A COMPUTER GAMES APPROACH TO EXPLORATORY LEARNING
LAVA: A Case Study in System Design

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Abstract: This paper presents an approach to utilising computer game technologies and methodologies to support explorative learning. This approach has particular relevance to subjects such as archaeology and geography which contain a significant fieldwork component. A detailed case study, the LAVA project, is presented and the design decisions taken discussed. LAVA was motivated by the need to provide support for explorative learning and an understanding of fieldwork for classes of students in the face of the very few opportunities available for participating in real archaeological excavations. The aim of LAVA is not to replace real world fieldwork, but rather to provide realistic simulations that allow students to better prepare for any involvement with a real excavation. These objectives have initially been achieved through the combination of a 3D game engine, 2D maps and a group-based learning environment.

1 INTRODUCTION

Computer games are engaging for their audience. They have a series of objectives which must be achieved by a player in order for the overall objective of the game to be realised. They utilise the concept of progression and advancement through the separation of objectives into a series of contiguous stages or levels and encourage exploration and character development through trial and error. In short computer games are good at providing an environment within which a player can learn how to achieve the game's final objective. Most importantly however, games are able to successfully engage with their target audience and encourage a player to progress forward.

The level of engagement that players have with computer games is often coveted by those charged with developing learning materials (Savery and Duffy 1995; Merrill 2002). There have been a number of attempts to harness the engaging power of computer games in 'edutainment' (educational entertainment) titles (Wikipedia); however most of these products have had difficulty integrating the game play and educational dimensions, and have consequently struggled to attract the desired level of interest from their target audience (Okan 2003). In many ways these failures are not surprising as there are marked differences in the way computer games and educational materials are designed.

This paper proposes, through the use of a case study, an alternative approach to the development of educational resources which allows more emphasis to be placed on the aspects of computer games that make them appeal to their target audience. It is hoped that this alternative approach will facilitate the development of more engaging and interactive explorative learning resources. Section 2 of this paper discusses the aims of good educational practice and how these can be met by games and learning environment technologies. Section 3 introduces the Laconia Acropolis Virtual Archaeology (LAVA) excavation simulator, initially focussing on the educational problem the simulator addresses before describing the software from a student's perspective. Section 4 outlines the architecture, design and current implementation while section 5 provides a brief overview of related work before the paper concludes in section 6.

2 LEARNING AIMS

The excavation simulator has been shaped to meet four pedagogical goals. The system should:

- Be engaging.
- Be realistic.
- Provide support for cooperative working.
- Promote self paced learning.

Computer games were used as a starting point for the design as they provide high levels of audience engagement. Realism is achieved by deploying a range of technologies from 3D virtual worlds to high definition photographs and maps, as shown in figure 1. A group-based framework for learning environment composition and deployment is used to provide teamwork support and to aid the integration of the different technologies in use. This is all delivered via a web interface, so "anytime anywhere" access and consequently self-paced learning is supported.

As discussed by Malone (Malone 1980), computer games can be dissected into a series of contiguous goals which challenge and stimulate the user. For a goal to be effective it must be possible for the user to identify with the knowledge domain in question and to judge their performance with respect to reaching the final objective (Malone 1980). Within each goal, the outcome of game play should be uncertain. This can be achieved in a variety of ways:

1. Through the development of different levels of difficulty that act to challenge the user.
2. By hiding and selectively revealing information within the game environment, thereby controlling the way in which the user is able to access information that assists them in fulfilling the game objectives.
3. By introducing randomness into the game play so that each time a specific scene is reached by the player, the outcome cannot be pre-empted.

Whilst the game play has a degree of randomness, it is important to ensure that the attainability of game objectives is matched to the player's ability and skill level. Successfully achieving a goal can increase a player's self-esteem and therefore have an affect on their motivation to continue, with failure in small quantities acting to enhance this drive. However, if players perceive game goals to be impossible to achieve, they will become disillusioned by repeated failures and hence become increasingly de-motivated by the game (Barendregt, Becker et al. 2006). Obtaining the optimal level of informational complexity (Piaget 1952; Berlyne 1965) is of real importance when considering in-game engagement; a player needs to be able to understand the gaming environment if they are to engage with it. By closely aligning the game goals and educational objectives, LAVA seeks to encourage players to unknowingly advance their educational progress by developing skills that satisfy the in-game challenges presented.

3 CASE STUDY: LAVA

The LAVA project virtual excavation scenario is based around the work undertaken by the British School at Athens at the Sparta Acropolis Basilica, Greece during the 2000/1 seasons (Sweetman 2000-2001; Sweetman and Katsara 2002). It has been developed to provide students with experience in dealing with the type of issues that arise during

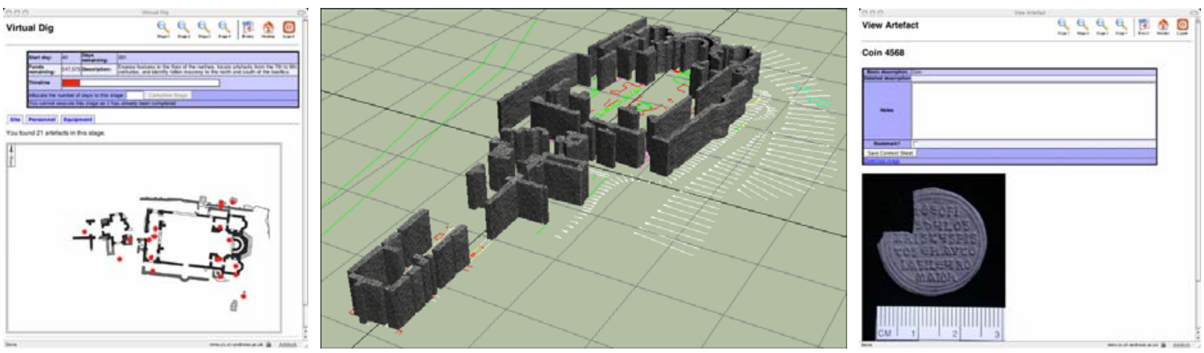

Figure 1: 2D Map, 3D Model and Photographic Artefact Screenshots.

archaeological excavation work. This aim encompasses both the practical considerations relating to the way in which the excavation is planned and managed, as well as the way in which it is undertaken.

By modelling the activities undertaken on an excavation, LAVA is able to provide students with a realistic idea of what fieldwork entails, prior to them actually taking part in a real-world excavation.

During the development of the virtual excavation, there was a strong emphasis on building the stages to closely mimic the concept of levels found in many popular computer games, with each having distinct start and end states as well as specific learning objectives and metrics against which a group's relative success can be judged. As with computer games methodology, only when a group has achieved the requisite level of competence within a given stage can they progress to subsequent stages, thereby integrating into the virtual excavation the concept of progressive skills development; a concept which is used in computer games as well as when teaching students practical archaeology on real excavation projects.

In order to complete a virtual excavation, a group must complete 5 stages within the simulation:

Stage 1: Background work; groups perform an initial review of the Sparta region to identify areas of archaeological interest.

Stage 2: Funding Application; groups undertake a virtual site visit, using the information they obtain to write a formal funding application.

Stage 3: Site Excavation; once funding is secured each group undertakes their excavation work using the excavation simulator. It is the design of this part of the LAVA software that is the main focus of this paper.

Stage 4: Publication Preparation; following the completion of the excavation work the groups are required to prepare publications to disseminate the site data discovered during their excavation projects.

Stage 5: Reflection and Feedback; the final stage of the excavation process is used to allow the groups to reflect on their performance. It also allows the students to be formally assessed by the course coordinator.

This paper focuses on the design and implementation of the simulator used during stage 3. Further information regarding the other components of the LAVA system can be found in (Getchell, Miller et al. 2006), whilst (Getchell, Nicoll et al. 2007) (to be published March 2007) discusses the evaluation of the LAVA system carried out to date.

4 THE EXCAVATION SYSTEM

There are 5 main components within the simulator:

1. A bespoke browser which provides a unified interface to all simulation components.
2. A virtual learning environment which provides support for resource development, group work and authentication.
3. A 3D game environment which provides support for collaboration and site exploration.
4. A set of 2D resources for management, exploration and reporting.
5. A database engine which maintains the state of the excavation for each group.

From a student perspective there are two views into the excavation: A set of 2D maps and resources that expose management related processes and support exploration, and a 3D first person game-based view which allows students to investigate and explore the excavation site from a first person perspective. The two distinct interfaces have been adopted to allow time to be managed by the students in a flexible way. The high-level web-based management interface allows groups to undertake time consuming processes quickly, i.e. removing top soil from the site, by short-circuiting the actual work processes. When an area of interest needs to be explored in more detail, the 3D first person perspective interface can be used, offering groups the ability to cooperatively investigate a scene in real-time. This approach allows the students to concentrate their focus on more interesting aspects of the excavation whilst getting an overview of the entire process.

To allow groups to control the excavation work, a three step process has been implemented:

Step 1: The 2D management interface is used by the group to control how much virtual time, personnel and equipment are allocated to each task being undertaken.

Step 2: The simulator short-circuits the work process, automatically performing the work required based on the time, personnel and equipment constraints specified by the group. If the group assigns too much time to the work, then equipment utilisation is low and resources are wasted. If the group assigns too little time to the work, then the work is rushed and the quality of the material culture uncovered degraded.

Step 3: Once the tasks have completed, the group are able to investigate the materials uncovered using a 2D map based interface. Within the map a series of hotspots are used to highlight any discoveries made. Group members can click on the hotspots to bring up graphical and textual descriptions of the finds. The level can also be explored from a 3D perspective, thereby allowing the group to gain a more detailed spatial understanding of the entire excavation site.

In the following sections we discuss the 3D Based exploration, game logic and underlying data structures that support the simulation engine.

4.1 3D Exploration

The 3D game-based viewport provides students with a first person perspective of the excavation site. Within the viewport they are able to interact with each other and explore detailed areas of the excavation site. The aim is to allow students to collaboratively study, at close range, areas of significant interest within the excavation. Whilst in the 3D viewport the students are able to communicate textually with each other and view each other's avatars.

The 3D viewport offers exceptional first person perspective views of the excavation site. As has been discussed by (Haggren, Junnilaninen et al. 2004), sequencing of static images can help students to build a more detailed understanding of an environment. On one level, the virtual environment displayed by the 3D viewport is directly equivalent to a large number of static images sequenced together to provide an overview of an environment. The main difference between sequenced images and the game world, is that the user perspective within the game world can be moved and adjusted, thereby allowing students to focus in on areas of specific interest. It should also be noted that, unlike statically sequenced images, the students of a particular group share their 3D virtual environment will all other group members and can, through their representative avatars and the variety of in-game communication tools, interact both with each other and also the environment as a whole.

Within the 3D viewport time is modelled in an inelastic fashion; it is not possible for individual group members to jump forward in time as this would cause problems with other group members who were not intending to progress time forward so quickly. In order to maintain consistency between group members, time is modelled in a uniformed fashion within the 3D environment. This poses a problem when it comes to undertaking slow and repetitive work; either group members will be required to undertake the work in real time, else they will have to depart from the 3D environment prior to any leap forward in time which is intended to short circuit the work process. In the current implementation, the group is provided with the 3D environment following the completion of the (possibly drawn out) preparation work which is undertaken using the 2D management interface. This separation allows the group members to jump in and out of the virtual environment as required.

During the investigatory work undertaken to determine how best to build the simulation system, a comparison between a number of popular game engines was undertaken. There are broad similarities between each of the engines in terms of capabilities as discussed in (Bishop, Eberly et al. 1998; Stang 2003). Whilst there is a whole raft of commercial game engines available, the Quake (IDSoftware) and Unreal (EpicGames) engines seem to be the most developed in terms of flexibility and usability, with both benefiting from active and responsive developer communities. It is true that there are engines such as Everquest's LichTech engine (Sony) that are able to offer enhanced performance and increased visual quality over Quake and Unreal, however, during a number of tests the performance and capabilities of the open-source Quake 2 engine was found to be adequate for the purposes of the project; the excavation simulations in LAVA are more concerned with faithful maintenance of the player-, object- and terrain-location relationship than of the ability to construct photorealistic environments.

When deciding on an engine upon which to base the simulations, the open source nature of the Quake 2 engine had a number of benefits: Not only could the engine be used without royalties, it could also be modified to more accurately fulfil the requirements of the LAVA project at a lower level than merely applying game modifications (mods). Unlike game mods, which are generally developed to slot into the top two levels of the modular game engine structure shown in figure 2 (Gamespy; ModDB), the LAVA excavation simulator has a strong educational motivation behind it. If one considers the model of an archaeological excavation outlined in section 3, there are clear areas in which the first person perspective of modern games fits in well; for example during the excavation work undertaken in stage 3. However, there are also areas in which a direct game 'mod' would be unsuitable; much of the

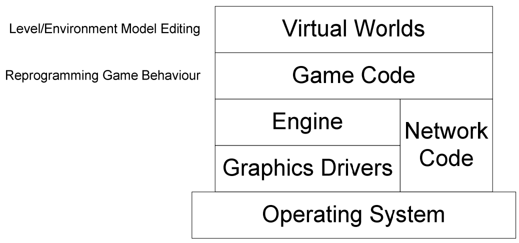

Figure 2. Modular Game Client Structure.

paperwork exercises undertaken in stages 2 and 4 for example. With these differences in mind a hybrid solution has been developed. This solution combines the advantages of 2D and 3D perspectives, with integration into our institutional Virtual Learning Environment (VLE), Module Management System (MMS) (Allison, Bain et al. 2003), allowing the simulation software to read directly from institutional data sources. This greatly reduces the need to manage user authentication and access control from within the excavation simulation itself, as many of the required protections are provided automatically by the MMS VLE.

There are two components of the 3D viewport; the client software which runs on the client machine using Java WebStart technologies and the server software which runs on the MMS server and integrates with the MMS database using an XML based API. In the current implementation, both software components are based on a Java implementation of the Quake 2 engine. A Java implementation was chosen in preference to the original C implementation as the rest of the MMS framework has been developed in Java and by having a unified development language, component integration was more straightforward.

Within the 3D viewport students are able to explore and interact with the excavation environment, but are unable to instigate changes to it. This limitation is due to the way in which the MMS management interface and 3D viewport coexist. The API presented to the 3D environment allows data from the MMS database to be read, but does not allow the 3D viewport to submit changes to the environment to the MMS database. This separation of management and exploratory work helps delineate the roles that the members of an excavation team perform within the site itself by forcing the students to adopt a role suitable for the task in hand.

4.2 Game Logic

The game logic allows the success of the excavation to be scaled in relation to the appropriateness of resources applied to it, and introduces a level of randomness that ensures that no two excavations will be carbon-copies of each other. As discussed in section 2, this randomisation is used to reduce the predictability of each stage of an excavation, therefore enhancing the learner's interest in the outcome of their decisions.

The game logic iterates through each day that the students have allocated to the current task and performs the following calculation:

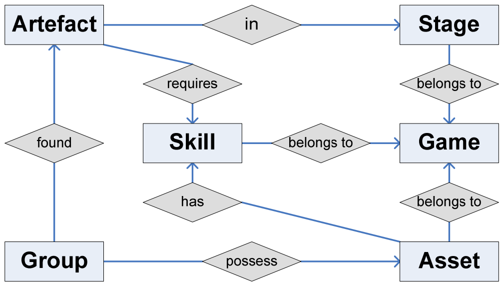

Figure 3. Relationship between key LAVA data types.

1. For each allocated person select a piece of equipment with the highest skill level, matching their skill, that isn't already in use.
2. Iterate through the hours of each day.
3. During each hour, test up to 4 artefacts that have not yet been found or identified, and whose find or information skill matches the person's skill.

The probability of someone finding or identifying an artefact is calculated by comparing the skill levels of the person and any equipment they are using, with the difficulty level of the artefact. Each person and piece of equipment calculates their find probability using the following expression:

```
p = 0.4 + ((person/equipment skill - artefact difficulty) * 0.1)
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In the case of a person having a piece of equipment, the two probabilities are combined using:

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p = 1 - ((1 - person probability) * (1 - equipment probability))
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This probability is then compared to a random number in the range 0 to 1. The artefact is found and identified if the probability is greater than this random number.

4.3 Data Layer

The data layer maintains a consistent game state. This enables multiple learners to progress through a changing environment. It ensures that learners who are part of the same group receive the same view of the game at all times. The views of each learning group are, however, distinct.

The game state consists of 6 key data types; artefact, asset, game, group, skill and stage. The relations of these data types are shown in figure 3.

- Game represents a single simulation instance, containing key data such as the length of the simulation and a reference to the logic to be used in calculating the success of each stage. Assets, groups, skills and stages are associated directly with a simulation instance, in a many to one mapping. The only objects not directly associated with a specific simulation are artefacts; these are related to stages in a many to one mapping, meaning, like all other objects, they only exist in a single simulation.

- Artefacts are items that students can find in an excavation. They have basic and detailed descriptions, a find skill, an information skill, and a difficulty level for each of those skills. The find skill is the skill required to locate the artefact; by default this is digging, but the mechanism provides scope for artefacts that are too fragile or difficult to be excavated by anyone without a specific skill. Finding an artefact automatically reveals its basic description. The information skill is the skill required to get the detailed description of an artefact. If the artefact is found by someone without this skill level, then only the basic information is made available.
- Assets are people or items that help with the excavation. Three core classes of asset are used; accommodation, equipment and people. Accommodation is not directly used to help with the excavation, but is required in order for the excavation to proceed (this not only includes tents, but also items such as pots and pans, food, etc.). Equipment objects help directly with the excavation and require a person with the relevant skill to use them (for example, shovels, trowels, dental equipment). People are the workers excavating the site. Equipment and people both have a single skill and associated skill level, although there are plans for people to have multiple skills in later revisions.
- Groups are the objects to which students are associated, and are used to keep track of the number of days spent on the excavation so far, original and remaining budget, assets bought and hired, and artefacts found.
- Skills are a name string, and are used to store the authoritative list of skills that equipment and people involved in the excavation can have.
- Stages store the maps to be shown to students as they progress through the excavation, as well as an explanation of what tasks the next part of the excavation involves (for example, clearing topsoil). These also have a list of skills that are required in order for the task to be completed, for example a survey skill is required for a group to progress past the first stage.

5 RELATED WORK

The potential for computers to be used in the teaching of archaeology and related disciplines has been widely recognised. Not only has software been developed to allow students to gain an appreciation of spatial relationships within a site through the development of virtual walkthroughs based on a series of site photographs (Raynier 2006), but it has also been used to allow students to practice their ability to interpret the material culture they may see within a site (Goodrick and Earl 2003). Other software projects have focussed on the use of VRML (Wikipedia 2007) and its successor X3D (Web3D 2007), which have been widely used in the field as the toolset with which to reconstruct archaeological sites. The reconstruction of Avebury, an important Mesolithic site discussed in (ACRG 2006) and (Pitts 2001) shows how successful VRML reconstructions can be. Additionally VRML has also been used in museum display reconstructions (Terras 2006).

Unlike LAVA, these types of reconstruction, as well as those used in popular television series such as Time Team (Channel4 2006), are static representations of archaeological scenes and as such cannot be easily modified by educators or students. Whilst they are constructed using data from real world archaeological excavations, in much the same way as the LAVA simulators, they are difficult to integrate with other types of archaeological data, and show only a single, static representation of an excavation site.

6 CONCLUSION

In this paper we have presented the motivation for the design and implementation aspects of a computer games approach to exploratory learning. The domain we have operated in is archaeology, but we believe that the approach taken is applicable to a number of other domains, including geography and history.

The system integrates 3D game engines with 2D exploratory interfaces, document management systems and a novel VLE that provides support for group-based working. The combination of these technologies with digital resources sourced from real excavations allows us to provide an engaging, realistic and pedagogically sound environment for enhancing students' learning of archaeology.

An initial prototype implementation of the LAVA software platform has been developed and trialled within an accredited University Degree program. More rigorous evaluation of the LAVA platform is currently ongoing, and we are actively pursuing the opportunity to evaluate the effectiveness of the LAVA platform in alternative educational domains: Of particular interest are the fields of geography and geology owing to their potential for virtual fieldwork.

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