Marker Detection Method on a Fabricated Surface in Augmented Reality

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Abstract

Augmented Reality (AR) is a technology that enables the virtual object display on the real world scene. A fundamental method to make this possible is the tracking system that involves a physical marker, two-dimensional (2D) image target, can be recognized by the camera. Due to the fastest growth of AR technology, the mobile-phones are widely used in AR application since it’s currently available with built-in camera and proper graphics specification. The recognition is crucial in tracking to make sure the coordinate system in virtual world is in-alignment to the coordinate marker system in real world. This process allows the virtual object correctly appear in the real environment. The misalignment or incorrect virtual object placed in real world is due to lack of accuracy during marker detection and occlusion problems. The biggest challenge to solve these remaining problems is having a difficulty to provide robust and accurate recognition on the surface of a fabric in mobile-based AR. When the mobile camera use to track the complex surface such a logo or a pattern on the t-shirt becomes the image target. Therefore, this project aims to construct marker-based recognition for fabricated surfaces using mobile AR application. In order to actualize the aim, this project involves four phases. The first is preliminary investigation and data collection on the different types of tracking techniques in AR. The second phase is to design and develop the marker-based method to perform the feature extraction for the Media and Game Innovation Centre of Excellence (MaGIC-X) logo as a marker. In the third phase, mobile AR application is developed with integrated marker-based method. The testing is carried out to measure the marker-based performance with the variation of possible markers deformities that can be detected by the applications. Based on the result, this project achieves its aim to develop mobile based AR application to detect the markers on the fabricated surface in intuitive ways.
Keywords: Augmented Reality, Mobile Application, Marker Detection, Fabricated Surface, Android

1.0 Introduction

Augmented Reality (AR) is the form of virtual image overlays on the real world scenes. This technology act differently from the Virtual Reality (VR) which allow user to experience the artificial surroundings, augmented reality enable the graphics that are generate from the computer such as extra information from user surroundings to be displayed for their viewing (Azuma and Nagao, 1997). Rekimoto (1995) in his previous research on the Optical See-Through head-mounted display (HMD), had stated the problems with the technology such as calibration issues that involve the correct correlation between real and virtual positions. The frequent shifts of the system measurement on the human eye make it difficult to gain accuracy. In term of sense of depth, he stated that the human vision system are usually confused by the stereo disparity of the virtual objects when it is compared to the real scene. This is because of the properties of the virtual objects that have the fixed focal length even when it is represented as stereo images. Occlusion is another issue discussed by Rekimoto (1995), he stated the difficulty in hiding the real scene by using virtual objects and the weakness of optical see-through HMD in providing the occlusion effect that can gives the strongest effect on the sense of depth.

As stated in the research by Klein (2006), the primary technical hurdle AR must overcome is the need for robust and accurate registration. The results in registration error will lead to disrupt illusions that occurs when the formation of virtual objects look like floating in real world space. AR system should enhance more on the dynamic registration such when the user are moving, there are supposed to be no jitter or lag between the virtual and real world. Before the year of 2005, there are least existence of algorithm that have been published to help in the detection and registration of a non-rigid surfaces. Some might could have track them, providing the position in the previous frame, but all need manual intercession or pre-defined beginning location for initialization purpose. Hence, there is an importance in the dynamic of registration.

Mark Fiala (2007), in his previous research on the magic mirror system with a wearable augmented system had stated the least of AR literature available to focus on the problem of creating the correct occlusion handling. For most of the basic AR scenario, the augmentations are usually visible on top of piece of paper and there is no presence of any real object in front that can occluded the virtual object. But, when it comes to National Research Council (NRC) magic mirror system, there persist an issues where the virtual objects need to be occluded by the real object to satisfy the co-existence illusion. This is because it is not enough by just simply rendering the virtual content over the real world image as it will results in the incorrect occlusion problem if it is not being handle carefully.

From all the problem stated by the earliest research, it gives some overview on the challenges faced throughout this project. There will also be some questions that might arise such as, what is the suitable marker detection methods on a fabricated surface that can provide dynamic registration? What is the tracking technique that can provide better occlusion handling?
The objectives of this paper is 1) to investigate and analyze the marker detection methods that can be used on a fabricated surface. This involved the study of the suitable tracking techniques and marker detection method on a non-rigid surface from the previous related works, 2) to design the marker detection method in order to recognize the markers that be printed on the fabricated surface. This includes the planning for the system development and algorithm for the marker detection on the fabricated surface, and 3) to integrate the marker detection method into a mobile-based application in AR. This consist of several steps such as, system architecture design, interface design and coding of the system.

1.1 Augmented Reality

Azuma and Nagao (1997) has defined AR as one of the variation that comes from Virtual Reality (VR). VR is the technologies that makes people experienced the immersion of man-made environment and it somehow blocked the user from seeing their surroundings. While in AR, people can still be exposed to their surrounding as it involves the superimposed of the virtual objects to be overlay on the real world. It also make the people see the virtual and real object exist in the same spaces. They also stated the importance of the AR technology as something that enhance people perception and the information carried by the virtual object can assist people in real world task. For example, in the medical fields, doctor could use AR as training aid and visualization for surgery. However, the definition of AR are not only specifically for display technologies as it can be widen and applied into the human common sense such as, touch, smell and hearing.

Milgram et al. (1994) in their elaboration of Reality-Virtuality Continuum concept had discussed the relation between AR and VR as shown in figure 1 below and also stated AR as a part of Mixed Reality (MR). They also had introduced the Augmented Virtuality (AV), as partially or completely immersive technology that coexisted near to the virtual environment. The differences between the environment in AV and VR with AR is both of them are virtual environments while AR environment is real.

![Figure 1 Reality-Virtuality Continuum](image)

**Figure 1** Reality-Virtuality Continuum
1.2 Vision-based Tracking Techniques

In vision-based tracking, the system will determine the pose of the camera based on its observation. In an undetermined environment, this will take a lot of work as it takes some time to gather an adequate information to enable the determination of the pose and then the calculated estimation of the pose are easily drifts over time. It will be inconvenient for the user to use the system in an unknown environment as the system will randomly selects the coordinate axis orientation and thus made it impossible to determine the correct scale just with a visual observations (Siltanen, 2012). The possible solution to solve the occlusion problem is by using an AR marker-based tracking approach. This approach executes in a way of adding a predefined sign which can be easily detect by a computer vision to the environment. A marker appears to be the sign or image that can be detected by a computer system from a video image. Once the sign is detected, it will determine the pose of the camera and its exact scale.

ARToolKit is one of the vision-based tracking technique in AR that can calculate the real camera viewpoint in relative with the real world marker. This is done by turning the live video image captured by the camera into a binary based on a threshold value. Then the square region is searched from the image and the process of the identification for the markers will thoroughly carried out until the system found the matching one. The information of the markers that has been found such as its square size and pattern orientation will then being used by the ARToolKit system to calculate the position of the real video camera with the marker. After that, a 3x4 matrix will be filled with the coordinates of real world video camera relative to the marker so that the virtual object can be perfectly overlay on the real marker.

1.3 AR Marker Detection on Fabricated Surface

In real-time, the process of displaying the virtual image into a real world scene will require a video images of a superimposed virtual objects to be inserted in a real scene. It is necessary for the process to calculate the camera pose for the purpose of accurate and precise aligning of the virtual objects with the real objects in one scene. In most of the AR applications, augmentations are aligned with a 2D plane which is defined by a rigid pattern on a real world objects. It works differently with the marker-less AR, as in a scene, the planes are aligned with rigid real objects.

ARDressCode is the technology inspired from the FingARtips by Kjærside (2005), which also implements the tag-based multi-point motion tracking. It is basically the creation that allow user to fully having a virtual clothes try-on experienced. The display will be the user real image body append with the digital model of the clothes shape that fitted the user body. The system use the visual representation of a digital mirror that can augment the small AR markers attached on the user’s body. The markers are placed on the spot that are the central for all the basic motions of human. However ARDressCode still facing a difficulties in providing the comfort aspects in using the system. User still have to select and patches the markers on their clothes which can cause small destruction of the user cloth.

Two years after that, Pillet (2007), has discovered the new AR framework that can efficiently deforming augmented surfaces in real time. This system does not any calibration procedure and it is suitable for the end user. The system methods on the real time registration of an image is basically on wide base-line feature matching. Therefore, a new robust estimation technique which enable both 2D and 3D non-rigid surface registration. Pillet also tried to achieve the realism in in the illumination handling specifically by estimating the illumination
for rendering purpose without neglecting the ease of use. The occlusion handling in the system just only require a single camera and the occluded object models at runtime. These system has been used in various objects and the one that are related to the proposed system which is the fabric surface or in this case a T-shirt.

Although the system discovered by Pillet have open up the possibilities for the augmentation of the non-rigid objects, this system still have a lacking in terms of restrictions of the detection for a certain object. The object that can be recognized by this system must be of the known texture, geometry and the surface must be planar and continuous as no holes or gap are allowed. Bradley et al. (2008), have proposed a method of a non-rigid augmented reality by separating it into three parts which started with locating the cloth, acquiring the illumination and lastly rendering augmentations. In the system, a set of track-able markers are placed on a cloth surface which will enable the cloth to be located. The marker locations at the cloth is used to create a 2D mesh representation in image-space before it is rendered with a texture and placed on the top of video image of each frame. During rendering, the system also produce a shadow texture that is mixed with the augmentation to achieve the real world illumination from the input image. Hence, the output of the system will be a mixed-reality video which contains the correct illumination of 2D augmentation on the surface of cloth.

In January 2013, Marga Weimans, a fashion designer had introduced the fully augmented reality dress during the Amsterdam Fashion Week. This invention is not only implement the printing of 2D AR marker on the clothes, but it also used the 3D-tracking and the effect of occlusion to enable the augmented additions to move around the wearer of the so-called “hyper-fabric” dress. This hyper-fabric dress will opened up more possibilities to the creation of AR wearable cloth that can be updated from a distance. However this creation only limits to the people who can afford to buy this hyper-fabric clothes due to its expensive scale and super lightweight. The system proposed by the existing researcher starting from the 2005 to the 2013, has its own significant contributions in determining the path of AR improvement in the system development. However all of these ideas and inventions still having the constraints on the realism of the clothes augmentation and it still need some of further research to cater the trouble with the limitations in using the 2D markers such as the marker used need to be of a known texture, geometry and has the continuity on its surface.

2.0 Methodology

This paper discusses the mobile application development methodology that fully describes the four phase involved in the process of the development. The preliminary investigation and data collection is the first phase that will help in identifying the issues for the AR tracking and the type of the AR tracking that is suitable for the non-rigid surface. This phase also is important in discovering the previous research carried out by the past researchers and determining some of recommendations for the future works under the space of their discoveries. From this phase, in the study of the type of markers, marker-based is the selected option as it provides the ease for the developer and for the abundance of the source code available to be tested.

In terms of the properties of the markers that can be augmented for non-rigid object, Pillet (2007) has highlighted the few aspects of the surface of the markers that need to be consider which is the marker texture must be of the known texture and geometry. He also noticed the importance of the continuity of the object surface which makes even small little hole intolerable for the system. For the determination of the markers placement, Kjærside
(2005) has proposed the importance of placing the markers on the center of the human basic motion which is the torso. She also planned the placement of the markers close to the ulna joint of a human. This is corresponded to the relation of the movement of the joint which might affect the elbow and to ensure that the part of arms or clothes sleeves can also be augmented. The angle for the video capture camera that is suitable in this system, which is approximately 35 to 45 degrees also can be the consideration for the importance of the research.

Qualcomm Vuforia Software Development Kit (SDK) has been selected as the project mobile application developing tools, as it is the most prevalent SDK’s among others. Vuforia SDK can provide flexible SDK library which allows the recognition of the user defined markers through their image target technology.

Phase 2 involved the design of the internal structure of the application. MaGIC-X logo will served as the marker for the matter of detection and it will be printed on the shirts to test the capability of the application in the testing phase. By referring to the previous researched of Mark Fiala in 2007, the implementation of the ARTag marker-based detection on the surface of the non-rigid object requires the markers to be in a hybrid semi-rigid array of markers. This will involve the alignment and the placement of the markers of the same dimensions to be patch all over the surface in order to form the specified array. However, in the AR Fabtector project development, there is only one markers that will be used. This project will used the methods of image splitting through the features extraction of MaGIC-X logo. The logo will be extracted by considering the three aspects which is the characters shape, the percentage of deform and the probability of deform as shown in figure 2 below.

![Figure 2 Sample of Feature extraction of MaGIC-X logo](image_url)
Phase 3 is the implementation of marker detection on the fabricated surface. Based on the figure 3 below, the implementation phase for the mobile application development will involve the process of registering the markers on the application system, providing the suitable tracking technique for the markers detection on a fabric and also deploying the application to be used on the mobile phones. By the end of this phase, a complete working application will be ready for the testing and evaluation phases.

![Markers Detection on a Fabricated Surface Framework](image)

**Figure 3 Markers Detection on a Fabricated Surface Framework**

In order for the AR markers to be detected on certain object, it must go through the process of marker registration on the system. For this case, the natural feature marker-based detection method through the image tracking features provided by Vuforia Software Development Kits (SDK) will be used. It is because through the tracking technique provided by this SDK, it enables the developer to create their own AR marker by simply convert the marker’s image into the image target data that is automatically stored in device target database. This will not only provide the flexibility for this application to define the MaGIC-X logo as a markers but it also avoid the limitation of the variety in markers representation after the image splitting process in features extraction take places.

In order for the application to be tested on the real environment, the application development process is handled inside the Unity3D software. The development process will involve some integration with Vuforia SDK’s to enable the use of Vuforia image target tracking and the AR Camera functionality. There are several resources required for the application development such as images from the features extraction of the MaGIC-X logo in device target database that will be imported into the Unity3D. The camera of the mobile phone devices will passed every captured preview frame into the tracker. Along the way to pass the frame, the pixel format converter will converts the camera format to the format that are suitable
for rendering and tracking. This conversion will result in the different resolutions of the camera image available in the stack of the converted frame.

The tracker in Vuforia SDK has the computer vision algorithm that provide detection of the real world object in camera video frames. Based on the image that has been detected, it will handle the detection for the markers in the device database before storing the results in the state object that is used by video renderer and accessible by the application code.

The last phase is the testing and evaluation of the mobile application. Black-box testing will be the method used for testing this application. Black-box testing is one of the type of testing that only concern on the functionality of the application as a whole. This testing does not require the use of knowledge of the internal code or structure of an application. The application testing will involve three condition for testing. The first testing part will cover the registration of the marker into the system which only could be satisfied once a simple 3D object can be augmented from the surface of the markers on different rate of recognition and its capability on detecting multiple markers.

### 3.0 Result

Fabricated surface like shirts are very light and soft. The ideas of having the markers to be printed on the shirts without considering the properties of the shirts deformable structures will caused the markers imprinted on it remain undetected. Hence, by considering those properties, some of the attempt that have been made is to produce lots of possibility for the markers in any kind of shirts deformation rate. The rate of deformation is calculated by a percentage of the markers visible to the user’s eyes.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Recognition Rate (%)</th>
<th>Output</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>3D Model visible</td>
<td>Pass</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>3D Model visible</td>
<td>Pass</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>3D Model visible</td>
<td>Pass</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>3D Model visible</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Based on the table 1 above, cases field indicates the number of cases for the testing to be carried out respective to their particular condition. In this case, the rate of deformities of the markers will be the variables for the testing. The results for this testing will only be under the case of “Pass” or “Fail”. The “Pass” criteria is the remarks for all of the testing that had been done with the 3D model visibility as the expected output. While the “Fail” will be the remarks for the all of the testing that unable to produce any detection of the markers that will make the 3D model visibility as the final output. Based on the results shown above, for all of the rate of deformities tested on the markers, most of them are able to be detected by the AR Fabtector. The wrinkles produce by the shirts might deform the shapes of the MaGIC-X marker and make it harder to be detected on the shirts However, due to some of the image targets that have been recognized to be the most optimize marker’s for the detection by considering its high augmentable rate features, the testing for the deformation rate had become truly a success as shown in figure 4 above.
Figure 5 Flow of the AR Fabtector Interface

Figure 5 shows the flow of the working scene of the completed application of, “AR Fabtector”. This application was built on the Unity3D with the integration of Vuforia SDK. This application can only provide marker detection for the MaGIC-X logo. Once the marker is detected by the phone camera, the virtual object will be augment and the button for user interaction will be visible and they also can use the extra features for this application which is to display the yellow sparks animation.

4.0 Discussion

Marker detection on a fabricated surface is actualized by using a method of handling several markers that have been extracted from the image extraction process. All of the image was then being stored in the Vuforia image target database before it is used as the source for developing the application. From the testing that had been done to test the marker detection by varying its recognition rate, the positive results retrieved have shown some good sign of the marker detection by the AR Fabtector application. Vuforia SDK served as the library that providing all of the AR tracking functionality but it was usually used to track a marker from a flat and planar surface or a three-dimensional (3D) image by using its object tracker functionality.

In AR Fabtector application development, it is important to have a control mechanism for the image tracking hence an algorithm for the image tracking has been constructed to match
the need of simultaneous image tracking for all of the image target used in the development of the project as shown in the figure 6 below.

<table>
<thead>
<tr>
<th>Pseudocode</th>
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</thead>
<tbody>
<tr>
<td>1.0 Start</td>
</tr>
<tr>
<td>2.0 Set list of image target</td>
</tr>
<tr>
<td>3.0 Start Single-if</td>
</tr>
<tr>
<td>3.1 Condition : tracking is found</td>
</tr>
<tr>
<td>3.2 Invoke Object() : animation, 3D object, 2D images</td>
</tr>
<tr>
<td>3.3 Display Object()</td>
</tr>
<tr>
<td>4.0 End if statement</td>
</tr>
<tr>
<td>5.0 Start Single-if</td>
</tr>
<tr>
<td>5.1 Condition : tracking is not found</td>
</tr>
<tr>
<td>5.2 Disable Object() : animation, 3D object, 2D images</td>
</tr>
<tr>
<td>5.3 Search list of image target</td>
</tr>
<tr>
<td>5.4 End if statement</td>
</tr>
<tr>
<td>6.0 Start While Loop</td>
</tr>
<tr>
<td>6.1 Condition : Object() is True</td>
</tr>
<tr>
<td>6.2 Start If statement</td>
</tr>
<tr>
<td>6.2.1 Condition : Button &amp;&amp; Toggle is True</td>
</tr>
<tr>
<td>6.2.2 Play Animation</td>
</tr>
<tr>
<td>6.2.3 Set Toggle is False</td>
</tr>
<tr>
<td>6.3 Else</td>
</tr>
<tr>
<td>6.3.1 Stop Animation</td>
</tr>
<tr>
<td>6.3.2 Set Toggle is True</td>
</tr>
<tr>
<td>7.0 End While loop</td>
</tr>
<tr>
<td>8.0 Update : List&lt;image_target&gt;</td>
</tr>
<tr>
<td>9.0 End</td>
</tr>
</tbody>
</table>

**Figure 6 Pseudocode for the Image Tracking**

There are 14 image target that has been placed on the application. In order for the Vuforia SDK to handle all of these image targets, it must be able to track only one of the image target at time. At the start of this application, once the user has click the AR Camera button in this application, it will display the gameplay scene which will initiate the process of the tracking for the image targets. If the image target has successfully been found, it will display the augmented object altogether with the unity canvas that contain the Magic and Home button. These button will only visible and functional as long as the image target is found during the tracking process. This is the suitable time to use the Magic button to display the yellow sparks animation. When the image target is lost, the augmented object with the buttons on the canvas will be hide from the screen and the camera will try to track the new image target. The tracking lost and found condition that occurs simultaneously will helps in encounter the problem faced by the resulting crease and wrinkle formed by the marker printed on the shirts.

From the results of the testing also it can be stated that this project has achieved the second and third objectives for the project development, which is to design the marker detection method on a fabricated surface and to integrate the marker detection method into a mobile application.
5.0 Conclusion

In the development of the AR Fabtector mobile application development phase, there are several limitations that had been encountered during the process. The first limitations would be on the flexibility of this application itself to provide another recognition for the markers rather than the already made logo of MaGIC-X as the markers had been initially recognized during the development of the AR Fabtector application. Maybe for a meantime, this marker are relevant to be used as the company are using the same logo for their business identity in this past few years. However, there would be some time to consider on the possibilities of rebranding the logo. If this happens, some changes of it can results in the failure of the AR Fabtector in detecting the new rebranding logo of the MaGIC-X.

The project development for the application had gone through all of the phases as what have been described in the abstract. From the first phase, the source of knowledge for the issues in handling the tracking of the markers on the non-rigid surface have been collected and some of the ideas by the researcher had given this project some first insight in getting to know all of the challenges that will be faced throughout the development. In the phase 2, the internal structure of the application and all of the content such as the features extraction for the MaGIC-X logo marker for the development have been acquired before it is proceed in the third phase which is the implementation of marker detection on the fabricated surface. In this phase the markers that have been stored in the device database have been used and only some of the highest features marker are used to test the capability of the application. Overall results for the testing shows a good sign for the application to detect the markers in any rate of recognition. Hence, by going through all of the process, this project development have finally reached all of the objectives stated in the section 2.

References


