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Use of Reverse Engineering in Medical Applications

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Abstract: The concept of Reverse engineering is used worldwide in industrial applications. This comprises of getting the geometric CAD model from the clouds of 3D points obtained by scanning existing components. Introducing the concept to medical applications requires specialized skills in both medicine and health as well as CAE (Computer Aided Engineering) applications. Many reverse engineering uses in medicine focused on building technologies around case studies performed in vitro and in vivo. This paper demonstrates an algorithm for applying the reverse engineering concept to medical applications. The research concentrate on developing different applications as well as other potential advances in the area of medicine and health with regard to in vitro applications.

Keywords: CAD modelling, 3D Scanning, Inspection, Rapid Prototyping, Medical applications.

INTRODUCTION

The definition of reverse engineering is described as "the method of duplicating an established component, subassembly, or product without sketches, documents, or model of a machine. Reverse engineering is also characterized as the process of obtaining from 3-D points a graphical CAD model acquired through scanning / digitizing actual parts / products [1]. The reverse engineering concept's principles are common and are used in various fields such as software engineering, film, aerospace, consumer products, microchips, electronics, mechanical designs and chemicals. That area adapted the definition to suit its specific needs and established specific technologies and tools.

In the manufacturing industry the idea of reverse engineering is mostly used throughout applications where models use materials such as cement, concrete, wood or clay to create the complex shapes of the component, but the part's CAD model is needed for manufacturing. These devices are very difficult to design using CAD tools, and sometimes impractical. Using reverse engineering the physical model created offers the template for the CAD software and is called the guide that includes all the necessary information. This technique is prevalent specifically in the automotive sector where designers try to build ever more complex forms.

In the area of health and medicine, one specific application of the reverse engineering principle is. As in the case of medical applications in the automotive sector, modelling parts often involve complex shapes which are hard to design using any kind of CAD software. Reverse engineering medical applications present particular needs for the devices and technology used. A cross-disciplinary approach requires the collaboration of both medical staff with specialized technical experience and engineers who is acquainted with the particular equipment and software needed. The reverse engineering medical applications focus on the areas of tissue and bone reconstruction, design of dental, orthopaedic prosthetics applications. Investigating other future reverse engineering uses

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in the area of health and medicine is a growing task for researchers worldwide [2].

Concept of Reverse Engineering:

Figure 1 illustrates the process of Reverse Engineering. With the help of CAD technology, the model can be constructed or duplicated (existing object).

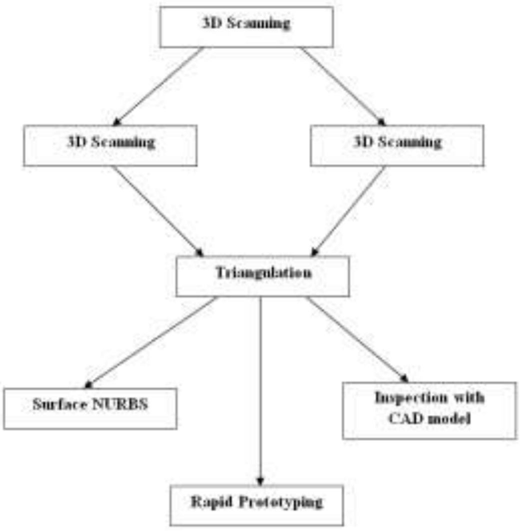

Figure 1: Process of Reverse Engineering

The major steps of the reverse engineering process assisted by the computer are:-Performing a physical object scan in 3D. This process commonly referred to as data capture involves collecting the XYZ coordinates of various space points and then representing the existing model as a point cloud. In some instances a registration process is necessary where several scans in a global coordinate system have to be synchronized. The digitized point cloud typically contains a lot of redundant points due to overlaps due to the nature of the scanning. In such instances the data set obtained is handled by sorting duplicate points [3].

The mesh is created through the point cloud. This method generally called triangulation entails creating a discrete image of an entity through a series of triangles that characterize the object. The triangulation accurately follows the contour of the scanned point cloud, without deviating from the collected point cloud by more than a given tolerance. Using triangles the triangulation approximates the object's shape and size. The result of smaller triangles is a better approximation of the shape at the expense of increased computational time [4].

CAD model generation: The surface is calculated from a mesh obtained by triangulating the cloud of points. The surface is not the actual CAD model but rather an approximate physical object model. In some cases editing is required to obtain the desired CAD model by eliminating certain physical model imperfections; Computing quick prototyping of the STL file. It is now possible to process the produced CAD model to create the STL file that is used by rapid prototyping techniques or to generate the NC code for CNC manufacturing [5].

Reverse Engineering in Medical Sector:

Because of the high cost of the equipment required, reverse engineering has been used primarily in mass-produced products. Medical applications require the production of one of a kind of parts that are tailored for each individual. That approach is labour intensive and quite expensive up to now. Digital models created for medical applications require the use of modern manufacturing systems to ensure accurate reproduction of the CAD model during the production process. In modern medical uses, new materials have been created that are more appropriate for the reverse engineering method relative to those used in conventional manual approach.

There are two kinds of medical applications which use techniques of the reverse engineering concept: in vivo and in vitro studies. In vivo experiments apply to tests that use living organisms to replicate the simulated model using X-rays, MRI (Magnetic Resonance Imaging) and CT (Computed Tomography) scans. Such non-invasive techniques allow the conduction of studies under natural conditions of living. The accuracy and precision of the virtual produced models is not as high as that which can be obtained through in vitro studies [6].

Studies conducted in vitro refer to research on samples that require preparation prior to scanning. In order to generate the virtual model, typically a 3D scanner is used to accurately trace the complex shape of the sample. The paper presents case studies and applications developed using samples taken from in vitro. Medical applications require specific requirements regarding the material being used as well as the steps involved in the process. The proposed algorithm by the authors presented in Fig 2 represents the major steps involved in developing reverse engineering application in the medical field. Complex forms require special fixing devices and surface preparation. In some situations, such as porous materials such as bone structure, a special lacquer is added to the target so that the surface is screened laser.

To obtain the point cloud, scan the target with a 3D scanner since artefacts have complex forms it requires a high degree of flexibility. To increase mobility one solution is to connect the laser scanner to a measuring arm. The mesh is computed using triangulation and the surfaces are generated. Generate and make changes to the CAD model as appropriate (e.g. restoration of the missing portion). Build standards for production using advanced CAM software; Prototype manufacture using either rapid prototyping or CNC fabrication. Checks the quality of the product made. The inspection phase guarantees that the constructed structure conforms to the requirements. Use of a physical model or CAD software to test and evaluate new materials or create other applications has been proved beneficial in medical sector.

Current hardware and software has evolved to the exactness and precision required for medical applications. Today's scanners will provide precision greater than 1µm. Through combination with simple to use tools, the structure and type of different parts of the human body can now be replicated. Health and dentistry reflect an area in which reverse engineering technologies may benefit. Medical products help us overcome disability and improve living standards. The design and manufacture of reverse engineering medical products is just one possibility to use the concept in the field of health and medicine.

The main applications where the reverse engineering concept in health and medicine can be applied are:-reverse engineering for the manufacture of injection molds for human foot prosthesis, development of educational material using the human teeth 3D CAD model,-generation of human bone 3D CAD models for finite element simulation and analysis,-reverse engineering to develop reverse engineering We can be done with detailed calculations surrounding the durability of these structures and materials [7].

Figure 2: Algorith, for using Reverse Engineering in Medical Field

The case studies presented highlight the ongoing efforts the authors have made to further explore the possibility of using currently available software and hardware to develop medicine and health applications. The hardware setup consists of a laser scanner of the Zephyr KZ50 (Kreon Technologies) attached to a measuring arm of the Cimcore Stinger II (Hexagon Metrology, Inc) for greater flexibility. The emphasis is on researching new ways of using aspects of the principle of reverse engineering for new applications.

Manufacturing of injection moulds of a human foot*:*

This case study reflects classic reverse engineering methodology. Beginning from an established prosthetics of a human foot, displayed in the center of fig 3, the aim is to create the prosthesis ' digital 3D image. This virtual model is then used to design and manufacture the molds for injection shown in fig 3. The first step of the process involves scanning the prototype prosthesis surface through a laser scanner. The Zephyr KZ50 (Kreon Technologies) laser scanner's high precision ensures that the shape generated is nearly identical to the original model [8].

As shown in figure 4 (a), the point cloud acquired after the scanning process is triangulated to create the mesh presented in figure 4 (b) using Dassault Systems' module Digitized shape editor in Catia V5. The obtained mesh is edited to fill the remaining holes and eliminate any artifacts generated by the 3D triangulation process. The finishing surface is generated from this triangulation. The Catia V5 software's Fast Surface Reconstruction Module is used to automatically generate the surface.

Figure 3: Injection molds and the original prosthetics in the middle.

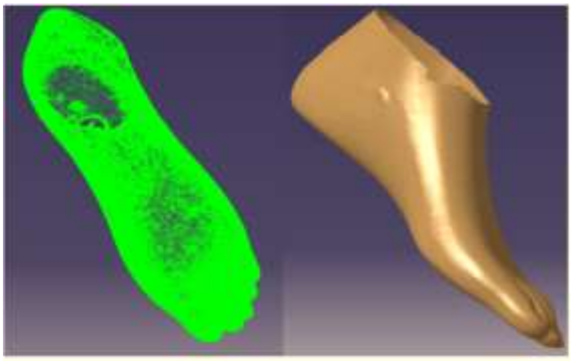

Figure 4(a): Scanned point cloud (left), (b) Traingulated mesh (right)

The resulting molds are shown on figure 5 Next to prototype original. The hardware and software used helps the development of the prototype's exact graphical model as well as the construction of the molds, first as a CAD model, then utilizing CNC processing to turn the model into the functional injection molds [9].

This program shows the opportunities that the current software and hardware infrastructure has to bring. Furthermore, utilizing specialized software such as Delcam's Shoe Design to update the CAD model will generate additional requirements such as custom-made sizes of foot prosthetics.

CONCLUSION

This paper presents the importance and benefits of using reverse engineering techniques and methods in health and medicine as well as case studies carried out by the authors showcasing applications in the field. Healthcare and dental services are areas of interest where elements of the concept of reverse engineering are implemented with great success. Technologies in these fields improve the overall efficiency, speed and accuracy of the distributed medical services. Shorter production times and mass customisation ensure that each patient receives a product tailored to their unique features.

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Applications in these areas improve the overall quality, speed and accuracy of the delivered medical services. Shorter production times and mass customisation ensure that each patient receives a product tailored to their unique features. Some of the traditional steps can be eliminated by using state-of - the-art hardware and software thus reducing costs and providing a shorter delivery time. To create an exact virtual replica of the physical model, reverse engineering can be used. To produce valid scientific results that match the results obtained through physical tests, this is very important for simulations and analysis.

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