Implementation of a videogame: Legends of Girona

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Abstract. Legends of Girona is a serious game which can be used to teach local history to students in the province of Girona in Spain. The game is a graphic adventure taking place in both present-day and medieval Girona. We describe in this paper the design of the game, including aspects related to artificial intelligence, advanced computer graphics, immersive displays, exergaming and mobile platforms. We also present some directions of future work.

Keywords: serious game, history, immersive devices

1 Introduction

We present here Legends of Girona: a serious game aimed at learning the local legends of the city of Girona in Spain. The game can be used by high school students to ease retention of important happenings and dates of local history. The game is a graphics adventure which aims at providing players an immersive environment in the relevant period.

The game is a result of a collaboration between our Computer Graphics group and the TIC Education group. The storyline and plot was designed by the Education group to maximize the learning experience while maintaining the enjoyability of the game, while the Computer Graphics side used the storyline to design and implement the game.

The next section provides a historical background of the events described in the game, while section 2 describes the game architecture. The state diagram of the game can be seen in section 2.1; then section 2.2 describes the Artificial Intelligence algorithms programmed. Section 2.3 and 2.4 provide a description of photorealistic and non-photorealistic algorithms used in the game. Then section 2.5 describes the use of Microsoft Kinect to control the game. Section 2.6 describes the use of immersive display devices, and section 3 shows the adaptation of the game to run on iPhone and iPad devices. Finally, section 4 concludes the paper.

1.1 Historical Background

The game starts in present day Girona to provide a familiar setting to users, and to increase believability and identification with the main game character.

After spending some time familiarizing themselves with the city (or recognizing familiar streets in the case of players living in Girona), time travel is used to lead the player to the desired date (in our case, the siege of Girona during 1285). A similar technique has been used in the Assassin's Creed series of games [8].

We have modeled a realistic walkthrough from the Stone Bridge in Girona to the St Feliu Church along the Rambla and the Ballesteries streets. This provides a view of two landmark medieval structures, and their situation as extremes of a modern-day touristic, cultural and commercial street.

After the walkthrough, the player is transferred to Girona in the year 1285, during the siege of the city. The siege of Girona in 1285 was part of the Aragonese Crusade (1284-1285), in which the pope declared the crusade against the Aragonese king who had just conquered Sicily (a territory under papal control then). The French armies attacked the Roussillon, and besieged Girona in 1285, which was taken. A further battle saw the French defeat, with further loses due to a dysentery epidemic. The crusade ended in 1291 with the lift of the church ban on the Aragonese king.

With these historical facts as a basis, the Girona legend of the flies of St Narcis took the following form: The legend states that when the French invaders opened the St Narcis sepulcher searching for loot, a large quantity of flies exited the sepulcher instead, covering the whole city and bringing illnesses to the French soldiers, which had to retreat in haste.

1.2 Game description

The game starts in Girona's boulevard, near the tourist's office. In the office, the player is given some initial comments; then he is free to walk along the boulevard. On the other side of the boulevard is the St Feliu church, where the player is given a puzzle to solve. After solving the puzzle, the player is transferred to 1285.

The player is now outside the city and notices the siege. He must flee from the soldiers. After getting help from some citizens, he manages to enter the city. During the process, he notices that the inhabitants of Girona consider him a hero which will save the city.

Inside the walls, the player should collect some flies under the guidance of a sorceress, and search for the entrance of a labyrinth leading to St Narcis' sepulcher. The flies are to be put inside the sepulcher, so that when the soldiers open it later, the flies attack them. After the soldiers are defeated, the player is transferred back to the present.

2 Game Architecture

The game was implemented using Unity [9], which is a multiplatform game engine running on Microsoft Windows and Apple OSX which can create games for the Web, PC, OSX, IOS, Android, Flash, Xbox, PS3, and Wii platforms. Currently, we are targeting the PC, OSX and IOS platforms for our game.

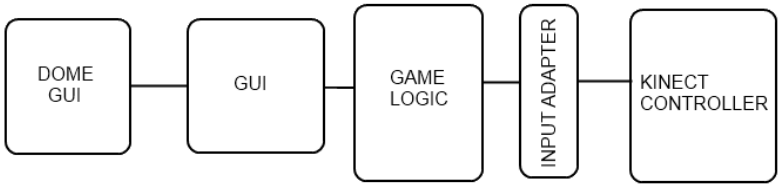

Fig. 1. Game Structure diagram

Figure 1 shows how the game class structure is divided in different blocks. The decoupling of Input and Output has been highlighted to show how this architecture can allow the use of non-conventional immersive displays (which traditionally require higher integration in the game engine) and new input devices with little effort.

The game logic block is composed of the game state and of the actors affected by the game state. There are two types of actors: friendly and hostile. A friendly actor helps us advance in the story and interacting with them changes the game state. Hostile actors produce a penalty when we interact with them. The next section describes the game states.

2.1 Game levels and State diagram

The game is structured in six levels:

1 Current-day Girona
2 The St. Feliu Church
3 Outside of the city walls during the 1285 Siege
4 The city wall gate puzzle
5 Inside of the city walls
6 The labyrinth

Screenshots of the different levels can be seen in figure 2. A description of the state diagram shown in figure 3 follows.

Current-day Girona Current-day Girona is divided in two states: the initial state, in which movement is limited to a five meter radius of the original position, and which only allows interaction with the tourist office.

After interaction, the second state allows the user to move along the streets leading to the St Feliu Church. Entering the church loads the second level.

The St. Feliu Church This level has four states.

1 In the initial state we may either find a key or a door.
2 The key produces a change in state prompting the user to search for the door.

Fig. 2. Levels of the Legends of Girona game

3 Seeing the door without the key will prompt the user to search for the key.
4 After the key has been found in state 3, the user is prompted to return to the door.

In states 2 and 4, the door may be activated to load the third level.

Outside of the city walls during the 1285 Siege This level is the most complex one, with eight states which include an optional intermediate sub-mission.

1 In the initial state we see how the protagonist wonders where he is and concludes that he needs to search for help. After the initial monologue is ended, there is an automatic transition to the next state
2 We are outside of the city of Girona surrounded by guards to avoid and with the objective of finding help. The player is shown in a first-person perspective. To change state, we must find the Merchant and ask for help, after which state 3 is achieved.
3 In this state we wear medieval clothes to be less conspicuous and a pendant marking us as the chosen one. A third person perspective is used to ease navigation in the city outskirts. The objective is to talk to a lame man in the city while avoiding the guards. Once we talk to the man state we reach state four.

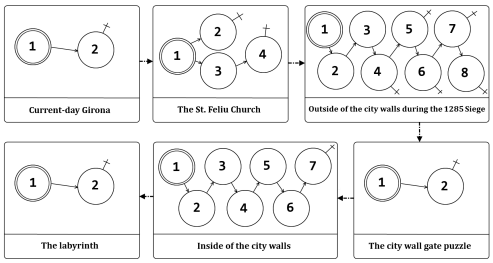

Fig. 3. State diagram of the Legends of Girona game

4 When entering state 4 we see night fall on Girona and the lame man has told us how to enter inside the city walls. From this moment we may go to the city gates and that will induce the load of the next level. If we want the walk to the gates to be easier, a sub-mission may be done so that the lame man helps us distract the guards. The sub-mission consists in getting 500 coins for the lame man. To change the state, we can go and talk to the Merchant, which triggers state 5.
5 In this state we have a package given to us by the Merchant. We may take the package to the blacksmiths house so that the Merchant gives us the coins we need. After delivering the coins, state 6 is entered.
6 In this state we need to tell the Merchant that the package has been delivered. Once we do, we receive the 500 coins and enter state 7.
7 In this state we have the coins and giving them to the lame man ends the sub-mission, leading to state 8.
8 The lame man distracts most of the French guards which were patrolling outside of the city wall. We only need to go to the city gates to change to the next level.

The city wall gate puzzle This level has two states, the initial one until the year of the siege is provided by the user, and a final state to provide the transition to the next level.

Inside of the city walls This state has seven states, but without optional sub-missions.

1 We start in the inside of the city walls and must investigate to know what to do. After talking to a boy near the gates, state 2 is reached.
2 In this state, our purpose is clearer. We need to search for a sorceress and request her help. After crossing the city to find her and talking to her, state 3 is triggered.
3 Now we need to use a basket (given to us by the sorceress) to collect a series of flies which are located all around the city. The higher the difficulty level,

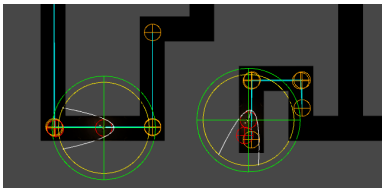

Fig. 4. Pathfinding and detection zones for soldiers

the more flies we need to find and the less time we have to complete the task. If the task is complete, state five is triggered; otherwise state four will occur.

4 Time is over, and the flies have escaped the basket, breaking it. We need to talk to the sorceress again to get another basket, after which we reach state 3 again.

5 The basket is full of flies, so we need to go back to the sorceress' place. After talking to her, she gives us a hint and state six is reached.

6 We now need to talk to a Jew to get the labyrinth's key. After talking to him the transition to the 7^{th} state is triggered.

7 We have the flies, the hint and the key, so when we reach the labyrinth door the next level is loaded.

The labyrinth This level also has two states, the initial one and a final one with the end of labyrinth animation, which leads to the end of the game.

2.2 Artificial Intelligence

The control of the behavior of the non-player characters is based on artificial intelligence rules to predict and anticipate the player [6]. This is the most relevant aspect in the city guard characters, which follow the player through medieval Girona.

Three aspects need to be taken into account:

– **Pathfinding algorithms to patrol and move** All soldiers and some scripts which will be applied in the future to simulate the population of both current-day and medieval Girona use the standard pathfinding integrated in the Unity 3 engine to calculate the path to their destination. The colliders of the objects and the terrain of the scene are used to create a walkability map; this map can be used to calculate a path to any point, as long as the point is contained in the map. Furthermore, it includes a waypoint system so that soldiers patrol in the zones delimited by them. Soldiers will decide which waypoint to visit next using a probabilistic function. To simulate more characters, waypoints which are not visible for the player, and which allow NPC to appear and disappear also exist. Figure 4 provides an overview.

– **Detection algorithm** All soldiers have a detection algorithm to find objectives in a circular detection zone. Additionally, a vision zone exists, modeled by a parabola in the (x,z) plane. When an enemy enters the intersection of both zones, the soldier will prosecute the enemy. The player has two ways to flee: move farther than a predefined distance of the guard, or moving out of sight by hiding behind a building. If the guard cannot see the player, he will go to the last point the player was visible from the guard position and search around randomly for a few meters. If the player stays out of view, the guard will find the closest point in its patrol area and return there.
– **Prediction and anticipation algorithm** This algorithm uses the last movement vector of the player to calculate the future position of the player, so that the guard tries to intercept the player at that point. This is especially effective for soft turns (easily anticipatable) and hard turns, as this reduces the player speed and allows the guard to close in.

Additionally, all behaviors are affected by the difficulty level, thus:

– **Pathfinding algorithms to patrol and move** The patrol and persecution speeds are affected. At high difficulty levels, the guard and the player run at the same speed, so the user cannot exit the prosecution area and needs to hide.
– **Detection algorithm** The detection and prosecution radii are increased in high difficulty levels and decreased in low difficulty levels. The latus rectum of the vision field parabola (defining the amount of periferic vision) is also increased or decreased depending on the difficulty level.
– **Prediction and anticipation algorithm** The prediction distance for the guard is changed, using optimal levels for high difficulty levels and disabling the feature for low difficulties.

We have requested users' impressions on the behavior of the guards, and the response has been positive. These easy to implement procedures create a behavior for the guards which the users of the game consider realistic.

2.3 Realistic Graphic Effects

The realism in a video game contributes to game immersion and enjoyability. We are using the GameTools routines [2] to produce realistic materials such as metals, including pseudo-raytracing reflections, in realtime and with low computational cost.

The routines work by creating and updating distance and color cube maps centered at the objects with the GameTools materials, and using a GPU shader to evaluate the correct pixel color using a binary search on the distance cube map followed by a texture access to the color cube map. The use of this technique provides realistic images even when the maps are only updated rarely, providing highly realistic images with low computational cost. The slight decrease in fps does not affect gameplay. These routines can be integrated easily in already existing games using drag-and-drop of templates to create the necessary environment maps. The resulting effects can be seen in figure 5.

Fig. 5. Realistic reflections using GameTools effects

2.4 Stylized Rendering

In certain cases such as historical storytelling, artistic stylization may provide greater experience and a more memorable atmosphere then realistic depiction. We adapted a collection of screen-space Non-Photorealistic Rendering (NPR) techniques to Unity, enabling game designers to easily change the rendering style of the game. We designed our effects based on popular techniques from visual arts, especially comics. A common characteristics of comics is simplified depiction with large flat surfaces and minimal texture details, while enhancing important information such as character contours. In order imitate this style, we implemented texture simplification methods and luminance quantization based on [11, 3] to remove unwanted details, and the artistic edge detection of Winnemöller et al. [10] to enhance important ones. Changing the color of rendered shadows can create a variety of effects, such as impressionism or chiaroscuro [7]. Shadowed pixels are determined by rendering the image once with and once without shadows and comparing the two results as a post processing, shadow color is changed using the obtained mask. To enhance the illusion of depth, we provide depth varying detail level of textures, edge thickness and color saturation, each technique commonly used by painters and comic drawers. The atmosphere of the rendered images can be changed by adapting the color palette to a given example image, as in Reinhard et al. [5]. Most of the effects can be used with no measurable effect on speed. At Full HD resolutions, the Abstraction effect can reduce fps around 25 %, while shadow effects are the most expensive, at 33 % reduction in frame rate. All our effects are applied to a camera object as a post-processing filter [4], permitting them to be used in any games. Figure 6 illustrates several styles created by our implementation.

2.5 Kinect

In addition to realistic graphics and game physics, functional realism can greatly enhance immersion in the virtual world. Natural User Interfaces (NUIs) allow users to perform different actions in the game as they would do so in the real world. We have integrated the Microsoft Kinect into our game, and implemented a Unity package based on the official OpenNI wrapper for Unity along and the

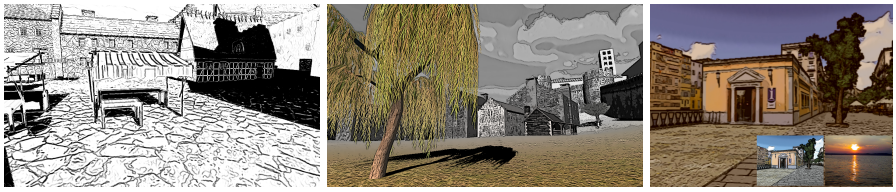

Fig. 6. Stylized renderings of Legends of Girona (left to right): black and white, depth-based desaturation, color style transfer.

NITE middleware that supports control by user gestures. The package contains a compact Kinect control object dealing with user selection, skeleton extraction and gesture tracking and providing a selection of gestures that can be added to any scene using drag-and-drop. The Kinect control integrates seamlessly into the system, it works in conjunction with the standard mouse-keyboard input without any modification of the underlying game logic.

Game control in Legends of Girona consists of navigation (moving, rotating and jumping), interaction with game objects and help (world map and quest log). Our implementation is an "exergame" requiring the user to mimic the real world actions, for example, walking in place toggles the avatars forward movement, jumping makes the avatar jump and opening the map requires the arms to be spread (similarly to holding a large map). Figure 7 shows examples for the different gestures in the game. The performance of the game was not significantly affected by the use of Kinect.

Fig. 7. Examples of Kinect gestures (left to right): jump, walk, open map.

2.6 Immersive displays

Immersive displays surround the player and provide a better viewing experience. Figure 8 shows the devices we support. We have developed a unity package which can integrate easily in existing in games and add the required functionality to display in immersive displays. The package consists of a cubemap-generating

game object and a set of post-processing GPU shaders to generate the final image (some details on the internal structure of the package can be seen in [1]). In a 3.1 GHz Intel Core i5 Mac with 8 GB of RAM and an AMD Radeon HD 6970M with 1GB of RAM, the game can be rendered at 200 fps in a flat monitor, while the Dome and immersapod visualizations render at 66 fps. The reduction in performance is compensated by the increase in realism, and in any case does not impede gameplay.

The result of the shader for Dome devices can be seen in figure 9 (left). The corresponding images for an immersapod device can be seen in figure 9 (right). The deformed images shown here correspond exactly to the inverse of the transform provided by the camera lens in these devices, so the final image shown to the user is an undistorted view of the scene with a large field of view.

Fig. 8. Dome (external and internal views) and immersapod.

3 IOS Port

To port the Legends of Girona game to the iPad 2 hardware, some things had to be modified and adapted to ensure correct performance. In particular, the polygonal load, the draw calls and the memory load had to be reduced. Additionally, specific controllers were designed. The game was ported during a period of three weeks by a single developer.

The polygonal load in the scenes was reduced by simplifying some of the models in the current-day Girona level. The decorations in the Rambla street have been remodeled, and the tree models have been simplified. Level three (outside of the city walls) required similar changes, plus a limitation on the number of soldiers. Furthermore, night scenes suffered from an excessive number of lights (the torches). Although Unity will disable non-visible lights, a more stringent method was developed and programmed to ensure that only the most nearby torches are active.

To reduce the memory load, in order to allow execution on the iPad 2, the resolution of all game textures was lowered, and the game audio was changed to use streaming from disk, alleviating the memory pressure. The current-day Girona level required more drastic measures: the scene was changed to take place during the evening, in order to justify a decrease in visibility. The far

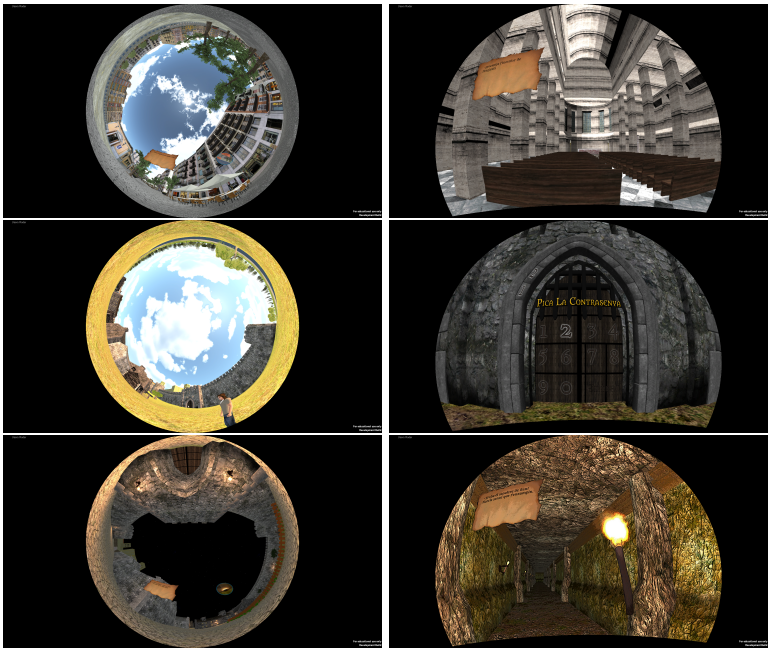

Fig. 9. Output of the shader for visualization on a dome (left) and immersapod (right)

plane of the camera was reduced to a quarter of the original distance, and black fog was added to hide the transition. The number of loaded textures was thus sufficiently reduced to fit the whole scene in memory. However, during scene transitions both scenes are loaded, so in order to avoid this (which would put the memory use above the permitted limits) a new, empty scene was added to enable the unloading of all the resources from the previous level before loading the next one.

To adapt the controls, the solution chosen was to add two simulated analog controls, one on the bottom right corner and another one in the bottom left corner of the touch screen. The right one controls the movement of the player while the left one controls camera rotation. To ease gameplay, the actions to take and activate objects, and to talk with other characters, are now performed automatically when the player comes in close vicinity to them. The gameplay has also been changed to use a first-person perspective in all scenes. The game performance is 25-30 fps, so playability is conserved.

4 Conclusions and future work

We have shown the detailed architecture and design of the Legends of Girona game. The main purpose of this serious game is teaching the history and legends of the city of Girona to high school students, while providing an enjoyable

experience. We have shown how advanced graphic effects and new interaction devices can be included in a straight manner into the game, and how to port the game to mobile architectures.

Our future work will focus in two different aspects: a) creating new content to show other historical periods and legends, and b) extend and abstract our libraries so that more graphic techniques (both photorealistic and non-photorealistic effects) and other interaction devices and techniques can be integrated seamlessly into games.

5 Acknowledgements

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