A Concept for 3D Damage Mapping with Augmented Reality Technologies

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Abstract

Augmented Reality (AR) is a new form of human/computer interaction (HCI), whereby computer data is superimposed onto real life photographs and all kinds of information can be displayed to the operator depending on the content.

In this article, a possible application of AR technology will be introduced using the example of the damage mapping carried out on the monumental sculpture "Bavaria" in Munich. Techniques such as AR have great potential in this area, especially when combined with a complete, laser scan recording of the 3D geometry of the object. Using this technique, the virtual object, whose precision depends on the quantity of measured points, can be superimposed with a 1:1 scale 3D photograph. Damage mapping can be carried out on the virtual object and on computer simultaneously, and then converted into a corresponding damage map. In this way, effective documentation, visualisation and structured data records are created, which can be managed in a content management system (CMS). The application is supported by 3D user interfaces, information filtering and automatic integration mechanisms.

We at ArcTron GmbH, are currently still in the development stage of this system. In the future, it will provide a 3D information system, specifically conceived for 3D documentation in archaeology and monument heritage at a variety of different levels.

Key words:

- 3D Information system
- 3D Laser scanning
- 3D User Interface
- Augmented Reality

Initial Proposal

The requirements for computer-supported, scientific classification of archaeological excavation features are computer-supported recordings and the integration of work carried out by various specialists in an information and communication system.
Existing, potential IT solutions for mastering this task have only been inadequately exploited until now. At ArcTron we are working on methods and techniques of 3D mapping and documentation. Our aim is to develop a total concept using existing object surveys, which will enable all recorded data, geometries and other documented descriptions to be efficiently collected, managed and represented. It will also enable recorded information to be flexibly maintained and made available for later projects/ restoration and so on.

To meet the requirements to work with existing monuments and archaeological excavations reliable and expressive data are needed. Objects need only be recorded using laser scanning if no other viable data exists and if laser scanning proves to be the most suitable method for creating accurate damage mapping, despite the high cost (e.g. if the object or objects must be surveyed completely, partially or in order to check existing data).

The most serious problem for computer-supported data collection today is the loss of semantic coherence during data transfer. The reason for this is that every specialist involved in a project employs solutions from their own sector for collecting and processing data. Transferring data or merging one representation with another can lead to this loss of coherence.

Fields of application in 3D Mapping

3D damage mapping is the structured collection and management of information in an information system. During data collection, the data is reduced down to that which will later be of use. The most important data comes from the recording of a point cloud and the wire mesh model generated from this. Other factual and general data is also collected (photographs, video sequences, sketches etc.). All existing recording techniques (e.g. laser and stripe light scanning, total station surveying, photogrammetry, hand drafting, photography etc.) have certain technical merits. If the task formulation is adequate, these various advantages can be combined to produce the best-possible, most efficient result. On the other hand, no single method alone can meet the ever-changing, diverse demands made by object recording. It is essential to combine available methods and technologies in order to avoid inefficiency.

Main focuses of 3D mapping:

Damage mapping:

- Segmentation of the object
- Surveying damage
- Documenting damage

Archaeology/ Stratigraphy:

- Finds/ Feature mapping
- Finds/ Feature classification

The aim of our research is to examine how far 3D mapping can be realised using AR/VR technologies. Other main focuses of our research are:

- The evaluation of existing recording methods (accuracy/ interfaces/ compatibility with other applications
- Assistance for recording and recording instruments / mobile data collection (including speech recognition)
- Integration in a total system (CMS / ArchaeoData/ Aspect3D)
- Classification of processed data (Organisation system)
- Modifying and adding information (context relative information)
- Processing and monitoring data, attaching information to the 3D model (Ranze 1999)
- Structured storage of recorded data (Database)
- A modular tool for recording and logging the work stages
- Displaying information relevant to the plan at the right time (“context awareness“) (Rose 1995)
- Filtering information (Julier 2000)
- Providing a mobile client for a communications and conference system
- Effective, direct monitoring facility (Plausibility check)

AR technology has proved itself to be useful in the following situations:

- Supporting communications between project colleagues/ communication and provision of filtered information (Julier 2000)
- Displaying information that is not directly accessible/ visible (clearness)
- Direct, in situ collection and recording of object information (illustration)
- Generating and processing new information
- Structured data storage in a content management system (CMS)

AR & VR and the mapping process

Definition of Augmented Reality (AR)

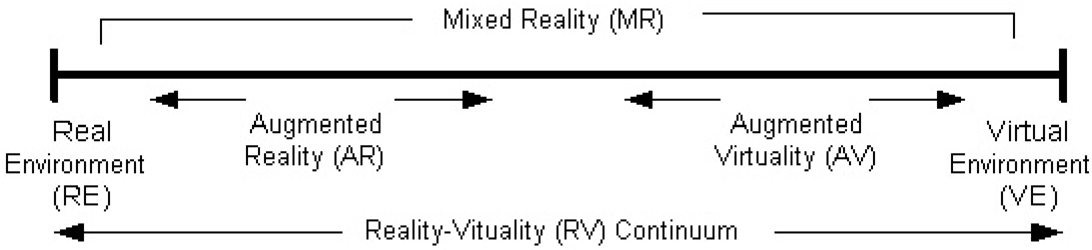

Fig. 1 Definition of Mixed Reality (Milgram 1999)

An AR system generates a composite (augmented) view for the user. In order to be able to see the view it is necessary to use a special piece of equipment called a Head Mounted Display (HMD). It displays a combination of a real image and a computer-generated image and enhances the picture with additional information. The superimposed image is continuously recalculated depending on the users' head movements. Optical see-through or Video see-through HMD's are generally, though not always, used. In all AR applications, the superimposed image, presented to the user, improves performance in the working environment and sharpens perception of the surroundings.
Three facts that defines AR (Azuma 1997):

1) Combines real and virtual space
2) Interactive in real time
3) Registered in 3-D

See-through HMD

There are two different see-through HMD'S used in AR and VR systems, the optical see-through HMD (ost-HMD) and the video see-through HMD (vst-HMD).

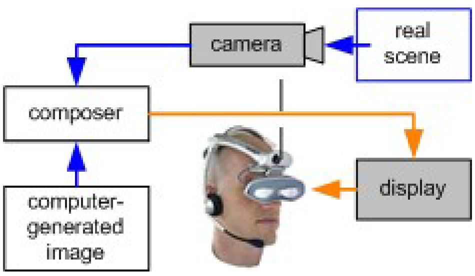

Fig. 2 Video see-through HMD (Azuma 1997)

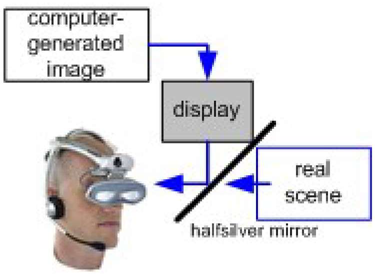

Fig. 3 Optical see-through HMD (Azuma 1997)

The optical see-through HMD combines a real and a computer-generated image by using an optical mechanism with a half-silvered mirror. In this way, the surroundings can still be directly observed.

Video see-through HMD's record and display the surroundings to the user using a video camera. The software (Video composer) ensures that the video of the surroundings and the computer-generated images (constructed using a Scene generator) coincide. Control and coordination of the HMD is carried out on computer by a section of the graphics system. Evaluation of the collected input data and coordination of the output data make great demands on the performance of the system and on the interface technology employed.

Tracking

The position and orientation of the user's head must be known so that virtual objects can be correctly placed. This is achieved using tracking. Tracking is the method of measuring the position of bodies moving in 3D space. When location (3 positional coordinates) and orientation (3 independent angle coordinates) are measured at the same time, we call it a 6 Degrees of Freedom measurement (6dof). Various tracking systems exist based on diverse principles. Among these are, for example, position encoders, magnetic systems, optical systems in VIS or IR, ultrasound and tracking systems based on acceleration and gyro sensors. Tracking principles that are "hands free", i.e. those that do not work with mechanical position encoders, are the most accurate for use in optical tracking. It is important for the system to be able to react to the movements of the user in real time and deliver the calculated images without delay. The time lag is calculated from the time that elapses between the movement of an object and its realisation through the computer.

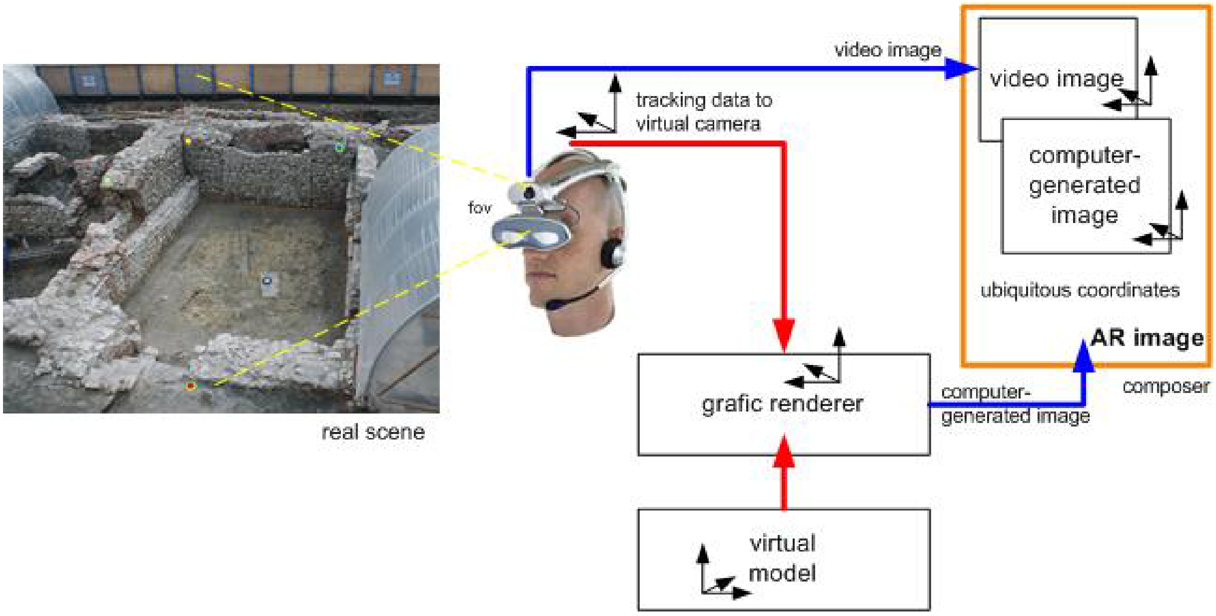

Fig. 4 Coordination of the image superimposition within a vst AR system

For this research project, we intend to employ a camera-based Marker Tracker using the ARToolkit (ARToolkit) During Marker Tracking (Fiducial Tracking), recording markers are attached to the object that is to be tracked. The position and orientation of the object markers is constantly updated in real time. The markers can consist of bar codes (Rekimoto 1995) or be made of different coloured circles that are scaleable (Neumann 1999). The individual bar codes can be given ID's that contain information about the object, its orientation and position that can be read by the camera (Feiner 1999).

Further, promising prospects are arising in the field of outdoor, camera-based tracking (Azuma 1999) in combination with GPS, DGPS and a digital compass. "Landmark Tracking" (State 1996, Neumann 1999) retrieves positioning and orientation data from prominent landscape structures. Tracking using planar structures (Simon 2000) recognises various surfaces, defined in the foreground of a scene, and superimposes the overlay onto these. These methods of tracking could also be used in 3D damage mapping as adjacent buildings could be defined as prominent orientation points by the tracking system.

Measurement data collection in the field

Basically, there are two approaches to data collection in the field:

1. Examination of existing plan documents

Existing 2D drawings or 3D models form the basis of the documentation that can be examined, especially the geometry. The user is shown these in a see-through display. By correctly positioning the superimposed images on real objects, the model can be aligned with reality using geodetic measurements, manual measurements or manual corrections. For this method, the user needs to have a combination of measuring instruments and an interface for the virtual model. Distances are measured by a total station, the same instrument also serves to line up the overlying points of the model on the real contours. The AR/VR system provides assistance for the user by employing corresponding contour recognition methods.

The concept of using a combination of existing recording technology (laser scanners, stripe light scanners, total stations, photogrammetry, hand drafting) is an allusion to work carried out on a prototype system called CyliCon that was developed by Siemens (Navab 1999, 2000).

Furthermore, the focus of this work lies in the direct integration of data into the generated geometric model and it's storage in a Content Management System.

2. Collecting measurement data

At ArcTron we record data using laser scanners (LS) and stripe light scanners. Descriptions of the LS systems will be given in the lectures by M. Schaich: “3D Laser scanning and 3D Information system – New High Tech Surveying Techniques for three dimensional Heritage Recording” and by W. Neubauer, A. Ullrich, N. Studnicka, J. Riegl: “Terrestrial 3D laser scanners and their applications in archaeology”.
Stripe light scanners are employed for high-accuracy, 3D digitisation (to a tenth of a millimetre) and reconstruction as well as for documentation in the field of heritage. They consist of a 3D sensor, based on the stripe projection method, and high-performance software that can process the digitised 3D data (Schaich 2000). The generated models can be given photo-realistic textures using the optional texture module. To ensure a complete survey, objects that are large or that have complex shapes are recorded from several angles and the results are then transferred into a mutual coordinate system using registration. Finally, the data sets are triangulated and, if necessary, textured using additionally recorded photographs. In this way, a photo-realistic 3D model can be generated.

The plausibility of measurement data is checked by overlaying the generated model on the real object. The model can be visually compared to the real object in situ, any necessary corrections of contour measurements can be made or the virtual model can be manually adjusted.

The scenarios described in the following sections can be realised with existing technology from the area of AR/VR. Procedures from the following branches are employed:

- Image-based-tracking (Coors 2000), ARCHEOGUIDE (Stricker 2001)
- wearable computing (Behringer 2000)
- Finger-Tracking (http://mevard.www.media.mit.edu/projects/wearables/augmented-reality.html)
- Voice memos (http://hci.rsc.rockwell.com/)
- Displaying non-graphic information in the user’s field of vision (Butz 2000)

The individual systems and the combination of these have not been extensively tested. In order for the systems to be constructively employed in our ever-changing working conditions, the interaction of the components must be examined and adjusted for each case for the following reasons:

- Every object is unique
- Operational possibilities outside of laboratory conditions
- Environmental influences

- Minimum calibration input

3D Mapping Scenarios

Scenario 1 – Plausibility check

The system supports the user by displaying the data that has already been recorded. The plausibility of the data can be checked the same second that it is recorded and the data can then be linked to a suitable context. Additional information can be inserted at the correct position on the object.

- Tracing areas of damage with a finger (Fingertracking MIT)
- Recording visual details (digital photography/ damage documentation)
- Refining the mesh in order to document the exact positions of damage
- Voice memos for making notes and determining damage classes
- Virtual surveying tool for determining the amount of damage
- Arranging the objects in the 3D virtual illustration

Fig. 5 "Plausibility check"

Fig. 6 “traced area” for damage mapping

Scenario 2 –Excavation documentation

Recordings taken using an Laserscanner (LS) system can produce exact documentation of an excavation. Automated integration mechanisms assist with the structured storage of information in the database and it’s integration in the CMS.

- Finds, such as ceramics, finds complexes etc. can be recorded on site using digital finds labels.
- Finds locations are directly incorporated into the 3D information system using finds symbols.
- Features, such as individual parcels of strata, post holes etc, can be described, classified and digitally recorded on site.
- Visual representation of the excavation is possible at any time.

Fig. 7 "Registration markers"

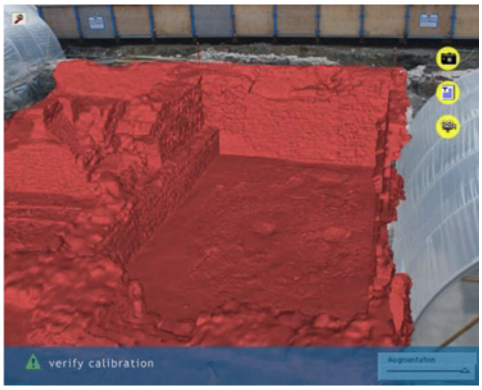

Fig. 8 “excavation documentation”

New and efficient methods of archaeological excavation documentation are created when laser scanning is used in connection with Augmented Reality technology, especially when recording complex stratigraphic sites such as medieval, inner-city excavations. The stratigraphy and circumstances of an excavation can be precisely described three-dimensionally when data from successive laser scanning is integrated into the AR system. Archaeologists can subsequently enter detailed observations directly onto the object, enter classifications and object notes by content and accurately survey, photograph and describe individual finds or record them in a database. The separate strata are recorded as 3D solids in a geometric database using corresponding processing methods and can then be mapped in 3D space. In this way, the stratigraphic relationships can be represented and verified in a realistic Harris-Matrix.

Scenario 3 – Magic Book Metaphor - Documentation

The “Magic Book“ (Azuma 2001, Billinghurst 2001) metaphor is a new form of interpretation and leads to a new understanding of damage mapping. Using markers on the printed pages of documentation, the object in question or a section of the excavation can be viewed in 3D either via a web cam on a monitor, controlling a virtual camera in a special documentation application (Fig. 9), or using a st-HMD for viewing the object directly on the documentation page (Fig. 10).

- Visual monitoring of the section in question
- Easy access to the corresponding source data

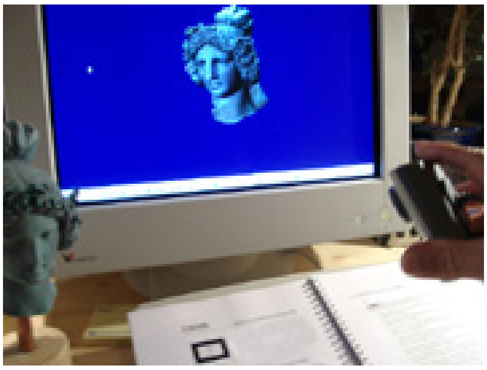

Fig. 9 "MagicBook“ pattern recognition, controlling a virtual camera in the documentation application

Fig. 10 “MagicBook- Metaphor” st-HMD view

Further fields of application

AR/VR as a resource for historical contexts

One of the best prospects for the use of AR/VR is offered by the constant trueness-to-scale (see Archeoguide (Fig. 11-12), Reconstruction of historical buildings (Höllerer 1999, Stricker 2001). At a very early work stage, the user can view realistic images of the historical situation without the mental burden of the compilation procedure, as is the case when using conventional two dimensional graphic or screen based three dimensional representations.
Official investigation of factors and their influence on the development of presence (Regenbrecht 1998). Further information can be brought to the user by using position and focus.

Fig. 11 3D model of demolished building at its original location. (Höllerer 1999)

Fig. 12 „Archeoguide“ (Stricker 2001)

Conclusion & future works

Future research will increasingly concentrate on system specification and prototypical implementations as well as the further development of data management and the database.

The scenarios presented here illustrate the continuing high demand for technical solutions and the wide field of potential applications for AR/VR technologies in the mapping process. Continuing research calls for close collaboration between the various disciplines involved.
AR offers us the opportunity to decrease the duration of the working process and to link information to the correct locations. This can be achieved by combining several work stages (various recording techniques and subsequent digitisation, linking information and documentation in a database system) and through collaboration between different organisations. Continuous work and uniform data maintenance is required from the start. An improvement of the information technology infrastructure would reduce the cost of projects and maintenance, reduce consequential maintenance costs and optimise the running of projects.

The developments in this area correspond to the general situation, which is characterised by:

- a continuous increase in the complexity of projects,
- optimising and improving the efficiency of the conception and planning processes,
- increasing specialisation of applications and among professional planners
- globalisation of the market (virtual organisations).

Therefore, it is becoming increasingly essential that all parties involved in a project, from different technical division and companies, cooperate and deploy highly specialised technical applications in a heterogeneous system environment when making decisions within the planning process.

Thanks to growing distribution and development of the basic technology, future projects may include the following:

- Integration of superimposition technology for quality assurance (data accuracy).
- Mapping instructions for complete, integrated and uniform documentation.
- Devolution of existing data (for future scientific evaluation, restoration).
- Transfer of captured data into superior information systems, e.g. GIS/WCS and georeferenced data.

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