

Developing the Custom Made Femoral Component of Hand Prosthesis using CAD/CAM

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Abstract: *The Femoral component is different for different patient. In this paper, Clinical experience and Engineering Knowledge was developed for the development of Femoral Component of Hand Prosthesis by integrating the approach of CAD/CAM technology. The image of the femoral component obtained according to the patient's 2D picture and the necessary constraints based on surgical experience were integrated. Designing of 3D Model is done in 3D Studio Max, one of the Autodesk Software. Rapid prototyped Model was fabricated as a reference for review. The patients upload their 2D picture and get 3D model in the software. Now through the application of CAM software the interference free tool path and cutter location file for multi axis NC machining are generated. The result of this work brings a change in the benefit in research and development.*

Keywords: 3D Modelling, Femoral component, Hand Prosthesis, NC machining, Rapid Prototyping.

1. Introduction

Imagine an artificial arm that moves naturally, that allows you to feel both the outside world and your own movements, and that is as strong and graceful as an intact, biological limb. Artificial limb replacement surgery is becoming more common as the population of the world. Worldwide, two millions osteoarthritis joints are replaced by artificial joints each year^[1]. The main reason of replacing is to eliminate the pain and improved the mobility by providing a support by artificial limbs. The goal of this paper is to develop a process that facilitates the use of such methods which is based on the Computer Aided Design techniques. Today so many new techniques are available by which an artificial limb is made. But in this paper, software is used named as 3D studio max in which 3D designing of any body part is easily possible. The animated view is created and then scaled to actual size. After that a rapid prototyping technique is used to create actual full scale model. Lastly the CAM techniques are used to manufacture the full scale model.

2. Literature Review

The introduction of CAD/CAM in medical is essential as the requirement of amputees growing worldwide. Among them, the use of CT images/ MRI reconstruction for 3D model to assist medical professionals performing surgery planning and guiding has the longest history and the most mature one^[2].

CAD/CAM in prosthesis is the way to find an optimal socket shape from information of stump. This is basically a computer aided socket design step. Then there are rational ways to manufacture the model. The last step is to modify the model after checking it on the stump.

Lee et al.^[3] presented an integrated approach of CAD/CAM for the concurrent development of custom made femoral stem and femoral component of knee prosthesis. The solid modeling, rapid prototyping, virtual multi axis machining are used in the system to establish the interface among conception, design and manufacture. The CAD/CAM techniques are applied to develop the complicated surface

and multi-axis machining by inputting a group of geometric data provided from surgeon. Then after Rapid Prototyping and Multi-axis NC Machining for the Femoral Component of Knee Prosthesis.

Lee et al.^[4] presented a Rapid prototyping and multi axis NC machining for the femoral component of knee prosthesis. CT/MRI images are used for generation of CAD model by taking CT/MRI images of each individual patient.

Chen et al.^[5] presented a CAD/CAM system for fabrication of facial prosthesis. This system integrates non-contact structured light scanning and reverse engineering with RP manufacturing technology. Three-dimensional data of the facial surface of a patient needing a facial prosthesis were obtained with almost no harm to his body.

Lee et al.^[6] presented the critical Dimension Definition of Femoral for Custom made Total Knee Arthroplasty by the application of Geometric modelling. Since the image format of CT/MRI cannot be read by CAD software, conversion software is needed to convert DICOM format into CAD readable format. Mimics, commercial software was chosen to do the format conversion.

Chen et al.^[7] develop the Custom-made Femoral Component of Knee Prosthesis using CAD/CAM. Mimics software was obtain the CT image to construct the complete knee actual 3D model and The CAD/CAM techniques are applied to develop the complicated surface and multi-axis machining by inputting a group of geometric data provided from surgeon. This Paper introduced new software to develop the 3D animated model of any body part. That Model will be fabricated by Rapid Prototyping Technique and final design is prepared with the help of CNC machines.

3. Geometry of Femoral Component

In theory, any part of the body from your ear or nose to finger or toe could be replaced by prosthesis. In practice, there are four common types of prosthetic limb, which replace either a partial or complete loss of an arm or leg.

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Below the knee (transtibial): A replacement lower leg attached to an intact upper leg. Above the knee (Transfemoral): A complete replacement leg. Below the elbow (transradial): A replacement forearm. Above the elbow (transhumeral): A complete replacement arm.

The 2D picture is taken as reference to built the three dimensional model. The dimensions of the hand can be set in any unit. This model can be scaled to actual scale model by changing dimensions and scaled by setting offset. Figure 1 shows the 2D image of hand. For the sake of convenience of making 3D, picture is taken from different- different angle mainly Front view, Left view, Right view and it is taken from a particular distance. Camera should have fixed focal length. By taking these pictures as a reference, 3D is designed.



(a) Front view of hand



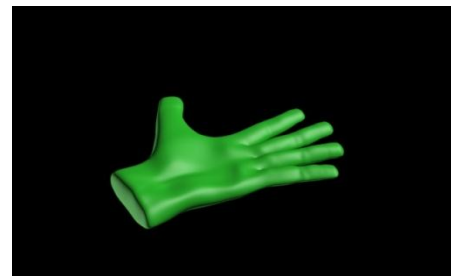
(b) Left view of hand

Figure 1: 2D picture of Hand

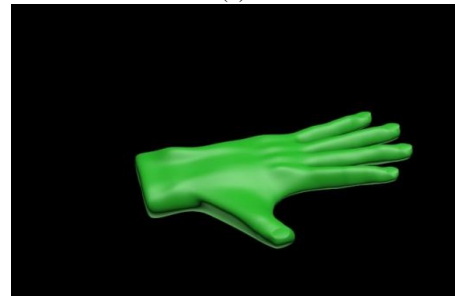
4. Creation of 3D Model using 3DS MAX

Here the Autodesk 3DS max is used to create the three dimensional model. With this software any 3D part of the body can be built shown in Figure 2. In this the 2D pictures are taken as a reference to create 3D model. The pictures are taken by camera. It should be keep in mind that camera has fixed focal length.

Here in the figure 2 (a), (b) the animated model of hand is shown which is made over 2D picture which is taken by itself by self adjusting camera having fixed focal length. Having fixed focal length helps us in designing 3D appropriately. And also we make sure that pictures are taken from a fixed distance so the right view and left view remains same in size.



(a)



(b)

Figure 2: Animated Hand model in 3DS MAX

Scaling is one of the most tedious tasks. Because from a 2D picture it is very typical to know that how much scaling is required? So picture is taken from a fixed distance so 3D modelling is appropriate. It is clear that 3D can be made in any unit (meter, centimetre, inches etc.). So according to the requirement the size of the limb can be changed.

To obtain a complete and view independent representation, several images (from different- different perspectives) depicting an object from multiple unknown viewpoints are acquired with a single camera. To estimate an object's scale the simple approach is to employ a single static camera. This single static camera is used to acquire two views of the object in different poses with known relative displacement. Then, the pose of the object in each view is determined. The two estimated poses can be used to compute the object's displacement up to the unknown scale because the camera is static. To ease the task of measuring 3D displacements, the object is placed so that it is aligned with the checkers of a checkerboard grid. Such a guided placement allows the distance between the object's locations to be known through the actual size of each checker^[8].

In 3DS max when right click on animated model, the scale option is shown in option panel list. Choose that option then another window will open in which absolute: local and offset: world can be adjusted.

For scaling the formula is used as follows:

$$\text{Actual length in particular axis (x or y or z)} = \frac{\text{Lenght in 3DS max (x or y or z)}}{100} \times x \quad (1)$$

From here the value of x is calculated which is equal to the value which is put in the offset bar in the scaling window. When this value is put in the offset then value in x, y or z directions are changed and the model is scaled to actual full scale model.

Prototyping or model making is one of the important steps to finalize a product design. It helps in conceptualization of Design. RP is a generic term for a number of technologies that enable components to be made without the need for conventional tooling in the first instance or indeed without the need to engage the services of skilled model-makers [9]. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models and models for engineering analysis.

Rapid prototyping is used to provide the actual full scale models. And that actual model can be made with the help of three dimensional Autodesk 3DS MAX model. This model is taken as a reference among surgeon. With this model surgeon plan the process and analyze the cost.

But the most important part is for generating an actual full scale 3D model; max file should need to be converted into the format which is acceptable by 3D printers and the file should be a stereo lithography file. There are so many techniques which are used for generating a rapid prototype model such as stereo lithography, selective laser sintering, fused deposition modelling, laminated object manufacturing etc. Rapid prototyping technique has abilities of enhancing and improving product development while at the same time reducing costs due to major breakthrough in manufacturing.

The rapid prototyping primitives provided actual full scale models that can be handled analyzed and used for future used. That rapid prototype model is discussed among surgeon and further modifications are done.

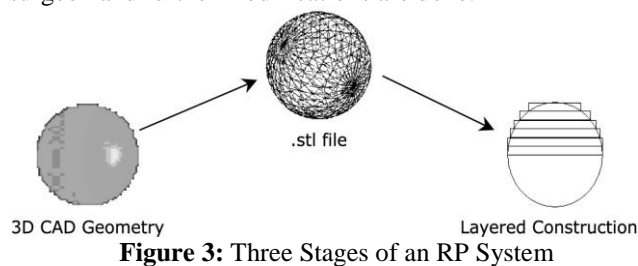


Figure 3: Three Stages of an RP System

Stereo-Lithography

A stereo lithography file is imported into rapid prototyping machine. In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a UV Helium-Cadmium or Argon ion laser [10].

The laser scans the first layer and platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation. The new slice is then scanned.

In new SL systems, a blade spreads resin on the part as the blade traverses the vat. This ensures smoother surface and reduced recoating time. It also reduces trapped volumes which are sometimes formed due to excessive polymerization at the ends of the slices and an island of liquid resin having thickness more than slice thickness is formed. Once the complete part is deposited, it is removed from the vat and then excess resin is drained. It may take

long time due to high viscosity of liquid resin. The green part is then post-cured in an UV oven after removing support structures.

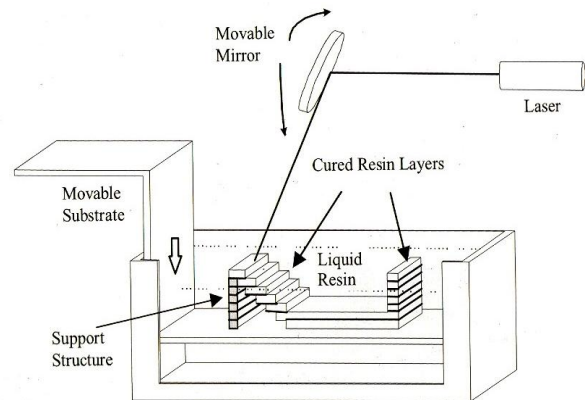


Figure 4: Stereo-lithography

6. Exporting .max file to .stl file

The model in Autodesk 3DS MAX can be made in any of the unit and after that it can be scaled to actual size. This software store the file in .max format which need to be converted into (stereo lithography) .stl file format for 3D printing which can be done by exporting the .max file to .stl file. To check that whether this stereo lithography file will feasible (it is correct to be print or this file contains not any errors) this software contains an option named as STL check modifier which show any errors if found in error panel. These errors are removed and now stereo lithography file is ready to be print.

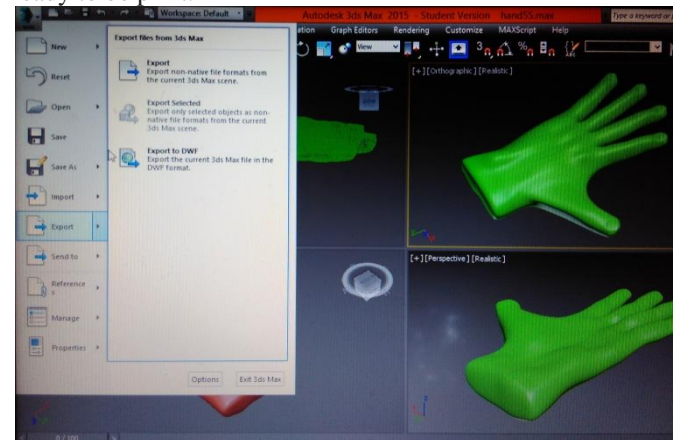


Figure 5: Exporting .max file to .stl file

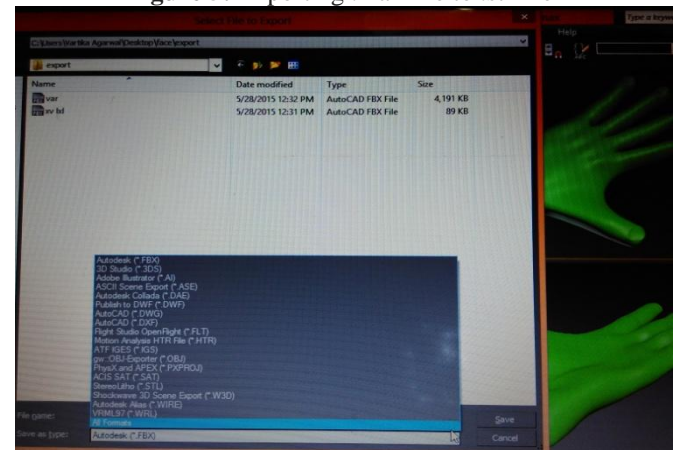


Figure 6: Saving file as .stl file

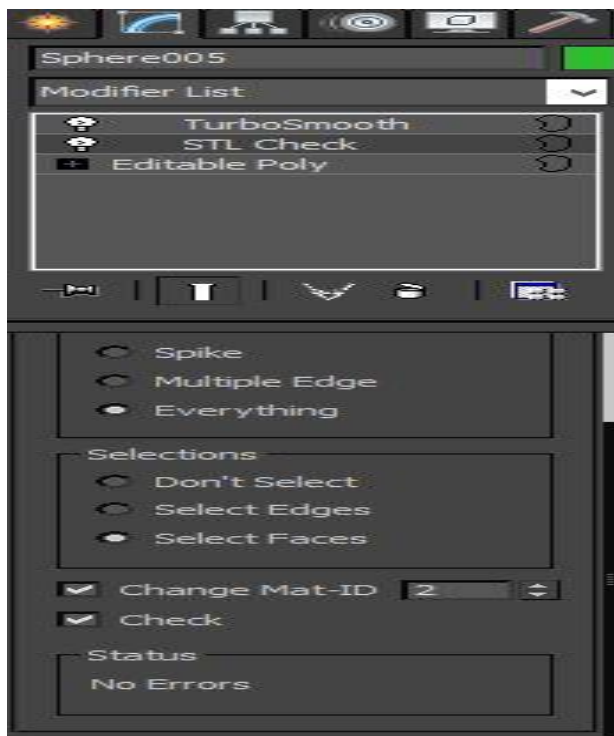


Figure 7: STL check modifier showing NO ERROR

After STL model files creation, first of all simulate the process of built prototype which is done in the Catalyst® software. In the model is automatically converted into sliced model [4].

7. CAM for the Femoral Component

The femoral component has to be machined on multi-axis CNC machine tools because the model is complex in shape. In the manufacturing module of Unigraphics NX software, Machining sequences and cutter location (CL) files can be created, which is the same CAD/CAM environment that the solid model was created in. In order to manufacture the femoral component, the design model was modified to become the work piece model for cutting simulation. Five-axis NC machining is widely used in the machining of aerospace parts, turbine blades, impellers, dies, molds and spatial cam. Five axis machining in the set up environment of manufacturing module for the femoral component, an alike femoral component work piece is built first and then assembled with the manufacturing model. The operation of multi-axis milling is used to machine the complex surface. In specifying tool orientation for multi-axis machining within CAD/CAM software, two constraints, i.e. collision and gouging, are the major consideration. The generated CL file can be verified through the function of solid cutting simulation built in this module.

The generated tool path is converted to the analytical NC code expression by the postprocessor, taking account of the kinematic description of the multi- axis machine tool. In this study, the postprocessor built by the UG/Post builder is used in this system to establish the interface between design and NC machining [3].

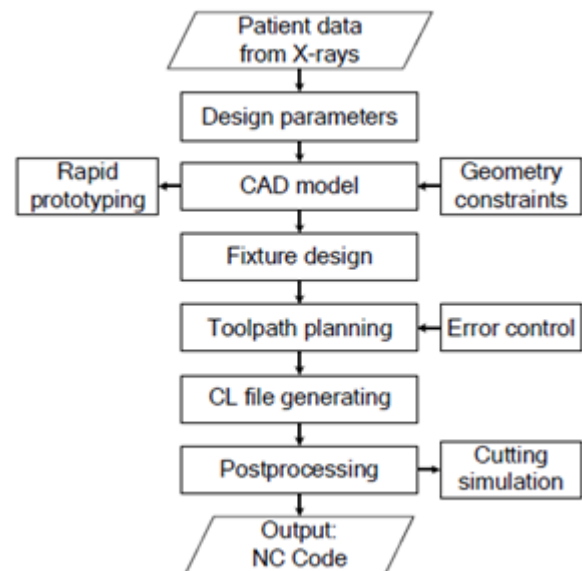


Figure 8: Flowchart of the integrated research for design and manufacture of femoral stem [3].

8. Conclusion

In this the integrated approach of CAD/CAM is presented. The rapid prototype model is used for review and discussed among surgeons. The 3DS MAX is used to design the 3D model only by taking the 2D pictures. So patients can upload their pictures and the 3D model is built according to that picture. The model can be scaled to any size or in any unit. So patients need not come to the hospitals. They just upload their pictures and 3D is made. After the same CAM techniques are applied to fulfil the design of complicated surface. This technique is used to get the actual model. The results are useful for the development of custom made femoral component of hand.

References

- [1] Huang B. W. Medical devices industry yearbook, Industrial Economics & Knowledge Center, Taiwan (2007).
- [2] Jacobs, N. A., Murdoch, G. (in press) Report of ISPO Workshop on Prosthetics and Orthotics in the Developing World with respect to Training and Education and Clinical Services. Moshi, Tanzania, 6-12 May, 1984. Glasgow: ISPO.
- [3] Jeng-Nan Lee1 and Kuan-Yu Chang2, "An Integrated Investigation of CAD/CAM for the Development of Custom-made Femoral Stem", Life Science Journal, Volume 7, No 1, 2009
- [4] Jeng-Nan Lee1, Hung-Shyong Chen1, Chih-Wen Luo1 and Kuan-Yu Chang2, "Rapid Prototyping and Multi-axis NC Machining for the Femoral Component of Knee Prosthesis", Life Science Journal. 2010; 7(1): 79 – 83(ISSN: 1097 – 8135)
- [5] Jin Sun Juntong Xi Xiaobo Chen Yaoyang Xiong, (2011),"A CAD/CAM system for fabrication of facial prostheses", Rapid Prototyping Journal, Vol. 17 Issue 4 pp. 253 – 261
- [6] Hung-Shyong Chen1*, Tsai Yau Bin M.D.2, Chyohwu Huang1, Jeng-Nan Lee1, Huang-Kuang Kung1 "The Critical Dimension Definition of Femoral for Custom-

made Total Knee Arthroplasty by the Application of Geometric Modeling”, Life Science Journal 2012; 9(2):196-201] (ISSN: 1097-8135).

- [7] Jeng-Nan Lee, Chih-Wen Luo, Hung-Shyong Chen, Huang-Kuang Kung and Ying-Chien Tsai,” Developing The Custom-made Femoral Component of Knee Prosthesis using CAD/CAM”, Life Science Journal 2013; 10(2)
- [8] Manolis Lourakis and Xenophon Zabulis, “Accurate Scale Factor Estimation in 3D Reconstruction”, CAIP 2013, Part I, LNCS 8047, pp. 498–506, 2013.
- [9] Pulak M. Pandey, “Rapid Prototyping Technologies, Applications and Part Deposition Planning”, 2006
- [10] <http://www.emeraldinsight.com/0144-5154.htm>

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