for resource allocation in an adversarial context. We have presented some preliminary quantitative evaluations of this game via real play. The performance per player can serve as a good reference for a measure of player ability in competitive sports. In ongoing work, we are developing suitable mathematical and simulation models that capture game metrics as a function of player strategies, number of players, size of the field and so on. In the process of developing and analyzing other game applications on motes, our goal is to explore different facets of individual player behavior and add more sophistication into the games.

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