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ORIGINAL RESEARCH PAPER

Real-time structured light coding for adaptive patterns

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Abstract Coded structured light is a technique that allows the 3D reconstruction of poorly or non-textured scene areas. With the codes uniquely associated with visual primitives of the projected pattern, the correspondence problem is quickly solved by means of local information only, with robustness against disturbances like high surface curvatures, partial occlusions, out-of-field of view or out-of-focus. Real-time 3D reconstruction with one shot is possible with pseudo-random arrays, where the encoding is done in a single pattern using spatial neighbourhood. To correct more mismatched visual primitives and to get patterns globally more robust, a higher Hamming distance between all the used codewords should be suited. Recent works in the structured light field have shown a growing interest for adaptive patterns. These can account for geometrical or spectral specificities of the scene to provide better features matching and reconstructions. Up till today, such patterns cannot benefit from the robustness offered by spatial neighbourhood coding with a minimal Hamming distance constraint, because the existing algorithms for such a class of coding are designed with an offline coding only. In this article, we show that due to two new contributions, a mixed exploration/exploitation search behaviour and a $O(n^2)$ to $\sim O(n)$ complexity reduction using the epipolar constraint, the real-time coding of patterns having similar properties than those coded offline can be achieved. This allows to design a complete closed-loop processing pipeline for adaptive patterns.

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1 Introduction

The projection of coded structured light is a technique widely used as a means to bring additional knowledge to an unknown scene. This method has been extensively used for depth recovery or full 3D reconstruction even for poorly textured surfaces [3, 7, 10, 13, 19, 21]. Figure 1 illustrates an example of the approach with a 100 $\times$ 100 pattern using 4 cuneiform shapes projected onto a highly coloured surface. But as usual, when dealing with stereo-vision techniques, here a projector-camera system, the correspondence problem between the features on the grabbed images of the projected pattern and the original generated pattern still remains. One solution to solve this is to associate unique codes to light patterns for identification of image elements with spatial or temporal structures.

Several approaches have been recently summed up in [5, 22]. In our application of concern, in the context of minimally invasive surgery, the depth distribution of intra-abdominal scenes has to be recovered. This task should be done in real time to target robotized assistance with deformable organs surfaces. Therefore, we look for approaches based on the spatial neighbourhood coding. Indeed, time-multiplexing approaches do not allow reconstruction of moving scenes and direct coding is too sensitive to illumination changes. Finally using colours, shapes and intensity levels in the close neighbourhood of features of interest leads to a higher number of possible neighbourhood combinations which increases their discriminating power, yielding patterns robust to noise, occlusion, out-of-focus, or highly curved surfaces (Fig. 2).