CALIBRATION ASPECTS OF MULTIPLE LINE-SCAN VISION SYSTEM APPLICATION FOR PLANAR OBJECTS INSPECTION

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Abstract: The System Set-up Time it is one of the characteristics of an Industrial Vision System, besides the accuracy performances and response time. Minimizing the set-up time while keeping the performances in accuracy and in response time is one of the goals of any advanced Vision System. Starting from the purpose and the required performances of the proposed Industrial Vision System, in the paper is presented a calibration method developed for a multiple line-scan camera Vision System (in particular for a dual line-scan camera system). The calibration method presented is based on analyzing the image of a calibration tool exposed to the Vision System. There are presented the type of dimensional distortions identified from the experimental results. The second part of the paper presents the calibration method. The Industrial Vision System described in the paper is designed for silhouette inspection of planar objects located on a moving scene (transport conveyor), in a robotic handling application (it is a pure 2D Vision System, the volumetric characteristics of the analyzed objects being not relevant for the application). However the height of the object is varying in time (from one set of objects to another). Due to the fact the distance between the cameras and the objects is changing, the measuring results are affected. The proposed calibration method allows the Vision System to self adjust the calibration parameters for a known change in height of the objects, without affecting the accuracy system performances. In the final section of the paper are presented some practical aspects of the proposed calibration method, and the balance between the off-line and the on-line required computational efforts from the Vision System.

1 MULTI LINE-SCAN CAMERA VISION SYSTEMS CHARACTERISTICS

The class of the Artificial Vision Systems dedicated for analyzing objects located on a moving scenes (conveyor) presents some specific characteristics relative to the Artificial Vision Systems dedicated for static scenes. These characteristics are identified also on the Image Calibration Process (Borangiu, et al., 1994)., (Haralick and Shapiro, 1992).

Figure 1 presents the model of the image obtained from a dual line-scan camera Vision System.

For this class of the Artificial Vision Systems we could identify as relevant for the calibration process the following characteristics:

- The system is using line-scan cameras for the image acquisition.
- The system is a dual-camera.
- The obtained image has significant distortions on (and only on) the image sensors direction.
- There is an overlapped image area between the two cameras. The end of the acquisition line of the 1st camera is overlapping the beginning of the acquisition line of the 2nd camera. This overlapping area is significant in dimension and is a constant parameter resulted during the artificial vision system installation process.
- There is a lengthwise conveyor distance between the acquisition lines of the two cameras. This distance is also a constant parameter and its value is fixed during the system installation process.

2 THE PATTERN BASED CALIBRATION TOOL

For the calibration process we adopted the method of using a Pattern based Calibration Tool.
This Pattern based Calibration Tool represent a set of blobs with a priori known dimensions and locations for the real world (millimeters and not image pixels) (Croicu, et al., 1998).

The outcome of using this type of calibration technique was to obtain the following:

- Estimation with the highest accuracy of the scene model parameters on the distortions direction
- Estimation of the size of the overlapped image area for both cameras
- The parallelism of the two acquisition lines if obtain during the installation process, using the support of the Calibration Tool
- The accuracy of installing the cameras in such a way to obtain the perpendicularity of the acquisition lines on the moving direction of the scene (of the conveyor).
- Obtain a high accuracy on the distance lengthwise the conveyor of the acquisition lines. The shape and the dimensions of the pattern adopted for the Calibration Tool force this characteristic.

3 CALIBRATION TOOL DESCRIPTION

In Figure 2 it is presented the pattern adopted for the Calibration Tool used for the dual line-scan camera Vision System (the dimensions are presented in millimeters) (Croicu, et al., 1998)., (Hossu, et al., 1998).

The characteristics of the adopted Pattern:

- The pattern contains dark blebs (marks) placed on a bright background (with a high level of light intensity for the image)
- The pattern is symmetrical on the vertical direction (lengthwise the conveyor). The two cameras have the acquisition lines parallel one each other but located on different position on the conveyor (due to the lighting system adopted – built from two fluorescent tubes used for obtaining the image from the reflection on the object surface). 1st Camera will have the acquisition line located on the top edge of the lower section of the pattern, and the 2nd Camera will locate its acquisition line on the bottom edge of the upper section of the pattern.
- The pattern is partially homogenous on the horizontal axis (the direction crosswise the conveyor, the direction of the distortions)
- The pattern contains a characteristic of a small difference (1 mm.) between the even and the odd marks. This will force the installation process to be very accurate in obtaining the parallelism of the acquisition lines of the cameras and also the perpendicularity on the conveyor direction.

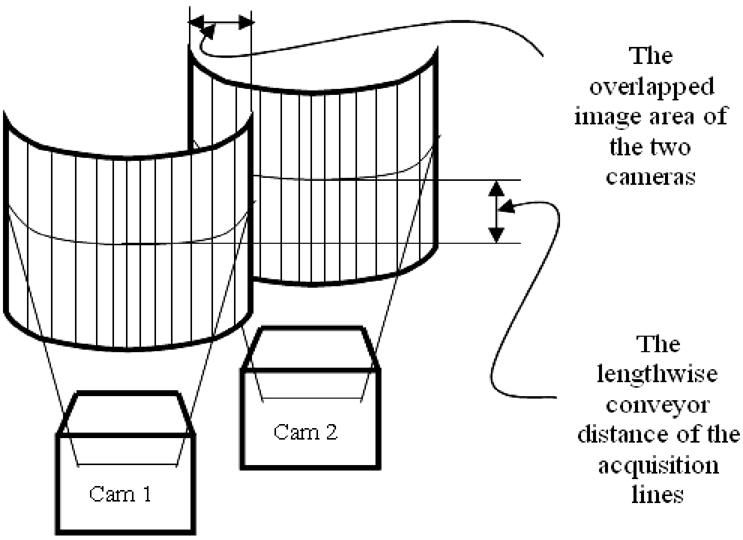

Figure 1: The image obtained from a dual line-scan camera Vision System.

4 EXPERIMENTAL RESULTS OF THE CALIBRATION PROCESS

In Figure 3 are presented the results obtained from the Calibration process performed on the 1st Camera.

The Excel Cell used as support for representing the results of the Calibration on the 1st Camera contains the following:

- The 1st column (called Mark) contains the number of the corresponding Mark existing in the pattern
- The 2nd column (called Calib. Cam) contains the values of the coordinates of the marks on the Calibration Tool.

  These values are obtained from the “real world” from direct measuring of the Pattern applied on the Calibration Tool (represented in millimeters).
- The 4th column (called Pixel(x)) represents the coordinates of the existing Marks on the image. These coordinates are represented in pixel number.
- For both cameras we chose a Polynomial Trend of order 3 for the approximation of the conversion function of the image coordinates values (pixels) into the conveyor coordinates values (millimeters). Using this type of trend the calibration method will provide results with a maximum approximation error inside the accuracy requirements of the particular Vision System
- On the top and right side of the Excel Cell (the first two rows and the last four columns) are stored the parameters of the 3rd Order Polynomial estimated as trend.
- The last column (called Estimated (y)) contains the estimated of the marks coordinates values (on the conveyor), obtained from applying the Polynomial trend of order 3.
- In the bottom right side of the Excel Cell is presented the graphical chart of the trend of the coordinates values of the marks on the conveyor related to the pixel coordinates.

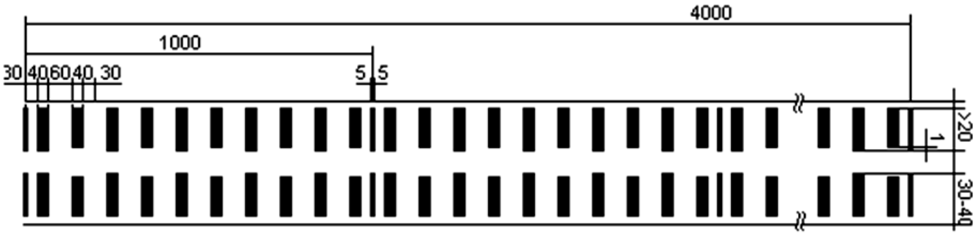

Figure 2: The pattern of the Calibration Tool used for the dual line-scan camera Vision System.

a1	b1	c1	d1
1.448567E-09	-9.128585E-06	0.5088785	338.9459

Mark	Calib Cam1	Real Cam1	Pixel (x)	Estimated (y)
1	436	429.08037	175	427.7278
2	535.5	529.18545	380	531.0810
3	635	629.31390	576	629.3081
4	734.5	729.46574	777	729.5128
5	834	829.64098	979	829.7479
6	933.5	929.83962	1181	929.5853
7	1036	1033.08381	1390	1032.5400
8	1135.5	1133.32999	1595	1133.2616
9	1235	1233.59960	1799	1233.3085
10	1334.5	1333.89265	2004	1333.7361
11	1434.5	1434.71331	2210	1434.6181
12	1534	1535.05337	2415	1535.0504
13	1633.5	1635.41690	2621	1636.0883
14	1733	1735.80390	2825	1736.3342
15	1832.5	1836.21437	3028	1836.3487
16	1932	1936.64834	3231	1936.6953
17	2036.5	2042.15453	3443	2041.9242
18	2136	2142.63667	3644	2142.1760
19	2235.5	2243.14232	3844	2242.4668
20	2335	2343.67150	4046	2344.3760

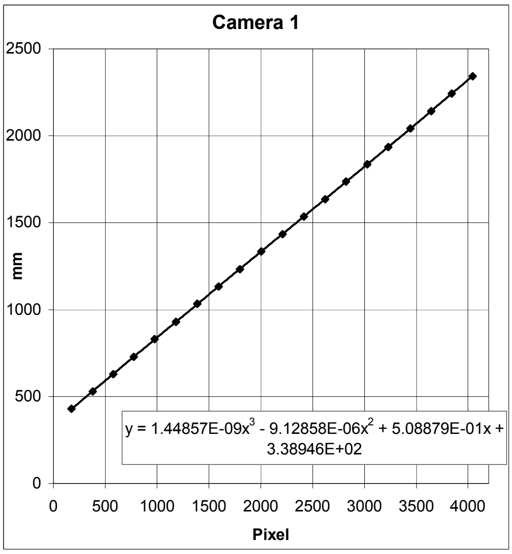

Figure 3: Experimental results of the calibration process on the 1st camera.

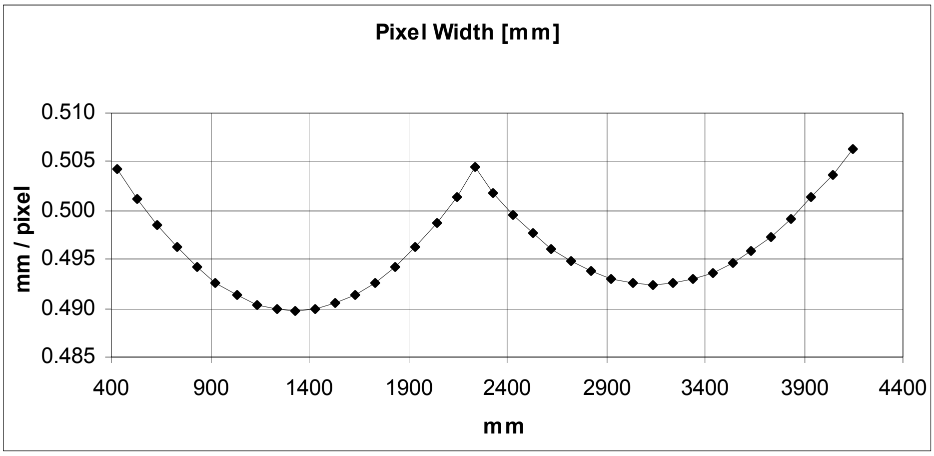

Figure 4: The distortions estimated on the acquisition lines direction.

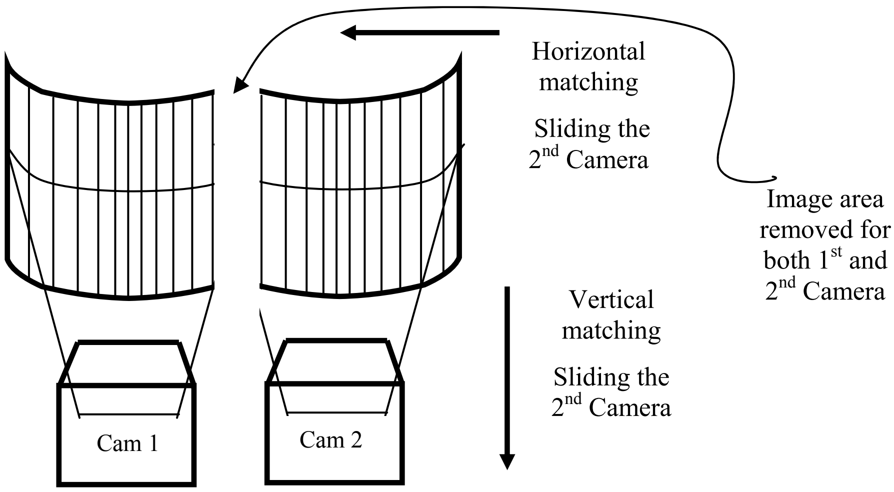

Figure 5: Using the calibration results for a dual line-scan camera system.

In the figure we are using the following notations:

- x coordinate value in image – **(pixels)**
- y coordinate value on the objects scene (on conveyor) – **(mm)**
- $y = a_1 x^3 + b_1 x^2 + c_1 x + d_1$ for the 1st Camera and
- $y = a_2 x^3 + b_2 x^2 + c_2 x + d_2$ for the 2nd Camera

In Figure 4 is presented the graphical chart of the evolution of the distortions estimated on the acquisition lines direction. The two cameras are covering around 4 meters wide view. The figure represents the behavior of the two acquisition cameras: in the are from 400 mm to 2250 mm it is represented the behavior of the 1st camera and in the area from 2250 mm to 4400 mm it is represented the behavior of the 2nd camera.

We can notice the distortions are effecting the pixel width of the image form 0.49 mm/pixel to 0.507 mm/pixel.

Ignoring this variation of the pixel width along the image acquisition line, would lead to accumulation of very high errors in some areas of the image, due to the fact the amount of pixels contained in an acquisition line is high (8096).

5 CONCLUSIONS

The most important thing obtained from estimating the scene parameters, is the estimation of the image distortions.

This end of the process of distortion estimation leads to obtaining a table for conversion the image coordinates (pixels) in scene coordinates (millimeters) for each of all the 8096 pixels of the acquisition lines. This lookup table will contain 8096 values (double representation) representing the real values of the scene (conveyor) coordinates of each pixel.

The CPU effort of the image processing algorithm will be minimal on converting the image coordinates into conveyor coordinates, using the pixel coordinate as the index of the offline built lookup table.

In order to minimize the processing time of the image, the polynomial estimation is not used on-line. The polynomial estimation is used for building the pixel to millimeters lookup table, in the offline stage of the presented method. In fact using a polynomial trend of 3rd order or other type of trend is not relevant for the response time performances of the vision system but only for obtaining the required approximation error. This stage, being offline and using a relative small amount of data, another more sophisticated approximation method could be used.

In Figure 5 are presented the ways the last two steps of the calibration process are performed.

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