Image Mosaic for On-machine Measurement of Large-scale Workpiece

[1] Zhongren Wang, [1] Shuxian Wang, [2] Yanming Quan
[1] Xiangfan University，Xiangfan, P.R. China
[2] South China University of Technology ,Guangzhou, P.R. China
xfu_wangzhongren@126.com

***Abstract*—At present, the large-scale workpiece need to be measured on the coordinate measuring machine(CMM) in the manufacturing process resulting in low efficiency and hard quality controlling. In this paper, an image mosaic method for on-machine vision measurement of large-scale workpiece was presented. The camera was mounted on the numerical controlled milling machine to acquire multi-images by controlling the moving of working table. Rule of image taking, definition of overlapped image pairs, feature point detection and projective matrix computation were discussed. Image mosaic of large-scale workpiece with high precision was realized. Size measurement result proved the effectiveness and high efficiency of this method.**

Keywords- Image Mosaic; On-machine Measurement; Large-scale Workpiece

I. INTRODUCTION

In the automated manufacturing system, such as numerical controlled machine, using online or on-machine inspection technique possess significance and wide prospect for improving efficiency and quality and reducing cost of cutting process[1,2]. Vision measurement uses computer vision to measure accurately and locate for spatial geometric dimension[3]. Because of being effected by camera vision and photographic distances, it is needed to mosaic and fuse sequence images in different times and angles to obtain panoramic image of workpiece when the the length of measured workpiece goes beyond camera view field. The objects of image mosaic are sequence images with partly overlapped area in a set of adjacent images. At present, various motion modes of camera are often used for image mosaic to make corresponding cylindrical or spherical projection.

In general, the large-scale workpiece needs to be measured on the coordinate measuring machine(CMM) in the manufacturing process resulting in low efficiency and hard quality controlling. In this paper, we present a new method of image mosaicing for on-machine vision measurement of large-scale workpiece. The camera was mounted on the numerical controlled milling machine with no moving in order to keep invariable for calibrated parameters in the camera. The workpiece moves with working table controlled by operating panel and numerical controlled program to acquire sequences images block by block. In fact, the image mosaic process for measurement of large-scale workpiece is different from that of common two images. It associates to camera calibration, elimination of lens distortion and overall configuration relationship of multi-images in order to acquire panoramic image of large-scale workpiece with high precision. It is the base for achieving on-machine vision measurement of two dimensional sizes.

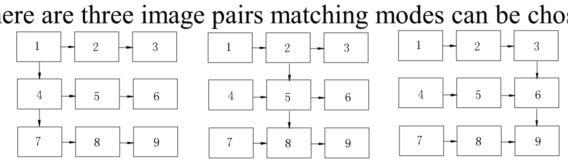
II. IMAGE MOSAIC METHOD FOR LARGE-SCALE WORKPIECE

A. Rule of images taking for image mosaic

After repeated experiments, we summarized rules of sequence images taking. Firstly, there are overlapped parts in images. Secondly, the overlapping images should be textured in order to make the following automatic image registration identify feature points. The lack of textured overlapped parts of images can e overcome by choosing larger overlapped area. Thirdly, overlapped areas should have approximately the same scale. Generally, the size difference should not exceed than 5%-10%. Fourthly, every image should be radiometrically similar. Otherwise, if the brightness differs heavily between neighboring images, it will cause image matching difficulty and clearly visible seams between them. Hence, homogeneous illumination is critical for image mosaicing.

B. Definition of overlapped image pairs

Definition of overlapped image pairs depends on quantity of mosaic images of measured objects. While quantity of mosaic image pairs is up to size of CCD or CMOS, focal length and the distance between the object to camera. We should decrease the number of mosaic image pairs in order to advance matching efficiency, mosaic efficiency and even measuring efficiency. As three by three arrangement of nine images as shown in Fig.1, there are three image pairs matching modes can be chosen.



(a)mode 1 （b）mode 2 (c) mode 3

Fig.1. Configuration modes of nine overlapping images

The image pairs matching configuration mode as shown in Fig.1(b) is the optimal mode because of high precision of image mosaic. For mode 2, No.2, No.5and No.8 in the center array images should be matched after three rows of image pairs matching.

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C. Feature point detection

Generally, many matching feature point pairs in two images need to be detected for mage mosaic. The relationship between feature points determines location of image mosaic[4]. However, on-machine workpieces are usually smooth and have less feature points. In addition, because of the influence of noise and illumination in factory, it is easy to cause to appear many outliers in image after feature point detection. The method of feature point detection in this paper is Harris feature point detection method[5]. When using Harris method, two things should be considered. Firstly, smooth value of gradient integrals must be optimum. If the smooth value is too large, though the computing speed can be improved, few feature point can be detected resulting in match failure. If the smooth value is too small, there are enough feature points detected ,but it will result in slower calculating speed and even computer corruption.Generally, smooth value of gradient integral should be about 2.0. Secondly, smooth value for computing gradient should be large enough to reduce noise effect for first-order differential in the most extent.

D. Projective transformation matrix computation

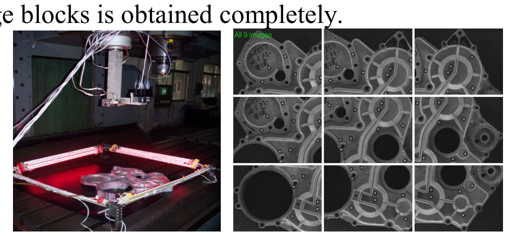
The key of image mosaic technique is image registration. The projection transformation need to be calculated according to image consistency in overlapped area. The relationship between two overlapped images can be represented by a 3×3 projective matrix named plane homography matrix. At present, there are three main methods for computing the plane homography matrix: the method based on feature, the method based on gray scale information, and the method based on transform domain[6-8].

In this paper, projective matrix computation is computed by finding corresponding point relation between image pairs. The initial matching methods of finding corresponding points include SSD, SAD and NCC. Every method has both advantages and disadvantages. We usually choose the method of NCC. After initial match, we use the method of RANSAC for robust matching. RANSAC algorithm is a method of robust parameter estimation presented by Fischler and Bolles in 1981[9].RANSAC has been widely used in on-machine vision engineering practice for high robustness and efficiency.

The way judging whether a point is the correct matching point is to set a threshold value which makes the distance between expected coordinate of the transformation matrix and this point to be less than the threshold value. Therefore, the threshold should be appropriate. In practice, the threshold should be determined by choosing and comparing.

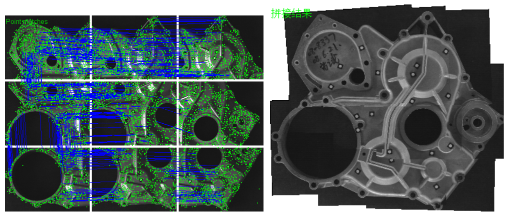
III. EXPERIMENTAL RESULTS AND ANALYSIS

The object of vision measurement is a large-scale automotive die-casting with dimension of about 450mm×450mm under workshop environment as shown in Fig.2 (a).The camera is HV2000FC CMOS, and the industry lens is COMPUTER M1214-MP. CPU of the computer is Intel dual-core E6420 2.13GHz. The memory of the computer is 1G. The system environment was Visual C++6.0. In order to ensure the success rate of feature matching, we paste some paper markers on the work piece. The camera was about 390mm away from the workpiece. The size of image sensor was $7.176mm \times 5.319mm$ .The effective focal length of the lens was 12mm. After computation, the view size of view field is 232.7mm×172.9mm. Because certain overlap region was required between the adjacent two images, we can choose 9 images for image mosaicing. Before image taking, the optical axis of the camera should be adjusted to be perpendicular to worktable. According to field of view size at this time and the required overlap size of adjacent two images', moving distance of the worktable before and after two adjacent images taking is determined. Then, the camera and the lens are adjusted manually till high quality images can be taken. We place the calibration board on the workpiece for camera calibration. Finally, we take the images of the workpiece from the upper left corner to the lower right of the workpiece. The images were named Part_01～Part_09. According to the method described previously, image mosaic of the 9 image blocks is obtained completely.



(a)On-machine measurement scene (b) Original 9 images
Fig.2. on-machine vision measurement

Fig.2(b) shows the arrangement of the original 9 image blocks of a large-scale aluminum alloy casting. Using the above idea of mosaic, we carry out distortion elimination, we implement the steps of camera calibration, feature extraction, initial image matching, robust image matching, projective matrix calculation, projective mosaicing to obtain quite good mosaic effect. Fig.3(a) shows the matching process with robust RANSAC algorithm. The green points are feature points extracted by Harris detector. The blue lines are the epipolar lines of correct matching points between the two adjacent images after robust matching. Fig.3(b) shows the final mosaic result. As we can see, the mosaic effect is perfect with almost no distortion. The course of mosaic takes 25.4 seconds.



(a) robust matching with robust RANSAC (b) mosaic result
Fig.3. Image mosaicing result

Threshold Segmentation, subpixel edge extraction are carried out to obtain the precise edge localization. The centers of the measured holes are determined using the subpixel detection algorithms of ellipse center, and marked with the red "+" .The distance between two big holes center is obtained, and the display result of mosaic image is returned as shown in Fig.4. The difference between the measured result and the measured value (202.6033 mm) with three-coordinate measuring machine is less than a pixel which further verifies the property of high precision of image mosaic.

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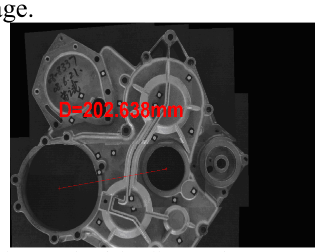

Fig.4. Measuring result of the distance between two large holes

IV. CONCLUSIONS

The method of image mosaic for on-machine measurement of Large-scale workpiece was discussed .Image pairs configuration, feature extraction and the projection matrix calculation methods of image were analyzed and utilized. The results show that the image mosaic method using the feed movement of numerical control machine, we can realize image mosaic and on-machine vision measurement of large-scale workpiece with high precision and high efficiency under proper illumination.

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