



Individual Optimization of a New 3D-printed Prosthetic Foot

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Agenda

1

Mecuris vision

2

Prosthesis development

3

Functional robustness

4

Validation & User testimonial



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Mecuris Products and Services

Prosthetics

- ✓ FirStep
- ✓ NexStep
- ✓ ComfyStep
- ✓ Cover



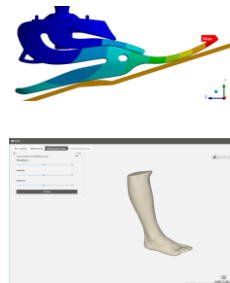
Orthotics

- ✓ Night Splints
- + AFO (Ankle Foot Orthotics)



Digital Services

- ✓ Digital Test Stand
- + Platform Services





3D-printed prosthetics

German patent pending: DE 10 2019 100 584.1

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3D-printed prosthetics



German patent pending: DE 10 2019 100 584.1

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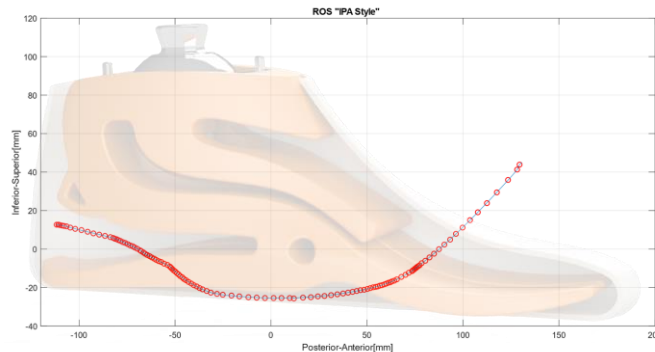
Validation & User testimonial



Requirements

- > **Medical benefit**
 - Functional parameters
 - User testing

- > **Safety**
 - Safety parameters
 - Machine testing





Machine testing

- > Durability test - ISO 10328
 - Heel & Forefoot loading (patient weight)
 - 2 million cycles – 1 Hz
- > Overload test - ISO 10328
 - Up to 4-5000 N
- > Rollover-shape - ISO 16955
 - Full gait cycle
- > Energy return
- > ...



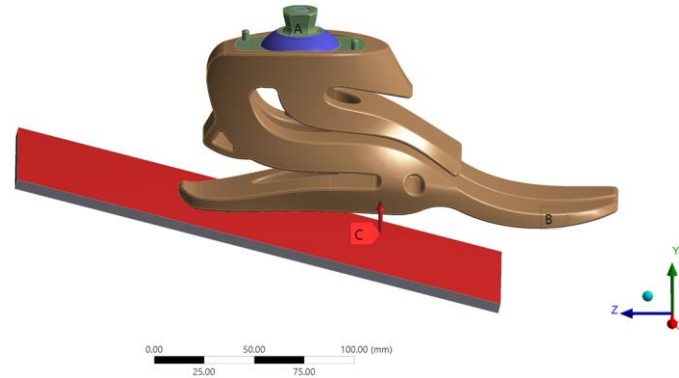


Finite Element model

- > Large deformations
- > Plasticity (PA12)
- > Non-linear contacts
- > Boundary conditions:
 - ISO 10328

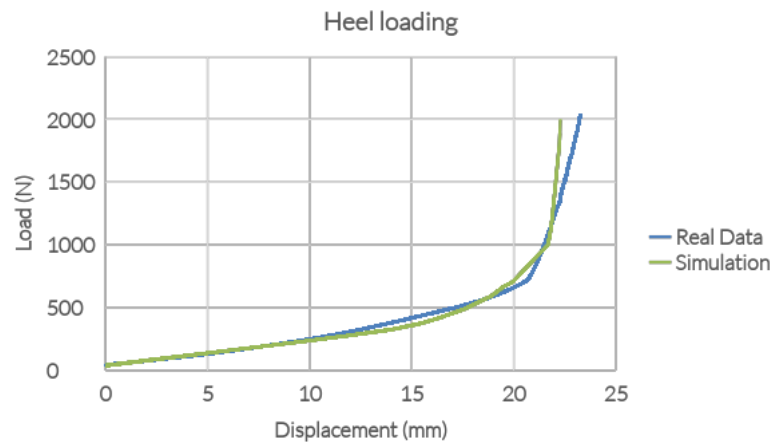
B: reference, 26, 1, 1, 1, 1040
Static Structural
Time: 1. s
7/13/2018 2:46 PM

A Fixed Support - Pyramid
B Remote Displacement - Heel
C Force - Heel: 1040. N





Validation - Finite Element model





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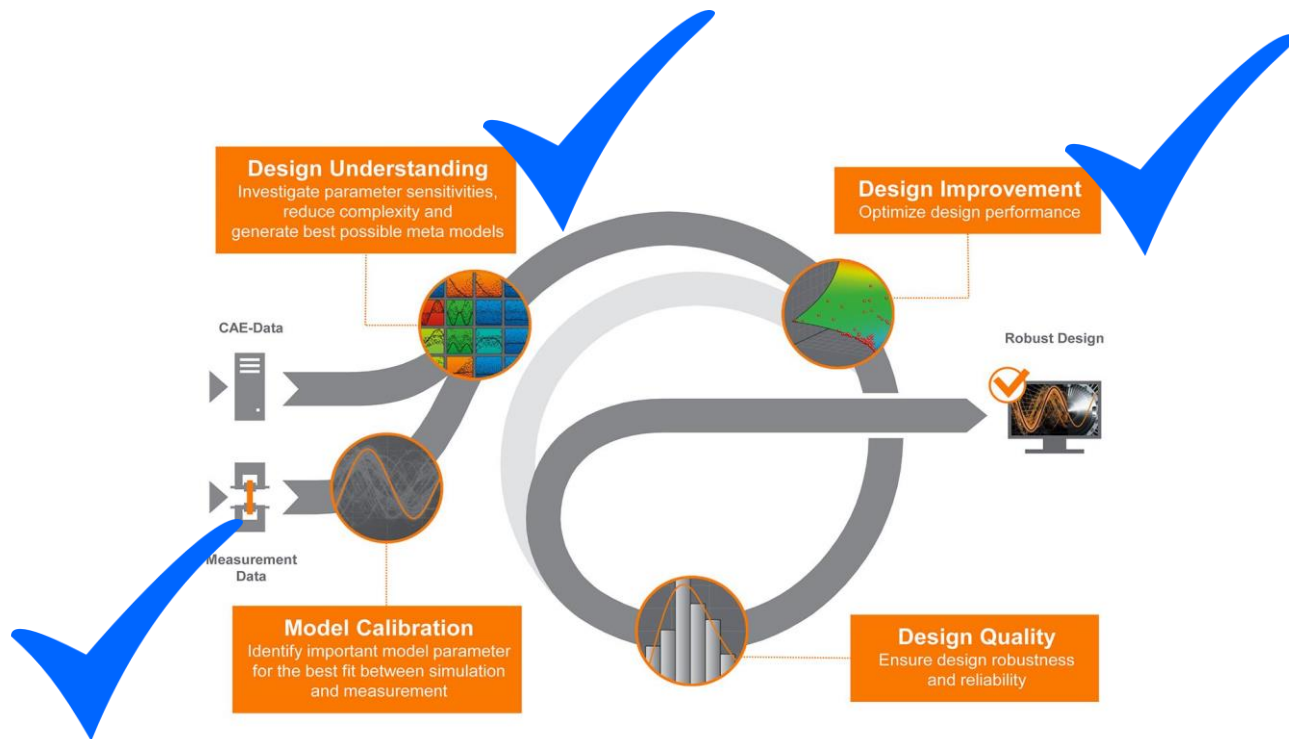
Functional robustness

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Validation & User testimonial

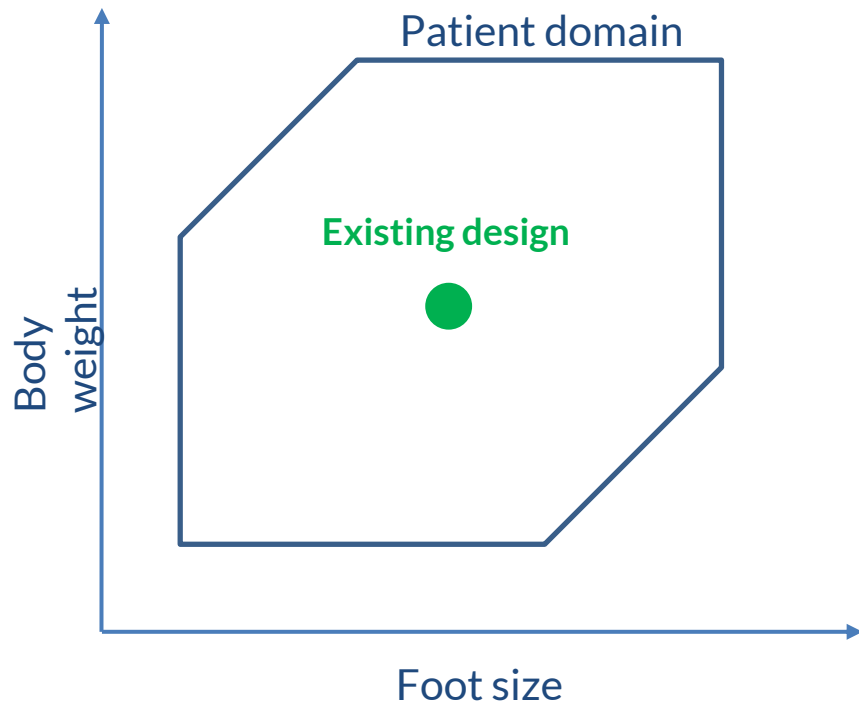


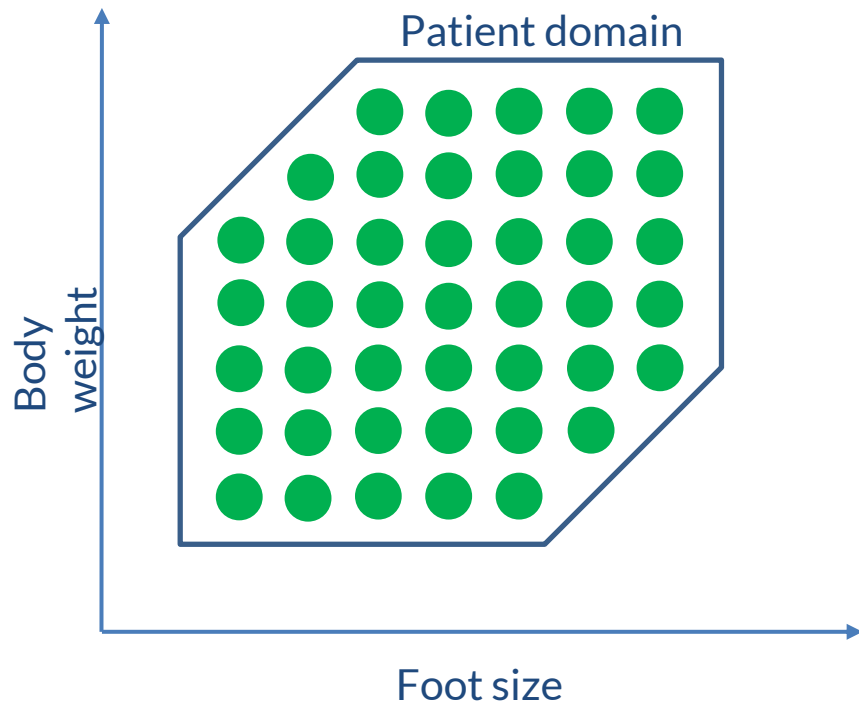
Product goals



German patent pending: DE 10 2019 100 584.1

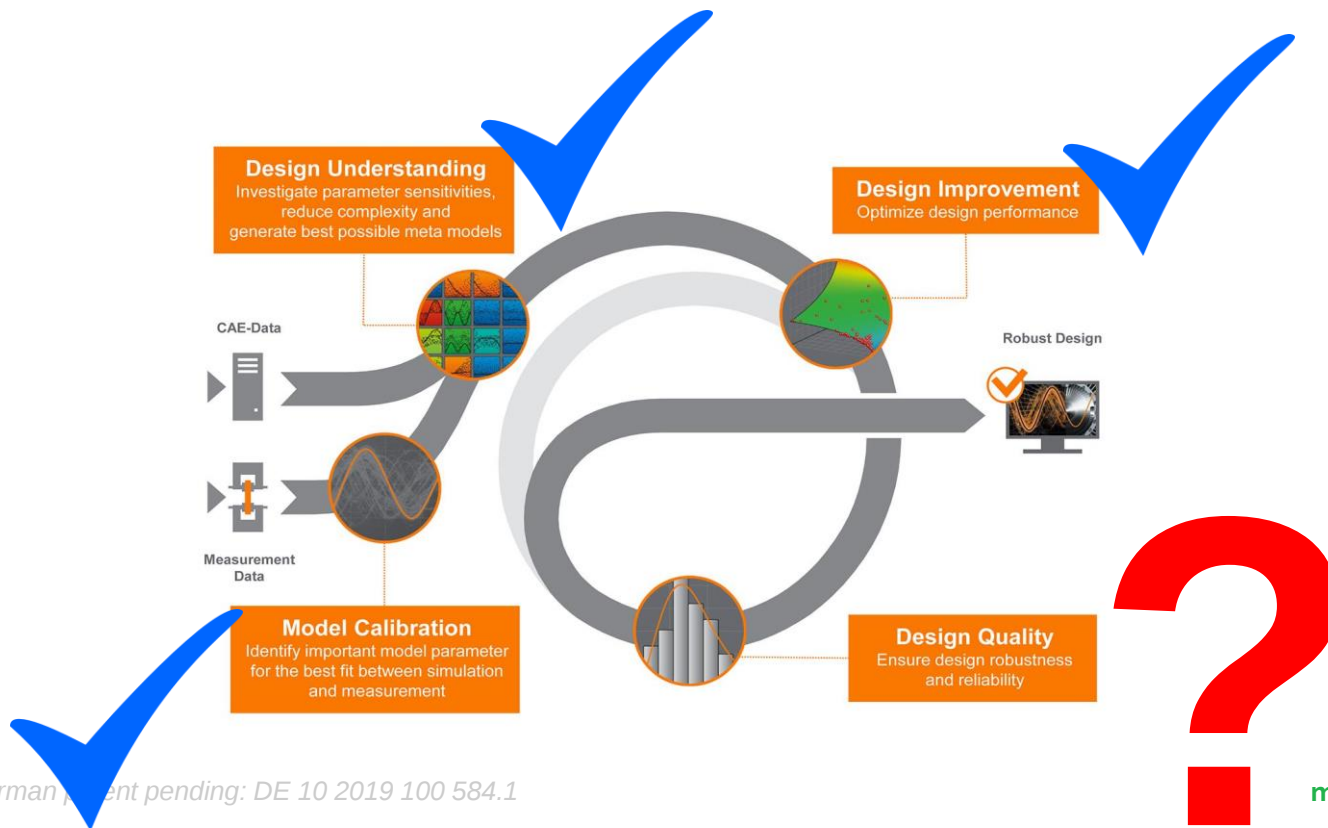
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Product goals

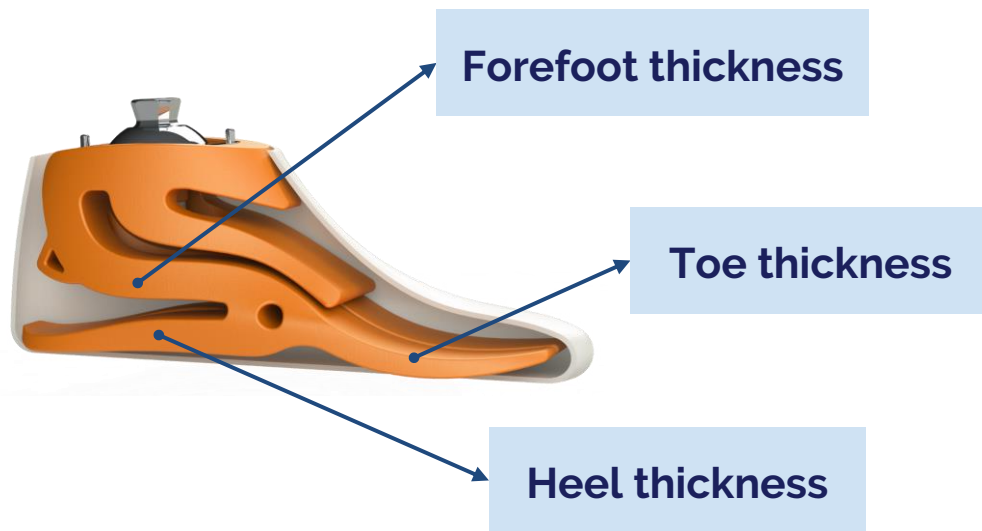


German patent pending: DE 10 2019 100 584.1

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Input parameters



Body weight



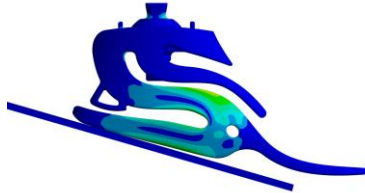
Foot size



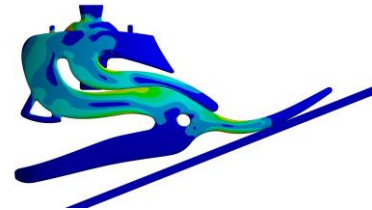


Design of Experiments

75
samples



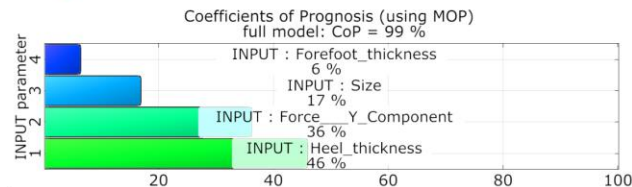
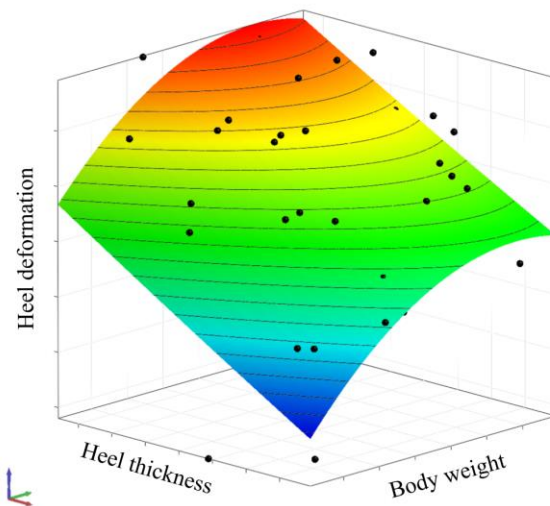
150
samples





Sensitivities

	Size	Forefoot_thickness	Heel_thickness	Force_Y_Component	Total
F2	33.3 %	35.8 %	26.2 %	11.2 %	96.3 %
F3	16.8 %	6.3 %	45.8 %	36.1 %	98.9 %
S6	23.7 %	46.2 %	8.3 %	27.0 %	93.7 %
S7	48.1 %	20.9 %	6.4 %	30.6 %	95.1 %
S8	26.9 %	23.1 %	31.4 %	22.9 %	98.7 %
S9	45.2 %	10.4 %	4.6 %	44.8 %	93.2 %
S10	22.2 %	18.3 %	56.9 %	8.2 %	96.6 %
S11	22.0 %	18.7 %	49.4 %	15.5 %	98.1 %

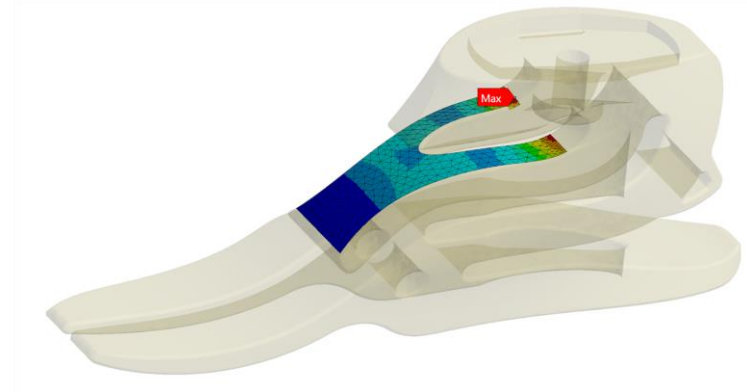




Optimization constraints

- > 2 load cases
 - Same input domains

- > 11 safety constraints
 - Max. eq. strain (element sol.)
 - Same areas for 2 load cases





Optimization

- > Forefoot stiffness
 - > Heel stiffness
 - > Forefoot lowering
-
- > Combined objective
 - 3 functional parameters
 - > Reference design values

Parameter Start designs Criteria Initialization Selection Crossover Mutation Other Result designs

Parameter

Name	Value
Force__Y_Component	1580
Forefoot_thickness	1.008

Responses

Equivalent_Tc
Equivalent_Tc

Criteria

Name	Type
obj_FUNCTION_C4	Objective
constr_SAFETY_Equivalent_Total_Strain__CONT_Heel_Bottom__UA_Maximum_C4	Constraint
constr_SAFETY_Equivalent_Total_Strain__CONT_Heel_Top__UA_Maximum_C4	Constraint
constr_SAFETY_Equivalent_Total_Strain__CONT_Toe_Bottom__UA_Maximum_C4	Constraint
constr_SAFETY_Equivalent_Total_Strain__MESH_Heel_fillet__UA_Maximum_C4	Constraint
constr_SAFETY_Equivalent_Total_Strain__RES_Heel_mounting__UA_Maximum_C4	Constraint
constr_SAFETY_Equivalent_Total_Strain__RES_MidSpring_Bottom__UA_Maximum_C4	Constraint

Create new

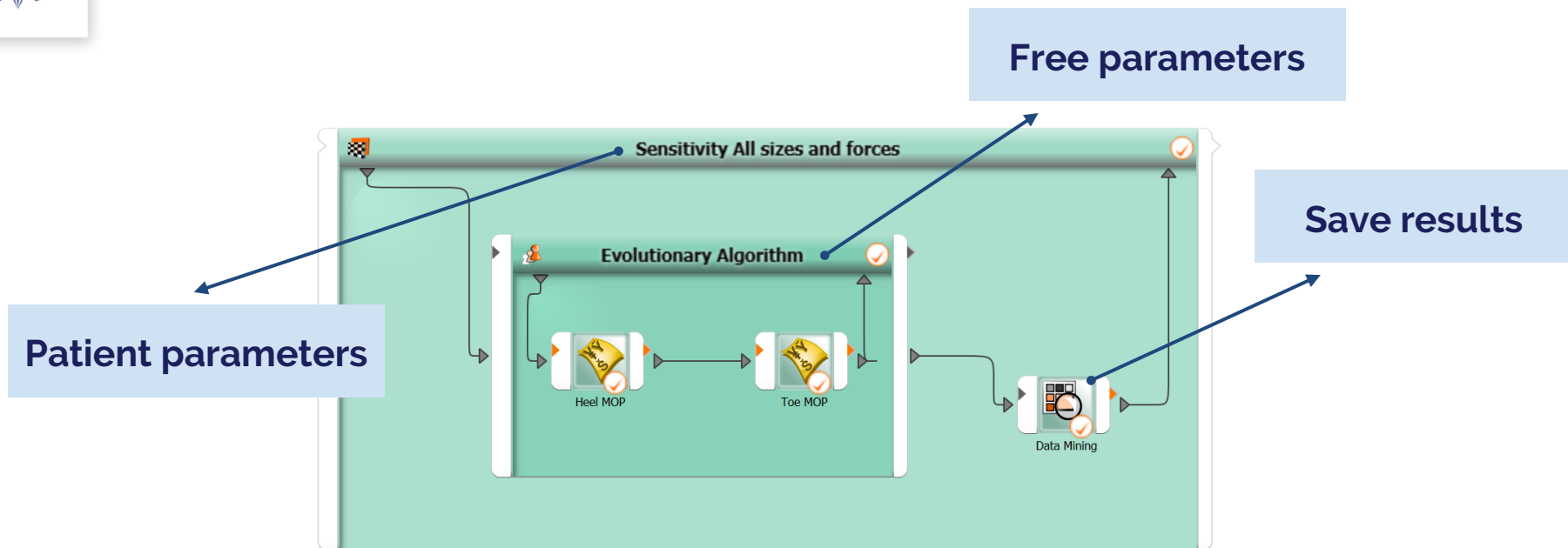
$f(x)$ Variable

Objective

Prefer criteria from slot



Functional robustness





Software

- > Solidworks 2017
 - > Ansys Workbench
 - > optiSLang (add-in + standalone)
-
- > Simulation time: ~10 days
 - > Optimization time: 2 hours
 - 56 cases
 - Only once





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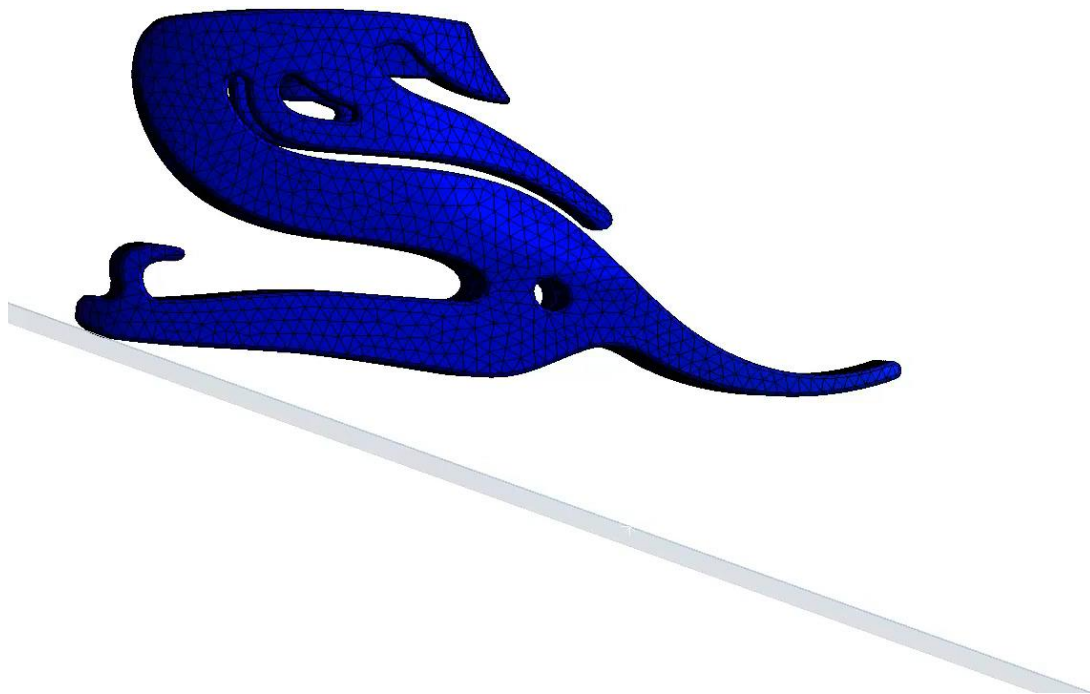
Validation & User testimonial



Rollover-shape Finite Element tool

German patent pending: DE 10 2019 100 584.1

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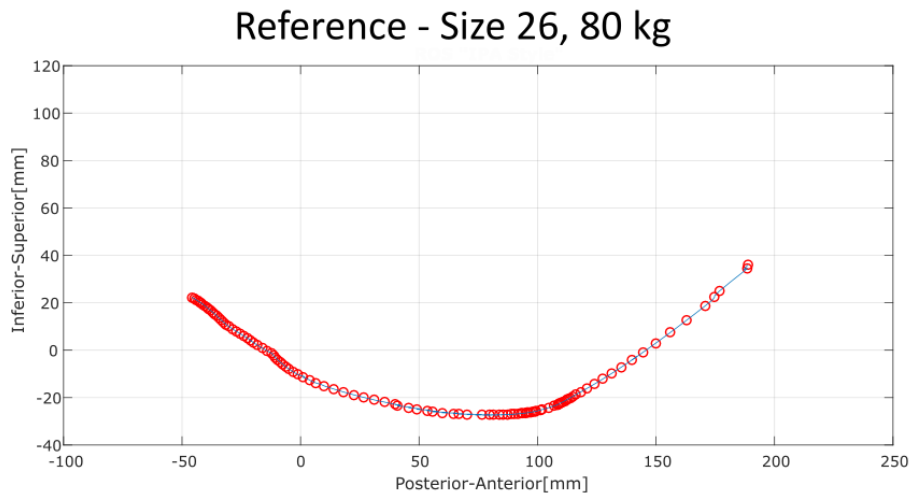


German patent pending: DE 10 2019 100 584.1

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Validation: rollover-shape



Optimised - 80 kg





Proof of concept: expert wearer





"The prosthetic knee harmonizes well with both feet. [...] One foot is a soft variant for usage at home, the other is a stiff variant for outdoor usage and fast walking. My subjective impression confirms the different behaviour of the feet."

Michael Kramer, Rehatreff, 1 | 2019 (translated from German)



Thank you for your attention!



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