Weaving Augmented Reality Markers

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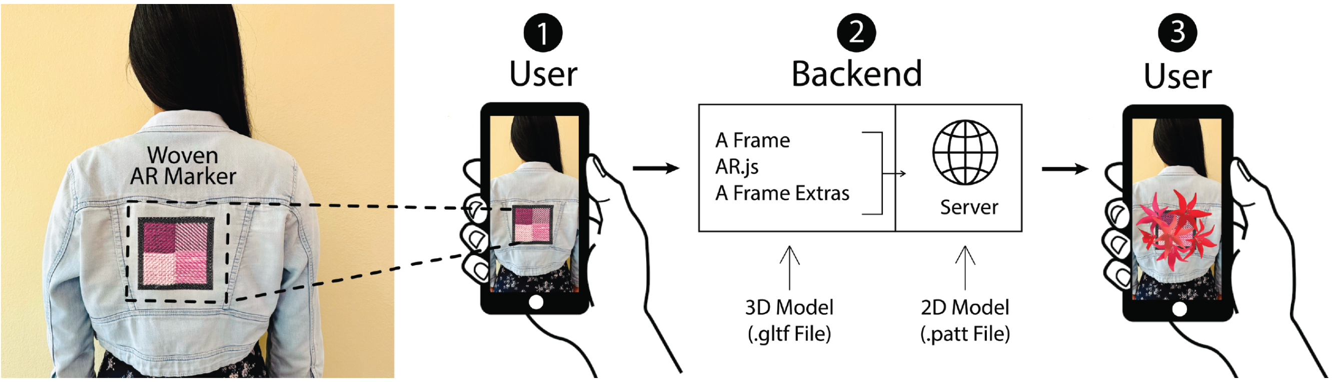

Figure 1: User interaction workflow: 1. The user scans a woven marker, 2. Communication with the backend happens invisibly to the user, and 3. The user's phone shows the Augmented Reality (AR) interface.

ABSTRACT

This paper presents the use of weaving as a technique to create functional augmented reality (AR) markers using different textile structures and colors. We conducted experiments with plain, twill, and satin weaves, as well as varying colors in the warp, to test the effectiveness of the markers. Our findings show that weaving is a viable method for creating AR markers, and the software can detect markers even with varying colors and slightly misaligned quadrants. This work opens up new possibilities for weaving and textile structures in AR design.

CCS CONCEPTS

- **Human-centered computing** → *Interactive systems and tools.*

KEYWORDS

woven AR marker, wearable technology, weaving

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1 INTRODUCTION

In recent years, Augmented Reality (AR) has emerged as a promising technology that enables the integration of digital content into the physical world. We can find examples of AR being used in everyday life activities in the form of QR codes, gaming, immersive educational experiences, or virtual try-on clothing. Even though AR has been explored in multiple domains, integration of AR and textiles through fabric structure is still an emerging design space.

Textiles are fabricated through multiple methods such as weaving, embroidery, or crocheting. Each of these techniques provides different structures and qualities to the fabric and each requires different levels of expertise to be made. Weaving in particular, remains a fairly untapped field due to its niche nature and the limited number of skilled practitioners with the required expertise.

We chose weaving as our methodology as it involves the interlacing of threads to form a fabric, while embroidery and knitting involve surface embellishments that may not offer the same level of intricacy and distinctiveness needed for textile AR markers. Furthermore, weaving is a technique with which our team has deep familiarity. Weaving is a process by which two parallel sets of yarn, the warp and the weft, are interlaced to produce cloth. Warp threads

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run lengthwise and the weft threads interlace perpendicular to the warp, forming the fabric. The specific colors of the yarns, and the pattern with which they are interlaced, can give rise to different colors, textures, and physical appearances. Additionally, the flexibility and durability of woven materials could make them suitable for use in a wide range of applications in AR, including clothing, accessories, and home decor.

Exploring woven AR markers could open up new opportunities for engaging and immersive AR experiences, blending technologies or graphics and textiles. Thus, our paper aims to answer the following research question: What combination of weaving techniques and colors can be used to create AR markers that are detectable by mobile devices? In this project, our objective was to assess the fabrication capabilities of woven AR markers without modifying existing software systems. We performed tests with different colored yarns in both the weft to assess how contrast works on the AR marker, and the warp to see if the colors distract the software from recognizing the marker. In addition to color, we also experimented with different weaving structures, namely plain, satin, and twill to explore their impact on the recognition of woven AR markers by available technology (see Section 5.1).

This paper presents an investigation into the viability of integrating AR in textiles through weaving, discussing various techniques such as structural variations, color choices, border designs, and attachment methods, and conducting tests to assess the effectiveness of these approaches in creating AR markers.

2 RELATED WORK

Some of the most common AR types are location-based AR, projection AR, and marker-based AR [10]. Examples of location-based AR can be found in the gaming industry such as Pokemon Go [11]. These games use AR to create a virtual world that blends with the physical environment. Projection AR, on the other hand, can be found in AR apps for use in education or engineering. These apps are designed to provide students with virtual models of complex concepts, such as anatomy or engineering [3]. In regards to marker-based AR, they are images or patterns that are recognized by computer vision algorithms and used to overlay digital content onto the physical environment. AR markers play a critical role in AR systems, as they enable the AR device to track its position and orientation in the physical world.

Lately, AR markers are being used by commercial organizations to make clothing interactive. H&M created Angry Birds AR markers in a clothing series they did in collaboration with the game [7]. Several other organizations have been using AR markers in ornaments on rings, to share medical information on bracelets, and so on. Similarly, Japanese fashion designer Kunihiko Morinaga of the line ‘Anrealage’ sent models down the runway wearing what he called “augmented reality receptors”. The garments featured black stripes in different widths–some a thin pinstripe, and some a large stripe over patterned fabric, reminiscent of a redacted document. A few of the models walked out with large bands of black fabric wrapping around their arms and torso. When those models stood in front of an iPad, the redacted imagery was revealed [1].

In 2014, artist and poet Alix Anne Shaw created a jacquard woven blanket that featured a grid of QR codes, called ’Other Peoples Dreams’. When scanned individually, each QR code in the grid would bring up a text of a dream the artist had collected[12].

In previous work with embroidered markers [9], it was seen that patterns have a distinct direction and can be viewed from a certain angle to work best. It was also seen that the type of string and the amount of light falling on the marker made an impact on whether the marker could be detected or not. It was found that having contrasting colors helped and also that using a grey background usually made it easy to detect the marker. These markers could only be used in the form of patches or additionally on top of existing garments. This field has been working in paper-based markers, embroidery-based markers [9], and patch-based markers [8], however, an unexplored design space has been weaving-based markers.

3 AR MARKER SOFTWARE DEVELOPMENT

This process uses AR markers, specific graphic patterns which can be easily recognized by a camera. When an AR graphic is detected by a camera via the camera viewfinder, the software displays a custom animation atop the camera view at the location of the AR graphic. The software we used to test our AR makers uses three libraries. The first is A-Frame, which allows us to build a virtual world to hold all assets. The second is AR.js, which provides marker-based (and location-based) AR features through A-Frame. The third is the "aframe-extras-loaders" library from a-frame extras to load the glTF (GL Transmission File) 3D model. All code using web-based tool and libraries are hosted on a local server on Firebase.

As we stated before, the AR marker is a physical image in the real world and is detected by the device's camera to know where to place the 3D model. To turn the image into a marker, it needs to be trained through AR.js Marker Training developed by Jerome Etienne. This takes the image and exports it as a .patt file that can be recognized by the software as the marker. Once hosted, the user will need to access the server on a device with a camera and will be brought into the virtual A-Frame scene. When the camera detects the marker, the 3D model will be displayed on the device's screen over the marker. Fig.1 displays this user interaction workflow.

4 TESTING SETUP

In phase 1, the co-author Hannah designed the digital markers and AR models. Initially, the website underwent testing by printing the markers on paper and holding them in front of the camera to assess the software's marker detection capability. Multiple variations of marker design were tested, including those with 3-4 quadrants and varying levels of contrast within the quadrants (Fig. 2).

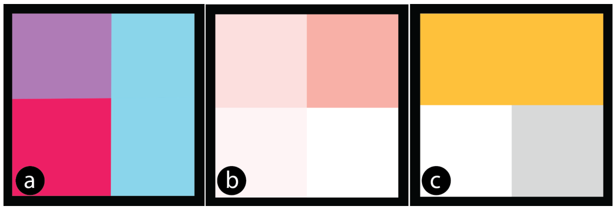

Figure 2: Digital markers with a. 3 quadrants and high contrast, b. 4 quadrants and low contrast, and c. 3 quadrants and medium contrast

Phase 2 began with weaving one of the digital markers (Figure 2b) followed by testing it with the software. The system had a baseline success criterion of detecting the marker if the 3D model popped up when the phone was placed perpendicular to the marker. We determined the system's effectiveness by testing it at varying distances and noting if the entire 3D model was visible. This was demonstrated by testing it with the marker being extremely close and also attached to clothing at a distance of 4-5 feet away from the camera. The testing was conducted during the day with natural light both indoors and outdoors. Additionally, the system was tested after attaching the marker to the sleeve of a t-shirt. The system was not tested with large deformations.

5 WEAVING EXPLORATION

In this section, we describe our design exploration weaving AR markers. The tests involved exploring different weaving structures, variations in warp and weft colors, multi-colored warps and high-contrast markers, to evaluate their impact on marker detection and the software's recognition threshold. These tests highlight the versatility and complexity of weaving techniques in integrating AR markers into textiles. The design we employed in this study was based on co-author Hannah's previous work, which adopted a quadrant-based approach. We chose to build upon this design in our research.

5.1 Color and Structure Tests

We tested three basic techniques used to create different patterns in the fabric: plain, satin, and twill weaving (Fig. 3). Each of these techniques shows different levels of contrast of warp and weft colors and was created manually on 8 shaft looms.

In ***plain weave***, the warp and weft threads cross over and under each other in a simple, alternating pattern. As a result, plain weave fabrics exhibit an equal balance of warp and weft threads. We use the black warp threads in the border and the white warp threads in the body of the marker (Fig. 3a). In ***satin weave***, long floats in the warp or weft create a smooth and lustrous surface with more warp threads visible on the surface than weft threads (Fig. 3b). In ***twill weave***, there is a diagonal ribbed pattern formed by a regular sequence of warp and weft floats. This pattern creates a fabric with a visible warp and weft color, with the warp being more prominent on the front side of the fabric and the weft being more prominent on the backside. Twill and satin weaves create textiles that have higher contrast due to higher packing than plain weaves (Fig. 3c). We experimented with both white and multi-colored warps (Fig. 4) while using twill and satin patterns. For the multi-color warps, we incorporated different colors in the weft in each quadrant of the marker. The objective of this set of tests was to push the boundaries of woven marker detection by changing color and weave structure until the software could not detect the marker. We also use *satins* and *twills* to weave the marker but did it in a double-layer structure so that we have 4 warp colors in different sections. One set of experiments had high contrast and another had similar shades in order to test if the marker needs high contrasting colors alone. Each of the weaving techniques we tested provides a different level of prominence to warp and weft threads, resulting in unique experiments that showcase the versatility and complexity of weaving.

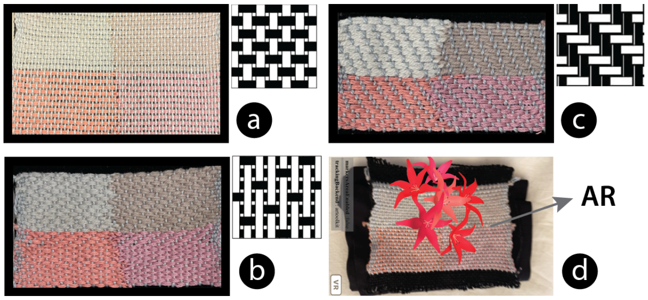

Figure 3: a. Plain weave, b. Satin weave, c. Twill weave, d. Woven AR marker recognition

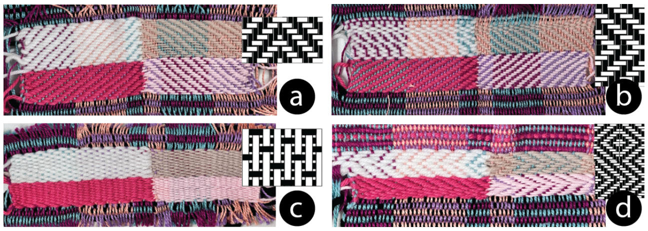

Figure 4: Woven swatches in 4 colors and double layer in an 8 shaft floor loom: a,b. Twill weave, c. Satin Weave, and d. Herringbone pattern.

5.2 Techniques for making borders

This subsection explores the use of attached and detachable borders in creating AR markers. The inclusion of black borders was a crucial aspect of our exploration, as they serve as a key element for marker recognition in AR applications. These black borders were added and explored to evaluate their impact on marker detection and assess their effectiveness in enhancing the overall performance of the AR system. During one set of experiments, we created a multi-colored warp to test the AR marker detection system (Fig. 4). To simulate the effect of adding a border to the marker, we placed a black cloth below the marker to make a detachable border.

In the next set of experiments, we used Tapestry weaving to weave borders with the markers. It was important for us to test the possibility of having the marker integrated into the textile itself. We did so by weaving the border in along with the 4 quadrants. In

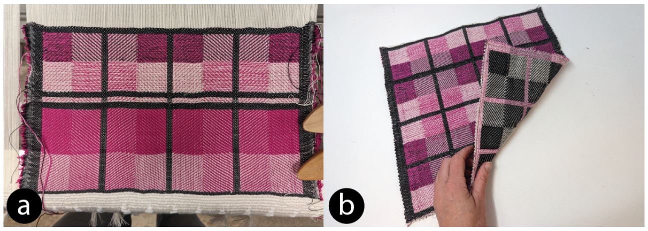

Figure 5: a. Double weave swatch in the loom, and b. Double weave swatch off the loom.

our first set of experiments, we tested plain weave in the border by only incorporating the black threads from the black and white warp. In the next set of experiments, we integrated the border into the marker using only the black warps. There were 2 main objectives of these tests: to integrate the border into the woven marker and to see if having white in the border and the main quadrants allows the marker to be detected.

In our final exploration (Fig. 5), we created the borders using a technique known as double weaving [4, 5], whereby two layers of cloth are woven at the same time. The warp was 60/2 white cotton, threaded at 60 ends per inch. The materials in the weft were cotton and wool. This allowed us to bring a layer of black wefts to the surface of the cloth only in the regions in which a border was needed.

6 FINDINGS

Detectable markers: Our experiments revealed that plain, twill, and satin weaves can all be used to create functional AR markers. The AR marker detection system was not confused by the visible white warps in all three weaving structures. Additionally, the detection time for all three markers was consistent, irrespective of the visibility of the weft yarn.

Border Integration: Both detachable and attached borders were effective in creating functional markers, and the variation in texture and integration did not affect their performance.

Contrast: During the experimentation, we created one swatch that had four colors that were vastly different from each other (Fig. 3c), while the other had 4 shades of pink colors (Fig. 3a). Interestingly, both of these swatches had pinks and browns that did not match the original paper-based design model precisely. Despite this discrepancy, the AR marker detection system produced favorable results for both samples.

Alignment of quadrants: The AR marker detection system successfully recognized markers with slightly misaligned or unevenly sized quadrants, even though it was originally programmed to identify a perfect square with equally sized quadrants.

Multi-colored warps: We observed that the AR marker detection system was able to detect markers that had varying colors in the warp suggesting that the system handles slight variations in color. This finding was significant to us because it allowed us to experiment with different shade combinations in the warp without worrying about affecting the functionality of the AR marker. Our system was able to detect a wide range of markers with varying color schemes and designs.

7 LIMITATIONS

Despite the promising results obtained from our experimentation with AR markers in woven textiles, there are several limitations to our study that should be acknowledged. Firstly, we only tested the markers with four quadrants, which limits the versatility and complexity of the marker designs. It would be worthwhile to explore the use of markers with more quadrants or other shapes and pattern elements to assess their functionality and potential applications in different contexts. Secondly, our experimentation was limited to cotton/wool and acrylic fibers of a specific color palette. This is an important limitation, as color can have a significant impact on the visibility and detectability of AR markers.

8 DISCUSSION AND FUTURE WORK

By harnessing the unique properties of woven markers, we can envision new types of interactions that diverge from traditional paper/printed mediums, opening up exciting opportunities for immersive and engaging experiences in various applications. For example, we can imagine a whole class of plaids or tartans that might double as AR marker interfaces.

While this work has tested the most common weaving structures and the same palette of colors showing success in AR detection, we believe more complex weaving structures can be further explored in future work. For instance, the integration of historical or cultural iconography into AR markers could create fascinating opportunities for storytelling and immersive experiences.

We also think there is a great opportunity for HCI researchers to develop new tools and technologies to support this integration to make the process more efficient and less manual. For instance, the use of tools like AdaCad [6] with an added feature for AR markers design could help weavers turn any design into an AR marker which could greatly expand the possibilities for designers.

Our work envisions contributing to research in an accessible way for prototyping AR markers. Using weaving as a fabrication technique for creating AR markers in textiles can facilitate the engagement of individuals from textile crafts in technology, thereby reducing the obstacles to adopting this method in textile design.

In future work, we would like to explore different color schemes and combinations in marker designs to assess their impact on marker detection and functionality. We look forward to seeing the many ways in which woven AR markers can be used to push the boundaries of creative expression. It would also be interesting to test our markers with different commonly used frameworks such as Vuforia AR which has been previously tested for optimal markers performance [2].

9 CONCLUSION

In this paper, we aimed to explore the potential of weaving as a method for creating AR markers using different textile structures and colors. Through our experiments, we tested the effectiveness of plain, twill, and satin weaves and found that all three created functional AR markers. We also observed that colors and patterns within the marker did not significantly affect the software's ability to detect the marker. Our discussion suggests that weaving can be a viable technique for creating AR markers, and there is potential for further exploration of the intersection of weaving and AR. We believe that this research could inspire further investigation into using traditional textile crafts to create digital interactions and that there is an opportunity for HCI researchers to develop tools to support the textile craft process.

ACKNOWLEDGMENTS

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