# Adaptive Substrate for Enhanced Spatial Augmented Reality Contrast and Resolution

Markus Broecker*   Ross T. Smith†   Bruce H. Thomas‡

Wearable Computer Lab
University of South Australia

**ABSTRACT**

This poster presents the concept of combining two display technologies to enhance graphics effects in spatial augmented reality (SAR) environments. This is achieved by using an ePaper surface as an adaptive substrate instead of a white painted surface allowing the development of novel image techniques to improve image quality and object appearance in projector-based SAR environments.

**Index Terms:** H.5.2 [Information interfaces and Presentation]: Graphical User interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

## 1 INTRODUCTION

Spatial Augmented Reality [2] employs projectors to directly illuminate, texture and augment physical substrates (or 'props') using computer graphics. These props are usually simplified mock-up models of 3D models painted matte white to provide a good projection surface. For example a small white rectangular box could be the prop for a mobile phone while the final appearance and interactive functionality is provided by the SAR system. Using projectors allows the texturing of arbitrary shapes in this manner.

However, using projected light restricts the greatest achievable contrast, as the projection of 'black' is achieved by projecting no light at all. The final colour of the surface is therefore the substrate colour, lit by ambient light. Our solution to this problem is by substituting the uniformly painted substrate by an adaptive substrate which is able to modulate its surface colour on a per-pixel basis. We constructed a prototype using an ePaper display to project on.

The problem of contrast is closely related to the problem of dynamic range. Efforts to create displays with dynamic ranges greater than currently available have been discussed before. Seetzen et al. [3] used a projector (and a LED array) as a dynamic lightsource to change the background lighting of a LCD display.

Closely related to our research has been research conducted by Bimber et al. [1] in which an image is projected onto a static display, either a print-out or an ePaper display. The main focus here was increasing the dynamic range of the final composite display.

In contrast to Bimbers work, our research focuses on image techniques using this composite display. Having an adaptive substrate surface allows for finer control of the final image appearance on the object. Existing details can be preserved at a much higher resolution and additional details can be added.

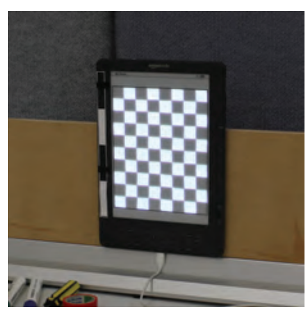
## 2 DISPLAY TECHNIQUES

Projected textures in SAR environments suffer from a number of limitations. Texture filtering in hardware might reduce visible detail. Using 3D computer graphics with projective transformations will distort the displayed texture even further. And finally, the finite resolution of raster displays in current projectors can prove to be inadequate for larger distances between projector and projection surface. As the distance between projector and projection surface increases, so does the projected size of single pixel. At the same time, the density or *effective* resolution on the surface of the substrate decreases with increasing distance.

An adaptive substrate solves this problem by providing projector-independent display surface on the object itself. It is therefore not subject to computer-graphics related texture modifications, such as projective transforms or texture interpolation. Additionally, it provides a distance and projection independent resolution.

### 2.1 Contrast Enhancement

To achieve better and darker blacks, we are able to turn black selected pixels of the adaptive substrate. As less light gets reflected, the surface appears darker. Figure 1 contrasts the difference between a projected-only black and white checkerboard pattern with the same pattern also displayed on the Kindle. This effect is especially noticeable with ambient lighting. In this case, a luxmeter measured the lighting to be about 200lx.



(a) Checkerboard projected only

(b) Checkerboard on the composite display

Figure 1: Comparing the black level of a projector alone (1a) with the black level of our composite display (1b).

### 2.2 Detail Preservation and Enhancement

An example for detail preservation is the rendering of fonts. In many cases, the effective resolution on the SAR prop is not sufficiently high enough to depict fine details of fonts therefore making text unreadable. In a hybrid SAR environment with adaptive substrates, the substrates are displaying the text at a much higher resolution while the projected image leaves out space in the projected texture. For coloured or bold text, the adaptive substrate can depict a clearer outline of the text, while the projected image fills this outline in.

*e-mail:Markus.Broecker@unisa.edu.au
†e-mail:ross@r-smith.net
‡e-mail:Bruce.Thomas@unisa.edu.au

IEEE International Symposium on Mixed and Augmented Reality 2011
Science and Technolgy Proceedings
26 -29 October, Basel, Switzerland
978-1-4577-2185-4/10/$26.00 ©2011 Crown


(a) ePaper only (b) Projector only (c) Composite display

Figure 2: An example of an animated display. (2a) shows the ePaper displays output, (2b) the projector output and (2c) the final image on the composite display.

Previously, all surface information in SAR systems were provided by projections alone. An adaptive substrate allows the simulation of surface texture independent of "surface painting" which is provided by a projector. Detail textures on the adaptive substrate depict surface textures, for example concrete or canvas. Both images can be exchanged independently of another. Figure 3 shows the 'Lena' image projected onto a simulated surface of concrete (3a) and canvas (3b).

(a) Concrete (b) Canvas

Figure 3: Demonstration of concrete and canvas detail-textures employing the high resolution ePaper display for details and projector for colour information.

The surface detail textures example can be extended further, by not using detail textures alone, but also larger-scale normal and bump maps. Simulating shading on the adaptive substrate has the additional advantage of having a darker black level.

### 2.3 Animation

Current ePaper displays lack the necessary refresh rate to be suitable for dynamic applications or animations. Our prototype was operating with a refresh rate of under 1 Hz. This shortcoming can be compensated for by splitting the desired image into a static and a dynamic part. The static part is displayed on the adaptive substrate, while the dynamic image is overlaid by the projector and is therefore only restricted by the projector's refresh rate. Figure 2 shows this process and the final result.

## 3 Implementation

We implemented a prototype by using an an Amazon Kindle DX (with an eInk "Pearl" display) ebook reader as one possible implementation of an adaptive surface substrate. The Kindle's resolution is 825x1000 pixels and it is able to display 16 shades of grey. We placed a NEC 501W LCD projector roughly 2.5 meters away from it. This distance represents a typical *Desktop SAR* environment. Images for the Kindle were created in an image editing program and uploaded per USB.

A python script, responsible for aligning a displaying a textured quad, was running on a computer. The user is responsible for aligning the projected quad onto a calibration outline displayed on the Kindle. After calibration, this quad is then displayed textured with the desired texture. Projected images were generated with OpenGL.

We found that manual alignment of these quads was sufficient due to the increased relative size of a single projected pixel, compared with the size of a pixel on the eInk display. Moving a vertex of the aligning quad a single pixel distance moves it a greater distance on the adaptive substrate.

## 4 Conclusion

SAR systems suffer from a loss in projected image detail and low projected image contrast due to ambient light. Our approach of using an adaptive substrate solves these problems by creating a composite display. Replacing the commonly employed uniform white projection surface of SAR objects with our composite display has allowed us to develop a series of theoretical approaches that define how this form of display can be employed. We have developed image enhancement techniques based on the core concepts of projection-independent resolution and increased contrast. SAR object appearance has been significantly increased by controlling the adaptive substrate to work in synergy with the a digital projector.

## References

[1] O. Bimber and D. Iwai. Superimposing dynamic range. In *SIGGRAPH Asia '08: ACM SIGGRAPH Asia 2008 papers*, pages 1–8, New York, NY, USA, 2008. ACM.

[2] O. Bimber and R. Raskar. *Spatial augmented reality: Merging real and virtual worlds*. AK Peters Ltd, 2005.

[3] H. Seetzen, W. Heidrich, W. Stuerzlinger, G. Ward, L. Whitehead, M. Trentacoste, A. Ghosh, and A. Vorozcovs. High dynamic range display systems. *ACM Transactions on Graphics*, 23:760–768, 2004.