Practical Approach for Product Dimension Measurement Using Stereoscopic Vision

Zoheir Mentouri, Salah Bouhouche, Slimane Ziani, Adel Boudiaf, and Me Samira Benchiheub
Applied Research Unit in Steel and Metallurgy BP 196 Annaba, Algeria
Of the Welding and NDT Research Centre BP 64 Cheraga-Algeria
Email: urasm_mz@yahoo.com, bouhouhe11@yahoo.fr, slimane_z@yahoo.com

***Abstract*—Vision techniques have become, since many years, a relevant means for mastering product quality parameters, as dimensions, especially in on line control and in a hard working environment. This development has been reached thanks to technologic progress in equipements, sensors and data processing power.**
Indeed, in dimensionnal control, industrial vision allows the detection of specific points of the object, to compute the sought dimension. This latter is, in a cartesian coordinates system, the two points Euclidean distance. However, depending of the application type and in spite of their performance, used cameras present, some constraints as parallaxe error. It is due to the natural shift, at the installation, of the cameras optical axis regarding target object; or to the dynamic state of the object. This error may affect significantly the measure precision.
Stereoscopic vision is a solution that allows minimizing the above error and presenting the compromise between precision, installation space and costs. Two cameras are used to observe, each one, the whole object to be measured.
In the proposed practical approach, the application is highly depending of a calibrating step, that consists in creating a data base composed of a maximum image points related to the target plan and their geometric positions in a considered coordinates system. When executed, the algorithm detects, thanks to the two cameras acquired information, pixels corresponding to object edges, find their correspondance in the created data base, computes their coordinates (xi,yi) in the defined coordinates system to, finally, computes the sought dimension.

***Index Terms*—measure, product dimension, stereoscopic vision, calibration grid, edge coordinates**

I. Introduction

As known, in all processes there are some parameters that should be controlled in order to reach a certain aimed quality of the final product. Dimension is the quality parameter so important, since products that are not conform to requirements are obviously lowered and even thrown causing, thus, huge money lost.

This imperative of quality has always imposed a continuous product control allowing to producer to apply necessary and adequate corrections in real time or to dispose at the end of production of a recorded summary of dimension profile that is useful for decision.

Thus, in the hard industrial environment, the control/measurement of product dimensions and quality [1] is done, in the major cases, with non-contact measurement techniques as industrial vision of which the known development level has been reached thanks to the technologic progress in equipments, sensors and data processing power.

These hardware and software tools are chosen according to their adequation with application technical needs and obviously their cost in order to have a complete and perfect measurement/supervision application. Moreover, the type of the object to be measured, its distance from sensor, its static or dynamic state and environment conditions are parameters defining the complexity of such aimed applications.

In fact, using cameras in an industrial vision application for dimension measurement presents the constraints related to the position of the camera optical axis regarding target. There may be created a parallax error which could be important and affects the dimension result. It depends of the importance of the created shift.

The present work deals with this aspect aiming to present a dimension measurement method using stereoscopic vision technique that allows overcoming the mentioned constraint.

The paper reminds, before all, the classical principle to compute a distance defined by two points in a coordinate system. It gives, after; an overview on cameras based vision application for dimension measurement dealing with detection principle and used sensors type. In methodology chapter, explanations on stereoscopic vision, the important calibrating operation and coordinates points determination method are given. The experimental study shows how the exposed concepts were exploited, and of which, results are presented in the following chapter.

The present paper ends with conclusions related to what has been done and to possible future improvements.

II. Dimension Measurement

The considered principle in object dimension measurement is based on the Euclidian distance [2] between the two points that correspond to object boundaries or more precisely its edges of which

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coordinates E1(x1, y1) and E2(x2, y2) should be computed

$$D=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2} \qquad (1)$$

Is the dimension value to be found at the final step

III. Cameras Based Vision Application for Dimension Measurement

A. Principle

In a grey level image, a maximum lightened surface corresponds to an image grey level of 255 whereas a dark one to 0, [3] and [4].

Then, when an object, as sheet steel, is adequately lightened by the bottom Fig. 1, its image would show a created contrast between the object and its near environment. In fact, the object would be seen by camera darker than its environment. This principle is used to detect the two object edges, using camera and suitable image processing functions as 'Edge' in Matlab.

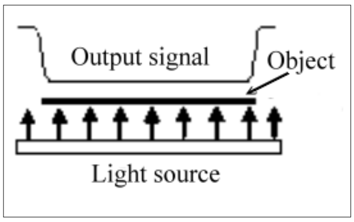

Figure 1. Object lightning and edge detection.

B. Optical Sensors

Optical sensors have greatly advanced during last time. Among the most recent used ones, with cameras, are CCD (charge coupled device) Sensors. It is an integrated analog circuit that converts an optic image to a proportional output signal. CCD elements may be disposed according a single line or a matrix. More important is the number of sensors elements Fig. 2, better is the obtained resolution.

For 1024 pixels representing a field of 1500mm, the resolution is of 1,464mm, whereas 2048 gives the half value representation,

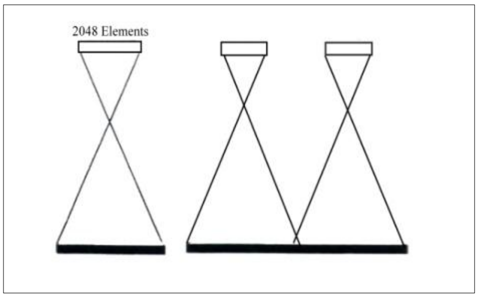

Figure 2. Camera resolution.

However with a camera system, the optic axis position, remains the constraint that should be overcame in order to minimize parallax error on the final computed dimension. This error results from the shift of the camera optical axis regarding the target object. The situation may occur at installation or when the object moves vertically during production. As shown in Fig. 3, for the same horizontal position of the object, and with different high the value detected by camera is not the same.

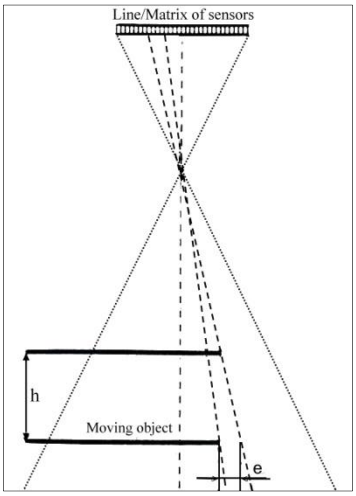

Figure 3. Object positions and corresponding pixel order.

IV. Methodology

A. Stereoscopic Vision

To reduce θ angle corresponding to 'e' error in Fig. 3, then the parallax error, solutions as placing the camera as far as possible from the object or as using a mechanism that allows camera to move horizontally for being in front of object sides are limited and complex. Easier to bring into operation, Stereoscopic vision [5] is the technique allowing elimination or at least a better minimization of this error.

Two fixed cameras (1 and 2) are placed at a distance from the target object and observe the whole object dimension to be measured Fig. 4. When Acquiring simultaneously the object image, edges are detected and their pixel orders are defined: PixE1 and PixE2 .

The corresponding edges positions are computed, too, using a calibration data.

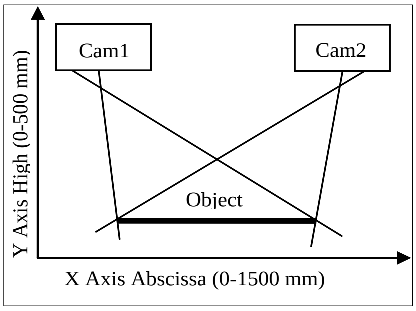

Figure 4. Cameras positions.

B. Calibration Step

Calibration is the main operation. It aims to create a useful tables of correspondence between images of many reference edges viewed by each camera and their real physical positions.

It consists in acquiring images of a calibrating bar that is designed to present several slits (presenting several calibrating edges) of known size Fig. 5. This bar is positioned each time at a different high (H_i) while acquiring images. It is a manner of meshing the vertical zone allows to finally obtain a grid for which all nodes are referenced by a pixel order (N_i) on each camera , and reference edges geometric coordinates (x_i, y_i).

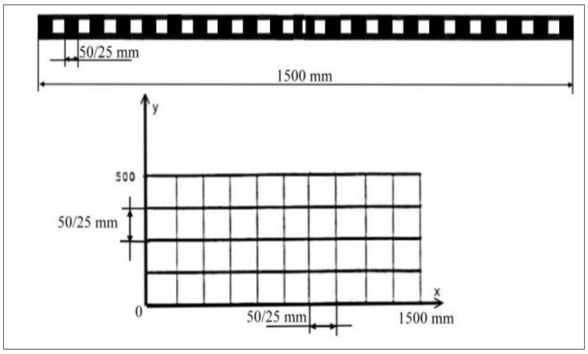

Figure 5. Bar with slits and resulting calibration zone.

C. Edges Coordinates Determination

With the camera's optical system, pixels order (number) is a function that varies with a linear manner in terms of points viewed positions Fig. 6 and Fig. 7.

i.e: For geometric positions $x_A < x_B < x_C$ would correspond pixels order $Pix_A > Pix_B > Pix_C$, according a negative slope, as shown below and vice versa.

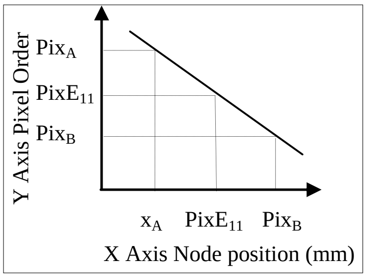

Figure 6. Pixels order function.

The following Fig. 7 presents a sample of saved calibrating edges detected on the calibration bar and their corresponding pixels order.

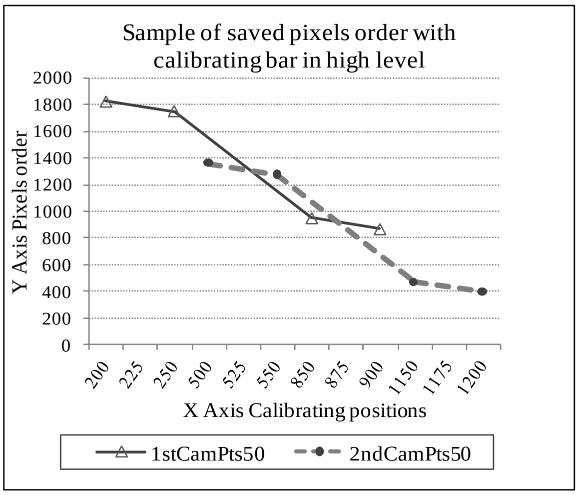

Figure 7. Pixels order of sampled calibrating positions.

The same edge Fig. 8a, seen by the two cameras, is considered situated at the intersection of their two respective optical lines. These lines, obviously, intersect with horizontal grid lines and more precisely the lowest and the highest ones, as shown in the Fig. 8b.

Thus, for an edge, there are eight nodes pixels that are the nearest from edges pixels and of which the corresponding positions are, by couple, respectively belonging to the two main calibrating lines Fig. 8b.

After the determination, from calibration data base, of these eight nodes pixels, it would be easy to find their corresponding geometric position (abscissa) and, by approximations [6] and [7] to compute the position of new points E_{H11}, E_{H12}, E_{L12} and E_{L11} which are respectively common points to the camera optic lines 1 and 2 with the concerned horizontal calibrating lines

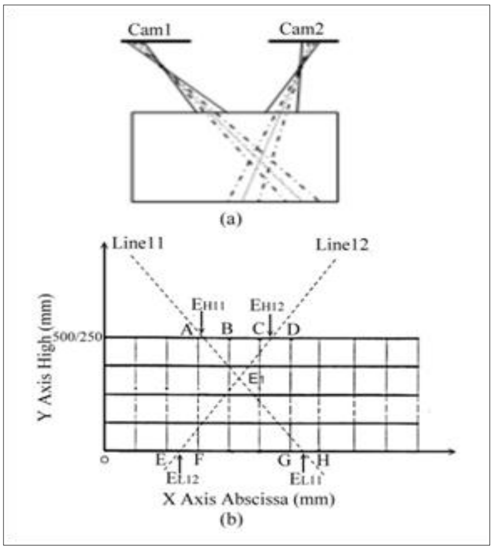

Figure 8. Intersection points and 1st edge coordinates.

Then, for the first object edge the following points would be available. They are related to the highest horizontal calibrating line, and the optic line 11 of the 1st camera Fig. 8b:

$A(x_A, Pix_A)$; $B(x_B, Pix_B)$; and $E_{H11}(xE_{H11}, PixE_{11})$; Allowing the determination of xE_{11}

$$xE_{H11} = \frac{(PixE_{11} - Pix_A)}{(Pix_B - Pix_A)}(x_B - x_A) + x_A \qquad (2)$$

Coordinates of the remain three intersection points are computed thanks to analog information on C, D; E, F and G, H points. Then, considering the orthogonal coordinates system xoy in "Fig. 8b" following coordinates points are obtained : $E_{H11}(xE_{11}, y_H)$, $E_{H12}(xE_{12}, y_H)$; $E_{L12}(xE_{L12}, y_L)$ and $E_{L11}(xE_{L11}, y_L)$,

i.e: xE_{H11} is the abscissa related to the <u>first edge</u> and defined by the intersection of the optic line of the <u>first</u> camera with the highest calibration line,

Two lines equations are then established:

$$y = a_i x + b_i \qquad (3)$$

where:

$$a_1 = \frac{y_L - y_H}{xE_{L11} - xE_{H11}},\ b_1 = -\frac{y_L - y_H}{xE_{L11} - xE_{H11}} xE_{H11} + y_H \qquad (4)$$

Coefficients of the second optic line (Line12) are determined with the two points E_{H12} and E_{L12}.

$$a_2 = \frac{y_L - y_H}{xE_{L12} - xE_{H12}},\ b_2 = -\frac{y_L - y_H}{xE_{L12} - xE_{H12}} xE_{H12} + y_H \quad (5)$$

The first edge is at the intersection of these two lines

$$X_{E1} = \frac{b_2 - b_1}{(a_1 - a_2)} \quad (6)$$

Y_{E1}, is thus easily computed using one of the two above equations (3).

The same computing approach is applied to find 2nd point coordinates corresponding to the 2nd edge, and finally the formula (1) is applied to compute the sought dimension value.

What should be mentioned is when applying (2) to (6) with the use of other information points related to other levels of which calibrating data have been created, edges coordinates positions might be better approximated. This is due to the fact that these new lines or different calibrating levels which are lower and higher than the mentioned and used main lines may be nearer to the edge geometric position.

V. Experimental Study

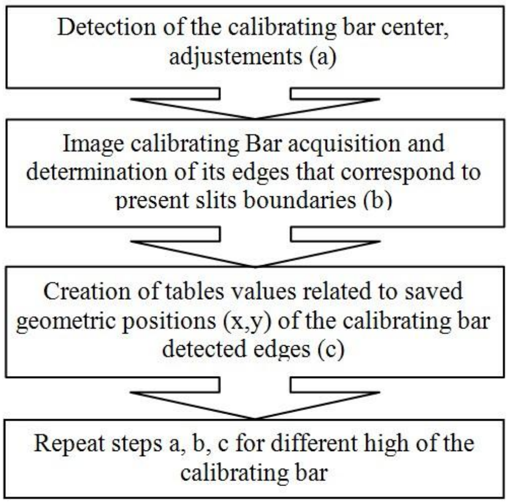

Figure 9. Calibration procedure.

To apply concepts and the above exposed methodology some parameters were considered owing to their impact on results. Used camera are of 2048 points of resolution, to measure an object of 1500 mm maximum size; what represents on the field to be measured a size of d=0,7324 mm per pixel(*).

With a distance between cameras and the object of more than 4m, adjustments were made on linear cameras enabling them to have the whole object dimension in their vision field. Information as pixel width, pixel line width, focal distance and so on are not, at this step used in computing algorithms, but rather for other checking routines.

The origin of geometric coordinates system is taken at the beginning of the measurement field (from the left to right side) and at the low level, as shown on Fig. 8b.

Different tasks were executed according the two procedures below Fig. 9 and Fig. 10; and tests were made with different sized calibrating bar, 50 and 25mm of slits width.

Fig. 9 shows tasks of the calibrating operation in which, edges of known geometric positions are detected, and their related information are saved. The measurement operation is executed according the measurement procedure presented in Fig. 10. It is based on the detection of the object edges for computing object dimension.

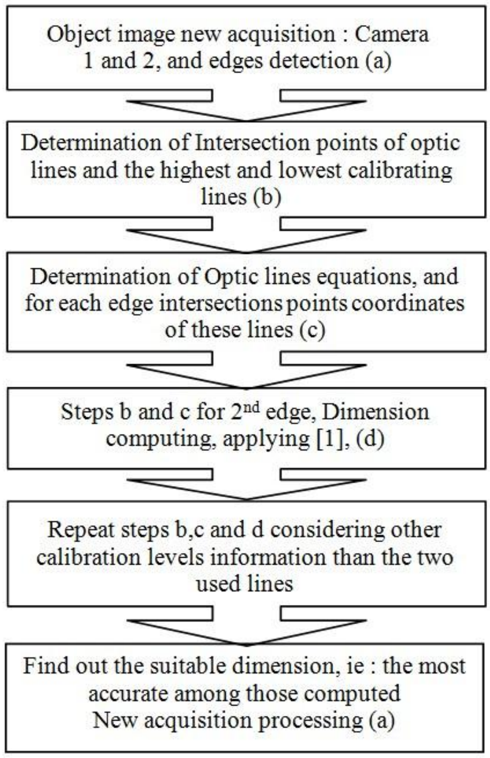

Figure 10. Measurement procedure.

VI. Results and Discussion

TABLE I. (a) AND (b): COMPUTED COORDINATES OF INTERSECTION POINTS. 1ST CASE CALIBRATION BAR OF 50 mm SLITS SIZE

(a)

	Type	1st Edge			
		1st Cam		2nd Cam	
High positions	Calibrating positions	200	250	500	550
	Pixel order of Calib. Posit.	1825	1749	1359	1275
	Pixel order of Edge	1752		1280	
	Intersection pos. of Optic line and Horiz. Line	XEH11= 248,0263		XEH12= 547,0238	
Low positions	Calibrating positions	300	350	650	700
	Pixel order of Calib. Posit.	1285	1225	1755	1687
	Pixel order of Edge	1280		1752	
	Intersection pos. of Optic line and Horiz. Line	XEL12= 304,1667		XEL11= 652,2059	

(b)

Type		2st Edge			
		1st Cam		2nd Cam	
High positions	Calibrating positions	850	900	1150	1200
	Pixel order of Calib. Posit.	952	870	471	397
	Pixel order of Edge	873		435	
	Intersection pos. of Optic line and Horiz. Line	XEH11= 898,1707		XEH12= 1175,6757	
Low positions	Calibrating positions	950	1000	1400	1450
	Pixel order of Calib. Posit.	436	370	876	818
	Pixel order of Edge	435		873	
	Intersection pos. of Optic line and Horiz. Line	XEL12= 950,7576		XEL11= 1402,5862	

TABLE II. (a) AND (b): COMPUTED COORDINATES OF INTERSECTION POINTS. 2ND CASE CALIBRATION BAR OF 25 mm SLITS SIZE

(a)

Type		1st Edge			
		1st Cam		2nd Cam	
High positions	Calibrating positions	225	250	525	550
	Pixel order of Calib. Posit.	1787	1749	1317	1275
	Pixel order of Edge	1752		1280	
	Intersection pos. of Optic line and Horiz. Line	XEH11= 248,0263		XEH12= 547,0238	
Low positions	Calibrating positions	300	325	650	675
	Pixel order of Calib. Posit.	1285	1255	1755	1716
	Pixel order of Edge	1280		1752	
	Intersection pos. of Optic line and Horiz. Line	XEL12= 304,1667		XEL11= 651,9231	

(b)

Type		2st Edge			
		1st Cam		2nd Cam	
High positions	Calibrating positions	875	900	1150	1175
	Pixel order of Calib. Posit.	911	870	471	434
	Pixel order of Edge	873		435	
	Intersection pos. of Optic line and Horiz. Line	XEH11= 898,1707		XEH12= 1174,3243	
Low positions	Calibrating positions	950	975	1400	1425
	Pixel order of Calib. Posit.	436	403	876	847
	Pixel order of Edge	435		873	
	Intersection pos. of Optic line and Horiz. Line	XEL12= 950,7576		XEL11= 1402,5862	

With the chosen sheet steel of 656 mm sized, used to experiment the above method, the results on Table I: a, b, and Table II: a, b (a and b are respectively for the first and second edge) were obtained with respectively the use of 50 and 25 mm slits sized calibrating bar. Only the highest and lowest calibrating levels were considered. Results do not present a dimension approximation since edges coordinates approximation is not based on the change of calibrating levels information. Dimension is, rather, computed once. Whereas, what are approximated are positions of intersection points.

These results show that obviously the parallax error is as important as the shift of the camera optic axis is. Example: if couples of edges pixel order on Table I: a, b, are taken, as (1752, 873), with Cam.1 or (1280, 435) with Cam.2, the dimension that would be found thanks to only the first camera information would not be the same as with the second one and would be different from the real dimension too.

For the (1752, 873) that corresponds to edges pixels of Cam1, the Dimension is

$$D = (1752-873)*(1500/2048) = 643{,}798, \text{ Or:}$$

For the (1280,435) that corresponds to edges pixels of Cam2, the Dimension is

$$D = (1280-435)*(1500/2048) = 618{,}896$$

This is a normal case because of the important shift, presented above, of the corresponding cameras which were placed as near as possible from the boundaries of the measurement field for stereoscopic vision needs. Moreover, even if one of the two cameras is placed in front of the center of the field, the parallax error would remain and would concern the two sides. The dimension result would present an important error.

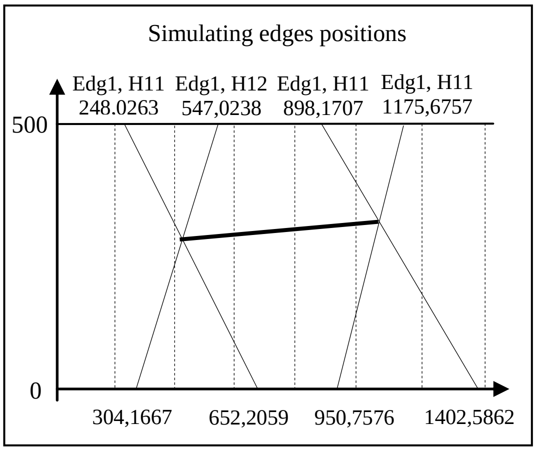

Figure 11. Edges position related to the 1st case.

For the applied method and with results shown on the above tables, pixels order indicated by each camera separately, are not directly used to find the dimension but rather combined to compute real geometric edges positions. The stereoscopic vision is based on such a method of using the simultaneous cameras acquired information. It is the means for not only minimize the mentioned error, but allows measuring the object in all its positions too, especially when it is in moving state Fig. 11.

Table II: a and b shows the importance of calibrating grid dimension. It presents information on new calibrating positions and corresponding pixels orders when using a new calibrating bar with a 25 mm slits size; which are rather narrow. Image information is then more precise what allows a better intersection points approximation, then a more accurate dimension result, as shown in Table III,

TABLE III. SHEET STEEL DIMENSION

Edges Coordinates		X	Y
Calib. Bar 50 mm	E1	434,79884	268,94859
	E2	1090,09634	309,75444
	Dim	656,56678	
Calib. Bar 25mm	E1	434,74976	268,84755
	E2	1089,51626	310,32944
	Dim	656,07920	

The above Table III, shows the cited measurement accuracy improvement, with the measurement conditions mentioned above (Section V). Considering a pixel representation (*), the first case give an error ratio of “Error/d” of 0, 77, while in the second, where error is equal to 0,079 mm, the ratio is reduced to 0, 10. What means that with the chosen 2048 points cameras to measure the object maximum size of 1500 mm and with fixed conditions, an improved calibrating operation limited the error value to approximately 1/10 of a single pixel representation (*).

VII. CONCLUSIONS

The presented work shows a method of a dimension non contact measurement. Many points of interest are taken in consideration in such an application.

However, since the work is a practical approach, the calibrating step was focused to show the importance of used tools and the care that should be taken to carry out this step.

As presented, the method is efficient to measure thin object elsewhere, with thick ones, another type of error may cause a bad edges detection due to the object thickness.

As a conclusion, the work gives ideas for camera based measurement application, describe the used method and shows how it would be possible to minimize errors in such an application or eliminate it. Then, a good dimension computing may be reached thanks to:

Adequate and relevant calibrating tool presenting rather narrow slits.

The use of different levels information to compute the dimension with the smallest mesh that contains edges positions.

The approach may, of course, be an object of other improvements by detailing the second alternative, by choosing other type of tool/method to calibrate the system or even extended for other object shape measurement. Algorithms should be, in this case, adapted consequently.

REFERENCES

[1] J. P. Gastellu, *Digital Image Processing and Acquisition*, Department of Physical Measurements, Paul Sabatier University, April 2008, ch. 1, pp. 4-37. Original French.

[2] S. G. Stanciu. (2011). *Digital Image Processing*. 1st ed. INTECHWEB.ORG. Croatia. [Online]. ch. 2. pp. 95. Available: www.intechopen.com

[3] M. Bergounioux. (February 2011). *Some Filtering Methods in Image Processing*. [Online]. hal-00512280. version 2. ch. 2. pp. 3-4. ch. 4. pp. 19-25. Available: http://www.hal.archives-ouvertes.fr

[4] H. Sahli, *Vision-Based Dimensional Measurements*, Engineering edition, R1392-2, 2011, pp. 1-7. Original French.

[5] A. Bhatti. (2012). *Current Advancements in Stereo Vision.* 1st ed. INTECHOPEN.COM. Croatia. [Online]. ch. 1. pp. 1-3. ch. 8. pp. 161-165. Available: www.intechopen.com

[6] S. Salmon, *Numerical Analysis, Research and Training Unit in Mathematics and Computer Science*, Louis Pasteur University, Strasbourg, 2005-2006, ch. 1, pp. 15-15. Original French.

[7] P. Gaotin, *Numerical Analysis*, Institute of Engineering science, South Toulon-Var University, ch. 3, pp. 18-18. Original French.

Zoheir Mentouri was born in 1966, in Algeria and Graduated from University of Annaba-Algeria. He obtained the Engineer degree in Electronics /Process control in 1990; Higher Applied Studies Degree in technical English, in 1998 from University of Annaba; Trainer in management Consulting in 2000 from the Management Higher Institute (I.S.G.A), Annaba. From 1991, he worked in laboratory of instrumentation field at the R&D unit of a steelmaking company in Annaba, then as a head of process control laboratory in the same unit he dealt with PLCs applications development for process parameters control. From 2005 he is a Researcher at the Applied Research Unit in steel and metallurgy-Algeria (Urasm) of the National Research Center in Welding and Non Destructive Testing (CSC), depending of the Ministry of Higher Education and Scientific Research, Algeria. His activities are related to measurement/Control applications as a technical field and implementation of management system according ISO17025 for testing laboratory accreditation as quality field.

Salah Bouhouche was born 1960, in Algeria and Graduated from Algerian Institute of Hydrocarbons (I.N.H) Boumerdes Algeria in 1985. In 1995 he obtained his master degree in control engineering from the Algerian Institute of Technology. In 2002, he received his Ph.D.degree maschinenbau from TUBergakademieFreiberg,Germany. In 2005, he obtained a DSC in control engineering from Algerian Institute of Technology Algiers, Algeria. From 1989, he worked in the R&D unit of a steelmaking company in Annaba. He is a senior Researcher in the field of quality and process monitoring, control and optimization of the industrial processes in the Applied Research Unit in steel and metallurgy (Urasm) of the National Research Center of Welding and Non Destructive Testing (Urasm-CSC), depending of the Ministry of Higher Education and Scientific Research Algeria

Slimane Ziani, born in 1961, in Algeria and Graduated from Algerian Institute of electricity and electronics (I.N.E.LE.C) Boumerdes -Algeria in 1987. he obtained a degree of Engineer in Electronics. From1988, he worked in the field of instrumentation, measurement and control in Research centre of steel industry, Sider company, Algeria. From 2005 he is a

Researcher in the field of quality and process monitoring, control and optimization of the industrial processes in Applied Research Unit in steel and metallurgy (Urasm) of the National Research Center in Welding and Non Destructive Testing (CSC), depending of the Ministry of Higher Education and Scientific Research Algeria

Adel Boudiaf was born in 1977 in Algeria and Graduated from University of Batna-Algeria in 2004. He obtained his Engineer degree in Electrotechnics. In 2009 he received the magister degree from University of Biskra-Algeria. From 2009 he is Researcher in the field of conditions monitoring and image processing in Applied Research Unit in steel and metallurgy (Urasm) of the National Research Center of Welding and Non Destructive Testing (CSC), depending of the Ministry of Higher Education and Scientific Research Algeria.

Samira BENCHIHEB was born in 1968 in Russia and Graduated from University of Badji Mokthar Annaba-Algeria in 1992, where she obtained a degree of Engineer in Control process. From 1992, she worked in process control field in the R&D unit of the steel industry company in Algeria. From 2005 she is a Researcher in the field of process monitoring, control and optimization of the industrial processes in the Applied Research Unit in steel and metallurgy (Urasm) of the National Research Center in Welding and Non Destructive Testing (CSC), depending of the Ministry of Higher Education and Scientific Research Algeria.