Towards Standardized Wound Imaging

Self-Calibrating Consumer Hardware Based on Lattice Detection on Color Reference Cards

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Abstract. Photographic documentation in medicine is of increasing importance. Efficient methods are required to properly register and calibrate the images. Usually, a standard reference card with special color pattern is placed in the aperature of the image. Localization and extraction of such cards is a critical step. In this paper, we adopt an iterative lattice detection algorithm developed for outdoor images. Once the lattice is extracted, crossing points of the color fields are used for perspective geometric transform while the color plates guide the color calibration process. Our method is tested on 37 images collected within the German Calciphylaxis Registry. At least, 28 out of the 35 possible grid points have been extracted in all the non-standardizes photographs, with at most two false positive detections. The lowest F-measure was above 80%. Hence, ruler and other calibration devices become obsolete and wound imaging can be performed with low-cost hardware, too.

1 Introduction

Photographic documentation is a crucial process in medical imaging. Expensive high-quality hardware and time-consuming calibration steps are required usually for quantitative photographic documentation. Calibration of images is cruical under different illumination, time, and aperture, in particular, if different hardware is used for image capturing. Any attempt to quantify the progression of the disease needs geometric as well as color calibration and therefore, as per clinical protocol it is not performed yet [1].

In a previous work [2], a color reference card and a ruler was used for color and geometric calibration, respectively. Detection of the color card was carried out by finding the scale invariant feature transform (SIFT) [3] point correspondences to a standard card image. The accuracy was dependent on precise SIFT point location and relied heavily on the SIFT parameters, which needed to be adjusted manually for different images.

A probability map computation in red white black yellow (RWBY) color space for quantitatively assessing chronic wound images was proposed by Fauzi

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et al [4]. This method also relies on a white label card for measurement calibration. Thus, the color card extraction is the most critical step and the success of effective photographic documentation thus depends on the robustness of the calibration card detection step. It was done making use of a reference pattern, which was printed on a white paper and placed near the wound. Manual localization and automatic delineation of images was required for color calibration. Due to corrugation and paper bending, this pattern does not support any geometric reference. However, correction of the geometric distortion is essential for assessing quantitatively the spread of a disease.

In this paper, we introduce a combined color and geometry calibration by automatic detection of a color reference card. Preliminary results of this approach have been published already in [5].

2 Materials and methods

2.1 Imaging equipment and color card

The main imaging equipment used were smart phone integrated cameras. The color card used was from CameraTrax, USA. It is a 2×3 inches card with 24 color plates. It consists of 24 squared color plates and covers the entire red green blue (RGB) color space. There are 35 corner points which can be used for correcting the geometric distortion. For calibration, the card is placed in the region of interest (ROI), which is usually a skin lesion or wound that needs to be monitored over a period of time to document the progress of the desease over the time.

2.2 Image processing

Park et al. have used a mean-shift belief propagation algorithm for automatically detecting deformed lattices in real world images [6]. Such lattices usually occur in man-made structures such as buildings, fences, and so on. Park's algorithmis adapted to medical images since our reference color card also contains a lattice structure. This structure becomes more prominent when we take the gradient of image after Gaussian smoothing. The main advantage of Park's approach is its robustness, which is attributed to an iterative growth of the deformed lattice interleaved with thin-plate spline (TPS) warping [6].

2.3 Calibration of geometry

Once we have detect the corner points of the color plate's lattice, the perspective transform matrix relating the distorted card as captured to the reference card's image is estimated. At least four pairs of corner points are required to find the perspective transform. We apply the least squares approach if the number of point correspondences exceeds this threshold.

The relationship between n world and image plane coordinates, (X, Y) and (x, y), respectively, is given as

$$\begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -X_1x_1 & -X_1y_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -Y_1x_1 & -Y_1y_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -X_2x_2 & -X_2y_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -Y_2x_2 & -Y_2y_2 \\ .. & .. & .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. & .. \\ x_n & y_n & 1 & 0 & 0 & 0 & -X_nx_n & -X_ny_n \\ 0 & 0 & 0 & x_n & y_n & 1 & -Y_nx_n & -Y_ny_n \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \end{bmatrix} = \begin{bmatrix} X_1 \\ Y_1 \\ X_2 \\ Y_2 \\ .. \\ .. \\ X_n \\ Y_n \end{bmatrix} \tag{1}$$

where the eight parameters are denoted by $a, b, \dots h$.

2.4 Calibration of color

The color calibration is based on averaging the 24 colors within the color plates of the color cards, as described previously [5]. In red, green, blue (RGB) color space, each color is represented by a triple (r,g,b) and (r',g',b') in source and target image, respectively. Assuming an affine three-dimensional (3D) transform in RGB color space, a set of 12 parameters is estimated, again using a least squares approach.

2.5 Evaluation study

The approach was tested on 37 photographs collected from the German Calcyphylaxis Registry [7]. We define precision p as the ratio of the number of correct lattice points detected to the total number of lattice points detected in experiment. Recall r is defined as the ratio of number of correct lattice points to the total number of lattice points in an image. The F-measure is calculated as

$$F = \frac{2pr}{p + r} \tag{2}$$

3 Results

3.1 Image processing

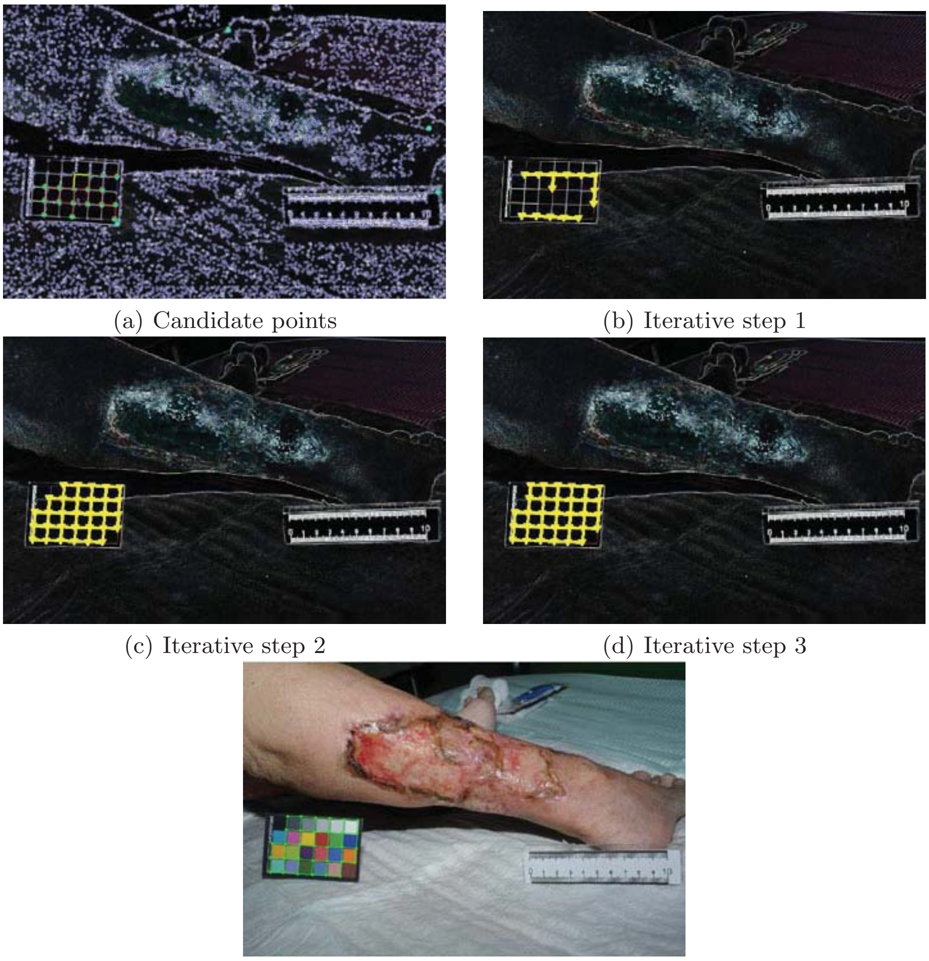
The iterative card detection process is visualizes in Fig. 1. The candidate corner points detected is shown in panel (a). It is obtained by the Karhunen Loewe transform (KLT) corner detector on a gradient image after applying Gaussian smoothing. Panels (b) to (d) show the intermediate results during the iteration process. In Fig. 1 Panel (e), the detected lattice image is superimposed on the actual image. We could observe that the corner points are stable with respect to their exact location. The results of lattice detection algorithm are depicted in Fig. 2.

3.2 Calibration of geometry

In all cases, geometric calibration is based on a high number of corresponding pairs of reference points. Applying an inverse geometric transform is visualized in Fig. 2.

3.3 Evaluation

The recall r assesses the robustness of the geometric transform. At least, 24 out of the 35 available point correspondences have been detected correctly in all the images. With respect to just 4 required points, the least squares approach yielded reliable transform parameters. In average of all 37 images, $\bar{r} = 0.89$.



(a) Candidate points
(b) Iterative step 1
(c) Iterative step 2
(d) Iterative step 3
(e) Lattice detected

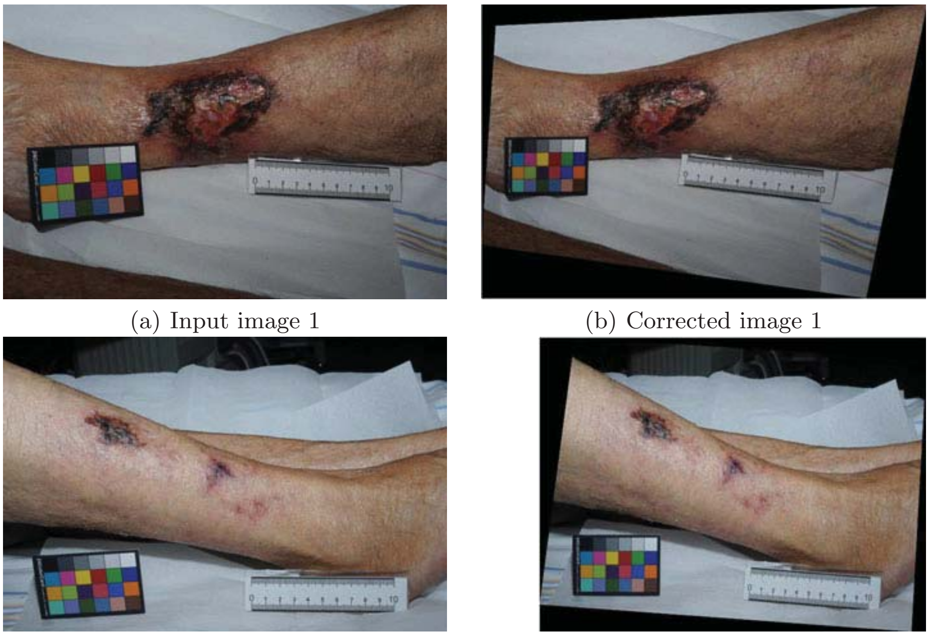
Fig. 1. Results of lattice detection.

The precision p determines the exactness of the geometric calibration. At most 2 dis-located point pairs have been detected, which do not contribute to the least squares estimation. In average of all 37 images, $\bar{p} = 0.97$.

The average F-measure on all images yields $\bar{F} = 0.93$. Hence, geometric as well as color registration is considered sufficiently accurate.

4 Discussion

A novel lattice detection algorithm approach is successfully adapted to medical domain from real world application. The approach helped in proper detection and extraction of the color card that is applied to photographic wound imaging. The method is more robust and automated compared to the previous SIFT-based algorithm. On all our images that have been acquired with low-cost hardware, a robust and fully automatic processing was possible. In future, we will perform calibrated measures of wounds with respect to their size and color. The method is applicable for other wounds of different size, such as burning lesions, if two reference cards are placed on both sides of the lesion. Robustness might also increase by moving the black and brown color plates into the middle of the card away from the black boundary.



(a) Input image 1 (b) Corrected image 1

(c) Input image 2 (d) Corrected image 2

Fig. 2. Results of perspective correction. After correction, the color cards appear perfectly rectangular and appropriately aligned to the horizontal and vertical axes.

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