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Augmented Reality of Robust Tracking with Realistic Illumination[1]

Young-Baek Kim, Hong-Chang Lee and Sang-Yong Rhee[2]

Division of Computer Science and Engineering, Kyungnam University
449 Woreong-dong, Changwon, Gyeongnam, Korea

Abstract

In this study we augmented a virtual object to an image of a flexible surface such as a paper, which is acquired from a web camera. To get more presence feeling, we consider realistic illumination on augmenting. To get the geometric relation between the camera and the flexible surface, we use markers that are printed on the surface. Using marker information in prior, three dimensional coordinates of the surface can be calculated. After the marker is removed from the input image, we attach a two dimensional texture and shadow to the flexible surface by considering realistic illumination.

Key Words : Augmented reality, Realistic illumination, Flexible surface, Shadow

1. Introduction

Augmented reality is a technology for real-time fusion of computer-generated digital content with real world. The digital content can be either two dimensional texts/textures or three dimensional complex models.

By displaying information which does not exist in real world, a user can experience events which are hard to occur or are very expensive easily. The simulations of wars or the virtual restorations of destroyed vestiges are its examples.

The core technology of augmented reality is to calculate a camera's or a viewer's location and direction and to render the virtual objects to proper location of a screen in real time. Most of the AR research papers have rendered the virtual object to a flat plane which is not bendable until now [1,2].

That is why to use the flat surface is much easier to obtain homography to calculate the camera's location and direction. Also it is easy to render the virtual objects on the screen. But in realistic environment, the majority substances are non-rigid; bendable, crumpled or etc.

Also, most of current augmented reality applications don't consider conditions of the realistic illumination or shadow. This leads to inconvenient feeling when the rendered virtual object is seen on the image of the real scene. Therefore, in this study, a two dimensional texture is augmented on the flexible plane such as a thin paper and its shadow is processed by considering the realistic illumination, so it can give more presence feeling.

To represent the flexible surface in the augmented reality, a process such as mesh generation is necessary but it is not easy to obtain all the information which is need for mesh generation by using only input video images due to the deformation of the surface and self-occlusion.

So in current studies, deformation amount of the surface was calculated through physical simulation[3] or three dimensional detail models were made and three dimensional coordinates of feature points were calculated by matching the extracted feature points of the camera image and the selected ones of the model [4,5,6]. But because the augmented reality application which uses those methods takes too much time to display the virtual objects in real-time, they implemented the applications without considering illumination of the objects [7,8].

To solve the problems, there was a research that several identifiable markers were attached to the flexible surface and the mesh of the surface can be generated in real time [9]. This technique can calculate and augment in real-time but it applies high order polynomial transformation using parameters based on the two dimensions, which could have errors depending on location and the number of the extracted corresponding points.

For this reason, we calculate the relationship between each marker based on three dimensions, so the error can be reduced. It can obtain the geometric information of the surface fast and easy but the illuminations of the real environment are hard to be considered because of markers' black color.

The reason is that markers are artificial, which are made to be distinguished from the object in the real environment so they have different colors and shapes at all. To solve this problem, current studies used the inpainting technique to erase markers [10] but its weak-point was that it needed repeated processes which take much time.

Also an interpolated method by using intensity values of corner of markers is used to erase markers in real-time [11] but in the case that shadows' border exists in the middle of the marker; It did not show good results. Hence, while the pattern of the upper, below, right and left's intensity value is kept intact in this study, we estimate intensity value on the markers'

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[2] Corresponding author

area of the surface so the realistic illumination or shadow can be applied more rapidly and accurately.

The remainder of this paper is organized as follows. In section 2, we discuss our method to render augmentations on the flexible surface. In section 3, we show the results. Section 4 concludes with future improvements that can be made to our system.

2. Augmented reality on the flexible surface

2.1. The system overview

The system of this study is performed on the live images acquired from a webcam. Geometric information of the flexible surface is obtained from the image using markers.

The illumination and shadow of the detected flexible surface is calculated by using HLS color model and the augmenting texture is attached to the surface.

In the other hand, after the mesh is generated using the calculated geometric information, texture considered the realistic illumination is rendered the user' s display monitor. So each output frame has the augmented virtual object that did not existed in the real world' s input image. Figure 1 is the block diagram represented the proposed method.

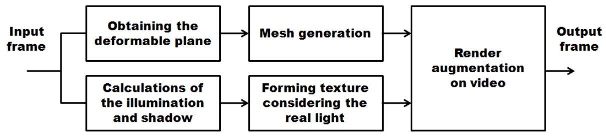


Fig. 1 System block diagram

2.2. Detecting the flexible surface

In this study, to obtain the flexible surface' s geometric information, a paper that is printed identically recognizable markers is used. Nine squared markers which have each different pattern are printed in cross pattern; 3 rows and 3 columns. Figure 2 is the markers to detect the flexible surface.

To recognize each marker rapidly from the input image, ARToolKit[1] is used. Information obtained from ARToolKit is 4 corners, a center and homography of each marker. The homography information is defined in 3 x 3 matrices [12] and used for perspective transformation.

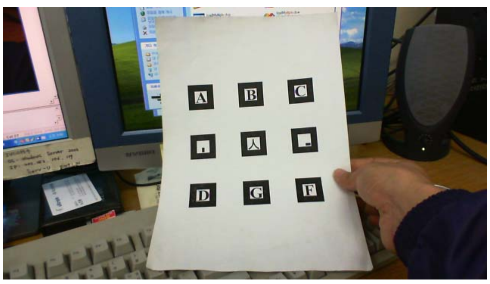


Fig. 2 Markers to detect the flexible surface

The perspective transformation is used to define the relationship between objects in three dimensional space. In other words, if the augmented object is a plain surface, we have enough geometric information obtained from the situation in order to augment the surface. But because we have to augment the flexible surface instead of plain surface, we can't use the information as it is. That is why that the information is not the geometric information of the curved surface that we need but just indicates the relationship between planes of each marker.

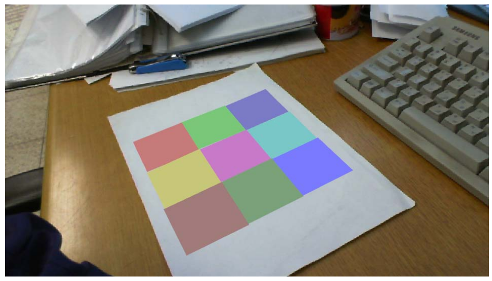


Fig. 3 Augmentation on a plain surface

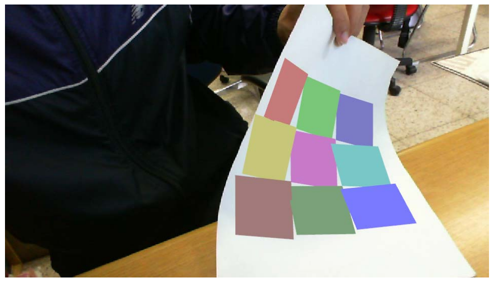


Fig. 4 Augmentation on a curved surface

Figure 3 and 4 are images that used each homography to obtain geometric information and augmented the object for two cases; a plain surface and a curved surface. In case that the object is a plain surface like Figure 3, the geometric information used the homography obtained from each marker and object's geometric information are same, so augmentation is done well. On the other hand, as Figure 4 shows, when the object is curved, the discord of the obtained geometric information which is plain and the object which is curved cause inaccurate matching.

From the Figure 4, we catch that the farther the distance gets from the center of markers, the bigger geometric information's discord happens. On the contrary, each marker's center coincides with the geometric information. Therefore when center points of the each marker are used solely to obtain the geometric information, accurate matching will be possible on the curved surface.

But it is the problem that each coordinate system attached the center point is different. The fact causes by that each homography is calculated from each marker. So each marker has different coordinate system. That is, all center points have same x, y and z coordinate value, (0, 0, 0), so we can get global information of the curved surface.

Therefore, to solve this problem, a marker is assigned as a basis and its relations with other markers are calculated using equation 1. This way gives us that geometric information of the curved surface by transforming each marker's center point based on the base marker coordinate value.

$$H_r = H_n^{-1} \times H_i$$
$$\begin{pmatrix} x' \\ y' \\ z' \\ w' \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \times H_r \qquad (1)$$

In this equation H_n refers to the base marker's homography, H_i indicates homography of each marker except the base marker and H_r is a homography represented the relation of the base marker and the other markers. In the second operation, the matrix H_r is transformed into homogeneous coordinate system, 4 x 4 matrix and is used.

2.3. Mesh generation

After calculating the flexible surface's geometric data, three dimensional mesh generation is possible along to the marker's center points. However, when we try to attach two dimensional texture to the mesh, an angled, not smooth virtual image is shown, which is augmented differently with the actual surface.

It gives low presence feeling. Therefore, to present smoother surface, Bezier surface equation is used to generate the mesh which is essential for presenting more realistic curved feature of the surface.

To generate mesh using Bezier surface equation, the control points of the Bezier surface should are calculated first. From the data gathered from previous process, we know coordinates value of 9 markers' center points. Since it is so, 2nd order Bezier surface defined by 9 control points can be applied. 2nd order Bezier surface is expressed as equation 2.

$$q(u,w) = \sum_{i=0}^{2}\sum_{j=0}^{2} J_i(u) J_j(w) P_{i,j} \qquad (2)$$

Here, P is a matrix of the control points and J is a Bernstein polynomial equation. But control points of Bezier surface are not on the Bezier surface. In other words, the surface does not pass through the markers except marker A, C, D, and F on Figure 2.

For accurate augmenting, however, each markers' center point should be passed through by the Bezier surface. In this reason, we have to calculate control points to pass each center point of markers by using Bezier curve which has 3 control points. Applying equation 3 to correct the control point so the curve can pass through the marker B's center point in Figure 2 is the solution.

$$B = B - (0.25 \times A) - (0.25 \times C) \qquad (3)$$

In this figure A, B, C refers to $P_{0,0}, P_{0,1}, P_{0,2}$ in the equation 2 and is value, 0.25, is obtained using the Bernstein polynomial.

After correcting other control points by the method, more accurate mesh as shown in the Figure 6 is formed. Figure 5 is an image before the correction of the control points that shows big difference between the mesh and the surface of the actual objects. And figure 6 is after the correction which represents that the mesh coincides with the surface of the actual object.

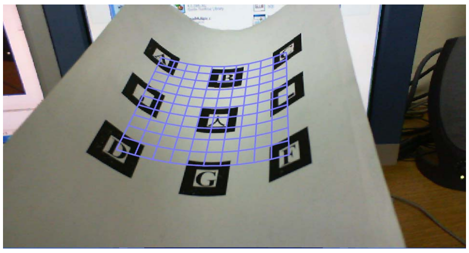


Fig. 5 Before correcting the control points

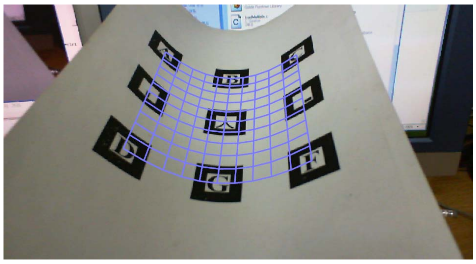


Fig. 6 After correcting the control points

2.4. Calculation of the illumination and shadow

The flexible surface of augmented reality has opportunity with having shadows by self-occlusion while the object is bent. Also light location makes difference on the quantity of light that the object is irradiated.

If these situations are not considered, the lack of presence feeling of the augmented object will be caused. Therefore to improve the presence feeling, accordingly, the actual light and the shadow should be calculated.

Because an RGB image does not have intensity information, most of the researchers have changed the RGB format to another format in general. In this research we change it to HLS format. After changing the input RGB image into a HLS image, we can obtain L's values from the area of augmented object and combine them to the texture image. This method's merit is to change intensity value without affecting texture's color or saturation.

At this moment, the big problem happens on the printed marker area. The area except the marker is white color which reflects the light so presenting the brightness from the illumination is not a trouble. However the markers' area has black color that easily absorbs the light from the illumination, which makes it hard to present the brightness. Inpainting, a classic method, can be a solution but much load of operation is an another issue in real time.

By interpolating the marker area with intensity value of area around edges of each marker, illumination error caused by the markers can be minimized. Figure 7 is an original image and figure 8 is an image after interpolating marker areas with surrounding area and smoothing by using the average filter.

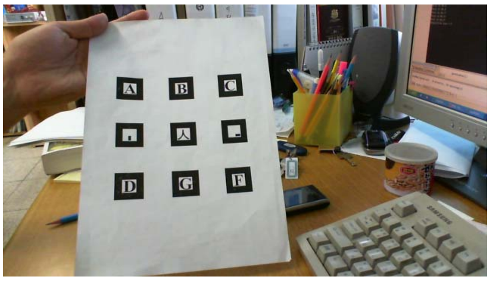


Fig. 7 Original image

Fig. 8 Image of removing marker areas

2.5. Representing texture with realistic illumination

After the illumination and the shadow are calculated, the color value of the area is normalized on the basis of texture's size and the new texture that is changed only intensity value is generated.

By multi-texture method which compounds the new texture and the original, texture which considered illumination and shadow of augmented area, is completed. Figure 9 shows less presence feeling due to lack of consideration of the realistic illumination but figure 10 shows a better image that harmonizes with the illumination.

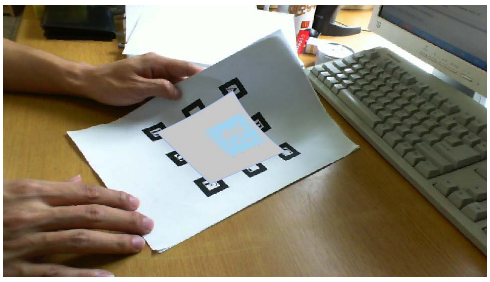


Fig. 9 Texture without realistic illumination

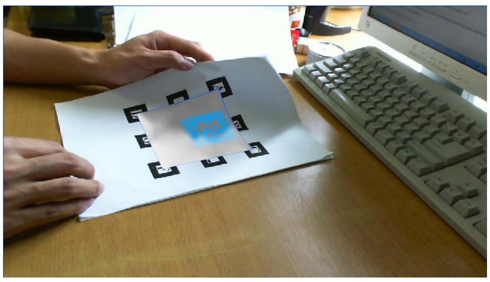
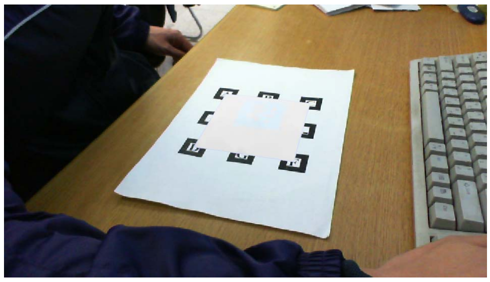
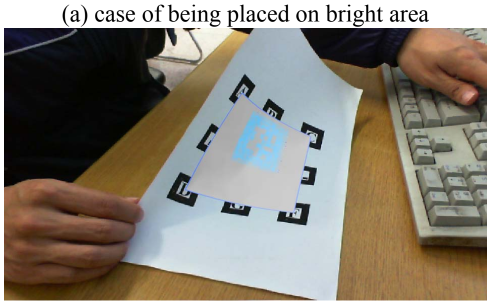


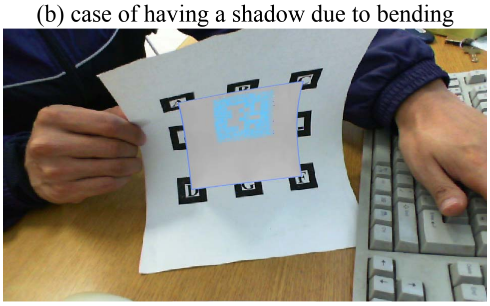
Fig. 10 Texture with realistic illumination



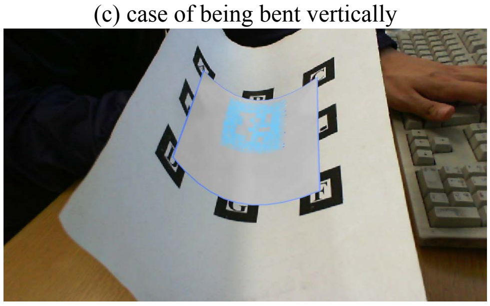
(a) case of being placed on bright area



(b) case of having a shadow due to bending



(c) case of being bent vertically



(d) case of being bent horizontally

(e) case of having a shadow of the actual object

Fig. 11 Augmented reality with realistic illumination on the flexible surface

3. Implementation and analysis

The system was implemented by acquiring 640x360 resolution images taken from a webcam installed on a PC which was INTEL CORE Duo E4500 2GB RAM. The OpenCV and OpenGL library were used for image-processing and rendering each. Figure 11 is an augmented image to apply the suggested method with the realistic illumination on the flexible surface.

Average processing rate of the implemented system was 15f/s. To evaluate our system, we compared to previous researches on Table 1. Though our method used markers, it was faster than the previous ones. It becomes generally known the 15f/s can be accepted as pseudo-real time performance when objects in the scene don't move so fast.

Table 1. Comparison with other methods

	Use Markers?	Processing time
Our approach	Yes	15f/s
Pilet [13]	No	9f/s
Bradley [9]	Yes	10f/s

4. Conclusions

We have implemented an augmented reality system which compounds two dimensional texture to an image of a actual world using a webcam with 15 frames per second. The suggested method calculated each marker's relative position to obtain geometric information on the flexible surface for augmentation.

This way, a virtual object could be augmented more accurately not only on a plain surface but also on a flexible surface. And, to represent texture that the realistic illumination was considered, the presence feeling was improved by removing the markers in the image while sustaining the illumination pattern around the markers.

Nevertheless, when severe bend or self-occlusion happened, it didn't work well. Therefore, to implement a more plausible augmented reality system, we have a plan to solve the situations of the severe bend or self-occlusion by using two or more cameras and we will give more presence feeling by using a HMD instead of a computer monitor.

References

[1] ARToolKit: http://www.hitl.washington.edu/artoolkit

[2] M. Billinghurst, H. Kato and I. Poupyrev, "The magicbook moving seamlessly between reality and virtuality," *IEEE Computer Graphics and Applications*, vol. 21, no. 3, pp. 6-8, 2001.

[3] R. Bridson, S. Marino, R. Fedkiw, "Simulation of clothing with folds and wrinkles," *Proceedings of the 2003 ACM SIGGRAPH/Eurographics symposium on Computer animation*, pp. 28-36, 2003.

[4] D. Pritchard, W. Heidrich, "Cloth motion capture," *Computer Graphics Forum(Eurographics 2003)*, vol. 22, no. 3, pp. 263-271, 2003.

[5] V. Scholz, M. A. Magnor, "Cloth motion from optical flow," *Proc. Vision, Modeling and Visualization 2004*, pp. 117-124, 2004.

[6] V. Scholz, T. Stich, M. Keckeisen, M. Wacker, M. Magnor, "Garment motion capture using color-coded patterns," *Computer Graphics Forum (Proc. Eurographics EG'05)*, vol. 24, no. 3, pp. 439-448, 2005.

[7] I. Guskov, "Efficient tracking of regular patterns on non-rigid geometry," *Proceedings of ICPR*, pp. 1057-1060, 2002.

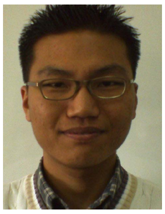
[8] I. Guskov, S. Klibanov, B. Bryant, "Trackable surfaces," *ACM/EG Symposium on Computer Animation*, 2003.

[9] D. Bradley, G. Roth, P. Bose, "Augmented Reality on Cloth with Realistic Illumination," *Machine Vison and Applications*, vol. 20, no. 2, pp. 85-92, 2009.

[10] M. Bertalmio, G. Sapiro, V. Caselles, C. Ballester, "Image inpainting," *Computer Graphics Proceedings*, pp. 417-424, 2000.

[11] D. Bradley, G. Roth, "Augmenting non-rigid objects with realistic lighting," *Tech. Rep. NRC 47398*, National Research Council of Canada, 2004.

[12] R. I. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, ISBN: 0521623049, 2000.



Young-Baek Kim received the B.S. and M.S. degrees in computer science and engineering from Kyungnam University, Changwon, Gyungnam, Korea in 2005 and 2007, respectively. He is currently in the Ph.D. course. His current research interests include image processing, context awareness and augmented reality.

Hong-Chang Lee received the B.S. degree in computer science and engineering from Kyungnam University, Changwon, Gyungnam, Korea in 2009. He is currently in the M.S. course. His current research interests include image processing, computer vision and motion analysis.

Sang-Yong Rhee received the B.S. and M.S. degrees in industrial engineering, Korea University, Seoul, Korea in 1982 and 984, respectively and the Ph.D. degree in

industrial engineering, POSTECH, Pohang, Gyeongbuk, Korea in 1992. He is currently a professor in the Division of Computer Science and Engineering, Kyungnam University, Korea. His current research interests include computer vision, neuro-fuzzy system, intelligent robot and augmented reality.