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Image Detection and Responsivity Analysis of Embroidered Fabric Markers Using Augmented Reality Technology †

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Abstract: In this paper, we investigate the use of augmented reality technology within an E-textile environment. We place particular emphasis on the analysis of key performance and responsiveness metrics when utilizing augmented reality (AR) applications for embroidery-based logo/design image detection and recognition. To support this analysis and validation, we designed and created four test embroidered images, a fabric quilt with embroidered marker images, and a supporting augmented reality application. From an E-textile point of view, we explore the effects of high/low contrast thread colors, diverse light levels (lux measurements), and the range of angles at which the mobile device/camera, with the associated AR application, can be pointed towards the fabric-embroidered marker. This allows us to assess the level of functionality and responsiveness of the AR application and the overall performance in the testing environment, enabling more fluid usability of the AR-enabled E-textile application.

Keywords: augmented reality application; E-textiles; responsiveness; embroidered images

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1. Introduction

In this paper, an AR application was developed to specifically detect and recognize embroidery-based markers in a fabric environment. Each Embroidered marker of varying colors were created, and the thread design of each marker images were selected in order to be able to compare the effects of high- and low-contrast thread colors, as shown in Figure 1a,b, and their detection responsivity by the AR application. Several observations were made, as shown in Tables 1 and 2, Also each marker was assigned an animated 3D model which was displayed on a mobile/tablet screen, as shown in Figure 2a. We further investigated and explored the effects of various other factors affecting the response time of the application, such as recognition accuracy at seven different angles and at varying light levels. These observations allowed us to identify the most suitable ranges for the above-mentioned factors and enabled us to effectively enhance the response time of the application, hence improving the interaction time for users and making the AR textiles application more user-friendly and data-driven.

(**a**) (**b**)

Figure 1. (**a**) The left image is the embroidery-woven wall hanging (high-contrast colors) with different embroidery symbols, which represent different animated 3D models. These 3D assets are triggered when the above-shown markers are recognized by the augmented reality camera. The above-shown markers are embridered in high-contrast colours and on a gray/black background, which make them easy to detect by an AR camera. (**b**) The right image is the embroidery-woven wall hanging (low-contrast colors) with different embroidery symbols. The above-embroidered symbols are mostly blue and black in color on a light, jute-textured background, which makes them difficult to recognize by an AR camera.

(**a**) (**b**)

Figure 2. (**a**) The left figure is the AR view on a tablet. A light (lux) meter application on a different device is used to detect the amount of light. We can see in the image that a 3D object is triggered because of an embroidery marker on the wall hanging. (**b**) The right figure shown above is the apparatus used to measure angle using a rotating sphere inclinometer application. We can see that the device is inclined at a 60° angle and the inclinometer detects the angle.

Table 1. The table below contains the observations made for the response time at seven different angles at which the device is held for high- and low-contrast markers. Here, we can see that the application responds fastest when the phone is between 75° to 105° for both low- and high-contrast markers.

Sr. No.	Angle of the Device Held (x-Axis)	Response Time for High Contrast (s) (y-Axis)	Response Time for Low Contrast (s) (y-Axis)
1.	45°	40.28 s	52.27 s
2.	60°	30.28 s	38.25 s
3.	75°	16.17 s	16.11 s
4.	90°	5.43 s	7.51 s
5.	105°	8.68 s	8.39 s
6.	115°	15.32 s	26.32 s
7.	120°	31.12 s	43.14 s

Table 2. The table below contains the observations made for the response time at fifteen different light levels on high- and low-contrast markers. Here we can see that the fastest response of the application is when the light levels are moderate (232 lux -141 lux) for both high- and low-contrast markers.

Sr. No.	Brightness Level (lux) (x-Axis)	Response Time for High Contrast (s) (y-Axis)	Response time for Low Contrast (s) (y-Axis)
1.	337	26.66	45.07
2.	325	20.12	37.59
3.	318	17.35	30.35
4.	312	15.03	28.03
5.	308	13.77	28.77
6.	258	11.23	26.23
7.	232	9.64	19.41
8.	201	5.99	18.39
9.	192	5.64	17.28
10.	172	5.02	18.98
11.	168	5.23	20.33
12.	141	16.29	27.65
13.	113	18.63	28.42
14.	46	28.47	32.26
15.	5	31.28	48.52

As per the observations recorded below, in Table 2 and Figure 3, we proved that the AR application takes more time to respond to embroidery-based markers if the light levels (lux measurements) are too high or too low. We can also prove that the response time of the application is enhanced when the light levels are moderate. The contrast levels of the threads used for the embroidery marker design have a major impact on the performance of the application. From the results, we see that the response time for the low-contrast markers is significantly higher than the response time for the high-contrast markers. Thus, we can say, from the observations shown in Tables 1 and 2, that the recognition operates at peak performance when we have a higher degree of contrast in the color of the threads. We used white and purple threads on a black and grey background for high-contrast markers, and blue and black threads for low-contrast markers. Observations of the response time of the

AR application when the device is held at different angles for both high- and low-contrast embroidered markers can be viewed in Figure 4; here the graph clearly shows that the most suitable angle range for a device to be held for best results, for both low- and high-contrast markers, is 75° to 105°.

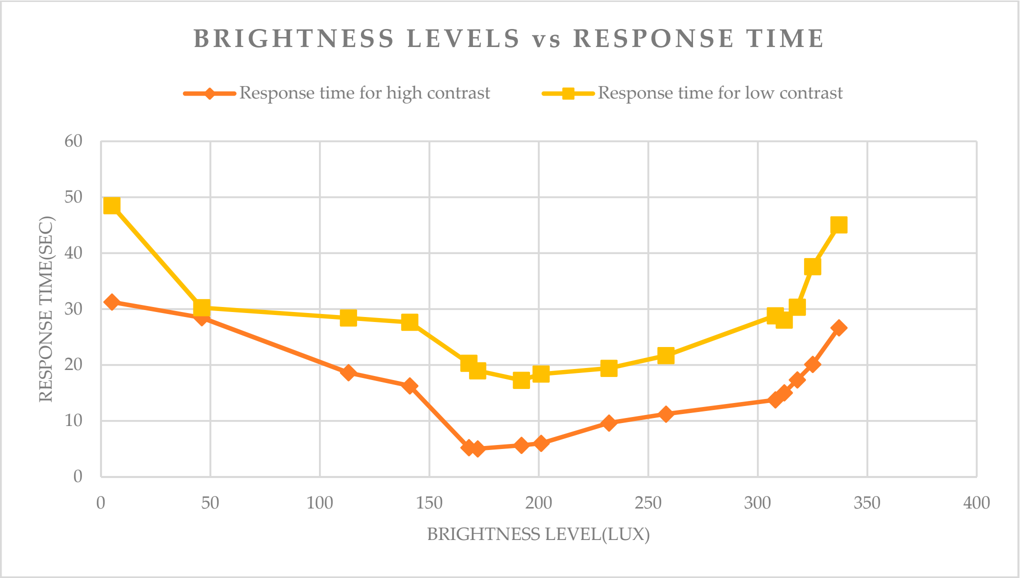

Figure 3. The above graph contains the observations made for the response time at fifteen different angles at which the device is held for high- and low-contrast markers.

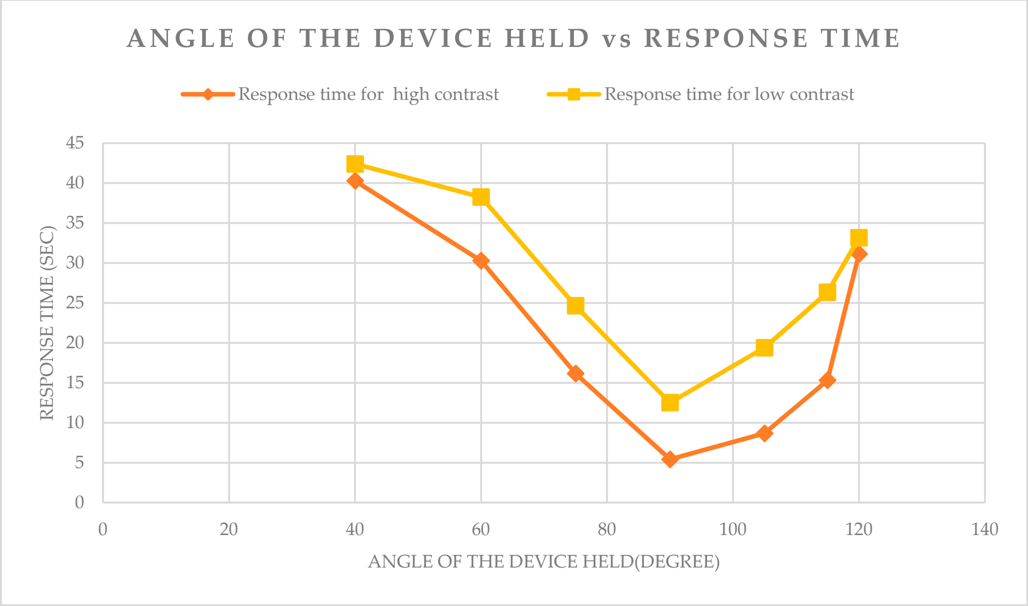

Figure 4. The above graph contains the observations made for the response time at seven different angles at which the device is held for high- and low-contrast markers.

2. Conclusions and Future Scope

In this paper, we explored the use of augmented reality technology within the E-textiles environment. We designed various experiments to find out how various factors—namely the brightness level, and the angle at which the device was held for both high- and low-contrast thread colors—affected the performance of the developed AR application.

In the future we would like to take this investigation further to see how the AR application would be affected if the embroidery markers were on curved surfaces with various light settings, thus simulating fabrics being worn by an individual. Doing so would allow us to further understand the nature of AR recognition for E-Textile use. We would also like to explore various color combinations and examine the effects of high-, medium- and low-contrast threads in more detail, to identify the optimum marker composition for E-Textile based embroidery. Our research will help us to build a more sustainable and reliable Augmented Reality E-textiles application and create various uses for it, such as a personalized story-telling AR application blanket for children, wall hangings, and many more. We also would like to explore the ways in which we can use augmented reality technology with E-textiles for health-monitoring purposes. Using a combination of infrared sensitive fabrics and the sensor array present in modern mobile devices, we aim to collect the captured data, process them using a custom shader to detect temperature changes in measured color metrics, and display the temperature in real time on the mobile device in augmented reality. Thus, we aim to deliver a low-cost health-detection feature, as well as a means to evaluate smart fabric solutions in an unobtrusive manner.

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