MonkeyBridge: Autonomous Agents in Augmented Reality Games

István Barakonyi[1*] Markus Weilguny[2] Thomas Psik[3] Dieter Schmalstieg[1]

[1] Graz University of Technology, Institute of Computer Graphics and Vision, Inffeldgasse 16, Graz, A-8010, Austria

[2] Hagenberg University of Applied Sciences, Media Technology and Design, Hauptstraße 117, Hagenberg, A-4232, Austria

[3] Vienna University of Technology Institute of Design & Assessment of of Technology, Argentinierstr. 8/187, Vienna, A-1040, Austria

*Contact email address: bara @ icg.tu-graz.ac.at

ABSTRACT
MonkeyBridge is a collaborative Augmented Reality (AR) game employing autonomous animated agents embodied by lifelike, animated virtual characters and "smart" physical objects. The game serves as a pilot application to examine how "smart" software and hardware components capable of observing and reacting to events in the physical and virtual world can be useful in AR applications. We describe the implementation details of our test setups as well as how autonomous agents offer a rich gaming experience in AR games.

Categories and Subject Descriptors
H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems - *Animations, Artificial, Augmented, and Virtual Realities.* I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – *Intelligent Agents*.

General Terms
Design, Experimentation, Human Factors

Keywords
Augmented Reality, Autonomous Agents, Multiplayer Games

1. INTRODUCTION
A key element in games and stories is fantasy. While playing, a virtual, imaginary world is created within our mind, inhabited by characters obeying our imagination. In classic make-believe games this fantasy world and their characters connect to the real environment through physical game props to which various roles are assigned, thus making heretofore passive objects active players in the game story. Augmented Reality (AR) applications are aiming at achieving the same effect by superimposing a virtual world on top of the real environment. Since the virtual world is registered with the real one, they appear to coexist. As pointed out by Stapleton and colleagues in their mixed-fantasy framework [1], the combination of the real and virtual help suspend disbelief and enrich the audience's fantasy experience. AR is able to visually change real world attributes, make passive objects appear animated and play sound effects besides sounds in the real environment to further enhance the atmosphere of the perceived mixed environment.

In collaborative virtual game environments co-players are often represented by avatars. The behavior of the avatars is constrained and controlled by the game logic, which maps player actions to the set of capabilities and behavior elements of the avatars. In addition to players there is often a large variety of non-player characters serving as allies, bystanders or competitors. As games become increasingly complex, it is desirable that some workload is taken off from both game developers and players by adding autonomy to player and non-player characters. An autonomous character does not need constant user guidance or thoroughly scripted behavior prepared for all possible situations. Instead it proactively makes decisions based on events coming from sensors present in its environment. Thus only high-level goals are needed to be set, while the character's reasoning engine takes care of low-level details to achieve the goals as quickly as possible. Such a character that appears to have a "brain" behind its movements is called an *embodied autonomous agent*.

As pointed out in our previous work [2], agents in AR environments are capable of automatically taking care of low-level details such as network communication between components or switching between representations. Because of the highly dynamic and complex nature of AR systems, agents enable users to focus on higher, application-level objects instead of low-level details such as networking, synchronization or pose tracking, thus improving usability. Therefore AR agents represented by autonomous software and hardware components can serve as key user interface elements in AR applications.

2. RELATED WORK
Bolter and Grusin [3] make the point that a new media, such as AR, starts to gain wider public acceptance once it enters the game, art and entertainment domain. Background work for AR games embraces several domains including indoor and outdoor AR, ubiquitous and social computing and recently even mobile computing. Early augmented tabletop applications include the Mah-Jongg game from Szalavári et al. [4] and the AR^{2}Hockey [5]

applications from Ohshima and colleagues. The ARQuake [6] and Human Pacman [7] projects are technically challenging, pioneering projects in outdoor, collaborative AR gaming. The TouchSpace system [8] examines ways of smoothly traveling between AR and VR within the same application while letting its users walk around and explore a room-sized augmented world with “magic” windows fixed to tracked, handheld props. The experimental games from Magerkurth et al. [9] emphasize and rely on the rich social experience and collaborative interaction that players may be already familiar with in traditional board games.

Although extensively researched in VR, agents have only recently appeared in AR environments. An early AR application providing character support is the ALIVE system [10], where a virtual animated character composited into the user’s real environment responds to human body gestures on a large projection screen. This type of display separates the user’s physical space from the AR environment, which demands carefully coordinated user behavior. The Welbo project [11] features an immersive setup, where an animated virtual robot assists an interior designer wearing an HMD. The character lacks a tangible physical representation and can only interact with virtual objects. Another HMD-based system from MacIntyre et al. [12] creates an interactive theater experience by placing prerecorded video-based actors into an AR environment. The characters do not possess any autonomy, as their behavior is scripted, and interaction is limited to changing viewpoints and roles in the story. Cavazza et al. [13] place a live video avatar of a real person into a Mixed Reality setting, and interact with a digital storytelling system with body gestures and language commands. Balcisoy et al. [14] experiment with interaction techniques with virtual humans in Mixed Reality environments, which play the role of a collaborative game partner and an assistant for prototyping machines. Cassell et al.’s Sam agent [15] is a virtual playmate assisting children in a natural storytelling play with real objects. Access to the real game props is shared between the child and the animated agent.

We believe that the next step in agent-enabled gaming is mixing physical and virtual embodied autonomous agents in a single augmented game space. We are currently not aware of any applications that would fully exploit both the virtual and physical domain as input and output communication modalities except the ActiveCube project [16]. This application implements an interactive toy consisting of a set of computerized tangible blocks equipped with several input/output devices that are used to construct and interact with a virtual 3D model. The key difference between ActiveCube and our project is the clear border between the real and the virtual world. In ActiveCube the virtual content appears to be separated since it is not overlaid on top the physical environment, which is a key requirement for true AR applications.

3. THE MONKEYBRIDGE GAME

A “monkey bridge” is a fragile wooden construction over a river in South-East Asia [17]. People frequently risk their lives as they try to keep their balance crossing to the other side. In our application players dynamically build a monkey bridge for their own monster-like characters using virtual and physical pieces of landing stage, which vary in shape. The goal is to reach a dedicated target in a virtual ocean. Figure 1 provides a screenshot of a typical game scene. In this picture one of the players has already built a bridge for his character, which consists of virtual blocks (models with the dark wooden texture) and physical tiles (bright balsa-wood and stone cubes showing through the virtual objects).

Players do not have direct influence on the game characters’ behavior; instead they indirectly control character movement by providing the agents with building blocks to walk on above the virtual ocean. In a typical setup the ocean is divided into 10x10 cells yielding a 1m x 1m rectangular physical game board. The grid and cell size can be customized. Each cell may host a building block functioning either as a bridge element or an obstacle. All possible building blocks can be seen in Figure 2a-c. Bridge elements are either physical or virtual and are composed of simple geometrical shapes that fit together smoothly, while obstacles are physical objects that serve as strategic hindrances to players as well as decoration elements.

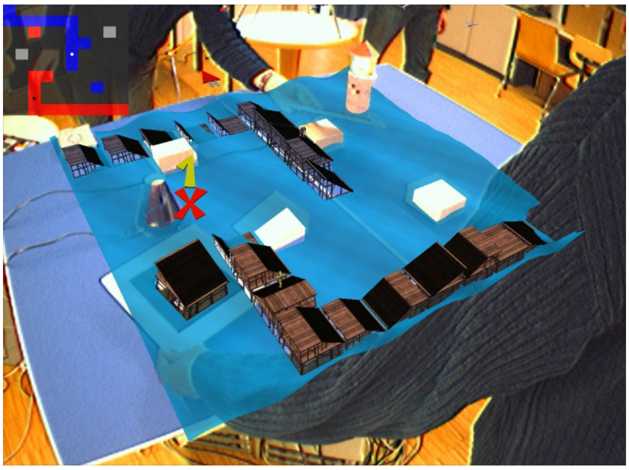

Figure 1. Screenshot of a typical MonkeyBridge game scene

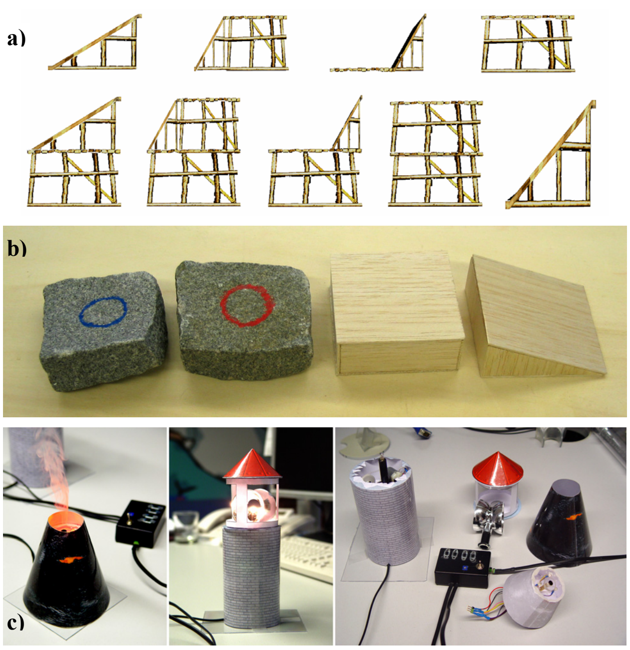

Figure 2. Building blocks: a) Virtual bridge elements, b) Physical bridge elements, c) Physical obstacles

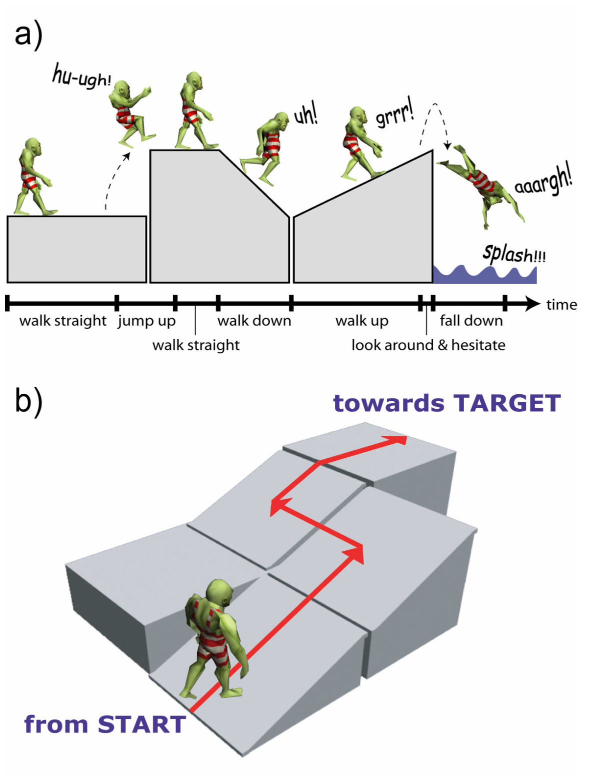

Figure 3. Autonomous agent behavior: a) choosing animation and sound based on platform type, b) path planning depending on the spatial distribution of available blocks

Figure 4. Dual-user setup using a magnetic tracker

The virtual bridge elements are auto-generated in a similar way to Tetris games and are dynamically laid onto the game board by the players. The position and orientation of the blocks are automatically snapped to the cells to make positioning easier. If left unmoved above an unoccupied cell for a given time, the block becomes fixed, and the player occupies the given cell. A player is allowed to place a tile only into cells that are adjacent to other cells already occupied by the player. The real building blocks are crafted from stone and wood. Unlike their virtual counterparts, the position and orientation of the physical blocks are fixed during the game, although they can be arbitrarily configured before start-up. The physical blocks represent the start and target platforms for the characters as well as strategic points to reach.

We have built two physical obstacles: a lighthouse with rotating spotlights and a volcano puffing real, illuminated smoke. The casing can be quickly assembled from paper templates that then host electric engines, LEDs and a smoke generator. Our setup lets users manually control electric parts using a custom-made control box besides built-in microcontrollers for computer control.

3.1 Autonomous Behavior

The monster-like characters are embodied autonomous agents since their behavior does not require careful scripting. Instead a dedicated control logic or virtual "brain" decides which animations and sound effects to play, which direction to turn or whether the target has been reached. The only factors that directly influence agent behavior are the spatial distribution, pose and shape of the virtual and physical building blocks placed on the game board. Figure 3a-b provides illustration.

The characters autonomously choose: the path they walk on; decide how to get from one platform to the other, e.g. jump up or down when there is a slight difference in height between platform edges; automatically choose the straightest path from several available tiles; and fall into the water if there is no suitable piece of landing stage to walk on. They happily cheer with their hands up when they win, and cry over a lost game.

Our game includes responsive physical agents embodied by the volcano and lighthouse obstacle objects that currently incorporate a rather simple behavior to prove our concept: whenever a virtual agent reaches a cell adjacent to an obstacle, the associated object is turned on. The fun factor of seeing the volcano puffing smoke or the rotating lights of the lighthouse motivates players to lead the path of the monsters towards these objects, imposing influence on play strategy.

4. IMPLEMENTATION

Our game is grounded in the Studierstube AR platform [18], which is a middleware supporting a wide range of collaborative multi-user AR applications. Its modular structure enables experiments with several game setups using various tracking systems, displays and interaction devices. The game can be configured to be a distributed application or to run on a single computer. Since users may choose from several setups, they may consider financial and technical factors such as cost, installation time and calibration efforts of the tracking system and display.

We realized three demo setups to test MonkeyBridge: a simple desktop-based setup running on single computer with a keyboard-based tracking simulator and no video background. The second prototype relies on a multi-user setup with two computers sharing application data and tracking information provided by the ARToolKit optical marker recognition system. The setup requires two computers equipped with webcams and optical markers to register the physical game board with the virtual game environment and to place the bridge blocks on the game board. A live video stream recorded by the cameras is augmented on the user's computer screen residing next to the physical game board. The setup is highly portable though sensitive to lighting conditions, may produce jitters in tracking and offers only a static viewpoint. The third setup (see Figure 4) uses Ascension's Flock of Birds magnetic tracking system to track two Sony Glasstron optical see-through Head-Mounted Displays (HMDs) and two Plexiglas pucs to place the virtual tiles. This setup requires a specially manufactured table lacking any metal parts (screws, bolts etc.) to avoid distortion of the magnetic field. This setup yields the best visual quality enabling dynamical viewpoint change, however, requires expensive hardware and tedious calibration upon installation.

5. CONCLUSION AND FUTURE WORK

In this paper we have examined aspects how embodied autonomous agents can be used in AR games. Our pilot game application called MonkeyBridge demonstrates how these agents offer rich game experiences by stimulating users in several domains at the same time, while being embodied as responsive physical objects and lifelike animated virtual characters. We have built three test setups from which we gained experience how to design technically and financially feasible, visually attractive AR games.

MonkeyBridge incorporates novel concepts for AR gaming since it exploits the real world in an advanced way. Our project has made the following contributions:

- The game employs embodied autonomous agents that are able to dynamically recognize changes and events in both the virtual and ***physical*** game environment and proactively generate real-time behavior without direct user control.
- Physical, responsive objects act as active partners of virtual characters yielding output information in the augmented game space while appearing to coexist with virtual game objects.
- Our modular software architecture enables the use of various tracking and display technologies without changing the game application. Thus several game setups are possible so that issues such as financial constraints and portability can be considered.

An important aspect we would like to improve in the future is playability. Although we wanted to create a real game with rules, not just a simple demo, some people were not willing to invest time into learning the game and just focused on the technical aspects. We hope that if the game becomes more intuitive, we manage to hide the underlying technology. We also would like to improve our content by integrating shaders for more attractive visual content, experiment with new responsive objects, and add more intelligence to the game logic so that it can assess and adapt to the players' current level.

6. ACKNOWLEDGMENTS

This project was sponsored by the Austrian Science Fund FWF (contract no. Y193). The authors thank Circled Cube for the sound effects and Gerhard Reitmayr for his useful comments.

7. REFERENCES

[1] Stapleton, C., Hughes, C., Moshell, M., Micikevicius, P., Altman, M., "Applying Mixed Reality to Entertainment", *IEEE Computer* 35(12), 2002, pp. 122-124.

[2] Barakonyi, I., Psik, T., Schmalstieg, D., "Agents That Talk And Hit Back: Animated Agents in Augmented Reality", *Proc. of IEEE and ACM International Symposium on Mixed and Augmented Reality 2004 (ISMAR'04)*, Arlington, VA, USA, 2004, pp. 141-150.

[3] Bolter, J.D., Grusin, R., "Remediation: Understanding New Media", *MIT Press*, Cambridge, Massachusetts, 2000, ISBN-0-262-52279-9

[4] Szalavári, Zs., Eckstein, E., Gervautz, M., "Collaborative Gaming in Augmented Reality", *Proc. of Virtual Reality Software and Technology Conf. (VRST'98)*, Taipei, Taiwan, 1998, pp. 195-204.

[5] Ohshima, T., Satoh, K., Yamamoto, H., Tamura, H., "AR2 Hockey: A Case Study of Collaborative Augmented Reality", *Proc. of the Virtual Reality Annual International Symposium (VRAIS '98)*, Atlanta, GA, USA, 1998, pp. 268-275

[6] Piekarski, W., Thomas, B., "ARQuake: The Outdoor Augmented Reality Gaming System", *Communications of the ACM* 45(1), 2002, pp. 36-38.

[7] Cheok, A.D., Goh, K., Liu, W., Farbiz, F., Fong, S., Teo, S., Li, Y., and Yang, X., "Human Pacman: a Mobile, Wide-Area Entertainment System Based on Physical, Social, and Ubiquitous Computing", *Personal and Ubiquitous* Computing 8(2), 2004, pp. 71-81.

[8] Cheok, A.D., Yang, X., Ying, Z.Z., Billinghurst, M., Kato, H., "Touch-Space: Mixed Reality Game Space Based on Ubiquitous, Tangible, and Social Computing", *Personal and Ubiquitous Computing* 6(5/6), 2002, pp. 430-442.

[9] Magerkurth, C., Engelke, T., Memisoglu, M., "Augmenting the Virtual Domain with Physical and Social Elements Towards a Paradigm Shift in Computer Entertainment Technology", *Proc. of Advances of Computer Entertainment 2004 (ACE 2004)*, Singapore, 2004, pp. 163-172.

[10] Maes, P., Darrell, T., Blumberg, B., Pentland, A., "The ALIVE System: Wireless, Full-body Interaction with Autonomous Agents", *ACM Multimedia Systems* 5(2), 1997, pp. 105-112.

[11] Anabuki, M., Kakuta, H., Yamamoto, H., Tamura, H., "Welbo: An Embodied Conversational Agent Living in Mixed Reality Space", *Proc. of Human Factors in Computing System (CHI 2000)*, Extended Abstracts, The Hague, The Netherlands, 2000, pp. 10-11.

[12] MacIntyre, B., Bolter, J.D., Vaughan, J., Hannigan, B., Moreno, E., Haas, M., Gandy, M., "Three Angry Men: Dramatizing Point-of-View Using Augmented Reality", *SIGGRAPH 2002 Technical Sketches*, San Antonio, TX, USA, 2002.

[13] Cavazza, M., Charles, F., Mead, S.J., Martin, O., Marichal, X., Nandi, A., "Multimodal Acting in Mixed Reality Interactive Storytelling", *IEEE Multimedia* 11(3), 2004, pp. 30-39.

[14] Balcisoy, S., Kallmann, M., Torre, R., Fua, P., Thalmann, D., "Interaction Techniques with Virtual Humans in Mixed Environments", *Proc. of International Symposium on Mixed Reality (ISMAR 2001)*, Tokyo, Japan, 2001.

[15] Cassell, J., Ananny, M., Basu, A., Bickmore, T., Chong, P., Mellis, D., Ryokai, K., Smith, J., Vilhjálmsson, H., Yan, H., "Shared Reality: Physical Collaboration with a Virtual Peer", *Proc. of Human Factors in Computing System (CHI 2000)*, The Hague, The Netherlands, 2000, pp. 259-260.

[16] Itoh, Y., Akinobu, S., Ichida, H., Watanabe, R., Kitamura, Y., Kishino, F., "TSU.MI.KI: Stimulating Children's Creativity and Imagination with Interactive Blocks", *Proc. of the 2nd International Conference on Creating, Connecting and Collaborating through Computing*, Kyoto, Japan, 2004, pp. 62-70.

[17] Florence, M., Storey, R., "Vietnam", *Lonely Planet Publications*, 2001, p. 530.

[18] Schmalstieg, D., Fuhrmann, A., Hesina, G., Szalavári, Zs., Encarnação, M., Gervautz, M., Purgathofer, W., "The Studierstube Augmented Reality Project", *PRESENCE -Teleoperators and Virtual Environments*, MIT Press, 2002.