2020 **TH-OWL** 

## **MASTERTHESIS MID-CD**

Arbi Sinoimeri

Parametric Approach - Open Source Platforms and Digital Fabrication In the Field of Prosthetic, Lower Limb

> Prof.Dipl.-Ing. Hans Sachs Prof.Dipl.-Ing. Jens Uwe-Schulz

#### **ABSTRACT**

...We now have sophistication in artificial intelligence, in motor technology, in material science, setting the foundation for the end of human disability....

'Hugh Herr'\_ professor of media arts and science, MIT. 2017

#### ABSTRACT

#### STATISTICS

650 M

The World Health Organization estimates that **650 million people** worldwide have disabilities, the vast majority of whom live in low-income countries

3%

The small percentage of people with disabilities in low-income countries who have access to rehabilitation services, **3 percent** according to estimates, further aggravates this disparity.

30 M

Specific to prosthetic rehabilitation, recent estimates suggest that there are roughly 30 million people in low-income countries who need prostheses.

## **ABSTRACT**

#### **STATISTICS**

Lower extremity prosthesis (leg) can range in cost from \$5,000.00 to \$50,000

Upper extremity device (arm) can range \$3,000.00 to \$30,000

Considering the living conditions and life standarts the correct rapresentation should be...





**DESIGN PARAMETERS** 

OPEN SOURCE SYSTEM

NOT 'STANDING' DESIGN

LOW COST

FDM PRINTERS

EASY TO FABRICATE

SELF CUSTOMIZABLE

VERY ACCESSIBLE

#### FORCE DISTRIBUTION

The classical prosthetics have a 'column' force distribution scheme



#### FORCE DISTRIBUTION

The classical prosthetics have a 'column' force distribution scheme





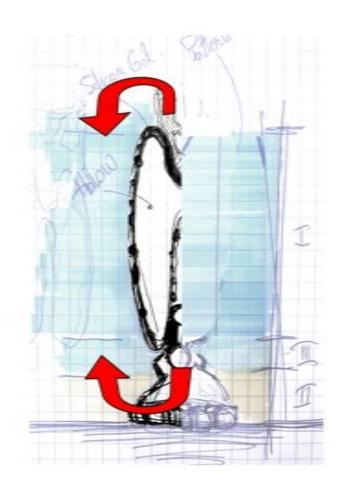
#### FORCE DISTRIBUTION

#### **PROPOSAL**

Distribution of the forces through the 'shell'

More elasticity on the walking



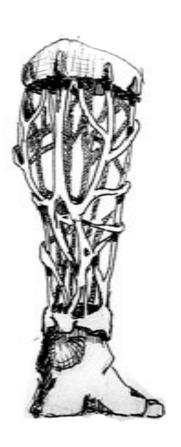


#### FORCE DISTRIBUTION

#### PROPOSAL

Distribution of the forces through the 'shell'

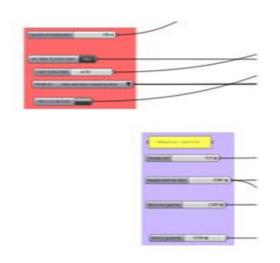
More elasticity on the walking Leaves the space on the inside empty More than one part so is easier to replace

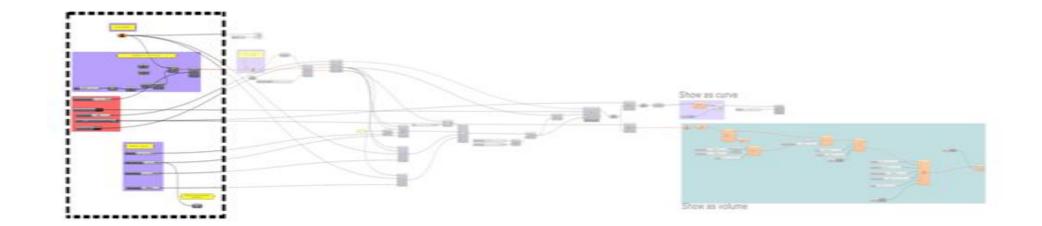


PROPOSAL MODULAR SOLUTIONS

#### Fase 01

Loading the geometry as a surface and running lines through it to generate the desired pattern \* Always grouping the sliders

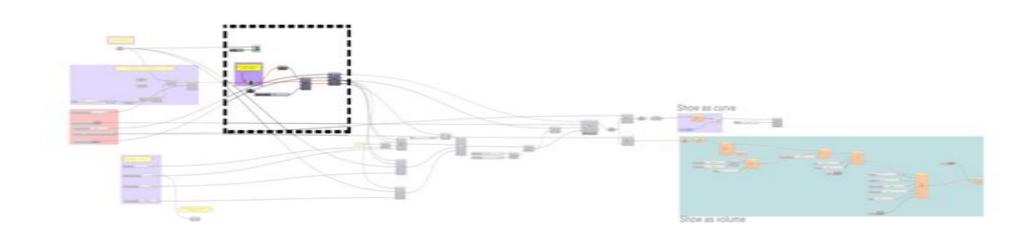




#### Fase 01

Loading the geometry as a surface and running lines through it to generate the desired pattern 
\* Always grouping the sliders

Fase 02
Getting the NODES and starting the Swarm Growth



#### Fase 01

Loading the geometry as a surface and running lines through it to generate the desired pattern 
\* Always grouping the sliders

#### Fase 02

Getting the NODES and starting the Swarm Growth

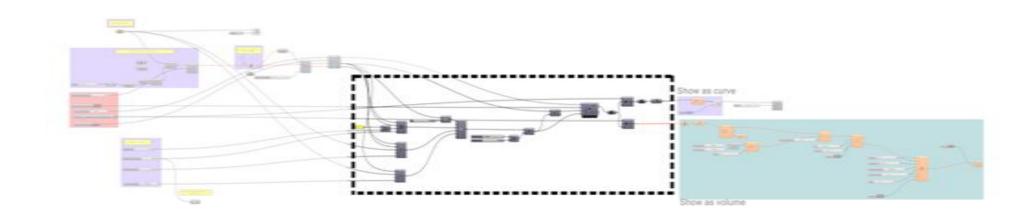
#### Fase 03

Using BOID and ANEMONE plugins to generate 'ruled' swarm intelligence growth

#### BOID ANEMONE





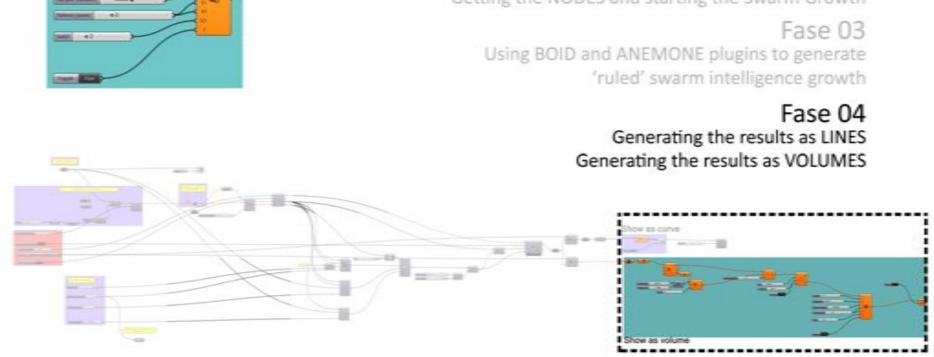


#### Fase 01

Loading the geometry as a surface and running lines through it to generate the desired pattern \* Always grouping the sliders

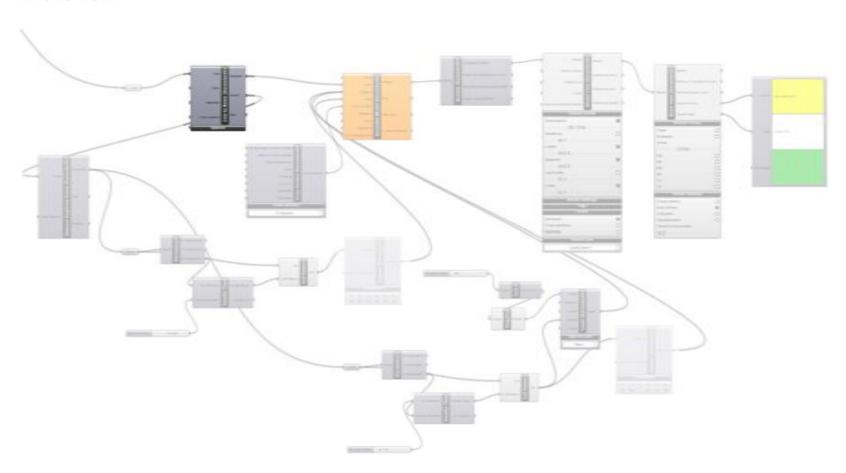
#### Fase 02

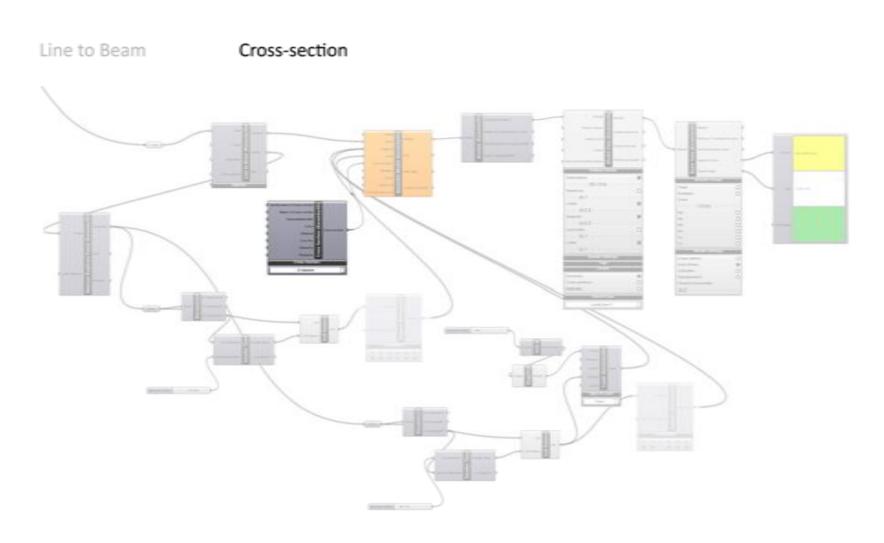
Getting the NODES and starting the Swarm Growth

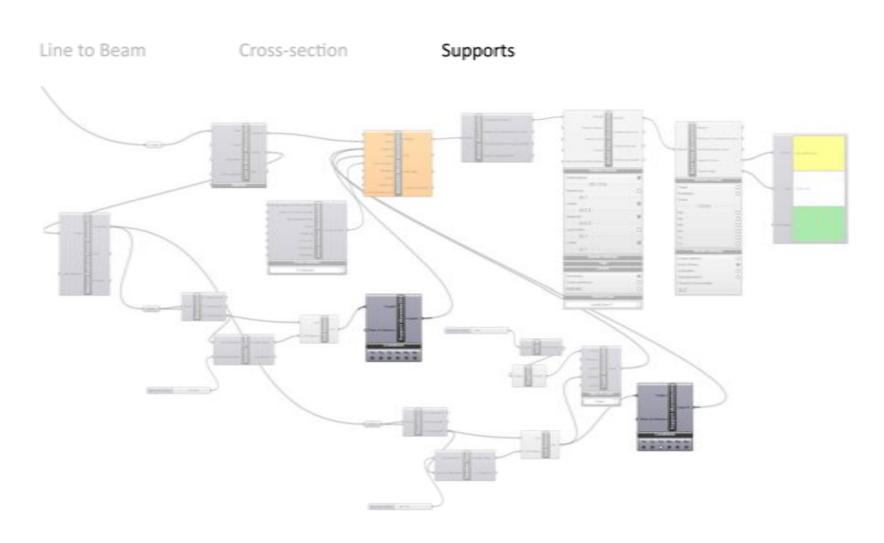


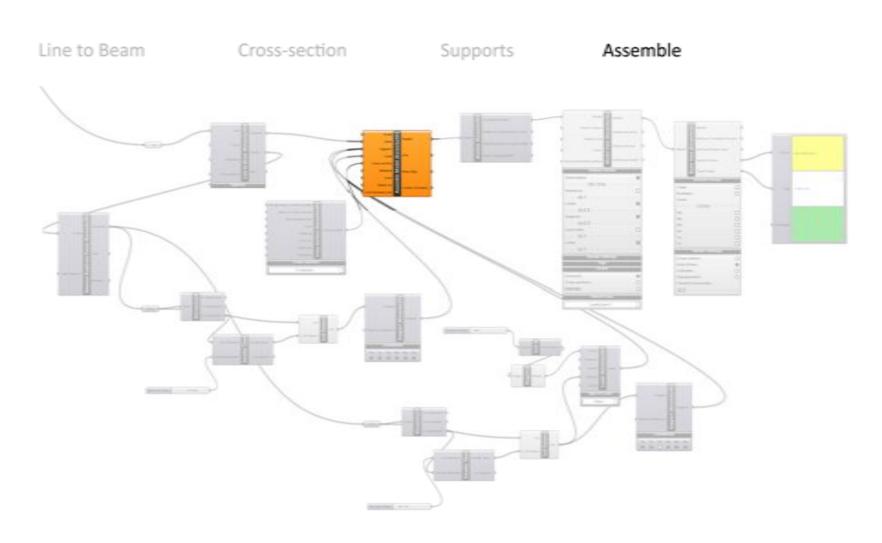
## LINE ANALYSIS

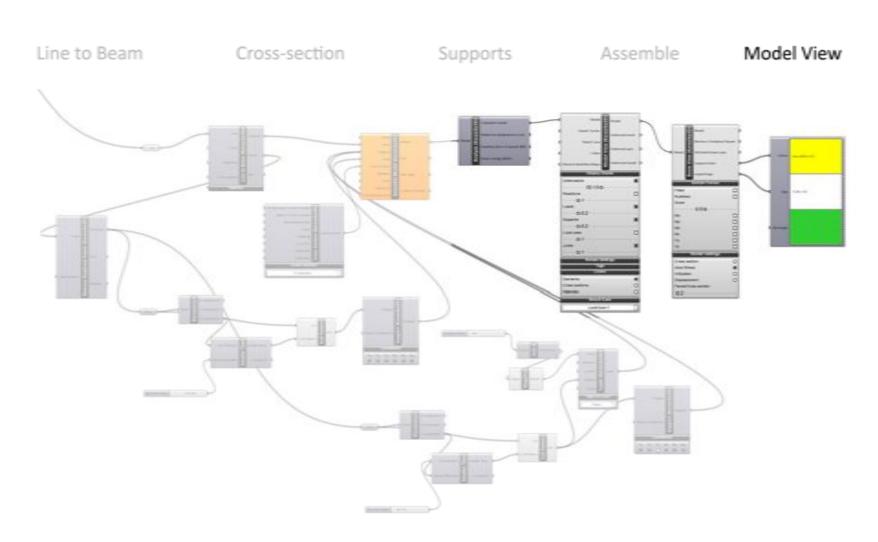
#### Line to Beam

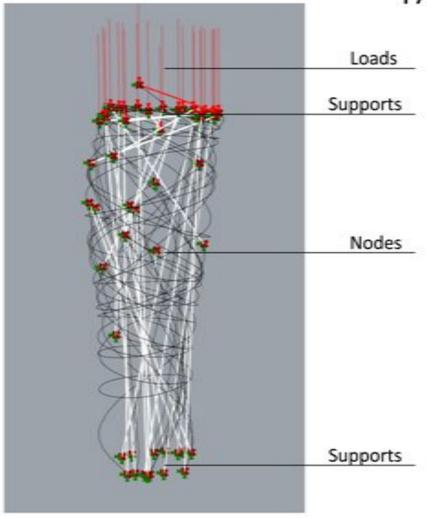






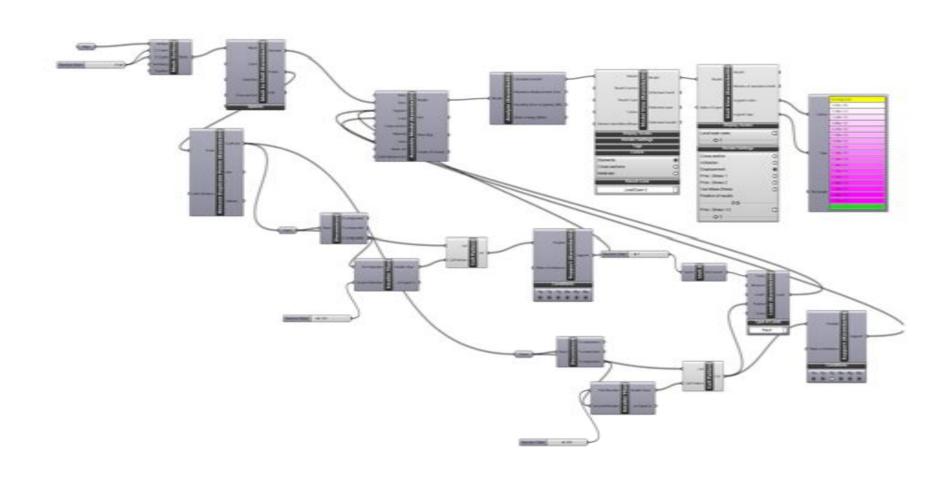






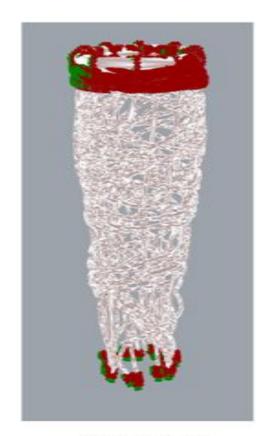
Model View

# PARAMETRIC SIMULATION SHELL ANALYSIS

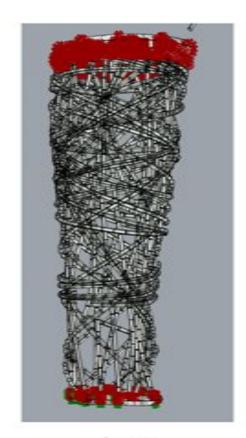


## SHELL ANALYSIS

Model View



Displacement



Stress

INPUT DATA

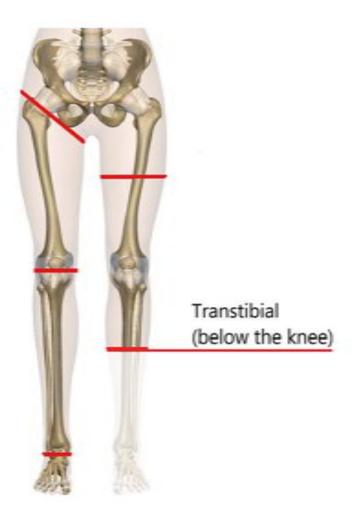
DESIGN

SIMULATION & OPTIMIZATION

**FABRICATION** 

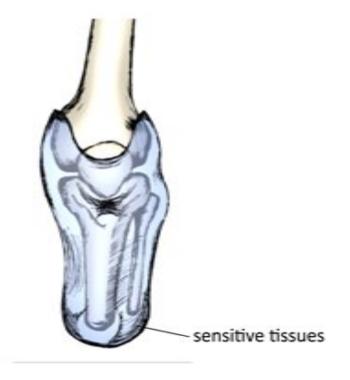
AFTER USE - RECYCLE

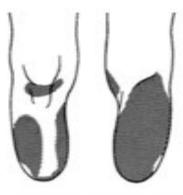
CASES Transtibial amputation



CASES

## DIFFERENT PRESSURE AREAS Pressure sensitive areas





Pressure sensitive areas

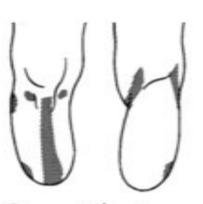
CASES

#### DIFFERENT PRESSURE AREAS

Pressure sensitive areas

Pressure tolerant areas





Pressure tolerant areas

CASES

DIFFERENT PRESSURE AREAS

SOCKS AND SILICA Gel liner





Gel liner

CASES

DIFFERENT PRESSURE AREAS

SOCKS AND SILICA
Gel liner
Homemade/Special socks
Sleeve.lest





Sleeve

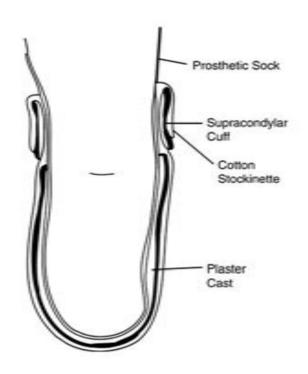
CASES

DIFFERENT PRESSURE AREAS SOCKS AND SILICA

CASTING THE PVC SOCKET



3D printed

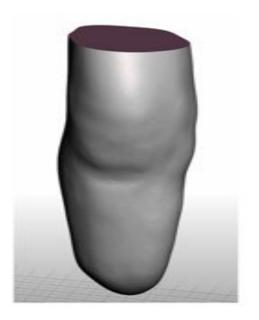


Traditional

CASES

DIFFERENT PRESSURE AREAS SOCKS AND SILICA CASTING THE PVC SOCKET

MEASURING / GETTING THE DATA







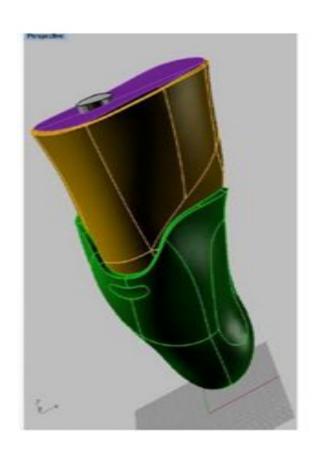
Converted to mesh



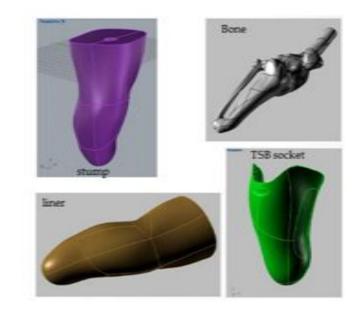
CASES

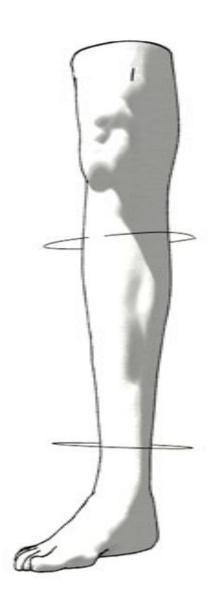
DIFFERENT PRESSURE AREAS
SOCKS AND SILICA
CASTING THE PVC SOCKET
MEASURING / GETTING THE DATA

INITIAL RESULT



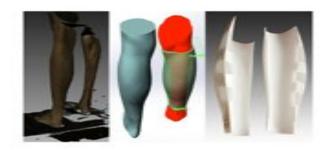
Final structures: bone, stump, liner and Transtibial socket





## **GETTING THE GEOMETRY**

3D Scanning



## Image Acquisition

MAGNETIC RESONANCE IMAGING (MRI)



Image Processing



DICOM TO STL

On CAD softwares or Parametric Approach

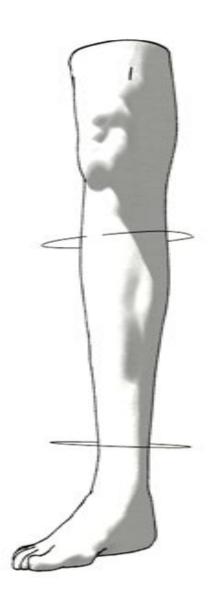


3D print model physical model ready to be assembled







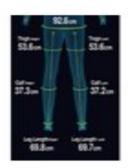


#### **GETTING THE GEOMETRY**

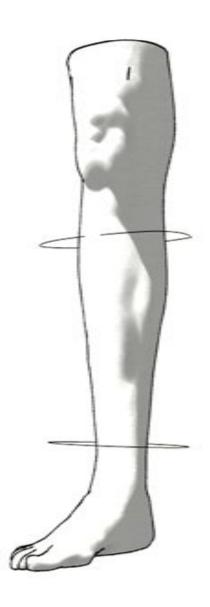
3D Scanning

Inertial measurement unit (IMU) Socks





The objective of the sensor is to measure the exact position of each point on the grid and the relationship between each point.

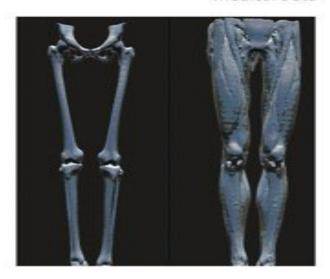


#### **GETTING THE GEOMETRY**

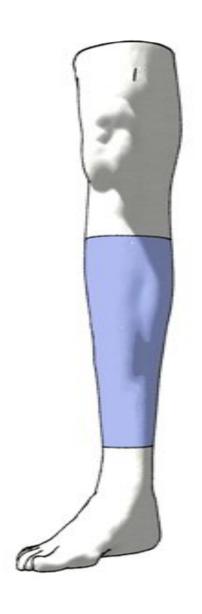
3D Scanning

Inertial measurement unit (IMU) Socks

Medical Data

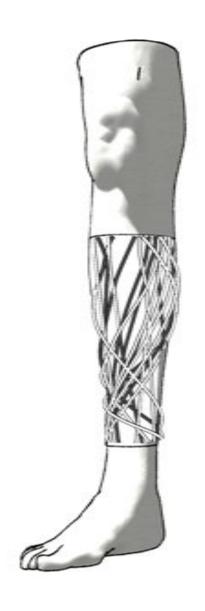


The collaboration with medics is very important, when possible. And the data that Medical Infrastructure provides are very precise.



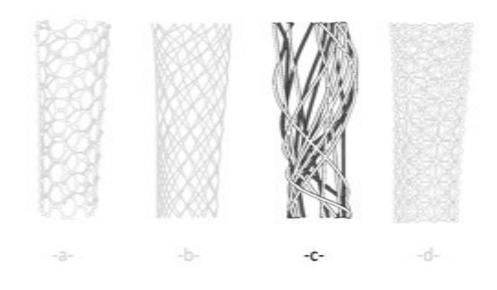
# SLICING THE GEOMETRY

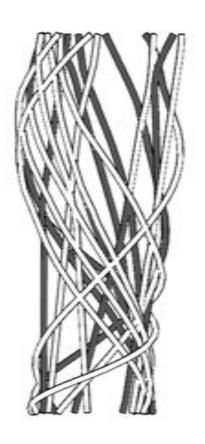




# GETTING THE GEOMETRY SLICING THE GEOMETRY

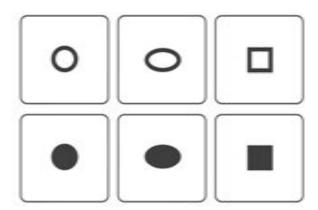
### SELECT A PATTERN - THEME

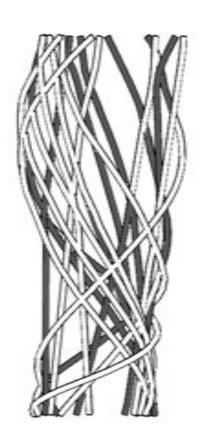




GETTING THE GEOMETRY
SLICING THE GEOMETRY
SELECT A PATTERN - THEME
DEFINE SUPPORTS
DEFINE LOADS
MATERIAL SELECTION

#### SELECT A CROSS SECTION



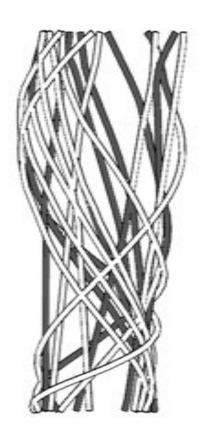


SLICING THE GEOMETRY
SLICING THE GEOMETRY
SELECT A PATTERN - THEME
DEFINE SUPPORTS
DEFINE LOADS
MATERIAL SELECTION
SELECT A CROSS SECTION

#### **RUN THE SIMULATION**

CHECK THE DISPLACEMENT
CHECK THE ELEMENTS STRESS
CHECK BENDING FACTOR

. . .



**GETTING THE GEOMETRY** SLICING THE GEOMETRY SELECT A PATTERN - THEME **DEFINE SUPPORTS DEFINE LOADS** MATERIAL SELECTION SELECT A CROSS SECTION RUN THE SIMULATION

### ASSIGN CONSTRAINS

MAXIMUM DISTANCE BETWEEN NODES MAXIMUM DISTANCE BETWEEN NODES MAXIMUM DEFORMATION

MAXIMUM MEMBER STRESS 30 MPA

3D PRINT ORIENTATION 45 DEGREE

10 MM



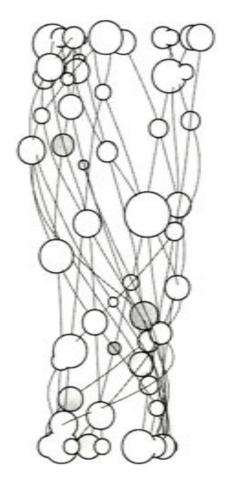




SKELETRON

**GETTING THE GEOMETRY** SLICING THE GEOMETRY SELECT A PATTERN - THEME **DEFINE SUPPORTS DEFINE LOADS** MATERIAL SELECTION SELECT A CROSS SECTION RUN THE SIMULATION ASSIGN CONSTRAINS

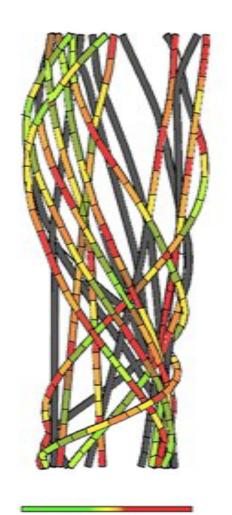
FROM LINE TO BEAM



SPHERES

**GETTING THE GEOMETRY** SLICING THE GEOMETRY SELECT A PATTERN - THEME **DEFINE SUPPORTS** DEFINE LOADS MATERIAL SELECTION SELECT A CROSS SECTION RUN THE SIMULATION ASSIGN CONSTRAINS FROM LINE TO BEAM

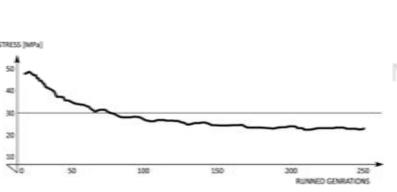
NODAL DISPLACEMENT AS A LIST



**GETTING THE GEOMETRY** SLICING THE GEOMETRY SELECT A PATTERN - THEME **DEFINE SUPPORTS** DEFINE LOADS MATERIAL SELECTION SELECT A CROSS SECTION RUN THE SIMULATION ASSIGN CONSTRAINS FROM LINE TO BEAM NODAL DISPLACEMENT AS A LIST

**ELEMENT STRESS FACTOR** 



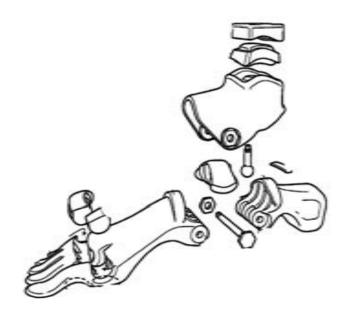


GETTING THE GEOMETRY SLICING THE GEOMETRY SELECT A PATTERN - THEME **DEFINE SUPPORTS DEFINE LOADS** MATERIAL SELECTION SELECT A CROSS SECTION RUN THE SIMULATION ASSIGN CONSTRAINS FROM LINE TO BEAM NODAL DISPLACEMENT AS A LIST **ELEMENT STRESS FACTOR** 

MOST EFFICIENT SOLUTION

## III - PART THE FOOT

SOLUTION FOUND WITHIN THE OPEN SOURCE
EXISTING/SHARED PART
SPONSORED/COLABORATIVE CO.
WORLD WIDE STANDARD PARTS
EXISTING 3D PRINTED PROTOTYPES





PANELS Customization









#### PANELS

Customization

Protection of the structure Shock absorption

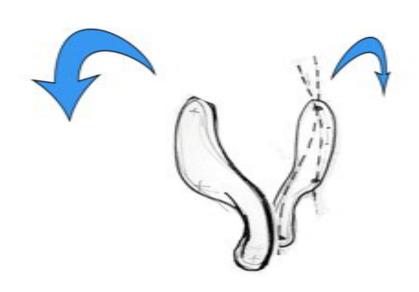


### **PANELS**

Customization

Protection of the structure Shock absorption





#### PANELS

#### CONNECTIONS

Reinforce the nodes Support the panels

Join the main parts







PANELS CONNECTIONS

ACCESSORIES
Option to attach different types of accessories
Power Bank







PANELS CONNECTIONS

ACCESSORIES
Option to attach different types of accessories

Power Bank Speaker



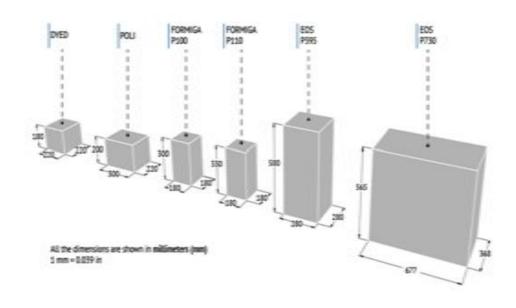
## **FABRICATION**

#### LIMITATIONS

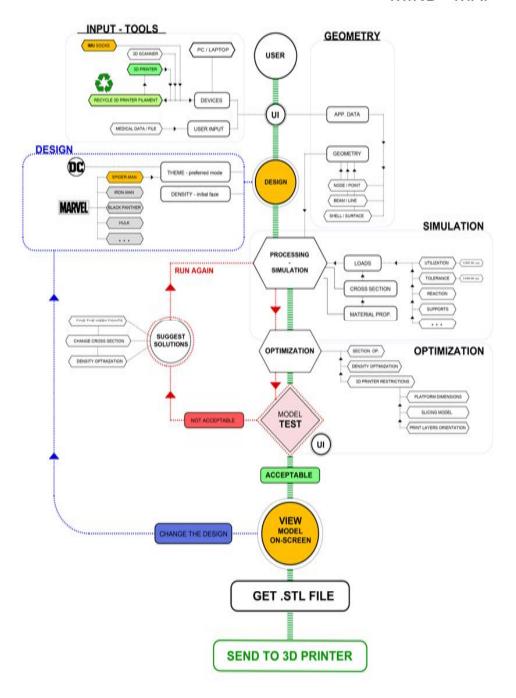
3D Printer platform size

Possibility to slice the model into as many pieces as needed





MIND - MAP



## **CREDITS**



Prof.Dipl.Ing. Hans Sachs

Prof.Dipl.Ing. Jens-Uwe Schulz

















#### REFERENCES

MECURIS.GmbH , MECURIS SOLUTION PLATFORM https://www.mecuris.com/

FREEDOM-INNOVATIONS https://www.freedom-innovations.com/

> ENABLING THE FUTURE https://enablingthefuture.org/ E-NABLE DEVICES

https://hub.e-nable.org/s/e-nable-devices/wiki/overview/list-categories

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Hoang D, Perrault D, Stevanovic M, Ghiassi A. Surgical applications of three-dimensional printing: a review of the current literature & how to get started.

NATIONAL GEOGRAPHIC YOUTUBE CHANNEL, How 3-D-Printed Prosthetic Hands Are Changing These Kids' Lives | Short Film Showcase https://www.youtube.com/watch?v=Cl8ijPGEKO8

YOUTUBE ORIGINALS YOUTUBE CHANNEL, Using A.I. to build a better human | The Age of A.I. | Short Film Showcase https://www.youtube.com/watch?v=lrv8ga02VNg&list=PLwMgvoumlNVu5WqxqD9YH7YLGUd3WXxzD&index=11&t=0s