A Study on M2M-based AR Multiple Objects Loading Technology using PPHT

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Abstract: - Since the researches on augmented reality have recently received attention, M2M market started to be activated and there are numerous efforts to apply this to the real life in all sectors of society. However, with the existing marker-based augmented reality technology, a designated object only can be loaded from one marker and one marker has to be added to load the same object additionally. To solve this problem, the relevant marker should be extracted and printed in screen so that loading of the multiple objects is enabled. Therefore, in this paper, M2M-based AR multiple objects loading technology using PPHT has been developed.

Key-Words: - Augmented Reality, Multiple Objects Loading, PPHT, M2M, MOL Technology, Machine to Machine

1 Introduction

Augmented reality (AR) refers to a virtual world which can provide a sense of reality in interaction with users, where images of real world and virtual graphic objects are generated by computer, and it is almost a lower level of virtual reality rather than a virtual reality realizing complete immersion environment. Core technologies to establish augmented reality system include marker detection to locate an object, matching, tracking, camera calibration to synthesize virtual objects into actual images and calculate camera variables, display and 3D modeling technology [1]. That is, it is a technology field that provides the image with information such as characters and graphic objects in real life to enhance users’ understanding of the situation of moving objects in 3D space [2].

At first, AR system had been developed using HMD (Head Mounted Display) by Ivan Sutherland in 1968, which could only display some very simple wire frames in real time, due to the limitations of the computer performance at the time [3]. After that, in 1992, Tom Caudell developed the display technology using HMD in earnest and began to use the term, AR [2], and since then, consistent research has been conducted. In modern times, as the performance of easy-to-carry computing terminal and display environment has been developed, the AR technology has been rapidly developed, being used in many areas including medical care, education, game, military and industry etc., and researches on AR technology are actively being conducted with consistently increasing demand. For the realization of AR, real life, what point of the image captured by camera the object should be augmented needs to be decided, and augmentation method is classified into marker recognition method and markerless recognition method. Since the markerless recognition method requires feature points which are extracted from the image captured by camera, much time and labor are needed for image processing [4]. Besides many researches need to be done to increase extraction rate and the researches are actively on progress in the country. The marker recognition method is a method of augmenting an object in a point where the computer recognizes the tag interface serving as a pointer connecting real world and virtual world, which is called a marker. This method, due to high recognition rate and easy use, is widely used in the realization of AR [5].

However, the existing marker-based AR technology only can load an object designated in one marker and actually has to add one marker to load the same object additionally. To solve this problem, the relevant marker should be extracted and printed in screen so that loading of the multiple objects is enabled. Therefore, in this paper, M2M (Machine to Machine)-based AR multiple objects loading technology has been developed.

2 Related study : Hough transform

Hough transform is a method of detecting straight lines, circles or other simple shapes out of the image [6]. The Hough transform is based on the fact that there are countless straight lines passing through any point in the binary image. If a line has a y-intercept of b and a slope of \(a(y = ax + b)\), a point on the \((x, y)\) coordinate plane is expressed as a
A straight line on the (a, b) coordinate plane. In case no zero pixels in the input image are all expressed as straight lines on the (a, b) coordinate plane image and the pixel values located where the lines pass through are accumulated, a line on the (x, y) coordinate plane is shown to have a local maximum value on the (a, b) coordinate plane. Since all loci of the lines expressed by each point are summed, the (a, b) coordinate plane is commonly called an accumulator plane [7]. However, the method of expressing a straight line with a slope and a y-intercept is not appropriate to express all straight lines on the (x, y) coordinate plane. This is because to express the common straight lines of which slopes range from $\infty$ to $\infty$ in the binary image is difficult. Therefore, in practical realization, it is expressed as a point, $(\rho, \theta)$ on the polar coordinate system by means of other method. A line expressed as $(\rho, \theta)$ on the polar coordinate system means a straight line perpendicular to a line passing through this point and the origin, which is expressed in the following numerical formula (1):

$$\rho = x\cos\theta + y\sin\theta \quad (1)$$

A point $(x_0, y_0)$ (a) on the image coordinate system becomes a point (b) where many straight lines expressed as $(\rho, \theta)$ on the polar coordinate system intersect and it can be expressed as a line (c) on the $(\rho, \theta)$ plane as follows:

In this paper, reflecting local maximum values on $(\rho, \theta)$ coordinate plane, the marker recognition method was expanded to include not only a simple straight line but other general shapes.

**3 Multiple objects loading Technology**

**3.1 Maker detection using PPHT**

In this paper, 8 bit input image is processed into binary image, no zero pixels are handled all equally and an $N \times 1$ sized matrix is stored in the memory storage as a pointer of the space where the result of Hough transform is to be stored. The most important thing in case of detecting a marker using PPHT, is to set a critical value to estimate it as a straight line on the accumulator plane. This paper set the critical value to optimize this in experimental condition and derived the result image. The methods of implementing the edge tracing algorithm to achieve contour information of the marker’s contour out of the result image derived, and extracting edge points from the contour information existing within the marker region are as followings:

First, if all edge points inside or outside of the marker region appear, one point out of tag region’s contour information is selected and an edge point locating farthest from the point is extracted by means of Pythagoras’ theorem as shown in Fig. 2(a). Next, an edge point lying...
farthest from the extracted point is investigated as in Fig. 2(b), and then an edge point locating farthest from the obtained edge point is extracted again as in Fig. 2(c). As illustrated in Fig. 2(d), a point which maximizes the area of the square becomes the rest one point. Based on the four points extracted, the marker ROI (region of interest) in marker tag can be extracted as shown in Fig. 2(e).

\[
\text{RectArea} = \frac{1}{2} \left( x_1(y_2 - y_3) + x_2(y_3 - y_4) + \cdots + x_4(y_1 - y_2) \right)
= \frac{1}{2} x_1(y_2 - y_3) + x_2(y_3 - y_4) + \cdots + x_4(y_1 - y_2)
\]  
\hspace{1cm} (2)

PPHT (Progressive Probabilistic Hough Transform)[8] which is to be finally used for marker detection can calculate the beginning and the end of each line as well as the direction of line. This method only considers some voluntarily selected edge pixels, not increasing values for all edge pixels on the accumulator plane. In case a value in a specific location appears to be higher than the critical value, no more of value increase is allowed, and the edge pixels displayed by this point into a straight line will be ignored in the further calculation. Besides, since this method can reduce the calculation time drastically, it is highly effective in real time marker detection.

![Fig. 3 Marker Detection using PPHT](image)

The above figure shows the tag detected using PPHT, from the original image captured from Webcam. For easy distinction, the detected parts are marked in bold.

### 3.2 Video output of replicated marker

This study suggests a template matching method that makes warping into the marker registered in a square form from edge points which are extracted within the image, and performs matching.

First of all, when the four edge points outside the marker are designated as \((x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4)\) respectively, a point where the straight line passing through \((x_1, y_1)\) and \((x_2, y_2)\), and the line through \((x_3, y_3)\) and \((x_4, y_4)\) intersect becomes the center of the marker. The formula to calculate the center of the marker using the equation of straight line is as below;

\[
C_x = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(C_y - x_1) + y_1
\]  
\hspace{1cm} (3)

\[
C_y = \left(\frac{x_2 - x_1}{y_2 - y_1}\right)(C_y - y_1) + x_1
\]  
\hspace{1cm} (4)
is obtained by calculating formulas (3) and (4) and then \( C_Y \) is obtained by substituting this for formula (3). If the height of the tag of a specific standard and the height of the extracted marker tag set to \( h_r \) and \( h_d \) respectively, the Sdiff (Scale difference ratio) according to the change of plane for the extraction can be calculated as the following formula (5).

\[
S_{\text{diff}} = \frac{h_d}{h_r} \times 100
\]  

(5)

If the center of the marker which is finally calculated is estimated as the origin, the size error correction (\( T_{\text{total}} \)) can be expressed as the formula (6), and \( D_T \) here refers to transform matrix.

\[
T_{\text{total}} = \begin{bmatrix} \frac{1}{S_{\text{diff}}} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot D_T
\]  

(6)

The figure below shows that a marker tag extracted from the image is copied and moved to the desired location.

The binarized image of the marker marked for the function of a marker is as shown below.

### 4 Conclusion

In this paper, to solve the problem of the existing marker-based AR technology, one marker to one object loading, PPHT-based AR multiple objects loading technology which enables multiple objects loading without another marker added has been developed, by extracting the same marker from the image and copying it at a desirable location.

This study can be most widely used since it is applicable to the researches on feature points extraction of not only the marker-based AR but non-marker-based AR.

Based on this study, an application that enables real objects loading will be added to the future researches. Besides, researches on an algorithm which reduces more marker detection time and a system that implements marker detection smoothly even in an environment that users cannot predict are required to be carried out.

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