AR Markers Meet Fashion

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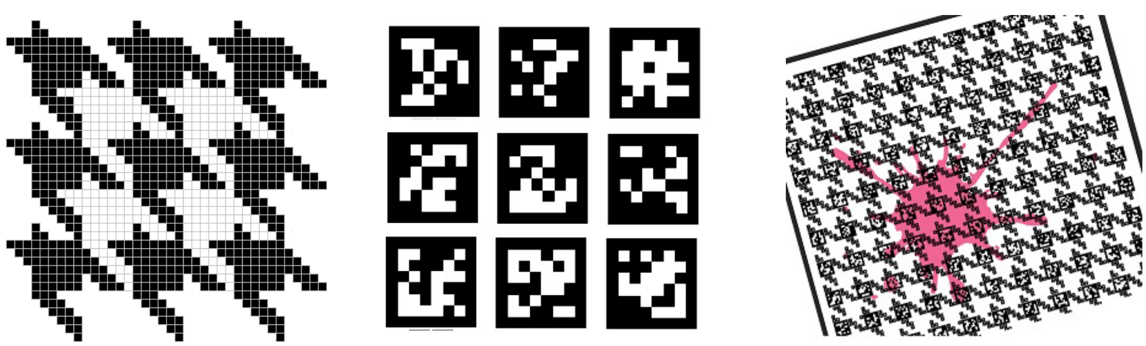
Abstract

In this paper we describe the design of a fashion statement piece where we embed AR markers in a Pied-de-poule pattern. Thus, the two digital technologies of markers and weaving patterns come together in one piece. At the same time, we are interested in the ethical aspects of AR entering our daily life. We summarize the digital technologies involved and present the innovative garment.

Introduction

Mathematics is a powerful tool to describe and understand the world around us. On top of that, a wide range of digital technologies are being developed which are also based on mathematics. These digital technologies are more and more shaping the world around us. An early example of digital technology is weaving, and it is a well-known story how Jacquard looms gave rise to the birth of punched cards, the forerunners of early-day computer storage media. Weaving has given important impulses to fashion aesthetics such as the famous Pied-de-poule pattern (houndstooth) shown in Figure 1(a). The mathematics of classic Pied-de-poule has been described in [2] whereas fractal, cellular and orbifold-based variations have been presented, e.g. in [3,4]. Another example of digital technology is found in the various augmented reality (AR) markers such as QR codes and ArUco markers, see Figure 1(b). There is some serious mathematics which went into the design of these codes and markers, notably error-correcting codes [5][8][11]. The form of these codes and markers is based on functional principles such as recognition rates, yet without much attention for their aesthetical qualities.

In this paper we describe the design of a fashion statement piece where we embed AR markers in a Pied-de-poule pattern. Thus, the two digital technologies come together in one piece. At the same time, we are interested in the ethical aspects of AR entering our daily life. The fashion piece contains hundreds of markers and therefore a camera system can identify the garment and observe the wearer's posture. Whether this is a good or a bad thing is an interesting question (discussed in the last section of this paper).



(a) (b) (c)

Figure 1: *Digital patterns: (a) Pied-de-poule, (b) ArUco markers, (c) ArUco Pied-de-poule with splash.*

The digital and mathematical nature of Pied-de-poule implies that compact programs exist to generate Pied-de-poule. For this project, we took the Java code of [2] as a starting point. The code of [2] produces rectangles, but instead of drawing rectangles we now call a marker generator. Thus, we get a Pied-de-poule pattern where the small squares become markers. We could do that for every rectangle, but we turned to a less straightforward scheme, where the big block of 4×4 small blocks is used for the marker (Figures 2,3).

Markers and their Mathematics

The advantage of embedding markers in an environment has been noted for automated production and later also for augmented reality applications. Already in 1986 Van Gils [6] proposed the two-dimensional representation of product identification numbers using square dot codes. The design of such markers [5][6] follows from the application of Shannon's theory of error correction and coding [11]. Certain bit errors can be corrected and the recognition still works when the marker is rotated. Consider a 6×6 matrix of dots or rectangles, each either black or white (1 or 0), which means that there is a space of 2^{36} distinct messages. It is possible to sacrifice some of the space by choosing code words which are evenly distributed over this space. In our case, the minimal distance between code words is 10. This distance between code words is called the Hamming distance, defined as the number of bit positions to be modified to get from one code word to another. In Figure 1, the first tag is 111000 010110 010101 001001 010100 111000, which differs on 20 positions compared to the second tag 001100 100011 010110 000100 101000 000100 (the Hamming distance is 20). We used a scheme with 2320 code words and a minimal Hamming distance of 10 from [8].

Garment Design Considerations

Fashion is not just about garments; it is about personal identity and about showing versus not showing. Fashion has grown into a rich and complex *fashion system* [1]. Today's fashion is less and less about the physical garment and more and more about what appears in digital media (example: Angella Mackey's greenscreen dress [9]). Cameras are abundant; they see more than one is aware of, and no one knows what will happen with the images once they are online. In words, this is our statement: *fashion has become a digital game of showing and hiding*. We have chosen to express this statement not just in words, but in the language of fashion, in a garment. The result is shown in Figure 3. We used a novel ArUco-weaving generator written in Python (generating the print pattern), laser cutting, sublimation printing, draping, and traditional sewing to develop the fashion statement.

Graphic Integration and Marker Arrangement

Marker tracking in the garment shown in Figure 3 fails at the intersections between the overlain graphics and the ArUco markers. Figure 1(c) and Figure 2 show alternative designs for which we could ensure the detectability of these markers by an off-the-shelf camera and the default ArUco marker detection algorithm, as shown in the results depicted in Figure 2. The default algorithm begins with 1) adaptive thresholding; 2) extracts candidates that look like square-shaped markers from the thresholded image. It then applies a perspective transformation to each marker candidate to obtain its canonical form; then 3) decodes the payload using the locations of black/white bits.

The marker arrangement maintains the square markers' appearance. Each marker is sufficiently (Euclidean) distant from the others and their surrounding decorations, so their edges and corners remain intact.

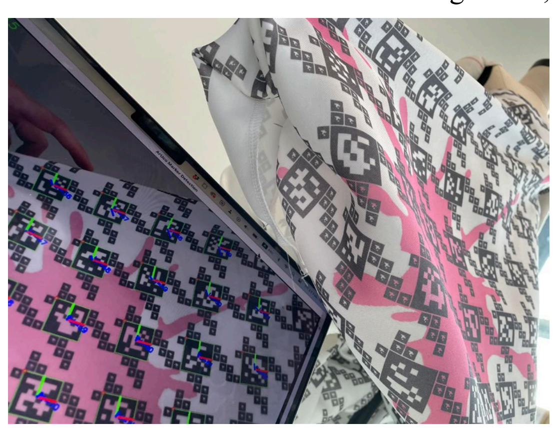


Figure 2: *The recognizer in action.*

Figure 3: *The finished garment. Photographer: Holly Krueger. Model: Deniz Korkmaz.*

Social and Ethical Aspects

What happens when considering what fashion patterns could look like, or their potential for technical performance, when created including the perspective of an automated robotic industrial gaze? From a human perspective, what appears to initially present as decorative, a fanciful fish on a classic check, could prove to be read digitally by surveillance cameras, telephones, and other reading devices.

We considered the nature of technologies, sometimes conceived as laboratory tools but later becoming products owned by many. The oscilloscopes used in electronic labs gave birth to the development of television, once cathode ray tubes could be made larger. Berners-Lee's wide-area hypermedia information retrieval system for scientists turned into the World-Wide Web used by billions. In the same way, the markers described in [6][5] are intended for production automation and robotic guidance, but here we ask: is it possible that they will spread beyond the factory floors into the streets of our cities? We found that the camera recognition of the markers in the garments of Figures 2 and 3 works well in short range, but not well beyond a few meters. For now, there seems to be no big privacy issue (yet). But if camera technology progresses, the recognition of people, their gait and body postures across the street may become a reality.

Camera surveillance has been explored in movies and series, e.g. Person of Interest [7]. Privacy is an aspect of life but the tensions inherent in it are more complex in the digital age [10]. As noted in [10], most consumers are willing to accept some loss of privacy in exchange for personalization of the right experience.

We play with the idea of hiding data in plain sight [12] (like Poe's Purloined Letter). In Figure 3 is a fashionable garment, but it is also a red herring. We did not make the markers totally invisible, as that would defy the purpose of a statement piece. Coupling the robotic gaze with a fashion appreciation gaze through a layered visual feedback loop of 'who's looking at whom', the metaphor of a red herring may be just what we need to tickle notions of new layered realities and consider the ripple effect of future surveillance.

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