Spatial Augmented Reality for Architecture – Designing and planning with and within existing buildings

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At present, more than half of all building activity in the German building sector is undertaken within existing built contexts. The development of a conceptual and technological basis for the digital support of design directly on site, within an existing building context is the focus of the research project “Spatial Augmented Reality for Architecture” (SAR). This paper describes the goals achieved in one aspect of the project: the sampling of colors and materials at a scale of 1:1 using Augmented Reality (AR) technologies. We present initial results from the project: the development of an ad-hoc visualization of interactive data on arbitrary surfaces in real-world indoor environments using a mobile hardware setup. With this, it was possible to project the color and material qualities of a design directly onto almost all surfaces within a geometrically corrected, existing building. Initially, a software prototype “Spatial Augmented Reality for Architecture-Colored Architecture” (SAR-CA) was developed and then assessed based on evaluation results from a user study.

Keywords: Augmented Reality, Renovation, Design Support, Color and Material Sampling
1. Designing and planning in existing built contexts

1.1 Building in existing built contexts: the current situation in Germany

The focus of building activities in Germany is characterized by a mixture of new buildings and renovation work. After the period of reconstruction following World War II and the expansion of the built environment in the last 20-30 years, a process of consolidation and renewal of existing building stock has begun. A variety of factors contribute towards this development: sinking population figures are leading to a general decrease in demand for living space, the population is drifting away from the former industrial regions, and there is a steadily increasing need to renovate existing buildings.

Since the early 1990s, the focus of planning activities has shifted away from new building to renovation and building within existing built contexts. More than half of all building investment is in the renovation sector and this proportion will continue to rise [7].

Building in existing built contexts is becoming ever more important and this looks set to increase still further in the coming years.

In contrast to new building, planning within existing built contexts necessitates a more complex interaction with the existing building form, its infrastructure and their respective special requirements. The actual presence of the building, including an analysis of its history and changes made during its lifetime, are a central aspect. The existing building is in all cases the basis for the design and planning tasks that follow.

1.2 Computer aided design and planning for existing built contexts

The use of computers in architectural practice is widespread and complements traditional tools such as drawings and physical models. Computers can support the design process in three dimensions with the help of a building information model (BIM), however, the output devices are still generally ‘traditional’ 2D devices, such as screens or plotters.

Rapid technological advances are however enhancing the possibilities of architectural design, for instance three-dimensional VR and AR environments. Immersive and semi-immersive projection displays, such as CAVEs™ and workbenches are already used to support virtual reality applications in many professional domains, including the field of architecture. The visualization of data using such displays requires dedicated rooms for setting up non-mobile screens.

A look at current computer aided systems reveals a gap in the (possible) IT-support for the design and planning of existing buildings. The current software and hardware market in this field is characterized by a variety of individual products, mostly adaptations of CAAD-Systems or specific
computer-supported solutions already available for new building or else adaptations of products from other fields, e.g. VR/AR supported design in the automobile sector or SAR applications [2].

2. Spatial Augmented Reality for Architecture

The aim of the “Spatial Augmented Reality for Architecture” [12] research project is to investigate and develop the conceptual and technological foundation for the ad-hoc visualization of interactive three-dimensional (stereoscopic) and two-dimensional (monoscopic) data on arbitrary surfaces in real-world indoor environments using a mobile hardware setup.

This is a prerequisite for developing systems that can support the architectural design process in real-world environments. In other words, the interaction in and within existing buildings at a scale of 1:1, and the support of design and planning processes at true scale (see Figure 1; [20]).

The project is an interdisciplinary research project with two core areas:

2.1 Technological basis – core technologies

Projection technology allows the creation of images that are larger than the devices themselves and in locations that are impossible to achieve with other display technologies. With conventional technology, the need to erect projection-optimized screens nevertheless remains a major disadvantage. Visualizations projected without screens onto everyday surfaces are, however, fraught with difficulties. Projected images are often geometrically distorted, blend with the color of the background and portions are out of focus.

The focus of this research area is the investigation and development of a conceptual and technological basis for realizing visualizations in real-world environments – enabling immersive and semi-immersive virtual reality as well as augmented reality implementations without the need for special display surfaces or permanent screen configurations. This includes:

- **Data acquisition** – the investigation of computer graphics techniques for extracting the real environment’s local and global illumination parameters,
- **Rendering techniques** – the development of real-time and non-real-time image correction techniques that enable the correct projection onto geometrically and radiometrically complex surfaces,
Projector-based augmentation and illumination – the implementation of techniques that augment real environments with synthetic objects and simulated illumination effects,

Basic interaction technology – the realization of fundamental forms of interaction (devices and techniques) appropriate to this new form of visualization.

2.2 Computer-supported architectural planning in and within existing built contexts

Based on the evolving core technology a second focal area is the investigations of new forms of interactive information visualization to support the entire architectural design/planning process. The projection technology enables one to project data in real-time onto almost any surface of an existing building, color-calibrated and geometrically rectified so that it fits the real context. The setup can be positioned freely, much like pointing a torch. The technology makes it possible to provide both purely immersive virtual environments as well as to augment real situations with additional virtual data to show changes in the surfaces of objects.

The aim of this research stage is to develop a software concept, to implement selected aspects of the concept and then to evaluate these in real environments.

Research began with an empirical examination of existing computer-assisted planning software and IT-solutions in the architectural field and an analysis of the “traditional” day-to-day work process. In addition, related fields such as product and automotive design were also examined.

From these a software concept was developed and individual tools developed as prototypes to provide support for the respective phases of the architectural design in and within existing buildings, for example:

- **Support for the planning-oriented measured survey**, such as the comparison of existing plans with the real situation (superimposition of plan and room), or the localized surveying of additional data (for instance verification of the model against the real situation, augmentation of the model with image detail and geometric information).

- **Support for on-site design methods** such as the rapid creation and assessment of design variants undertaken on site in the room in question. The technology enables new information to be superimposed and existing situations to be ‘cancelled out’. The real environment serves as the basis for planning. The design support can be loosely categorized into the immersive formulation of design intentions, and functions and on-site simulations that support decision-making processes.

- **Support for interactive presentation** using a low-cost CAVE™.
like immersive stereoscopic projection in room corners for the interactive creation, display and presentation of design intentions and different types of architectural models.

3. Low-cost stereoscopic projection in room corners

Immersive display projections, such as CAVE™, have been used for many years to support the design process in fields such as the automotive industry. These require specialized, large and immovable setups. In the architectural environment, CAVE™ solutions allow the creation and display of building and urban contexts as well as 1:1 simulations. The technology required is both expensive and dependent on immobile hardware solutions.

A two-sided stereoscopic forward-projection served as an initial test platform for our project (see Figure 2). Instead of using specialized projection screens, two walls meeting at the corner of an ordinary room were used to create an immersive experience. In this test scenario, we used only planar white surfaces. Here the focus was to test and evaluate the algorithmic compensation of indirect scattering for immersive and semi-immersive projection displays (see Figure 3; [3]). The hardware setup used on-site will be a mobile projector and camera.

Surfaces need not necessarily to be white or planar — it is also possible to project images correctly onto arbitrary existing complex surfaces, such as walls or curtains. This Smart Projector technology as shown in Figure 4 has already been implemented in an earlier software prototype (see Figure 4; [20]). The projection onto reflective or transparent surfaces is yet not practically possible [19].

“Low-cost stereoscopic projection in room corners” makes use of standard commercially available equipment, making the system both inexpensive and portable. Two ceiling-mounted 120Hz DPL projectors with front-mounted wide-angle lenses create a 6×2.2 meter image at a resolution...
of 1600×800 pixels. The image extends beyond the user’s field of vision and supports disparity-based depth perception of the presented content. An optical tracking system ensures that the projection is correct from different perspectives. The system uses techniques to compensate for secondary scattering effects [3].

The software solution developed allows the use of different sources, for instance VRML-Models or a video stream.

In this scenario the off the shelf application Quest3D serves as the architectural content environment (see Figure 5). Quest3D is a software package that can be used for virtual reality projects – architectural content means a walk-through through a building, the interactive visualization of design intentions, simulations or life-size design at a scale of 1:1 [10].

The visual programming of Quest3D (“channeling”) is easy to learn. The Quest3D C++ SDK allows one to build “new” channels – a channel is a “functional brick” in the visual programming language (see Figure 6). A dedicated Quest3D channel was developed that renders two stereo-pairs and combine them into a single 1600×800 image (see Figure 7). This image is streamed from the application PC to the display PC, which decomposes the

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**Figure 4.** Stereoscopic projection onto a non-trivial surface. Reprint from [20], © 2005 IEEE

**Figure 5.** Two-sided stereoscopic projection – Architectural walk through.

**Figure 6.** “Two-sided stereoscopic Projection Channel” used in Quest3D.

**Figure 7.** Two stereo-pairs.
sub-images and projects them with two 120 Hz stereo projectors onto the walls. The user has to wear synchronized shutter glasses to see the 3D content.

4. A Spatial Augmented Reality toolbox for architecture

The concept of the system follows a modular principle. Different modules for information capture, design and planning can be combined as required. The individual modules form a continuous, extensible, flexible and in real-time dynamically adaptable system, which covers all aspects from the initial site visit to detail planning. Each tool was developed for an individual aspect taking into account its role and the requirements of the entire planning process. This software concept called “Freak” was developed in an earlier research project “Collaborative Research Center 524” and adapted and expanded for this framework “Freak+” [8, 5].

To manage all the hardware and software components, such as projectors, cameras and applications, we opted for a distributed software architecture based on a communication protocol (TCP/IP) for linking networked architectural applications. A central lightweight server (called server 4+) manages a database, which stores the raw architectural data.
(such as geometry or surface properties) and can be accessed by clients through shared software kernels (see Figure 8).

The distributed architecture allows existing architectural application clients to access the functionality provided by new service clients. Shared libraries (called kernels) act as interfaces to the server and provide basic functionality for all clients. This structure makes the system extremely flexible and extendable.

The different clients all access and save to the centrally stored building data. Application clients provide architectural functionality, such as the tachymeter-based, photogrammetry-based, or sketch-based geometric surveying of building structures, color and material sampling or modeling and inventory management [4, 9]. These clients represent a selection of common working tools for architects — although support is only for desktop-based visualization and interaction. To enable projector-based augmentations, individual service clients and kernels have been developed and integrated into this system. They provide specific functionality, such as real-time image correction for projections onto complex surfaces, projector-camera calibration, and synchronization management between different devices (see Figure 9).

5. Designing on-site

Imagine the following scenario: an architect enters an existing building charged with devising a new color and materials concept. Out of his shoulder bag, he takes a laptop, a camera and a projector. He sets up the equipment in the room, allows it to self-calibrate automatically and shortly afterwards the planning model of the room is projected superimposed life-size onto the walls of the room. He reaches into his pocket and draws out a
laser pointer, switches it on and uses it (in place of a mouse) to begin editing by simply pointing the laser into the room (the camera tracks the position of the pointer). He tries out colors and materials and their impact on the atmosphere of the space – all without having to set up white projection canvases: the self-correction algorithm of the projector compensates for any uneven shapes, surface texture and color of the walls. This is the ultimate vision of the following paragraphs.

6. Colour and material in the design process

The professional support of color and material sampling using Augmented Reality technologies has great potential. To augment the existing architecture life size with the color and geometrically corrected digital model while designing directly on site is an especially promising field of application.

The design of colors and materials in architectural design is particularly demanding, and is often carried out by professional specialists. It requires good knowledge of how light, material and color interact with one another and the resulting spatial impression. The tools used by professional color and interior designers are not yet adequately supported in the IT environment. Instead only insular solutions exist for architectural visualization, presentations or complex physical light simulation. In architectural practice, digital color is not yet regarded as sufficiently accurate or reliable, and accordingly tools for color or material design are rarely employed. The use of traditional color charts, material samples and small sample panels on site are still commonly used to determine a design and to present alternatives to the client (see Figure 10 and 11).
However, with traditional tools, one sees only small sections – it is particularly difficult to communicate the vision and the spatial effect of large expanses of color and materials. The projection technology offers the advantage of being able to provide large-scale color and material proposals and enables the design to be visualized, assessed and modified on site more effectively. Whilst the advent of new affordable color calibration tools for monitors (e.g., ColorVision Inc. “Spyder2” 2004), projectors (e.g., [1]) and printers (e.g., [11]) has made the IT-supported design of color and material concepts a realistic proposition, such calibration tools are not the subject of this article.

7. Color design using Augmented Reality

The software prototype “Colored Architecture” was developed to support the design process for colors and materials [12, 14]. The tool addresses the deficits of digital color and material design and supports digital planning with color and materials from the initial design, through the planning phase to specification. Due to the modular design of the server-client software framework used called Freak+ [6], it was possible to extend the software and add projection and calibration clients. The derived software prototype “Spatial Augmented Reality – Colored Architecture” (SAR-CA) is able to superimpose the digital planning model onto the existing building at a scale of 1:1.

7.1 Description SAR-CA

The digital support of color and material design in SAR-CA uses and adapts existing strategies, instruments and representations, e.g., alternative variants, color studies and color relationships such as harmonies and contrasts. To reliably assess and evaluate the results of color and material choices, integrated radiosity visualization is employed; as it is able to represent interactions between different surfaces such as reflections. Radiosity light distribution computation is an integral component of commercially available visualization programs such as Cinema4D (Maxon Computer Inc.) or 3D-Studio (Autodesk Inc.). Using such software it is necessary to carry out the time-consuming radiosity calculation each time material, color or light changes take place.

In SAR-CA a physically correct radiosity calculation is used to enable interactive color and material design. Of particular relevance, here is the visualization of daylight. The sun is not regarded solely as a single light source but as a diffuse source – the sky lights up the model from all directions. The parameters ‘position of the sun’, ‘illumination’ and ‘material color’ can be edited interactively and one can assess the updated radiosity visualization immediately [16].
7.2 Technology, setup and calibration

In addition to the computer, the technology used consists of conventional commercially available projectors and a camera. Before the technology can be set up, a digital model of the architectural situation must be created. The software framework used (described in section 4) incorporates a set of tools which support the manual surveying or the use of tacheometry and photogrammetry. In the example shown a tacheometer was used to derive a precise digital model of the room (see Figure 12).

Setup begins with the installation of the projectors and the camera in the room. The projectors are pointed towards the surfaces in question. It is then necessary to determine the position, the direction, opening angle and optical axis of the projectors. For this reason, a semi-automatic and an automatic calibration were implemented.

Applying the semi-automatic calibration, markers are placed in the field of projection and measured with the tacheometer. During calibration, the digital 3D measuring points are associated with their 2D picture positions in their respective projections. This association is done by clicking the physical markers in the picture of the projector with the computer mouse (see Figure 13). Afterwards a mathematical compensation calculation is launched, which determines the parameters of the respective projector [14].

Because the projectors are now geometrically calibrated, it is possible to superimpose the digital planning model onto the real architecture. The position of the edges and points of the model in the projection should tally with the room. As part of the research project, three further correction procedures for the projection clients are planned:

1. **Blending** – The intensities of the projections are modulated where several projectors project on the same surface (compensation for projection overlap).
2. **SmartProjector** – This correction procedure involves scanning the structure and color of the projection surface and modifying the projection in real-time to compensate for differences. The viewer...
perceives the picture as if it were the original image projected onto a neutral, white surface [1, 18].

3. \textit{InverseRadiosity} – This correction procedure takes into account the self-illumination of the projection. This error occurs most commonly in room corners, where adjoining wall surfaces reflect parts of the projection onto one another [3].

An important aspect of the research project is the integration of a Pan-Tilt-Zoom camera (PTZ) for automatic calibration, for measurement and for user interaction. The automatic calibration of the projectors using the PTZ-camera does not need physical markers in the projection. The camera can determine its position and orientation automatically in the room using a built-in laser distance-measuring instrument. After positioning, automatic calibration starts and the necessary marker dots are projected and captured by the camera. Based on their mismatch, the parameters for projection can then be computed. In addition to the well-proven measurement technologies, it should become possible in future to semi-automatically capture the room geometry using the PTZ-camera and its laser distance-measuring instrument. Finally, the camera tracks the position of a laser pointer to enable users to interact directly with the digital model [21].

7.3 User study

An initial evaluation was carried out using a user study to determine the direction for ongoing research. As the integration of projection correction procedures, new interaction forms and technologies progressively continues, we plan to repeat such evaluation to allow a comparative analysis with previous studies.

The test took place with test subjects in the windowless AR-Vis lab of the Bauhaus University in Weimar. Their aim was to develop a color design proposal for the room and to equip the room with a window, so that the effect of natural lighting and its influence on the design could be assessed. Four different ways of working were compared using the same assignment:

- \textit{Traditional Sampling} – The test subjects received a printed plan of the room, RAL color charts and colored pens for the sampling (see Figure 14).
- \textit{Computer-aided Sampling 2D} – The test subjects received the same plan of the room as a 2D digital image and the image manipulation software Adobe Photoshop CS2 (see Figure 15).
- \textit{Computer-aided Sampling 3D} – The test subjects worked with the software prototype of “Colored Architecture” using a 3D model of the room. Interactive radiosity visualization was optionally displayable (see Figure 16).
- \textit{Augmented Sampling} – The test subjects used the software prototype...
“Spatial Augmented Reality – Colored Architecture” to carry out the design, using the augmentation of the room corner for visualization (see Figure 17). An interactive radiosity visualization was optionally displayable.

After the different working methods had been completed, each test person was asked 10 questions, answered on a scale as follows: “no/never” (-2), “not really/seldom” (-1), “don’t know/neutral” (0), “probably/sometimes” (1) to “yes/often” (2) in the questionnaire.

7.4 Evaluation of the user study
25 persons aged between 21 and 57 years took part in the user study. 72% of the test subjects were male and 28% female. 48% – nearly half of the test subjects – indicated they had previously produced color design proposals in professional practice.

In Table 1 and 2 the evaluation of the user’s questionnaire answers are presented. The colors of the table cells represent the order of the four working methods. Light grey is the best and dark grey the worst evaluation. The columns headed “Traditional” list the average value of the user
### Table 1. Evaluation of all test subjects to the four methods (light grey = best, dark grey = worst).

<table>
<thead>
<tr>
<th>Question</th>
<th>Traditional</th>
<th>2D</th>
<th>3D</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you applied this working method often?</td>
<td>0.36</td>
<td>0.68</td>
<td>0.96</td>
<td>1.76</td>
</tr>
<tr>
<td>2. Can you imagine the whole room with the color design?</td>
<td>0.28</td>
<td>0.68</td>
<td>1.44</td>
<td>0.64</td>
</tr>
<tr>
<td>3. Could you imagine the room with a window and natural light?</td>
<td>-0.04</td>
<td>-0.04</td>
<td>1.6</td>
<td>0.16</td>
</tr>
<tr>
<td>4. Do you think this way of working is suitable for architectural practice?</td>
<td>-0.24</td>
<td>0.4</td>
<td>1.4</td>
<td>0.52</td>
</tr>
<tr>
<td>5. Were you able to develop your design ideas well using this method?</td>
<td>0.12</td>
<td>0.24</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>6. Could you experiment and try out easily using this method?</td>
<td>-0.28</td>
<td>1.12</td>
<td>1.6</td>
<td>1.44</td>
</tr>
<tr>
<td>7. Did you feel this method was limiting to use?</td>
<td>0.16</td>
<td>-0.32</td>
<td>1.72</td>
<td>-0.46</td>
</tr>
<tr>
<td>8. Were you able to try out different design alternatives?</td>
<td>-0.96</td>
<td>1.2</td>
<td>1.68</td>
<td>1.72</td>
</tr>
<tr>
<td>9. Could you use this working method efficiently?</td>
<td>-0.6</td>
<td>0.56</td>
<td>1.6</td>
<td>0.84</td>
</tr>
<tr>
<td>10. Do you feel you can trust this tool and this way of working?</td>
<td>0.04</td>
<td>0.94</td>
<td>1.04</td>
<td>0.64</td>
</tr>
</tbody>
</table>

### Table 2. Professionals and laymen in comparison (light grey = best, dark grey = worst).

<table>
<thead>
<tr>
<th>Question</th>
<th>Professionals</th>
<th>Traditional</th>
<th>2D</th>
<th>3D</th>
<th>AR</th>
<th>Laymen</th>
<th>Traditional</th>
<th>2D</th>
<th>3D</th>
<th>AR</th>
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<tr>
<td>1</td>
<td>0.33</td>
<td>0.58</td>
<td>-0.75</td>
<td>-1.75</td>
<td>0.38</td>
<td>0.77</td>
<td>-1.15</td>
<td>-1.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.33</td>
<td>0.50</td>
<td>1.50</td>
<td>0.17</td>
<td>0.23</td>
<td>0.85</td>
<td>1.38</td>
<td>0.68</td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>0.33</td>
<td>-0.08</td>
<td>1.58</td>
<td>0.08</td>
<td>-0.38</td>
<td>0.00</td>
<td>1.62</td>
<td>0.23</td>
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<tr>
<td>4</td>
<td>0.00</td>
<td>0.42</td>
<td>1.58</td>
<td>0.58</td>
<td>-0.38</td>
<td>0.38</td>
<td>1.23</td>
<td>0.46</td>
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<tr>
<td>5</td>
<td>0.08</td>
<td>0.17</td>
<td>1.58</td>
<td>0.42</td>
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<td>0.31</td>
<td>1.62</td>
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<td>6</td>
<td>-0.42</td>
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<td>7</td>
<td>0.35</td>
<td>-0.33</td>
<td>1.25</td>
<td>-1.25</td>
<td>0.08</td>
<td>-0.31</td>
<td>1.00</td>
<td>-0.69</td>
<td></td>
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<tr>
<td>8</td>
<td>-1.00</td>
<td>0.92</td>
<td>1.67</td>
<td>1.75</td>
<td>-0.92</td>
<td>1.46</td>
<td>1.69</td>
<td>1.69</td>
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<td>9</td>
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<td>0.50</td>
<td>1.58</td>
<td>0.92</td>
<td>-0.46</td>
<td>0.62</td>
<td>1.62</td>
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<td>10</td>
<td>0.00</td>
<td>0.50</td>
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<td>0.00</td>
<td>0.92</td>
<td>1.00</td>
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responses to the traditional sampling. "2D" stands for the computer-aided 2D sampling, "3D" for the computer-aided 3D sampling and "AR" stands for augmented sampling. The standard deviation of the responses is in the range from 0.45 to 1.61. The following trends can be derived from the study:

- Overall, the test subjects gave the most favorable responses to the computer-aided 3D method, closely followed by augmented reality sampling, with traditional sampling valued worst.
- The usability and the functionality of the computer-aided 3D sampling and the augmented sampling were valued best of all (question 6, 7, 9).
- The augmented sampling was valued slightly better than the computer-aided 3D sampling when checking different design alternatives (question 8).
- The laypeople accorded most trust in the augmented sampling, while the professionals favored computer-aided 3D sampling (question 10).
During the augmented sampling, an aspect of particular interest arose during the user tests. While for the computer-aided 3D sampling using “Colored Architecture” it was very important to display the radiosity light visualization on the display, it was almost intrusive in the projection onto the real wall. To gain a proper impression, it was necessary to simulate the room atmosphere and the depth on the display, while in the projection a more authentic impression was generated without the light calculation. A reason for this could be the absence of an InverseRadiosity-correction procedure, which will be integrated in future. The sunlight illumination onto the side walls also seemed to be more intrusive in the projection onto the walls than on the display. We plan to integrate a corrective procedure, which simulates the adaptation of the human eye to the brightness level.

8. Summary and outlook

This paper presented an overview of a current research project, a description of the core model based on a client-server architecture and first results – a by-product “Low-Cost Stereoscopic Projection in Room Corners” and the software prototype SAR-CA, which supports the planning of color and material designs in the existing built context using new augmented reality technologies. The software prototype was subjected to an initial evaluation in order to receive feedback and identify areas for future research and development. Other functionalities will also be integrated in addition to intended integration of blending, SmartProjector, InverseRadiosity and eye adaptation correction procedures.

The software prototype SAR-CA offers the possibility of interactive radiosity visualization in daylight conditions. Presently this is limited to the material color. The next step will be the integration of surface textures and surface relief texture. Using hardware-accelerated graphic card shaders, these material properties will be implemented to allow the interactive design of daylight together with enhanced material properties. Future research will concentrate on the continued development of a mobile hardware setup, real-time algorithms for geometric and color correction, new tracking methods and a new means of interaction – the laser pointer interaction. In addition the implementation and evaluation of further architectural applications will be pursued, e.g. designing with images – Augmented Reality supported on-site trompe-l’œil [13]. We intend to use the pictures taken by the PTZ-camera for synthesizing materials from them. In the simplest case, a straightforward texture tiling can be used, while for increased quality texture synthesis will be applied. Using such synthesized materials it should be possible to ‘fade out’ elements of buildings and installations (e.g., doors), making it easier to design with images within existing buildings. The support of color and material design using augmented reality technologies has major potential for architectural planning practice. The ongoing improvement of the projection technologies used and the
concepts discussed offers much hope for a rich future of color design in architectural practice.

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9. References


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