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Real Positioning in Virtual Environments Using Game Engines

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Abstract

Immersive virtual environments offer a natural setting for educational and instructive experiences for users, and game engine technology offers an interesting, cost-effective and efficient solution for building them.

In this paper we describe an ongoing project whose goal is to provide a virtual environment where the "real" location of the user is used to position the user's avatar into the virtual environment.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism

1. Introduction

Only until few years ago, using 3D videogame engines to create immersive environments was a sparely used technique in spite of the commercial success and the high level of photorealism that is achieved by current software/hardware technology.

More recently, interest has grown on the efficiency and photorealism that can be provided on inexpensive hardware by using engines. Several (so called) "Serious Games" have been studied, and the interest is witnessed by the crowded tracks in the Computer Games Conferences (in the last few years) and by the growing number of non-ludic applications that are based on 3D videogame engines (see, e.g., [ABDF, CS02, MH]). In general, several reasons and experiences support and strongly lead [ADES05, ADE*05] to use videogames technology for the development of virtual environments. By "virtual environment" we mean a 3D world rendered through a computer which provides highly interactive experience to users who navigate it and prefer it to the often abused "virtual world" or "virtual reality".

In general, various arguments are supporting this view: *(a)* the presence of development tools (e.g. map modeler, exporter from/to modeling software); *(b)* support for modern graphics hardware; *(c)* scripting language providing great expansibility.

In this paper we present techniques for integrating real (i.e. physical) positioning within virtual environments based on videogames. Namely, we present an architecture and some current developments that are meant to ensure that the feedback and the immersivity of a user is depending (also) on his/her position in a real, physical environment.

Adding location awareness means to provide a context to the information that is delivered to users. In general, it is a considerable improvement on the usability and efficacy of a system that has to convey consistent amount of information to users. As a matter of fact, while this is true for several network activities (think of a WWW query on a search engine for a good and for the contextualization of providing the cheaper price the user can buy it, within 10 Km radius) it is as well recognized, in psychology, that the effectiveness of immersive virtual environments in studies on spatial cognition and orientation [LBB99] is, indeed, positively influenced by the positioning.

In fact, introducing real world positioning is meant to enhance the quality of the experience, by augmenting the psychological proximity [Sch05] of the user that is able to relate

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his/her own position in the real world to what happens in the virtual environment.

Our study is meant to ensure that the same objectives can be effectively, efficiently and smoothly delivered by videogame engines. Examples of similar ad-hoc architectures are shown in [NYH*03]. We describe how to add positioning features within a game engine product, by describing the current status of an ongoing project, PaestumGate, that is meant to develop a virtual visit assistant to the archaeological site of Pæstum in south of Italy.

1.1. Paper organization

Section 2 contains a detailed description of the current state of the reconstruction of PaestumGate. In Section 3 we describe how the UnrealEngine can be programmed to be made player-position aware and describe the application to PaestumGate that are under development. The final Section 4 outlines future possible research applications in this area.

2. The Virtual Reconstruction of PaestumGate

In this section we describe the virtual reconstruction used for ours purposes. For more details, the interested reader can consult [ADES05, ADE*06] or the web site [PP].

2.1. The Ancient Town of Paestum

The town of Poseidonia was established by Greek settlers around the end of the seventh century b.C. on the left side of the river Sele in the Salerno gulf, south of Naples (in south Italy). The town flourished in the successive centuries because to its wide territory and to its agriculture and was embellished with magnificent temples.

In the fourth century b.C. it was occupied by an italic people, the Lucanians and, successively, since 273 b.C., it became a Roman town and its name was changed in Pæstum. The Romans changed the aspect of the city and (with evident symbolic reasons) removed some of the most important monuments that represented the Greek autonomy. The Romans built several new buildings like the *Forum*, the *Comitium*, some *Templa*, the *Curia*, the *Amphitheatrum* and the *Thermæ*. The maximum prosperity of the town was reached in the last century of the Roman Republic until the firsts two centuries of the Empire (100 B.C. - 200 A.D.). Today, Paestum is one of the most famous and important archeological sites in Italy. The ruins of Paestum (see 2.1) include the walls (long about 5km), 3 well-preserved temples, the amphitheatre and other minor remains like religious buildings.

2.2. The Game Engine

The interactive reconstruction has been implemented using UnrealEngine 2 (*UE2*) Runtime Edition from Epic Games [Unr]. The first version of UnrealEngine has been made

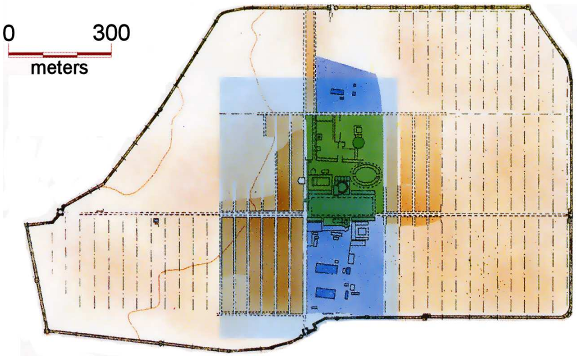

Figure 1:

A Posedonia-Paestum map. In green and blue major greek and roman buildings. In red the urban zone.

available in 1998, since more than 2000 releases have succeeded. Epic is about to release UnrealEngine version 3. UE2 is the current version, and, as discussed in [ADES05], it is a modern videogame engine that can be fruitfully used also for other purposes. This means that, within the common interface of a programmable system UE2RE provides specialized engines for physics, sound, world animation etc. . . that are the main functionalities needed in a videogame but also for any interactive virtual reconstruction. Among the most interesting general features, we would like to emphasize the following ones:

- *Tools.* Developments tools are a fundamental aspect of every game engine because they provide an integrated environment to enable rapid development of games exploiting core functionality of the game engine. Then, tools allow reducing costs and complexities which are critical factors in the video game industry.
  UE2 provides an integrated development environment through a content creation tool called UnrealEd. It allows exporting and the visual placement of the objects modeled with 3D editors. Furthermore, editing of behavior objects such as triggers, players, non-player-character or new customizable properties designed via UnrealScript are fully modifiable inside UnreadEd.
- *Programmability.* Unreal Engine supports UnrealScript as built-in programming language for third-party developers. It is object oriented and has a syntax similar to the Java programming language. The main goals of UnrealScript is in supporting concepts of time, state, properties, and networking which simplify considerably the game logic programming as for instance triggers, artificial intelligence or network replication of the data. An interesting feature is the network socket support which permits data communication over a network with a server or client written in any programming language. This feature has been leveraged

in order to obtain the location-awareness we are aiming to.

- *Licensing policies.* The version 2 of UnrealEngine has been made public with an appeal licensing policy: there were two licenses, a free one, dubbed "Demo Version" targeting a student audience, particularly suitable for universities' game design courses and a "Registered Version", which costs 7999$. The Registered Version allows to distribute an unlimited number of clients as long as the product is not a videogame (in the stricter sense).

2.3. Virtual reconstruction

The reconstruction of the archaeological site is completed and in Figure 2 is shown a panoramic view of the city. In [ADE*06] we report how the programmability and the general flexibility of UE2 have allowed to develop a system in which professional figures can convey their knowledges and skills to develop a product that can be considered "sound" from various points of view:

- *Technological level*: UE2 manages various typology of geometries static meshes, CSG and Heightmaps. UE2 supports dynamic lighting on all geometry types. The light within the scene can be provided as directional lights, point lights and spot lights. More complex lighting effects can be obtained using projected textures (e.g. the shadow produced by a tree foliage). Various "special effects" are available to increase the visual appeal of a the final results, in particular, is possible to use particle system to simulate things like flames, fluid surfaces dynamically deformed can reproduce the water surface of a lake or a pool. In a virtual reconstruction, further than the details provided by the geometry, also the texturing has a great importance. In particular experimented how the texture details, whose UE2 was capable of, was suitable to represent particular artifacts like crockery and vases. The maximum resolution for textures in UE2 is 1024x1024 pixels. A fundamental gain in using a UE2 as a framework to develop virtual environments is the support for network gaming, an UE2 server is able to support up to 64 players.
- *The psychological level*: PaestumGate, as an immersive virtual environment, provides an excellent bridge between knowledge contents (historical and archaeological) and several essential psychological features of a successful learning process. The reconstruction is a gratifying background for educational activities. The quality of virtual reconstruction allows the learners to have an impressive sensation of "real participation". As contemporary educational psychology extensively highlights, the importance of the participation (physical or virtual) is one of the necessary conditions of learning. Situated Cognition and Activity Theory represent two of the significant paradigms that suggest an idea of learning as "apprenticeship". Apprenticeship is to consider a process that may reflect the "participation" to the more efficient modes of learning involved in everyday situations.
- *The historical level*: The importance of a reconstruction. The virtual reconstruction of Poseidonia-Paestum has to face an important historical problem: the structures, whose rests are present in the archaeological site, belong to different epochs of the history of the town. In the Poseidonia-Paestum site have been found at least three different levels of exploration: the Greek-Lucanian, the Republican Roman and the Imperial Roman. This is a problem quite common among archaeological sites that had different dominations along centuries, and the casual tourist rarely is aware of this phenomenon. To tackle this problem we have fixed some didactic goals: the ability of orientate oneself in the ancient town and in its history, the ability of identify the urban environment through the various epochs, the ability of identify the most important monuments and archaeological find. In our opinion meeting these goals in a reconstructed town would enable the tourist to visit the archaeological site with an increased awareness.

3. Real Positioning in a Virtual Environment

The goal we are aiming to is to let a tourist to visit the Poseidonia-Paestum archaeological site carrying a lightweight tablet PC to provide, together with the visit to the real site, a virtual visit to PaestumGate. This scenario of use suggests several applications that we will describe in details in the following sections.

One of the most recent application is *location based games* called also Urban Game [Dun05] in which the gameplay involves the player's location obtained using some kind of localization technology. An example of such application is Geocaching [Dye04] a kind of treasure hunt played using hand-held GPS receiver and Pac-Manhattan [PM] where players play a real live version of Pacman. Another example of augmented reality environment is Human Pacman from the Mixed Reality Lab of University of Singapore [Hum06]. In these applications the location awareness was provided by GPS receivers plugged into mobile phones or PDAs. Because of the small screen size of these devices and the low computational power these games were usually oriented to provide an appealing gameplay rather than immersivity using, for instance, role-play-game elements. We think that the growing interest around these games will increase further as along as full fledged graphics cards will become available on mobile phone or PDA. In this scenario location based games will be able to use the world as a game board and the mobile phones as a sort of 'head up display' as an interface to the game.

Location tracking. There exist different methods to track user position within a bounded geographical areas. We are currently investigating two of them in order to have suitable solutions for both indoor and outdoor use: GPS [PS96]

Figure 2: *A landscape view of the reconstructed Poseidonia-Paestum. The builts Amphitheatrum, Forum, Comitium and some Templa are visible.*

for outdoor and WiFi (IEEE 802.11) tracking for indoor and outdoor. Using this tracking methods on users machine is cheap: GPS antennas cost around 50$ while WiFi cards are commonly available for free in laptop.

While GPS is a well-known and widespread system for users tracking, based on the time a signal takes to reach the earth surface from a satellite, WiFi tracking deserves some more explanations.

Several techniques can be employed [TS05]. The simplest is the association method that bases location on the association of the mobile device with a specific access point, but it does not provide the needed granularity and precision.

The propagation method uses the trilateration to calculate distances from a WiFi antennas and a some fixed position WiFi access points. This method bases the estimates of the distance on the degradation of the wireless signal in an ideal propagation model. Several attempts have been made to use a more realistic model, such as RADAR project [PP00] that proposed a Wall Attenuation Factor to take into account the obstacles that are present in the environment.

Also empirical methods are used such as multipath location fingerprinting that consists in collecting a rectangular grid of measures of the received signal strengths and relating the known values to the grid, using the multipath propagation of the signal (i.e. the signal is bounced back by several objects and received multiple times).

In general, the methods above can be used also with more precise measures such time-of-arrival (TOA) or time-difference-of-arrival (TDOA) where the time a signal requires for traveling (or the difference between measured times from several stations) infers the distance. The precision of these measures comes at the cost of deploying a well-equipped computing infrastructure for the synchronization.

Figure 3 illustrates the architecture of the system: the tablet PC carried around by tourists contains to main software pieces, the actual UE2 client, which shows the virtual reconstruction, and the Location Awareness server (LAs) that injects into the UE2 client the location coordinates it obtains from the tracking system (GPS-based or WiFi-based). The link between the UE2 client and the Location server works over TCP ports within this same machine, this method has some useful results: independence from the server actual implementation, generality respect of the actual way the location information are obtained.

Our prototype will use WiFi tracking service offered by the Alcatel OmniAccess 4308 (OAW-4803) switch that coordinates the data coming from 16 access points. The access points contains the antennas used to implement the trilateration.

Deployment issues. Another point that must be taken into account in choosing a location tracking system is to evaluate the impact of the installation in the area we intend to trace. For GPS the installation is null, because the system relays on satellites which are available worldwide.

On the other hand, WiFi tracking system installation can be quite invasive because its precision relays on a variable number of fixed access points; the number of access points depends on various factors like surface area, typology of the obstacles and number of clients. Installing an access point in an archaeological site like Poseidonia-Paestum can be a complex issue: the installation must be very respectful of the artifacts (e.g. column, walls etc...) and has to take into account the aesthetic of the site itself. Moreover, bringing electrical power to the access points and antennas can be extremely challenging, given the strict requirements of non-intrusiveness in the archaeological site.

3.1. Implementation details

As already said, we are planning to use at least two different methods to trace user position. For this reason we have implemented a tracking system independent solution for using location data within the game engine.

UnrealScript provides a basic network support through TCP and UDP communications, two classes `UDPLink` and

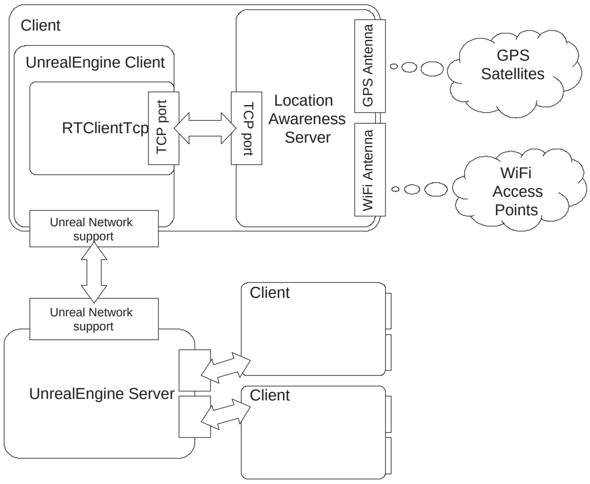

Figure 3: *The architecture of the system: in the upper part the details of a single client implemented on tourist tablet PC, in the lower part the UE2 Server, on the right the tracking system.*

`TCPLink` are available to the developers. We used `TCPLink` to connect to the LAs running on the same TabletPC the tourist brings. The LAs that is contacted by the UE2 client is in charge of obtaining the real world positioning. Several choices are available. The server can query a GPS receiver, possibly enhanced by additional hardware in order to use Differential Global Positioning Systems (DGPS) in order to improve the precision. It can also rely on magnetic compasses to derive the direction. On the other hand, the server can use WiFi location tracking, either by monitoring different access points and providing client-based evaluation of the position by trilateration, or, as in location-tracking appliances like Alcatel Omniaccess 4308, it can query (via Web Services, for example) the position of its client. Once data are collected the UE2 client is able to move the tourist avatar inside the virtual reconstruction. An avatar driven by real coordinate is managed in the same manner as every other player present on the map.

3.2. Location based visit

The user experience we are aiming to is to provide tourists visiting an archaeological site a TabletPC, equipped with the suitable location tracking technology, that will accompany him during the visit. The tourist will be able to check the virtual reconstruction as along as he walks in the site. It is worth noting how the virtual reconstruction can be a platform to provide the tourist different information on the place he is visiting, not just the 3d vision: panoramic view of the site, historical information, reconstruction of citizens' lives through non playing characters [ADES05] (e.g. a religious ritual kept in the temple the tourist is visiting).

3.3. Location based games

In the virtual environment Unreal Script is used to create a narration driven by trigger. When a trigger is touched by a valid object (usually a player) it causes a certain event to be started. This kind of programmability is the backbone of the narration that involves the player visiting the virtual environment. In order to create a location based game, is possible to embed this scenario directly in the site (obviously where is possible) considering the tourist location. In this way, a big game is created transforming the entire heritage site into a large board game.

Triggers placed inside the virtual environments are fired each time a visitor 'touch' it in the real environment. Using a Tablet PC which furnishes the 3D reconstruction the visitor can orientate itself inside the site. The visitor can be involved to accomplish some sort of tasks inside the site taking really part into the narration of the story. As a result, the archaeological visit is proposed to the visitor as a sequences of steps, historically motivated, whose goals are to engage and stimulate the visitor to explore the site and participate to its daily life. Several tasks are possibles using this idea: search for the Temple of Athena, find all roman monuments, take a vase and search for the perfume store where deposit it and so on.

Furthermore, this approach allows collaborative practices. As for instance, two groups of students can share their visit by using the Tablet PC and a GPS receiver for each member of the group. In this way each other avatar or student is visible inside the virtual environment allowing collaboration into the tasks. Or as a students walks into the site, she/he can put some objects into the virtual environments which can be subsequently taken by other students. This idea allows to organize an archaeological treasure hunt using typical artifacts like vases, statues, bowls and so on.

4. Conclusions

Among the future work, it is planned to experiment in a mixed setting, where different technologies are used for the location tracking (i.e. GPS outdoor and IEEE 802.11 indoor) and the server should smoothly offer the interoperability between the two technologies, by providing a unique interactive experience to a user that moves from the exterior (i.e. the archaological site) to the interior (i.e. a museum) (in the real as well as in the virtual world).

Future works include enhance of the overall experience of the visitor of the heritage site by providing augmented reality in the same spirit of ARCHEOGUIDE system [VIK*02]. In order to use state-of-the-art game engines, this idea must takes into account the tradeoffs between fat clients equipped with recent GPUs and thin clients equipped with integrated graphics card. The main goal remains to provide a high quality 3D reconstruction through game engines.

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