Sphero - Multiplayer Augmented Game (SMAUG)

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ABSTRACT
The current paper exposes the development of a game application that combines augmented reality, modern robotics, mobile features and multiplayer networking in order to create an immersive collaboration system, where people can interconnect to have fun and complete entertaining tasks together. SMAUG is a game based on Sphero 2.0 robotic ball, where multiple players share the same driving control of the robot. Depending on the game session and quest, a player can influence a certain moving direction or the robot's speed. Furthermore, the playground is augmented on the driving surface, so each player is looking to the game scene through his/her mobile's camera. The main objective here is that players need to collaborate in order to accomplish various tasks: collecting game artifacts, drive on augmented tracks, break down walls/gates, escape mazes and so on. In order to accomplish this objective the game is demanding collaboration: the game artifacts are distributed to different players augmented views, so they will need to communicate often in order to drive Sphero in the right direction. Finally, the most important objective was to open a new perspective on the Sphero-driven application development, creating at the same time the possibility of using mobile devices to conduct team-building activities.

Author Keywords
Augmented Reality; Robotics; Multiplayer Networking; Mobile Application.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces. H.3.2. Information Storage and Retrieval: Information Storage.

General Terms
Human Factors; Design.

INTRODUCTION

Sphero 2.0
Designed as a toy with an educational purpose in mind, the Sphero 2.0 robotic ball [1] has a series of particular characteristics: instead of using wheels, rails or spider legs as many other robots, this one has the shape of a sphere with no extra parts. As a consequence, all the hardware and mobility components are encapsulated inside the sphere's shell. The shell and chassis are made out of polycarbonate, raising the robot's resistance to impact and providing waterproof properties.

Hardware specifications
Beside the special mobility system, Sphero is equipped with an inductive charging base, a Bluetooth device (10 m range), 1 RGB and 1 blue LED and the following sensors: (i) Three axis gyroscope; (ii) Three axis accelerometer; (iii) Battery voltage sensor. All these mechanical and electronic modules provide the robot with capabilities to roll horizontally in any direction (0 to 360 degrees), maintain its stability, communicate over Bluetooth and glow in various RGB colors.

Software toolkit
From a software perspective Sphero implements primitive mobility operations (like rolling in a specific direction with a provided speed, etc.), approximate location tracking, collision detection and color switch. However, for more complex tasks, for example describing a 1 meter square, the robot's platform offers two possibilities: (1) Robot-interpreted languages; (2) SDK API commands.

Robot languages
An easy way to create small programs/routines that control the robot, and which can be used also by non-programmers, are using one of the three robot-interpreted languages offered by the Sphero suite [3]: *Macros, OrbBasic* and *Oval*. The development and deployment of programs written in one of these languages are managed through mobile applications that provide text/visual programming capabilities.

Sphero SDKs
Unlike the interpreted languages, which are run locally on the robot, the Sphero toolkit provides mobile SDKs that can be used to send remote commands to the robot, using the Bluetooth communication capabilities. In this scenario, the Sphero acts like a server, while the mobile application is a client. One disadvantage to this approach is the communication overhead, for which the protocol allows the client to send only around 12 commands per second.

At the moment, the Sphero developers can choose between three major mobile platforms to develop for: Android, IOS and Windows 8.1. Considering our experience with the Android SDK and the handy tools that support the development for this platform, we chose it as the deployment platform for the current application.

STATE-OF-THE-ART

As it was already mentioned, SMAUG is a game that combines multiple technical fields and paradigms, but its main objective is to demand collaboration for completing entertaining activities. However, another important characteristic is also the use of AR, which can be found in a wide range of applications today. Following these traits, the following items will present some carefully selected applications that have a good resemblance to the present project.

Color Grab - Based on the Sphero's color glowing and acceleration detection features, Color Grab [4, 5] is a mobile multiplayer game with a simple and entertaining task. The game consists in a few rounds where each player needs to score by grabbing the robotic ball while it randomly glows a certain color.

The Rolling Dead - While the two presented applications compare to SMAUG on social interaction side, The Rolling Dead [6, 7] similarity resumes to the use of Augmented Reality. As such, the main character of the game is again Sphero, but this time the robot is placed into an augmented scene, where it is attacked by virtual zombies. The quest of the game is to defeat as many zombies as possible by using virtual abilities of the augmented Sphero.

Temple Treasure Hunt - This AR multiplayer game [8] classifies the players in two parties: Treasure Protectors (which are creating treasure trails, place various guardians and set challenges) and Treasure Hunters (which take up the challenges and explore the treasure trails by locating the treasure guardians in given time limit). The game can be played either indoor or outdoor (using geo-location map).

Ingress - This is an AR MMO location-based game, available on Android and IOS platforms. The gameplay is based on capturing virtual portals in culturally significant places (landmarks, public arts, monuments etc.), and link them to create virtual triangular "control fields" over geographical areas. Depending on which faction is the player joining (Enlightened or Resistance), the map areas will be marked with green or blue color [9].

APPLICATION DEVELOPMENT

In this section we'll discuss in details the steps involved in developing the Sphero driven application, and the main features that contribute to creating the immersive experience of the game.

Game workflow design

As presented in Figure 1, most of the setup phase is handled by the *Main Menu Scene*, where the first displayed panel has the same name. All available options from the menu are represented by the arrow labels from the image, each arrow representing a transition to another panel or scene.

Furthermore, a brief presentation of each panel/scene's logic would be the following:

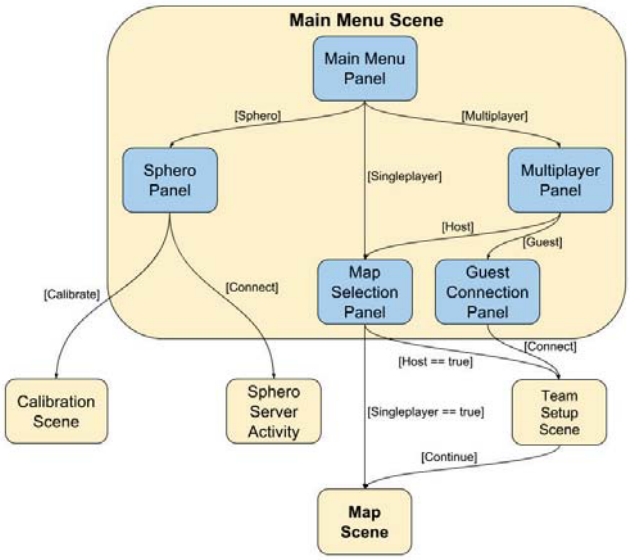

Figure 1. SMAUG Application/Game Workflow.

- **Sphero Panel** – offers the possibility to open a new connection to Sphero and to calibrate its orientation;
- **Sphero Server Activity** – for connecting to Sphero, the application starts a separate Android activity which handles the connection and runs a tiny TCP Server in background;
- **Calibration Scene** – this scene contains the necessary UI for calibrating the Sphero orientation and perform a quick drive test;
- **Map Selection Panel –** allows players to navigate between available maps, select the one to play and proceed;
- **Multiplayer Panel** – allows a player to choose between *Host* and *Guest* roles when starting a multiplayer session;
- **Guest Connection Panel** – before connecting as guests, players are asked to enter the IP of the host server, which they do using this panel;
- **Team Setup Scene** – after connection to the game, either as host or guest, the players will choose a role in the team (one or two driving directions);
- **Map Scene** – this is a generic name for the scenes corresponding to each map, being the place where the actual play is happening.

Map/Level design

This is the most important part of the SMAUG game, as it is the place where the players will spend most of their time in the application. This part links all the pieces together in order to create the entertaining experience for the users. As exposed in Figure 2, every map consist of four main pieces: driving layer, UI, game logic and AR components.

The **Driving Layer** offers the necessary functionality for collecting direction and speed input from the players and transferring this parameters to the robot. In order to accomplish this task, there is a direct collaboration with

the UI, where each player interacts with a virtual joystick, and with the Network Manager.

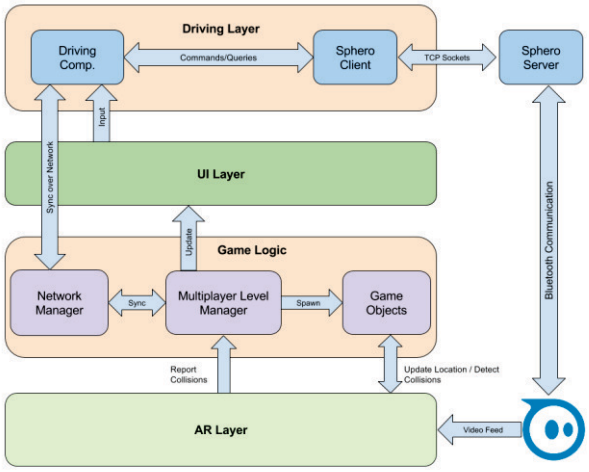

Figure 2. Map/Level System's Architecture.

The **UI Layer** holds graphical controls that facilitate communication between the game and the users. Beside the virtual joystick that we already mentioned, the UI contains also components like status bars and various message/dialog boxes.

The third, but not last piece, is the **Game Logic**. The central business block of this layer is the *Multiplayer Level Manager*, which orchestrates all the activity that takes place within a game scenario (map). The **AR Layer** is a very important one as it provides the necessary means to detect the *Sphero playground* surface and augment the game objects over the video feed.

Figure 3. Main Menu UI.

USER EXPERIENCE

In order to display an attractive look and feel, as presented in Figure 3, the menu's UI provides a colorful 3D scene view, with a transparent panel and symbolic elements which support the game's story.

Game Stories – Diamonds Hunting

In this quest, the wizards sent the "magical Orb" to the "Valley of Stones", to find and collect as many "enchanted diamonds" as it can (see Figure 4), before they run out of energy and teleport Sphero back with the collected amount (this motivates the players to collaborate efficiently in order to return with the highest amount possible).

Figure 4. Collecting diamonds with Sphero.

Game Stories – Portals Maze

With a similar plot-line as the previous quest, this time the Orb needs to find only one artifact: "The Sword of Victory" (see Figure 5). By teleporting around and paying attention to their path, the players will finally arrive at the destination point, their goal being to obtain the shortest time possible.

Figure 5. Portals Maze - finding the Sword of Victory.

Game Stories – The Dragon's Treasure

This scenario is about using one player to distract the dragon, while the others are guiding Sphero to steal its treasure. Timing is an important aspect of this mission, as if the dragon comes close to the Orb the game would be over.

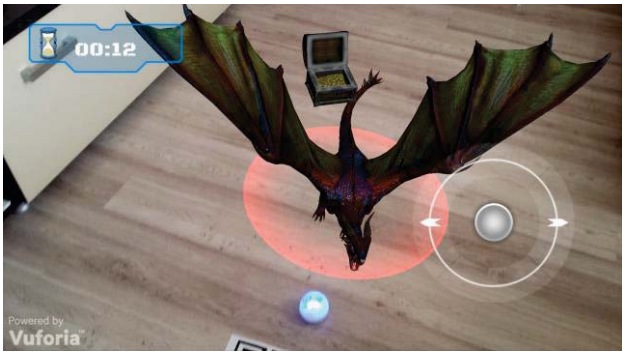

Figure 6. Sphero facing the furious dragon.

As it can be observed in Figure 6, the current version of the game exposes only the dragon and the treasure, while the diversion logic is yet to be implemented.

USABILITY TEST REPORT

"SMAUG makes a better world!" (Participant quote) On 23 June 2016 we invited four users to a specifically

arranged place and during the playing sessions, we've recorded their experience with the game while they were performing usual tasks. Recordings analysis clearly showed that:

- The UI looks very attractive, despite a few points where it's a bit confusing;
- The multiplayer feature presents minor performance and stability issues;
- Sphero driving went smoother than expected;
- Social interaction, visual effects, game dynamics and quest plots are the main selling points of the game.

Participants

We've recruited four participants for the present tests. Their selection was random, the group being formed of 2 women and 2 men. The occupations varied from teacher and accountant to student and QA engineer, while only one of them didn't have previous experience with multiplayer games. We also took into account their social interaction activity, having 2 participants with high activity, 1 with moderate and 1 with reduced.

Methodology

The conducted usability test consisted of an introduction, six tasks, a short interview and a post-test questionnaire. We instructed the participants to think out loud and express their thoughts during the test. After the task series that we communicated verbally to the participants, we gathered their assessment of the overall experience using the *QUIS scale*.

The tasks that users performed covered the operation of Sphero (connect, calibrate and drive) and playing the available quests in both, singleplayer and multiplayer modes.

Results

UX element	User1	User2	User3	User4	AVG
Menus	9	8	9	8	8.5
Selection controls	9	9	9	8	8.75
In-game messages	8	8	9	8	8.25
Game status bar	8	7	7	8	7.5
Sphero driving	8	9	9	8	8.5
Singleplayer	9	8	9	8	8.5
Multiplayer	7	7	6	8	7
Quest engagement	8	8	7	7	7.5
Overall look and feel	9	9	9	9	9
Team-building experience	8	7	7	7	7.25

Table 1: Post-test questionnaire results.

From our observation during the test sessions, the users had the best experience while performing the first four tasks. They found the necessary menu actions very quickly and were able to successfully connect and drive Sphero around, as well as play any map in singleplayer mode. On the other hand, the participants had some trouble while trying to complete the last two tasks.

The main issue was that the game was not synchronizing well between devices, the users not being able to spot the objects from the augmented scene. Also the application seemed to work a bit slowly in this mode which indicates some performance issues that need to be addressed.

Another data point that confirms the above results comes from Table 1, which summarizes the user responses to the post-test questionnaire. The participants were asked to rate their experience with the elements from the left column, giving a note from 1 to 9, where 1 stands for confusing/frustrating experience, and 9 for clear/pleasant experience.

CONCLUSION

The paper presents a multiplayer augmented game called SMAUG, based on Sphero platform. The user can control the Sphero with an intelligent device, with augmented reality, via a lane, with game objects and a virtual joystick, which can be seen only on devices, by all players.

In the current state the application offers only a basic experience, but as the testing users agreed, there are plenty of areas that can be improved in order to transform SMAUG into a great game, such as: (1) Enabling players to compete each other in the arena, controlling one Sphero each; (2) Develop other game scenarios, with increasing complexity and difficulty; (3) Introduce player/team profiles, special abilities, rewarding system and ranking; (4) Connect with social networks, allowing players to share their best scores; (5) Introduce UI themes and rich audio content.

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