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Alignment of grid points

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ABSTRACT

Point alignment is an important topic in computer vision. In order to implement cross-stitch embroidery in an automatic way, the grid points in a raster like pattern are desired to be recognized at first. In this paper, we design an algorithm to align the grid points in a raster like pattern in case of checkerboard pattern, and the proposed method was used to recognize the weave holes in a cross-stitch pattern. The method implemented in four steps. First, vertices on the boundary were extracted via removing the inner points. Next, the four corner points were detected in the extracted boundary points. Then the left-lower and left-upper points were positioned. Finally, the points alignment was implemented starting at the left-lower point from the bottom to top, left to right. The comparison experiments demonstrated that our method is robust to geometrical distortion and pose change. The method was applied to align the weave holes in a cross-stitch pattern. The results showed that the proposed method addressed its potential application to the machine weave of the cross-stitch.

1. Introduction

Cross-stitch is a popular form of counted-thread embroidery, which may be found all over the world [1]. Traditionally, cross-stitch requires manual production. In order to increase the ease of use and the speed of production, Karen [2] proposed some new computer-based visualization techniques, in which the contribution of the visualization aimed to map the colored symbols onto a grid to generate the cross-stitch pattern. Before the embroidery being implemented in an automatic way freely, the stitch pattern is desired to be recognized in computer vision. Since cross-stitch is often executed on an easily countable even weave fabric, which is made by little squares with four holes at the corners, the alignment of grid points should be studied as a preceding work so as to meet the requirement of the automation.

Point alignment is an important topic of study in computer vision [3]. Although point alignment is a complex question, the main task of alignment may be defined as the extraction of simple structures in a points set [3]. Point alignment may be divided into 2D [4,5,3] and 3D [6,7] types. The alignment of points not only belongs to geometry, but also involves context [3]. Due to different applications, even the extraction of straight line in points set is an open topic up to date [8,9]. The alignment of points in a checkerboard pattern and a cross-stitch pattern were the focus of attention of this paper. A checkerboard

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0030-4026/

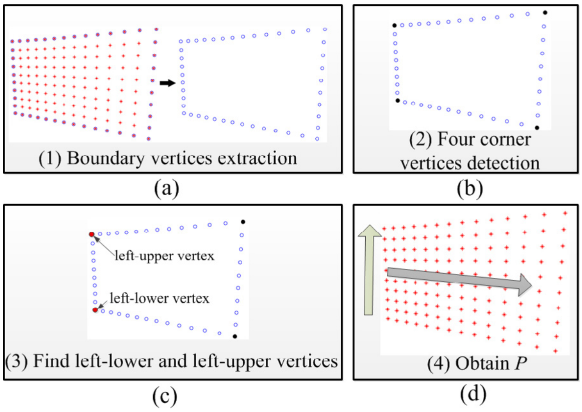

Fig. 1. The outline of the proposed method. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)

is usually employed as an image pattern in camera calibration. Although there were a mass of calibration literature, little attention is drawn to the topic of the alignment of grid points in the pattern. The alignment of grid points in checkerboard pattern is usually supposed to be known in those literature [10–12]. However, the checkerboard used in calibration may be rotated and sloped forward or backward, the alignment of the grid points in checkerboard should not be ignored in the study of the camera calibration.

The alignment of grid points is an important topic for the automation of the cross stitches. Although Escalera and Armingol performed checkerboard recognition by means of the analysis of quadratic Hough transforms in [4], the research of the alignment of grid points seems to be insufficient. It is known that every point in 2D space corresponds to a Hough curve in Hough space. Furthermore, if some points in the first Hough space are collinear, their corresponding second Hough curves have a common intersection point. The common intersection points in the second Hough space correspond to parallel lines in 2D space. In this way, the grid points on checker board were aligned in [4]. In case of the checkerboard pattern, an alignment method for grid points was proposed in this paper. In order to demonstrate the efficiency and robustness of the proposed algorithm, the methods proposed in Escalera [4] and Lezama [3] were employed for comparison. In Lezama [3], a single probabilistic a contrario model, which was extended from a contrario detection theory, was designed for collinear points detection. Starting from the study's motivation, the method was applied to align the weave holes in cross-stitch pattern.

In this study, proceeding from the aim of the implementation of the cross-stitch embroidery in an automatic way, an alignment method for grid points was proposed. The method is proposed in section 2. The comparison experiments are presented in section 3. In addition, the method was applied to align the weave holes in cross-stitch pattern in section 4. Concluding remarks are presented in section 5.

2. Proposed method

Let the coordinates of the grid points detected in pattern image be arranged in order from top to bottom, left to right, and denoted as matrix $\boldsymbol{P}$, i.e.,

$$\boldsymbol{P} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix}$$

where $p_{ij} = (x_{ij}, y_{ij})$ is the pixel coordinate of the grid points of the pattern image at the ith row jth column. For all vertices in the ith row, there is a horizontal fitting line. Similarly, for all vertices in the jth column, there is a vertical fitting line. After detecting the pixel coordinates of the grid points in the pattern, the alignment task is to extract all the horizontal and vertical fitting lines in accordance with matrix $\boldsymbol{P}$, i.e., the grid points should be aligned in order so that the vertical and horizontal fitting can be carried out.

Now, we design a method to align the detected grid points in pattern image. The proposed method contains four modules as shown in Fig. 1. First vertices on the boundary (the blue vertices in Fig. 1a on the right) are extracted via removing the inner points (the red vertices in Fig. 1a on the left side). Second the four corner points as shown the black points in Fig. 1b are detected on the extracted boundary. Then the left-lower and left-upper points are positioned (Fig. 1c). At last, the points alignment are implemented starting at the left-lower point from the bottom to top, left to right as shown the two directions in Fig. 1d.

In detail, Algorithm 1 shows the alignment of the grid points, where the unordered points set $D = \{d_i\}$ is the input, the aligned points, which are recorded in matrix $\boldsymbol{P}$, is the output.