OPTIONS FOR MEASURING PARAMETERS OF SURFACES IN METALLURGY WITH EXPLOITATION OF OPTICAL METHODS

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Abstract

There exist a lot of technologies in metallurgy, which need to know certain specific parameters of surface of processed materials or tools. Usually these parameters are acquired by mechanical methods, but these methods can be successfully replaced by exploitation of active optical methods as well as passive optical methods. In the paper are presented some of the approaches of exploitation of optical methods for acquiring the global and local parameters of surface. The monitoring of degradation of operational areas of production tools and devices or quality of surface of produced product can be used as an example. For the most of the active optical methods were used laser beam devices in combination with methods of image analysis. These methods enable acquire 3D information about monitored surface. By processing these information could be acquired entire relief of monitored surface as well as localization of important surface anomalies.

Keywords: computer vision, laser, 3D surface, image processing

1. INTRODUCTION

Quality of surfaces of products and production tools, which more or less influence the final quality, are in the lots of the metallurgical technologies one of the most important of monitored parameters. One of the options, how to monitor the surface quality of solid objects is exploitation of optical methods, when usually is the monitored surface alight by laser device and then is captured the image of alight scene and used image processing methods. After image processing we acquire the important features of captured scene from the image and these features are subsequently analyzed by mathematical methods, which allow to acquire 3D information about captured part of the monitored object. Acquired information by these methods along with required technological parameters of the surface allow us to detect such a differences, which exceeds required limits. This will allows deciding whenever the products or tools are still usable for acquiring of the desired standards of quality and technology. Even though there exists a lot of areas in metallurgy, where could be possible this approach implement, for purpose of this paper was chosen as an example the application for quality detection on surface of crystallizer. In this case is possible to watch both important parameters. One of them in entire shape of surface of crystallizer's plates (global parameter) and second one is the quality of surface itself (local parameter).

2. SCENE ALIGHTING AND CAPTURING

When are the active optical methods exploited, then principles of active triangulation [1] are used. Active triangulation uses knowledge about mutual position of laser device and capturing camera. Laser device is alighting scene with laser beam formed in the shape of line. This line is captured by camera, which is firmly placed towards laser device. The color of the laser beam has to be selected regarding the temperature or the color of the object in the time of measuring. Next important factor is performance of laser device, which has to be selected based on intensity of alighting of neighborhood of the captured scene, reflectance of the material and distance from targeted object. Important factors with influence on measuring quality are camera parameters. To ensure correct capturing, the camera should have fixed focal length. In the case, when camera does not have fixed focal length the measuring software has to contain another subprogram, which would take care of auto-calibration of camera whenever the focal length was changed. Auto-calibration software is usually very complex and even acquiring of the inputs is very complicated. For example just detection of focal length change is not easy task. Next parameter of the camera, which is checked, is camera's chip resolution. The accuracy of optical methods is bound to the resolution. It is because the acquiring chip of the camera digitizes then captured image therefore is not possible to get better accuracy then is the smallest element of the image, the pixel. Another parameter is the type of the camera, if it is full color camera or grayscale camera. For proper identification of laser beam has to be used the full color camera. The grayscale cameras are not suitable for this application.

2.1 Principal of measuring of the distance by optical methods

Principal of the presented method is active triangulation. Active triangulation uses the source of the light, in our case the laser beam and its projection onto scene captured by digital camera. Entire assembly of the laser device and camera has to be firmly bounded together and each of the components has to be in correct position to each other. One of the components has to be pointed perpendicularly towards captured scene and the second one is pointed with some fix angle. It does not matter if the perpendicularly oriented is laser device or camera, but from our experience is more convenient to place the laser device into perpendicular position and camera in angle Θ. Next condition, which has to be respected, is that principal point of the camera is in known distance from light source (laser device) and the spatial axis z coincides with optical axis of the camera. Distance between camera and light source is called baseline. In image coordinate system the baseline coincides with x axis going through the principal point. Principal point is the place in the image, where the optical axis is going through.

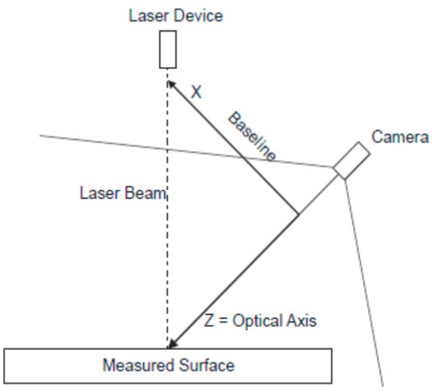

Fig. 1 Principal of Active Triangulation

Each camera has the principal point in the little bit different position, because the lenses are not always on the exactly same position above chip. Laser beam is used mostly in the shape of line, which is easy to identify in the captured image. The complete assembly and its orientation towards the measured surface can you see in **Fig. 1**. If our assembly is correctly set and we know the intrinsic parameters of camera, we are able to convert x and y image coordinates to 3D coordinates in defined space by equation (1) [1]. Intrinsic parameters of the camera are important factor in accuracy of measuring. When the calibration (obtaining the intrinsic parameters of the camera) is not good, we cannot ensure that the baseline is going through the principal point. Also because the captured scene is projected onto the chip through the sets of lenses, we can observe the distortion on the image edges. To get rid of these undesired influences has to be used optimal calibration methods.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{b}{f\cos\theta - x}\begin{pmatrix} x \\ y \\ f \end{pmatrix} \tag{1}$$

2.2 Computing of the camera parameters

Process of computing of the camera parameters is called calibration. If the stereoscopic data are used then we have to compute the intrinsic parameters as well as extrinsic parameters. By extrinsic parameters of camera is meant rotation and translation matrix. Rotation and translation matrix help us to transfer the points from one camera coordinate system to the second camera coordinate system. Intrinsic parameters includes lens geometry in form of distortion parameters, focal length and coordinates of principal point, where goes through the optical axis of the camera. Most often is used the manual calibration with exploitation of calibration pattern (see **Fig. 2**). Also there exists auto-calibration methods, which use the calibration and the method, which does not need the calibration pattern at all.

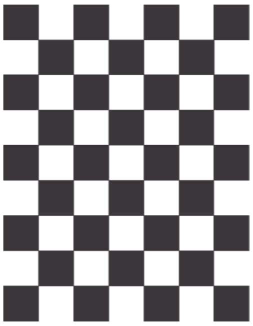

Fig. 2 Calibration pattern

The advantage of auto-calibration methods is in their adaptability to parameters change, i.e. focal length change. These methods are usually very time consuming and is complicated to use them in real-time applications. That is the reason, why is still used manual calibration. Disadvantage of manual calibration is that in the case of change even one of the parameters, the all parameters has to be calibrated again and that is in some cases impossible, therefore the results can be corrupted. In our application is possible to run the manual calibration again, when the change of the parameter occurs and so we can use the manual calibration. The manual calibration of one camera with exploitation of calibration pattern, which is the most often black and white chessboard, is working as follows. First the calibration pattern is placed into field of view of the calibrated camera. Then the series of images with different orientation of the pattern towards camera is taken. There exists two methods, how to change the orientation of the pattern towards camera. First method is, when the camera is in static position and the calibration pattern is moved around. Second method is, when the static is calibration pattern and camera is moving. After capturing the required series of images are these images processed by suitable software. Good example of camera calibration software is Matlab calibration toolbox [6] from American Caltech University. The algorithm used in this Matlab script was implemented into OpenCV library. The OpenCV library enables exploitation of the algorithm in other programming languages, i.e. C++, python and so on. When the calibration is done, the camera is ready to be used for measuring.

3. MEASURING OF SURFACE INEQUALITIES

First task for selected method is to detect laser stripe in the image of measured surface. Success of extraction of laser stripe depends on many factors. Is necessary for laser beam to have enough contrast with measured surface. In the case of low contrast is lost a lot of valuable information and their absence can corrupt entire measuring. Important factor is the reflectance of the material of measured surface and performance of laser device. The unsuitable values of these parameters also corrupted the measuring. In the case of optimally selected parameters of laser device is the stripe clear enough and it is easy to extract it from the image by image processing methods (see **Fig. 3**). Result of the laser stripe extraction is saved into binary image, where one means the pixel is part of the laser stripe and zero means the pixel is not part of the

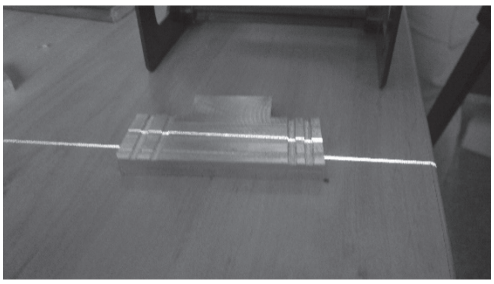

Fig. 3 Captured image

Fig. 4 Extracted laser stripe

laser stripe. Then the result has to be processed again. Usually, when is chosen the high resolution, the laser stripe is too wide (see **Fig. 4**). Sometimes even tens of pixels, therefore the strength (width) of the stripe has to be reduced to one pixel. One of the options we have is just compute average of y coordinates in each x coordinate, but this method is under strong influence of false positive pixels, which are created from inconsistency of the stripe, shadows and occlusions. Next method is to compute weighted average, which is less sensitive to false positive pixels. Last method is to compute it from center of gravity. After the stripe is reduced to one pixel the stripe is locally approximated with line using the Hough transformation [3]. Because the line is search only locally around find pixels, it could be used better accuracy of used method with keeping the moderate amount of data to process.

4. POSSIBILITIES OF EXPLOITATION OF METHOD FOR MEASURING

Presented method is possible to exploit i.e. for measuring of parameters of crystallizer planes. Similar application is solved in [4]. Crystallizer planes and some of their parameters, especially of local character can be measured in disassembled state, when only one plane is measured and computed its parameters. For main global parameters of crystallizer planes, i.e. conicity, is necessary to known profile of each plane as well as their mutual position. For this purpose has to be created the device, which is rigid enough, to ensure linear translation of entire measuring assembly. Apart from rigidity of entire device, has to be ensured synchronous movement when the assembly is rotated to scan next crystallizer plane. To make such an assembly can be achieved by placing rigid pole in the center of the space between the crystallizer planes. If this placing is not done, then the measuring of conicity can be corrupted. In the case, we are not able to place the pole precisely enough, it has to be applied some mathematical methods to computed correction of misalignment of the pole and central axis.

CONCLUSION

Acquired profile sufficiently maps the measured surface and it could be used for identification of local and global parameters of crystallizer desks. For acquiring the absolute real values, the measured values has to be calibrated. This calibration can be done with exploitation of knowledge of location and dimensions of some known anomalies. Example of calibrated image is in **Fig. 5**. In some cases the knowledge of absolute real values is not necessary. If we are try to determine if the profile of crystallizer desks exceed the given limit lines, it could be used just relative values and watch the exceeding of defined line. In computer vision is a lot of areas, where could be used elements of artificial intelligence and comparison of these methods is mentioned in [5]. Selected method proved, that is possible to replace mechanical methods by optical methods.

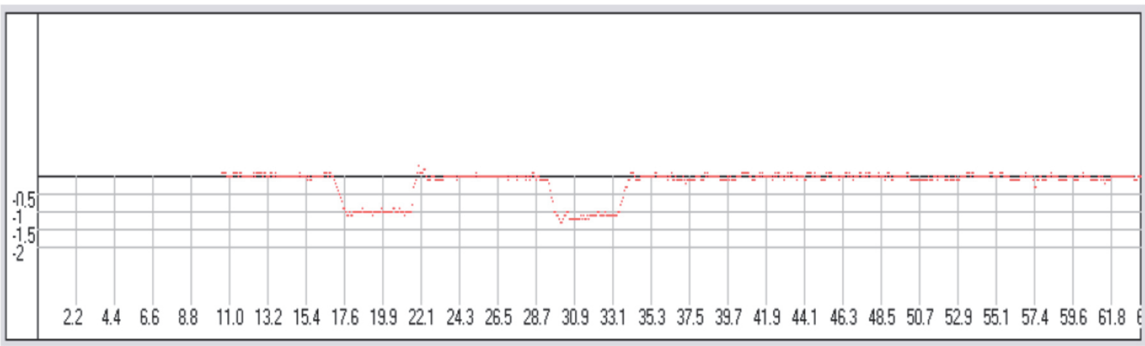

Fig. 5 Anomalies with absolute real values

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