FAST 3D OBJECT RECOGNITION USING MULTIPLE COLOR CODED ILLUMINATION

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ABSTRACT

The acquisition and measurement of two- and three-dimensional contours of objects are important tasks in modern production processes and quality control. Specially, the nontactile methods like optical triangulation and the digital image processing get more and more importance.

The color image processing in combination with a color coded illumination could be used to realize new methods of nontactile 3D-object ranging. Two of these methods are the color-coded triangulation and the color-coded phase-shift method. We use a combination of these two methods to realize a fast 3D-object ranging with unambiguous results.

The color-coded phase-shift method is able to reach a good spatial resolution, but the measured range values are ambiguous. Using the color-coded triangulation an unambiguous three-dimensional image could be achieved, but compared to the color-coded phase-shift method, the spatial resolution is poor. Since both methods are able to generate a 3D-object description by processing only a single RGB-image, it is possible to combine these two methods.

1 INTRODUCTION

Presently, the existing measuring systems are applicable only for relative slow processes. The principal for all these methods is the triangulation measurement. Scanning techniques like the pencil-beam-triangulation and the light-section method belong to these methods. Generally, these methods use moving sensor elements like scanners and rotating mirrors.

The advantage of coded illuminations is the renunciation of the moving sensor elements. The Gray-code triangulation and the phase-shift-method belong to these methods. The Gray-code-triangulation is a light section triangulation with multiple light stripes. These stripes are coded by different gray levels to distinguish the separate light stripes during the image-processing.

The phase-shift method uses up to four sinusoidal and shifted fringe patterns, projected onto the object sequentially, as illumination. From the detected phase-shifts in the viewed gray scale images the three-dimensional object range could be calculated. However, the periodicity of the coded illumination causes ambiguities in the calculated range map.

To sum up it can be say that the scanning systems obtain a very good spatial resolution, but the necessity of the exact and reproducible mechanical motion makes these systems very expensive and usually the complete acquisition takes a long time. The Gray-code-triangulation and the phase-shift method combine some sequentially taken snapshots to calculate the object range. Hence an object ranging in video-real-time could never be reached. No object motion during the separate snapshots is permitted and a discontinuous object supply is necessary. For rapid three-dimensional object ranging the number of snapshots has to be reduced.

One way to reduce the number of snapshots is the use of color-coded illuminations. In the following several single-snapshot-methods are presented. These methods are the color-coded triangulation, the color-coded phase-shift-method and the combination of these two methods. The color-coded phase-shift method offers the best spatial resolution, while the color-coded triangulation has the highest reliability of the measured quantities. Therefore it is advantageous to combine these two methods.

2 THE COLOR-CODED TRIANGULATION

2.1 The illumination

The color-coded illumination used with the color-coded triangulation is composed by three components. The intensity and the color saturation of the illumination

are constant in the complete illumination field, while the hue changes continuously along one direction of the illumination field (Figure 2.1).

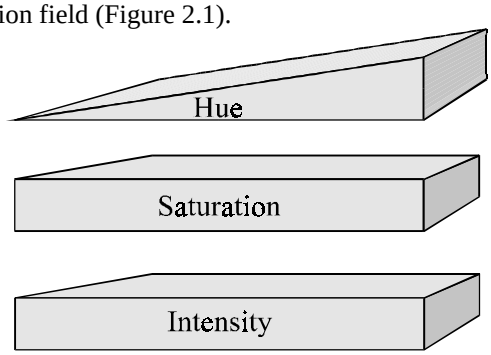

Figure 2.1: Hue-, saturation-, and intensity-distribution for the color-triangulation

The resulting colored lines are comparable to the light stripes of the light-section method. Altogether a higher resolution, compared to a multiple light section is realized and the problem of the ambiguity is resolved because each used color appears only one time in the illumination field.

2.2 The construction

All required measurements could be done at the same time by taking one color image only. The used construction of the color-coded triangulation system is shown in Figure 2.2.

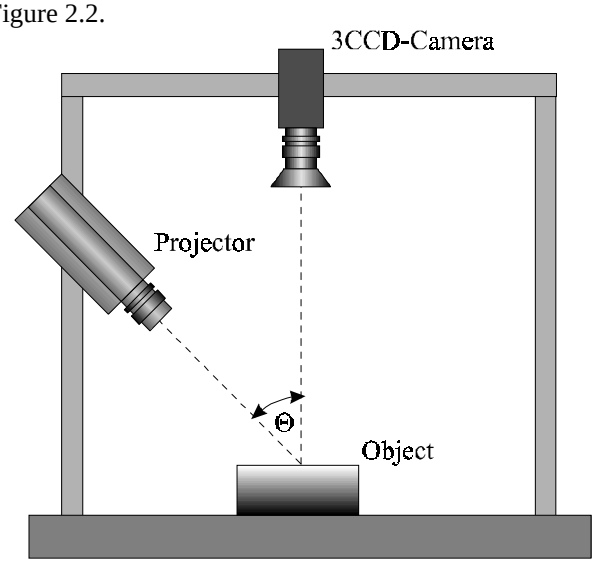

Figure 2.2: Construction of the color-coded triangulation system

2.3 The image analyze

In the first step the acquired RGB-image is transformed into the HSI-color-space. Then all pixels with the same hue (H) are joined together to lines through the illumination field. With respect to the angle of triangulation Θ the deformations of the lines are used to calculate the z-coordinates of the objects.

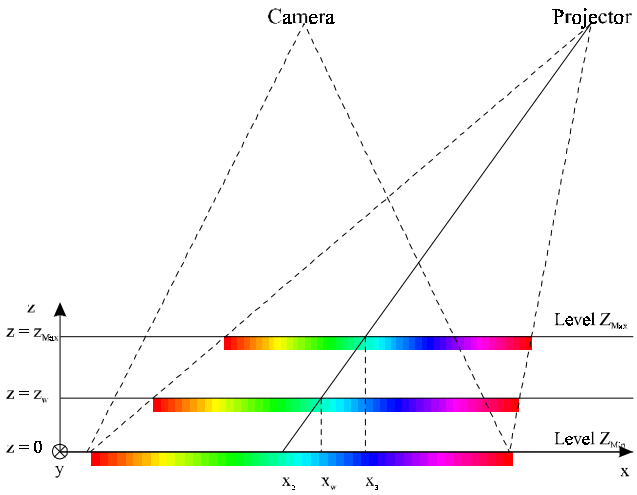

Figure 2.3: Geometrical conditions between projector and camera

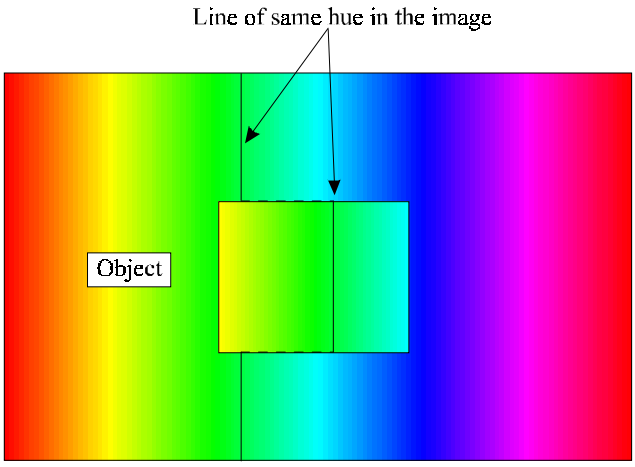

Figure 2.4: Illustration of the camera image with object and line of the same hue

3 THE COLOR-CODED PHASE-SHIFT METHOD

The color-coded phase-shift method is based on the gray-coded phase-shift method. The three required sinusoidal illuminations of the gray-coded phase-shift method are coded in red, green and blue and they are combined to one color-coded illumination. Using this illumination, the acquisition time, compared to the gray-coded phase-shift method is reduced to one third. Compared to the color-coded triangulation, with the color-coded phase-shift method a higher spatial resolution could be realized, but still the ambiguity is present.

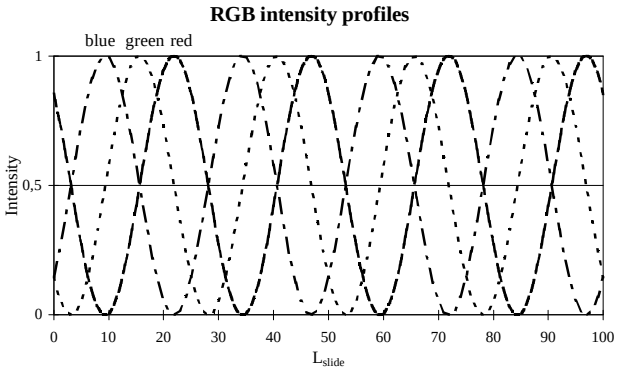

Figure 3.1: RGB-illumination profiles of the color-coded phase-shift-method

4 THE COMBINED METHOD

A suitable illumination for a combined analysis using the color-coded triangulation and the color-coded phase-shift method has been developed. With this new structure of illumination it becomes possible to resolve the ambiguities of the phase-shift method through analysis with the color-triangulation, while the analysis with the phase-shift method guarantees the required high spatial resolution.

4.1 Description of the combined illumination

There are different color spaces for the description of the color coding of the illuminations. The HSI-color space is very convenient to describe the illumination and the algorithms of color-coded triangulation, while the RGB-color space is convenient to describe the illumination and the algorithms of the color-coded phase-shift method.

The hue of the color-coded triangulation illumination changes continuously along one object coordinate while the intensity and the saturation are kept constant. (see Figure 2.1).

The RGB-description of the illumination used with the color-coded phase-shift-method is shown in Figure 3.1. These RGB-illumination curves could be analyzed with the phase-shift method. This illumination causes ambiguities in the hue curve, hence the analysis with the color-coded triangulation becomes no more unambiguous. This relation is shown in Figure 4.1.

One approach for the solution of this problem is the fact, that the analysis with the color-triangulation is using only the H-component. Respectively, the intensity and the saturation are not considered for calculating the range map. The intensity is unsuitable for the adaptation of the HSI-illumination curves.

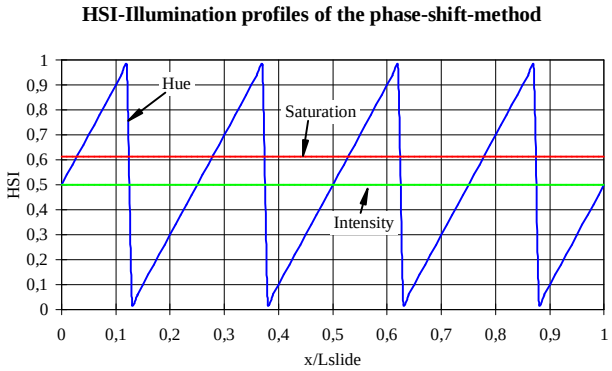

Figure 4.1: HSI-illumination profiles of the phase-shift-method

If the distribution of the intensity keeps constant, different reflection properties of the object surface could be eliminated. Therefore the color-coded triangulation becomes independent of the object brightness. Varying the hue and the saturation along one object direction leads to the following illumination curves in the HSI- and in the RGB-color space shown in Figure 4.2 Figure 4.3:

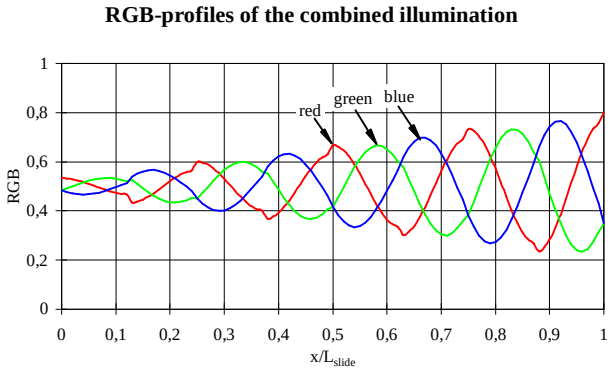

Figure 4.2: RGB- profiles of the combined illumination

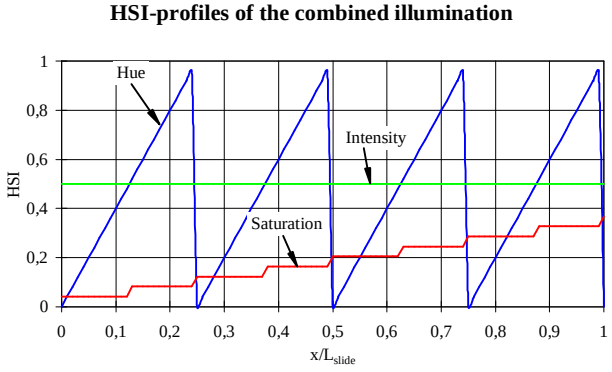

Figure 4.3: HSI- profiles of the combined illumination

5 EXAMPLES

The following examples are measured with our color-coded triangulation system:

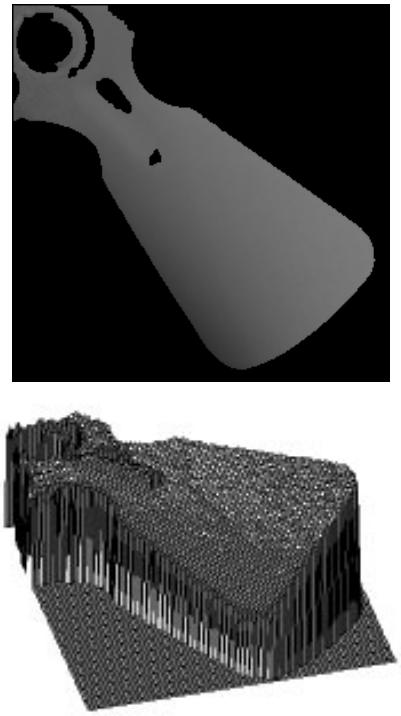

Figure 5.1: 3D-ranging of a fan blade (8cm*8cm*2 cm)

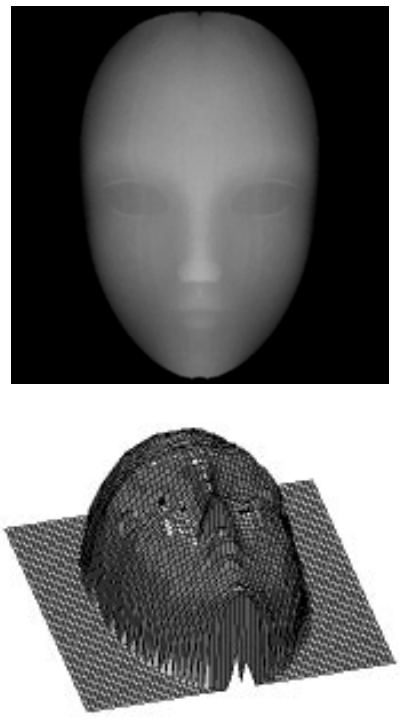

Figure 5.2: 3D-ranging of a face mask (10cm*10cm*3cm)

6 DISCUSSION

With the combination of the color-triangulation and the phase-shift method a fast system for three-dimensional object ranging could be developed. This new method is able to process three-dimensional objects in video-real-time. Since the presented method needs only one color-coded illumination, it becomes possible to process even moving objects using a flashlight illumination. With the special coding of the saturation in sections with a constant saturation it is possible to simplify the necessary phase-unwrapping step of the phase-shift-method. The 2π phase correction function of the phase-unwrapping is coded in the saturation function directly. An additional important advantage of this method is, that no moving components are used inside the sensor system.

7 REFERENCES

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