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A High Quality Image Stitching Process for Industrial Image Processing and Quality Assurance

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Abstract The size of the recording area of a camera is limited. The resolution of a camera image is also limited. To capture larger areas, a wide angle lens can be used, for example. However, the image resolution per unit area decreases. The decreased image resolution can be compensated by image sensors with a higher number of pixels. However, the use of a high pixel number of image sensors is limited to the current state of the art and availability of real image sensors. Furthermore the use of a wide angle lens has the disadvantage of a stronger distortion of the image scene. Also the viewing direction from a central location is usually problematic in the outer areas of a wide angle lens. Instead of using a wide angle lens, there is still the possibility to capture the large image scene with several images. This can be done either by moving the camera or by using several cameras that are positioned accordingly. In case of multiple image captures, the single use of the required image is a simple way to evaluat e a limited area of a large image scene with image processing. For example, it can be determined whether a feature limited by the size is present in the image scene. The use of this simple variant of a moving camera system or the use of single images makes it difficult or even impossible to use some image processing options. For example, determining the positions and dimensions of features that exceed a single image is difficult. With moving camera systems, the required mechanics add to the effort, which is subject to wear and tear and introduces a time factor. Image stitching techniques can reduce many of these problems in large image scenes. Here, single images are captured (by one or more cameras) and stitched together to fit. The original smaller single images are merged into a larger coherent image scene. Difficulties that arise here and are problematic for the use in industrial image processing are, among others: the exact positioning of the single images to each other and the actual joining of the imag es, if possible without creating disturbing artifacts. This publication is intended to make a contribution to this.

Keywords Image processing, lens, image stitching, large image scene

1 Introduction

With a single camera system, capturing a scene is limited in the size of the scene and the resolution of the image. Furthermore, the image may contain distortion and perspective errors that become larger toward the edge of the shot and are especially prevalent with wide angle lenses. Multi camera array systems (Fig. 1.1) can reduce such problems. The difficulty, however, is to combine the individual images from the multi camera system (Fig. 1.2) into a complete image in high quality and without errors. Typical stitching algorithms have problems if the individual images show major distortions, depict different perspectives or do not have exactly the same brightness [1]. A typical stitching result can be seen in Fig 1.3. The idea presented here is to enhance the individual images before the actual stitching process. Th is creates better preconditions to enable a high quality stitching process.

2 Homogeneity Correction

A problem that can occur with the single images is that within an image a non-uniform illumination can occur (Fig. 2.1). This happens, for example, due to uneven illumination or vignetting.

Proposed solution: Determine the inhomogeneity of the brightness distribution and correct it in LAB color space. Since the brightness distribution is different in different brightness scenarios, it must be

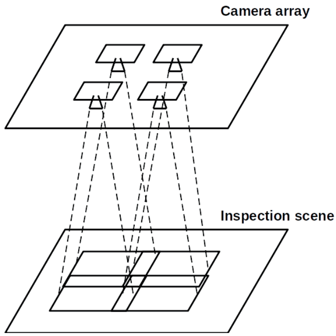

Figure 1.1: Multi camera array system.

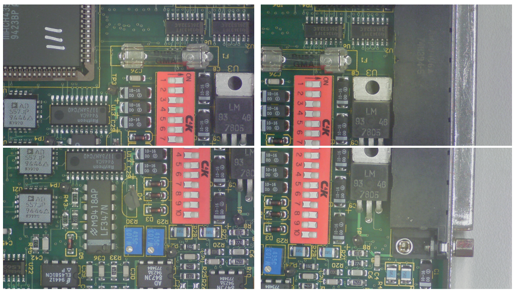

Figure 1.2: Single images from multi camera array system.

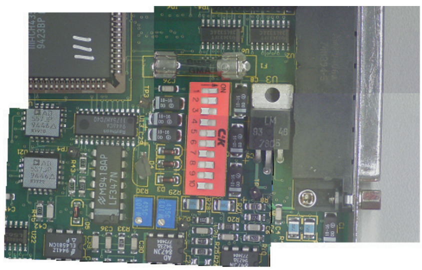

Figure 1.3: Not optimal stitching result.

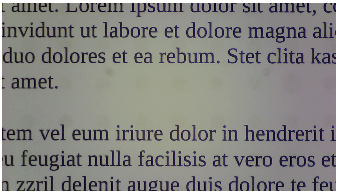

Figure 2.1: Uneven brightness distribution due to uneven illumination and vignetting.

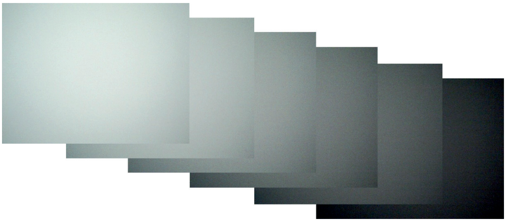

Figure 2.2: Determined brightness distributions of a neutral white body in bright, medium and dark scenarios.

determined for bright, medium and dark scenarios (Fig. 2.2). This is done by means of a neutral white body.

To correct a single image (Fig. 2.3), the brightness scenario is first determined by determining the average brightness. This determines the corresponding correction data set to be used from the neutral white body (Fig. 2.4). By addition/subtraction, the uneven brightness distribution of the image can be improved in the brightness channel L of the LAB color space (Fig. 2.5). In addition, the overall brightness of the image can be brought to a uniform brightness level for all indi vidual images of the multi camera system at the same time in this step.

3 Distortion and Perspective Correction

Another major problem with stitching is the distortion of the individual images (Fig. 3.1). Likewise, different perspectives can already occur within an image, especially at the edges compared to the center of the image. In industrial image processing, systematic distortion correction

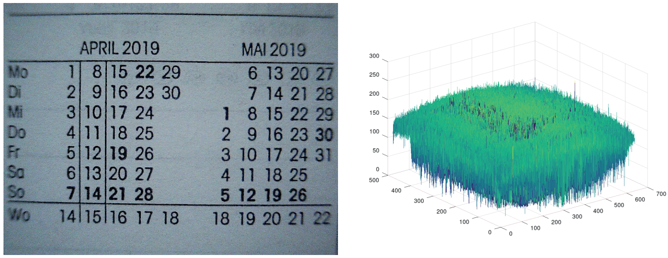

Figure 2.3: Image acquisition with uneven brightness distribution.

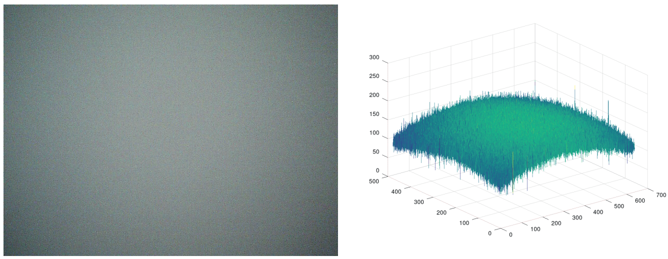

Figure 2.4: Selected correction data set from the neutral white body according to the determined brightness scenario.

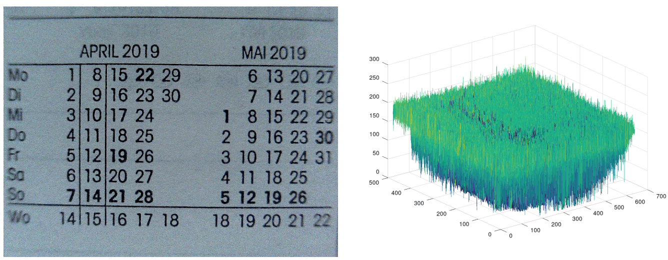

Figure 2.5: Brightness distribution corrected with the correction data set.

can be determined and compensated. This also performs a perspective correction at the same time.

Proposed solution [2]: An areal correction is calculated by means of polynomial interpolation. Deviations from the ideal position can

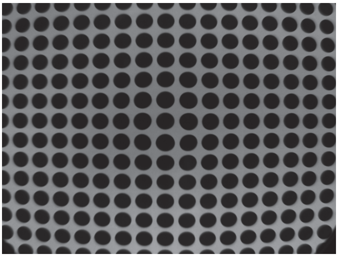

Figure 3.1: Distorted image that may also contain perspective errors.

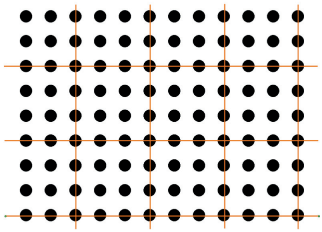

Figure 3.2: Decomposition of the total area into smaller areas to be corrected.

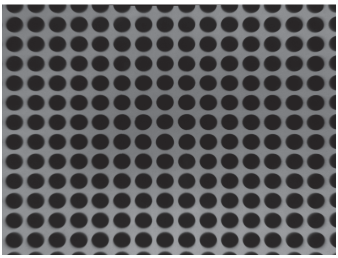

Figure 3.3: Distortion and perspective errors minimized by correction.

be determined and subsequently corrected by grid shap ed support points. To enable a highly accurate correction, many grid points are necessary. In order to handle such a system better, it is advisable to divide the total area into individual smaller areas (Fig. 3.2).

Support points are arranged in the grid to form n columns and m

rows. Distorted actual values $(x_k, y_k)k \in (0, l)$, for $l + 1$ interpolation points are determined by image processing. Associated ideal coordinates $(x_{Soll,k}; y_{Soll,k})$ are known. Place polynomials of the $(n-1)$th or $(m-1)$th degree over interpolation points.

$$x_{Ideal,k}(x_k, y_k) = \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} a_{ij} * x_k{}^i * y_k{}^j \qquad k \in (0; l) \tag{3.1}$$

$$y_{Ideal,k}(x_k, y_k) = \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} b_{ij} * x_k{}^i * y_k{}^j \qquad k \in (0; l) \tag{3.2}$$

System of equations in matrix notation:

$$\begin{pmatrix} x_{Ideal,0} \\ x_{Ideal,1} \\ \vdots \\ x_{Ideal,l} \end{pmatrix} = \begin{pmatrix} 1 & y_0 \ldots y_o{}^{m-1} & x_0 \ldots x_0{}^{n-1} & x_0 y_0 & x_0{}^2 y_0{}^2 \ldots x_0{}^{n-1} y_0{}^{m-1} \\ 1 & y_1 \ldots y_1{}^{m-1} & x_1 \ldots x_1{}^{n-1} & x_1 y_1 & x_1{}^2 y_1{}^2 \ldots x_1{}^{n-1} y_1{}^{m-1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & y_l \ldots y_l{}^{m-1} & x_l \ldots x_l{}^{n-1} & x_l y_l & x_l{}^2 y_l{}^2 \ldots x_l{}^{n-1} y_l{}^{m-1} \end{pmatrix} * \begin{pmatrix} a_{00} \\ a_{01} \\ \vdots \\ a_{n-1m-1} \end{pmatrix}$$

$$X_{Ideal} \tag{3.3}$$

$$\begin{pmatrix} y_{Ideal,0} \\ y_{Ideal,1} \\ \vdots \\ y_{Ideal,l} \end{pmatrix} = \begin{pmatrix} 1 & y_0 \ldots y_o{}^{m-1} & x_0 \ldots x_0{}^{n-1} & x_0 y_0 & x_0{}^2 y_0{}^2 \ldots x_0{}^{n-1} y_0{}^{m-1} \\ 1 & y_1 \ldots y_1{}^{m-1} & x_1 \ldots x_1{}^{n-1} & x_1 y_1 & x_1{}^2 y_1{}^2 \ldots x_1{}^{n-1} y_1{}^{m-1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & y_l \ldots y_l{}^{m-1} & x_l \ldots x_l{}^{n-1} & x_l y_l & x_l{}^2 y_l{}^2 \ldots x_l{}^{n-1} y_l{}^{m-1} \end{pmatrix} * \begin{pmatrix} b_{00} \\ b_{01} \\ \vdots \\ b_{n-1m-1} \end{pmatrix}$$

$$Y_{Ideal} \tag{3.4}$$

4 Image Stitching

The stitching process requires multiple source images that have overlapping areas. Due to the previous corrections of the individual images (Fig. 4.1), the conditions are very good for obtaining a very good stitching result [3]. Fig 4.2 shows the high quality result of the stitching process with OpenCV.

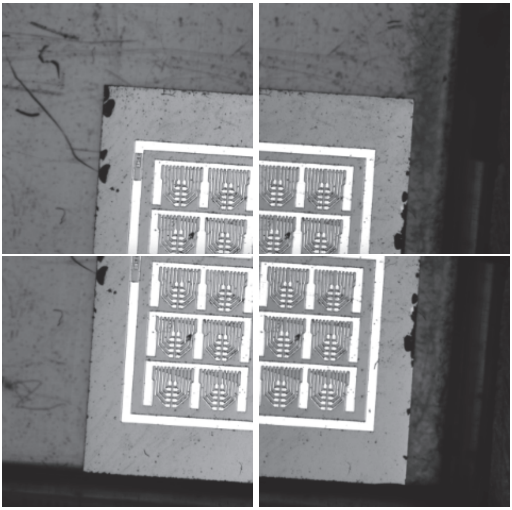

Figure 4.1: Single images optimized by previous corrections serve as the basis for the subsequent stitching process.

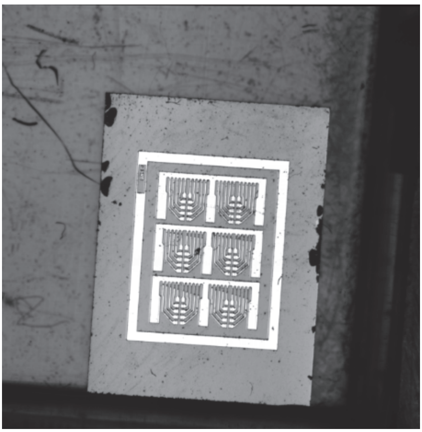

Figure 4.2: High quality result of the stitching process.

5 Results and Conclusions

Camera arrays can be used to inspect large areas. The individual images from all cameras must be combined to form one large overall image. This stitching process can be significantly improved if each individual ima ge is enhanced before stitching. In this paper, homogeneity correction and distortion and perspective correction are demonstrated before the stitching process.

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