*American Journal of Mechanical Engineering, 2013, Vol. 1, No. 6, 149-154*
Available online at http://pubs.sciepub.com/ajme/1/6/1

DOI:10.12691/ajme-1-6-1

# VUDJOOD Algebra Theory from the Viewpoint of 3D Object Recognition

**Amin Mirahmadi, Kamran Vafaee, Behdad Geranmehr***

Mechanical Engineering, Iran University of Science and Technology (IUST), Tehran, Iran
*Corresponding author: geranmehr.behdad@email

*Received August 19, 2013; Revised November 13, 2013; Accepted November 19, 2013*

**Abstract** The goal of VUDJOOD (existence) algebra is to provide the capability of visual intelligence for intelligent machines that are like humans. These machines should visually recognize surrounding objects and machines and finally decide which manufacturing disciplines, to be applied on the object. The present work is an effort to accelerate achieving this purpose. In this paper we focused on the 3D recognition process using VUDJOOD algebra theory. 3D Rotary Raster Photogrammetric Scanner (3D RRP Scanner) is designed and built at the Machine Tools Control lab of IUST. This scanner is used to generate the points-cloud of objects. Then these points-clouds are checked in the VUDJOOD equations. Finally the object which has the most overlapping with the points-cloud is recognized as the desired object. Objects identifying Algorithm has been studied for a few objects with simple geometry using the experimental tests. Dimensional accuracy of detection results is acceptable.

***Keywords:*** *VUDJOOD algebra, computer integrated manufacturing, 3D laser scanner, 3D object recognition*

**Cite This Article:** Amin Mirahmadi, Kamran Vafaee, and Behdad Geranmehr, “VUDJOOD Algebra Theory from the Viewpoint of 3D Object Recognition.” *American Journal of Mechanical Engineering* 1, no. 6 (2013): 149-154. doi: 10.12691/ajme-1-6-1.

## 1. Introduction

In recent years, many researchers have presented different methods for identifying three-dimensional objects. The ultimate goal of identifying three dimensional objects is access to technology of making robot eyes that acts Similar to the human eyes. Most studies are based on image processing of 2D image and artificial neural networks [1,2,3,4,5].

Alternatively, it is possible to estimate the 3D object shape from its already available various 2D views. Moreover, the object can be viewed from any angle regardless of the acquisition process, and displayed through standard rendering techniques. Another source of information to capture 3D object shape is the direct 3D information acquired actively by laser range scanners or other coded light projecting systems. Such 3D data acquisition systems can be very precise, but have several drawbacks [7-19].

VUDJOOD algebra is a mathematical method that describes a domain or region. The application of visual artificial intelligence in manufacturing will be the next developmental step in production technology. Operators in this field will be universal humanoid robots that can visually recognize surrounding objects and machines. These robots will work with mathematical models of the surrounding objects and machines. VUDJOOD algebra can accelerate the development of autonomic-acting machines and provide a tool for shape manufacturing [6].

It has been shown that body can be described by mathematical operations. We know that all machine parts are information carriers programmed to perform a designer-defined task. Machines are mechanical computers, and the manufacturing process is a method of programming. The human environment is full of bodies that can be influenced and changed by other humans or machines. Every small relative movement or change must be calculated by brain internal virtual reality. Because of this internal virtual reality, a person knows what would occur. The result of this calculation capability is visual intelligence. To create intelligent machines that are like humans, the mathematical laws of imagination must be fully understood. VUDJOOD algebra provides a fitting mathematical tool for comprehension and can be applied to different manufacturing disciplines. Shape manufacturing is not a human invention. Since the beginning of time, nature has created bodies with the characteristic laws of VUDJOOD algebra [6].

In this paper, we present our opinions on VUDJOOD algebra theory from the viewpoint of 3D object identification. Firstly, we analyze characteristics of VUDJOOD algebra that are adapted to the study of object identification. Secondly, we present our opinions on object identification. Finally, we introduce our work on the points- cloud of three-dimensional scanning device which is used for identification i.e. Coordinates of points checked out in the VUDJOOD algebra equations of geometrical models.

## 2. VUDJOOD Algebra Theory

VUDJOOD algebra is a mathematical method that describes a domain or region, which can be used for designing manufacturing software [6].

The application of visual artificial intelligence in manufacturing will be the next developmental step in production technology. Operators in this field will be universal humanoid robots that can visually recognize surrounding objects and machines. These robots will work with mathematical models of the surrounding objects and machines.

The main objective in VUDJOOD algebra (VUDJOOD is a Persian word which emphasizes the existence of an object in real world ) is the representation of the region that a material occupies in space and for this intend three generator functions are employed:

1) Shape function: the surface of an object could be recognized applying a body function. In fact, any point on the object surface has an aspect in which the body function for its adjacent points has a variation from 0 to 1 or from 1 to 0 (Figure 1).

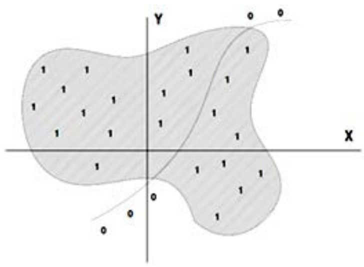



**Figure 1.** Shape Function

Definition of Shape Function:

$$\begin{cases} Body : x \rightarrow \{0,1\} \\ Body_A(x_1,\ldots,x_n) = \begin{cases} 1 (x_1,\ldots,x_n) \in A \\ 0 (x_1,\ldots,x_n) \notin A \end{cases} \end{cases} \quad (1)$$

2) Cutting function: A multi variables function with real value that divides its definition domain space geometrically in to section with the oblique line $W = aX + bY + c$, so that each section is described by one of inequalities W>0 and W<0 .

3) Cost function: it has three types S, E, G which are all defined in $R \rightarrow \{0,1\}$ . “W” is the input variable of cost function which is also called Cutting argument. (Figure 2)

$$\begin{cases} G : R \rightarrow \{0,1\} \\ G(w) = \begin{cases} 1 w > 0 \\ 0 w \le 0 \end{cases} \end{cases} \quad (2)$$

$$\begin{cases} E : R \rightarrow \{0,1\} \\ E(w) = \begin{cases} 1 w = 0 \\ 0 w \ne 0 \end{cases} \end{cases} \quad (3)$$

$$\begin{cases} S : R \rightarrow \{0,1\} \\ S(w) = \begin{cases} 1 w < 0 \\ 0 w \ge 0 \end{cases} \end{cases} \quad (4)$$

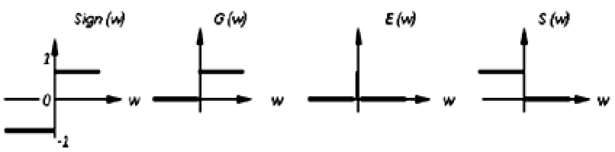



**Figure 2.** Operator Function

## 3. 3D Object Recognition and Modelling

The task of recognizing a specific object in an image, video, range scan or generally in real world is known as object recognition. Humans find so many objects in a single image with high precision, low effort and very low time. As we tried to use the human vision pattern for humanoid robots, our opinion is 3D object recognition, the same as human eyes. In 3D object recognition, the object can be identified despite all the translations, rotations or when they are partially obstructed from view. This problem is still a challenge in computer vision systems. As a simplified problem some objects is presented to the system and a database is created. And then for an arbitrary input which is a range scan of the real world, the system decides whether there is a predefined object in the scan or not. And if there is, the system locates the object. The advantage of our RRP 3D scanner is the capability of doing this complicated task, real time.

The process of representing 3D objects as mathematical matrix using specialized software is called 3D modeling (or meshing). As a product of this process the 3D object is represented by a collection of points which are connected together by geometric entities. Various ways are available to be used as these entities. For instance the 3D model of a human body is illustrated in Figure 3.

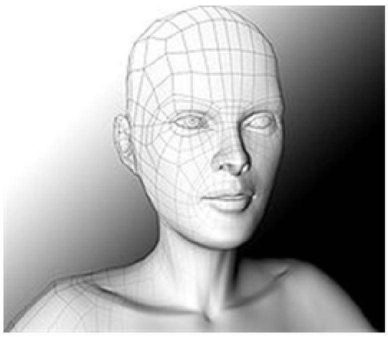


**Figure 3.** 3D Object Modeling sample [20]

In order to collect data for the sake of modelling and recognition we built a 3D scanner. A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color) [20]. After collecting data and analyzing them, they have been used to build 3D models. These models are also digital models. Despite various technologies which can be used to build these 3D scanners, by considering their limitations, advantages and costs, we built a RRP 3D scanner. The details are available in section 4 of this paper.

### 3.1. Our Idea on Object Recognition

VUDJOOD algebra theory was developed at 2009 by Mirahmadi [6] to accelerate the development of autonomic-acting machines and provide a tool for shape manufacturing. The purpose of VUDJOOD algebra is to obtain a Mathematical model for bodies by the autonomic-acting machine and then the application of its rules in computer-aided manufacturing.

Considering the Object Recognition methods, concluded that most of these methods are unable to create an accurate 3D model of the body. And in methods such as 3D scanners, a schematic model of the body is obtained so none of these methods can develop a mathematical model.

Firstly we used a data base of different bodies with their algebraic model from the viewpoint of VUDJOOD algebra theory. Then the points cloud of the body which is obtained by a 3D scanner is checked in the VUDJOOD algebra equations of the database elements to show whether it is one to these elements or not. This method uses a digital 3D approach in the recognition process.

The main contribution of this method of recognition is using real dimensions of the body. Thus not only the process of recognition is done, but also the results are available to generate the CAD/CAM files of the body.

## 4. RRP 3D Scanner

3D scanner is a special type of machine vision and is used in 3D scanning of the surfaces of object. [21] Laser based 3D scanners are designed and programmed on the basis of coincidence and triangulation. In categorization of optical 3D scanning methods, Rotary Raster Photogrammetric method which belongs to non-contact methods which are established according to coincidence [22].

As it is illustrated in Figure 4. In this method an optical spot seeps the object surface meanwhile this spot is tracked by two rotational cameras in Tilt and Pan Planes.

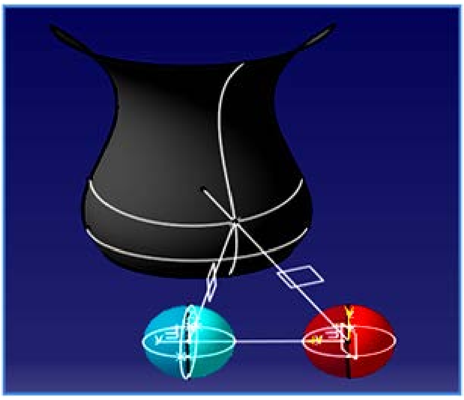


**Figure 4.** Rotary Raster Photogrammetric

### 4.1. Calculation of Focus Point

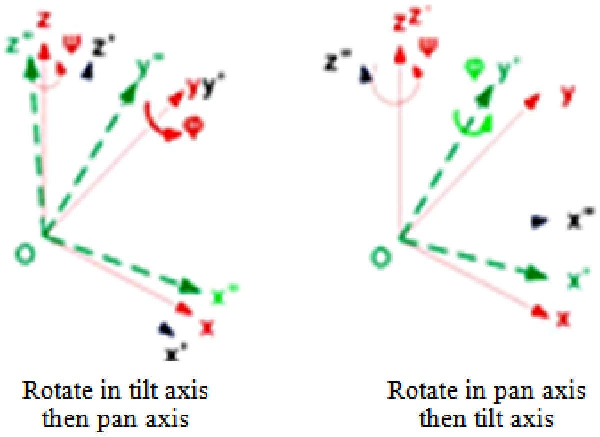



**Figure 5.** Rotation Sequences [23]

As Figure 5 suggests, there are two possibilities of calculating of focus point regarding that which axis should rotate first. For this article calculation is based on first Tilt axis and then Pan Axis order. Image processing at last ends with calculating of coordination (x, y) of focus point (laser spot) in image's matrix. Values of Cameras angels (Φ, Ψ) in Pan and Tilt planes are feedback in each iteration, depicted in Figures 6.a and 6.b, with knowing focal length(f) and distance between two cameras(b) and writing geometrical relations, 3D co ordinations of object is calculated with coincidence method of rotation matrix.

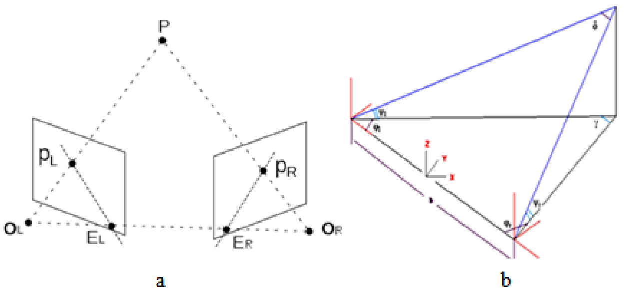



**Figure 6.** a) Coincidence in 3D Scanner [24], b) Angles in RRP 3D Scanner

φ: rotation angle in pan plate or Roll angle

$R_\varphi$: rotation matrix in pan plate or roll matrix

ψ : rotation angle in tilt plate or yaw angle

$R_\psi$: rotation matrix in tilt plate or yaw matrix

$(x_l, y_l)$: pixel number of laser spot in image of left camera

$(x_r, y_r)$: pixel number of laser spot in image of right camera

$(X_l, Y_l)$: coordination of laser spot in left camera

$(X_r, Y_r)$: coordination of laser spot in right camera

$$x = b * \frac{(x_l + x_r)/2}{(x_l - x_r)} \quad (5)$$

$$y = b * \frac{(y_l + y_r)/2}{(x_l - x_r)} \quad (6)$$

$$z = b * \frac{f}{(x_l - x_r)} \quad (7)$$

$$R = R_\psi * R_\phi = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\psi & -\sin\psi \\ 0 & \sin\psi & \cos\psi \end{bmatrix} * \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix} \quad (8)$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = R * \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (9)$$

Substituting Pixel numbers of $(x_r, y_r)$ and $(x_l, y_l)$ and instant angles of camera (Φ, Ψ) in equation 9 would end with values of $(X_l, Y_l)$ and $(X_r, Y_r)$ and then 3D coordination could be implemented by using equation 5,6 and 7 at end.

### 4.2. Defining Coordinate Origin and Scan Surface of Object

In order to limit laser spot to object surface, edge detection is used to define object boundary and laser zone.

Laplacian of Gaussian and Canny edge detection is used in C# program to satisfy definition of laser zone. [25] The algorithm of program includes different steps. In the first step, program receives images coming from two cameras and it continues with edge detection of images. Completing the algorithm is done by coincidence of two boundaries which results in required dates for motor control of laser (Figure 7).

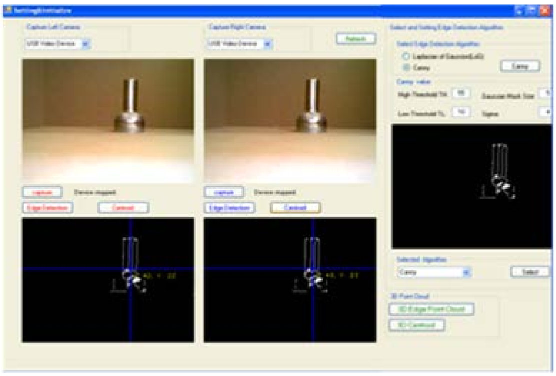


**Figure 7.** Canny Edge Detection

Centroid of object is achievable by polygon class using boundary information defined as mentioned. Polygon class uses equation 10-12 to define centroid and as a result center of mass [26]. As a matter of fact, centroid is coordinate origin of object.

$$A = \frac{1}{2}\sum_{i=0}^{n-1}(x_i y_{i+1} - x_{i+1} y_i) \quad (10)$$

$$C_x = \frac{1}{6A}\sum_{i=0}^{n-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (11)$$

$$C_y = \frac{1}{6A}\sum_{i=0}^{n-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (12)$$

### 4.3. 3D Scan of Surface

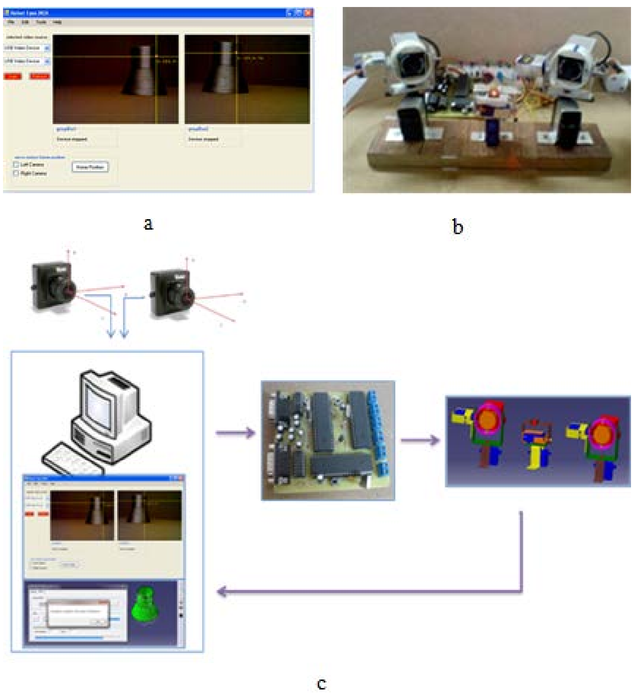


**Figure 8.** a) C# 3D scanner program, b) RRP 3D scanner and c) 3D scan of surface algorithm

Two motors provide degrees of freedom for each camera to rotate in tilt and pan plates. Actually, motors carrying cameras are positioned according to laser point data which are feedback from C# program to them. In a similar way, laser is equipped with two motors which in contrary of cameras, is positioned by data from boundary and scan strategy (Figures 8.a, 8.b and 8.c).

## 5. Case Study

In this section the performance of the proposed approach is evaluated for a user-defined database. The objects in the data base were comprised from the combination of three basic objects i.e. cylinder, sphere, and cone. The VUDJOOD algebra equations of these objects are given, and also the geometrical model of hybrid object with data base are defined by VUDJOOD equations.

### 5.1. VUDJOOD Algebra Equation of Basic Object

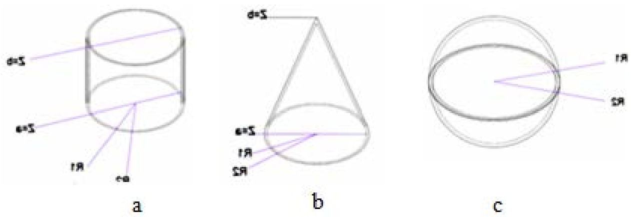


**Figure 9.** a) Cylinder, b) Cone and c) Sphere

Cylinder:

$$\begin{aligned} Body(w) &= \underline{G}(x^2 + y^2 - R_1^2) * \\ &\underline{S}(x^2 + y^2 - R_2^2) * \underline{S}(z - a) * \underline{G}(z - b) \end{aligned} \quad (13)$$

Cone:

$$\begin{aligned} Body(w) &= \underline{G}(\sqrt{x^2 + y^2} - z) * \\ &\underline{S}(\sqrt{x^2 + y^2} - z) * \underline{G}(z - a) * \underline{S}(z - b) \end{aligned} \quad (14)$$

Sphere:

$$\begin{aligned} Body(w) &= \underline{G}(x^2 + y^2 + Z^2 - R_1^2) * \\ &\underline{S}(x^2 + y^2 + Z^2 - R_2^2) \end{aligned} \quad (15)$$

### 5.2. VUDJOOD Algebra Equation of Hybrid Bodies

Hybrid bodies create from combined basic bodies, i.e. hybrid bodies' compound from basic bodies. Thus the VUDJOOD algebra equation of hybrid bodies defined by combined VUDJOOD algebra equations of basic bodies. As it is illustrated in Figure 10 and Figure 11.

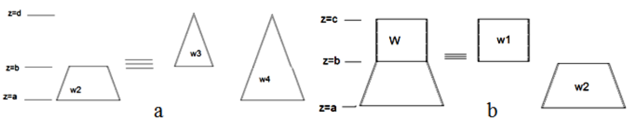


**Figure 10.** First hybrid body

$$Body(w2) = \underline{Body(w3) \cap Body(w4)} \quad (16)$$

$$Body(W) = Body(w1) \cup Body(w2) \qquad (17)$$

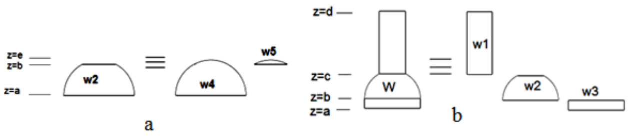



**Figure 11.** Second hybrid body

$$Body(w2) = \underline{Body(w4) \cap Body(w5)} \qquad (18)$$

$$Body(W) = Body(w1) \cup Body(w2) \cup BOdy(w3) \qquad (19)$$

### 5.3. Identification of Points Cloud

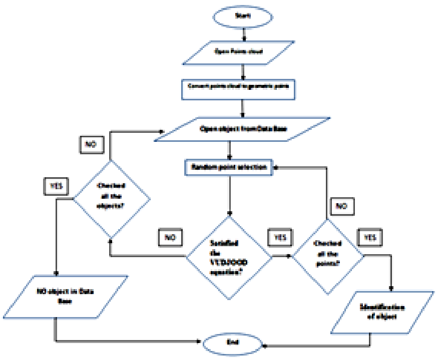
For fast identification of the object and also in order to performing real time identification, the recognition process is divided into two phases:

In the first step of recognition, the points-cloud of objects boundary is exploited. In this phase the points-cloud of the object are checked out in the VUDJOOD equations of data base object in order to filter the objects in the data base which are equivalent to under scanning object. The result of first-step is pre- recognition and remove of nonequivalent object which will lead to volume and time reduction for final recognition.

Second step of identification consists of using the points- cloud of the object surface and checking them out in the VUDJOOD equations of the filtered objects of previous step. Certain and entire recognition of the object is the result of second step.

### 5.4. Identification Algorithm

The identification algorithms in both steps are quite similar as shown in the flow chart:




**Flow chart 1.** identification algorithms

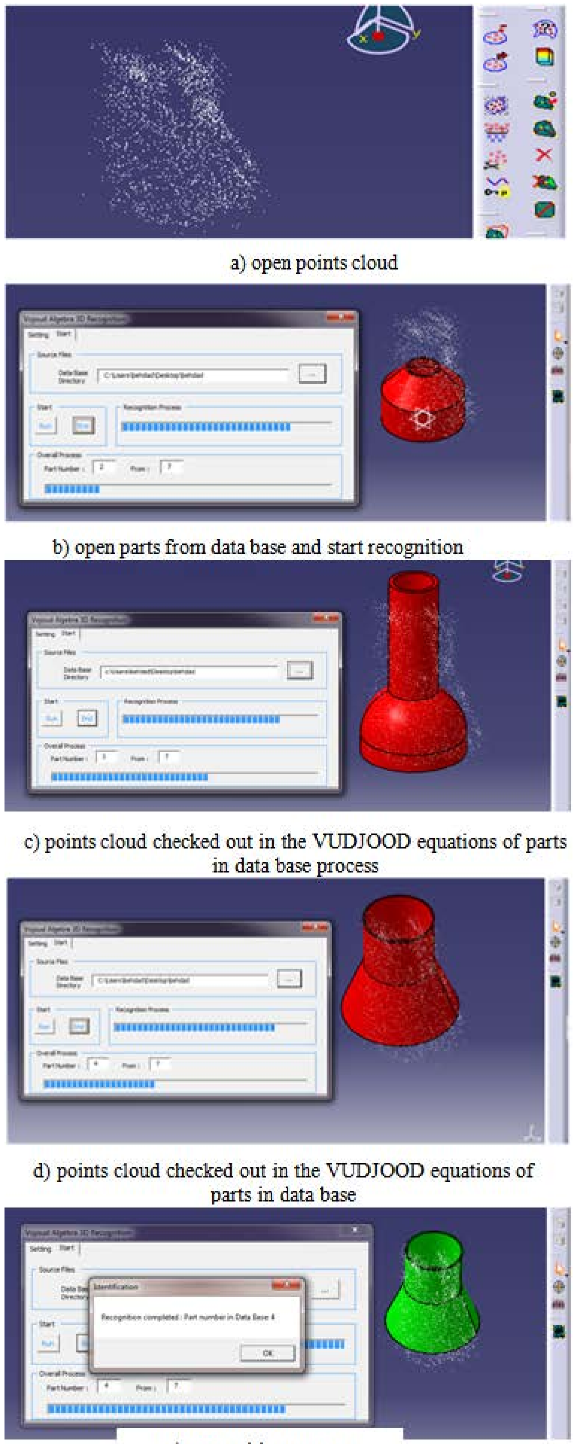
At first, the points-cloud are imported into Digitized Shape Editor in CATIA software, and then work space is changed to part space and according to the flow chart of points-cloud, are converted to geometrical points. The program opens the first object in the data base. When the programs reach this phase the work space of the soft ware is changed automatically and will be entered in to Product Engineering Optimization (PEO). The objective function of the program is to maximize the points which satisfied the VUDJOOD equation of each object. The free parameters which provide the conditions for being optimized with self-variation contains of three translation and three rotation, and also simulated annealing(SA) algorithm is employed to optimize the objective function.

Besides, total number of updates in optimization procedure, number of non-improved updates and total time of optimization process is determined through a trial and error procedure during programming.

At the end of the program the object which has the maximum number of points satisfied VUDJOOD equations are determined as the nearest object to the under scanning object.

## 6. Experimental Result

Identification of points-cloud and USERFORM of CATIA illustrated in Figure 12.



a) open points cloud

b) open parts from data base and start recognition

c) points cloud checked out in the VUDJOOD equations of parts in data base process

d) points cloud checked out in the VUDJOOD equations of parts in data base

e) recognition process

**Figure 12.** Identification of points-cloud

# 7. Conclusions

The main contribution of this paper is to propose an algorithm to detect the objects from points-cloud using VUDJOOD equations. In this study the points-cloud are obtained using laser based 3D scanner and image processing, then via programming in the Visual Basic Editor of CATIA the points-cloud are compared with the VUDJOOD algebra equations in the data base , and consequently the recognition is carried out according to proposed algorithm.

In this paper for the first time, the VUDJOOD equations were employed for mathematical description of geometrical model of the objects and the capabilities of these equations in object recognition was determined.

The accuracy of the proposed algorithm was investigated in terms of practical experiments and the speed and the precision of 3 sec, ±0.3mm for simple shapes such as cone, sphere, and cylinder were achieved, and the speed and precision of 6sec and ±0.3mm for hybrid objects were also attained.

# References

[1] Meribout, M., Nakanishi, M., Ogura, T., "*A parallel algorithm for real-time object recognition*". Pattern Recognition 35, pp 1917-1931(2002).

[2] Daliri, M R., Vanzella, W., Torre, V., " *A Vision System for Recognizing Objects in Complex Real Images*". ISVC 2007, Part II, LNCS 4842, pp. 234-244, 2007. (Springer-Verlag Berlin Heidelberg 2007)

[3] Chen, J-H., Chen, C-S., " *Object recognition based on image sequences by using inter-feature-line consistencies*". Pattern Recognition 37, pp 1913-1923, (2004).

[4] Shang, L., Greenspan, M., "*Real-time Object recognition in Sparse Range Images Using Error Surface Embedding*". Int J Comput Vis 89: pp 211-228, (2010).

[5] Mokhtarian, F., iKhalili, N., Yuen, P., " *Multi-scale free-form 3D object recognition using 3D models*". Image and Vision Computing 19, pp271-281, (2001).

[6] Mirahmad, A. , "*Mathematical models for manufacturing using Vudjood algebra*". IMechE Vol. 223 Part B: J. Engineering Manufacture, pp 865-873, (2009).

[7] Cyberware, Monterey, CA 93940. http://www.cyberware.com

[8] M. Rioux, F. Blais, A.B. Beraldin, G. Codin, P. Boulanger, M. Greenspan, *Beyond range sensing: XYZ-RGB digitizing and modeling*, IEEE Int. Conf. Robot. Automat. 1-111-115, (2000).

[9] C.H. Chien, J.K. Aggarwal, *Volum/surface octrees for the represen-tation of three-dimensional objects*, Computer Vis. Graph. Image Process. 36 (1) 100-113, (1986).

[10] A. Laurentini, *The visual hull concept for silhouette based image understanding*, IEEE Trans. PAMI 16 (2) 150-162, (1994).

[11] P. Beardsley, P. Torr, A. Zisserman, *3D model acquisition from extended image sequences*, Proceedings of the ECCV'96, Cambridge, UK, pp. 683-695, (1996).

[12] A. Fitzgibbon, G. Cross, A. Zisserman (1998), *Automatic 3D model construction for turn-table sequences*, European Workshop SMILE'98, LNCS 1506, pp. 155-170.

[13] R. Koch, M. Pollefeys, L. VanGool, *Multi viewpoint stereo from uncalibrated sequences*, Proceedings of ECCV-98, Freiburg, Germany, pp. 55-71, (1998).

[14] P.R.S. Mendonc ¸a, K.K. Wong, R. Cipolla, *Recovery of circular motion from profiles of surfaces*, European Workshop on Vision Algorithms, LNCS 1883, 1999, pp. 149-165.

[15] M. Pollefeys, R. Koch, M. Vergauwen, L. VanGool, *Flexible acquisition of 3D structure from motion*, Proceedings of the 10th IMDSP Workshop, Austria, pp. 195-198, (1998).

[16] J.M. Lavest, M. Viala, M. Dhome, *Do we really need an accurate calibration pattern to achieve a reliable camera calibration*, Proceedings of the Fifth European Conference on Computer Vision, vol. 1, Germany, pp. 158-174, (1998).

[17] C. Hernandez Esteban, F. Schmitt, *Silhouette and stereo fusion for 3D object modeling, Fourth International Conference on 3D Digital Imaging and Modeling*, Banff, Alberta, Canada, pp. 46-53, (2003).

[18] Y.Matsumoto, K. Fujimura, T. Kitamura, *Shape-from-silhouette/stereo and its application to 3-D digitizer*, DGCI 1999, pp. 177-190, (1999).

[19] M. Kampel, S. Tosovic, R. Sablatnig, *Octree-based fusion of shape from silhouette and shape from structured light*, 3DPVT02: First IEEE International Symposium on 3D Data Processing Visualization and Transmission, Padova, Italy, pp. 754-757, (2002).

[20] http://www.wikipedia.org/

[21] Millen, J., Mitchell, R., "*An Intelligent Robot Vision System for Research Applications*", IEEE, (1985).

[22] Kumar, M.S., Melvyn L.S., Lyndon N.S., Sagar, M. " *An Overview of Passive and Active Vision Techniques for Hand-Held 3D Data Acquisition*", Opto-Ireland, pp. 16-27, (2002).

[23] David A. Maluf,Ahmed S. Khalil, Gregory A.Dorias, Yuti Gawdiak. "*Laser-Camera Vision Sensing for Spacecraft Mobile Robot Navigation*". NASA Ames Research Center, MS 269-2, California 94035, (2002).

[24] http://en.wikipedia.org/wiki/File:Epipolar_Geometry1.

[25] Johen F.Canny."*Canny edge detection*", A Computational Approach to Edge Detection, IEEE Trans. Pattern Analysis and Machine Intelligence. 8(6):679-698, 1986, (1986).

[26] Roger A. Johnson, *Advanced Euclidean Geometry*, Dover, p. 173, corollary to #272, (2007 (orig. 1929)).