Intellectual Output_O1:
EMERALD e-book for developing of biomimetic mechatronic systems

MODULE 1
Computer Aided Design

Filip GÓRSKI, PhD, DSc, BEng, Associate Professor
Poznan University of Technology,
Faculty of Mechanical Engineering
filip.gorski@put.poznan.pl filip.gorski.employee.put.poznan.pl

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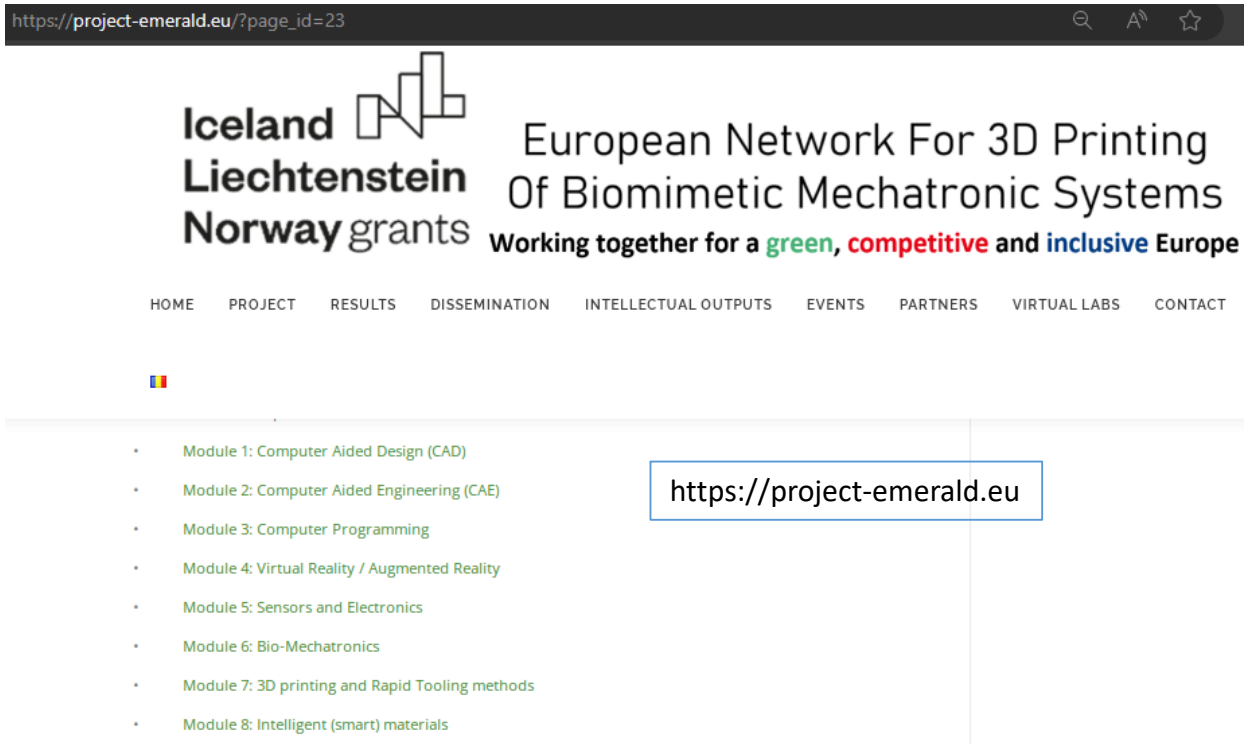
EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS - EMERALD



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EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS

MODULE 1 – CAD

Project Title	**European network for 3D printing of biomimetic mechatronic systems 21-COP-0019**
Output	**IO1 - EMERALD e-book for developing of biomimetic mechatronic systems**
Module	**Module 1 – CAD**
Date of Delivery	**July 2022**
Authors	**Filip GÓRSKI, Magdalena ŻUKOWSKA, Dominik RYBARCZYK, Roman REGULSKI, Remigiusz LABUDZKI**
Version	**FINAL VARIANT**

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Contents

CAD design of biomimetic devices

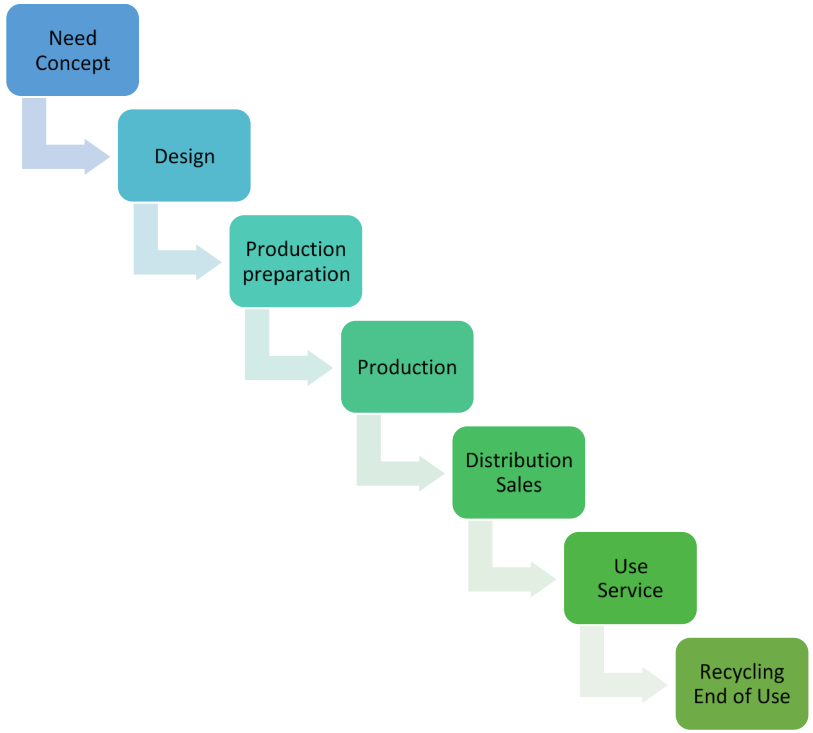

Figure 2.1 Product lifecycle stages including design

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Computer Aided Design (CAD) is use of computer technology to help the engineers prepare a design of a new or improved product.
3D modelling for the sake of this module, will be considered as a process realized in CAD software, focusing on formulating a three-dimensional shape of a designed product.

Figure 2.3 Biomimetic product example

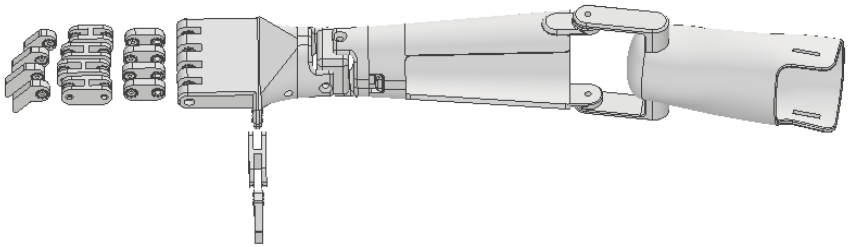

Figure 2.2 Parametric 3D model example – biomimetic arm prosthesis

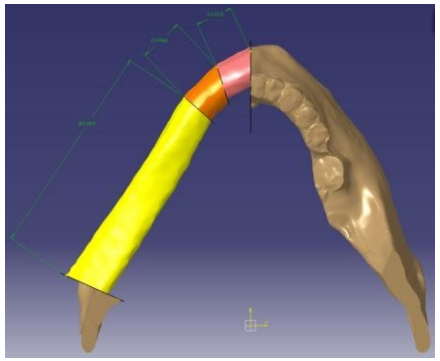

Figure 2.5 Hybrid modelling – CATIA software

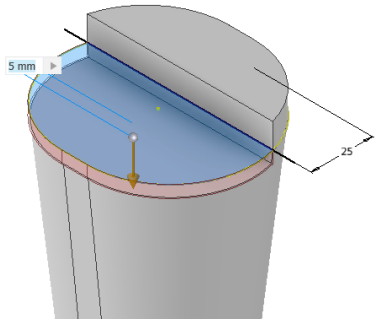

Figure 2.4 Solid modelling – extrusion, Inventor software

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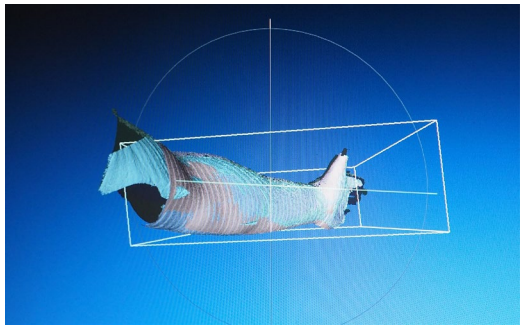

Figure 2.6 Mesh processing – human hand 3D scanned geometry

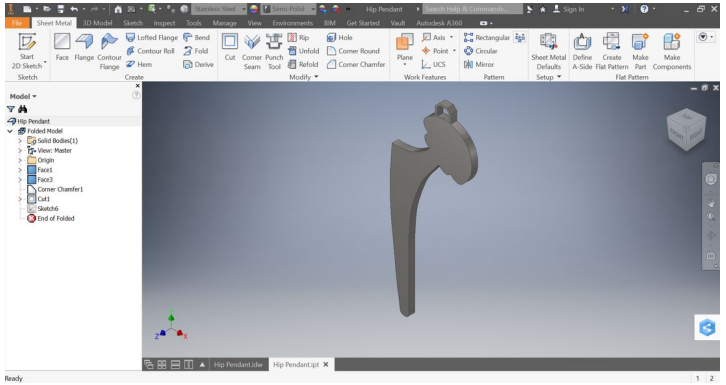

Figure 2.7 Inventor Window - hip

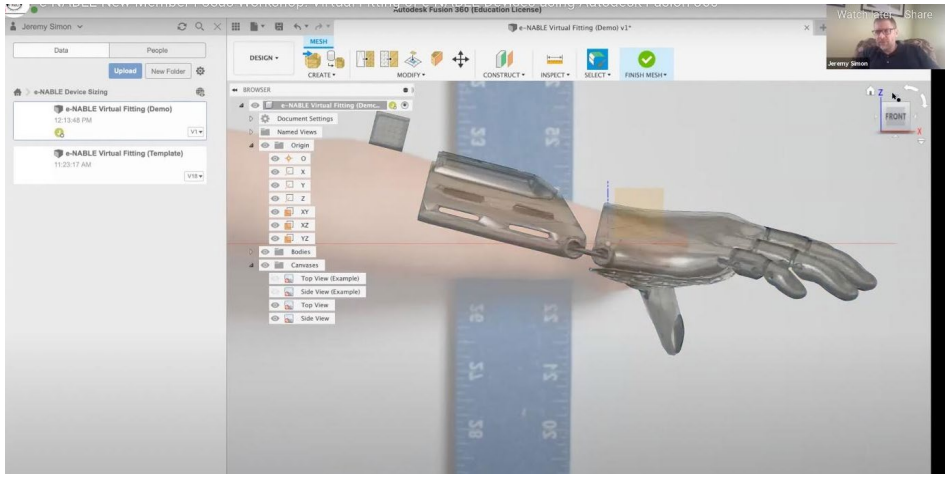

Fig. 2.8. Use of Fusion 360 for prosthesis design

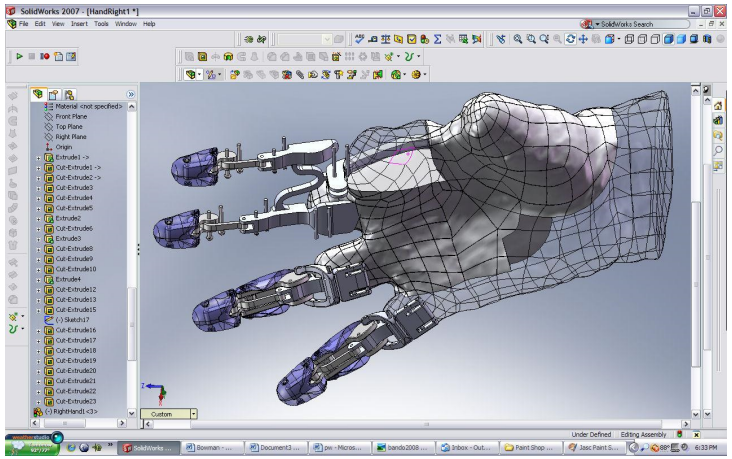

Fig. 2.8 SolidWorks window view

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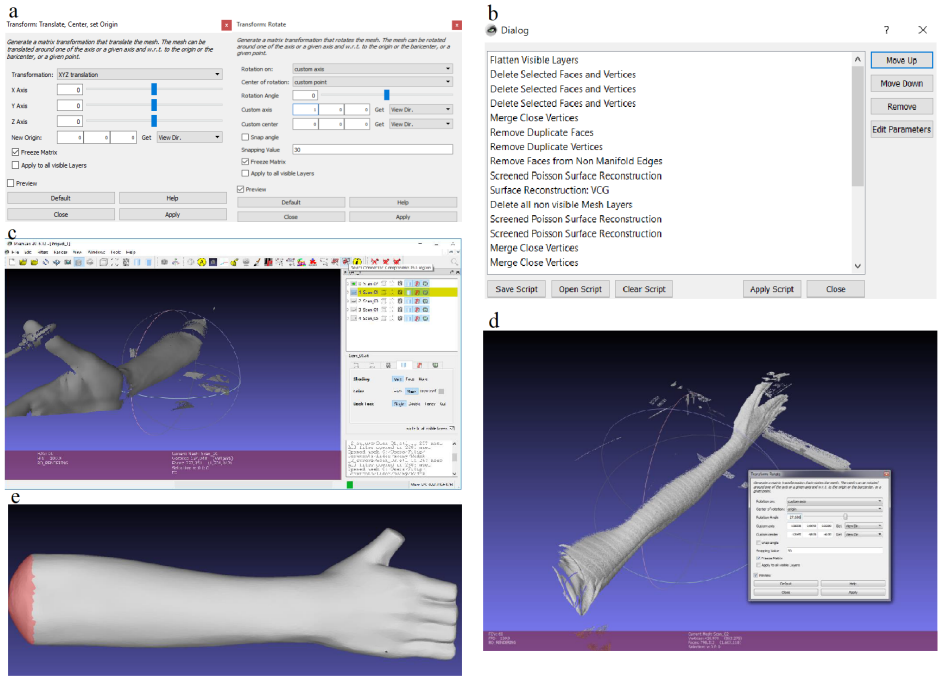

Fig 2.9 MeshLab exemplary features (a) translation and rotation operation, (b) list of operations, (c) mesh processing from the scan, (d) fitting two scans, (e) model after reconstruction

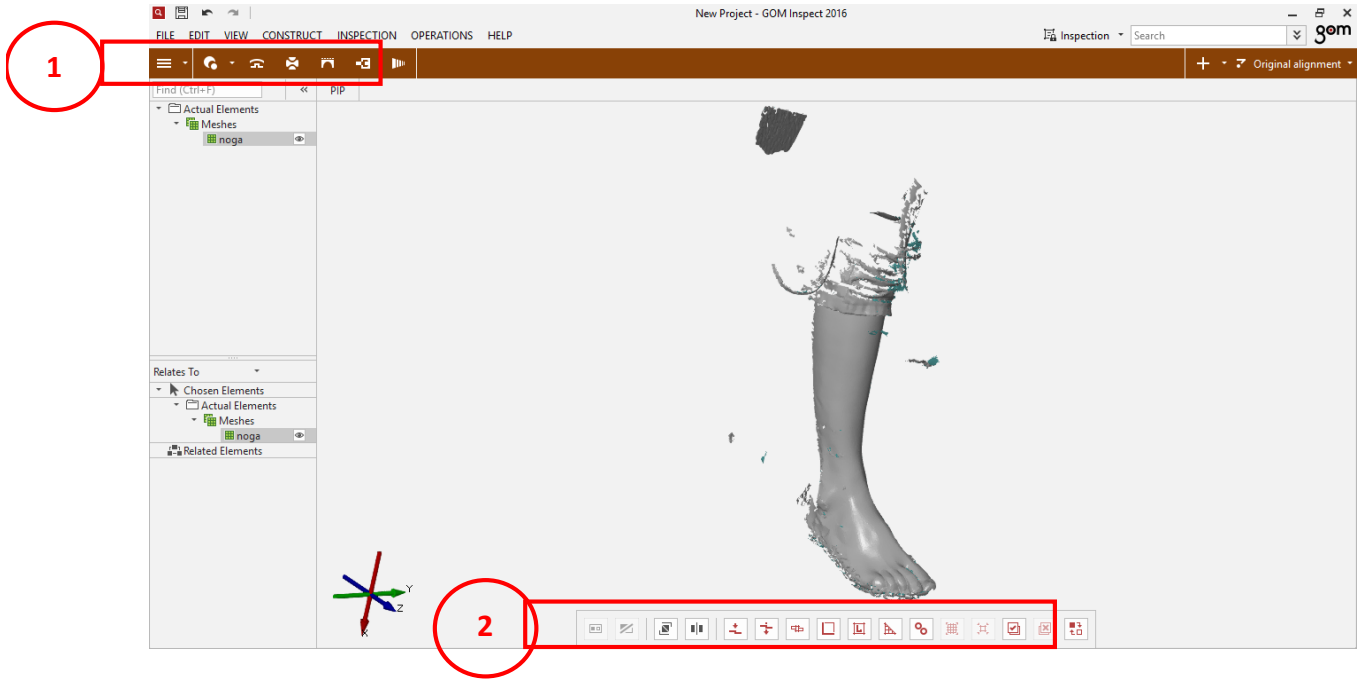

Fig. 2.11. GOM Inspect software interface

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Methodology of CAD design of 3D printed biomimetic mechatronic devices

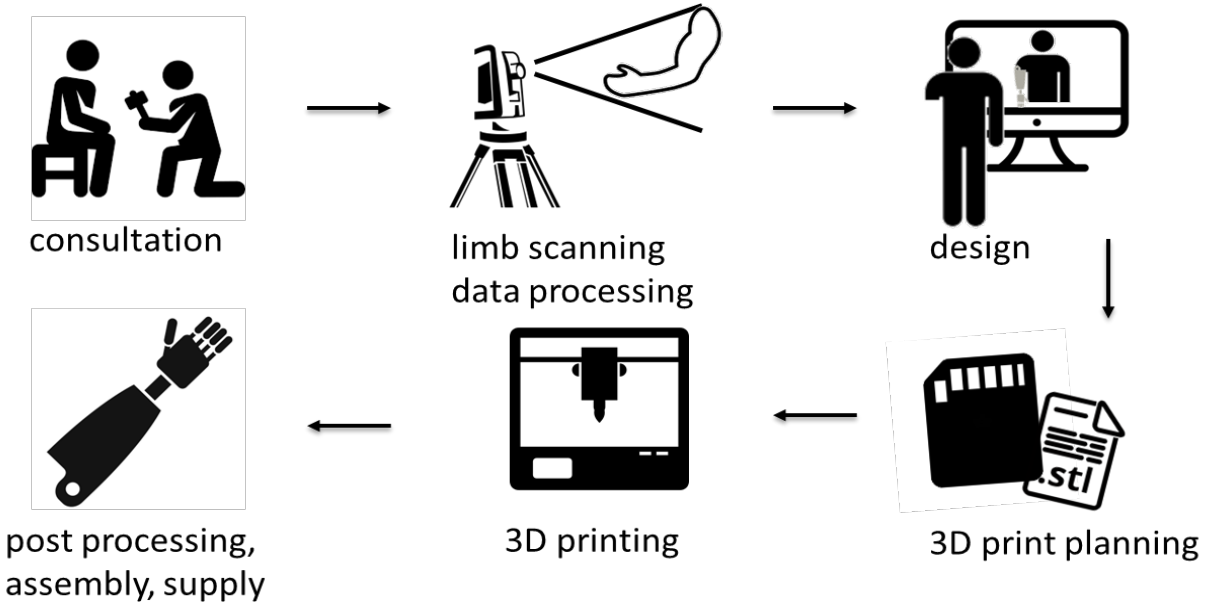

Fig. 3.1. Design and manufacturing of 3D printed anatomically shaped devices

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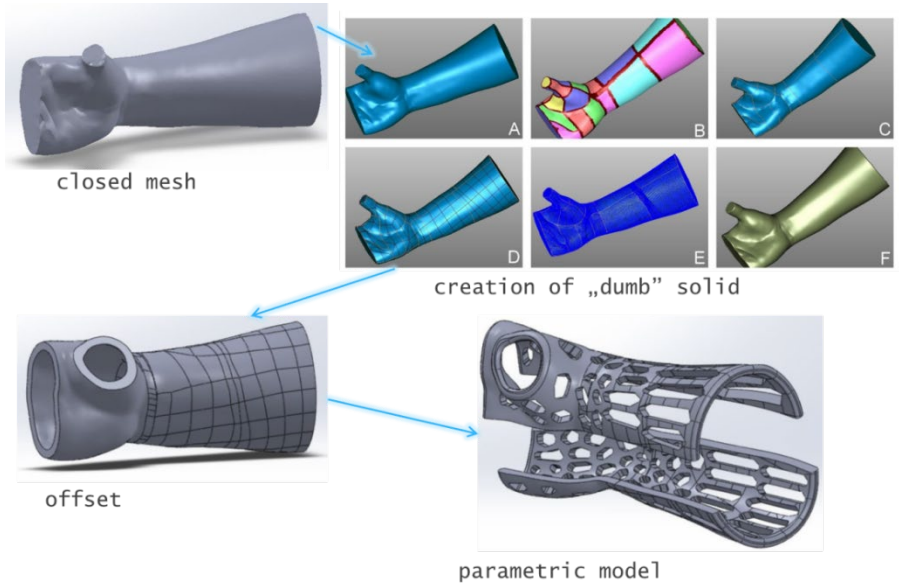

Fig. 3.2. "Shell" approach

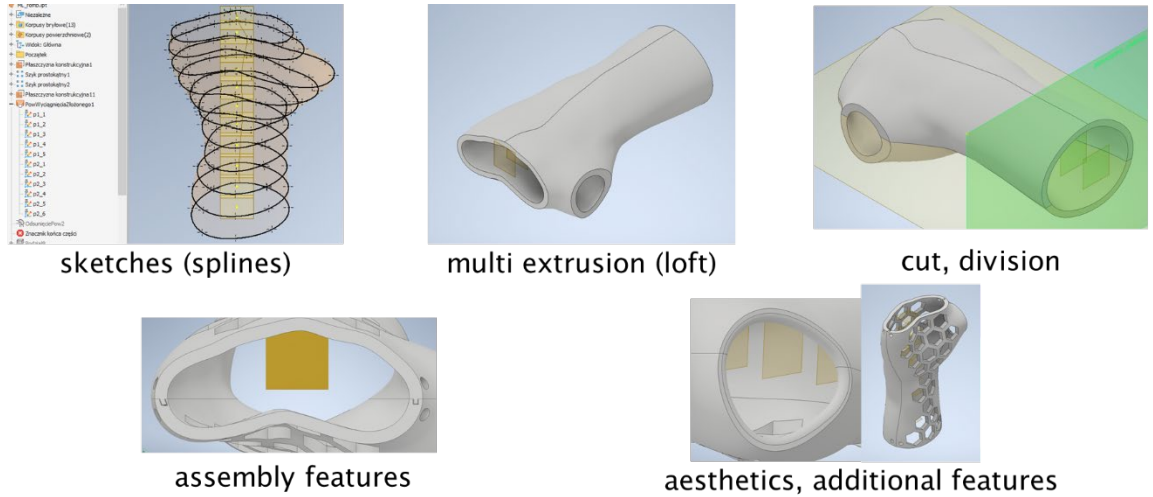

Fig. 3.3. "Spline" approach

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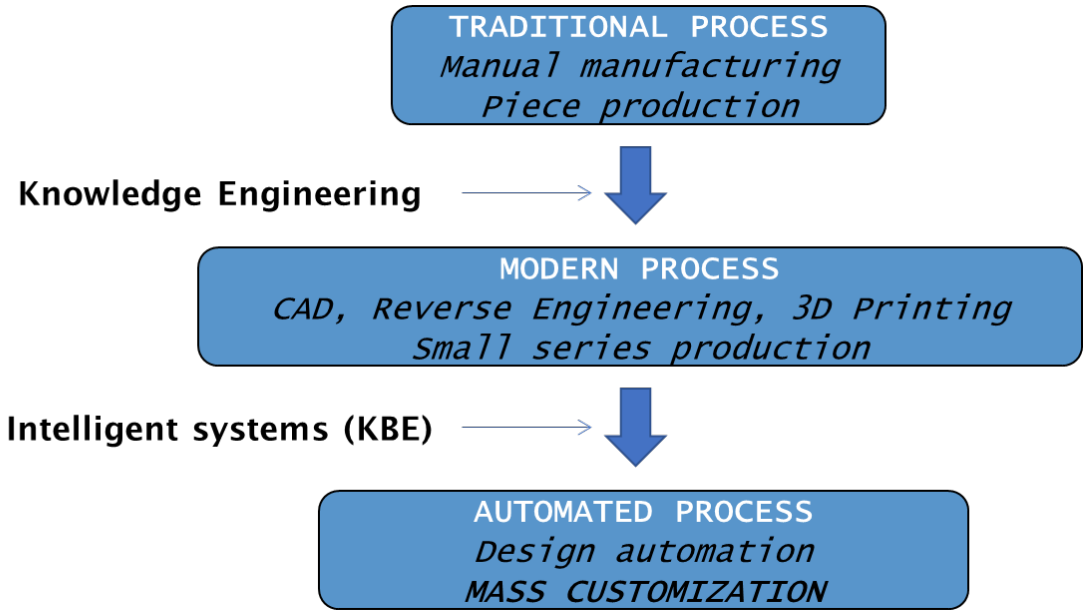

Fig. 3.4. Design automation – transformation stages

The central component of design automation is usually an intelligent model. Intelligent CAD model is a digital model, in which geometry is enriched with knowledge about:

- functional and structural features,
- relations between these features,
- rules describing selection of these features.

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CAD DESIGN

2 possible approaches in the design of anatomically fit devices:

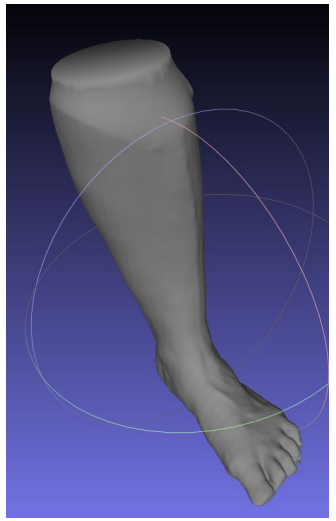
- **non-parametric ("shell")** - conversion of the mesh (e.g. of a hand) into a „dumb" 3D model,
- **parametric ("spline")** - parametric reconstruction of anatomy in the form of a surface or solid model using a series of closed spline curves obtained as a result of mesh sections.

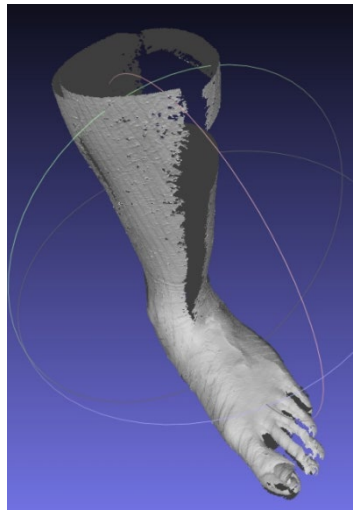
Data needed in the **"shell"** approach:

- complete, closed, „waterproof" STL mesh,
- characteristic distances - dimensions, distance range,

Data needed for the **"spline"** approach:

- a series of selected coordinates of points that control spline curves,
- characteristic distances - distances of planes with curves.





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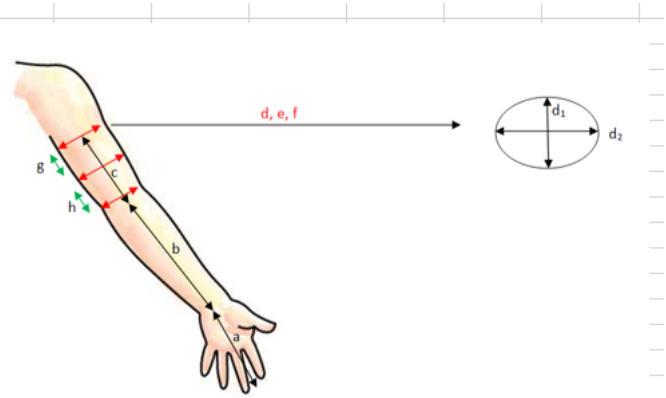
name	dimension	unit	
X1	110	mm	hand length "a"
X2	112	mm	don't change
X3	78	mm	don't change
X4	70	mm	don't change
promien_wew_C	17	mm	handle radius, don't change
wymiar_b	160	mm	forearm length (healthy limb)
wymiar_c	100	mm	arm length (stump)
wymiar_d1	70	mm	arm section 1 - bbox size y
wymiar_d2	60	mm	arm section 1 - bbox size x
wymiar_e1	60	mm	arm section 2 - bbox size y
wymiar_e2	60	mm	arm section 2 - bbox size x
wymiar_f1	60	mm	arm section 3 - bbox size y
wymiar_f2	55	mm	arm section 3 - bbox size x
odsunięcie	23	mm	offset value at the elbow



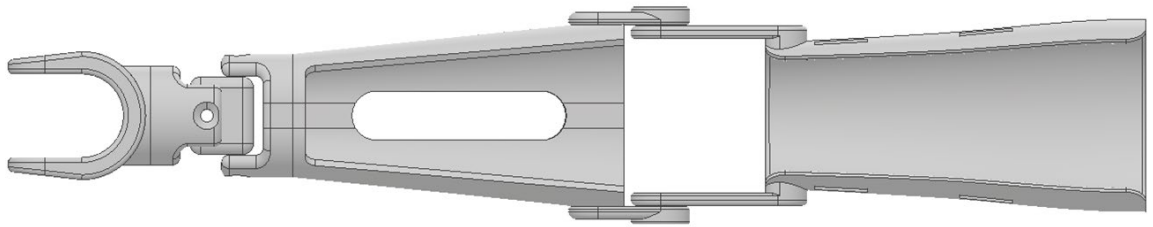


Fig. 3.6. Design table of an arm prosthesis

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CAD design of electronic circuits for mechatronic and medical purposes

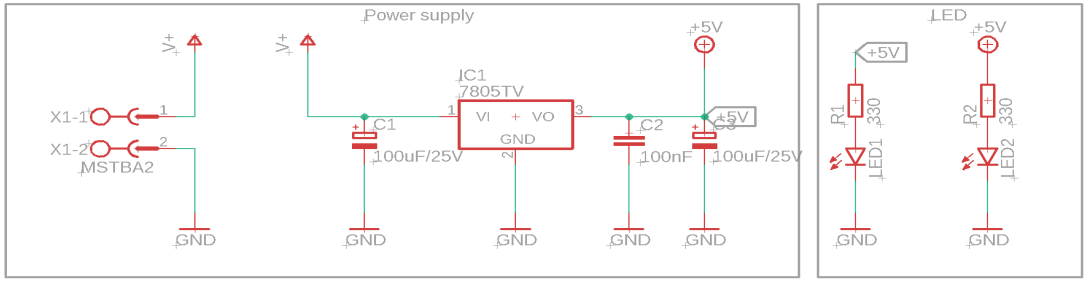

Fig. 3.7 Example of SCH scheme of power supply

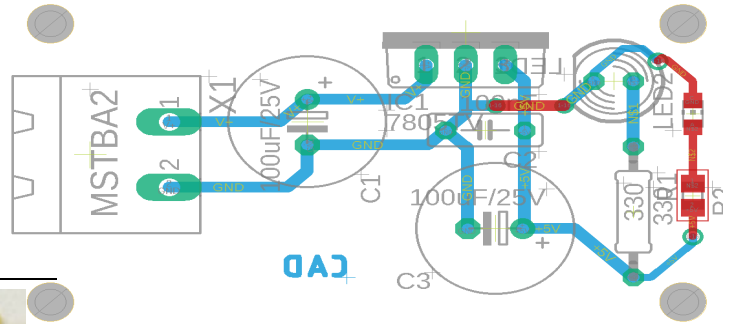

Fig. 3.8 Example of BRD scheme of power supply

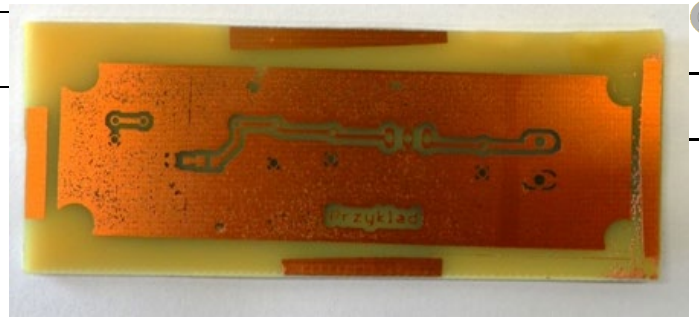

Fig. 3.10 Example of thermal transfer PCB

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Examples of 3D printed biomimetic devices

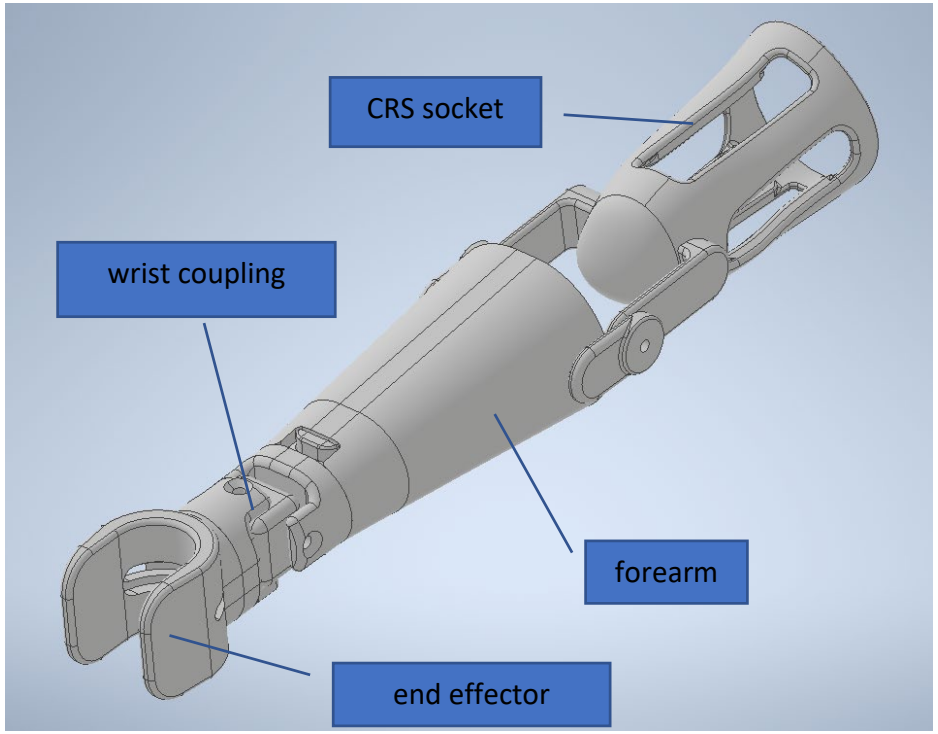
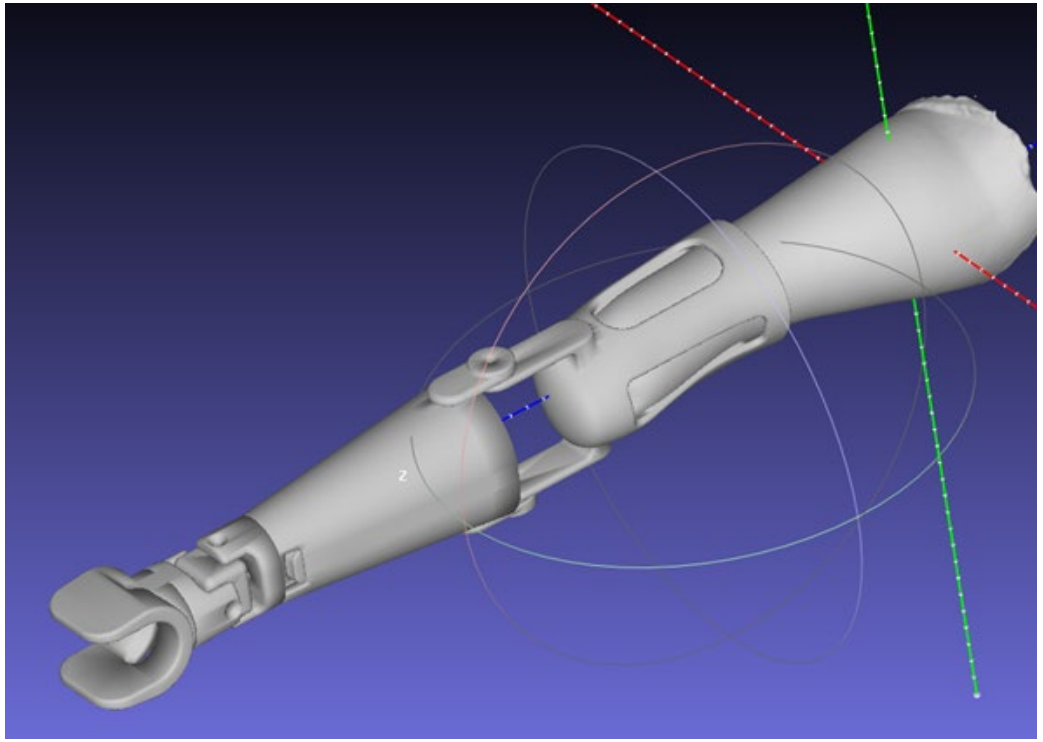


Fig. 3.17



Bicycle prosthesis

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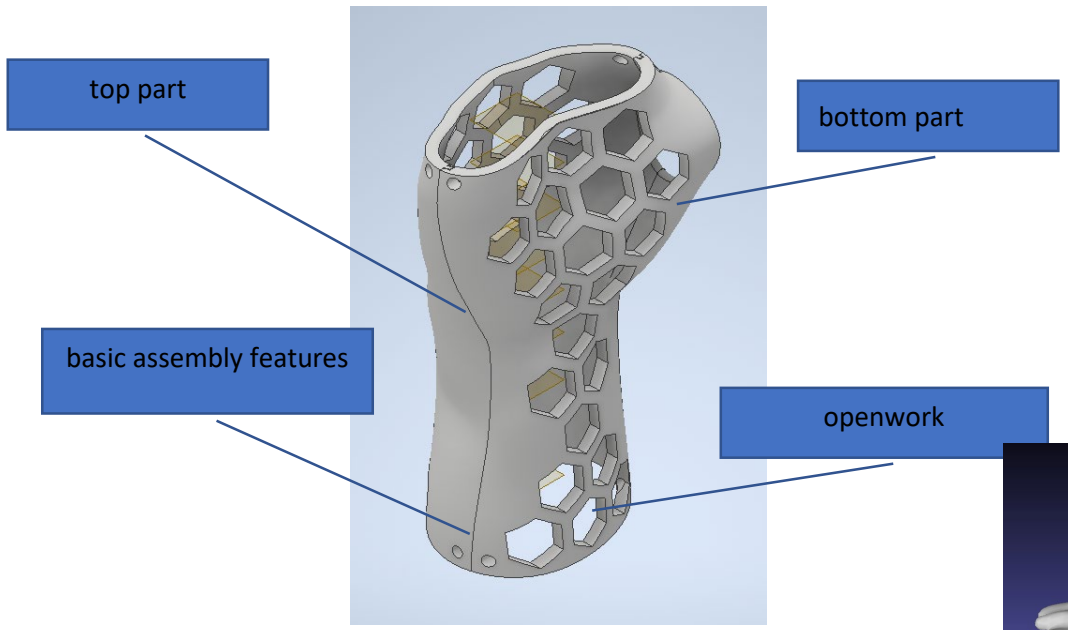
Examples of 3D printed biomimetic devices



Therapeutic hand orthosis

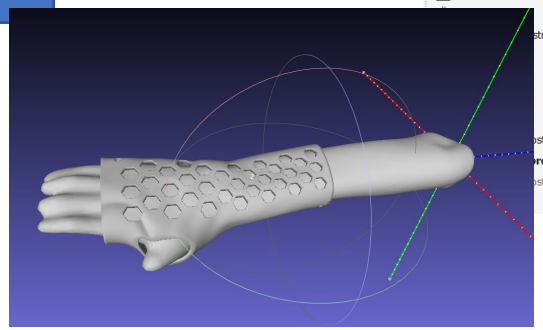


Fig. 3.22

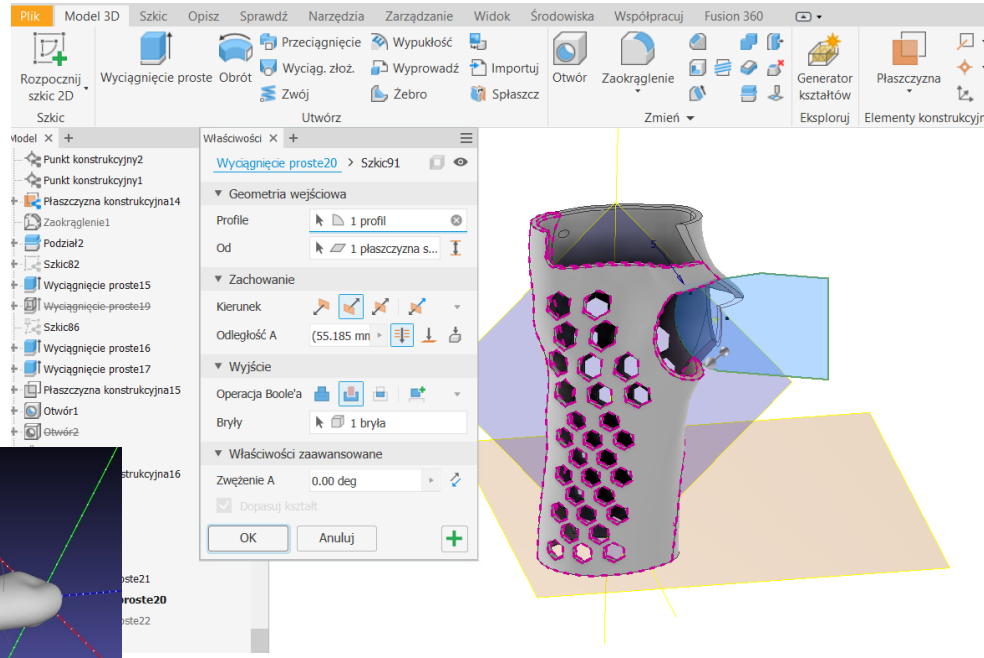


Fig. 3.21

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SOFTWARE REWIEV

DICOM data processing

- Slicer
- InVesalius
- MIMICS

Mesh processing

- GOM Inspect
- MeshMixer
- MeshLab

Computer Aided Design – 3D modelling

- Inventor
- SolidWorks
- CATIA
- NX
- …

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Summary

In this module, basic knowledge about computer aided design of 3D printed biomimetic mechatronic products for people with special needs was presented. The most important takeaways have been summarized below:

- using digital technologies can make design for medicine much faster and also more robust,
- 3D printing helps faster iteration of design, as well as easier obtaining of organic, anatomical shapes,
- designing individualized medical products requires anatomical data processing in several types of software,
- design for medicine requires participation of doctors at the beginning and often end of the process,
- some, if not most operations in the design process of medical parts can be automated for greater efficiency,
- functional, specialized, biomimetic prostheses can be 3D printed for a fraction of a cost of a traditional, expensive one – but the design can be time consuming,
- design changes can be introduced anytime, as many times as feedback is gathered from patients,
- 3D printed prostheses and orthoses could be converted into mechatronic devices by adding sensors and actuators, helping in therapeutic or daily activities.

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