VIRTUAL RECONSTRUCTION OF ROMAN MILITARY APULUM CAMP

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ABSTRACT:

We based our research on the Roman Apulum Castrum, located in Romania, in one of the oldest city in Transilvania, Alba Iulia. The XIII Geminae Legion was billeted here in one of the major Roman stone camps existing during the years when Dacia was a Roman province. Two roman cities, first Municipia and later Colonia, have developed near the Roman camps, into the fortress. The settlings became two of the most wealthy and important places of Dacia - ("Chrysopolis" 251-253 d. Chr.) - outstanding in diversity and the novelty of the local civilization.

The case study is based on archaeological researches in the South-Eastern half-part of the Mures river terrace, occupied in the 2nd Century b. Hr. by the Castrum and Canabae of the XIII Roman Legion Geminae. The Apulum Castrum has been built in 107-108 B.C., having both military and strategic or economic and commercial aims. In *Figure 1,* we presented a 3D reconstruction of the Apulum Castrum, looking from the Southern gate. Archaeological researches on the Apulum site were difficult because of successive overlapping of building constructions: on the same site at least three different citadels were built in the Middle Age and feudal period. All excavations needed depth of 2 meters or more to discover the Roman age. Starting with 1889, when Adalbert Cserni made the first digging in the area, he found the big blocks of stone, in neighborhood of the Southern gate, Porta Principalis Sinistra. Temples and polychrome mosaics, thermal baths, statues, amphitheatres, porticos, the governor's palace "Daciarum Trium" and external Canabae - these would be, briefly, the synthesis of this important military-political, economic-commercial and cultural-artistic centre, the miniature copy of mother Rome.

The application is structured in 3D reconstruction of landscape, graphic engines, programming interaction with the objects using voice or text, movement and interaction with movement devices proposing a virtual tour in military camp. The modular structure of the project components allows modification of the content, object interaction and dialog graph content. These mandatory guidelines are provided for preparation of physical interactions with objects in virtual environments. The virtual environments offer a good opportunity to change in real time some interaction factors like distances, speed and lighting. The application uses the free Irrlicht engine for rendering and sound interaction. The scenes contain various objects with various properties and also many types of interaction like text, sound or 3D moving objects. The application is organized into an XML database. By changing the landscape each object is reconstructed. The interaction with the objects is defined by skyboxes with different forms.

1. INTRODUCTION

1.1 Considerations on the General 3D Visualization

The development of the graphic devices between 2D visualization to the 3D one in the '80s covered various area of interest in sciences, simulation and Computer Games. New kids generation all over the world knows and tries different game systems. This means that 3D graphics and computer game simulation become a daily experience or even part of everyday life. Teachers in schools, visitors in museum, architects in reconstruction, engineering in simulations use 3D reconstruction and visualization.

Different components of the environment, pushed by a strong economic interest, are strongly connected to entertainment and to research and theoretical investments too. Archaeological, historical and artistic fields started their experiences in computer graphics and 3D visualization in the same period (L. Calori, 2003).

We would like to underline the importance of the Virtual Reality systems even from the cultural point of view. The museum activities become closer than games, the kids and teens like to "play to learn", interaction and environment feelings become a necessity for attractive learning activities.

Historical sites from Romania are poorly presented using 3D methods, one of the main reasons being the high performance requested for the computer structures and graphic devices that means high costs in developing projects of this type.

Our research and project start to develop also 3D reconstruction and interaction with object less than using high performance haptic devices but are well prepared, theoretically, to be included in such a project.

We are also interested in simulations and special 3D archaeological graphical reconstructions.

1.2 Aims Proposed

This paper proposes some theoretical and practical methods to create an interface between heritage activities and game interactions. First of all we create the landscape of the action, The Roman Citadel Apulum (Castru Roman Apulum, in Romanian), the Roman 13-th Legion Fortress, placed on the Alba Iulia city hill, in century II A.C., with the main buildings as they appear in the archaeological researches. Based on this reconstructed 3D environment, we place some ancient people and artifacts created using 3D Max Studio or Maya applications. According to archaeological information about position or temporal placements of the ancient artifacts we propose a real time interaction using three different types of interaction: selection of the object and its movement using a scale, rotation or translation, interaction with an object using

haptic devices and real time dialog using a graph dialog with both text and sound.

The application is created using open source software modules and free engines.

The research aims consist in offering an interactive, integrated, updatable, educational and open system for using real time interaction with objects in recreated virtual environments.

2. THE RECONSTRUCTION

2.1 Considerations on archaeological research

We based our research on the Roman Citadel Apulum, placed in Romania, in one of the oldest city in Transilvania, Alba Iulia.

The city is situated at an old gold and salt commercial crossroad, into the perimeter formed by the rivers Ampoi and Sebes and the peaks of Apuseni Mountains, erecting mildly and lithely towards the terrace of the river Mures and the Transylvanian Hills.

The gentle climate and the richness of the soil rendered in this area made it habitable even since ancient times. Archaeologists register rich vestiges of the material culture - dating since Neolithic, Bronze Era, Hallstatt, Latene and Middle Age - undeniable proof of our continuity in these territories.

The tribe of the Dacians from "the far-off Appulus" is mentioned in "Consolatio ad Liviam - Poetae latini minores", and the geographer Ptolemaios revealed in his "Geographical Guide" (written in the first half of the second century) the coordinates of the city: 49°15' longitude - 46° 41' latitude.

The XIII Geminae Legion is to be billeted here in one of the major Roman stone camp during the years Dacia was a Roman province. Along with the Dacians, the new comers (the Romans), "ex toto orbe romano", are the ancestors of the Romanian people, appropriating the Dacian ancient topological name of Apoulon (a fortress situated at Piatra Craivii, 20 km North from Alba Iulia, which became the Roman Apulum).

Two roman cities, first Municipia and later Colonia, have developed near the Roman camps, into the fortress, but also nearby Mures River, in Partos.

The settlings became two of the most wealthy and important places of Dacia - ("Chrysopolis" 251-253 d. Chr.) - outstanding in diversity and the novelty of the local civilization.

Figure 1 – Apulum Castrum, Southern Gate, *Principalis Dextra,* reconstruction based on the architectural research

The case study is based on the archaeological research in the South-Eastern half-part of Mures river terrace, occupied in the 2nd Century b. Hr. by the Citadel and Canabae of the XIII Roman Legion Geminae. The Apulum Citadel has been built in 107-108 b. Hr., with both military and strategic or economic and commercial aims. The first stage of the Citadel was only earth-like constructions having a base of 8.7m width and 3.7m height, stone Citadel being built on top of the same. The calcareous stones that were used lately were brought here from Sard, Barabant and Ighiu stone quarries.

Reconstruction was started with the Southern Gate, *Principalis Dextra*, Figure 1, 10.2m opening, double entrance, each being at 4.2m distance from the 1.8m thick wall. The entrance consists of two towers flanking the same, sized as 8.4x6.6 m inside and 8.2x6.3m outside (Moga V., 1999).

Recent discovered new sites prove that it had a rectangular shape, 440m on the east-west side and 430m its north – south side with the similar orientation like common roman citadels from Inchuthil (Piñata Castra, 477x463m) in Britannia, Bonn (Bonna, 520x515 m) in Germany or Vindonissa (Windich) in Switzerland and Vindobona (Wien) in Austria where XIII Geminae Legion passed trough during the first century (V. Moga, 2002, p. 45).

The *Praetoria* and *Decumana* Gates were placed in between the sides, *Principalis Dextera* and *Sinistra* Gates being 2/3 of Southern and Northern sides, respectively. In *Figure 2,* we present a part of "Pianta D'Alba Iulia" the first and the oldest map of the city designed in XVII-th century by an unknown Italian engineer, in which he placed two important buildings of the Citadel in the upper right site inside the castle and also the buildings placed around it, A - Castello, B - Grand Chiefa, e Palaszo del Principe, C – Citta (down town) and D – Chiefa de Greci on the Northern part of the Citadel.
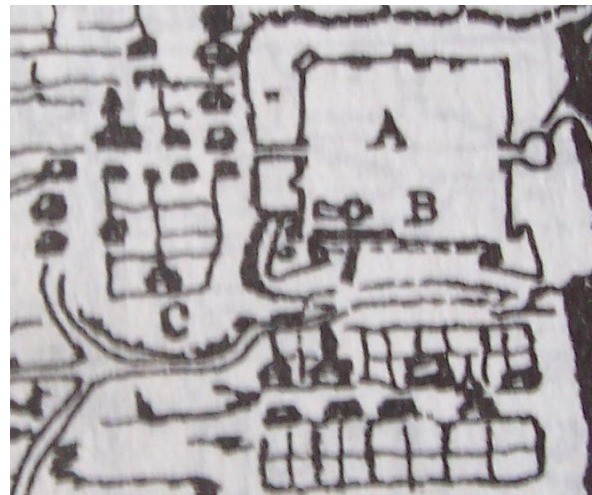

Figure 2 - A section of the "Pianta D Alba Iulia", XVII century (A. Kovacs, 1984, Gh. Anghel, 1985.1)

Archaeological research on the Apulum site was difficult because of successive overlapping of building constructions, on the same site at least three different citadels were built in the Middle Age and the feudal period. All the excavations needed a depth of 2m or more to discover the Roman age. Starting with 1889, when Adalbert Cserni made the first digging in the area, he found the big blocks of stone, 1.5 to 2m long and 0.80 to 1.5m high, in the vicinity of the Southern gate, Porta Principalis Sinistra (V. Moga, 2002, p. 47).

The important researches in the area were started in 1966-1968 when important utilitarian constructions started in the zone. Other three gates were discovered and also observation towers,

the rectangular houses ("bordei" in Romanian), building walls were constructed in *opus quadratum* style and *emplecton* (the core) in *open signinum* technique. The wall height was preserved as 6 to 7 m and three abutments were found in the exterior of the wall. The wall thickness was 2.1 m. Some stones had Aurelius Godes worker inscription, huts, ceramics, epigraphic monuments, coins chronologic evaluated from Hadrian to Gordian III and different sculptural monuments.

Building materials were carefully analyzed starting with land construction, stone dimension and construction style for texture composer. Also we developed a long research in the museum exhibitions to take photos and prepare good picture for the original bricks, tiles, pavements or stone pipes.

Temples and polychrome mosaics, thermal baths, statues, amphitheatres, porticos, the governor's palace "Daciarum Trium" - that would be briefly the synthesis of this important military-political, economic-commercial and cultural-artistic centre, the miniature copy of mother Rome.

2.2 Reconstruction and 3D modeling

The historical materials were carefully analyzed and the reconstruction was started with students from computer science specialty together with historical researchers working in the project "3D Virtual Museum", financed by the European Union, through "The National Cultural Found Administration", in 2007 - 2008.

The modeling has to decide between low-poly and high-poly object reconstruction. Our purpose is to offer real time interaction in this environment that we chose for representing the objects in low-poly format. Because our interest aimed the real time interaction with the objects and our platform uses different landscapes or environment reconstructed, we presented the archaeological studies briefly, mentioning that the whole reconstruction was made by rigorous documentation in cooperation with "Muzeul National al Unirii" (The Reunion National Museum) from Alba Iulia, coordinated by professors V. Moga and I. Lascu.

We chose to reconstruct the Roman Citadel, Roman Temple, Roman huts, cereal hangars, market places, roads, Roman houses and the headquarter villa. In the building reconstruction we kept the balance between efficiency, visual aspect, UV-layout, dimensions and scalability. Each object in the environment has less than 500000 polygon lines depending on its relevance in the context. Also, we have rebuilt various artifacts.
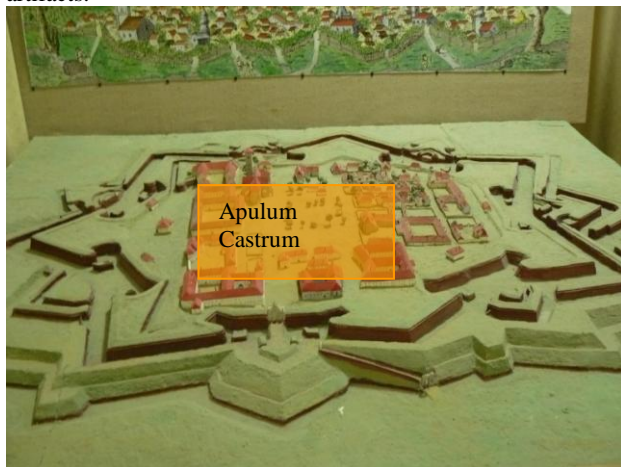

Figure 3 – Apulum Castrum location castrated in medieval map

We used for reconstruction 3D Studio Max and Maya applications converting each object in an individual, identifiable and unique component in the environment. The objects are designed using three different methods: frame interaction, 3D object interaction and dialog interaction. In *Figure 3*, we present the layout of the 17 th century map of the arrea where Apulum Castrum were rebuilt. The area was marked with sepia.

2.3 Interaction with objects

In the section below we talking about tree type of interaction with objects and environment similar with game interaction we propose. Because this application has an educational purpose we combine the game facilities with learning techniques and also interactive interfaces. All the interaction is based on the intersection between collisions mesh of the objects and collision ellipsoid of the camera.

Interaction with frames is based on the collision mesh integrated with The Irrlicht Graphic Engine. It is completely cross-platform, using 3D, OpenGL and its own software renderer, and has all of the state-of-the-art features which can be found in commercial 3D engines (N. Gebhardt, 2007).

Interactions are generated by the collisions of two or more than too collision mashes. We define camera to be the visitors, the player in the environment, ho has their own collision ellipsoid mash. The player can change the axis radius of the ellipsoid in real time using a short key on line. In that case a menu appear and player can change some futures of the environment like distances, light, visibility radius, frog or other parameters. When a collisions, ore more, appear the player may choose witch collision is interested for them and start the action specific to this selected collision.

Interaction with frame generate text or sound explication about the environmental or object interactions, storage in text or sound file each of them identified by unique ID. For each collision mash defined, also for frame, object or persons, is ID defined storage in the xml file (in the section data base and algorithms we explain the used technique).

In order to launch the event associate with the frame, object or persons interaction is defined a database trigger, a procedural code that is automatically executed in response to certain events on a particular table in database associate.

An interaction with object is similar like the frame interactions execute a trigger associate in two different ways. If the haptic devices are note connected to the computer a window appear on the screen containing 3D visualisation of the object guided by tree scroll line corresponding to rotation horizontal, vertical and scale object.

Interaction with persons is dialog based. In the Figure 4 an object interaction occurs with person. A trigger is launched with possible questions, answers and written text or sound dialog. The sound dialog is based on two different forms. Interaction with frames generate an explanation form both text and sound without outside interaction. Interactions with person generate both text and sound interactive dialog based on the graph dialog stored in the data base. For the beginning we have started with storage interaction dialog, but for the future we intend to develop an artificial intelligent system to upgrade the person knowledge in real time.

The dialogs contain educational questions and answers guided in to graph dialog based algorithm.

3. DATA STRUCTURES AND PROGRAMING

Our research is based on the simple and quickly data base access, open structure, free software modules, free engines and C# programming language application.

3.1 Data base structures

The data base structure is html oriented based, easy to update, universal recognized and program languages interpretable. We choose that way to organize data because classical data structure means servers or local data files access increasing time transfer and data search. The data base is structured in different html file with two types of data, each of them heaving similar structure. The structure for objects are described in Formula (1) and explained below.

Example:

```
<Object type="menu"
id="1"
mesh="../final/moneda1.my3d"
mesh_viewer="../final/moneda1v.my3d"    (1)
mesh_ viewer_scale= "2 2 2"
desc="Test text moneda 1." />
```

where

Object type = define the objects type, that may be menu, person or different objects defined
id = is numbered identification of the objects
mesh = contain the path to identify the mesh file
mesh_viewer = contain the path to identify the mesh viewer file
mesh_ viewer_scale= contain the path to identify the mesh viewer scale in three dimension x y z, separate by spaces

We use a binary search algorithm in the special html file to look for different elements, identified by their *id*. The object types determine the interaction type. Collision between camera ellipsoid and object collision mesh determine specific action. The action is defined by the trigger type, which may be windowed information, sound player and person interaction or object viewer interaction. The trigger data base format is presented in Formula (2).

Example:

```
<Trigger type="switch"
state="1"
id="12"
desc="Cazarma fortificata"            (2)
meta=""
visible="0"
position="-5 23 -861"
scale="2 2 2"/>
```

where

Trigger type = define de tiger type
state = the value 0 or 1 define the state of the trigger, not interaction or interaction with the object
id, desc, scale = are similar with formula (1)
meta = meta information's specify the input or output line in/off dialog graph, running parallel tasks like sound and text
visible = some elements like windows, information or menus may be invisible marked with 0 or visible marked with 1.

position = mark the real position in the tree dimensions space starting with origin in the middle of the general frame, meaning that we have also positive and negative values.

The dialog with person is structured in the html file, dialog line with dialog line, witch have a special format presented in Formula (3), presenting two examples for entrance and for exit. Lines are numbered that means each of them is an entrance in graph dialog containing the list of possible outputs line or null for exit.

Example:

```
<Line meta=""
npc = "Hello!"
pc="Question?"
vec="1,2,3"/>
<Line meta="exit"                    (3)
npc = "Answer"
pc="Bye!"
vec=""/>
```

where

Line meta = the same like in Formula (2)
npc = non playable characters, text answer to given question
pc = playable characters, possible questions
vec = a vector, containing separate by coma, possible answers line numbers, that follow the conversation starting with this question. Null is end of conversation.

Based on this data structure the player is pass question by question, answer by answer in the dialog graph. The question and answers are followed also by the sounds. The future development is to integrate the Microsoft speech but only in English. Those futures are supported by .NET.

3.2 Program structure and algorithms

Application was created using Microsoft.Net C# language, object oriented platform. To integrate de open source modules and free IRRLICHT engines it was necessary to create tree different classes.
In the Figure 4 is shown the Engines Integration Diagram. IRRLICHT Graphic Engine is the main engine in relations with IRRNEWT Wraper, providing for IRRKLANG Sound Engine resources and control.
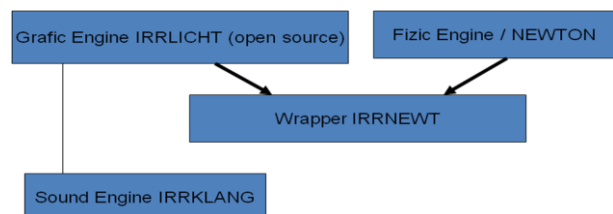

Figure 4: Engines integration diagram

Movement and motion is realized using Physic Engine Newton. The wrapper aim is to integrate objects in the frame, establish the mash for every environmental object and reconstruct the frame in real time.
We try to increase graphics loading, texture reconstruction, collisions conflicts and data base access to information or sound effects.
The application structured class based, containing *CApp*, main class, *CLevel*, designed for static geometry, objects

management, interaction with objects and dialog with persons, *CEventReceiver*, for input output management.

We had create a main class, *CApp*, with the structure designed for load settings, load level controls, get objects ID's, control the player camera, animation, viewers, image loading, trigger control. To reduce memory dimensions of the images we use crypt and decrypt methods for image loading and saving. Interactions with the objects are determined using collision mesh, bound by the 3D *bounding BOX*, like in *Figure 5*. The algorithm determine the radius R between players camera and bounding box centre, calculating minimum distances collision necessary for interaction.
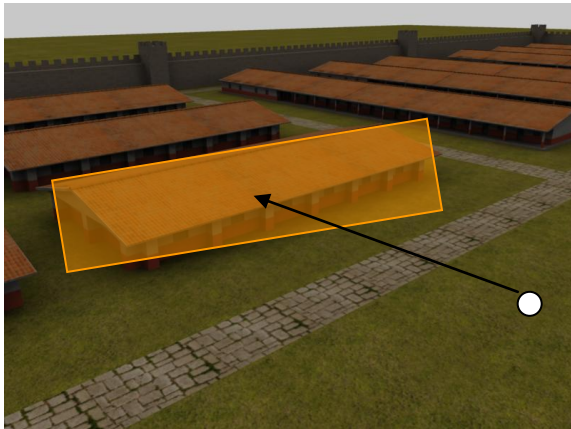

Figure 5- Distance between player and bounding boxes

CLevel class contain methods for static geometry engine methods accesses. *CLevel* class have methods designed for distance visibility and light flags.

CEventReceiver contain important methods for object triggers and associate event objects in input output devices. These methods describe and offer facility for chose different event in interactions with the objects. Interfaces are created using special windows for presentation, object interaction in view mode or interaction mode.

Important facilities developed in application are interactive menu witch offer possibility, for player, to change in time some interfaces characteristics, light effects, viewed distances, fog effects offered by Engine.

The main algorithm tries to maximize the efficiency loading scenes only if player is on the site. Initialization starts with the nearest objects from the camera loading. The mesh object on the area is loaded in scene keeping in the memory just coordinate of the objects identified by their ID's. The camera position determine the list of the loaded objects, they are loaded by the graphic and physic engine and shown. The object structure is defined by their components: Id, name, description, type, and relative position in 3D representation, mesh dimension for collisions in three directions, visibility and scene address.

Using the camera coordinates and objects coordinate the algorithm loop determine in real time collisions between camera and other objects to start corresponding trigger.

Corresponding with started trigger some windowed interfaces are displayed depending on the object interaction. The player have the possibility to interact with the object in new the window created or come back to the scene to look for another interaction. Shot keys are defined for easier interaction and rapidly interface parameters to be change.

All the futures of the application are growing up while the project is develop and we hope that interfaces are useful and easy to use for all the players.

Conclusions

Historical information was obtained with the researcher support from National Museum Alba Iulia, Ph. D. Moga Valer and ph. student Ilie Lascu. We mention that that research is financed by the "The National Cultural Found Administration", in two projects "Muzeul Virtual 3D", (3D Virtual Museum, engl.) in 2007 (www.afcn.ro/beneficiari_castigatori_sesiune_noiembrie _ 2005.php) and "Traseul celor trei Fortificaţii" (Three Fortres Ride, engl.) in 2008 (www.afcn.ro/finantari_proiecte_ culturale.).

The research is oriented to look for the simply end easiest ways to develop interactive 3D presentations used in the Cultural Heritage promotions. The combination between free software engines, interactive application and scientific archaeological documentation create a double effect. For the first time we have a good documentation and scientific support for future development of the archaeological research. On the second time we create a learning interactive scene well prepared for kids and heritage interactive presentations. The aim of this research is to obtain a real time interaction on the web using haptic devices. This platform is well prepared in that sense.

Supported be the archaeological team we try to develop a Real Time Virtual Platform for Heritage visitors on the web.

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4. POSTERS

The large architecture is presented in some posters viewed from different angles. The *Figure 6*, its show the exterior south-east corner with observation tower and surrounded by ditch defense.

Figure 6– Apulum Castrum outside view

In the *Figure 7*, we have a large perspective of the Apulum Castrum viewed from the same corner. Around these constructions we intend to reconstruct in the future the old roman Apulum town with the local flats and roman houses.
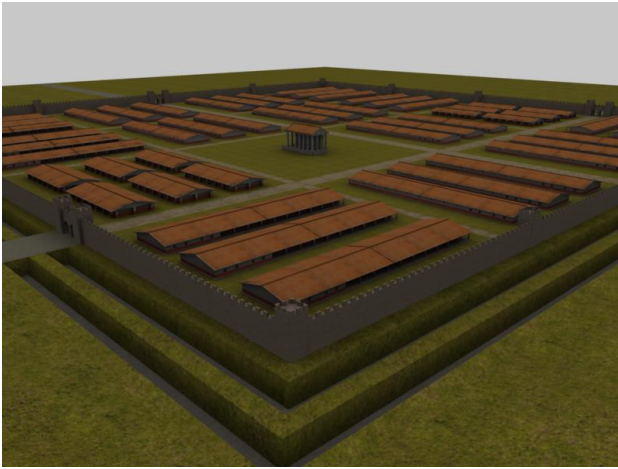
Figure 7– Apulum Castrum general view

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