

## AUGMENTED MAPS

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### ABSTRACT:

Cartographic visualizations are usually given as printed maps or screen maps. On the one hand the user can directly interact with a flat paper-map in a natural and familiar way like all other physical things in our environment. On the other hand there is a possibility to extend the dimensions of a map to more than two by the means of computer-vision. Three-dimensional landscapes and animation can be created and visualized. The usability depends to a great degree on the experience of the user and the possibilities of the computer program. Augmented Reality (AR) combines these characteristics, in that it places well known ways of handling and all potentialities of computer-science to the users disposal. In our approach the actual position and line of vision referring to the map is determined by the use of pattern-recognition techniques. Unambiguous tags are placed on the border of the map. These tags are captured by a small video camera. The computer determines all parameters for overlaying and combining the video-stream of reality with artificial virtual objects. As this calculation can be performed individually for different users, they can look at the same data and see the combination of reality and virtual objects. So every user can interact with the map in his own way and e.g. activate new layers or point on virtual object to get additional information. This technique enables cartographic applications to visualize and work on digital geographic data based on an analogue map. As an example the visualization of a digital terrain model in combination with the corresponding topographic map is shown.

### KURZFASSUNG:

Kartographische Darstellung erfolgen in der Regel auf einem analogen Träger oder in digitaler Form durch Bildschirmdarstellung. Während bei der Papierkarte die Interaktion in einer, dem Benutzer vertrauten Art und Weise erfolgen kann, besteht in der computerunterstützten Darstellung die Möglichkeit dreidimensionale Effekte durch virtuelle Landschaften zu erzielen. Die Bedienbarkeit hängt hierbei stark von der Erfahrung des Benutzers und den Möglichkeiten des Programms ab. Durch Augmented Reality werden die beiden Möglichkeiten vereint und ein System geschaffen, welches dem Anwender eine intuitive, und natürliche Bedienung erlaubt. Durch den Einsatz von Algorithmen zur Mustererkennung ist es möglich die Position und Blickrichtung des Betrachters relativ zu den Mustern zu bestimmen. Diese Muster sind an bekannten Positionen auf der analogen Karte angebracht und mithilfe einer kleinen Digitalkamera erfasst. Der Computer bestimmt die Parameter für eine Überblendung der erfassten Umgebung mit den virtuellen Objekten. Die individuelle Bestimmung der Darstellungsparameter für jeden einzelnen Benutzer erlaubt es, einen Datenbestand gleichzeitig aus unterschiedlichen Richtungen zu betrachten und damit zu interagieren. Als Interaktionsmöglichkeiten werden das Aktivieren zusätzlicher Themen über Schalter sowie die Funktion eines Zeigestabes erläutert. Für die Anwendung in der Kartographie ergeben sich so zusätzliche Möglichkeiten für die Darstellung und Bearbeitung digitaler raumbezogener Informationen auf der Grundlage einer analogen Karte.

## 1. INTRODUCTION

### 1.1 Overview

In cartography the definition of map is one of main issues and like in many other sciences these definitions are a subject of adaptation to actual demands. Professor Gao Jun presented in his keynote at the International Cartographic Conference in Beijing (Gao 2001) the different kind of maps. He classified maps as two branches of one tree. The first branch is the real (visible) map, this are maps or drawings displayed on the screen-printed on a media. The second branch is the invisible map, so mental maps or digital maps in a computer like virtual reality images.

Joining paper maps and virtual reality images will generate a new nature of map: the augmented map.

Augmented reality (AR) is defined as the mixture of sensory perception of the real environment and fictitious, virtual objects. Milgram (Milgram et al. 1994) shows augmented reality as a mixture between the real environment and virtual reality (Figure 1).

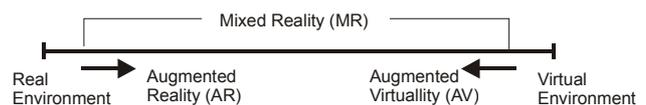


Figure 1. Milgram's Reality-Virtuality Continuum.

To keep a realistic impression this combination has to be done in real-time. So it is possible to immerse and interact in a natural way with both, the environment and the virtual objects.

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Augmented reality is used in many applications. Among those are medicine, car-navigation, energy supply, military (Piekarski et al. 1999) and data-visualisation in general (Vallino, 2002). (Azuma 1997) gives a survey in AR.

In cartography it can be used as a graphical user interface for spatial data.

In this way it is possible to visualize landscapes and other cartographic items in a graphically attractive and flexible way. Conventionally we can present digital landscape models in a perspective way on computer displays, but to get a representation of the terrain in which you can “dive in” and can perceive in a natural way, we have to apply physical models.

## 1.2 Related work

Through the use of computer-generated pictures, which can be overlaid on reality by a head mounted display (HMD) the viewer will get a stereoscopic impression not only of the real environment, but also of the artificial objects. Reality and virtuality will be melted and immersive interaction is possible.

As a prerequisite for an exact overlay of reality and augmented information, the exact viewing point and viewing direction have to be known. With these parameters we can establish the connection to additional digital geo-data and their thematic attributes. Through the simultaneous visualisation of the real environment and the three-dimensional view of geo-data the human perceptive facility is broadened. The determination of the users position and viewing direction can be accomplished in several ways:

- magnetic field sensors,
- positioning and orientation sensors (GPS, INS),
- or using image processing techniques.

(Broll et al., 2000) presented a virtual round table, where several participants can look at the same scenario on a desk. Tracking is made by an inertial tracking device and pattern recognition. Real Objects (cups) are placeholders as tangible interfaces. (Reitmayr et al., 2001) describe a mobile collaborative AR-System that supports true stereographic graphics, a pen, a pad interface and direct interaction with virtual objects. (Schmalstieg et al. 1996/2000) show the collaborative environment for shared space work in AR.

## 2. AUGMENTATION OF MAPS

To enrich the functionality and performance of printed maps, we have to examine the following points:

- Information we can handle by traditional maps
- Possible operations with analogous maps
- Additional (invisible) potential of digital information
- New optimised handling techniques
- Integration of these points in an AR-Map

Traditional maps are designed to visualize spatio-temporal phenomena in a flat, two-dimensional way. Cartographic methods have been developed to reach some pseudo-three-dimensional or pseudo-temporal effects. But they are all static and that's where the problem lies. The map cannot react on the users behaviour. There is no real interaction between user and map like in a virtual-reality-environment, where an action of the user causes reactions of the system.

The possible operations with analogous maps are limited to panning, rotation and zooming (approaching / getting off). Thematic selection of overloaded maps depends of the experience of the user (MacEachren 1995).

The enrichment of printed maps is the combination with dynamic, variable digital data. So processes can be visualized in real-time and, because of the variety in dimension, in more than two dimensions. Normally we use traditional maps as a close range application, outside or inside of buildings. We have to find a method to augment maps fitting all these needs. These demands are fulfilled by methods of pattern-recognition.

ARToolKit (ARToolKit 2002, Billinghurst et al., 2001) uses these techniques to determine the relative position of a video camera to a marker (square with unique patterns) in the video-stream. To speed up the process the video is turned into inverse black and white by a threshold operation. In this picture is then searched for square regions. All squares found are inspected for pre-trained patterns inside. If there is a match, a marker is found. Using the known pattern-size and detected orientation the position-matrix can be calculated. This matrix describes the real world coordinates of the real camera relative to the tag. This matrix is then used to set the position of the virtual display coordinates. Since the virtual display and real camera coordinates are the same, the graphic overlay is drawn precisely over the real pattern. An OpenGL API can be used to draw virtual objects in the virtual display. As the patterns are simple and easy to recognize, this operation can be executed in real-time. The algorithm runs with at least one pattern. Figure 2 describes the working method of ARToolKit (© Kato et al. 2000)



Figure 2. Working method of ARToolKit.

To realize an ARToolKit-application at least a video camera and a computer connected to it is necessary. By using a head mounted display (HMD) a more immersive experience will be created (Figure 3). So video capture and video and VR-object output are done in the same place. HMDs can be used in opaque or transparent/see-through-mode. In opaque mode the video and virtual data will be displayed. In see-through mode only the virtual objects are shown and the user can see the virtual objects overlaid the real environment.

The patterns are used as identical points to georeference the physical map and the artificial objects. So we can merge real and virtual information. The layout of an augmented map is shown in Figure 4. The actual map is bordered with four patterns. So the viewer can look at the map, always grasping one reference point to virtual reality at least. In order to recognize the pattern we have to pay attention to keep distance to other graphical elements.

As a concrete example the archaeological map of a castle is taken. Every summer our students survey historical locations within their courses. One result is the digital terrain-model of the surrounding of the castle. The graphic outcome is a new



Figure 3. Cameras and HMD in see-through-mode.

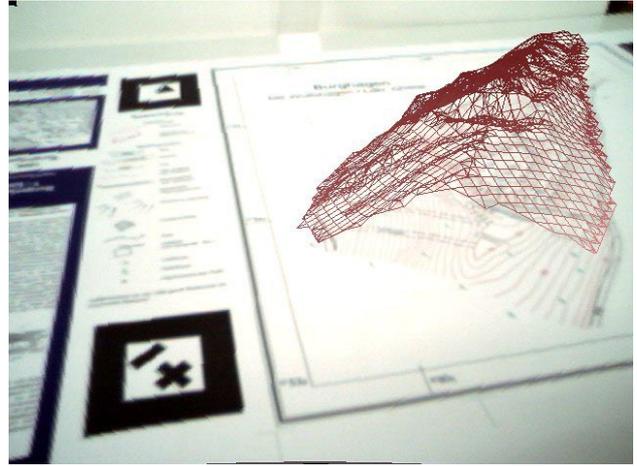


Figure 5. Overlay with 3D-TIN.

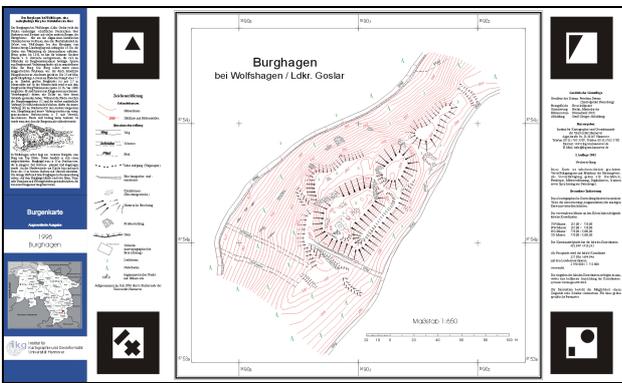


Figure 4. Layout of augmented map.

archaeological map. In the new map-design this map is in the middle of the sheet. If folded, you can see the blue title page. It is on the most left hand side and illustrates the greater location and gives a brief historical outline of the object. The legend between the left patterns describes the map-style in detail. The left text-block contains - apart from geodetic information - the local coordinates of the pattern and the local and global coordinates of one point of reference in the map. Assuming that the local coordinates are parallel to the global coordinates, digital terrain-models and other digital geodetic data can be matched to the analogous map (Figure 5 and Figure 6).

Since four patterns refers to only one virtual object and real-time processing is necessary the position of this object is determined by the first corresponding pattern.

At this stage of research the paper map is connected to digital data. Terrain-models can be shown on top of analogous representations. A further extension is in functionality. Map-users can interact by switching themes or layers, using an augmented signal disc. In our examples it would be useful to show all sites of archaeological discovery.

Repeated recognition of the pattern on the disc will on the one hand change the appearance of sphere on it and on the other hand alter the virtual theme on the AR-map (Figure 7). Themes can be switched on or off; symbolization of virtual map-object can be changed and so on.

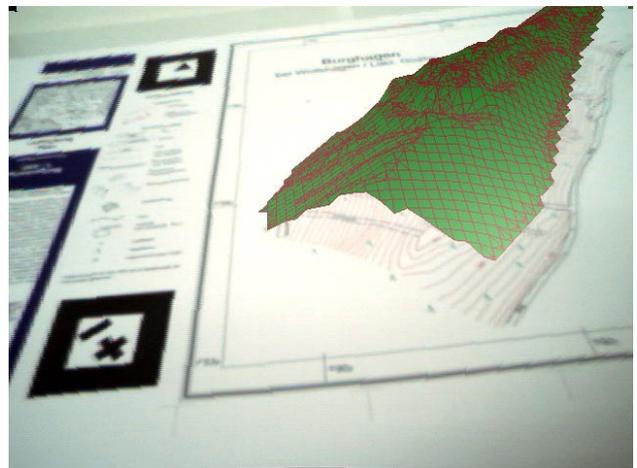


Figure 6. Overlay with DEM.

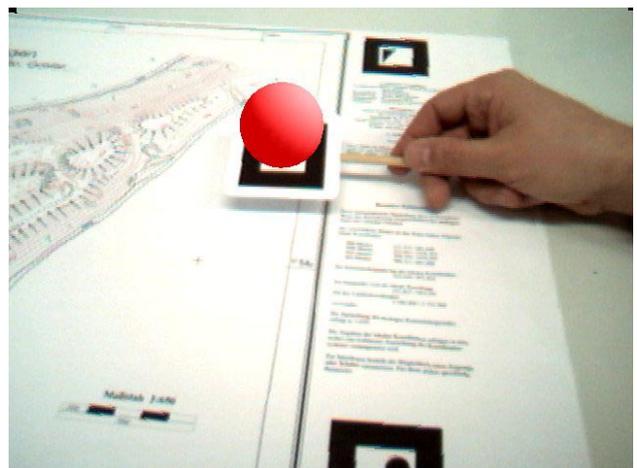


Figure 7. Augmented switch (red=off, green=on).

Another option is also a pattern as a proportional input device, which will modify the appearance of a theme in accordance with the discs angle of inclination. Linking the time index to the pattern can control the course of animations.

Additional information can be obtained by using an augmented pointer (Figure 8). Here virtual objects (visible or not) intersect

with the virtual end of the pointer. Depending on the object and the position of the pointer further actions can be triggered.



Figure 8. Augmented pointer.

In contrast to other immersive visualisation-methods the information can be projected into the HMD's of several users individually, thus this system greatly enhances collaborative work.

### 3. CONCLUSION

Pattern recognition techniques are applied for the visualization and inspection of topographic maps. The patterns are placed in the unused parts of the maps, so that the map can be utilized conventional as well. But the connection of the analogue map and a 3D digital landscape model allows for a three-dimensional presentation on top of the map. The user can interact with this model like with an analogue model: move and rotate it and change the point of view and distance. The only restriction is the recognition of at least one pattern in his field of view.

The advantage of this kind of data-visualisation is the possibility of natural interaction between user and system. Different operations are possible. Whereas rotation and movement of all degrees of freedom can be done in both, reality and virtuality, more interactions like zooming, scaling, selection of attributes, change of style, selection of themes and animation are possible.

These functions can be activated by different ways. The view of the real and virtual objects is changeable by the position and viewing direction of the user. Apart from keyboard-input virtual objects can be manipulated by virtual sensors to change their representation. The extension of this concept is that virtual objects can intersect with other virtual objects and cause a reaction.

A further improvement would be markers made with ink in the invisible spectrum. Special cameras could detect the pattern without disturbing the user of the map.

An augmented map represents a further step in interaction with digital cartographic data. Analogue maps are mixed with digital models. An immersive working method is possible for every single user of the system simultaneously. Furthermore by the Internet it does not matter where this user is located; several users can manipulate their own themes and place them into the common virtual environment.

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