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Using structured light for efficient depth edge detection

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Abstract

This research describes a novel approach that accurately detects depth edges with cluttered inner texture edges effectively ignored. We strategically project structured light and exploit distortion of the light pattern in the structured light image along depth discontinuities to reliably detect depth edges. In practice, distortion along depth discontinuities may not occur or be large enough to detect depending on the distance from the camera or projector. We present methods that guarantee the occurrence of the distortion along depth discontinuities for a continuous range of object location. Experimental results show that the proposed method accurately detects depth edges of shapes of human hands and bodies as well as general objects.

Keywords: Depth edge detection; Structured light

1. Introduction

Depth edges play a very important role in many approaches to computer vision problems because they represent object contours [1–3]. Reliable detection of depth edges facilitates tasks of the object and gesture recognition. Fig. 1 shows an example of texture edges and depth edges. The use of traditional edge detection methods cannot distinguish between texture edges and depth edges. We describe a structured light based framework for reliably capturing depth edges in real world scenes without dense 3D reconstruction.

1.1. Overview of our approach

The goal of this research is to produce a depth edge map of the real world scene. We illustrate in Fig. 2 the basic idea for depth edge detection. First, as can be seen in Fig. 2(a), we project a white light and a structured light consecutively onto a scene where depth edges are to be detected. The structured light contains a special light pattern. In this work, we have placed the projector and camera vertically so that we use a pattern comprising simple black and white horizontal stripes of equal width. Vertical stripes can be used with a similar analysis. We capture the white light image and then the structured light image. Second, we extract horizontal patterns by differencing the white light and structured light images and using a robust thresholding method. We call this difference image the “pattern image” (see Fig. 2(b)). Third, we identify depth edges in the pattern image guided by edge information from the white light image. We exploit distortion of the light pattern in the structured light image along depth edges. Since the horizontal pattern can be considered a periodic signal with a specific frequency, we can easily detect candidate locations for depth edges by applying a Gabor filter to the pattern image. The amplitude response of the Gabor filter is very low where distortion of light pattern occurs. Fig. 2(c) illustrates this process. Finally, we accurately locate depth edges using edge information from the white light image, yielding a final depth edge map as in Fig. 2(d).

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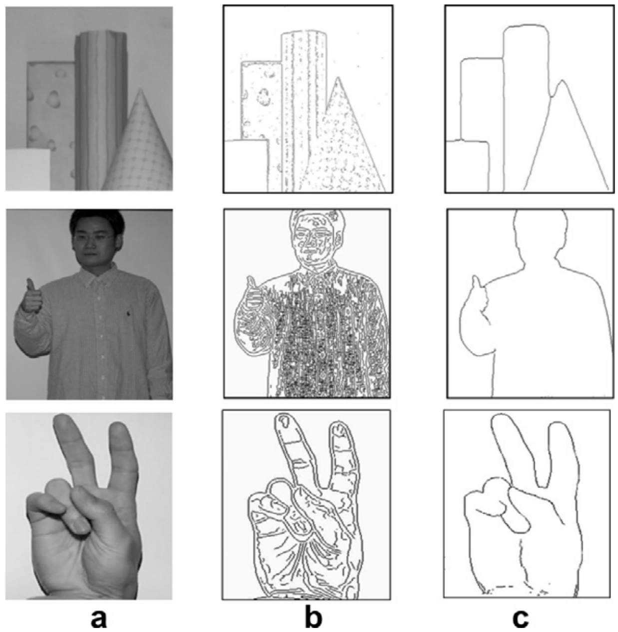

Fig. 1. Texture vs. depth edges: (a) input scenes, (b) Canny edges, (c) depth edges.

In practice, distortion along depth discontinuities may not occur or be sufficient to detect depending on the distance from the camera or projector. Fig. 3 shows an example situation.

Along the depth edges between objects A and B, and between objects C and D, the distortion, i.e., the offset of the pattern, almost disappears. This makes it infeasible to detect these depth edges using a Gabor filter. For successful application of the proposed approach, it is essential to have a solution that guarantees the occurrence of the distortion along depth discontinuities irrespective of object location.

We propose methods to guarantee the occurrence of the distortion for a continuous range of object locations. Based on a modeled imaging geometry of camera, projector, object, and its mathematical analysis, we first compute the exact ranges of object location where detection of distortion is not feasible. We present two methods that extend the range where detection of the distortion is guaranteed. The first method is based on a single camera and projector setup that simply uses several structural light images with different widths of horizontal stripes. The use of three gray level stripes instead of black and white ones is also described to cut the number of projections of structured light patterns by half. The other method exploits an additional camera or projector as compared with the first method. We have used a general purpose LCD projector; however, an infrared projector can be employed with the same analysis in order to apply the method to humans. Experimental results have confirmed that the proposed methods work very well for shapes of human hands and bodies as well as for general objects.

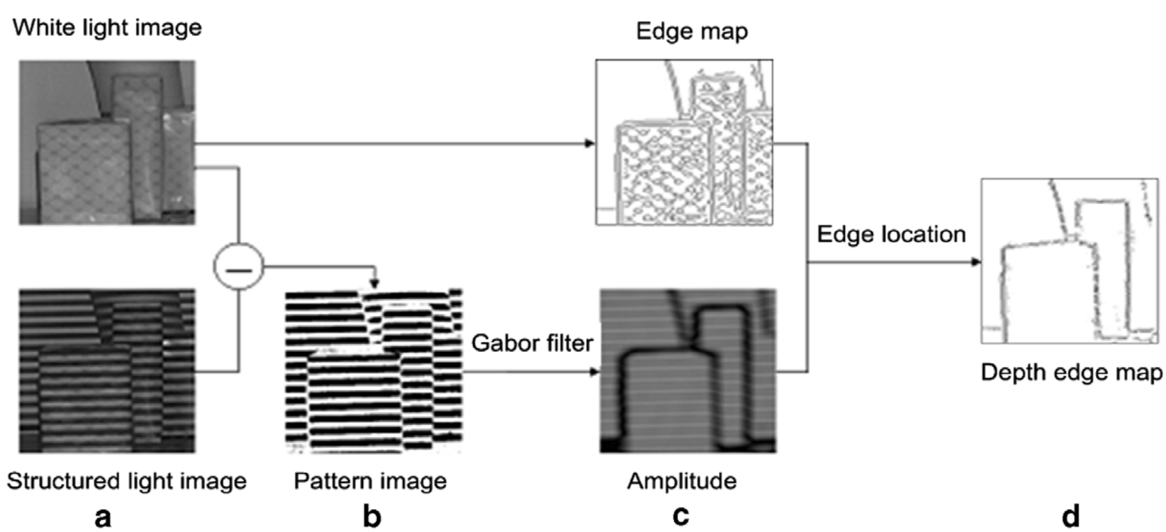

Fig. 2. Illustration of the basic idea to compute a depth edge map: (a) capture of a white light image and structured light image, (b) pattern image, (c) detection of depth edges by applying a Gabor filter to the pattern image with edge information from the white light image, (d) final depth edge map.

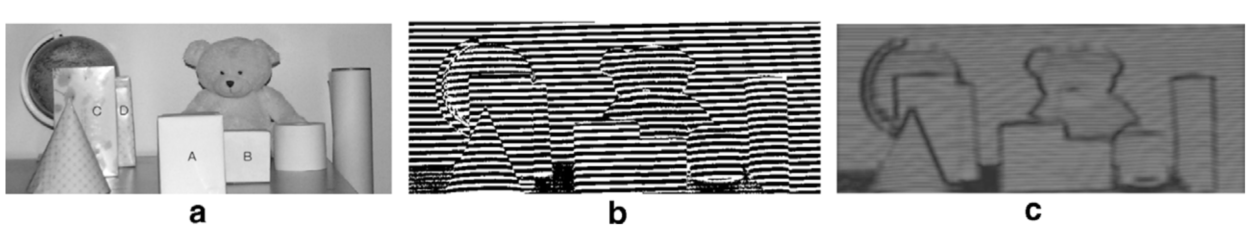

Fig. 3. Problem of disappearance of distortion along depth discontinuities depending on the distance of an object from the camera and projector: (a) white light image, (b) pattern image, (c) amplitude response of Gabor filter. Along the depth edges between objects A and B, and between objects C and D, in the pattern image (b), the distortion of pattern almost disappears. This makes it not feasible to detect these depth edges using a Gabor filter.