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Social Cooperation and Competition in the Mixed Reality Space eXperience Introduction Machine

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Abstract

Although the architecture of mixed reality spaces are becoming increasingly more complex, our understanding of human behavior in such spaces is still limited. Despite the sophisticated models deployed in psychology and behavioral biology to track and analyze the actions and movements of animals, we rarely find studies that focus on the understanding of human social behavior using such instruments. Here we address this issue by analyzing social behavior and physical actions of multiple human subjects in a mixed reality space. As a paradigm of social interaction we constructed a mixed reality football game in which two teams of two players have to cooperate and compete in order to win. This paradigm was deployed in the eXperience Induction Machine (XIM), a human accessible fully instrumented space that supports full body interaction in mixed reality without the need for body-mounted sensors. Our results show that winning and losing strategies can be discerned in specific behavioral patterns. This demonstrates that mixed reality systems such as XIM provide new paradigms for the investigation of human social behavior.

Keywords--- **Social Behavior, Cooperation, Competition, Interaction, Mixed Reality, XIM, Game Play**

1. Introduction

The study of social behavior is not trivial. The operation we use to analyze a phenomenon is also defining its concept. Like the exact measurement of time or length, the concept of a behavioral phenomenon is the result of its operationalization. We introduce a novel experimental framework to study human social behavior as expressed in cooperation and competition by analyzing the distance regulation of multiple users in a mixed reality space. Such a study is dependent on the ability to collect observational data. The question is how can we build intelligent experimental paradigms that allow us to observe social behavior without interference? The answer is of immediate relevance to our ability to construct and deploy complex and large-scale multi-user virtual and mixed reality systems.

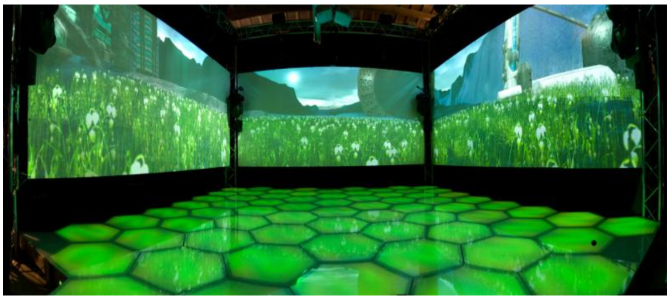

Figure 1 The eXperience Induction Machine or XIM is a fully instrumented human accessible space of 6x6 m. See text for further explanation

The mixed reality spaces that exist today can be divided into different categories. The main operational areas are: rehabilitation, gaming, social interaction, education, entertainment and navigation. Both, the contextual concepts and the technical implementations show a wide variation of concepts. Dependent on the use and function, the applications differ in size, design, number of modalities and their controlling mechanisms. A mixed reality space, that provides a sophisticated technical implementation is the 3D projecting space Allosphere at the California Nanosystems Institute (CNSI) [1]. The 3D representation system Cave [2] is a standard and existing example of a sophisticated virtual reality system. While design and usage of these spaces differ, they both excel in having either an advanced technical infrastructure or pursue an ambitious conceptual framework to control the action and user-interaction of the space. Systems dealing with social interactions in mixed reality include Disney's Pirates of the Caribbean Game [3], the magic carpet from the Mixed Reality Laboratory, Nottingham [4] and the kid's room at MIT [5]. Although all these systems provide an interactive mixed reality environment where a group of people has to behave in a coordinated way, they lack an elaborated framework to observe and quantify human behavior. It would appear that our ability to assess human experience and behavior does not keep up with our capability to build interactive virtual and mixed reality spaces. A notable exception is the Ada exhibition [6], built for the Swiss Expo 2002. Using data obtained from 556,000 visitors it was shown how human spatial distribution patterns depend on specific multi-modal cues and prior knowledge. Yet it is unclear how humans regulate their behavior at a smaller scale and with respect to each other, while they are engaging in a mixed reality world.

In the behavior of a group of people one of the main aspects is whether the group members are cooperating or competing. It is cooperation itself that culd be taken as a defining characteristic of a social group. Cooperation can be defined as a concurrent effort of multiple persons to reach a collective goal. Conversely competition is a rivalry between individuals or a group for a resource. Both phenomena show a wide variety of behaviors and actions. On a theoretical level cooperation and competition have been studied extensively using game theory. One of the best known cooperative game theory problems and a very good example to visualize a cooperative or competitive behavior is the so-called Prisoner's Dilemma [7]: Two suspects, interrogated separated from each other, have to decide if they want to cooperate with the authorities, not knowing what the other is doing. The outcome for each individual is directly affected if one, both or nobody is cooperative. While this problem is an example of a situation that addresses cooperation and competition on a theoretical and abstract level, we can also observe cooperative and competitive behavior on a spatial level. Team sports like football or basketball are good examples, where multiple players have to organize their spatial distribution in the field in a cooperative and competitive manner. Despite the popularity of these sports, these games have received little attention as a paradigm to study cooperation and competition also because of the instrumental challenges it raises.

In this paper we are focusing on the social behavior and the spatial cues of cooperation of people moving in space while engaging in a game. An approach that is of relevance to our question is the study of an on line pong game [8], where users were asked to build teams and compete against each other, while the action of the players was recorded. While the level of interaction in such networks is complex, communication remains mostly in the virtual dimension. This platform lacks a physical representative space of the virtual world, where users can interact directly with each other.

One methodological challenge in the investigation of spatial behavior of multiple subjects is to find an appropriate method to collect data. If we want to observe behavior in its authentic form, we have to use observational tools, which do not interfere or affect the actions of the subjects. A tracking system without any perturbing markers is a useful instrument to quantify and analyze the distance regulation of multiple persons over time. The challenge to track multiple people in real time produced in the last decade interesting technical solutions. Some studies try to solve this task by tracking people with multiple cameras [9], while others use GPS, or the movement of markers [10]. Another approach is to track the shape of people with a so-called snake method [11]. Such systems are often used to observe football players and acquire background knowledge of how players perform during a game [12]. In our study we use a XIM specific Multi Modal Tracking System [13] that allows us to observe and identify multiple subjects in real time (Figure 2).

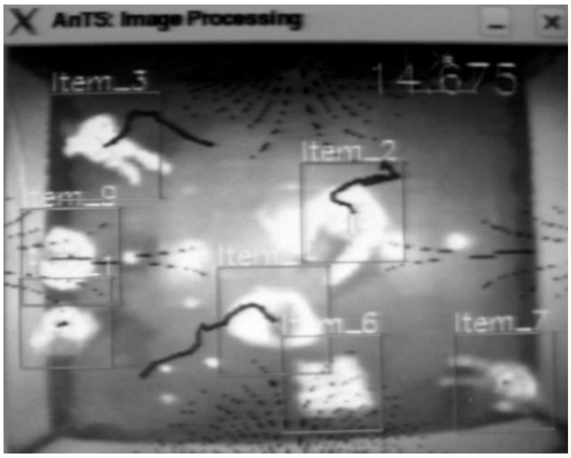

Figure 2 The XIM multi-modal tracking system uses floor generated pressure data and the images from overhead cameras to identify and label human subjects. Tracked paths of visitors are shown as black lines

As a controlled paradigm of social interaction we constructed a mixed reality football game in which two teams of two players have to cooperate and compete in order to win. We hypothesize that the game strategy of a team to cooperate and to compete against the opposing team will lead to discernable and invariant behavioral patterns. In particular we will analyze which features of the spatial position of individual players is predictive of the game's outcome. We hypothesize that coordinated movement patterns and the regulation of inter-subject distance are specific indicators of social interactions.

2. Methods

For our study we used the eXperience Induction Machine (XIM) [14], a mixed reality space that can be accessed by multiple users at the same time. XIM provides a controlled environment that allows the continuous collection of observational data of social interaction without interference. XIM is a further extension of ADA [15]. The main conceptual difference between Ada and XIM is that XIM is embedded in an interactive, virtual world. XIM's architecture can be divided into 3 different parts: The physical space, the virtual world and the internal controlling mechanism. The physical space measures 30 square meters and surrounds the visitor on three sides with wide screen projection walls (Figure 1). The luminous floor consists of 72 pressure sensitive hexagonal floor tiles [16]. The space has 8 loudspeakers that produce a surround sonification. People in the room are tracked by the

XIM Multimodal Tracking System MMT [17], which combines infrared tracking information from the overhead video camera with the tactile information from the floor. The MMT is the main perceptual modality of XIM. The virtual world of XIM is graphically produced by the game engine Torque [17] and the sonification is realized through the real time interactive composition system Roboser [18]. The XIM control system is implemented using the large-scale neuronal system simulator IQR [19] and it interfaces the physical system to Torque and Roboser. In this way we are able to produce a mixed reality interactive world, that adapts its visual appearance and sonification to the behavior of the visitors.

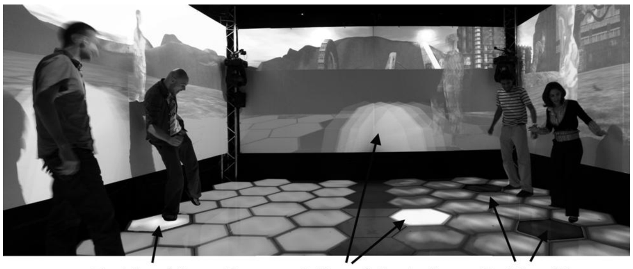

Figure 3 Participants are playing the game. The bright floor tile in the middle of the space represents the ball that would move through the floor. Players were controlling either a red or a blue floor paddle that could deflect the virtual ball. Through changing their positions in space, players could move their paddle and hit the ball. The physical game extended into the virtual world

For this study we programmed a mixed reality football game, where participants played in teams of two against two (Figure 3). All players had a paddle of the size of one floor tile. Depending on which team players belonged to they played either with a blue or a red paddle. The ball was represented as a yellow floor tile in the space. Through changing their positions in space, players could move their paddle and hit the ball. A goal was scored when the ball reached the edge of the floor lateral to the entrance of the space. The kick-off after a goal happened automatically in the middle of the field and the direction of the kick-off was randomized.

Overall 10 groups of 4 people played the game for 2 minutes each (40 subjects with an average age of 24, SD = 6, 11 women). All subjects played at least 1 game, some played 2 (n = 8). Both, the team assignment and the match drawing process were randomized. Whether participants played the game as the blue team or as the red one was chosen randomly. Before the experiment started, all players were informed about the rules of the game outside the space by an experimenter who used a standardized movie showing other people playing the game to facilitate the explanation. He answered possible questions to make sure that all players understood the rules of the game. All the players were informed that XIM was recording data, but not what kind of data and that they could leave the space at any time. During the game the players were alone in the space and there was no interaction between the experimenter and the players. The game started when the players were standing at their team's side. During the game people had no knowledge of the score. The positions of the people and the ball, collision events and the score were recorded.

3. Results

We hypothesize that the specific movement patterns of the players are directly correlated with the outcome of the game. Based on this assumption we analyzed the distribution of team members in space during the game.

In total 13 games were recorded. Participants playing the game as the blue team won 6 games, while participants playing with the red color won 5 games. 2 games were ties. Overall 114 goals were scored. The score was balanced in respect to the goal ratio (59 blue team goals to 55 red team goals).

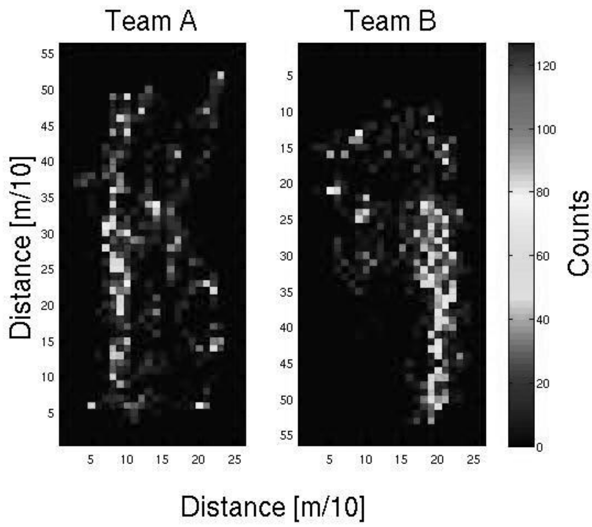

Figure 4 Energy plot representing overall positions of players during a single game. The left plot shows the positions occupied by members of team A while those of team B are shown in the right hand panel. In this example Team A won the game with a score of 6:5

We focused our analysis on the spatial behavior of the winning team members before they scored and the spatial behavior of the losing team members before they allowed a goal. For this purpose we analyzed in every of the 114 epochs the team member distance for both, the winning and losing teams. An epoch is defined as the time window from the moment when the ball is released until a goal is scored. For example, if a game ended with a score of 5:4, we analyzed for every of the 9 game epochs the inter-team member distances of the epoch-winners and the epoch-losers, without taking into account which team won the overall game. This analysis showed that the epoch-winners and epoch-losers showed significantly different moving behavior, for all epochs that last longer than 8 seconds. In this analysis epoch winning teams stood on average 1.47 ± 0.41 meters apart from each other, while epoch losing teams had an average distance of 1.41 ± 0.58 meters to each other (Figure 5). The comparison of the distributions of team member distance showed a significant difference between epoch-winning and epoch-losing teams (P = 0.043, Kolmogorov-Smirnov Test).

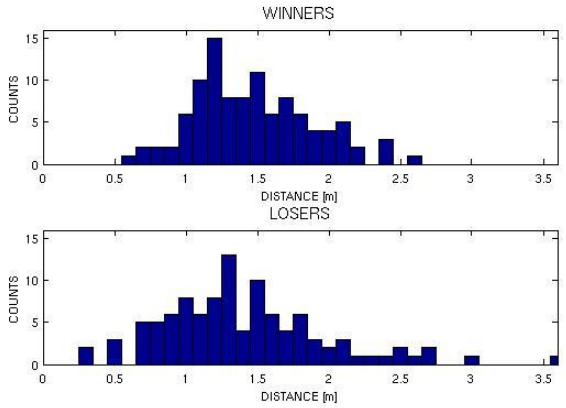

Figure 5 Distribution of the inter-team member distances of winners and loser for epochs bigger than 8 seconds.

The average duration of an epoch was 12.5 seconds. 20.3 % of all epochs did not last longer than 4 seconds. The analysis of the distributions of inter-team member distances for all epoch-winners and epoch-losers did not reach significance (Kolmogorov-Smirnov Test, p = 0.1). Also we could not find a statistical significant correlation between game winners and the number of scored goals or game winners with the inter-team member distance regulation. Winning teams that chose an inter-team member distance of 1.39 ± 0.35 meters scored on average 6 ± 2 goals. Losing team members scored 3 ± 1.5 goals and stood in average 1.31 ± 0.39 meters apart from each other. The trend that winners chose a bigger inter-team member distance than losers shows no significant differences.

4. Discussion and outlook

Our study introduces a new paradigm to assess human social behavior using game play in the mixed reality environment XIM. We hypothesized that the distance regulation between players can be understood as a measure of social interaction. Indeed, our results show that winners and losers employ a different strategy as expressed in the inter-team-member distance. This difference in distance patterns can be understood as a difference in the level of cooperation within a team or the way the team members regulate their behavior ro compete with the opposing team. Our study shows that in long epochs, winners chose to stand farther apart from each other than losers. Our interpretation of this behavioral regularity is that this strategy leads to a better defense, i.e. regulating the size of the gap between the team members with respect to the two gaps at the sideline. Long epoch winning teams coordinated their behavior with respect to each other in a more cooperative way than long epoch losing teams.

There are multiple interpretations for the behavioral patterns that are statistically different for the long epochs. We assume that in short epochs factors like chance, the starting direction of the ball after a goal or the readiness of the players had a higher impact on the score, than in longer epochs where the team play itself was more decisive. Short epochs indicate that players were not ready to play yet or the kick-off gave one team an advantage. Influencing effects like the duration of the break after a goal was scored or the direction of the ball after the kick-off will be considered for future tests.

The methodological concept we are proposing here provides an example of how we can face the challenge of quantitatively studying complex social behavior that has thus far eluded systematic study. We propose that mixed reality spaces such as XIM provide an experimental infrastructure that is essential to accomplish this objective. In a further step of our approach we will test the influence of virtual players on the behavior of real visitors, by building teams of multiple players, where a number of player's of the team will be present in XIM and the others will play the game over a network using a computer. These remote players will be represented in XIM in the same way as the real player, i.e. an illuminated floor tile and virtual body on the screen. With this set up we want to test the effect of physical presence versus virtual presence upon social interaction.

5. Acknowledgements

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References

[1] T. Höllerer, X. Amatriain, J. Kuchera-Morin, X. Amatriain. The Allosphere: A large-scale immersive surround-view instrument. In: *Proceedings of the 2007 workshop on Emerging displays technologies: images and beyond: the future of displays and interaction*, 3. August. 2007.

[2] T. A. DeFanti, C. Cruz-Neira, D. J Sandin. Surround-screen projection-based virtual reality: the design and implementation

of the cave. In: *Proceedings of the 20th annual conference on computer graphics and interactive technique*, 135-142. August. 1993.

[3] Pirates of Caribbean. URL: http://disneyworld.disney.go.com/wdw/entertainment/

[4] D. Stanton, V. Bayon, H. Neale, A. Ghali, S. Benford, S. Cobb, R. Ingram, C. O'Malley, J. Wilson, T. Pridmore. Classroom collaboration in the design of tangible interfaces for storytelling. In: *Proceedings of the SIGCHI conference on Human factors in computing systems*, 482-489. April. 2001.

[5] A. F. Bobick, S. S. Intille, J. W. Davis, F. Baird, C. S. Pinhanez, L. W. Campbell, Y. A. Ivanov, A. Schütte, A. Wilson. Perceptual user interfaces: the kid's room. *Communications of the ACM*, 43, 60-61. 2000.

[6] K. Eng, M. Mintz, T. Delbrück, R. J. Douglas, A. M. Whatley, J. Manzolli, P. F. M. J. Verschure. An investigation of collective human behavior in large-scale, mixed reality spaces. *Presence: Teleoperators and Virtual Environments*, 15, 403-418. 2006.

[7] W. Poundstone. *Prisoner's Dilemma*. NY, USA: Doubleday. 1993.

[8] Y. Vogiazou, M. Eisenstadt. Designing multi player games to facilitate emergent social behaviors on line. *International Journal of Interactive Technology and Smart Education*, 2, 117-130. 2005.

[9] M. Xu, J. Orwell, L. Lowey, D. Thirde. Architecture and algorithms for tracking football players with multiple cameras. In: *IEE Proceedings of Vision, Image and Signal Processing*, 152, 232-241. April. 2005.

[10] S. J. Edgecomb, K. I. Norton. Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian Football. *Journal of Science and Medicine in Sport*, 9, 25-32. 2006.

[11] S. Lefèvre, C. Fluck, B. Maillard, N. Vincent. A Fast Snake-based Method to Track Football Players. In: *Proceedings of IAPR International Workshop on Machine Vision Applications*, 501-504. November. 2000.

[12] Tracking how far soccer players run. The wall street journal. May 23 2007. URL: http://blogs.wsj.com/numbersguy/tracking-how-far-soccer-playersrun-112/.

[13] Z. Mathews, S. Bermùdez, P.F. Badia, M. J. Verschure. A novel brain-based approach for multi-modal multi-target tracking in a mixed reality space. In: *Proceedings of the 4th INTUITION International Conference and Workshop on Virtual Reality*, 26-34. October. 2007.

[14] U. Bernardet, S. Bermùdez i Badia, P. F. M. J. Verschure. The eXperience induction machine and its role in the research on presence. In: *Proceedings of The 10th Annual International Workshop on Presence*, 329-335. Barcelona, Spain. 2007.

[15] K. Eng, D. Klein, A. Bäbler, U. Bernardet, M. Blanchard, M. Costa, T. Delbrück, R. J. Douglas, K. Hepp, J. Manzolli, M. Mintz, F. Roth, U. Rutishauser, K. Wassermann, A. M. Whatley, A. Wittmann, R. Wyss, P. F. M. J. Verschure. Design for a brain revisited: the neuromorphic design and functionality of the interactive space 'Ada'. *Review of Neuroscience*, 14, 145–80. 2003.

[16] T. Delbrück, A. M. Whatley, R. Douglas, K. Eng, K. Hepp, P. F. M. J. Verschure. A tactile luminous floor for an interactive autonomous space, robotics and autonomous systems. *Robotics and Autonomous Systems*, 55, 433-443. 2007.

[17] Torque game engine. URL: http://www.garagegames.com/.

[18] J. Manzolli, P. F. M. J. Verschure. Roboser: A real-world composition system. *Computer Music Journal*, 29, 55–74. 2005.

[19] IQR simulator for large-scale neural systems. URL: http://iqr.sourceforge.net.