A CONTEXT–AWARE ADAPTATION SYSTEM FOR SPATIAL AUGMENTED REALITY PROJECTIONS

Anne Wegerich, Julian Adenauer
Research Training Group prometei, Technische Universität Berlin, Germany

Jeronimo Dzaack, Matthias Roetting
Department of Human-Machine-Systems, Technische Universität Berlin, Germany

Keywords: Spatial Augmented Reality, Projection systems, Context–aware user adaptation, User interfaces.

Abstract: To cover three-dimensional information spaces stationary or spatial Augmented Reality (sAR) systems involve installed projection systems, Head-Up- and other displays. Therefore, information presentation techniques for sAR contain three basic problems assigned to the questions which form, which screen position and which physical location the information should have in 3D space. This paper introduces an approach and presents the details of a corresponding system that concentrates on the location problem and the appropriate visualization adaptation. It manages the information presentation for physical occlusions and difficult light conditions of sAR floor projections with a light sensor matrix and a connected software for low and high-level context integration. With changing the size, position, and orientation of the projection area and the content of the presented information it implements a context-aware adaptation system for sAR.

1 INTRODUCTION

Augmented Reality (AR), the augmentation of the environment with virtual, computer generated information, is used in many different areas. If the user is required to move in large areas, he or she needs to carry a mobile presentation device or wear a head-mounted display (HMD). But whenever the user's movements are restricted to a small, controlled area, this burden can be loosened by realizing spatial or stationary AR (sAR).

Whereas in mobile AR the information is typically presented on only one display device, sAR systems use many displays distributed in a small 3D space. This bears the danger that the user is confronted with incoherent and/or redundant information because many displays or segregated (parts of) displays are used for showing one information. To avoid this, a central system is required to automate the selection and optimization of the information that is presented to the user.

Beside the display problems where on the screen and in which form the sAR information should be presented (view and presentation management) the main question especially for sAR is: Where (i.e. on which display or projection area) should the information be presented physically in a room (display management)? Furthermore, the definition of AR by (Azuma et al., 2001) requires that the virtual information has to be combined with the real world in real time and it has to have a content-related connection to the point where it is presented (spatial registration).

Altogether information presentation with (s)AR display technologies needs to attend to physical problems like edges, gaps, over-lappings of two or more projections, and occlusions without loosing spatial registration as a content-related requirement (Fig. 1).

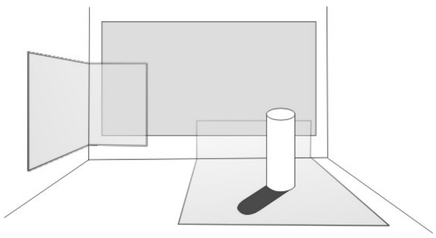

Figure 1: Gaps and overlappings of three projections (gray) in a room with particular occlusion (shadow and white column).

In this paper we address occlusions and we present

Wegerich A., Adenauer J., Dzaack J. and Roetting M. (2010).
A CONTEXT–AWARE ADAPTATION SYSTEM FOR SPATIAL AUGMENTED REALITY PROJECTIONS.
In *Proceedings of the 7th International Conference on Informatics in Control, Automation and Robotics*, pages 98-103
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a sAR system that handles the presence of occluding objects and related light conditions (shadows or reflections) with regard to the AR definition. More precisely the system manages the context-aware recalculation of location, size, orientation, and visualization of a projected information if a physical object (e.g. the user himself) occludes it.

After showing some related work concerning the display management and the measurement of environmental context information we present the proposed system in section 3 and 4. Afterwards we explain the purpose of the software and how it will be integrated in the further development of a sAR smart home system.

2 DISPLAY MANAGEMENT AND MEASUREMENT OF ENVIRONMENTAL CONTEXT

Several solutions exist for recognizing over-lappings and closing gaps in projected sAR scenarios. Therefore, a movable mirror combined with a projector is presented by (Pinhanez, 2001). So the presentation follows the user. Other rotatable projectors are suggested by (Ehnes et al., 2004; Ehnes and Hirose, 2006). These projectors offer only one screen that moves and does not produce any gap or overlapping. To solve the problem of roaming between different immovable projection systems these authors also designed an architecture that handles overlappings with selecting the best possible projection system (Ehnes et al., 2005). However, they did not make a suggestion for physical occlusions.

For the integration of high-level context a lot of AR applications are based on image processing systems which are able to recognize states of the environment or the user. This is usually used to provide automated user support in communication, work, or information processing. In AR applications this recognition is very important but often limited to special areas like city navigation or guidance in museums. However, an approach for a user-adaptation with high-level context integration is missing. Especially for 3D information spaces new research results give evidence that information visualization must be adapted for different 3D presentation depths and optimal information perception of proposed virtual distances and perspectives (Drascic and Milgram, 1996; Jurgens et al., 2006; Herbon and Roetting, 2007).

Separated from high-level context, environmental (or low-level) context registration is a field of research that is well investigated. Therefore, the current research is focused on new applications and combinations of them to facilitate the development of new technologies especially in the scope of Human-Machine-Interaction (HCI). Hence, there is a huge amount of applications in which environmental context data is collected with sensors. Especially for popular social applications a lot of psychophysiological data is measured to enable the automated recognition of emotional states of the user. Such systems concentrate for example on areas like e-learning platforms (Karamouzis and Vrettos, 2007), indirect or direct interaction in multimedia applications like web pages, virtual communities, and games (Ward and Marsden, 2003; Kim et al., 2008; Mahmud et al., 2007). Particularly in the scope of mixed reality games the use of low-level-context is a popular approach because it connects the real and the virtual world for the player (Romero et al., 2004).

For these and other upcoming technologies analyzing context information and integrating it to develop adaptable systems has led to context ontology models which are generic or domain specific and allow the standardized use of context information and the development of associated system or software architectures (Chaari et al., 2007).

With the presented approach we combine these context models with user-centred adaptation techniques for sAR information visualization. With this we want to optimize sAR systems, make them more useful, and establish generic models for context integration.

3 SAR SYSTEM SETUP

The system is part of the development of a sAR smart home environment which involves a number of different sAR devices. These are projection systems, video-see-through and head-up displays (Bimber and Raskar, 2005).

The proposed system is mainly based on an array of light sensors on the floor to control the position, size, and orientation of a projection. The sensors measure light conditions in the environment (low-level context information). A connected software module manages the context-related adaptation of the information visualization based on the feedback of the recalculated presentation and sends the resulting image to a projector. So the proposed low-level change of the projection will be recalculated again if the new projection got ambiguous in the current context. The support for a user searching an object for example could be showing a map with a target marker. If the projection area (location) for map presentation has to be changed because of difficult light conditions also the size and orientation or the whole visualization type of the new map have to be adapted. The first change could have made it incomprehensible for the user e.g. because of his current perspective.

The complexity of contentual changes increases if high-level context information is taken into account. If a projection area has to be changed, the content adaptation software perhaps has to present the same information with another visualization (content) to facilitate its perception. This assumption is based on a lot of requirements determined by the abilities of the user (background knowledge, cognitive capacity, experience, etc.) and the context. In the map example this perhaps means to change the visualization from a map to an arrow because the user currently is distracted and only can process simple visualizations in his peripheral vision. So the presented system relates to a complex network of decisions. Altogether the software has to automate having the right information presentation technique at the right position for the conditions the context provides.

The system we introduce in this paper is the first step towards a full home automation and support with sAR displays. The hardware of the presented system is a proof of concept and therefore is limited to a solution that includes one projector and a small projection area . But the framework is extendable to larger projection areas and sensor arrays.

4 CONTEXT–AWARE PRESENTATION SYSTEM

The task of the system we developed is to analyze lighting conditions on the floor of a room to make this surface usable for an sAR output of a projector that is installed above it. Thus, it solves a part of the problem to add information everywhere in a three-dimensional space without losing the relevant content of it and important parts of its formal representation. Furthermore, the system provides the possibility to adapt the visualization in terms of HCI criteria and the upcoming research of three-dimensional perception.

The system consists of a light sensor matrix that is integrated in a PVC floor coating, a connected microcontroller board which is connected to a PC, and a Java-based software. The size of the PVC floor coating and the sensor array is a proof of concept and could be extended for larger rooms and projections. The presented system is able to change the size and position of an at least possible projection area. This is the first step to adapt the presented content which depends on the resulting distance of the information to the user and additionally on the properties of other sAR devices which are in a similar distance, the type of device, its orientation, and of course the type of information which has to be presented and a lot of other context requirements.

After collecting information about the physical context (occlusions or lighting conditions) the software first evaluates possible projection areas and selects one. Secondly it has to access the properties of the selected area and analyzes further high-level context information to change the visualization of the content if needed.

4.1 Installation

The system consists of a sensor array for brightness measuring in a certain physical space and a microcontroller. It converts the analogue sensor data and sends it to a connected PC which controls the output of a projector (see Figure 2).

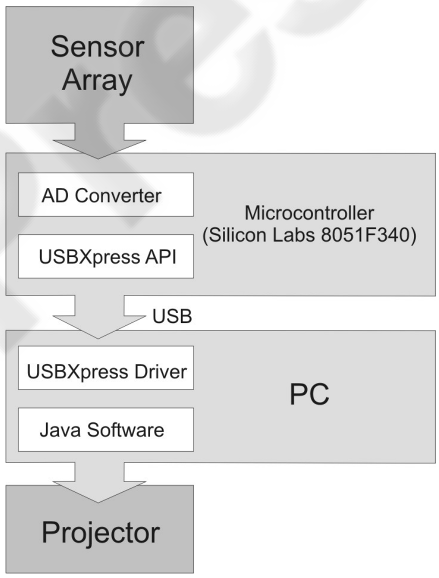

Figure 2: Schema of the context–aware presentation system.

A $0.75m \times 1m$ PVC floor coating is divided into twelve squares and a projector is placed $2.5m$ above it. The projector is connected to a PC and projects corresponding squares on the floor. In the middle of each square, a light sensor of Type AMS104Y from Panasonic's NaPiCa-series is set. The sensor's feature is a linear output and a built-in optical filter for spectral response similar to that of the human eye.

Each sensor is connected to an input of a microcontroller. The voltage over the resistor depends on the sensor's photocurrent and is therefore directly dependent on the amount of light on the sensor. This voltage is being measured by a 10 bit analogue–to–digital converter (ADC) which is part of the microcontroller (see Figure 3 for more detail on the sensor matrix).

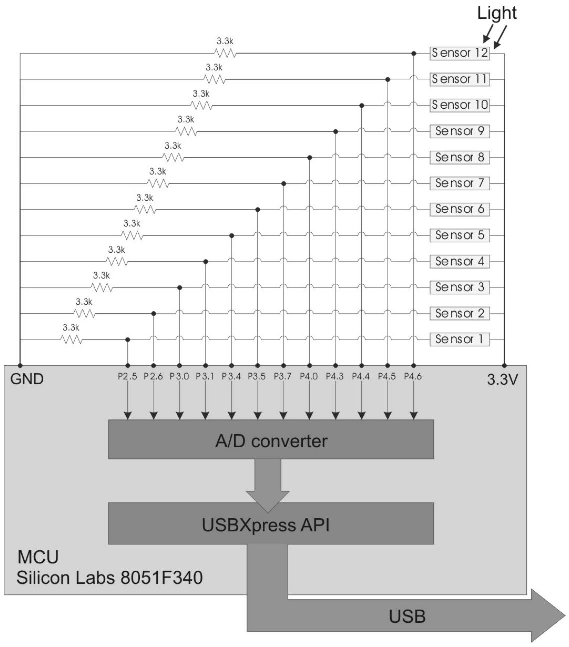

Figure 3: Diagram of the components and connections of the sensor matrix.

The microcontroller we used is an 8051F340 from Silicon Labs. It features a built–in analogue multiplexer for the ADC, enabling the controller to convert analogue voltages from 20 input pins. Moreover, it has an onboard USB controller which can be used with Silicon Labs' USBXpress API for easy USB implementation on client and host side. Via this USB interface the controller board sends the digital sensor values to a PC.

The PC is running a software that reads the converted sensor data from the USB port. These values are compared to predefined minimum and maximum values. Value below minimum means, the sensor is covered, so nothing should be projected here. A value higher than the maximum, on the other hand means, there is too much light on the area and the decreased contrast averts a projection. Therefore, only squares (one square per sensor) with light values in the range between minimum and maximum are taken into consideration, where information should be displayed.

From these squares that are in range the program selects the ones that build up the largest coherent quadrangular area according to an implemented hierarchy. In the resulting connection of these squares information could be displayed.

4.2 Functionality

The overall goal of the software component is the adaptation of the projected superimposition with regard to low-level and high-level data integration. Therefore, it incorporates two steps of projection recalculation: low-level and high-level data related adaptation (currently only the first software part is solved). The data is processed in real time. So the projected information is always in a visible position accepting a very small delay from the sensor data request.

In a first step the software calculates the most appropriate size, position, and orientation for a projection that can be used to present text, icons, or (rendered) images. It is made up of directly connected projection squares whose sensors are not in a shadow or in a direct light reflection. Then the new proposed projection is adapted to the unchanged orientation of the target (a text reading person or target position of a pointing projection, etc.). After this step the information has the correct orientation and is displayed in the best possible projection area for the target (e.g. the user). In Figure 4 this first adaptation step of the system is demonstrated with an arrow pointing at a designed target (red). This arrow is only one possible usage of a projection area.

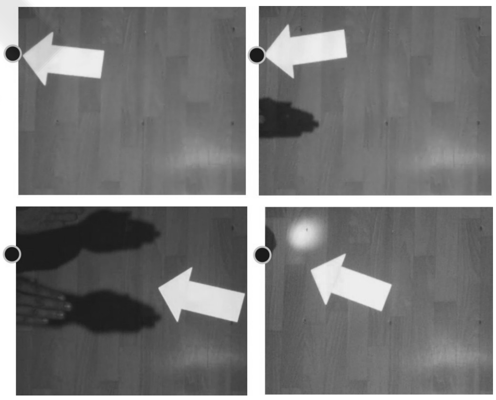

Figure 4: Examples for resulting projections (low–level recalculation) when sensors are covered or bright light falls on them, arrow always points in a target direction (represented by black dot).

The second part of the software uses the feedback signals about the proposed projection area and the current information visualization. It analyzes high-level data (context information about the user, his distance to the projection, current state of the needed information, etc.) to recalculate whether the visualization is still optimal for the user or not. If it is not, the visualization changes to an alternative image or text for a better understanding. Figure 5 shows an example for the proposed reaction of the system. The resulting visualization for a navigational hint in this case is a map instead of an arrow. We based this approach on findings from an indoor navigation experiment we made (Wegerich et al., 2009). In this experiment projected maps were rated higher and caused better performance when the target position is not visible for the user.

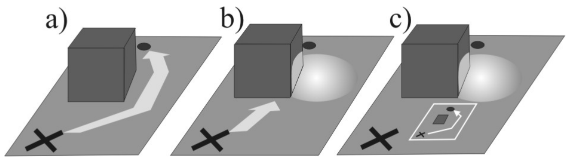

Figure 5: Example for an adaptation scenario and 2 steps of visualization recalculation a) shows the target and the starting point of the user, b) first step of adaptation where the projection area, size and orientation changes to the at least possible squares with no light reflection and the correct direction (low-level data integration), c) second step of adaptation; the visualization is changed to a map which shows the unambiguous target position.

5 DISCUSSION

The proposed system component for the adaptation of floor projections is a proof of concept. We presented a solution for the problem of occlusions in physical issues of information presentation with sAR. The sensor matrix is not limited to the presented size and amount of sensors. The usage of a higher resolution could be achieved by integrating more light sensors. Furthermore, this makes it possible to change the projection area not only to other rectangular forms but to a more adaptive shape of the presented information which we work on in the smart home scenario.

A higher resolution is also achieved with the usage of cameras which are very common in AR applications. In most cases they are integrated in the ceiling or higher edges. So image processing software is needed to solve perspectives and occlusions only the camera sees, but not the user. When a user lifts an arm and still can see the same area on the floor a camera system would change the projection area because it has difficulties to decide where the occlusion is in its distance to the floor. So the advantage of floor-based sensor matrices is that they measure the conditions at the point where the projection will be with less effort and as fast as a camera based system.

The presented sAR system component handles the formal information representation and the display management but at this point not the optimization of the content because of its complexity. Other high-level context information is needed to decide which form the information should have. This will be the result of the integration in the intended smart home system. One of the applications of high-level context integration is e.g. to pay attention to possible fast moves of a user or to distances the area adaptation causes. An arrow could be usable in this case but perhaps a map of the room (and its cabinets) is better if more detailed location information is needed.

6 FUTURE WORK

With the introduced system the foundation is made for using context information and properties of three-dimensional perception. It adapts the information visualization and furthermore solves parts of the display management problem of sAR systems. The next step is the development and evaluation of a more complex context model that follows specified guidelines for 3D information presentation and integrates different sAR devices. The aim is the enhancement of the software functionality on the basis of this model.

Afterwards, it will be combined with other context-aware system components which together form a user-adapted sAR presentation system. The resulting system will present information in larger 3D spaces where the form, position, additional interaction parameters, and especially the content is selected for 3D perception adaptation to the abilities of the user.

The presented system also solves a technical part of the Ubiquitous Spatial Augmented Reality (UAR) requirement to make information available everywhere in a larger 3D space with using context. This is an essential aspect of the underlying definition because of the so achieved connection between the concepts of Ubiquitous Computing and Augmented Reality. In this manner the presentation technology in a 3D information space needs to be context-aware in a more continuous way to adapt the presentation for any location in the room. Furthermore the underlying context model has to integrate location-based adaptation because of a possible dynamically changing environment. For example a projective sAR system used for superimpositions on a working surface should handle changing objects or tools and its positions on the surface.

Finally, we want to develop an ontology that describes and generalizes the automated decision of the adaptation system. Based on this ontology we will develop an expert system to manage the rules of perception and cognitive processing of 3D information presentation in UAR environments and to solve the high-level context integration. This will make the system scalable and adaptable to different use cases and also for mobile AR display applications.

ACKNOWLEDGEMENTS

We want to thank the DFG, the Department of Human-Machine Systems Berlin, and prometei for their support.

REFERENCES

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., and MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Comput. Graph. Appl.*, 21(6):34–47.

Bimber, O. and Raskar, R. (2005). *Spatial Augmented Reality: Merging Real and Virtual Worlds*. A K Peters, Ltd.

Chaari, T., Ejigu, D., Laforest, F., and Scuturici, V.-M. (2007). A comprehensive approach to model and use context for adapting applications in pervasive environments. *J. Syst. Softw.*, 80(12):1973–1992.

Drascic, D. and Milgram, P. (1996). Perceptual issues in augmented reality. In *Stereoscopic Displays and Virtual Reality Systems III, Proceedings of SPIE*, number 2653, pages 123–134.

Ehnes, J. and Hirose, M. (2006). Projected reality - content delivery right onto objects of daily life. In *ICAT*, pages 262–271.

Ehnes, J., Hirota, K., and Hirose, M. (2004). Projected augmentation - augmented reality using rotatable video projectors. In *ISMAR '04: Proceedings of the 3rd IEEE/ACM International Symposium on Mixed and Augmented Reality*, pages 26–35, Washington, DC, USA.

Ehnes, J., Hirota, K., and Hirose, M. (2005). Projected augmentation ii — a scalable architecture for multi projector based ar-systems based on 'projected applications'. In *ISMAR '05: Proceedings of the 4th IEEE/ACM International Symposium on Mixed and Augmented Reality*, pages 190–191, Washington, DC, USA.

Herbon, A. and Roetting, M. (2007). Detection and processing of visual information in three-dimensional space. *MMI Interactive Journal*, 12:18–26.

Jurgens, V., Cockburn, A., and Billinghurst, M. (2006). Depth cues for augmented reality stakeout. In *CHINZ '06: Proceedings of the 7th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction*, pages 117–124, New York, NY, USA. ACM.

Karamouzis, S. T. and Vrettos, A. (2007). A biocybernetic approach for intelligent tutoring systems. In *AIAP'07: Proceedings of the 25th conference on Proceedings of the 25th IASTED International Multi-Conference*, pages 267–271, Anaheim, CA, USA. ACTA Press.

Kim, Y. Y., Kim, E. N., Park, M. J., Park, K. S., Ko, H. D., and Kim, H. T. (2008). The application of biosignal feedback for reducing cybersickness from exposure to a virtual environment. *Presence: Teleoper. Virtual Environ.*, 17(1):1–16.

Mahmud, A. A., Mubin, O., Octavia, J. R., Shahid, S., Yeo, L., Markopoulos, P., and Martens, J.-B. (2007). amazed: designing an affective social game for children. In *IDC '07: Proceedings of the 6th international conference on Interaction design and children*, pages 53–56, New York, NY, USA. ACM.

Pinhanez, C. S. (2001). The everywhere displays projector: A device to create ubiquitous graphical interfaces. In *UbiComp '01: Proceedings of the 3rd international conference on Ubiquitous Computing*, pages 315–331, London, UK. Springer-Verlag.

Romero, L., SANTIAGO, J., and CORREIA, N. (2004). Contextual information access and storytelling in mixed reality using hypermedia. *Comput. Entertain.*, 2(3):12–12.

Ward, R. D. and Marsden, P. H. (2003). Physiological responses to different web page designs. *Int. J. Hum.-Comput. Stud.*, 59(1-2):199–212.

Wegerich, A., Dzaack, J., and Roetting, M. (2009). Optimizing virtual superimpositions: User centered design for a UAR supported smart home system. submitted.