

## Cad Model Of Lower Limb Prosthese

Assoc. Prof. Dr J. Caloska , Assoc. Prof. Dr A. Kocov, Prof. Dr Lj. Dudeski  
Faculty of Mechanical Engineering, Ss Cyril and Methodius University, P.O. Box 464, MK-1001 Skopje,  
Republic of Macedonia

**Abstract:** Nowadays, in the rhythm of modern existence, the disability problem becomes more frequent restrictive cause for normal living of the man with disabilities. The development of technology and electronics enables everyday improvement of the living and working conditions of the men with disabilities. This work emphasizes the sophisticated techniques and technologies in orthopedics, the achievements in this area and the future developments. It focuses on the 3D digitalization with particular emphasis on the following items: 3D digitalization and modernization in the procedures and identification, and production of the orthopedic aids.

**Key words:** Digitalization, Orthopedic Aids, CAD technology

### 1. Introduction

Since the beginning of the history of mankind, people have been using different types of artificial devices as a replacement of the lost extremities. Archaeological findings and written documents confirm that the ancient people used to make amputations of extremities as a result of many wars and the law enforcement in that period. There are written historical data that were found 300 years BC, which describe rough prosthesis made as a replacement of the missing lower extremities. They were made from metal plates nailed on a piece of wood.

In the beginning prosthesis were produced by the blacksmiths and weapon manufacturers.

The earliest scientific data about prosthesis made and applied by a physician were published in France in 1579 in a book written by the French surgeon Ambroise Paré (1510-1590) where he describes prosthesis applied on a person on whom he had made amputation as a military surgeon.

The greatest development was accomplished during and after the Second World War. Then new and light materials, for that period of time (such as aluminum and plastic), were used for the production of prosthesis for the first time (Figure 1).

75 % of the causes for amputations are illnesses such as cancer, circulation disorder related to diabetes, while 25 % are accidents and very small part is congenital.



Fig.1 Beginnings of the applying prostheses

### 2. About 3D digitalization

3D Digitalization's first usage was for the needs of the military, or to be more precise, this type of technology was developed in NASA laboratories. The first thing that had been made was digitalization of objects into the

space as a research for their characteristics in a virtual environment.

The result of the digitalization is a classical data which actually represents “cloud of points”, that can be further processed depending on the requirements.

Basic resources (for digitalization) are scanners and cameras which are optical, with laser or sensors. The implementation of 3D Digitalization into the modern world solves more than the possible and the fields of its usages are unlimited. 3D Digitalization in the field of mechanical engineering and medicine is very important, as well as in the other fields and aspects of human life.

The development in the medicine has brought important results and relieving circumstances in diagnostics. Nowadays, diagnoses are not concluded only by the physicians, but are also based on objective photos produced by the modern equipment. Visual effects are so explicit that all of the organs are shown with the original shape, color and texture and the hotbed or the infected areas is shown in a different color.

Orthopedics is a particular part of surgery where the technologies of 3D digitalization and 3D modeling find their usage.

CAD/CAM technology is based on 3D programs, in where the possibility of a human error is minimized.

Today the reconstructive and corrective medicine is based on virtual reality. This actually is computer modulated displayed solution, where the patient rejects or approve the solution of the experts in medicine (Fig.2). Crime Scene Investigators (CSI) also uses the latest technology in 3D digitalization.

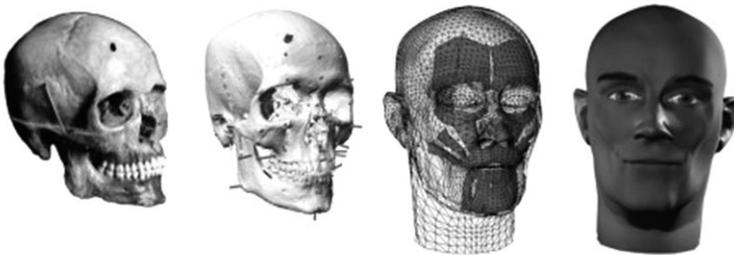


Fig.2 Examples of reconstructive medicine

In art, archeology and architecture this techniques are used for making copies of existing models as a result of removing or restoration. The examples of making copies are the stone plates from churches, family graves, archeological findings, fountains, historical and cultural monuments etc.

### 3. Characteristics of ATOS II

The camera ATOS II is a leading product in this field and is used for 3D scanning surfaces. It's produced by the German company GOM mbH, which was founded 1990. The basic activity, expressed in the name of the company (GOM mbH – Gesellschaft für Optische Messtechnik), is production of optical measuring technique such as 3D scanners (digitalization), and also 3D coordinating measuring machines.



Fig.3 ATOS II

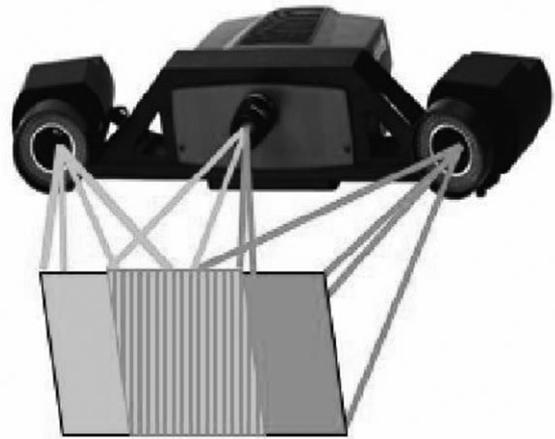


Fig.4 Sight area of ATOS II

As you can see on Figure 3, this system is consisted of: Source of light-projector (position 2) and 2 photosensible devices-cameras (position 1 and 3). With two cameras ATOS II is one of the best scanning devices on the market. On Figure 4 is shown that the lightened area is larger than the sight area of one of the cameras.

The first camera films one part of the lightened area and the second camera the other part of the lightened area. The common area that both cameras are filming is useful data and on the picture is the area in the middle.

Solid Works 2007 is ultimate applicative software for construction and modeling in Windows surrounding. Solid Works is easy to learn and use. Except for modeling separate parts and their assembly elements in 3D, with Solid Works 2D drawing can be automatically done.

#### 4. Creating CAD model

The creating of a CAD model is the last stage in the technology of reversible engineering. This stage is longer and more complex then the whole process of reversible engineering. The main purpose is to analyze, research and to do simulations with the model. The creating of a CAD model could be made with any applicative software that works with “points of cloud” and surfaces.

The best module to work with surfaces is on the software pack CATIA. But it can also be done with similar software like GeoMagic, DELLCAM and CopyCAD. There is no written procedure that tells how to create a CAD model from “points of cloud”, so everything depends on the software, because every software works on a different point of generating surfaces.

The procedure of creating a CAD model with Solid Works is by using the tool “Scan to 3D”. The final result is created surface or solid model that can later be used for different purposes. When the Scan is opened (points of cloud), there is an option to revert it as a new document or to as an existing document.

##### 4.1 Reference points

Reference Points are transformed multiple points, calculated from the summary of different measures in one coordinate system. In the measuring picture, the diameter of the reference points has to be with dimension from 6 to 10 pixels.

In the Table 1 are shown the needed dimension of the points for related measured area. The type of ATOS sensor is very important for the choice of objects.

**Table 1. ATOS II**

Volume	Diameter of reference points
35x28x28 mm <sup>3</sup>	0,6 mm
45x36x36 mm <sup>3</sup>	0,6 mm
50x40x40 mm <sup>3</sup>	0,6 mm
65x52x52 mm <sup>3</sup>	0,6 mm
100x80x80 mm <sup>3</sup>	1,5 mm
135x108x108 mm <sup>3</sup>	1,5 mm
175x140x140 mm <sup>3</sup>	2 mm
200x160x160 mm <sup>3</sup>	2 mm
250x200x200 mm <sup>3</sup>	2 mm
350x280x280 mm <sup>3</sup>	3 mm
550x440x440 mm <sup>3</sup>	5 mm
800x640x640 mm <sup>3</sup>	8 mm
1200x960x960 mm <sup>3</sup>	12 mm

#### 4.2 The scanning of the prosthesis

The first idea was to try the possibilities of ATOS II camera in medicine.

Human Osteoarticular system makes the human body to stand up straight, something similar to Steel construction.

The scan has been made on already made model of human calf, given form made in Orthopedic and Prosthetic Center SLAVEJ ltd. Skopje. Before the start of the scanning process, a small points were marked on the model that gives all the attributes like depressions, humps, rounding's etc. The 17 scans are made from different angles with moving the model to the position because the camera is very precise and it is static (Figure 5).

The measured volume of the part is 200x200x270 mm. The closest dimension of reference point that is used is 350x280x280 mm. The diameter of the reference point is 3mm. Measuring distance is 750mm. Camera Lens are 17mm and projector is 12mm.

The scanned parts from ATOS II camera are saved as text document (\*.txt). With that extension those parts can be imported in Solid Works 2007 and that part in "cloud of points" can be viewed (Figure 6). Using the "scan to 3D" tool the time for making a more complex 3D model is reduced.

Main commands used for making 3D model are: Mesh Prep Wizard and Surface Wizard.

The final result is created surface or solid model that later can be used for different purposes. We are making a polygon from the model and all of the points have to be calculated in triangles with different density depending from the rounding of the model (Figure 7).

Then we use the tools "Spline", "Loft" and we concluded the layer drawing made on the "cloud of points" so we can get a surface model (Figure 8).

### 5. Model analysis

The making of the prosthesis starts with taking plaster cast model. Then we have the negative of the prosthesis and it is the base for further making of positive. With the positive we will make prosthesis from adequate material. This method is very difficult for the patient because the whole process, measuring and corrections are made on the patient.

The purpose of this is to use 3D digitalization and ATOS II camera to take measurements on the patient so there wouldn't be any need to make plaster cast model on the patient, any physical contact with the patient can be avoid and every modifications can be done with computer software. While making a 3D model of the prosthesis the time of making one can be reduced, because the 3D model can easily be transformed to a CNC machine that will make the model.

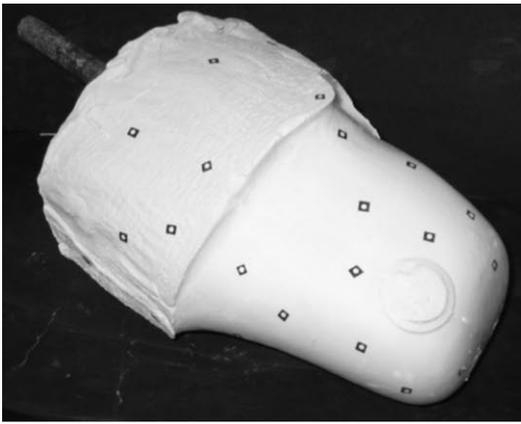


Fig.5 Preparing of the process of scanning

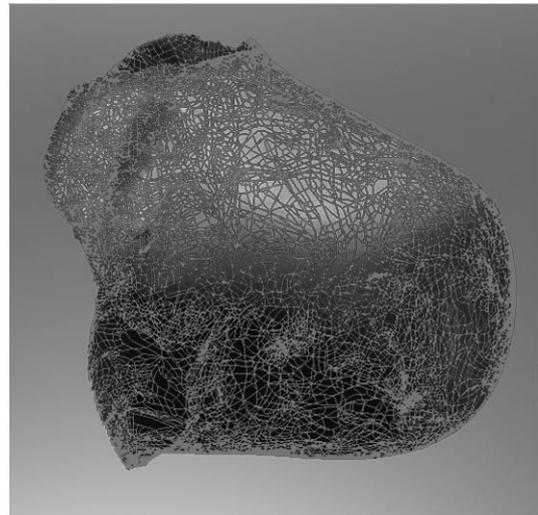
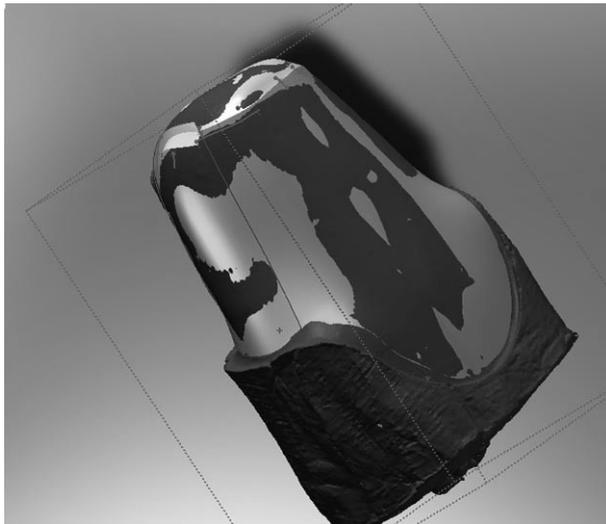


Fig. 6 Part of cloud of points

Fig. 7 Part made of triangles polygon

The time for scanning is approximately 1h 20 min and the making of a solid model takes several days. The time of making one prosthesis is 20 working hours (from taking measure to the first probe) and it gives the engineers a challenge to make faster and more efficient software that will reduce the time and give an optimal solution.

The software Solid Works is very sophisticated program and it is an answer to this challenge. However, there are still some problems in the process of making a solid model.

For a successful realization of this project the engineers need a software pack, technological solutions and experiences that will answer the requirements and the principles in orthopedics.

## 6. Conclusion

Team Work is the key to the gate called ‘successful project’. For successfully implementation of all new technologies and knowledge we cannot escape from the collaboration between medical and engineering experts, because the medical experts know what the engineers need in medicine and the engineers know how that could be done. The development of new technologies and the achievements make the dreams come true. The most medically developed countries are those countries that invest in knowledge, education and new equipment.

Nowadays the people with amputation are competing in races, drive bicycles, climb mountains and etc. Further development of production and applying of prosthesis reduces the gap between the functionality of prosthesis and human extremities.

One hundred years ago the crutch was revolution, today it is the micro processor controlled prosthesis. What about tomorrow?

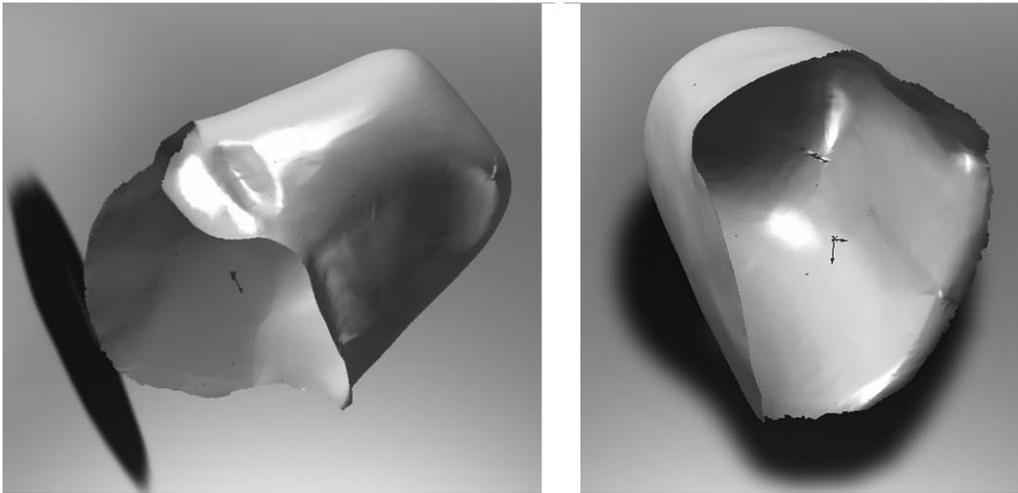


Fig. 8 Surface model

And finally with the tool “knife” we get the solid model (Figure 9).

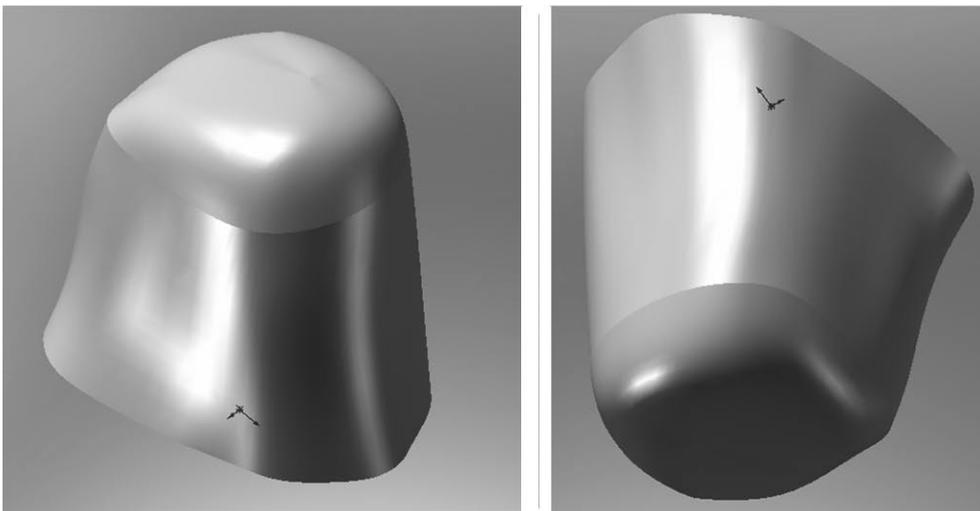


Fig. 9 Solid model

## 7. References

1. Brncick M: Computer automated design and computer automated manufacture, Department of Physical Medicine and Rehabilitation, Northwestern University, Chicago, Illinois, USA 2002
2. Trening tutorial ATOSII, 2007
3. Tutorial Solid Works, 2007
4. Wudblav N. Sankar, Josh A;brekston, Lawrence Lerman, Vernon T. Tolo, David L. Sklaggs: Scoliosis in-brace curve correction and patient preference of CAD/CAM versus plaster molded TLSOs, 2007
5. Smith DG, Burgess EM, The use of CAD/CAM technology in prosthetics and orthotics--current clinical models and a view to the future, University of Washington, Prosthetics Research Study, Seattle 98104, USA 2001