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wARna - Mobile-based Augmented Reality Colouring Book

Muhamad Fadhil Norraji#1, Mohd Shahrizal Sunar*2

#Media and Game Innovation Centre of Excellence (MaGIC-X),
Universiti Teknologi Malaysia, Malaysia

1fadhil@magicx.my

2shahrizal@utm.my

***Abstract*— Usage of Augmented Reality (AR) in educational environment is not an alien thing recently, especially when considering the multimodality and interactivity nature of some AR application that proves to be a lot more immersive and engaging learning than its traditional counterpart. Regardless, another aspect of educational AR, or any AR app, that should not be overlooked is the robustness as well as the availability of the app itself. In this paper, we are discussing a type of mixed-reality book experience that augments a colouring book with user-manipulated three-dimensional (3D) contents in a mobile-based environment. We explore tracking approaches in AR for its efficiency as well as computational load that is most suitable for mobile environment, and we also investigate texture extraction and mapping method for 3D content. Our system is then based on a marker-based tracking system using fiducial marker and simple image processing technique for the texture extraction and mapping part.**

***Keywords*— Augmented Reality, Marker-based Detection, AR in Education, Texture Extraction**

I. Background

Augmented Reality (AR) is an ubiquitous and rising technology sought after by a lot of major corporations and researchers due to its very high potentials. It can be said that all branches of knowledge or application benefits from the introduction of it and everyone wants a little piece of this technological titan. The field of education is not an exception as the usage of AR greatly augments an educational material by providing access to more information and new ways to interact, both with the material itself and the subjects. This is supported by the introduction of MagicBook by Billinghurst et al. [1], which spurs the masses into researching or producing AR book experiences due to its sheer potential of not only visually augments a book with added graphics and possibly animation [2], but is also capable of supplementing audio cues [3] and transitional interfaces [4], exactly what is lacking in a traditional learning book.

An interactive augmented colouring book introduced by Clark and Dunser is also one of the major breakthrough of AR in education [5], as it highlights the importance of direct interactivity with the content; by allowing the user to manipulate the resulting AR 3D content with their own shades of colour, thus giving more impact on the learning process because interactivity promotes learning by activating certain cognitive processes, as stated by Moreno and Meyer [6]. Clark and Dunser in the same paper also mentioned that interactivity doesn't only lie in the software part of an augmented reality book, but the most basic interactivity that might have been overlooked was the manipulation of the physical book itself as a tangible interface [5].

Regardless of the multimodality nature of AR app however, one of the more basic, more primitive aspect that might have been overlooked but still contributes to the majority of learning experience is the availability and robustness of the application itself. Availability in this context is the readiness of an application to be used by the masses; the means of getting as well as using it. This issue is readily addressed with the surge and rise in popularity of the mobile smartphone devices. Building an AR learning app for the mobile platform is a good way to have it available to most household. The second issue is tightly tied with the availability issue. Despite the boom in the production of high end smartphones capable of rendering 3D contents with ease, there is still the need to reduce the computational load of application on mobile platform in order to improve the efficiency and response time, which is tied to computational load time. This is especially true for learning application as an instant and concise feedback is one of the core principles in a learning environment. It promotes quick immersion and engaging learning to have a material directly shows the result of a user's work.

To address this issue, we explored the basic of AR itself in the area of tracking approaches. As our research deals with a physical book and there is a need for vision based marker detection, there are two approaches that can be considered - marker-based and markerless AR [7]. Marker-based AR, relies on fiducial marker, a system consisting of patterns that are mounted in the environment and automatically detected in digital camera images using an accompanying detection algorithm [8]. Examples of fiduciary markers include QR Code, ARTag and Frame Marker. The markerless AR here however, refers to the detection and tracking of natural features of an image such as the edges, corners and textures. . Defined by Neumann and You [9], natural feature tracking is computing the motion of a point, locus of points, or region in a scene.

Clark and Dunser's research regarding their AR colouring book uses the second approach while supporting the modification made towards the natural feature image by performing image processing technique (i.e.; colour removal) to match the image with its dataset [5].

Unlike marker-based detection, markerless AR has no ambient intrusive markers which are not really part of the environment. Furthermore, markerless augmented reality counts on specialized and robust trackers already available. Another advantage of the markerless systems is the possibility of extracting from the environment characteristics and information that may later be used by them. However, among the disadvantages we can consider for markerless augmented reality systems is that tracking and registration techniques become more complex.

Furthermore in the context of augmented coloring book, natural feature AR has several issues that need to be addressed. The nature

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of colouring book itself is detrimental to the use of natural feature AR as it involves modification of the real physical book and consequently, the image that needs to be detected. Clark and Dunser ingeniously addressed this issue by using a novel image filter pipeline to remove as much color as possible and registered it against known pages [5]. This of course resulted in a larger computational load for the hardware, which is what our research aims to reduce. Moreover, there is still the issue of thresholding if the user coloured with dark colour and/or over the lines, making it almost impossible to be registered with datasets even after color removal. Therefore, when considering these disadvantages and the target platform, we decided to use marker-based approach.

II. CURRENT RESULT

wARna is envisioned to be a mobile-based interactive Augmented Reality colouring book that extracts texture from the colouring book to be mapped onto the corresponding 3D content and employs marker-based detection in the form of frame marker for the augmentation part. To make up the system, three (3) core use cases are generated as followed.

A. Marker Registration and Detection

As mentioned above, wARna implements marker-based detection to augments the 3D content onto the colouring book. Using ‘frame marker’ in Qualcomm AR library, the colouring outline can be inserted inside the frame marker, reducing the intrusion and hopefully human error of mistakenly altering a fiduciary marker. Figure 1 shows examples of colouring outlines inside frame marker.

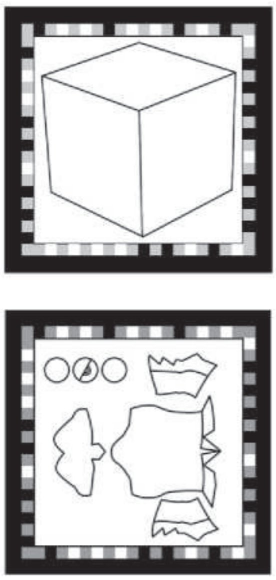

Fig. 1 Example of coloring outlines inside frame marker indexed 0 and 1 respectively.

Robustness of marker tracking is largely owed to the high contrast afforded by the black frame in a thresheld image. The frame itself is not disturbing in many situations, and by encoding a digital id with error correction at the interior side of the frame, a quicker content assignation can be done because it lacks the need for extensive image processing.

B. Texture Extraction and Processing

When a marker has been identified inside the frame, texture extraction process can be done. Identifying the marker’s edge as points, the area inside the frame marker, namely the coloured drawing is rectified, oriented and resized. This process is done using computer vision library such as OpenCV. The rundown of this use case is as followed:

- World-to-screen coordinate of marker’s four edges is retrieved.
- Feed from camera is snapped into an image.
- Warp the image by using getPerspectiveTransform and warpPerspective of OpenCV library to get a square image based on the coordinate retrieved before.

Figure 2 below illustrates the process of warping the image into texture for mapping.

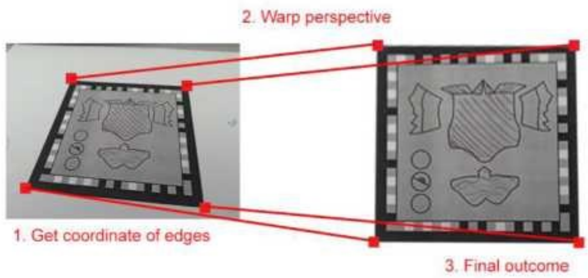

Fig. 2 Process of warping image snapped from AR into a resized, reoriented texture for UV Mapping.

Afterwards, the resulting texture can be manipulated even more using image processing techniques such as brightness and contrast, saturation, levels and curves. Ultimately, the following manipulation is optional but it can help the user to adjust the texture to their liking in the case of having insufficient lighting whilst they are using the application.

C. Texture Mapping

After the texture is retrieved and processed, it is then mapped onto the corresponding 3D object content. In threedimensional modelling process, one of the known ways to manipulate the appearance of the model is by UV mapping. UV mapping takes 2D image texture and projects it onto 3D objects, permitting the polygons that make up a 3D object to be painted with color from the image. The UV mapping process involves assigning pixels in the image to surface mappings on the polygon, usually done by "programmatically" copying a triangle shaped piece of the image map and pasting it onto a triangle on the object. The letters U and V denote the axes of the 2D texture because X, Y and Z are already used to denote the axes of the 3D object in model space.

There is two ways of processing extracted textures into UV texture mapping, in terms we like to coin as “UV Map Arrangement” and “UV Remapping”. UV Map Arrangement the technique of arranging the key features of UV Map texturing a priori to correspond directly with the extracted textures, an example of WYSIWYG. The disadvantage of this technique is that it requires more work on the designer side to arrange UV Map to cover all the tris whilst being as visually pleasing textures, an example of WYSIWYG. The disadvantage of this technique is that it requires more work on the designer side to arrange UV Map to cover all the tris whilst being as visually pleasing

as possible. The other technique is UV Remapping, a real time processing of extracted textures using computer vision library to redraw the UV Map from scratch by referencing the extracted textures using the coordinates specified beforehand. This method requires more processing on application side, and
can be quite heavy for mobile environment.as possible. The other technique is UV Remapping, a real time processing of extracted textures using computer vision library to redraw the UV Map from scratch by referencing the extracted textures using the coordinates specified beforehand. This method requires more processing on application side, and can be quite heavy for mobile environment.

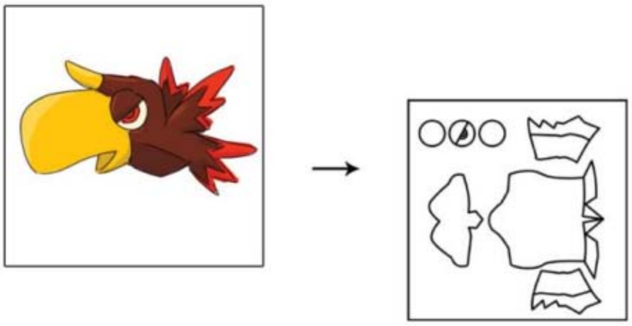

Fig. 3 An example of drawing and its corresponding UVMap.

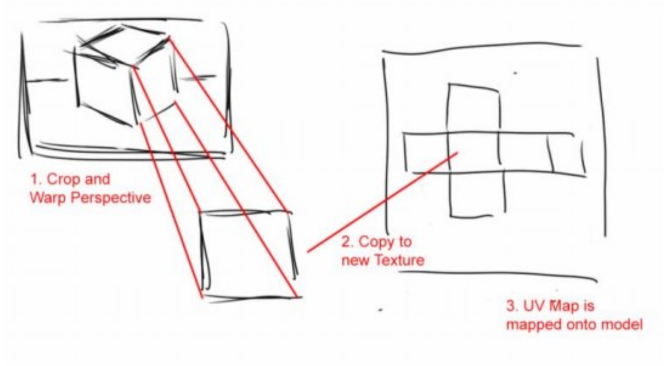

Fig. 4 The workflow behind UV Remapping.

Due to the latter technique being rather taxing for mobile environment due to having more image processing to be done, we opted for the former technique of arranging the UV Map during the modelling phase of the 3D content.

Combining these three use cases, Figure 5-7 shows the resulting outcome.

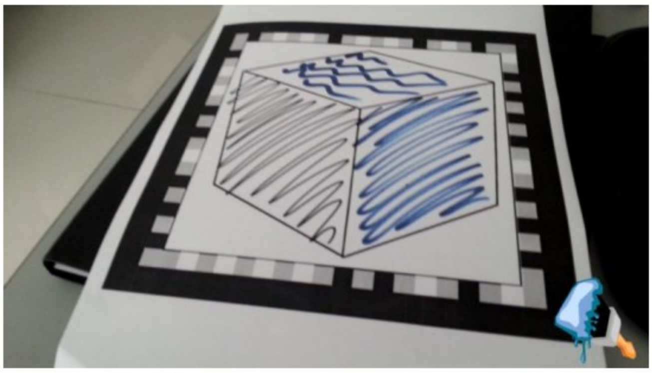

Fig. 5 Example of physical copy of marker of the book, colored using marker pens.

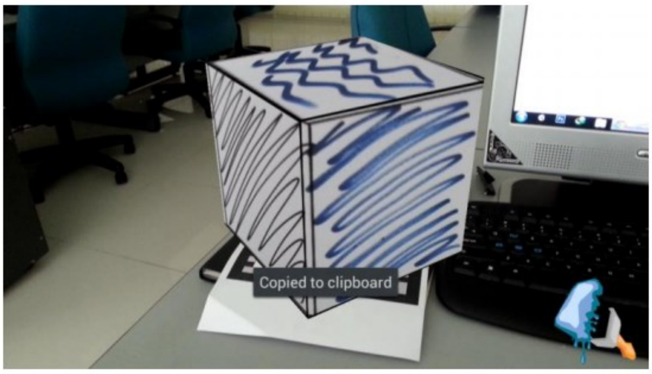

Fig. 6 The augmented 3D content with texture extracted from the marker.

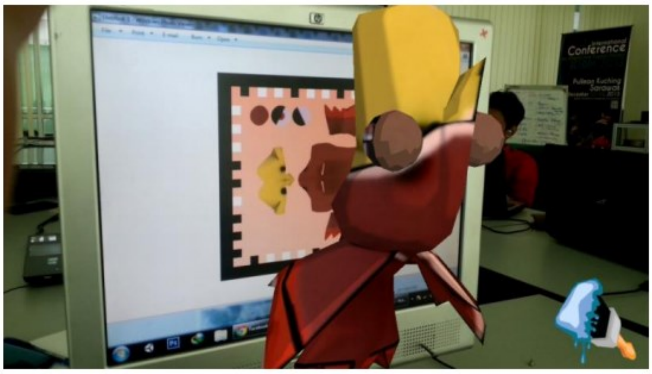

Fig. 7 Another example of augmented 3D content with texture extracted.

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