3D MURALE: A Multimedia System for Archaeology

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Abstract

This paper introduces the 3D Measurement and Virtual Reconstruction of Ancient Lost Worlds of Europe system (3D MURALE). It consists of a set of tools for recording, reconstructing, encoding, visualising and database searching/querying that operate on buildings, building parts, statues, statue parts, pottery, stratigraphy, terrain geometry and texture and material texture. The tools are loosely linked together by a common database on which they all have the facility to store and access data. The paper describes the overall architecture of the 3D MURALE system and then briefly describes the functionality of the tools provided by the project. The paper compares the multimedia studio architecture adopted in this project with other multimedia studio architectures.

1. Introduction

The primary motivation for using multimedia technologies in archaeology is the belief that they will produce rich new ways of recording, cataloguing, conserving, restoring and presenting archaeological artefacts, monuments and sites.

Advances in 3-D recording techniques have produced user-friendly and portable 3-D recording techniques. With these tools, the first goal is to register *in situ* all stratigraphical evidence, as archaeological fieldwork by its nature destroys this kind of information. The 3-D recording techniques should replace present techniques of 2-D recording that only offers a piecemeal representation and are both time consuming and labour intensive. The second goal is to develop techniques to build 3-D models of artefacts, mainly for cataloguing and visualisation, and of sculptures and buildings, mainly for restoration and visualisation. The third goal is to model the terrain of the site in 3-D as such topographic data yield important information for the archaeologists and is vital for a realistic visualisation. This is all the more important as the ancients designed their cities in harmony with their surroundings, adapting the city layout to the geographical landmarks.

Techniques need to be developed to use 3-D models of objects or their parts with multimedia tools to allow a virtual and possibly subsequently also physical completion or anastylosis of respectively single artefacts or buildings. These techniques must permit a virtual reconstruction of all excavation phases and their stratigraphy. They must permit a virtual reconstruction of ceramic objects, either to replace a physical completion of the real object for presentation or publication purposes, or to make the selection of objects to be restored easier and guide the conservators during this process. Finally, an integrated model must be built of the landscape, the buildings, and the artefacts for different eras, showing reconstruction for these periods or the current state.

Multimedia techniques need to be developed to swiftly visualise the site so that people can virtually navigate through. This will call for special measures, such as level-of-detail selection, predicting the next views, exploiting our reduced visual resolution when moving and so on. The visual experience will also include replays of the excavations, showing the different layers of the excavations being 'peeled off' one by one. This will help future archaeologists revisit the site in virtual reality in order to make their own interpretation of the finds.

A multimedia database needs to be created in order to store and retrieve the artefacts, buildings and their reconstruction. The database serves several purposes. Firstly, it contains information where all the pieces belong in the scene and in which period they were relevant. This will allow the user to set a time slider, after which a complete site model will be composed automatically, showing the buildings, the vegetation, and the artefacts typical for that period. Secondly, it serves as a repository that can be used by the archaeologists to help them classify finds, to prepare restorations, and to keep track of statistics. Thirdly, the database is a major gateway to the wider public and to other archaeologists, by making much of this information available over the Internet.

This paper starts with a brief description of the archaeological test site and then describes the overall multimedia system architecture and compares it with the design philosophy of other "new media" system architecture.

Finally it describes the main tools that are being developed in the project.

2. The Archaeological Test Study Site

The archaeological site at Sagalassos is one of the largest archaeological projects in the Mediterranean dealing with a Greco-Roman site over a period of more than a thousand years (4th century BC-7th century AD). One of the three greatest cities of ancient Pisidia, Sagalassos lies 7 km north of the village Aglasun in the province of Burdur, Turkey. The ruins of the city lies on the southern flank of the Aglasun mountain ridge (a part of the Taurus-mountains) at a height between 1400 and 1650 metres. A team from the Katholieke Universiteit Leuven under the direction of Professor Marc Waelkens have been excavating the whole area since 1990 and has dug up some wonderful treasures, such as the bust of the god of fertility and wine, Dionyssos (view bust). A consortium of universities and companies, led by Brunel University in West London, are collaborating in the European Union supported 3D MURALE project to develop 3D measurement, reconstruction and visualisation tools for use by Prof. Waelken's archaeological team.

3. Multimedia System Architecture

The 3D-MURALE system consists of the Recording, Reconstruction, Database and Visualisation components, as shown in figure 2. Recording tools are being developed for measuring terrain, stratigraphy, buildings, building blocks, pottery, pottery sherds and statues on the archaeological site. The results of these measurements are being stored in the 3D-MURALE database system. Reconstruction systems are using a 3D graphics tool to combine the individual measured components and reconstruct building elements and buildings from building blocks, pottery from pottery sherds, statues from statue elements and stratigraphy from all finds within the excavation.

Any missing elements will be added later through archaeological hypothesis using 3D graphics tools and custom-built software. An integrated model is being built of the landscape, buildings, and artefacts for different eras, showing reconstruction of these periods or the current state. The model is being processed to prepare it for high quality stereoscopic visualisation and for lower quality Internet visualisation. The visual experience also includes the display of the stratigraphy. Any individual artefact (building element, building, pottery sherd, complete pottery, stones or statues) may be queried on the database and the outcome of the query visualised individually. Queries may be formed and remotely visualised over the Internet.

The archaeological multimedia system architecture is based on a set of tools loosely associated with each other through a common database structure. The set of tools is shown in figure 3 and consist of a combination of professionally available multimedia tools that in some cases have been enhanced by software developed within the 3D MURALE project where necessary, and tools developed entirely within the 3D MURALE project.

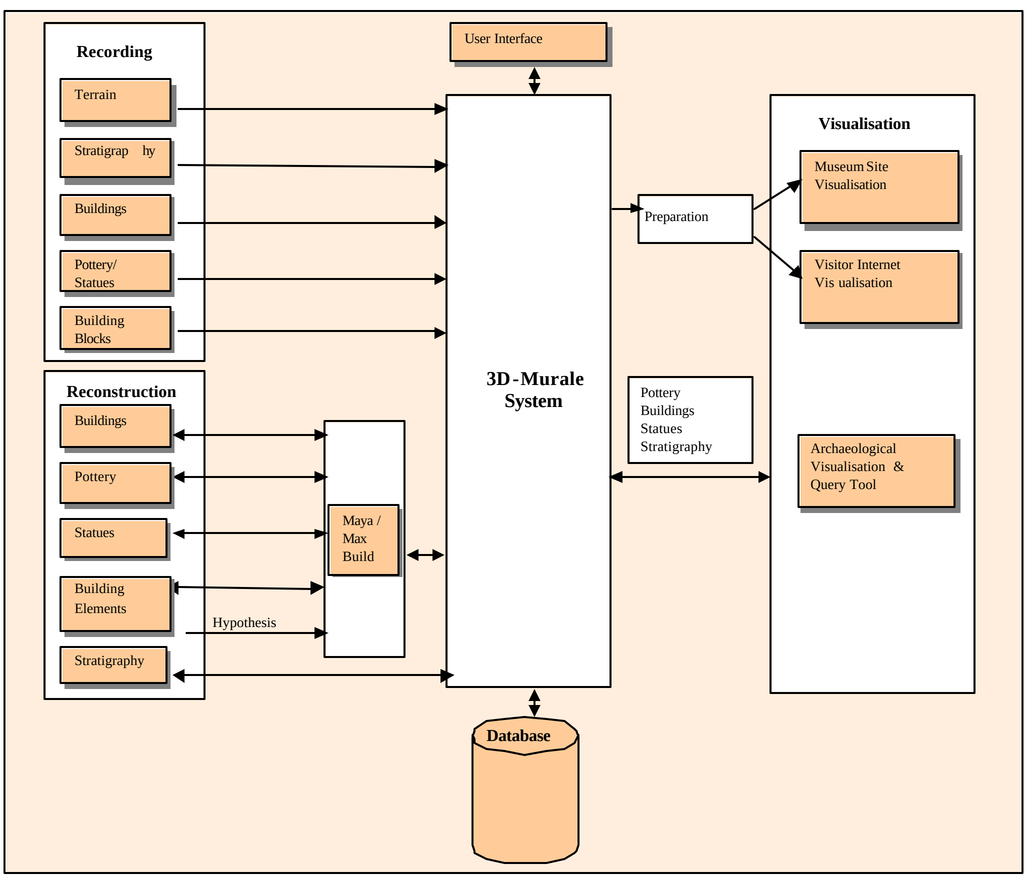

Figure 2: Archaeological Process Flow

Although the approach described has been developed for the creation of archaeological multimedia content, the same type of loosely associated set of tools approach has been used for the construction of a studio system for the creation of content for Digital Video Broadcast (DVB) transmission [1]. In this system content acquisition, creation, indexing/integration, encoding, searching and visualisation tools are associated with each other through a common MPEG-7 database structure. The tools are used for acquiring, creating and editing 2D video and audio, 3D graphics and XML based textual indexing content. This content is encoded in MPEG-2, MPEG-4 and MPEG-7 for transmission. There are further tools that query the MPEG-7 database, visualise the content and plan how content is delivered by transmission resources.

The approach introduced above has six clearly defined sets of functionality. The capture/recording level, creation or recording post-processing/reconstruction level, the encoding level, the indexing/integration level, the searching level and the visualisation level.

- *Capture/recording tools*: incorporates audio/video/image/text capture and creation.
- *Creation or recording post-processing/reconstruction tools* incorporates audio/video/image pre-processing, video/image pre-processing for 3D graphics generation.
- *Encoding tools* incorporates the encoding for compression or for efficient storage and transmission of all types of content with different quality. Changing the parameters of encoders as required will vary the quality of the stored or transmitted content.
- *Indexing/integration tools* incorporates the description of all types of content. The description of content can establish association between different types of content thus providing means for integration of content. Different aspects of content may be stored e.g. perceptual image properties (colour, texture, shape, spatial relationships), semantic image primitives (objects, scenes).
- *Search tools* incorporates the facility to make textual, image and 3D based queries and view the results of the query. Retrieval is based on search engines working in textual, image and 3D domains using query languages such as SQL or XQL. Accessed content is visualised and assessed for relevance before a new text search is initiated.
- *Visualisation tools* incorporate the visualisation of all types of content for the purpose of assisting the acquisition, creation, recording, and reconstruction process, for viewing the outcome of database search process and for dissemination.

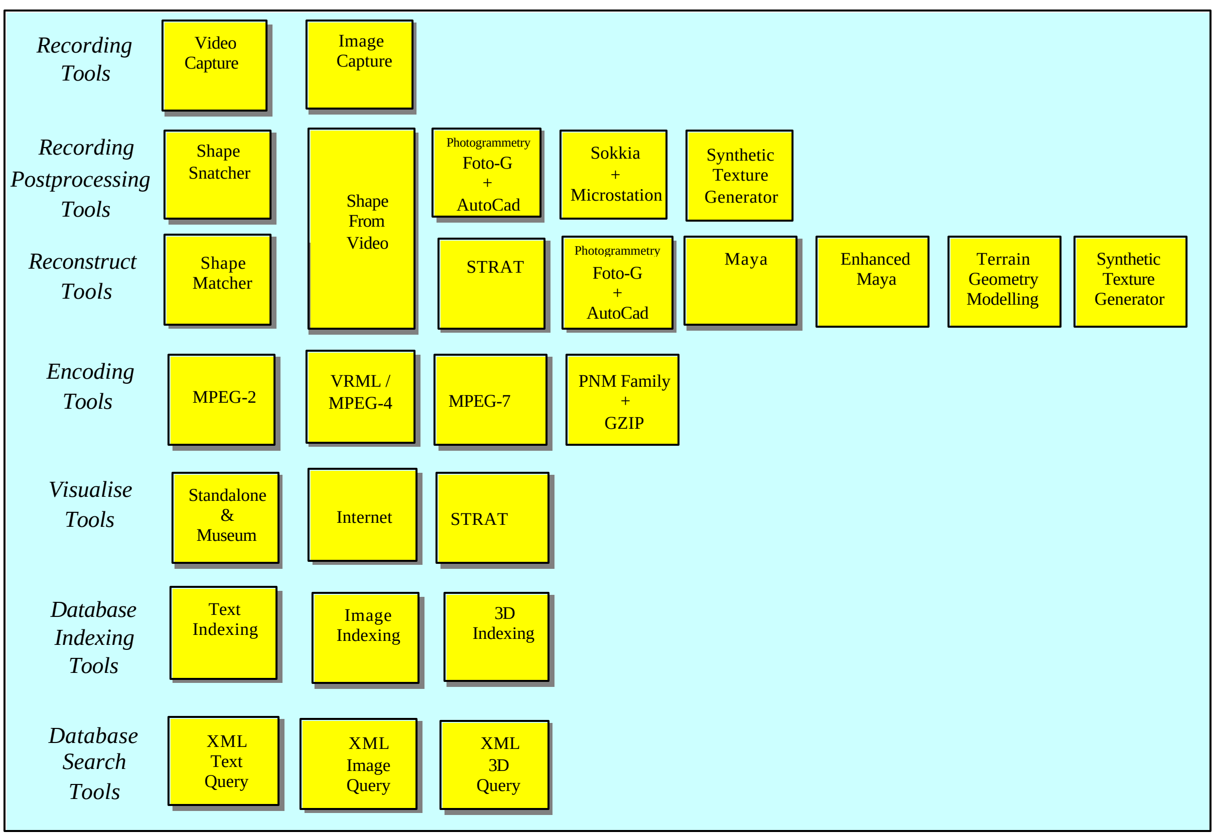

Figure 3: Set of tools

In the application of multimedia to archaeology all six levels described above are necessary. However the emphasis is placed on 3D geometry and texture acquisition tools through the post-processing of images and video and reconstruction tools due to the requirements of archaeologists to accurately record artefacts that are very often damaged or have missing parts.

4. Description of 3D MURALE Tool Set

4.1 Recording Tools

4.1.1 Shape Snatcher (Building Parts, Statues, Statue Parts, Pottery)

The ShapeSnatcher allows the generation of 3D models based on the use of a single image taken by an ordinary camera. It is based on the principle of structured light: a predefined grid or pattern is projected on an object or a scene and is viewed at by a camera from a (slightly) different point of view.

Characteristic for structured light techniques is that the 3D structure of the object can be deduced from the deformation of one or more grid projections. The use of these techniques is however restricted to very controlled lighting circumstances. It also requires tedious calibration procedures and heavily depends upon the hardware used.

Structured light techniques rely on the fact that when a grid is projected onto an object and is looked at it with a camera from a slightly different point of view, the grid will look deformed. The visible deformation of the grid is related to the three-dimensional structure of the object.

The heart of the system is the ShapeSnatcher Slide that comes with the software package. This specially etched slide contains the pattern that needs to be projected onto the objects before they can be modelled. The slide can be inserted into the slide projector in any way. The orientation of the slide does not matter.

The slide basically consists of two orthogonal sets of horizontal and vertical lines. An original slide -- the master -- is produced i.e. etched using lithographic techniques on a glass plate. The slides that are commercially sold are chrome copies of the original master. The software to design the slide as well as the tools to control the machinery is made in-house.

4.1.2 Shape from Video (Stratigraphy, Buildings, Building Parts, Statues, Terrain Geometry)

The shape from video technique is able to retrieve both the structure of a scene and the motion of the camera from an image sequence. Note that not only video but also sequences of photographs can be used. The processing is in principle fully automatic, although a limited user interaction can allow a more robust and flexible use of the software tool. In a first step, features are extracted and matched or tracked over consecutive images. Followed by a structure-and-motion algorithm, this step yields a sparse 3D reconstruction (i.e. the 3D features) and the path of the camera. These results are enhanced through self-calibration and bundle adjustment. To obtain a full surface reconstruction of the observed scene, the images are rectified so that a standard stereo algorithm can be used to determine dense disparity maps. By combining several of these maps, accurate depth is computed for every pixel. Using a volumetric technique, these are then integrated together to yield a single 3D surface. By making use of texture mapping photo realistic models can be obtained. A more detailed description of this approach can be found in [2]. The flexibility of the approach allows to apply this technique to offer a solution for many of the 3D modeling demands found in archaeology. In the context of this project Shape from Video will be used to record and reconstruct stratigraphy, buildings, building parts, statues and terrain geometry.

4.1.3 Photogrammetry FotoG+AutoCAD (Buildings, Building Parts, Statues)

Photogrammetry retrieves both the geometric structure of a scene and the positions and orientations of the camera at recording time from a series of overlapping images. Since digital cameras are available, very dense image series can be obtained at no extra cost. In such image sequences, homologous points can be automatically found with image matching algorithms and the camera positions and orientations can be computed automatically from these points using bundle adjustment for optimum results. We use the close-range photogrammetry package *FotoG* to perform this task. FotoG also provides a powerful modeling tool: it works as a plug-in to either AutoCAD or Microstation, so that the user can exploit the full power of this standard CAD environment.

To further automate the photogrammetric modeling process, we are working on techniques for automatic modeling. Our approach is a combination of dense matching as described in the shape-from-video section and feature-based modeling, where we try to find the object's important features and describe them with parametric lines and surfaces. This process is similar to interactive modeling like the behavior of a human operator and yields a structured and compact object model.

For visualisation of the model, texture can be obtained directly from the oriented images by rectifying the image content. We use an algorithm that merges the photometric information from all images and takes the different viewing angles and resolution into account to obtain high-quality textures.

4.1.4 Sokkia/Microstation (Stratigraphy)

For classical recording and drawing of stratigraphical and architectural features a combination of a total station with an electronic field book (Sokkia SET 4B/SDR33 Expert) and a drawing package (Microstation) is used. For every uncovered stratigraphic feature a number of points are measured using the Total Station. These points are recorded in the electronic field book and downloaded at regular intervals to a PC containing Microstation. The points (x,y,z coordinates) are imported into Microstation. The resultant model can then be used for the introduction of controls into Shape from Video software or, as is still the case, for the plotting of sheets with points at the scale and orientation requested by the drawing teams for completion by hand in the field. Since the number of points for any given surface is much higher when manual completion is envisaged (by a factor of 100 or more), compared to the automatic system of 3D MURALE, the intention is to reduce this manual procedure as much as possible.

4.1.5 Synthetic Texture Generator (Terrain Texture, Material Texture)

A statistical texture description is used for constructing a model at the analysis stage. Such models are used then to generate synthetic textures. The models with pair-wise interactions reproduce main visual cues of the terrain textures having strong stochastic character, for example grass or stones. Two cases can be separated for the task of recording.

The first case deals with the so-called flat or painted textures. These are textures that have relatively small roughness of the underlying 3D surface. For such textures the recording of only one example patch, as a rule, seen under the frontal view is needed. This single view is used then as an only input to the texture analysis procedure creating a texture model. The model is then saved in the database together with or instead of the example patch.

The second case deals with the so-called rough textures (sometimes referred to as 3D textures) having prominent changes in height (microrelief) of the underlying 3D surface. For such texture the recording of example patches for different views is needed as the visual appearance depends essentially on the viewing angle (self-occlusions, self-shadowing and other). The rougher the texture i.e. the stronger are its appearance changes, the denser should be the recorded views. They are all the input to the analysis procedure, which creates this time a multiview, texture model. Together with the sets of statistical parameters of texture, the information about the orientation in the 3D space for each of the views is saved.

4.2 Reconstruction Tools

4.2.1 STRAT (Stratigraphy)

STRAT is a tool that allows archaeological legacy data of recorded stratigraphic dimensions, artefacts and finds to be entered. This tool will allow accurate hypothesis testing of stratigraphic relations. The "shape from video" tool will be used to record stratigraphic layers. The 3D surface from each layer is recorded using the tool. In order to correctly position the successive layers on top of each other reference markers with exact known world coordinates need to be placed on the stratigraphic layer. The options for placing reference markers within the scene for detection of corners of stratigraphy were studied in order to position/reconstruct stratigraphic layers correctly. Options for recognising these reference markers were also studied.

4.2.2 Shape Matcher (Building Parts, Statues, Pottery)

The Shape Matcher software is a tool to combine different patches in order to obtain a complete all-around 3D model. It distinguishes itself from other approaches in the fact that:

- The matching procedure between different patches is automated and can be performed on more than two patches at the same time.
- There is no need for prior knowledge about the relative positions of the separate patches,
- Even patches that do not match perfectly or do not correspond can be integrated into a single surface.
- It takes into account specific information about the data acquisition (ShapeSnatcher's calibration file) to optimise the matching process.

An important part of the ShapeMatcher's interface is the 3D Viewer. The camera control resembles the one of the ShapeSnatcher but has been elaborated in a number of ways.

First of all the interface has been designed to allow the rotatation, scaling or movement of the set of patches as a whole or each of the patches relatively to one another within a 3D world frame. Each of the patches can be viewed in a different colour to make them easier to distinguish from one another. The number of colours used can be controlled in the preferences. All patches can be viewed in wire frame, shaded or textured mode.

An alternative way to initialise or set the relative position of each of the patches is based on the indication of corresponding points between two distinct patches. This part of the interface is 2D-based, as is the ShapeSnatcher, since there is a direct relationship between the point indicated on the 2D plane and the 3D coordinate on the surface. The resulting set of 3D points is used to determine the transformation that is needed to align the indicated points as close as possible, and thus to reposition the selected patches.

A thumbnail viewer of all the patches that are loaded in the software covers part of the interface. The thumbnail viewer allows selecting / adding or fixing a subset of patches on which the specific task needs to be performed.

The interface is crucial step in the modelling process since it allows one to put the different patches in their initial relative position, which is necessary for initialisation. From then on automatic tools can be called for: the matching proceeds in three consecutive steps:

- Alignment;
- Blending;
- Integration of the different patches into a single model.

4.2.3 Shape from Video (Stratigraphy, Buildings, Building Parts, Statues, Terrain Geometry)

See Section 4.1.2.

4.2.4 Photogrammetry FotoG+AutoCAD (Buildings, Building Parts, Statues)

See section 4.1.3.

4.2.5 Terrain Geometry Modelling

Digitized contour lines from analogue maps of Aglasun valley were available and have been converted to a digital terrain model (DTM) using a local implementation of the delaunay triangulation. Triangulation algorithms deliver good results even if the distribution of terrain points is very irregular, as is the case with digitzed contours (dense profiles along each contour, but no points between two contours). To avoid artefacts introduced by the 2D-nature of the delaunay algorithm, the triangulation is enhanced by swapping triangles to get rid of unwanted terrain steps [3].

4.2.6 Maya (Buildings, Statues)

The differences between the reconstruction processes for statues and buildings were analysed and found to be that reconstruction of statues involves few pieces with free forms and reconstruction of buildings involves many pieces with mostly regular geometric forms. Almost always a significant amount of pieces are missing, therefore hypothesis about these pieces enter into the reconstruction.

The process of reconstruction can therefore be divided into the following steps:

- Deriving the hypothetical building pieces from the real pieces recorded in site.
- Build a complete model with these hypothetical pieces.
- Identify the corresponding real pieces, if available.

A draft design for a digital reconstruction workflow was tested using Maya with the reconstruction of the Heroon. As a result the desired capabilities of a digital user interface for reconstruction were specified.

The analogue reconstruction drawings for the Heroon were converted to digital 3D data. Recording data from the Sagalassos site will be incorporated after this summer's campaign.

4.2.7 Enhanced Maya (Pottery)

A tool that identifies different fragments belonging to the same vessel pre-classification rules is being developed. One classification scheme works by the exploitation of so called ‘extrema points’ or points of variance (usually first and second derivatives). Using these points the relative ratios and distance of characteristic parts of the sherds could be measured and checked if they fit with a general classification scheme. Preliminary tests have been worked out on the restoration of a complete pot out of one of its fragments.

Another classification scheme is based on the shape, material and color. An approach is being developed for accurate colorimetric information of fragments, performed on digital images containing archaeological fragments under different illuminants with a priori known spectral illumination. It is assumed that the spectral reflectance of archaeological fragments varies slowly in the visible spectrum. Color measurements of fragments using a photospectrometer have been performed to achieve accurate colorimetric information and to get spectral reflectances of a set of fragments.

4.2.8 Synthetic Texture Generator (Terrain Texture, Material Texture)

A tool is being developed to restore texture. The restoration of texture requires synthesizing a patch of the required size using the model recorded on the analysis stage and probably under some environmental constraints. For the moment, the constraints mean simply that some neighboring fragments were already synthesized and the new synthesizing patch must fit seamlessly into such environment. Successful experiments were done on seamless knitting of textures.

As the texture synthesis takes a longer time, the required patches of textures should be generated off-line and mapped during the visualisation on the corresponding places of 3D surface. There should be two different mapping procedures. The first one is for the flat textures and the second one for the rough textures. In the first case for each fragment of the 3D surface a single synthetic patch of the flat texture will be used. In the second case for each 3D surface fragment there will be a set of synthetic patches, which correspond to the different views of the same rough texture. The real time visualisation in the last case is still possible, as the experiment with the “on-the-fly” view substitution during the mapping has been shown to work.

It will be necessary to have terrain models of the site at different epochs. These will be the same in large parts of the surroundings, but will differ considerably on the site itself. Furthermore the terrain model of the site must be changed, when new surveys are made with progressing excavation. However there is no guarantee, that the data is dense enough to obtain a satisfying representation of the terrain for all epochs. Therefore a tool was designed (and is currently being implemented), which allows to update parts of the terrain model, and to use information about the terrain form from one epoch together with height information of another epoch.

4.3 Visualisation Tools

The MURALE visualisation system addresses two different types of users:

- An archaeologist wants to focus on details and needs a very accurate visualisation of the finds such as pottery and statues. He/she does not need to be presented with a fully reconstructed virtual city, where all the buildings and objects are displayed as they could have looked at a certain period of time. Therefore s/he is interested in a visualisation of the strategraphic layers and the finds that were discovered within those layers. MURALE provides such a tool, which supports the archaeologists with their daily work (section 4.3.1).

- Unlike the expert, the normal visitor needs some assistance in building up a hypothesis of how the city would have looked like in former times. He wants to see a complete reconstruction of the site, were all the gaps, left unclear by the excavation are filled in by a fictitious 3D model based on the expert knowledge of the archaeologists. Thus, for site-visualisation MURALE will develop a prototype for an interactive museum installation. In order to reach a broader public the site-model will also be accessible over the Internet. The sections 4.3.2 and 4.3.3 focus on these two issues in more detail.

Since the MURALE multimedia database also stores different kinds of annotations to objects, this additional information will be used for visualisation. Representative objects will be located within the scene that will represent the class of objects found in the vicinity e.g. a particular type of vase or pot, etc. These objects will be annotated with a link to the database that contains all the artefacts, where other finds in the vicinity can be accessed. This content will also be made sensitive to different eras, i.e. only vases and pots of the selected era will be displayed and accessible.

A second peculiarity of the MURALE visualisation system is that users (visitors and archaeologists alike) will be able to navigate through time – i.e. by using a simple time slider. Especially visitors to a site are often confronted with a situation that is mainly the result of archaeological activities, which throughout the excavation have focused on different chronological periods in view of specific research questions. As a result, buildings that were never visible at the same time now figure next to one another. On the other hand, the final phase of a settlement also includes various buildings of much older date, which during the site's occupation have gradually been transformed, sometimes very drastically, so that their original shape and function can no longer be recognized. The site-visualisation tool will show the gradual transformation that the site and its environment underwent during the various phases of its occupation. For instance the transformation of pagan temples into churches and the incorporation of public buildings or space (e.g. squares, streets) into private structures will become visible.

4.3.1 STRAT (Stratigraphy)

The stratigraphic visualisation tool generates a textured or wire-frame 3D representation of the stratigraphic layering of archaeological excavations and provides plan, profile and perspective views to the data. Artefacts discovered in a layer can be represented by a symbol or by a 3D representation of the found artefact. Each layer can have an arbitrary shape. The tool:

- enables the archaeologists to more readily visualise the relative positioning of the stratigraphic layers
- selectively chooses a particular group of artefacts to be visualised within the stratigraphic layers for the purpose of analysis
- visualises each stage of the excavation using a time slider thus establishing the chronological sequence of stratigraphic layers
- visualises user defined cross sections of the stratigraphy
- highlights through visualisation the inconsistencies in the dimension of adjacent stratigraphic layers
- corrects through user interaction the inconsistencies in the dimension of adjacent stratigraphic layers

4.3.2 Internet

In order to make the virtual site accessible to users all over the world, the model needs to be distributed in an Internet-compliant way. Several choices exist ranging from a simple VRML-based scene that can be explored by today's standard web browsers to a customised plug-in offering functionality that is only relevant in the context of archaeology (e.g., the time slider).

When connected to the database using a slow dial-up connection, it is particularly important to reduce the amount of data to be transferred to a minimum. Early approaches [4] hierarchically organise the scene and provide versions of each object at different levels of detail (LOD). While this avoids the need to transmit the whole scene before the user can start to navigate, it increases the total amount of data and leads to distracting popping artefacts when switching between different representations of the same object. Unfortunately, this method is the only LOD-management incorporated into the VRML97 international standard.

More powerful techniques provide a continuous LOD representation of the scene, from which the optimal geometric resolution can be obtained for each viewpoint (see [5] for a recent method). Another way to reduce network load is to avoid transmitting redundant and irrelevant data. By exploiting topological and geometrical coherence, the size of a 3D model can be reduced dramatically [6].

Unlike in a controlled environment (see next section), no assumptions can be made about the user's hardware. Therefore the visualisation system has to automatically adapt to the available bandwidth and graphics performance of the user's system to avoid long delays during interaction.

An algorithm based on [5] is currently being developed that also features database support and compression. The prototype has successfully been tested as a standalone application, but is going to be transformed into a browser plug-in for all major platforms to be used together with a standard web browser.

4.3.3 Standalone & Museums

Whereas bandwidth is not of much concern in a museum installation, spatial scene organisation and the use of LODs still are important issues to overcome scene complexity – even when using state of the art graphics hardware. In this scene the work on Internet visualisation is also relevant for standalone and museum visualisation.

A high level of interaction is vital to attract the museum visitor. The use of virtual reality enables the user to actually walk through the ancient city in a very natural way. In order to avoid “motion sickness” images for both eyes need to be presented at a constant frame rate and the system’s latency when the user moves around should be low (within about 200 ms).

Often a visitor feels lost when the navigation through a complex 3D-model is completely unconstrained. He/she will be able to take different types of tours to explore the history of the ancient city. Besides by using predefined paths between major monuments and highlights the predictability of the visitor's trajectory is increased, which in turn leads to more efficient visualisation algorithms.

For instance, a virtual tour bus takes the visitor trough the site while explaining the most important things. Like on a hop-on hop-off tour bus, the visitor gets off at interesting points and explores the site himself. Once done, s/he continues with the tour. The visitor can also take a thematic tour, which explains a certain object or cultural tradition. He could for instance take a path trough the city up to the theatre. On the way to his destination the visitor learns more about Greek or Roman theatres.

Apart from the site model, different kinds of multimedia information such as photographs, movies, 3D animations, pre-computed camera animations and textual information will be included in the presentation. Navigable panoramic images and movies, revealing either an actual or a hypothetic view on the excavation, will be linked with interesting spots in the scene.

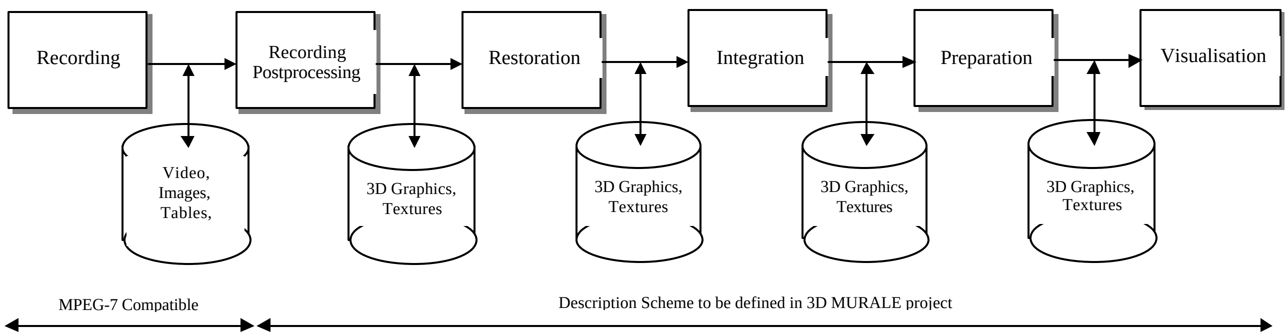

Figure 4: Layered Model of Database

4.4 Database Tools

A layered model will be used for the multimedia content in the database in the recording, recording post-processing, restoration, integration, preparation and visualisation phases, as shown in Figure 4. The recording process captures multimedia archaeological content (e.g. images, video, tables, text). Recording post-processing steps convert video and images into 3D graphics and textures. The restoration process makes good any broken artefact and through hypothesis adds missing parts of the artefacts through archaeological knowledge. The integration process brings together the artefacts into a complete object that is ready for museum presentation. The preparation process modifies the objects in preparation for Internet, Museum or stratigraphic presentation. The visualisation process is required for Internet, Museum or stratigraphic presentations.

The database may follow current CIDOC data model guidelines (CIDOC 1999) and will be extended where appropriate. Any archaeological extensions will be fed back to the CIDOC committee. The Multimedia Database will be a multimedia XML database, using an XML document paradigm for its interface. The XML document abstraction is simple and powerful, allowing standardised access to the database. Both GUI and API interfaces will accept an XML Schema and XML document as input and will output an XML, XHTML or VRML document (Figure 5). The XML document interface to the MMDB database will support MPEG-7 Description Schemes for the description of recorded content wherever applicable.

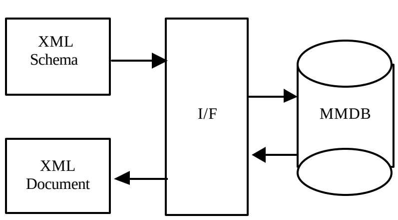

Figure 5 – XML Document

The database will only use agreed file formats. For video MPEG-2 will be used. For 3D vector and 3D vector/time formats VRML/MPEG-4 will be used and may be superseded by X3D. PNM family will be used for 2D pixel formats – to be compressed with *gzip* and the JPEG format will be used for *all* Web page images. PNM files to be converted to this format for presentation purposes. XML document formats are to be used for all future documents. Authoring and conversion tools are to be purchased where necessary. XHTML formats to be used for all Web pages.

A totally new logical schema will be defined for recording the archaeological process in the database. This will contain information of the archeological site, the excavation and its location, the teams of archaeologists that worked on the excavations, the objects that were found and any other data associated with the archaeological process. This data will be recorded during the stratigraphic excavation process. In the reconstruction phase of the stratigraphy this data will be integrated. A stratigraphic visualisation tool will allow this data to be visualised, queried, filtered and selected (STRAT).

5. Conclusions

This paper presents the overall architecture of a studio system for recording, reconstructing and visualising archaeological multimedia content. It consists of a set of tools for content recording/capture, creation/reconstruction, encoding, indexing/searching and visualising multimedia. These tools are applied to buildings, building parts, statues, statue parts, pottery, stratigraphy, terrain geometry and texture and material texture and are loosely linked together by a common database on which they all have the facility to query, store and retrieve data.

The presented architecture is compared with other multimedia studio architectures for creating cultural heritage content for broadcast programs.

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