ABSTRACT:

This paper presents an effective image processing for advanced applications. It will be a big step in the forward to find out the spark mechanism in gaps. The Image processing depends on the image camera in pair distributions. The transfer matrix for the transformation from the single 3 coordinates system to double plate images is derived. The mathematical analysis is given. The proposed technique may be used for many applications either in industry or in research fields. It is based on the software with the PC principles. This concept will simplify all complex problems related. Its application to find the exact points of sparking in gaps will be exact. The ignition process for streamers inside a gap may be defined accurately through the proposed software. Other items will be similar. The paper presents also some methods concerning the calibration during image digitization to get an accurate information about surfaces or points in space. The stereo vision technique with the double human eyes system is inserted while all problems, related to image purification are treated. An automated calibration model is installed, and the mathematical constraints are developed. This leads to a high rate of accuracy. The effect of cut off level is investigated.

Keywords: Image processing, Transformation matrix, Spark mechanism, Synchronism, Three dimensional coordinates, Camera Calibration.

Introduction

During the today revolution to advance science in all branches of life, it is necessary to serve the human activity in the Universe. One of the possible use equipment appears to be the computers. The digitization of either old manual or even automated problems will be a plus point and, consequently, the accurate determination of any process can be quickly done. Thus, the complicated subject of image processing can be realized once at a high resolution so that it may be implemented to surfaces of the objects in space coordinates through computer [1].

For computer-aided design (CAD) and computer aided manufacturing (CAM), the real applications may be simple and robots especially with complex shapes.
Then, the derivation of surface coordinates in double coordinates systems such as on planes or sheets, photographs and drawings would be a clear item but for three-dimensional coordinates (3D) it will be changed into a hard problem. In this concern, the scanners and digitizers as entry concept may simplify the processing [2].

However, a CAD model would be important for the determination technology of the surfaces and points in the 3D coordinates despite the high computational effort and time required for the analysis. Sensors are commonly needed for exact measurements of surfaces or even the moved objects and it may be applied through slow motion. This will be hurt if the used mechanical system must be touched with the object. The optical technique could be fast and more accurate as well as easy without danger. Thus, a large amount of 3D points on the surface within a suitable real time may be computed and then converting them to a CAD model where an automated machine for measurements should be added [3,4].

2. Image Processing

Many active and passive optical methods of image processing to digitize objects are in wide use today. Time of flight, depth of focus, triangulation, Moiré, interferomtery and stereovision are some examples [2-5]. Stereo Vision principal is based on optical triangulation. It is always applied with charge coupled devices (CCD) cameras [5,6]. The CCD line scan cameras deliver a profile of brightness along it using an image processing software but the position of the center of the major reflection can be found even with sub-pixel accuracy [7].

Passing a laser beam through a cylindrical lens, a strip of light may be created. Early computer vision systems with a strip of light for measuring objects have been presented [8,9] where integrated systems with sensing and control units, combined in a sensor head. Measuring complete range images can be achieved by projecting a 2D Periodical Pattern and applying the Phase Shift method [10] where applications in holographic interferometery, speckle-interferometery, and Moiré techniques were given for the measurement of a displacement and a curvature deformation under stress.

Projecting light stripes onto an object and identifying them to get an absolute and a non-ambiguous information about the surface leading to their coding. The use of color for identifying the rank of binary light stripes has been proposed while the application of binary pattern was given to identify them on the correlation base if needed [1, 11].
The photogrammetry is defined as the stereo vision using double camera eye system (Active or Passive) while in active digital sensors as CCD matrix cameras are important. The processing tools are needed for solving the problems of finding and marking the corresponding points in the different camera pair [10,12]. The traditional stereo vision concept like the human eye system can be successfully implemented where the distance between them as well as their orientation must be defined. The lines in each array are called Epipolar lines so that processing formula will be directed to deduce the template matching, single and 2D correlation or even coarse to fine matching for common features in each Epipolar lines.

The multi camera system was introduced as a generalized way for exact imaging with a pre-information about internal parameters of the optical means at the processor for absolute facility although the computational time will be increased. For CAD-CAM applications the problems of calibration, feature extraction, correspondence should be treated [10,11,12].

The previous work using the CCD cameras was dealing primary with static objects with the ability of several subsequent snap-shots. As an extension to this work to efficiently dealing with dynamic object the proposed work will be based on the video camera pairs instead. All pairs are controlled and synchronized by a host computer.

3. Experimental

The determination of exact coordinates of a moving point appears to be very difficult for some applications while this analysis will be more difficult in the space 3D coordinates. For example it could be implemented in the field of sparking processing. The image for an electric discharge inside a gap can be recorded by any camera, for instant. Thereafter, high speed camera has been introduced to get a plate picture while the exact coordinates for the initial ignition in the spark mechanism may need more investigations. So, the accurate determination for the Flashover on the surfaces of Insulators in electric networks may clarify this process and consequently an improved performance can be achieved [13, 14]. For this purpose, a vision system with an image processing hardware was developed. Eight Digital video cameras, expendable in even number, were installed in four pairs. Each camera pair is connected to PC that can accept images from the two cameras simultaneously. The four PCs (Intel-Pentium II-450/512 processors, 128-MB RAM and 8 GB Hard Disks) are connected to a Fast Ethernet Hub (100 Mb/s). A host (master) computer is also
connected to the same LAN. The host computer was a PC with Dual Intel-Pentium-550/512 processors and 256-MB RAM and two SCSI Hard Disks 9.1 GB Each. An analog monitor is also used to display the image with software switching control between the images. The Following Figure 1 shows a block diagram for

![Figure 1. The Processing System](image)

the constructed system.

4. Mathematical Analysis

The mathematical formulation depends on the transformation technique where 3D point \((x, y, z)\) will be transformed into two plane double coordinates points \((u, v)\) for each camera. The relation between points for each camera will be controlled by the transformation matrix 'T' which will be defined as:

\[
\begin{bmatrix}
  t_{11} & t_{12} & t_{13} \\
  t_{21} & t_{22} & t_{23} \\
  t_{31} & t_{32} & t_{33} \\
  t_{41} & t_{42} & t_{43}
\end{bmatrix}
\]

\[
\begin{bmatrix}
w_u \\
w_v \\
w
\end{bmatrix}_h = \begin{bmatrix}
x \\
y \\
z \\
1
\end{bmatrix}_h
\]
Where u, v are the 2D image coordinates and w is ……………?…… . Also, the elements (t_{11}, t_{12}, ... t_{43}) of the matrix are a function of experimental installation as given in Figure 1. The symbol h means ………?……….

Multiplying the vector of the object point with the transformation matrix and inserting the third equation into the first and second equations as a substitution yield:

\[(t_{13}x + t_{23}y + t_{33}z + t_{43}) u = t_{11}x + t_{21}y + t_{31}z + t_{41}\]  \(2\)

\[(t_{13}x + t_{23}y + t_{33}z + t_{43}) v = t_{12}x + t_{22}y + t_{32}z + t_{42}\]

Rearranging the two equations of (2), we get:

\[xt_{11} + yt_{21} + zt_{31}z + 1t_{41} + 0t_{12} + 0t_{22} + 0t_{32} + 0t_{42} - uxt_{13} - uyt_{23} - uzt_{33} - ut_{43} = 0\]  \(3\)

\[0t_{11} + 0t_{21} + 0t_{31}z + 0t_{41} + xt_{12} + yt_{22} + zt_{32} + 1t_{42} - vxt_{13} - vyt_{23} - vzt_{33} - vt_{43} = 0\]

With the coordinates of 6 non-coplanar points, 12 equations with 12 unknowns will be deduced in the form:

\[At = 0\]  \(4\)

Where A is a square matrix with its parameters are functions of x, y, z, u and v while t_{ij} are the coefficients of the transfer matrix T.

Setting \(t_{4,3} = 1\) and rearranging the equation and multiplying both sides by the transpose \(A^T\) of matrix A from both sides, and then the so-called 'normal equation' can be formulated by:

\[(A^TA) t = (A^T b)\]  \(5\)

where b is a scalar vector.
The camera pair would be named as right and left to produce pictures which must be called right and left, respectively. Considering the transformation equations of the left- and right-hand images and computing the matrix products, the single group of four equations can be simplified as:

$$\begin{align*}
(t_{L11} - t_{L13} u_L)_x + (t_{L21} - t_{L23} u_L)_y + (t_{L31} - t_{L33} u_L)_z &= t_{L43} u_L - t_{L41} \\
(t_{L12} - t_{L13} v_L)_x + (t_{L22} - t_{L23} v_L)_y + (t_{L32} - t_{L33} v_L)_z &= t_{L43} v_L - t_{L42} \\
(t_{R11} - t_{R13} u_R)_x + (t_{R21} - t_{R23} u_R)_y + (t_{R31} - t_{R33} u_R)_z &= t_{R43} u_R - t_{R41} \\
(t_{R12} - t_{R13} v_R)_x + (t_{R22} - t_{R23} v_R)_y + (t_{R32} - t_{R33} v_R)_z &= t_{R43} v_R - t_{R42}
\end{align*}$$

where the symbols R and L indicate the image of the right and left, respectively.

If the coordinates of two corresponding points and the transformation parameters \( t_{Lij} \) and \( t_{Rij} \) are known, the object world coordinates \((x, y, z)\) will be the only unknowns so that four equations with three unknowns would be obtained.

These above equations may be generalized in the matrix form as:

$$\begin{pmatrix}
X
\end{pmatrix} = \begin{pmatrix}
b
\end{pmatrix}$$

This may be rewritten in the form of elemental matrices in the form:

$$\begin{pmatrix}
I_{L11} - t_{L13} u_L & I_{L21} - t_{L23} u_L & I_{L31} - t_{L33} u_L \\
I_{L12} - t_{L13} v_L & I_{L22} - t_{L23} v_L & I_{L32} - t_{L33} v_L \\
I_{R11} - t_{R13} u_R & I_{R21} - t_{R23} u_R & I_{R31} - t_{R33} u_R \\
I_{R12} - t_{R13} v_R & I_{R22} - t_{R23} v_R & I_{R32} - t_{R33} v_R
\end{pmatrix} \begin{pmatrix}
x \\
y \\
z
\end{pmatrix} = \begin{pmatrix}
I_{L43} u_L - I_{L41} \\
I_{L43} v_L - I_{L42} \\
I_{R43} u_R - I_{R41} \\
I_{R43} v_R - I_{R42}
\end{pmatrix}$$

The normal equation may be deduced as shown before in the form:

$$A^T A X = A^T b$$

5- **System Flow Chart**

As described before (See Fig. 1), each camera pair is connected to a computer, specified only to this pair. The transformation matrices for the two cameras are loaded in the computer memory. Changing the position of any of the two cameras must be followed by the transformation matrix correlation concerning this
camera. The host computer sends signals to all PCs to take snapshots (all at the same time). Each PC is responsible of preparing its camera pair images. After detecting the edge points for the left and right cameras, the corresponding points should be calculated and then it must be used to deduce the 3D real coordinates and then pass them to the host PC.

The host will merge all coordinates and remove redundancy and consequently it will adapt the 3D coordinates for use by the spark analyzer. Figures 2 and 3 show the flow chart for the all process. Fig. 2 explains the synchronizing concept for image processes to get all images at the same instant. It is based on the control host computer which must check this condition every time. On the other hand, Fig. 3 indicates the importance of each PC, specified for each camera pair. In this procedure the calibration steps are included to determine the transformation matrix for each camera. The purification of the digital developed image is considered and it is normalized. This process includes the detection for edge points.
Start

Send a synchronized signal to all PCs to get snapshots

Wait for the 3D Coordinates from any PC

Save the coordinates in a proper form.

Did all PCs send their 3D Coordinates

Yes

Merge all calculated 3-D Image Coordinates from all Pairs and remove Redundant Points

Adapt the 3-D Coordinates for later uses

Stop

Figure 2: The Host PC Process Flow Chart
Capture Images from both Cameras

Detect all the Edge Points for Each Camera

Determine the Corresponding Points for the Left and Right Images

Use the calculated Corresponding Points to calculate the 3-D Image Coordinates

Send the 3D Coordinates to the Host PC

Start

Does any Camera position changed

No

Load the Transfer Matrices for all Camera-Pairs

Yes

Call the Calibration Procedure and calculate the Transfer Matrices for the Camera Pair and save them

Figure 3: The Flow Chart for slave PCs Process
6. Spark Mechanism

The operation of a network depends mainly on both the current carrying capacity of each element and its insulation level. The current may be controlled by breakers and the protective gear in stations. This can be achieved by dispatching centers but the insulation level differs. It means that the insulation may be broken down completely or a flashover on the insulation strings of overhead lines may be occurred. This will take a repeated character in the wetted area or that with fog phenomena. This would cause a sudden switching some parts in the network in spite of the changeable style if it has a temporary type [14].

Therefore, the operation of a network can be subjected to abnormal conditions due to false flashover on the surface of insulation strings or by complete failure of electric insulation of coils inside transformers and alternators or for other equipment. This may clarify the importance of exact determination for the phenomena of sparking specially, that related with temporary character such as flashover on transmission lines. The most important point will be the ignition starting mechanism while the spark mechanism would take the general form of the problem.

All works have been published related to the sequence of pictures for the gap spark while the determination of electromagnetic performance has been mathematically derived and plotted. In the present work, the problem will be studied based on advanced technology of computer applications. The accurate evaluation can be accounted by the transformation of images into digital analysis as well as each exact space image will be transferred into double surface digital images with the help of the transformation matrix technique. The given above flowchart is suitable for such application. A typical Transfer Matrix for an experimental installation is as follows:

\[
T_{i,K} = \begin{bmatrix}
-0.07 & -0.65 & -0.01 \\
-0.09 & -0.38 & -0.02 \\
0.36 & 0.60 & 0.01 \\
10.85 & 33.37 & 1.00
\end{bmatrix}
\]
The analyzed method may be implemented for many experiments such as the non-uniform gaps (Figure 4) where the high voltage is applied to a point (needle) and so the surface must be earthed. This introduces a non-homogeneous field inside the gap but the exact determination for the streamer growth (spark mechanism) is always a hard-complex process. The proposed concept simplifies this determination not only in 2D coordinates as before but also in the 3D coordinates according to an accurate manner. The ignition starting process would be easy registered without any error according to the above mathematical analysis.

The subject of calibration may be appeared as an important item for exact results so that its study would be analyzed and explained below.

7. Calibration

The measurement process of any physical dimensions for an object requires a calibration relative to the standard values where its description is usually given by diagrams or look-up-tables. This procedure can be stored individually for each measuring sensor through the operations of filing. The image processing needs such a calibrating three-dimensional (3D) system when the digitizers will have a multiplication unit as well as a sensor head. The analytical principle is a target for simplicity when a complex system is concerned.

Therefore, the coefficients of a calibration model under the automation consideration must be deduced initially before processing applications and consequently, a non-skilled operator will be able to calibrate through a small quantity of information [4]. This information may be images by camera or sometimes a mathematical knowledge. It could be more difficult when the work is implemented for objects (not plane) as a model must be based for such purpose.
Thus, the calibration body should be installed for exact results through the camera-pairs which will become a difficult way with stereo vision due to the non-coplanar points of calibration. Otherwise, this is related to the automated system of imaging, depending on the double camera system as the human eyes, as one will be the right (R) and the other is the left (L).

7.1. Model

With the previously presented hardware had been constructed and the show algorithms had been developed (C language), the calibration model (white top pins with black background) is illustrated through their projection as shown in Figure 5 in order to find transformation matrix elements for each eye ([T]_L,[T]_R) automatically to raise the accuracy of measurement according to the constraints (Figure 5) [6]:

\[
\{x, y\}_i < \{x, y\}_{i+1} < \{x, y\}_{i+2} < \{x, y\}_{i+3}
\]

where \(x_i\) and \(y_i\) are images of a point \(i\) in \(x, y\) coordinates, \((i = 1, 5, 9)\) but for \(x_i < x_j < x_{i+1}\), then \(y_j\) must be < \(y_i\).

If these constraints are considered the calibration will be completely correct but if they are not, a test algorithm would be necessary for check and to ensure that the calibration results are correct. This may be created in 3 cases as: firstly, when the number of points (Figure 5) is small with low light intensity for imaging, although secondly, for large number of points but with high illumination. Thirdly, if the number of points is suitable but there is no matching to constraints [13].
However, these conditions can be controlled by adjusting the number of points and light intensity while the model plate should be rotated slowly in one direction for multi readings correction. Then, a dark room for calibration is built at site with the possibility of rotation of the model although the camera set must be in the place without movement. This helps the automatically definition for image coordinates in both cameras whenever the high accuracy reached (less than 0.4 mm) at reduced time (15 s) for both images, scanning and generating the two transformation matrices.

This depends on converting the image into a binary shape [1] through a suitable dynamic threshold as the origin is taken at the bottom of left edge. This conversion helps only as a guide to allocate the first point of calibration in the image and so, this point will be needed to get the center point \((x_c, y_c)\). Three different approaches are used for this calculation [7,10]. Nevertheless, the binary image usually contains a little information where the algorithm, used for detection of the center point for the calibration procedure, may be implemented to find the middle points in both x and y coordinates depending on the first approach by:

\[
(x_c, y_c) = \left\{ \frac{(x_R + x_L)}{2}, \frac{(y_R + y_L)}{2} \right\}
\]

### 7.2. Cutoff level

The above results of equation (10) may include impurities because of either any distortion or the high intensity so that the second method would be introduced on the basis of the resulted approximated center for the detection of the original image. It can be considered as a generalization for the first one where this center will be accounted as the point of high intensity (I). If there are many points fulfilled for such a condition, their center should be obtained to continue the process according to the equation:

\[
(x_c, y_c) = \left\{ \frac{(x_R + x_L)_{\text{max}}}{2}, \frac{(y_R + y_L)_{\text{max}}}{2} \right\}
\]

Thus, in the third method (based on the center of gravity) will be deduced to reduce the effect of any noise or extreme illuminations leading to an exact values as a function of the relative coordinates \((ij)\) and light intensity. Then, the number of high intensity pixels (a typical number of 10-400 pixels) belong to pins (Figure 5) inside the typical test window will be introduced for operation raising highly the computational effort and time. The concept of cut off should be applied to
minimize this appeared phenomenon as shown in Figure 6 for the case of cut off leveling.

![Figure 6: Cut-off use](image1)

![Figure 7: Low pass filter](image2)

On the other side, Fig. 7 presents the effect of filtering relative to the condition without it. This removes noise and non-adjusted light and consequently the low pass filters treat the high frequency components. This leads to a more accurate value for the aimed center of gravity. Although the third approach (center of gravity) consumes more time, the deduced results are normally accurate.

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | 50 | 50 | 50 | 50 | 50 | 51 | 51 | 52 | 52 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 52 | 52 | 52 |
| 2 | 50 | 50 | 51 | 51 | 51 | 51 | 52 | 52 | 53 | 53 | 53 | 53 | 52 | 52 | 52 | 52 | 51 | 51 | 51 |
| 3 | 50 | 51 | 51 | 51 | 51 | 51 | 52 | 52 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 52 | 52 | 51 | 51 |
| 4 | 51 | 51 | 51 | 51 | 51 | 51 | 52 | 52 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 52 | 52 | 51 |
| 5 | 51 | 51 | 51 | 51 | 52 | 52 | 52 | 53 | 55 | 57 | 58 | 59 | 58 | 57 | 55 | 53 | 52 | 51 | 51 |
| 6 | 51 | 51 | 51 | 51 | 52 | 53 | 55 | 59 | 63 | 65 | 66 | 64 | 61 | 57 | 54 | 52 | 51 | 51 | 50 |
| 7 | 51 | 51 | 51 | 52 | 54 | 58 | 64 | 69 | 73 | 51 | 70 | 64 | 59 | 55 | 52 | 51 | 51 | 50 | 50 |
| 8 | 51 | 51 | 51 | 52 | 52 | 52 | 55 | 61 | 68 | 78 | 81 | 81 | 76 | 69 | 62 | 56 | 53 | 51 | 50 |
| 9 | 51 | 51 | 51 | 52 | 52 | 52 | 53 | 56 | 64 | 75 | 85 | 91 | 91 | 85 | 75 | 65 | 58 | 54 | 52 |
| 10 | 51 | 51 | 52 | 53 | 54 | 58 | 67 | 80 | 92 | 99 | 99 | 92 | 80 | 68 | 59 | 54 | 52 | 50 | 50 |
| 11 | 51 | 51 | 52 | 52 | 54 | 59 | 69 | 84 | 98 | 106 | 108 | 100 | 87 | 73 | 62 | 56 | 52 | 51 | 50 |
| 12 | 51 | 51 | 51 | 52 | 54 | 60 | 72 | 89 | 106 | 112 | 113 | 98 | 81 | 68 | 59 | 52 | 52 | 50 | 50 |
| 13 | 51 | 51 | 52 | 52 | 54 | 60 | 72 | 91 | 110 | 123 | 127 | 120 | 104 | 86 | 71 | 60 | 55 | 52 | 50 |
| 14 | 51 | 51 | 52 | 52 | 54 | 59 | 70 | 86 | 102 | 114 | 118 | 112 | 98 | 83 | 69 | 60 | 64 | 52 | 50 |
| 15 | 51 | 52 | 52 | 52 | 54 | 58 | 66 | 79 | 91 | 101 | 105 | 101 | 90 | 78 | 67 | 58 | 55 | 52 | 51 |
| 16 | 52 | 52 | 52 | 53 | 54 | 57 | 63 | 71 | 80 | 87 | 90 | 87 | 80 | 71 | 63 | 57 | 53 | 52 | 51 |
| 17 | 52 | 52 | 52 | 53 | 53 | 57 | 61 | 65 | 69 | 70 | 69 | 65 | 61 | 57 | 54 | 53 | 52 | 51 | 51 |
| 18 | 51 | 52 | 52 | 53 | 53 | 54 | 55 | 55 | 56 | 56 | 56 | 56 | 55 | 54 | 53 | 53 | 53 | 53 |
| 19 | 51 | 51 | 52 | 52 | 53 | 54 | 54 | 55 | 55 | 55 | 55 | 55 | 55 | 54 | 54 | 54 | 54 | 54 |
| 20 | 50 | 51 | 51 | 52 | 52 | 53 | 54 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
Three different concepts (without-, with-, fixed, and dynamic cutoff) are included although the center of gravity is always shifted to the center of the computation window in the first concept. This is appeared because of the illumination difference on the value required. The dynamic method is applied through four different means: the first is based on the maximum left top point but the second considers the lowest intensity illumination.

Contrary, the third one takes the highest illuminated point, and the last uses the average of the intensity values inside the specified window. Typical values of intensity are shown in Table 1 during one of the experiments done where all given methods would be sequentially introduced for high accuracy. This application is given in Figure 8 during cut off selection for calibration [2].

Figure 8: Cutoff Selection Methods

Figure 9: Offset of Cutoff
Whatever, in first two method the computed center of gravity will be shifted to the center of image window for small values but for zero value in the second approach the case will be the same as without cut off consideration. Moreover, with high values, a good accurate calculation must be appeared. Inversely, the third concept where the offset value is subtracted from the value of highest intensity leads to a good measurement. The results of experiment are shown in Fig. 9 where a minimum offset value is deduced. This means that the computations reach the maximum accuracy.

An algorithm is developed to verify the pre-specified error according to the calculated coordinates of tested points in the model. It depends on the feedback principle as it can remove the noise and the problems of illumination.

This is reflected to the resolution of measuring device, 400-800 pixel as a standard, and the computed coordinates are integer opposite to the real case causing a difference. Thus, the process can be controlled, and the computational time will be reduced.

8. Accuracy

Both accuracy and speed are the most important factors in the process of image recognition because they reflect the system characteristic replying the real time needs. The accuracy depends mainly on the sensor head (camera pair) while the mean error of the calibration model can be obtained during the calibration operation. Results present a mean error of 0.2 pixel per image (0.04 mm in 3D coordinates). A comparison data between methods and different systems is tabulated in Table 2 from the point of view fundamental specification.

The grid may be scaled with 0.1 mm division and an area of 0.01 square mm. Using the sensor head with a pixel size of 28 by 28 microns in space, approximately 12-13 single measurement points correspond to one discrete surface point. Whatever with in-correlated measurements, a reduction of noise leads to accuracy reaches 10 - 12 microns.

On the other hand, speed analysis at 450 MHz is applied to a calibration at about 5-10 seconds. This process will be affected if the ambient temperature is highly varied. The proposed system is compared with others in the final simple form (as given in Table 3) where the advantage of the suggested concept is clear.

In this Table the numbers 1, 2, 3, 4, 5 and 6 mean the trademarks of: Transfer Center, Moiré sensors of EOS, digitizer of Dr. Breukmann, laser scanner of Energetic, laser scanner of 3D scanners and the proposed concept, respectively.

Table 3 Comparison between different Systems
The results of Table 3 prove that the proposed system is an accurate and robust as well as the time required is reduced completely so that it can be recommended for wide applications in industry, military and medicine fields. For example, the digitization of a human foot model with an automated sequence of 8 images, 4 pairs of cameras, from different points with about 800000 measurement points takes about 40 seconds. This also prove the same conclusion, that has been derived.

Table 3: Comparison between different Systems

<table>
<thead>
<tr>
<th>Sensor System</th>
<th>Opto-Shape1</th>
<th>EOSCAN2</th>
<th>Opto-CAM3</th>
<th>Hyscan4</th>
<th>Replica5</th>
<th>Displace. Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (Pixel)</td>
<td>700 x 512</td>
<td>768 x 512</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>768 x 512</td>
</tr>
<tr>
<td>Field of View (millimeters)</td>
<td>20 x 14</td>
<td>120 x 80</td>
<td>150 x 120</td>
<td>90</td>
<td>50</td>
<td>300 x 300</td>
</tr>
<tr>
<td>Accuracy (microns)</td>
<td>±10</td>
<td>±100</td>
<td>±60</td>
<td>±125</td>
<td>±125</td>
<td>±50</td>
</tr>
<tr>
<td>Range in z (millimeters)</td>
<td>20</td>
<td>30</td>
<td>100</td>
<td>100</td>
<td>1000</td>
<td>200</td>
</tr>
<tr>
<td>Dimensions (millimeters)</td>
<td>160</td>
<td>100</td>
<td>300</td>
<td>260</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>100</td>
<td>120</td>
<td>112</td>
<td>120</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>33</td>
<td>100</td>
<td>86</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>Weight (grams)</td>
<td>1800</td>
<td>600</td>
<td>1500</td>
<td>2250</td>
<td>600</td>
<td>750</td>
</tr>
<tr>
<td>Speed (pt./sec.)</td>
<td>3000</td>
<td>N/A</td>
<td>N/A</td>
<td>10000</td>
<td>&gt;5000</td>
<td>6000</td>
</tr>
<tr>
<td>Price (1000 US $)</td>
<td>60</td>
<td>30</td>
<td>23</td>
<td>30</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>Number of axes (rotation-linear)</td>
<td>2+2</td>
<td>3+2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Merging of multiple range image</td>
<td>yes</td>
<td>Only on CAD sys.</td>
<td>Only on CAD sys.</td>
<td>--</td>
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<td>Yes</td>
</tr>
<tr>
<td>Automated and integrated calibration</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>Yes</td>
</tr>
</tbody>
</table>
9- Advanced Measurement

Since the initiation process for the spark mechanism has not been determined, it will be very important to reach to the real computer concept for such a point. This means that the cinema (high speed) camera could not give the actual picture for the spark in the gaps. Consequently, the computer facility would overcome on such a problem. So, the sequence of digital images for each camera pair at a time \( t_i \) (i=1, 2, …), can be recorded for any instant of time \( i \) while the next image of time \( t_{i+1} \), (i=1, 2, …), would be received. Then, the difference between both sequential images for each pair may develop a new important image, which can be named as \( X \) per each, \( (X =1, 2, ...) \). The new images \( X \) for each pair represent the traveling front of a spark inside the gap as generated in the space coordinates in arranged sequence. Also, the back ionization may be occurred so that a back ionization can be developed in the same process. The process of forward ionization will be traveled, and it will be very easy to record such a phenomenon. The new sequence of images for the traveling front can be then displayed with a definite accurate coordinate \((x, y, z)\). Therefore, the obtained traveling spark point, generated in the gap, will be developed accurately. This concept may be treated according to the flow chart of Fig. 10. The new deduced advanced images could not be determined before as all published works have determined such a process only as a picture or series of them through a high-speed camera. The proposed technique covers this lake point since it gives the facility to see the exact
traveling point of arc (spark front) across the gap in the 3D coordinates. It should be noted that a back ionization may appear during the process if the spark point is disappeared (or even if the ionization is stopped for a moment). These images can be excluded from the front one as a new type for display with accurate and complete information about them. Thus, we have three types of image story with accurate determination in 3D coordinates. The first is the spark time characteristic imaging. This type generates both second (traveling front imaging) and third (back ionization performance) types. The flow chart of Fig. 10 treats such a classification to find all the three types indicating the sequence of isolation for the second and third types from the first one.

10. Conclusion

1- The Central host computer controls the synchronism process for correct corresponding images for the same instant.

2- The proposed software simplifies the process of imaging for exact determination of spark in long gaps.

3- The ignition starting process can be exactly deduced in space coordinates (x, y, z).

4- The streamer development as a spark mechanism may be defined accurately with the help of the suggested method.

5- Simple and accurate calibration procedure model for stereo vision can be integrated with the practical techniques to reduce the computational time and effort.

6- The separation between forward and backward inside the ionization process in gaps or internally in insulating materials or even along the surface of insulators can be automatically displayed individually.

11. References


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