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Application of Reverse Surface Modelling in the Computer Aided Engineering Process

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***Abstract*—** *An important aspect of the CAE process is the development of a 3D design prior to the production of the draft representation of the design to be used for the process of product manufacture. The process of reverse engineering is used to produce a three-dimensional model directly from existing physical product without the need of design documentation. Reverse engineering is being applied mainly in the areas of product development, enterprise development and manufacturing technology across different sectors such as manufacturing, health care and engineering among others. This work involves the application of reverse surface modelling for the purpose of model reconstruction absent the developments of a CAD model. The successful completion of this work shows the versatility of the application of reverse engineering.*

Keywords*— *CAE, Reverse engineering, product development, CAD model.

I. INTRODUCTION

In the engineering industry, there are two established methods of the design and manufacture of a part or component. These methods are forward and reverse engineering. Forward engineering is regarded as the traditional method of engineering design and manufacture which involves moving from a high level of abstraction and logical designs to the physical implementation. This is the method of engineering which most engineers are familiar with. As opposed to the formerly mentioned method, there is the second method (reverse engineering) in which there exists a physical part or component with little or no technical details such as drawings or bill of materials or any other relevant data. Here, the objective is to replicate an existing part without any form of data except the part to be replicated. Fig 1 illustrates the engineering process flow

Fig.1 Engineering process flow

Reverse engineering can have defined more clearly as the process of obtaining a geometric CAD model from the 3-D points acquired by scanning/digitalizing existing parts or products [1]. By virtue of this definition, reverse engineering has been applied not only in engineering. Other areas where reverse engineering is being applied are, sculptors, jewelry design, medical engineering, dentistry among others. Reverse engineering is not only used to replicate a part, but where possible aims to improve the part.

1.1. Reverse engineering Process

Reverse engineering is regarded as a process which consists of three phases. These phases are scanning, point processing and application specific model development. Fig 2 refers to the reverse engineering methodology postulated by [1].

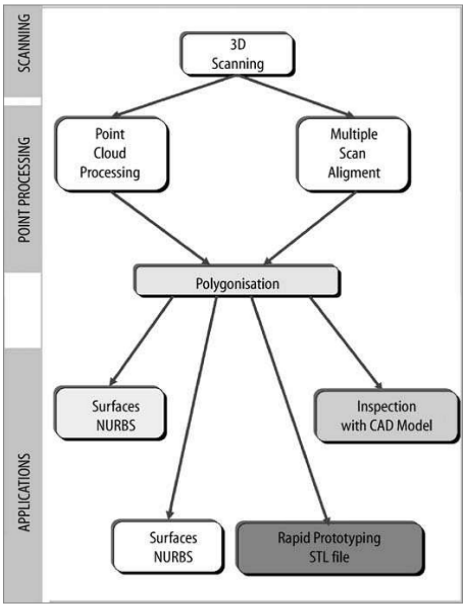

Fig.2 Reverse engineering process

Source; [1]

1.1.1. Scanning

This is the first phase of the reverse engineering process which involves the use of a three-dimensional scanner to scan the geometry with the aim of producing a cloud of points which defines the surface of the said geometry.

There are two distinct types of scanners used for this process, the contact and non-contact scanners.
As the name implies, the contact scanners performs the scanning operations by having some form of contact with the surface of the geometry. This type of scanner performs the scanning operations with the aid of probes that follow the contours of the surface of the geometry being scanned. The non-contact scanners scan the surface of the geometry without having any form of contact with the surface of the geometry. Non-contact scanners use lasers, optics and charge-couples' device (CCD) sensors to capture point data. Non-contact scanners have the advantage of being able to capture large amounts of data over a relatively shorter space of time when compared to the contact scanners.

1.1.2. Point processing

In this phase of reverse engineering, the noise is reduced, the numbers of points are reduced and finally the point cloud data are imported to be used in the final phase of the reverse engineering process. The aim of the point processing process is to obtain a clean merged point cloud dataset in the most convenient format for application in the specific model development phase. Different software exist which are used for this phase of reverse engineering process, they include; Geomagic studio, Agisoft, Metigo 3D among others.

1.1.3. Application specific model development

This is the final phase of the reverse engineering process which involves the generation of CAD models from the point cloud data generated from the scanning and point processing phases. The generation of CAD models from the cloud point data generated is probably the most complex activity within the reverse engineering process because a potent surface algorithm is required to generate surfaces that accurately represent the 3-D information described within the point cloud data sets products [1]. CAD software that can be used for this phase includes Siemens NX10, Solidworks among others.

II. LITERATURE REVIEW

There have been several applications of reverse engineering in several industrial sectors as highlighted earlier. This has caused different research endeavors for the application of surfacing techniques through the process of reverse engineering. This section attempts to review literature which x-rays different research conducted using reverse engineering techniques for surface construction of scanned data
In the paper 'from reverse engineering to shape engineering on mechanical design' [2], the fundamentals of shape representation, shape processing and mining at a conceptual, geometric and computational level to investigate the prevalent issues in the area of mechanical design. This research was conducted in an attempt to improve the body of knowledge in the area of reverse engineering for product development. This involved the proposition of the developed methodology that demonstrates the effectiveness of curvature-based vertex clustering on noisy modules. The framework proposed by [2] is based on the application of shape segmentation which is defined as the decomposition of a digitized product into meaningful sets of regions. The steps involved in shape segmentation procedure are discrete curvature estimation, boundary identification, vertex clustering, and connected region generation. This is illustrated in fig 3

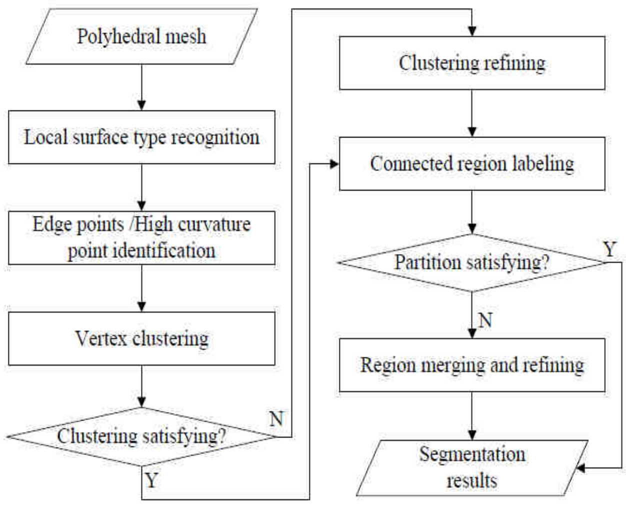

Fig.3: Shape segmentation framework

Source; [2]
In the same manner, research conducted by Lee and Park [4] explored the disassembly of a product for the purpose of obtaining and improved design. Based on the defined problem, a systematic approach was developed which was proposed from the implementation of an axiomatic design view point. The approach was created with the aim of obtaining a new design for a complex and large scale product. The reverse engineering method of axiomatic design was generated by [3] was adopted by Lee and Park for this work. As such, [3] defines the term axiomatic design as a methodology in design which employs the use of matrix methods for the purpose of transforming customer needs into functional requirements, process variables and design parameters.

III. SURFACE MODELLING

For the application of reverse engineering, the methodology described by [1] was followed systematically using the Geomagic Studios 2014 computer tool. The geometry shown in fig 4 was scanned to develop a cloud of point.

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Fig.4: Selected geometry

The completion of the scanning procedure led to the processing of the points to reduce the noise and subsequently the number of points generated from cloud. The last stage involves the generation of a surface for the geometry for the formation of the completed 3D model. These steps are detailed below

3.1. Scanning

The Faro arm laser scanner was used to scan the chosen geometry. Four different scans where performed each from a different angle in order to capture all parts of the geometry. This is due to the fact that the available scanner could only scan small sections of the geometry one part at a time. Fig 5 below represents the finished scans of the geometry.

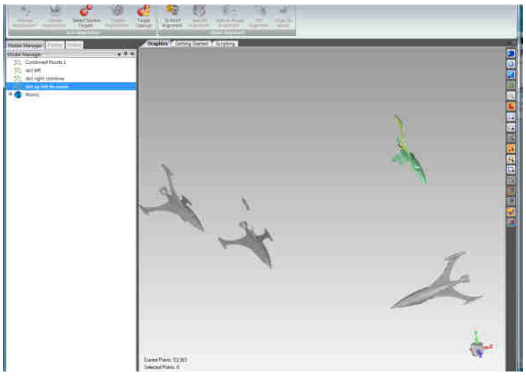

Fig.5: Completed scans

3.2. Point processing

The next step after the scans where generated on Geomagic studio 2014 was to merge the four different scans by picking three common points from all the scans in order to obtain the complete combination shown in fig 6.

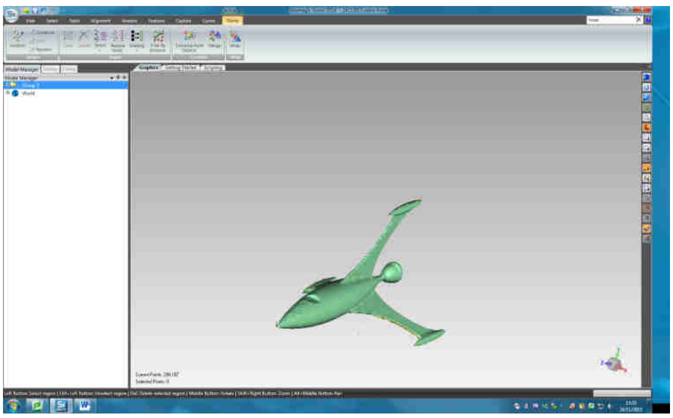

Fig.6: Completed scan combinations

The next step in the point processing was to reduce the number of point. This is a technique in reverse engineering adopted because most CAE packages are not designed to display and process large amount of data (points). After the initial scan and subsequent merge of the scans, the initial number of points was 298,187. The point was then reduced to 170,626 points.

3.3. Application specific model development

This was performed to obtain the required CAD model through the generation of surfaces inferred from the cloud of points obtained from the scanning procedure. The steps employed for the model development stage are itemized below

I. The point cloud data obtained were transformed into 3D polygon meshes. These meshes after being developed were analysed and based on the results of the analysis, irregularities such as spikes, tunnels, overlapping meshes and small holes were eliminated.

II. The removal of the iregualrities from the 3D polygon meshe during the correction process leaves holes behind. This results to those holes as seen in figure 7(b). The areas where the hole have been filled are represented by the red as shown in fig 7 (b).

(a)

(b)

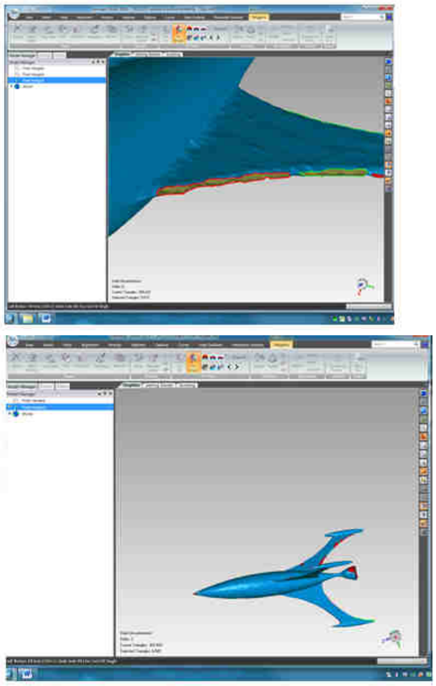

Fig.7: (a) Filling of the holes (b) After the holes have been completely filled

III. Patches are created on the 3d polygon meshes which is also analysed to check for irregularities.

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IV. After the above processes were completed, fig 8 (a) represents the complete surfacing from the cloud data points. The completed geometry is then saved in an IGES format to be exported to any other module for further editing, analysis and manufacture.

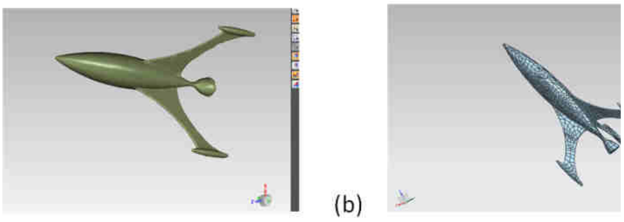
(a) (b)


Fig.8: (a) Completed surfacing on Geomagic (b) 3D model on Siemens NX for further operations.

IV. CONCLUSION

The applications of reverse engineering methods are endless as they eliminate the problem of CAD design from very complex geometries. As evident in this work, reverse surface modelling once successfully completed can be integrated into any Computer Aided Engineering (CAE) package for the purposes of further analysis, geometric editing and manufacturing.

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