An Analysis on Projection Suitability Using Projector-Camera System

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Abstract: In this paper, we propose an analysis on projection suitability using projector-camera system. Firstly, projector projects a horizontal-lines image onto the wall, and camera captures the projection image. Then, we obtain an edge image on the acquired image using Canny edge detector. Through the edge image, proposed system can calculate the total score on the wall using three complexities that are texture, color, and geometric complexity. The geometric complexity is calculated by signs of each slope of the edge in each local area, which is applied Hough-transform. In the experiments, we verify that the proposed method can analyze the projection suitability on the wall using projector-camera and proposed algorithm.

Keywords-- **Projector, Projector-camera, Plane Analysis**

1. Introduction

A projector has been generally used for simultaneously displaying image to quite a number of people, at some organization such as a school or a company, not household, because it requires a high implementation cost and has a big size. However, with advancement of the projector technology, the price is getting lower, and the size is getting smaller. These paved the way for widening the range of practical utilization. For example, the projector can be used for a home robot that can display the information, as shown in Fig. 1. When user asks some information to the robot, the robot can display the information image using projector. In order to project the image, two constraints are generally considered, preferentially. First, flat-screen is required for projection image. Second, the too bright light of indoor illumination ought to be avoided. A portable flat-screen can be a solution for former constraint, but it is not wise in terms of a spatial efficiency. Instead, walls can be an alternative to a flat-screen. The wall, however, could have several properties such as texture complexity, color complexity, and geometric complexity. These properties can be an obstacle to project an image onto the wall. Therefore, in such a case, the robot ought to find a fine-wall to project the information image, by oneself. Therefore, the robot needs an analyzer that can recognize the fine-wall to project an image.

In this paper, we propose an analysis on projection suitability using projector-camera system.

2. Algorithm for Proposed Method

In order to project an image onto the wall, three complexities, texture complxeity, color complexity, and geometric compl-

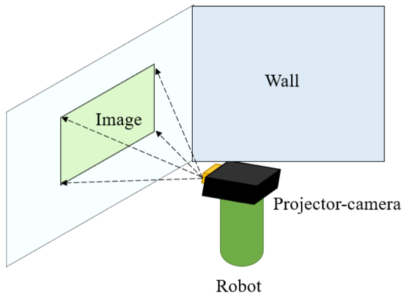

Figure 1. Concept of home robot.

exity, ought to be preferentially considered. Texture complexity means how complicated the texture of the wall is. Color complexity means how colorful the texture of the wall is. Geometric complexity means how flat the wall is. These complexities are described as score points between 0 and 1. In order to analyze these complexities, we use the projector-camera system where the camera and projector are fixed, as shown in Fig. 2-(a). Firstly, the projector projects an image onto the wall, and the camera captures the projection image. To measure score points of these complexities, the projector projects a horizontal-line pattern onto the wall, as shown in Fig. 2-(b). Then, the proposed analyzer calculates the scores. After calculating each compliexity score, the proposed analyzer judges whether the wall is suitable for projecting an image or not.

2. 1 Texture Complexity

A wall with complecated texture is unsuitable for projecting an image. Therefore, analysis on the texture complexity of the wall is positively required. In this paper, we propose a Canny edge dection-based analyzer for measuring texture complexity [1].

In the first, projector projects the horizontal-line pattern onto the wall. Then, the camera captures the projection image, and the Canny edge detector detects the edges in the

(a) Projector-camera system (b) Camera scene
Figure 2. Structure of projector-camera and camera scene.

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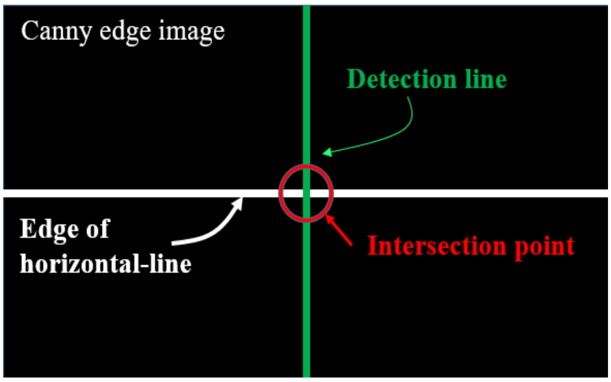


Figure 3. Detection of intersection point.

image. Then, the edge image is converted to the binary image. The next step is setting vertical detection lines, which are described as green line, as shown in Fig. 3. Then, intersection points between detected edges (horizontal direction) and the detection lines (vertical direction) are detected, which are described as red points, as shown in Fig. 4. The pixels which have rappid gradient of intensity value among the pixels on the detection lines are used as intersection points. In other word, the found intersection points has dramatic change of pixel intensity in vertical direction. The reason why we detect the intersection points is that if the wall has not texture, the number of the points are the same with the number of horizontal lines. After detecting the intersection points on each detection line, we average over the number of detection line. Through the averaged number, we can design an analyzer which can judge whether the texture complexity of the wall is high or not.

2. 2 Color Complexity

If the wall has colorful texture, a quality of projected image on the wall cannot be guaranteed. Therefore, an algorithm that can analyze a color complexity of the wall is positively required. In this paper, we propose an analyzer that can calculate a color complexity using chromatic image. The proposed analyzer is designed under the premise that the wall generally has the colors close to achromatic color. The process is as follows.

The first step is converting a color space of image from RGB (red, green, blue) to HSV (hue, saturation, value). Then,

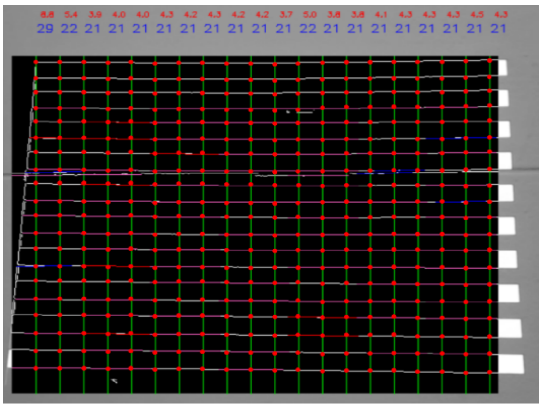
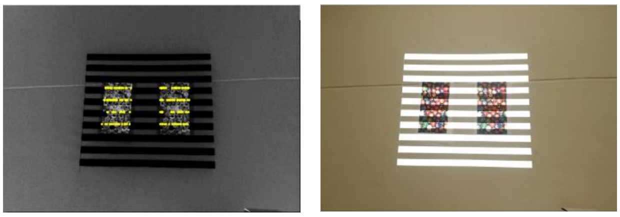


Figure 4. Intersection points on detection lines.



(a) Color change points (b) Color image

Figure 5. Detected color change points.

in the saturation image, we detect the points where the gradient of intensity value on the horizontal-lines is rapidly changed, as shown in Fig. 5-(a). We call this, color change point. Through the number of the points, we can design an analyzer which can judge whether the color complexity of the wall is high or not.

2. 3 Geometric Complexity

In indoor environment, we can face the various types of the wall, as shown in Fig. 6. When an image is projected onto the non-flat wall such as a corner, the image will be distorted. In order to avoid the distortion, we propose an analyzer which can calculate a geometric complexity of the wall. Actually, a structured light-based method can be a sure solution for obtaining the geometric complexity, since it can calculate a 3D information of the wall. However, it is not suitable for practical use in household, because it requires a high-performance camera and projector, and it needs a highly sophisticated camera-projector calibration, which is a very difficult task [2]. In order to avoid these problems, we

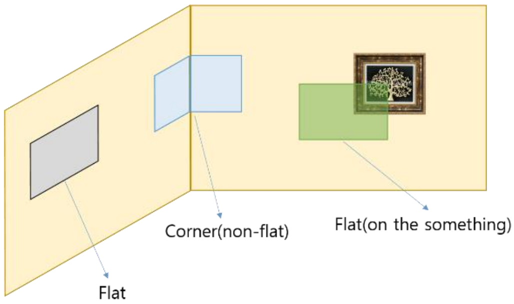


Figure 6. Various types of wall.

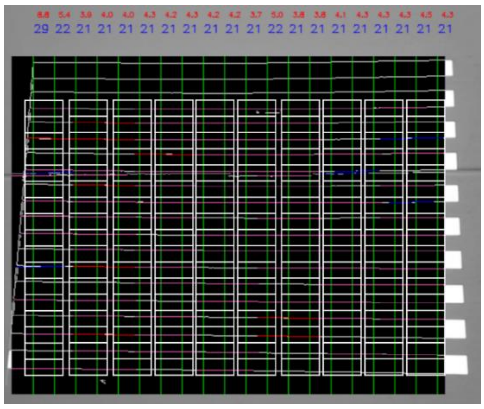


Figure 7. Setting local area for Hough-transform.

(a) Flat wall (b) corner wall

Figure 8. Sign of slope of edge.

propose a simplified and intuitive algorithm that can calculate a geometric complexity with a household projector-camera.

In this algorithm, the edge image mentioned in section 2.1 divided to some local areas with horizontal detection lines as shown in Fig. 7, which are described as white boxes. Hough-transform is performed in each local area to obtain line equation of the edges [3]. Through this, we can obtain slope value of the edges in each local area can be measured. Sign of these slope is used to measure geometric complexity. Measured slopes are three types of sign, negative (-1), positive (+1) and zero (0), as shown in Fig. 8. If the wall is perfectly flat, slops of edge in each local area have the same type of sign. In such a case, signs on the same horizontal line are all positive, or all negative, or all zero. Meanwhile, at corner, signs are rapidly changed from negative to positive, and vice versa, as shown in Fig. 9. In Fig. 9, the four cases are described, where the boxes are local area on the same horizontal line, as shown in Fig. 7. Through this, we can deduce that the sign is rapidly changed at corner. Therefore, we can design an analyzer which can calculate geometric complexity of the wall.

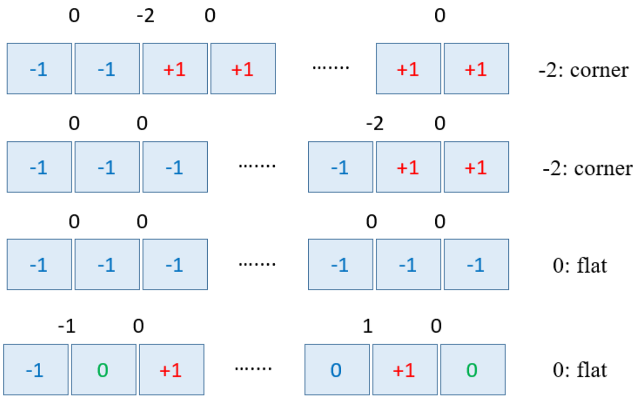


Figure 9. Change of signs according to geometry of the wall.

3. Experimental Results and Analysis

In the experiments, we used "LG BX-401C DLP Projector" and "Logitech Web Cam C920" as the projector, camera, respectively. These devices are combined as shown in Fig. 2-(a). Through this, a projection image is positioned at the center of the camera scene. To implement the proposed method, we used image processing library, OpenCV 2.4.9. To analyze a projection suitability, we calculated the complexity scores with Eq. 1.

$$S = \frac{1}{3}(C_\alpha + C_\beta + C_\gamma), \qquad (1)$$

where S indicates the total score, it has the value between 0 and 1. C_α, C_β, and C_γ mean complexities in terms of texture, color, and geometry, respectively. Each complexity score has normalized value between 0 and 1 using Eq. 2. The closer value is to 1, the wall has lower complexity and vice versa.

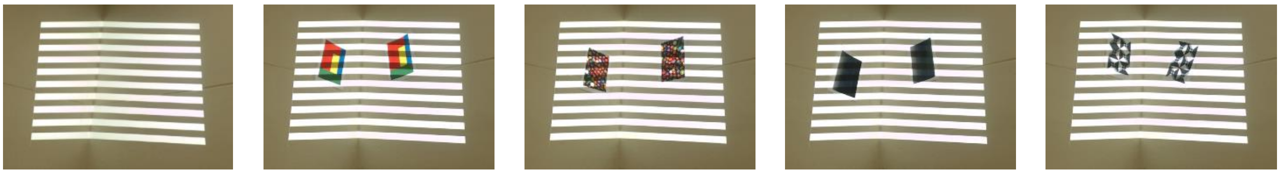
$$C_k = 1 - \left\{ \frac{x - V_{min}}{V_{max} - V_{min}} \right\}, \qquad (2)$$

where C_k is a normalized value, and k is index of complexity, α, β, and x is a value to normalize. V_{max}, V_{min} are maximum, minimum value, respectively. In the case of C_α, we set V_{max}, V_{min} to 40, 20, respectively. In the case of C_β, we set V_{max}, V_{min} to 150, 0, respectively. These values are empirically determined. C_γ has only two values, 0 or 1. When the wall is flat, C_γ is set to 1. When the wall is corner, C_γ is set to 0. After obtaining three complexities scores, we calculate a total score S using Eq. 1. When the wall has most complicated texture, color, and geometry, the total score is approximated to 0, when the opposite happens, it is approximated to 1.

As shown in Fig. 10, we conduct an experiment with various types of the wall. When the wall is fine which means textureless, monotone color and no distortion as shown in Fig. 10-(a), the total score is 0.97 points. In the case of Fig. 10-(b) that the wall is colorful, textureless and not distortion, the total score is 0.79 points. As shown in Fig. 10-(c), if the wall has colorful and complicated texture at the flat wall, the total score is 0.37 points. The total score is 0.94 points when the wall has achromatic, not complicated texture at flat wall, as shown in Fig. 10-(d). If achromatic and complex texture exist on the wall as shown in Fig. 10-(e), the total score is 0.82 points. In the case of the corner wall, the total score is 0.66 points, as shown in Fig. 10-(f). In the case of Fig. 10-(g), when the wall is colorful and textureless at corner, the total score is 0.49 points. As shown in Fig. 10-(h), when the wall is colorful, complicated texture at corner, the total score is 0.19 points. The total score is 0.62 points, when the wall has achromatic, not complex texture at corner, as shown in Fig. 10-(i). When wall is achromatic, complicated texture at corner, the total score is 0.55 points, as show in Fig. 10-(j).

In the experimental result, fine wall was the most suitable to project an image, as we expected. In addition, we could find out that in the case of the corner, total score S was low in general, since it strongly influenced by that C_γ is set to 0. In the experimental result, we could verify that the proposed method can analysis a projection suitability through the total score.

(a) Fine wall | (b) Colorful and textureless | (c) Colorful and complicated texture | (d) Achromatic and textureless wall | (e) Achromatic and complicated texture



(f) Corner wall | (g) Colorful and textureless at corner | (h) Colorful and complicated texture at corner | (i) Achromatic and textureless at corner | (j) Achromatic and complicated texture at corner

Figure 10. Experimental results.

Table 1. The propriety score of various types of the wall

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
C_α	0.92	0.83	0.10	0.90	0.52	0.97	0.90	0.56	0.94	0.75
C_β	1.00	0.54	0.01	0.92	0.93	1.00	0.57	0.01	0.91	0.91
C_γ	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
S	0.97	0.79	0.37	0.94	0.82	0.66	0.49	0.19	0.62	0.55

4. Conclusion

In this paper, we propose an analysis on projection suitability using projector-camera system. The proposed method calculates a total score on the wall using three complexities, in terms of texture, color and geometry. In the experiments, we could verify that the proposed method can judge whether the wall is suitable for projecting an image or not.

In near future, we are going to study on an analysis that can automatically calculate the projection suitability without empirical data set.

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