OBTAINING THREE DIMENSIONAL POINT CLOUDS FROM THE DIGITAL IMAGES OF RECTANGULAR PRISM SHAPED OBJECTS

Gürcan Samtaş[1], Mahmut Gülesin[2]

ABSTRACT

The processes applied on the pixels by the image processing methods provide us information about images. Image processing is a computer programming area which can be used in computer integrated industrial applications and it is one of the research areas of reverse engineering. In this study, a new system in which color digital images are interpreted by using image processing method was developed. The purpose of this study is to improve a system to interpret the images, which are taken with a hand camcorder or digital camera, and to obtain point clouds by evaluating with image processing and to convert these point clouds surface or solid model in a computer aided design program. In accordance with these purposes, the three dimensional point clouds are obtained from a rectangular prism shaped object in the specified area. These point clouds can easily be converted into three dimensional solid or surface models in a Computer Aided Design (CAD) program. In this reverse engineering study, the developed system is explained and sample parts are given.

Keywords: Reverse engineering (RE); 3D point cloud; image processing; pixel detection.

Introduction

The main objective in the image processing is to obtain geometrical information of an object, to improve or enhance the image quality. If the raw image is not clear enough it may be subjected to a sequence of processes for the required purpose. When the processes are carried out in the electronic medium or mostly by human, optical and electronic devices are needed for the obtaining of the image. When the digital image processing is applied according to the purpose of usage it has numerous advantages in terms of speed, low cost and reaching to the desired aim. Issues like the diversity of the input data which will be used in the processing of digital images, the obtaining of the information from the processed data dealing with the purpose and application of this information correctly, have become important research fields nowadays. The goal of this work is to obtain point clouds from color images which include prism shaped objects.

Literature review

In the interpretation of the object images, in the obtaining of Computer Aided Design (CAD) models of objects by the use of auxiliaries like grid pattern or object marker and in the obtaining of 3D motion parameters with the video cameras connected to a computer, special shooting media environment are used. In the reconstruction works, especially made for saving the architectural constructions, only the three dimensional (3D) models of front regions of objects can be obtained. A number of studies that have been conducted on image processing to develop and different techniques and algorithms comprise; object recognition, camera calibration, 3D reconstruction. Benlamri and Almarzoogi (Benlamri and Almarzoogi, 2004), in their study, described the depiction and 3D shaping techniques of recorded colored, serial and free-looking objects. With this approach, unified edge zone information, with the usage of algebraic closed surfaces, surface descriptions were obtained. In another study, Byne and Anderson (Byne and Anderson, 1998) developed a CAD based computer observing system. 3D geometric models of 3D objects which were defined in 2D objects were obtained through a widely used computer-aided package. Reed and Allen (Reed and Allen, 1999) presented a method for the solid model structuring from the consecutive images of an unknown object. Solid model description was realized by using the models containing the sequence data of each image on the net surface. Kimber and Blotter (Kimber and Blotter, 2006) designed a method for the determination of different external lines between digital and physical objects with squared interference meter. This method is an out of plane shifting measurement technique. A light source and the grid pattern in front of this source is reflected to a test piece through a lens. By using a camera connected to computer and with the grid pattern image CAD model is obtained. Hua and Weiyu (Hua and Weiyu, 2004) presented

[1] Yrd. Doç. Dr., Düzce Üniversitesi, Cumayeri MYO, gurcansamtas@duzce.edu.tr

[2] Prof. Dr., Gazi Üniversitesi, Teknoloji Fakültesi, gulesin@gazi.edu.tr

a new approach in the picture based realistic architectural modeling containing 3D library. With the presented model 1024x768, 24 byte digital pictures with “bmp” extension were used. In the developed system, a realistic modeling has been performed by forming a 3D model library.

Lee et al. (Lee et al., 2001), in their study, developed a model for modeling 3D face from the images of external line based general model and perspective images. In this study which was made in the field of virtual reality the 3D human head model was aimed to obtain in accordance with the real one. In the study an effective method was developed to obtain 3D images by taking the images of a human from different angles. Tubic et al. (Tubic et al., 2004), in their study, developed a 3D face modeling system from curves. In the method, the exposure of each individual curve of the free objects was used. Zhou (Zhou, 1997) used the primitive identification method employing model matching comment ratio in the computer aided design and line photometry measurement systems. The approach of the study comprises the comment angle, graph angle and model matching. Sturm et al. (Sturm et al., 2005), tried to estimate focal length of the camera from two pictures taken from the camera when the focal length was constant during the camera movement. In this approach Kruppa equations were used. Boufama and Habed (Boufama and Habed, 2004) carried out 3D reconfiguration computing without using calibration. The image of the 3D euclid structure was obtained without referring to the exact estimation of the main parameters. By the simplification of Kruppa equations three stepped procedure was applied and the problem was solved. Dornakai and Chung (Dornakai and Chung, 2001) brought an algebraic approach to the camera automatic calibration. New limitations were brought relating to the rotating part of the movements and the interior parameters of the camera by using single camera. Mülayim, Yılmaz and Atalay (Mülayim et al.,2003) realized silhouette based 3D model structure from the multiple images. In the study, at the image media with proper lighting the reconstruction of 3D graphical models of real objects was made. Grossmann, Ortin and Santos (Grossmann et al.,2001) developed algebraic ratios for the 3D reconfiguration of image structures which have one or more appearances. Generally in this study, 3D configuration was realized from the 2-dimensional (2D) points of the pictures having one or more appearances. Gaspar et al. (Gaspar et al., 2001) proposed a new procedure for the 3D reconstruction of structural media by reconstruction of interactive multi-directional image. This procedure is based on the reduction of the user information. Fruch and Zakhor (Fruch and Zakhor, 2001) developed model for cities using 3D aerial photographs and surface level laser beams. In this study they described techniques for 3D and obtained 3D models of urban areas using catching devices like 2D laser beam scanner and intensity cameras. In the formation of the 3D modeling of cities, there are a lot of approaches. In one example the objects on the images which were obtained through satellite or antenna are being fixed by stereo vision or synthetic aperture radar algorithms. In this approach, although the objects can be obtained rapidly, the resolution of models and the accuracy rates are very low (Frere et al., 1998; Huertas et al., 1999). In another system which was constructed by mounting laser beam and cameras on a robot, plenty of time is needed to get the data of the whole city and the reliability of this kind of portable systems in outdoors is weak (Stamos and Allen, 2000; Thrun and Burgard, 2000). Bleser, Pastarmov and Stricker (Bleser et al., 2005), in their studies, they proposed real-time 3D camera solution for the real applications increased in the industrial areas. With this solution, environment engineering like posing, observation systems and ground markers which are used in the similar applications are not needed. This kind of studies introduces new approaches in the fields like repairing machinery, design, medicine and cultural heritage (Bleser et al., 2005; Azuma, 1995; Bockholt et al. 2003; Wesarg et al., 2004). Song and Wang (Song and Wang, 2006) developed a new method of grid calibration for the 3D reconstruction. The automatically 3D construction of surfaces has become the research subject of linear photometry for many years. Photometry, nowadays is applied both in computer vision and in computer graphics fields like industrial control and reverse engineering (Xie et al., 2005; Song et al., 2005). Reconstruction of 3D models comprises four main steps; data catching, recording, surface integration and texture map. Partially formed 3D figures and texture information are obtained from different point of views (Song et al., 2005). Saha (Saha, 2005) realized a study on computer vision and image processing applications with local structure science parameters. Computer vision, understanding of image, number of incremental image, image quality, an object perception in an image are effective research areas (Witkin, 1983; Lindeberg, 1990). Barbero and Ureta (Barbero and Ureta, 2011) compared five digitization techniques in the field of Reverse Engineering for the quality of the distribution of points and triangular meshes: 1. An ordered point cloud obtained with a laser incorporated in a CMM; 2. A disordered point cloud obtained with a manual laser, the position of which is determined with a Krypton Camera; 3. An ExaScan manual laser with targets; 4. An ordered point cloud obtained by high precision

Computerized Tomography (CT); 5. An atos fringe projection scanner with targets. Zhao and Li (Zhao and Li, 2005) developed a 3D object pose estimation method for an automated manufacturing assembly process. Their experimental results show that the 3D pose estimation method produces accurate geometrical information for an automated material handling application. Bosche (Bosche, 2010) presented a new approach for automated recognition of project 3D Computer-Aided Design (CAD) model objects in large laser scans. Test results were given with data obtained from the erection of an industrial building’s steel structure. Yang et al. (Yang et al. , 2011), in their study, presented a fast and precise 3D laser scanner to retrieve point cloud data and then import the data into Rapid Form XOR2, an application used in reverse engineering, to process point cloud data and construct 3D models. Their study results were converted from 3D models into 2D pictures by parameterization software Pro/ENGINEER to provide designers precise and realistic dimensional data, which efficiently reduced time in cartography and increased historic building dimension precision during digitalization.

In this study, a system has been developed to obtain point cloud through processing images taken by a web camera, video camera or a digital camera. The system was formed by using NET programming infrastructure and PHP coding language. Graphical aid was provided by the library infrastructure of NET programming language and a rapid processing of images was made by using temporary folders with PHP coding language and its virtual server. In the first developed module the images taken from the rectangular-prismatic pieces are processed and evaluated. The object from which point cloud will be obtained is specified with reference points by the user on the images taken to the system. Then, the area which is specified with respect to reference points is processed according to color values and 3D point cloud of the object is obtained.

Analyzing of The Image

The objects from which point cloud will be obtained are in the rectangular –prismatic shape and the images of these objects were obtained in natural media without using a special shooting environment. In the developed system; “bmp” (bitmap) format images taken by a digital camcorder in avi (audio video interleave) format video images and “bmp” or “avi” format images taken by a camera can be processed. When looking at the general operational structure of the program, the file format of the images which are processed during obtaining of point cloud is “bmp”. Video images of any object are taken into the system and can be converted into pictures in “bmp” format through dividing into frames by the developed program. The horizontal and vertical resolution of “bmp” format images is 96 dpi (dot per inch) and the byte depth is 24. In the obtaining of pixel values on the images RGB (red, green, blue) color system was used. Red, green and blue color values must be mixed in certain proportions for the formation of a color in RGB standards. Every single color of the RGB color value takes maximum 256 value. A total of 16,777,216 colors are formed from the combination of three colors (256x256x256). These colors are expressed as real colors. As an example, a pixel, in the binary system, having 178, 229, 41 colors is expressed as (10110010, 11100101, 00101001).

The pixels on the image which are processed in the system are scanned with respect to the color values. During this scanning the pixels of the object are obtained according to the specified color values, and then converted into binary coding language and without distinction side by side they are kept in the file temporarily in 0 and 1 format. When the colors are scanned pixel by pixel, RGB color values which are between +12 or -12 are accepted as the same. For example, if the first pixel scanned in the specified reference area has a color value of (235, 39, 84), for the next pixels the pixel color values up to (223, 27, 72) values are accepted as the same (Fig.1).

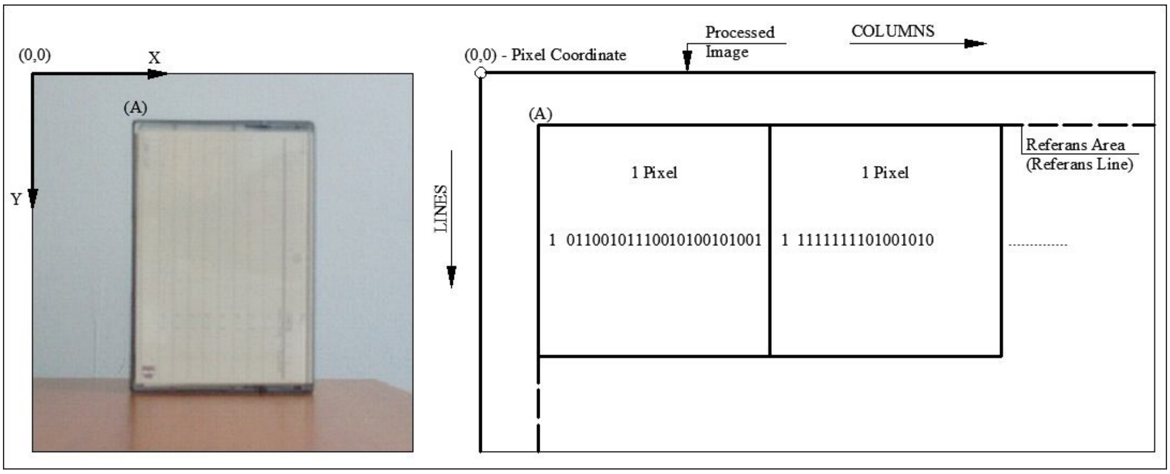

Fig.1. Color analysis applied to an image

When the scanning is made in the specified reference area from left to right, if a contradictory value in the colors is encountered, a new color scale selection is carried out for that color value. For each color value of RGB colors, when the value is less or more than the specified interval it is assumed as a different color and therefore a new color scale is determined for the new color. Since the pixel determination is done with color analysis pixels can be evaluated without applying other processes to the images.

Obtaining Point Clouds

The color scanning provides the obtaining of pixels directly. The determined pixels in the developed program are kept in two separate files as the pixels which were obtained at the front view of the target object and at the edge view of the target object. These pixels are used for point detection in the obtaining of coordinates. Each value of the pixels that are specified by the color analysis is converted to numerical value on the screen and transformed to spatial coordinates. When the images are processed, the top left corner of the screen is accepted as being zero. In the program when the images are brought to the screen for processing, each pixel is reflected to the screen numerically depending on its resolution. The pixels which are determined by color analysis are the pixels that express the target object in the processed image. In the point detection the spatial coordinates are accepted as the location of pixels. Owing to these locations the target object is expressed with the color analysis and the pixels take a numerical value. These values are used in the determination of general coordinates. The images that are taken naturally from the edge and front views of rectangular-prismatic object from which point cloud will be obtained are taken to the developed program as shown in Fig 2. The top left corner of the images which are taken into module media is accepted as zero. When the images are opened inside of module for processing, color analysis and pixel coordinates are introduced to program temporarily. After this stage, reference points are defined in front and side views.

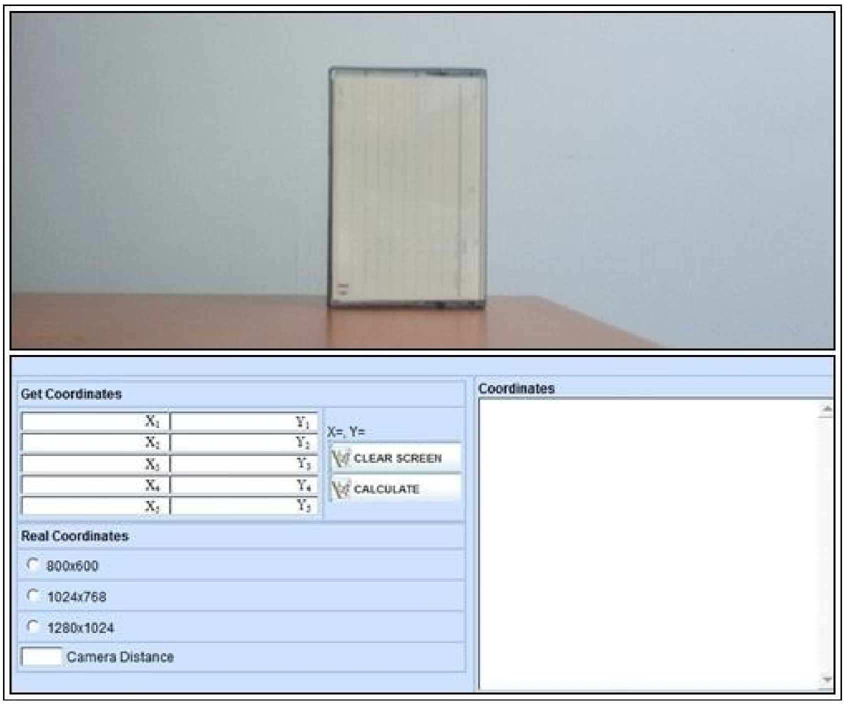

Fig.2. Processed image and developed image processing module screen

In Fig. 2, the image of a camera cassette cover to be processed and the developed module screen for rectangular prismatic objects to obtain point cloud is shown. In the section of Get Coordinates, there are five boxes indicating reference points which are marked by the user with a mouse. X_1 and Y_1 are the first reference points which are marked on the upper left side of the object's front view. X_2 and Y_2 are the second reference points which are marked on the upper right side of the object's front view. X_3 and Y_3 are the third reference points which are marked on the lower right corner of the object's front view. X_4 and Y_4 are the upper left corner of the side view and finally X_5 and Y_5 are the coordinate values of the upper right corner of the side view.

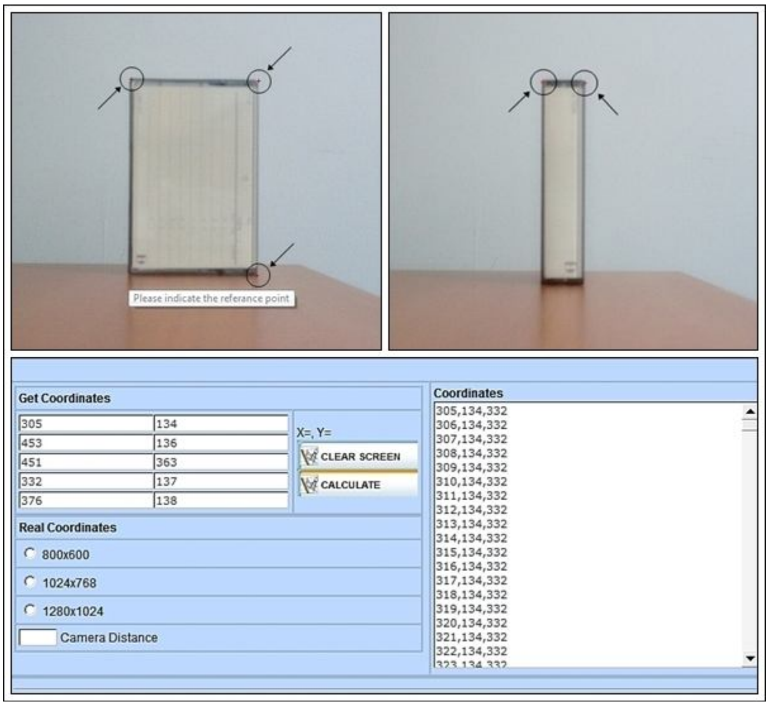

Fig. 3. Reference points marked on the image and obtaining coordinates

In Fig. 3, reference points marked on the front and side view of the object, points coordinates, module screen where coordinates *X, Y, Z* of point clouds take place are shown. In the part of Real Coordinates, resolution belonging to processed image takes place and if the camera shooting distance is known, point clouds which are close to the actual size of the target object can be obtained. Reference point marked on the front and side views, should be marked to express the target object as shown in Fig. 3. Reference points belonging to the side view of the object, should be marked parallel to each other as much as possible to express the side width of the object. After these markings, when Calculate button is pressed, the program performs operations and determines the coordinates of point cloud.

The marked reference points determine the area whose color analysis will be made. Because of the color analysis, both pixel and area limits can be detected and non-area pixel detection can be prevented. In this point detection, color analysis makes a confirmatory mission and the processing does not exceed the area which is determined for point detection. The system makes process for the front and side views of the image separately.

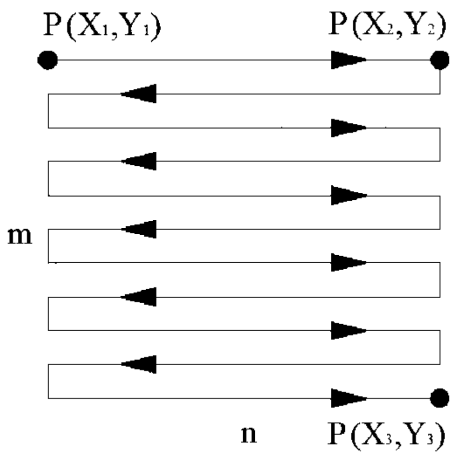

Fig. 4. Pixel detection for front view

In Fig. 4, color analysis for front view and the way pixels are detected is shown. Using the color analysis procedure, the edges of the target object can be detected and circumference of the processed object can be diagnosed by the system. Edge lines, in horizontal and vertical area, which is outside the marked area and between the points can be detected with this diagnosing. The system begins to scan with the first reference points $P(X_1\ Y_1)$, continues with $P(X_2\ Y_2)$, and scans to the point of $P(X_3Y_3)$ both in horizontal and in vertical as perpendicular and parallel, pixel to pixel to the edge line detected by color values. Points, which are obtained by this scanning, is in the area of '*m*' in length and '*n*' in width is expressed mathematically.

$$P_{(X,Y)} = \begin{bmatrix} (X_1,Y_1) & . \quad . & (X_2,Y_2) \\ . & . \quad . & . \\ . & . \quad . & . \\ . & . \quad . & (X_3,Y_3) \end{bmatrix} \Rightarrow X_2 = X_3, \quad Y_1 = Y_2 \qquad (1)$$

In the area which is between the first reference point and other two reference points, *X* and *Y* values of the pixels are determined by color analysis between the edges of this area. These identified pixel points are expressed as matrix by the system (Pratt, 1991) generally, each pixel point detected from the front view is expressed according to their locations. Each point has a *X* and *Y* value. Pixel points, whose locations are detected, are decomposed in themselves and a matrix is created for point clouds coordinates.

$$X_{(Coor)} = \begin{bmatrix} X_{(m,n)} & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \end{bmatrix} \Rightarrow \begin{matrix} m_f = Y_1, & m_e = Y_3 \\ n_f = X_1, & n_e = X_2 \end{matrix} \tag{2}$$

$$Y_{(Coor)} = \begin{bmatrix} Y_{(m,n)} & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \end{bmatrix} \Rightarrow \begin{matrix} m_f = Y_1, & m_e = Y_3 \\ n_f = X_1, & n_e = X_2 \end{matrix} \tag{3}$$

The equations used in choosing *X* and *Y* coordinates from pixel points are given in the Eq. 2 and 3. In the matrix string which has *mxn* row and column, *m* expresses pixels' *Y* location value and n expresses pixels' *X* location value. m_f expresses the first marked reference point's *Y* location and m_e expresses the last marked reference point's Y location. Similarly, n_f expresses the first marked reference point's *X* location, and n_e expresses the last reference point's *X* location. Obtained *X* and *Y* coordinates are kept in the system in matrix form showed in the Eq. 2 and 3. With these values, point cloud belonging to the object in the image is obtained when it is combined with *Z* coordinates obtained from the front view. To obtain *Z* coordinates, the side view of the image is used (Fig 5).

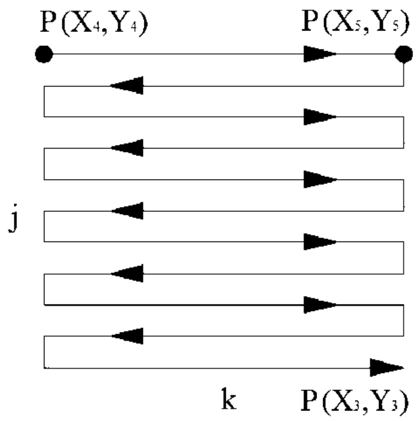

Fig. 5. Pixel detection for side view

In the Fig. 5, color analysis for appearance and scanning way to detect pixels are shown. Scanning fist begins with the reference point of *P(X_4,Y_4)*, and continues to the line of *P(X_5,Y_5)* until the limit point of *P(X_3,Y_3)* scanning is carried out both in horizontal and in vertical as perpendicular and parallel, pixel to pixel to the edge line detected by color values. Pixel points which are determined by reference points and specified as *K* in width and *J* in length for scanning area are expressed mathematically in the system.

$$P_{(Z)} = \begin{bmatrix} (X_4, Y_4) & . & . & (X_5, Y_5) \\ . & . & . & . \\ . & . & . & . \\ . & . & . & (X_3, Y_3) \end{bmatrix} \Rightarrow X_5 = X_3, \quad Y_4 = Y_5 \tag{4}$$

In Eq. 4, the area which is between two marked reference points and the reference point from the front view, and *Z* values of the pixels which are expressed as *P* and are between the edges of this area that are detected by color analysis, are determined. The detected pixel points are expresses in a matrix in the system. Each pixel point obtained from the side view consists of *X* and *Y* values as seen from the front view. *X* value is used for *Z* value. In fact, each *X* pixel point is *Z* pixel point. *Y* pixel points are used as pixel distance and it expresses the length of the area from *X* values to *Y* values of the front view. Among the obtained *X* and *Y* pixel points, *X* pixel points are written in matrix form for only *Z* coordinate points.

$$Z_{(Coor)} = \begin{bmatrix} Z_{(j,k)} & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \end{bmatrix} \Rightarrow \begin{matrix} j_f = Y_4, \;\; j_e = Y_3 \\ k_f = X_4, \;\; k_e = X_5 \end{matrix} \tag{5}$$

In Eq. 5, the matrix, which is used for *Z* coordinate points obtained from *X* and *Y* pixel points from the side view, is shown. In the matrix array which has *jxk* row and column element, *j* expresses pixels' *Y* location value, *k* expresses pixels' *X* location value for the object's side view. j_f indicates first marked reference point's *Y* location and j_e indicates last marked reference point's *Y* location. In the same way k_f indicates first marked reference point's *X* location and k_e indicates last marked reference point's *X* location. In the end, obtained *Z* coordinate values are saved in the system temporarily similar to *X* and *Y* coordinate values. *X, Y* and *Z* coordinate values are combined in a matrix and the point cloud is obtained.

$$X,Y,Z = \begin{bmatrix} X_{(m,n)} & Y_{(m,n)} & Z_{(j,k)} \\ . & . & . \\ . & . & . \\ . & . & . \\ (s,1) & (s,2) & (s,3) \end{bmatrix} \tag{6}$$

In the Eq. 6, this point cloud is shown as a matrix. In the developed system, coordinates are kept in a matrix form before they are written to a text file. Each *X*, *Y* and *Z* coordinate matrix's row and column elements are written to the general coordinate matrix starting from the beginning. This matrix has the dimension of sx3. In the equation 6, *'s'* shows the number of rows and this number has different values depending on the size of the object in the image. In the matrix column, the number of column has three elements because of *X, Y* and *Z* coordinates. Each element of *X, Y* and Z coordinates, which are combined in the (*sx3*) matrix form, are written to a text file by separating with commas. After writing process the coordinates are obtained (Fig. 6).

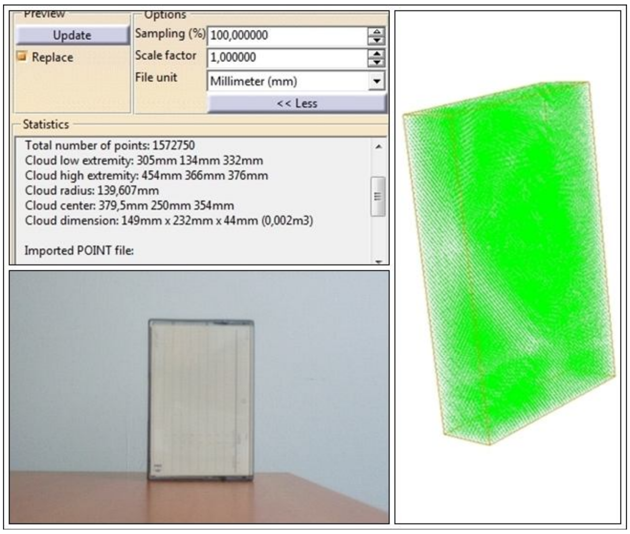

Fig. 6. Obtained coordinates and point cloud

Point cloud coordinates written to the file can be opened in Computer Aided Design and Manufacturing program and surface or solid models can be obtained from these point clouds (Fig. 7).

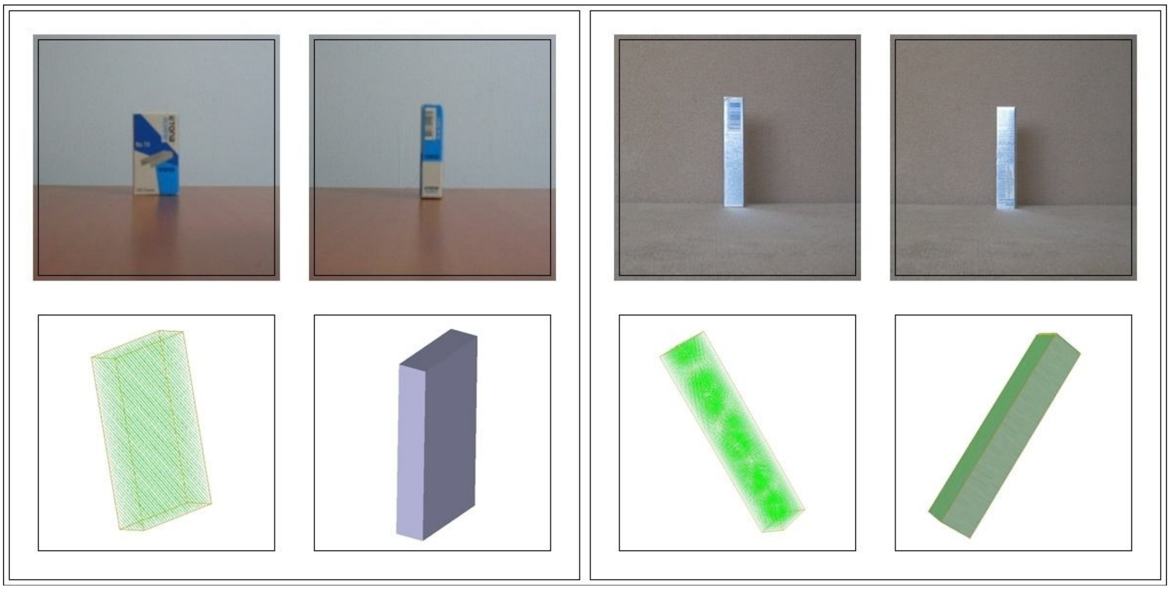

Fig. 7. Point clouds obtained from image and solid models

In the Fig. 7, the point cloud is obtained from another sample object's side and front views. The solid model of the object is obtained by using this point cloud.

Results and Discussion

In this study, a system, which obtains a three dimensional point cloud from a prismatic image and processes digital images without using a special shooting environment, has been developed. Within the system, color points of the image are evaluated pixel to pixel in the reference point area which is marked by the user. Since the reference points are used within the system, the program processes the limited area for the image therefore this method reduces the processing time. A few number of marked reference points are required and the processing time for obtaining point cloud is between 15 and 35 seconds. There is no limitation in resolution values used in images. However, the point clouds obtained in the resolution of 800x600, 1024x768 and 1280x1024 provides point cloud which are close to real dimensions of the object. In the real dimensions section of the developed program, the point clouds in real dimensions of different images can be determined by using real coordinates of the part. Obtaining point cloud in real size procedure will be given in detail in another study. If the image quality is good and shooting distance is given, exact dimensions of the point cloud of target object can be obtained. The developed system has both advantages and disadvantages for processing images.

The advantages of developed system:

- It is not necessary a special shooting environment for obtaining images and the objects can be shoot manually in any distance,
- Images having different resolution and color or black and white images can be processed,
- Processing time is between 15-35 seconds to obtain a point cloud. Marking reference points and completing process take about 1.5 minute,
- Surface or solid models can be obtained from point clouds using a CAD/CAM program.
- The system has a modular structure and new modules can be added,
- If the image resolution and shooting distance are known, by entering some parameters, point cloud with the real dimensions of the image can be obtained,
- Produced point clouds can be transferred to a CAD system and surface or solid models can be obtained.

The disadvantages of developed system:

- As it has algorithm structure only for rectangular prismatic objects, more complex object images cannot be interpreted in this module,

- As the number of points in point clouds which are obtained for the object is too much, approximately 1-4 million, in the marked image to obtain its solid model needs some time,
- In image processing which is done pixel to pixel according to the color analysis, color loss in the image cause regional point loss, which causes some problems to model the part,
- If the size of the object in the image and processed image is big, the size of the obtained point cloud file becomes big.

It is aimed to obtain three dimensional point clouds for circular, curved and complex forms of objects in further studies.

References

Azuma, R., (1995). A survey of augmented reality. *Computer Graphics SIGGRAPH Proc*., 1-38.

Barbero B.R. and Ureta, E.S. (2011). Comparative study of different digitization techniques and their accuracy. *Comp. Aided Design*, 43, 188-206.

Benlamri, R. and Al-Marzooqi, Y. (2004). Free-from object segmentation and representation from registered range and color images. *Img. and Vis. Comp*., 22, 703-717.

Bleser, G., Pastarmov, Y. and Stricker, D. (2005). Real-time 3D camera tracking for industrial augmented reality applications. *Journal of Winter Sch. of Compt. Graphics,* 47–54.

Bockholt, U., Bisler, A. and Becker, M., Müller-Wittig, W.K. and Voss, G. (2003). Augmented reality for enhancement of endoscopic interventions. *Proc. IEEE Virtual Reality Conf., (pp. 97-101). Los Angeles*, USA.

Bosche,F. (2010). Automated recognition of 3D CAD model objects in laser scans and calculation*. Adv. Eng. Informatics,* 24, 107-118.

Boufama, B. and Habed, A. (2004). Three-dimensional structure calculation: achieving accuracy without calibration. *Img. and Vis. Comp*., 22, 1039-1049.

Byne, J. H. M and Anderson, J. A. D. W. (1998). A CAD-based computer vision system. *Img. and Vis. Comp*., 16, 533-539.

Dornaika, F. and Chung, R. (2001). An algebraic approach to camera self-calibration *Comp. Vis. and Img. Under.,* 83, 195-215.

Frere, D., Vandekerckhove, J., Moons, T. and Van Gool, L. (1998). Automatic modeling and 3D reconstruction of urban buildings from aerial imagery. *IEEE Int. Geoscience and Rem. Sensing Symp. Proc.*, (pp. 2593-2596). Seattle.

Frueh, C. and Zakhor, A. (2001). 3D model generation for cities using aerial photograps and ground level laser scans. *IEEE Conf. on Compt. Vis. and Pat. Recog.,* (2:2, pp. 31-38). Kauai, USA.

Gaspar, J., Grossmann, E. and Santos-Victor, J. (2001). Interactive reconstruction from an omnidirectional image. *9th Int. Symp. on Intel. Robotic Systems (SIRS'01*), (pp. 139-147). Toulouse, France.

Grossmann, E., Ortin, D. and Santos-Victor, J. (2001), Algebraic aspects of reconstruction of structured scenes from one or more views*, in: British Mach. Vis. Conf.*, (pp. 633-642). Manchester, UK.

Hua, L. and Weiyu, W. (2004). A new approach to image-based realistic architecture modeling with featured solid library. *Auto. in Const*. 13, 555-564.

Huertas, A., Nevita, R. and Landgrebe, D. (1999). Use of hyperspectral data with intensity images for automatic building modeling. *Proc. of the Sec. Int. Conf. on Inf. Fusion*, (pp. 680-687). Sunnyvale.

Kimber, M. and Blotter, J. (2006). A novel technique to determine difference contours between digital and physical objects for projection moiré interferometry. *Opt. and Laser in Eng*. 44, 25-40.

Lee, K., Wong, K. and Fung, S. Y. (2001). 3D face modeling from perspective-views and contour based generic model. *Real- Time I*., 7, 173-182.

Lindeberg, T. (1990). Scale-space for discrete signals. *IEEE Trans. Pattern Recog. Mach. Intel*., 12, 234–254.

Mülayim, A. Y., Yılmaz, U. and Atalay, V. (2003). Silhouette-based 3D model reconstruction from multiple images. *IEEE Trans. on Systems, Man and Cybernetics*, 33(4), 582-591.

Pratt,W.K. (1991). Digital image processing, second ed., (pp. 3-167). A Willey-Interscience Publication*,* New York.

Reed, M. K. and Allen, P. K. (1999). 3-D modeling from range imagery: An incremental method with a planning component. *Img. and Vis. Comp*., 17, 99-111.

Saha, P.K. (2005). Tensor scale: a local morphometric parameter with applications to computer vision and image processing. *Compt. Vis. and Img. Under.,* 99, 384–413.

Song, L. and Wang, D., (2006). A novel grating matching method for 3D reconstruction. *NDT & E Int.*, 39: 282-288.

Sturm, P., Cheng, Z. L. and Chen, P.C.Y. and Poo, A.N. (2005). Focal length calibration from two views: method and analysis of singular cases. *Comp. Vis. and Image Under*., 99, 58-95.

Song, L., Qu, X., Xu, K., Lv, L. (2005). Novel SFS-NDT in the field of detect detection, *NDT&E Int*. 38 (5), 381-386.

Song L., Qu, X., Yang, Y., Yong, C. and Ye, S. (2005). Application of structured lighting sensor for online measurement. *Opt. and Laser in Eng*., 43 (10), 1118-1126.

Stamos, I. and Allen, P.E. (2000). 3-D Model construction using range and image data. *Proceedings IEEE Conf. on Compt. Vis. and Pat. Recog.*, (pp. 531-536). Hilton Head Island.

Thrun, S. and Burgard, Fox, W. D. (2000). A Real-time algorithm for mobile robot mapping with applications to multi-robot and 3D mapping. *Proc. of Int. Conf. on Robotics and Automation*, (1:4, pp. 321-328). San Francisco.

Tubic, D., Hébert, P. and Laurendeau, D. (2004). 3D surface modeling from curves. *Img. and Vis. Comp*., 22, 719-734.

Wesarg, S., Firle, E., Schwald, B., Seibert, H., Zogal, P. and Roeddiger, S. (2004). Accuracy of needle implantation in Brachtherapy using a medical AR system-a phantom study. *SPIE Medical Imaging Symp.,* (pp. 341-352). San Diego, USA.

Witkin, A.P. (1983). Scale-space filtering. *Proc. of 8th Int. Joint Conf. Art. Intel.*, (pp. 1019–1022). Karlsruhe, West Germany.

Xie, Z., Wang, J. and Zhang, Q. (2005). Complete 3D measurement in reverse engineering using a multi-probe system. Int. *Journal of Mach. Tools Manuf.,* 45, 1474-1486.

Yang, W-B., Chen, M-B. and Yen, Y-N. (2011). An application of digital point cloud to historic architecture in digital archives. *Advance in Eng. Soft*. 42, 690-699.

Zhao, D., Li, S. (2005). A 3D image processing method for manufacturing process automation. *Comps. in Industry,* 56, 875-985.

Zhou, G. (1997). Primitive recognition using aspect-interpretation model matching in both CAD and LP based measurement systems. *ISPRS J. of Photog. and Rem. Sensing*, 52, 74-84.