CHAPTER X

A New Generation of Entertainment Robots Enhanced with Augmented Reality

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While robots have been recently introduced in domestic environments to perform household chores, few robots are being used for entertainment, partially due to the lack of infrastructures for this purpose. In this paper, we propose an architecture that enables integrating interactive virtual elements in a robot-based gameplay. Several robot game concepts that may be enhanced with Augmented Reality are presented as guidelines toward the future of robot entertainment.

1 Introduction

Robotics and automation have been traditionally aimed towards improving our daily lives. From the static regime of industrial production, the past decade has seen these mechanisms subtly make their move towards our domestic environments, from motorized blinds to more sophisticated devices such as cooking helpers or robotic vacuum cleaners. While the original focus of these mechanisms has been to partially or fully automate difficult or tedious everyday tasks and chores, a subset of current household robots has been developed with a very different concept in mind: some for education, and some others for pure entertainment.

Robotics is capable of making difficult areas more appealing, even to the youngest and the elder. In entertainment, robotics has the potential to attract and engage players, entertaining in ways never dreamed of before. However, due to the intrinsic complexity of robotic systems, practical issues arise. Gameplay quality dramatically decreases as real-world issues such as sensor noise, actuator failure, and communication lag intervene. To fill this gap, researchers and developers have been experimenting with Augmented Reality (AR) to present useful gameplay information, or even overlaying this on a transmission of the robotic systems' vision of the world, thus providing enhanced interaction and playability in entertainment.

2 State of the Art

This section will be dedicated to describe the state of the art of games that involve Augmented Reality (AR), and AR games that involve robots.

2.1 AR Games

The first examples of AR games appeared in the context of research projects. One of the first examples of these games was developed by Ohshima et al., called AR2 Hockey (Ohshima, Satoh, Yamamoto, & Tamura, 1998). In this game, two players can play simultaneously in real-time a game of air hockey. A multiplayer AR racing game was presented by Oda et al. in (Oda, Lister, White, & Feiner, 2008). Fiducial markers define the game area, where several players can interact with the virtual racing car or the track, either by driving the car or by adding obstacles and waypoints.

Using techniques such as Parallel Tracking and Mapping (PTAM) to register the virtual objects over the real world, markerless AR games can be achieved, such as Ewok Rampage (Klein & Murray, 2007). This game can be played over any flat surface, both indoors and outdoors. The objective is to destroy the enemies before they reach the player. Other methods for makerless AR use 3D sensors and light projectors to overlay the virtual elements over the real world, and remove the need for the user to wear any display. Some applications exist using this method, such as IllumiRoom, which improves the game experience of existing games (B. Jones et al., 2014), or RoomAlive, an immersive game experience that projects a virtual world on top of the room (B. R. Jones, Benko, Ofek, & Wilson, 2013).

Due to the increase in performance of mobile devices such as smartphones and portable game consoles, the amount of commercial AR games available in the market has increased in the last years. They typically lack publications explaining their inner workings, apart from scarce online resources. Some examples of these games, that usually require one or more fiducial markers to achieve the augmentation, are Invizimals[1], Wonderbook[2] or AR Games[3]. The HoloLens[4], a Head-Mounted Display (HMD) being developed by Microsoft, is another development that, according to the information provided by the company, can work without fiducials for several applications such as games, designing art and engineering, and remote conferences.

2.2 AR Robot Games

A limited number of developments exist that achieve interaction between the AR-generated virtual elements and the real world elements. Even less mix AR with robots. Similar AR game developments to the concept presented in this work are the Parrot Drone quadcopter[5] and Sphero (Carroll & Polo, 2013) games. These games allow the user to teleoperate the robots from a mobile device, that overlays enemies or waypoints (depending on the game) on top of the video stream obtained from the on-board camera.

Our previous work, Robot Devastation (Estevez, Victores, Morante, & Balaguer, 2015) introduced the idea of multiplayer AR games with robots as the physical avatars of the players. It describes an AR game in which the player fights with a robot against other robots with virtual weapons, acquiring the robot's Point of View (POV) for the combat.

Lupetti et al. present a system in which people and a robot physically interact in a game (Lupetti, Piumatti, & Rossetto, 2015). Virtual elements are projected onto the playground to avoid the need for screens. The robot perform different roles (e.g. companion, adversary, avatar for a remote player) along each game.

3 Proposed architecture

In our previous work we envisioned an architecture in which the player has a First Person View of the world through a camera present in the robot. In this situation, the player can perceive the environment as if a miniature

1 http://invizimals.eu.playstation.com/, last accessed: Apr 19, 2016
2 http://wonderbook.eu.playstation.com/, last accessed: Apr 19, 2016
3 http://www.nintendo.com/3ds/ar-cards, last accessed: Apr 19, 2016
4 https://www.microsoft.com/microsoft-hololens/, last accessed: Apr 19, 2016
5 http://ardrone2.parrot.com/usa/apps/, last accessed: Apr 19, 2016

version of him was onboard in the robot. In this work we extend the existing architecture with a more general one, suitable for more kinds of game.

The proposed system has three main parts, as seen in Fig. 1. One or several robots provide an interface for physical interaction with the world and other players. Virtual elements are created in the Player's PC using a Game Engine that uses an AR engine to calculate how the virtual elements are overlaid on top of the real world view. Cloud communications between robots and player PCs coordinate the game.

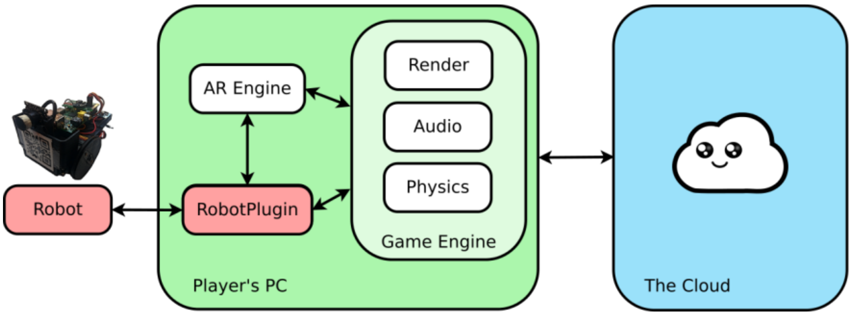

Fig. 1. The proposed architecture incorporates robot components (red).

3.1 Robots

The most basic robot architecture suitable for AR gaming includes one camera, wireless network hardware and some kind of motor to allow movement. Fig. 2 shows an example of basic robot platforms.

Fig. 2. Example of robots: current generation of Robot Devastation robots.

The camera obtains a view of the real world from the robot's POV, which is streamed wirelessly to the player. More than one cameras (or an RGB-D sensor) can be incorporated to the robot so that 3D information about the environment can be obtained, which also allows to provide a stereo video stream, which increases game immersion. The wireless connection is also used to teleoperate the robot and to send different commands. Finally, the robot needs some means of achieving locomotion, that can be wheels, legs or just a pan-tilt mechanism.

With the recent increase in miniaturization and reduction in size of modern dedicated GPUs (e.g. NVIDIA Jetson[6]) and VPUs (Vision Processing Units) the robot could perform most of the computations related to detection and tracking of other robots, elements of the environment and, in general, to leverage the amount of processing required at the player's PC, allowing the use of smartphones as game interfaces.

3.2 Player's PC

AR games require virtual objects the user can interact with, which are displayed on top of the real environment. They also need to manage the interaction between the real elements, the virtual elements, and the user. To generate and manage these virtual elements, current existing game engines can be used, as they can render high-quality graphics and have physics engines able to simulate physical interactions between virtual elements.

In order to perform convincing registration between the real and virtual elements, an AR engine needs to be added to the game engine. The purpose of this AR engine is to locate and model the real environment and robots. Different techniques are available for performing this registration, including classical techniques, such as using fiducial markers, or more advanced markerless techniques, such as Parallel Tracking And Mapping (PTAM).

3.3 Cloud communications

Cloud communications, depicted in Fig. 3, are managed at the different levels: between the robot and the player, between robots, and between players. Communication between the robot and player include, as described in the previous section, one or more video streams and some channel to send commands and receive telemetry from the teleoperated robot. Communication between players allows sharing scores, placement of play-

6 http://www.nvidia.com/object/embedded-systems-dev-kits-modules.html last accessed Apr 19, 2016

ers, environment maps, actions, virtual NPCs, etc. Communication between robots manages different interactions between robots (e.g. hits, power-ups…).

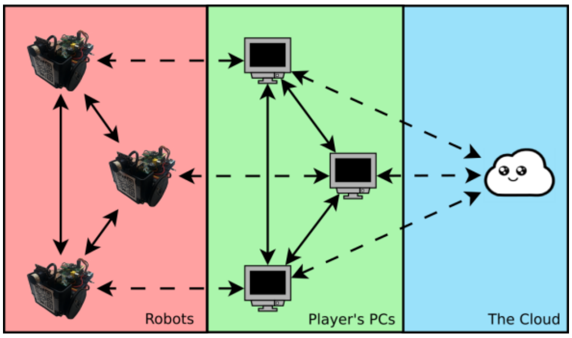

Fig. 3. Cloud communications share information across different layers.

4 Proposed games

The proposed architecture is general enough to allow different types of games. Some example games of combat, racing and sports are proposed in this section.

4.1 Robot Devastation 2.0

Robot Devastation is an AR game that emulates robot combats (Fig. 4).

Fig. 4. Conceptual image of Robot Devastation 2.0 gameplay. Source images: Ty'Onah Gallman (flicker) and footageisland (youtube).

The player assumes the role of the robot pilot, as if he were sitting inside the robot cockpit, and battles against other robots. Weapons and projectiles, as well as bullets, fire, explosions and damage inflicted to the robots are simulated using AR. This prevents damage to the player, other people around the robots, or the robots themselves, and at the same time it provides engaging gameplay. Virtual Non-Playing Character (NPC) autonomous robots can be added to balance teams or to increase game difficulty.

4.2 Augmented Reality Robot Racing

Similar to the previous setting, where the player assumes the role of the racing robot pilot as if he were sitting inside the robot cockpit. Fiducial makers or elements from the environment can be set as waypoints to mark the race track. Augmented reality allows this track to be shown on top of the real world, and to include different power-ups or obstacles along the race. The player can race against other physical robots, against virtual robots, or against a mix of them, in different environments (land, water, air).

4.3 Augmented Reality Robot Sports

This type of game allows the player to play a sport against other robot. Different sports may require more complex robot configurations, e.g. a mobile robot could play curling, whereas a humanoid robot would be required for playing volleyball or basketball. Popular robot competitions such as RoboCup could additionally benefit from incorporating AR, providing power-ups and secret items to unlock new features.

5 Conclusions

Most current AR games lack an embodiment of the agent. In practice, this leaves the environment physically “disconnected” from the virtual agents, and vice-versa. Certain AR games that involve robots have been recently developed. However, they are typically single or two player games, and present no multiplayer agenda. The authors believe that a new generation of entertainment robots, enhanced with augmented reality similar to the ones presented in this paper, will mark the future trends of robotics and entertainment.

Acknowledgements

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References

Carroll, J., & Polo, F. (2013). Augmented reality gaming with sphero. In ACM SIGGRAPH 2013 Mobile (p. 17).

Estevez, D., Victores, J., Morante, S., & Balaguer, C. (2015). Robot Devastation: Using DIY Low-Cost Platforms for Multiplayer Interaction in an Augmented Reality Game. EAI Endorsed Transactions on Collaborative Computing, 15(3), 1–5.

Jones, B. R., Benko, H., Ofek, E., & Wilson, A. D. (2013). IllumiRoom: peripheral projected illusions for interactive experiences. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 869–878).

Jones, B., Sodhi, R., Murdock, M., Mehra, R., Benko, H., Wilson, A., … Shapira, L. (2014). RoomAlive: magical experiences enabled by scalable, adaptive projector-camera units. In Proceedings of the 27th annual ACM symposium on User interface software and technology (pp. 637–644).

Klein, G., & Murray, D. (2007). Parallel Tracking and Mapping for Small AR Workspaces. 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality, 1–10.

Lupetti, M. L., Piumatti, G., & Rossetto, F. (2015). Phygital Play. Intelligent Technologies for Interactive Entertainment (INTETAIN), 2015 7th International Conference on, 17–21.

Oda, O., Lister, L. J., White, S., & Feiner, S. (2008). Developing an Augmented Reality Racing Game. Proceedings of the 2nd International Conference on INtelligent TEchnologies for Interactive enterTAINment.

Ohshima, T., Satoh, K., Yamamoto, H., & Tamura, H. (1998). AR 2 Hockey: A case study of collaborative augmented reality. In Virtual Reality Annual International Symposium, 1998. Proceedings., IEEE 1998 (pp. 268–275).