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# 3D SURFACE RECONSTRUCTION OF HUMAN BODY PARTS BASED ON 2D COMPUTERIZED TOMOGRAPHY SCANS

JAMILU SAMINU
Mechanical Engineering, Bayero University, Kano, Kano, Postcode, Nigeria
Jsaminu.mec@buk.edu.ng

## ABSTRACT

This study explores the technique that obtains the 3D contour of a human form using the reverse engineering method on a dummy (or) mannequin. The purpose of reverse engineering is to create a Computer Aided Design (CAD) model based on the physic of existing objects. The mannequin is scanned using a Computer Tomography (CT) scan machine. The point clouds captured by a CT scan machine are used to reconstruct the 3D model of the human body. The scanned data is taken as an input to Materialize Interactive Medical Image Control System (MIMICS) software which creates slice by slice model from CT scan data. The structural model of the body can be utilized for varied purposes like Pattern making for moulds, checking the fitness (sizes) of the produced garments, determine the volume of the sculpture objects, estimating human body surface area, and exhibiting (show case) the garment.

**Keywords:** Physical to digital approach (reverse engineering), Human body Modelling, Surface Reconstruction. Point Clouds, mannequin

## 1. INTRODUCTION

The reverse engineering (RE) method is the simplest and commonly used in modelling a sculptured object. As products become more complex in shape, designing the CAD model will become more challenging and there is no guarantee that the CAD representation will replicate the sculpted model exactly as it was built. The physical-to-digital process provides a solution to this problem, as the existing physical part is the source of information for the CAD model, as shown in Figure 1,


**Figure 1**: Reverse Engineering

In reverse engineering, the geometric model of the human body part is created from a cloud of points, which is obtained from a CT scan machine based on the physic of the existing object. The point clouds captured by the CT scan machine were utilized to reconstruct the 3D surface model of the human body. The CT image is a pixel map of linear X-ray attenuation coefficients of the soft tissue. The surface model development is carried out by using the captured data from CT images and then converting it to a CAD model with the help of MIMICS (Materialize Interactive Medical Image Control System) software. CT scan properties were 0.5-mm resolution and 1-mm slice spacing (thickness).

### 1.1 Software and Hardware Used in This Work.

- High-resolution computerized tomography (CT) scan machine
- MIMICS software
- Geomagic

### 1.2 The advantages of this method are:

- It records the complete information, not only the sizes of the object but the exact shapes of the object are also obtained.

- RE method gives efficient and accurate measurement compared to the traditional methods
- Reduce product development cycle times.
- Improve documentation shortcomings
- Part changes done without design documentation

## 2. LITERATURE REVIEW

SHI Xiu-jin et al. (2012) propose one new method to generate a personal virtual mannequin by capturing the 2D digital photos of customer's body characteristic information, and then some human body part templates corresponding with the customer are selected from the templates library. Finally, these templates are modified and assemble.

Tong et al. (2012) used three Kinect sensors to collect the 3D data from different parts of the human body and perform pair-wise non-rigid registration and global registration iteratively to combine the data sets collected in different time instances. A full human body can be reconstructed after registration.

Ko et al. (1994) propose a method to model a human face from a set of points. The discussion concentrates on the re-organization of the points, facet modeling and tool path generation in order to create a feature model of an object from a point cloud, the embedded features must be recognized. These features are then used to constrain the fitting process.

Chen Mao et al. (2009) presented a new approach, which has been implemented into Virtual Human Sketcher (VHS), a prototype system with a sketching interface, enabling anyone who can draw to sketch out 3D human bodies of various body sizes, shapes, and postures. The VHS allows freehand sketch input including multiple/overlapping strokes, foreshortening, occlusion, and drawing imperfections

## 3. METHOD

The primary source of reverse engineering data for the present work is high-resolution computerized tomography (HRCT) scan data. The approach taken in this paper requires an existing physical object from which the 3D digital CAD model is to be obtained. The post-processing data from high-resolution computerized tomography DICOM (Digital Imaging and Communications in Medicine) were then imported into MIMICS version 10 medical image processing software. The images were segmented and the point clouds of the mannequin surface were obtained. The point clouds were converted into surface models with the help of the software package Geomagic Studio software. Figure 2 shows the flowchart explaining the strategy for scanning and converting the scanned data into a 3D surface model.

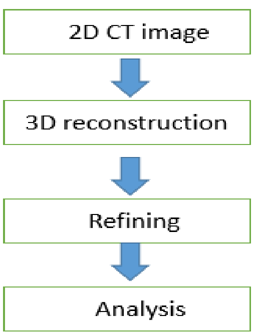


**Figure 2:** Flow chart of generating 3D virtual mannequin

### 3.1 CT Scan Images

The scanning strategy involves preparing the part to be scanned and performing the scanning to capture information that describes all geometric features of the physical part. Three-dimensional scanners (CT) are employed to scan the part geometry, it producing clouds of points, which define the surface geometry. A computer creates separate images of the body area, called slices as shown in figure 3 of thickness 1mm. These images can be stored, viewed on a monitor, or printed on film with the help of DICOM (Digital Imaging and Communications in Medicine): It is a standard for handling, storing, printing, and transmitting information in medical imaging. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format. It is used as an open format in mimics, the most common image format.

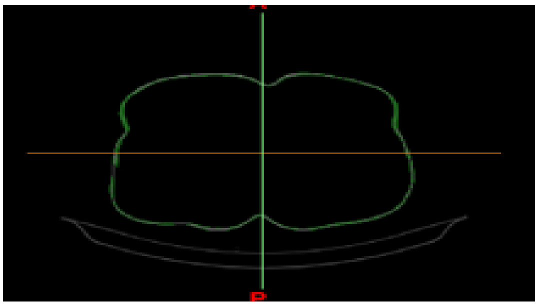

**Figure 3:** Slice 300

**Model generation**

MIMICS, the medical-based image processing software for 3D design and modelling, is used for the pre-processing of the CT images as well as for exporting the point cloud data. Mimics is used to create a 3D model from stacks of 2D image data (three-dimensional models of the body area can be created by stacking the slices together) as shown in figure 4. These 3D models can then be used for a variety of engineering applications. The ROI, selected in the segmentation process is converted to a 3D surface model using an adapted marching cubes algorithm that takes the partial volume effect into account, leading to 3D models.

Output file formats differ, depending on the subsequent application: common 3D output formats include Streolithography (STL), VRML, PLY and DXF. The 3D files can also be optimized for Finite Element Analysis (FEA) or Computational Fluid Dynamics (CFD) and can therefore be exported to Abacus in INP format, to Ansys in CDB format, to past ran in BDF format. To continue with Computer-aided design, the files can be exported in Initial Graphics Exchange Specification (IGES) format or as Point cloud. The 3D model is developed using the following feature:

## Windowing

It is adjusting the contrast of the images displayed in the different views. Contrast enhancement is a very good tool for selecting parts with different intensities.

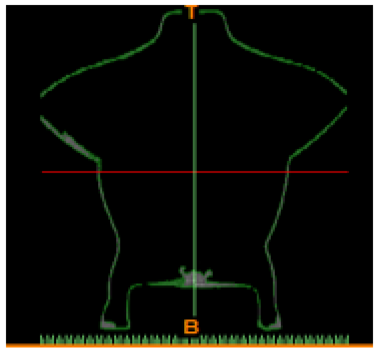


**Figure 4(a):** Front View

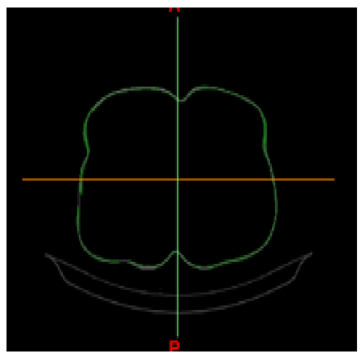

**Figure 4(b):** Top View


**Figure 4(c):** Side View

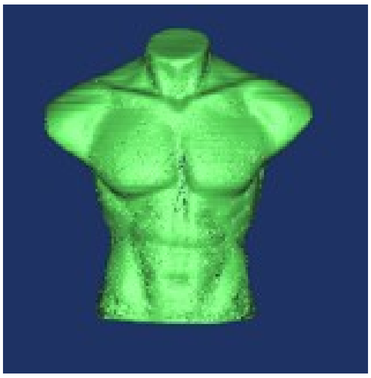

**Figure 4(d):** 3D Model

**Figure 4:** Mimics Model

**Image cropping**

CT images are imported into the MIMICS environment. The slices are cropped after observing 2D and 3D views to demarcate the region of interest. This is necessary to limits point cloud data and to avoid unnecessary noise.

**Segmentation**

Slice by slice fills the cavity result of image segmentation is a set of segments that collectively cover the entire image or a set of contours extracted from the image Each of the pixels in a region is similar with respect to some characteristic or computed property, such as colour, intensity, or texture. When applied to a stack of images, typical in medical imaging, the resulting contours after image segmentation can be used to create 3D reconstructions with the help of interpolation algorithms.

**Thresholding**

It means that the segmentation object (visualized by a colour mask) will contain only those pixels of the image with a value higher than or equal to the threshold value. The segmentation mask contains all pixels between these two values. A low threshold value makes it possible to select the Soft tissue of the scanned patient. With a high threshold, only the very dense parts remain selected.

**3.2 Conversion into STL file format**

Image data export: After thresholding, soft tissue pixels are exported as a text file that contains the geometric data, as well as the image intensity data. Point cloud data of the human body model is extracted from MIMICS and it has been imported in Geomagic for surface generation

**Model Refining**

Geomagic software products have focused on the process of 3D capture into usable 3D data so that the models can be used in engineering, product design, and medical procedures. Geomagic Studio is a product of Geomagic; it is the complete toolbox for transforming 3D scanned data into a highly accurate surface, polygon and native CAD models.

A vital component in a range of manufacturing workflows, Geomagic Studio provides the industry's most powerful point cloud editing, mesh editing, and advanced surfacing functions in an intelligent, easy-to-use application. . For reverse engineering, product designs, rapid prototyping, analysis and CAD export, Geomagic Studio is *the* core 3D creation tool. The main feature of Geomagic includes are:

**Wrap:** Point cloud data of the human models are imported in Geomagic Studio as IGES file format from MIMICS software. Then point clouds are converted into a polygon.

**Mesh Doctor:** It is used to identify the scan errors in the model and some of the errors are listed below; Non-manifold edges, Self-intersection, highly creased edges, Spikes, Small components, Small holes. Then these are rectified and then corrected as shown in figure 5.

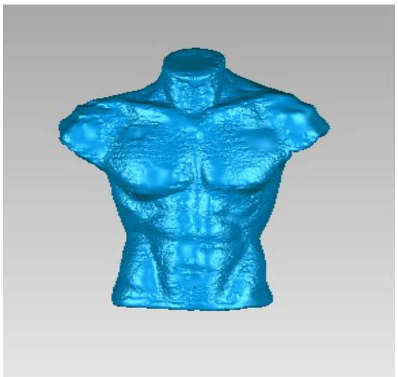

**Figure 5**: Rectified Surface model

**Exact Surface**: The exact surfacing tab contains tools for the conversion of a poly mesh to a CAD face that reflect the as build part. This workflow generates surfaces that match the object exactly as it is constructed. The output from Geomagic studio is highly accurate surface of 3D model as shown in figure 6.

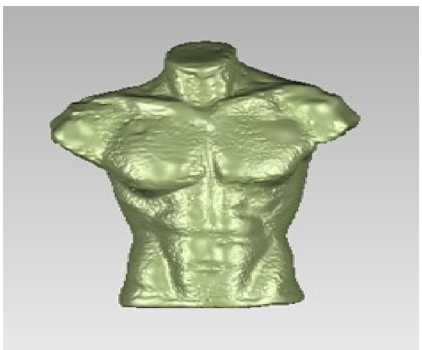

**Figure 6:** Geomagic model

## 4. ANALYSIS

The measurement was taken from the Geomagic software by using compute commands that calculate or measures the volume, Centre of gravity and total surface area. The volume and total surface area of the model were found as follows:

Volume of the model = $2.92*10^{-2}$ $m^3$

Total surface area of the model = 0.605 $m^2$

## 5. CONCLUSION

With the help of 3D scanning technology, the 3D surface model of the human body part was obtained from the CT images with minimal loss of integrity. Using thresholding option soft tissue were segregated and point clouds of human body part were obtained in MIMICS. Then the human body part point clouds are exported into Geomagic Studio where it was converted into surface models, the scanned errors were identified and corrected using the appropriate options and then the exact surfaces were generated that match the object exactly as it is constructed. The volume and total surface area of the model are $2.92*10^{-2}$ $m^3$ and 0.605 $m^2$ respectively.

The reconstructive approach generally builds the 3D body geometry automatically from existing shapes captured, this approach is referred to as the physical-to-digital process.

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