Gait Analysis on a Virtual Human Dummy Based on Patient Anthropometry

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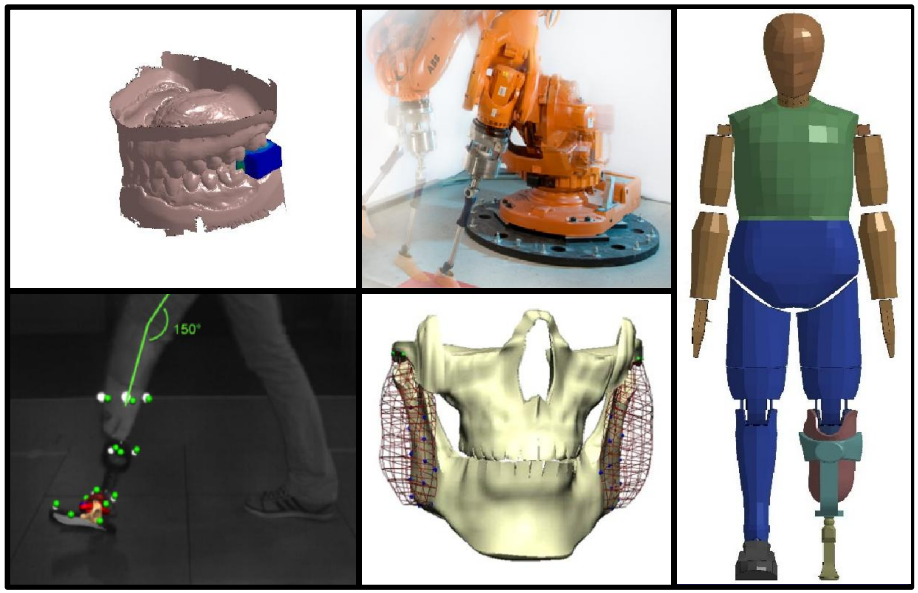
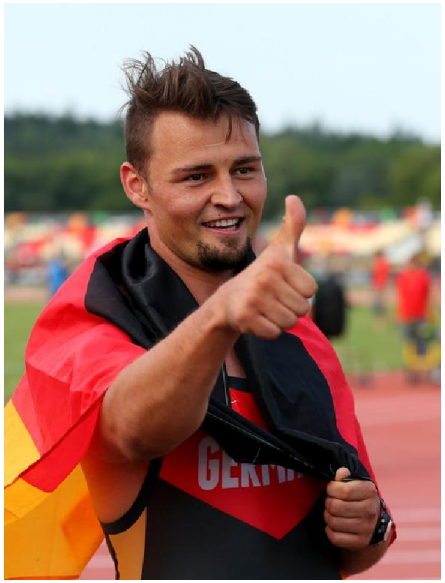


Fraunhofer IPA

What do they have in common?

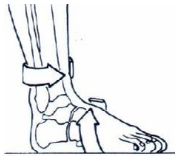


Fraunhofer IPA

Prosthesis and their function

Fraunhofer IPA

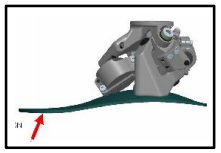
Steps in prosthesis development

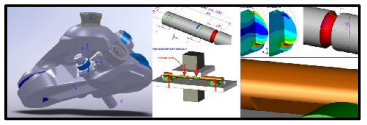


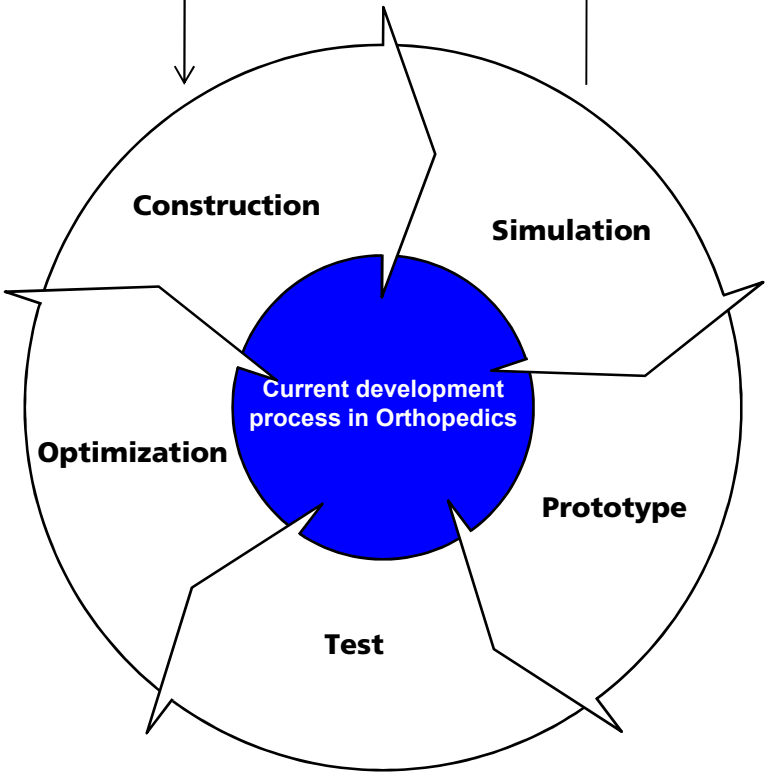
Invention and Patent
(FhG, 2007)

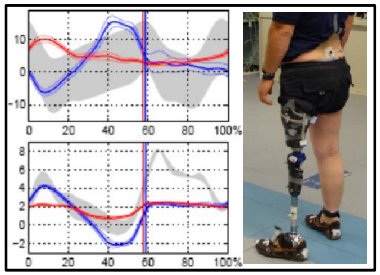
Product idea & Concept → Design process → Final state

Implanted prosthesis
(Bauerfeind AG, 2011)

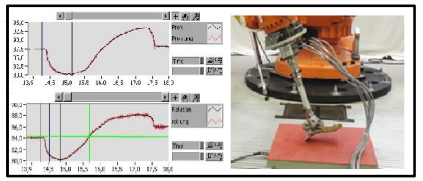








Cardan coupling
Trial in humans

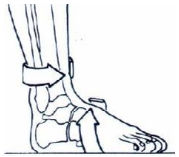


Cardan coupling
Robot testing

Fraunhofer IPA

Steps in prosthesis development

VOL – Virtual Orthopedic Lab



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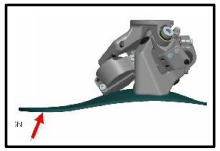
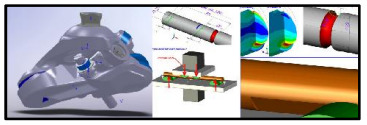
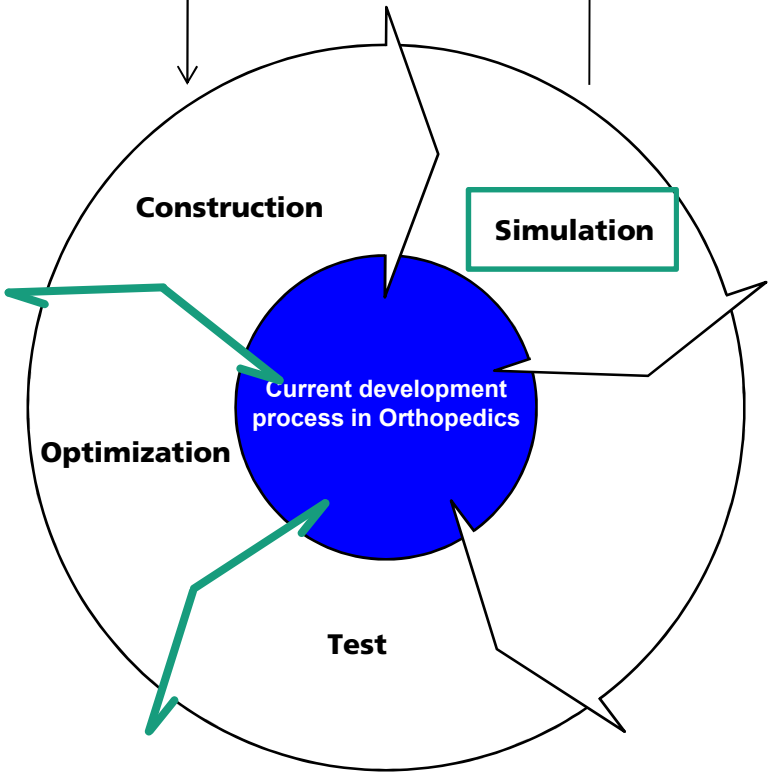
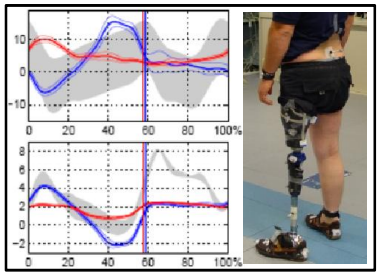
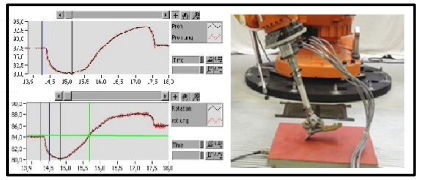








Cardan coupling
Trial in humans



Cardan coupling
Robot testing

Fraunhofer IPA

Prosthesis testing: ISO 22675:2006

- Test ankle-foot devices and foot units
- Cyclic and static test procedures

- Relatively new standard
- Very simple
- Cannot test complex, realistic loading patterns

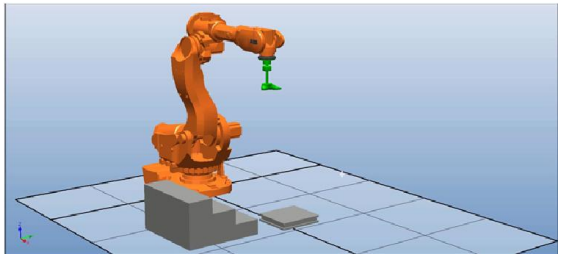
Alternative?

Accelerating and facilitating design –

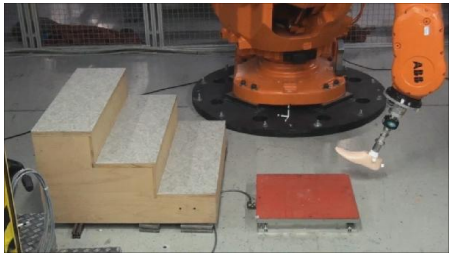
Gait to Robot

Motion Analysis

Patient Robot Simulation

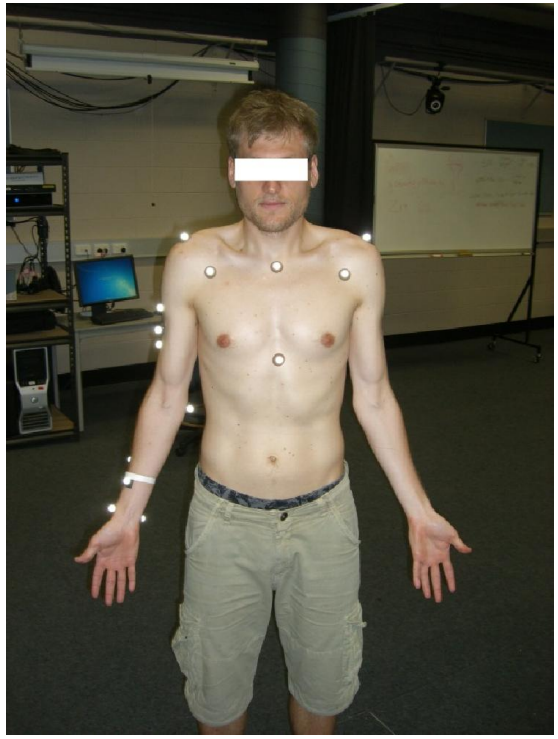


Patient Robot Test



What is a gait lab?

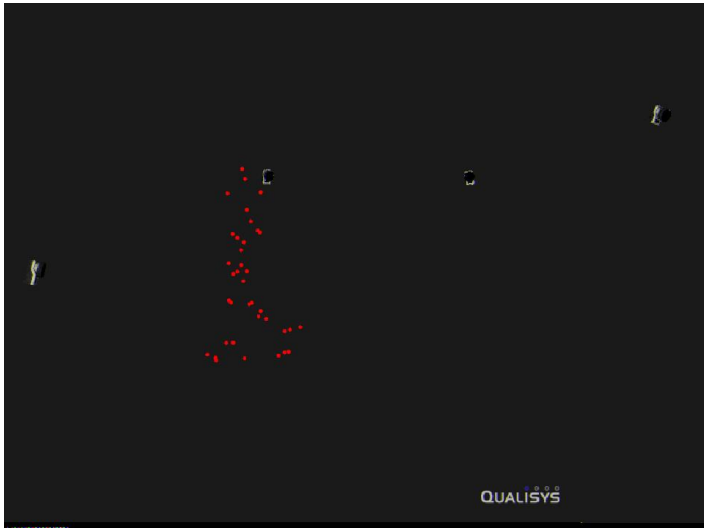
- A place to formally measure walking pattern
- Markers are placed on the subject's body
- Infrared cameras track marker positions
- Force plates measure the ground reaction forces



Why gait lab?

- To understand gait pattern
- Analyze gait abnormalities
- Track any motion

Gait lab at Fraunhofer IPA



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How is virtual gait analysis helpful?

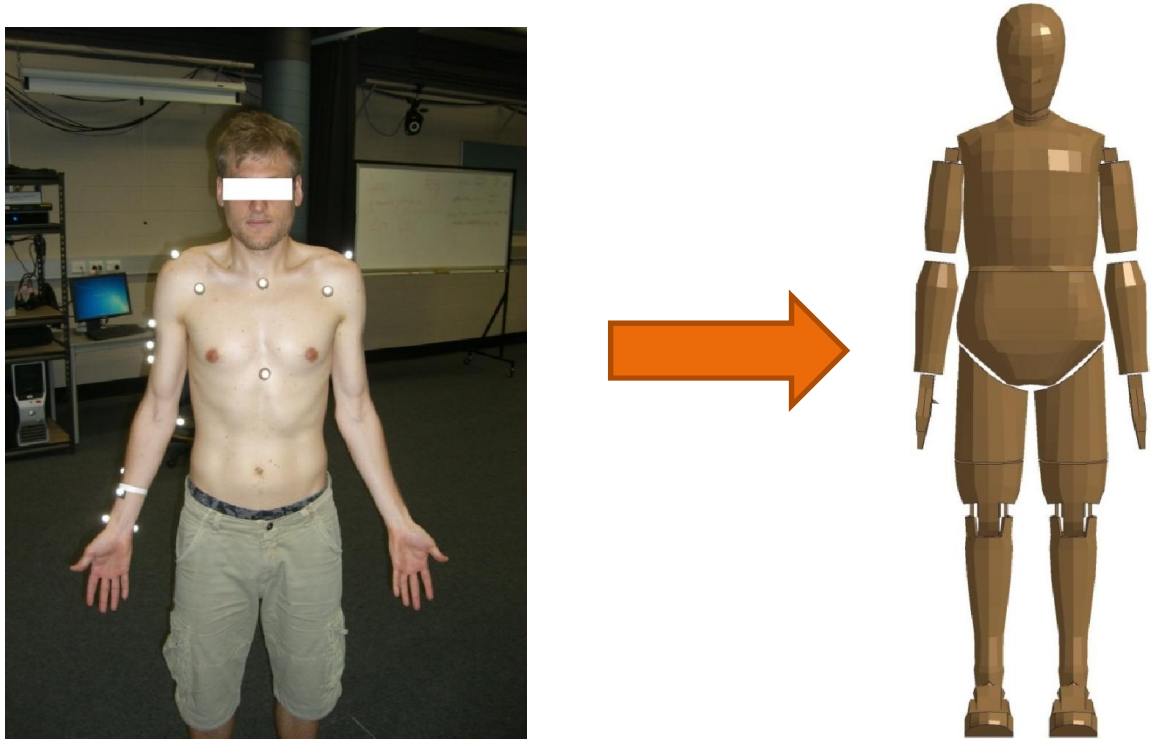
- Character animation
- In Sports: optimizing posture of athletes
- Clinical diagnosis of gait pathology
- Improve function of medical devices
- Analyze different scenarios (motion) quickly

- Gait does not refer just to walking but to any MOTION
- Dummy does not refer to only humans but to any model like spine, teeth,…

Virtualizing the subject: Anthropometric measures

- Anthropometry means measurement of man
- Anthropometric measurements could include:
  - Total height
  - Total weight
  - Segmental lengths and masses
  - More…
- Measurements included in this work:
  - Total height
- Weight and segment lengths of dummy still need scaling to match the subject

Virtualizing the subject: Anthropometric measures



Anthropometric dummy of subject: scaling

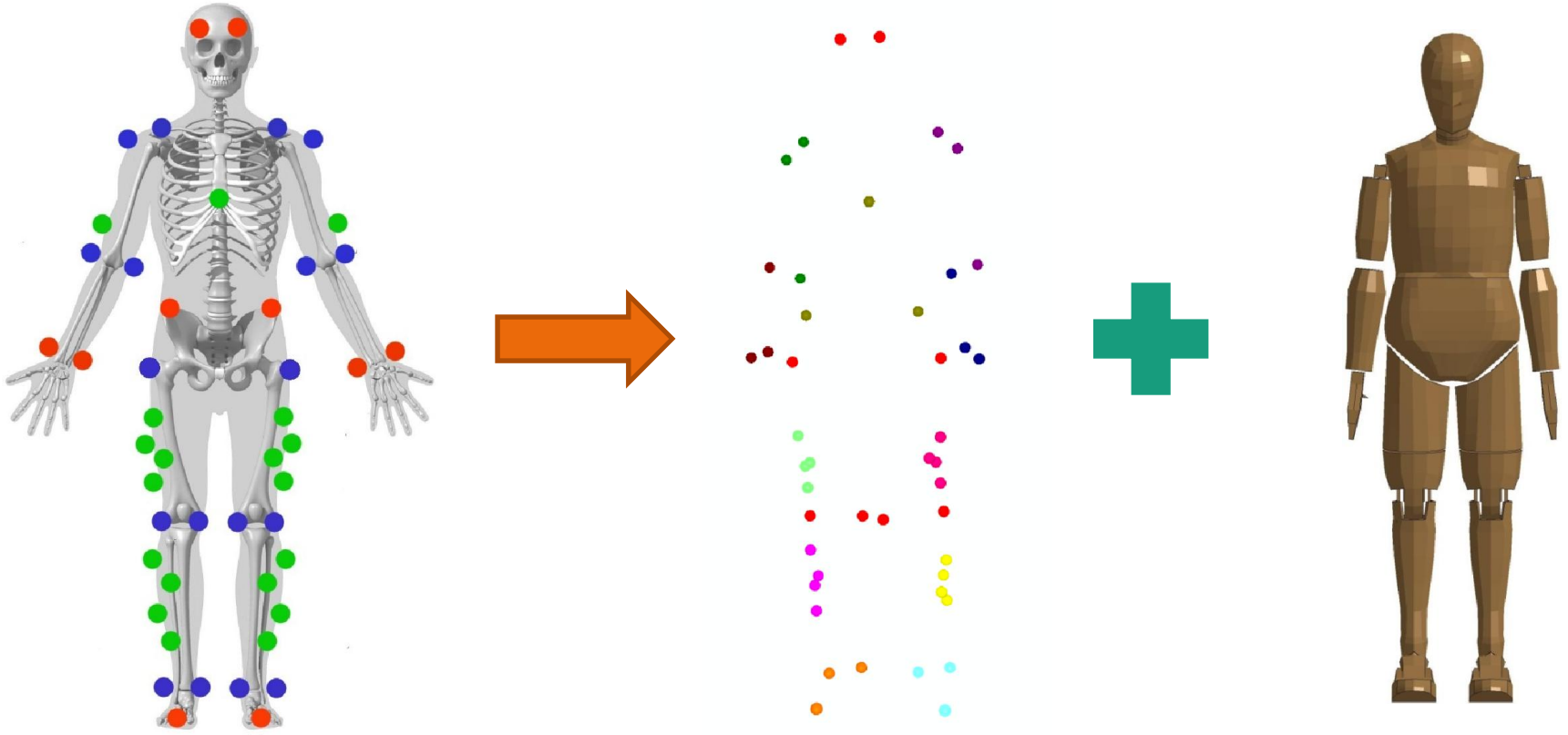
Subject

- Height: 1.8m
- Weight: 80kg

Dummy (LSTC 50th percentile Hybrid 3 Standing model)

- Height: 1.7m
- Weight: 52kg
- Nr of elements: 4293
- Nr of nodes: 7470
- Dummy is not completely rigid

Imposing marker trajectories on scaled dummy



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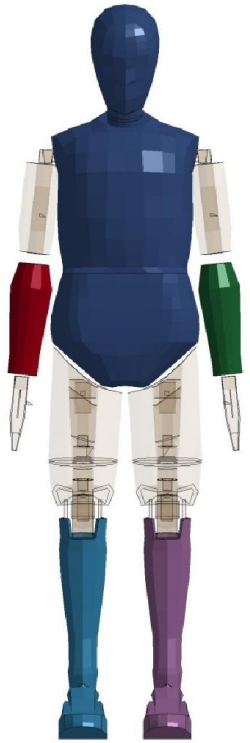
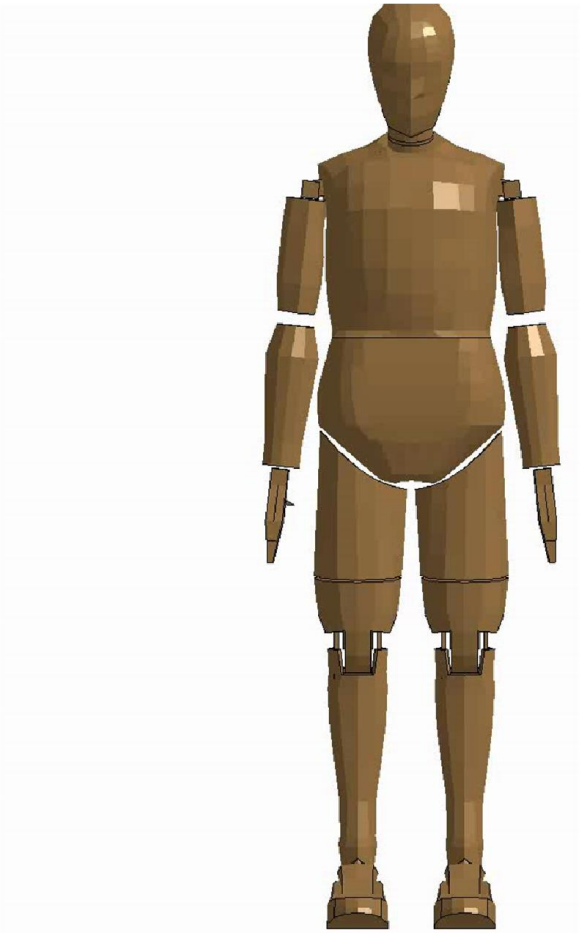
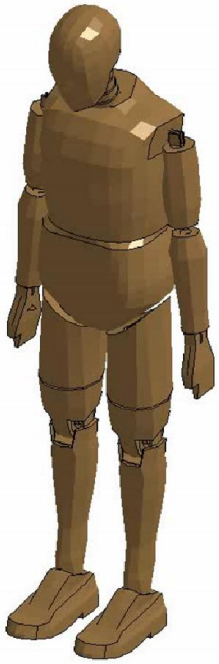
Model reduction

- The chosen LSTC Dummy has 115 parts (rigid, deformable and discrete)
- It is neither necessary nor possible to provide motion capture data for every part
- The rigid body trajectories are imparted to the arms, legs and torso
- *CONSTRAINED_RIGID_BODIES card is used for model reduction



Imposing marker trajectories on dummy





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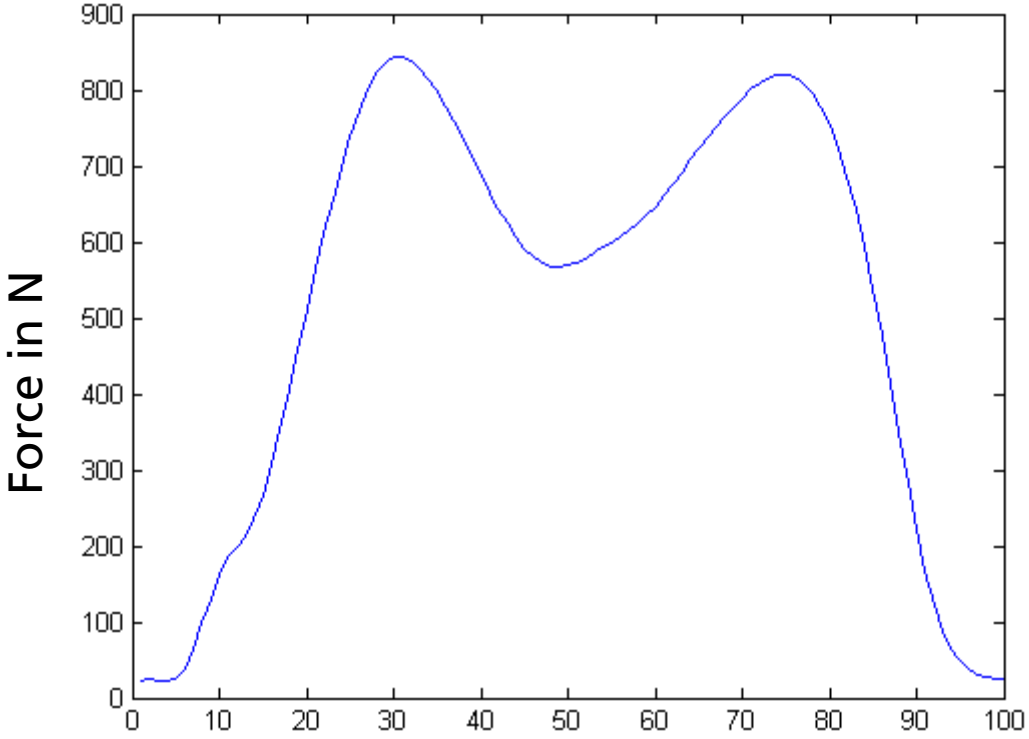
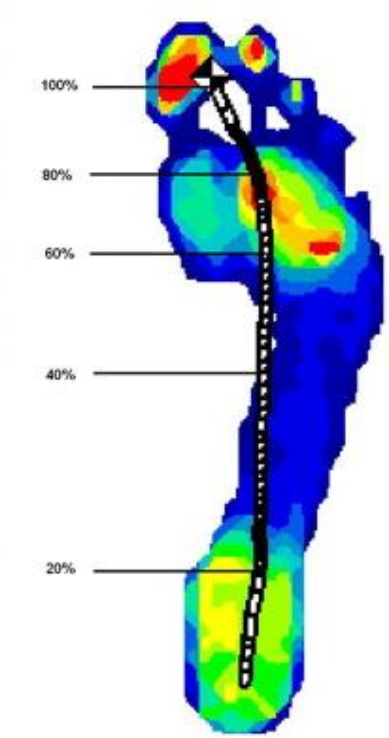
Ground Reaction Force (GRF) – Normal gait



Experimental GRF data



Source: *Center of pressure trajectory in participants with functional ankle instability*, Hopkins J.Ty et. al.

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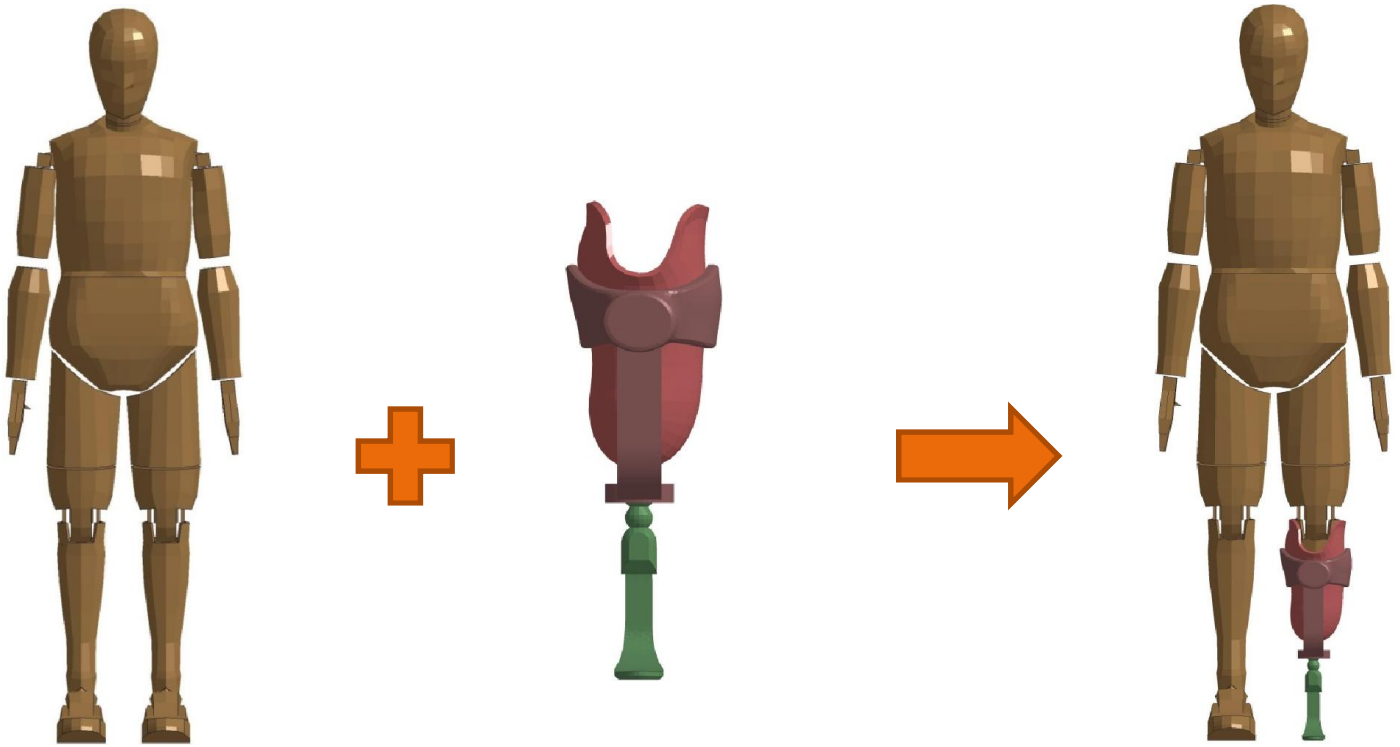
Dummy model of amputee



Elements: 4897
Nodes : 6469

Elements: 9197
Nodes : 6911

Elements: 13094
Nodes : 13374

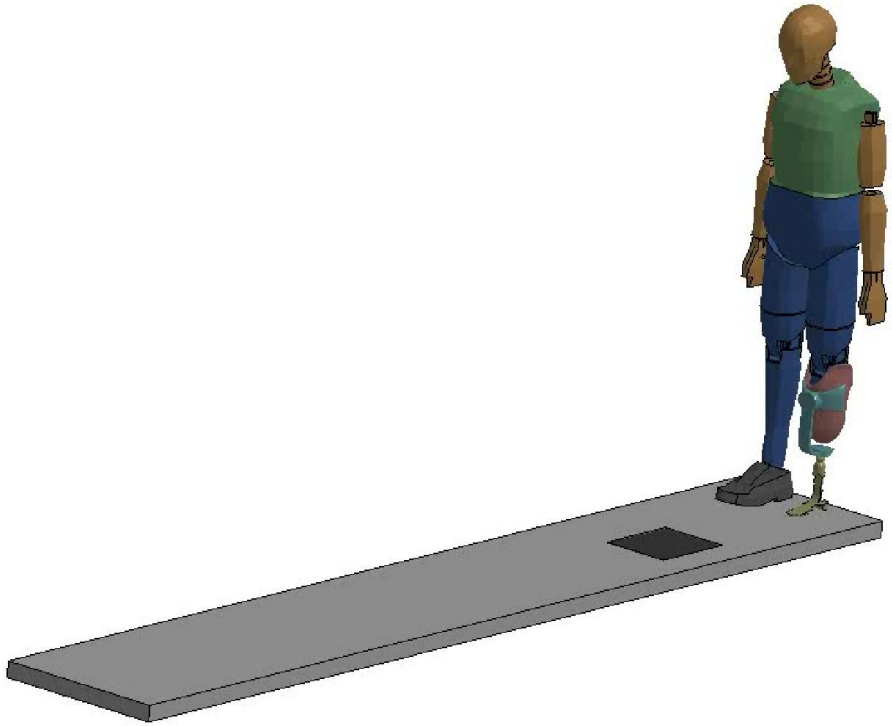
Fraunhofer IPA

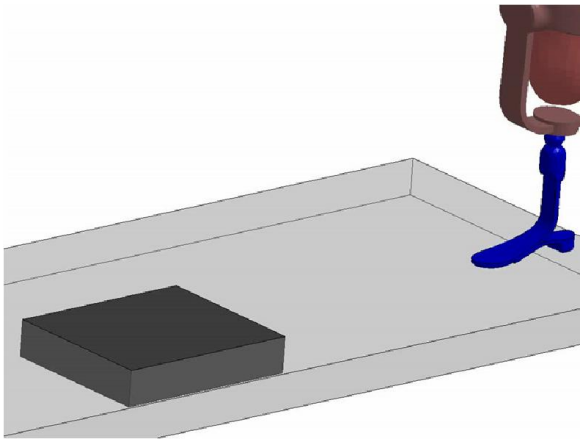
Semi-automatic fitting of prosthesis to Dummy: PCA

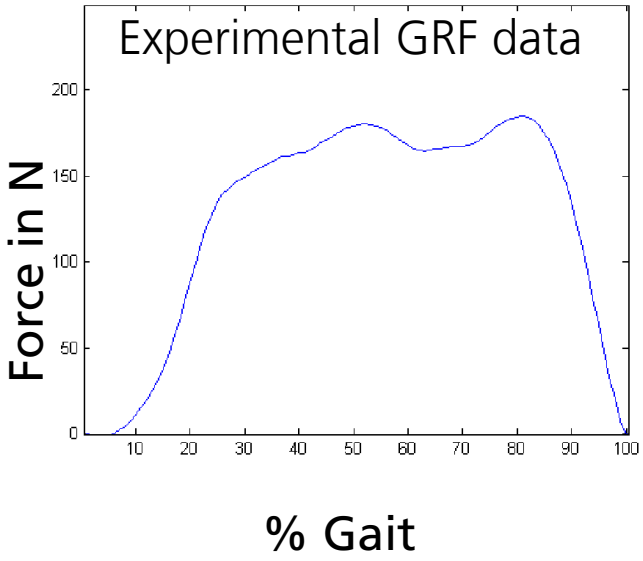
- Prosthesis and dummy could be randomly aligned
- Principal Component Analysis (PCA) helps to align the dummy and prosthesis
- Point cloud data of prosthesis and residual limb is required for alignment

Virtual gait:

Ground reaction forces and prosthesis loading pattern







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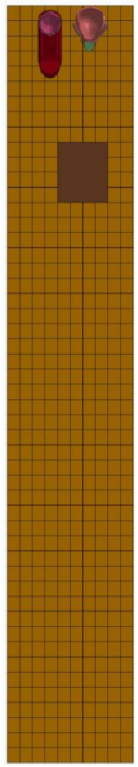
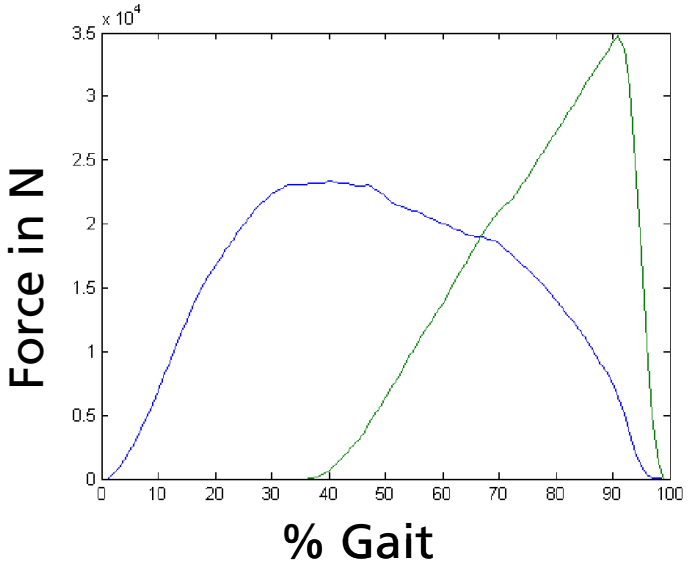
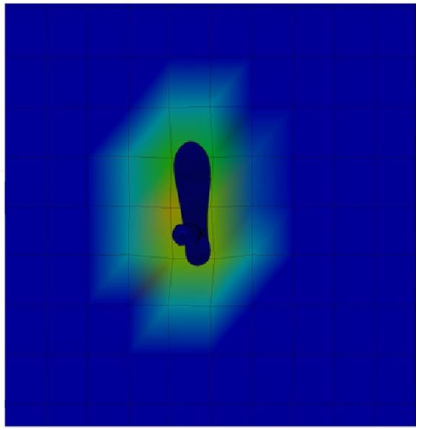
Ground reaction force (GRF) – Amputee gait

MODEL 1







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The ideal M-curve

Next steps…

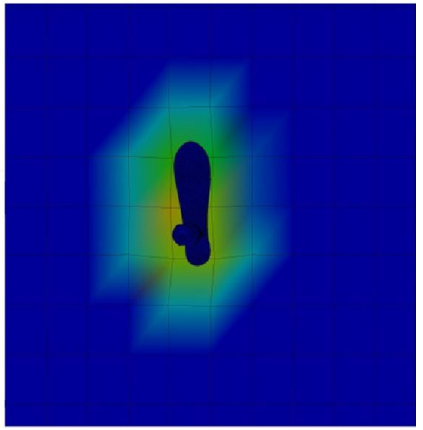
- Center of Pressure measurement
- Weighted averaging of element interface forces

or

Through moment equilibrium equations

$$x' = \frac{-M_{y'}}{F_z}$$

$$y' = \frac{M_{x'}}{F_z}$$



How would you design a prosthesis for an elephant?

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Dental Biomechanics

Fraunhofer
IPA

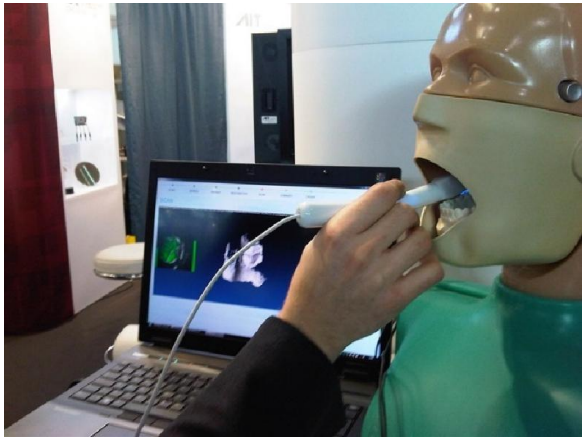
Significance of Dental Biomechanics

- Did you know that our Incisors can generate 25Kg force and our Molars can generate up to 122Kg force?
- Mechanics of the modern human jaw is very efficient but the modern humans have lost the ability to generate a powerful bite
  - *Stephen Wroe, University of New South Wales*

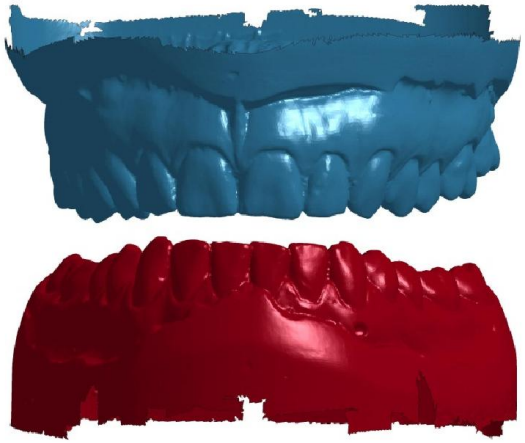
- What has changed and why?
- How will the chewing pattern evolve here on?

Analysis of chewing pattern

- Every person’s chewing pattern is unique
- No one has identical set of jaws
- Analysis of chewing pattern – Gait analysis

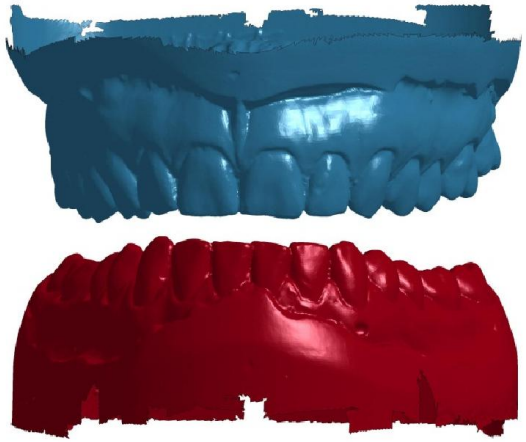


Intraoral scan



Digital CAD model

Biting forces estimation - Setup



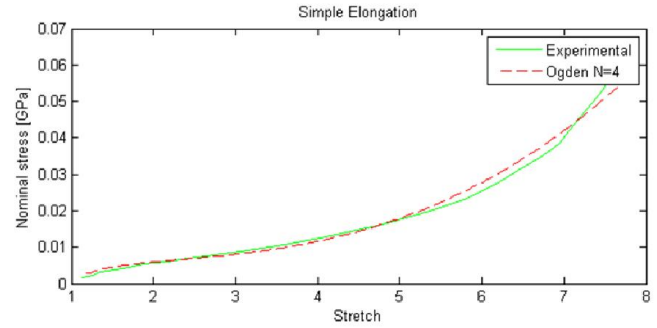
Fixed

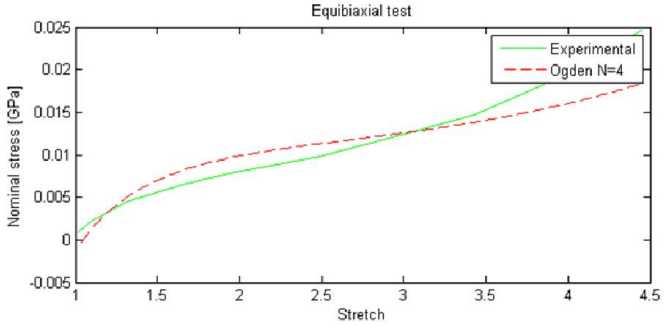
Translation

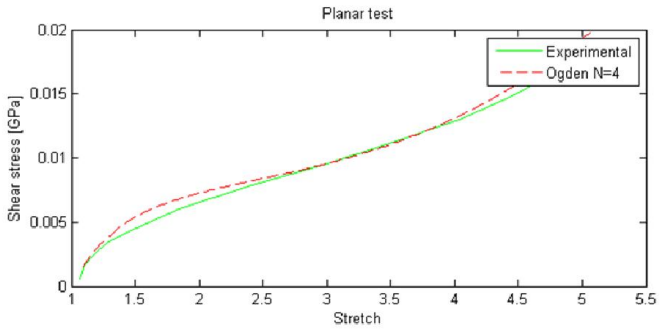
200000 nodes/elements

Biting force estimation - Setup

- Units: kg-mm-ms-kN-GPa
- Jaws:
  - Rigid (Enamel)
  - Elastic material 83GPa
  - Density 3e-6kg/mm^3
- Rubber
  - Ogden rubber (Latex rubber, Treloar)
  - μ=[304.89; 86.18e-6; -306.22; 1.3244]
  - α=[2.18e-7; 4.129; -28.5e-6; 1.817e-6]
  - Density 2.33e-6 kg/mm^3







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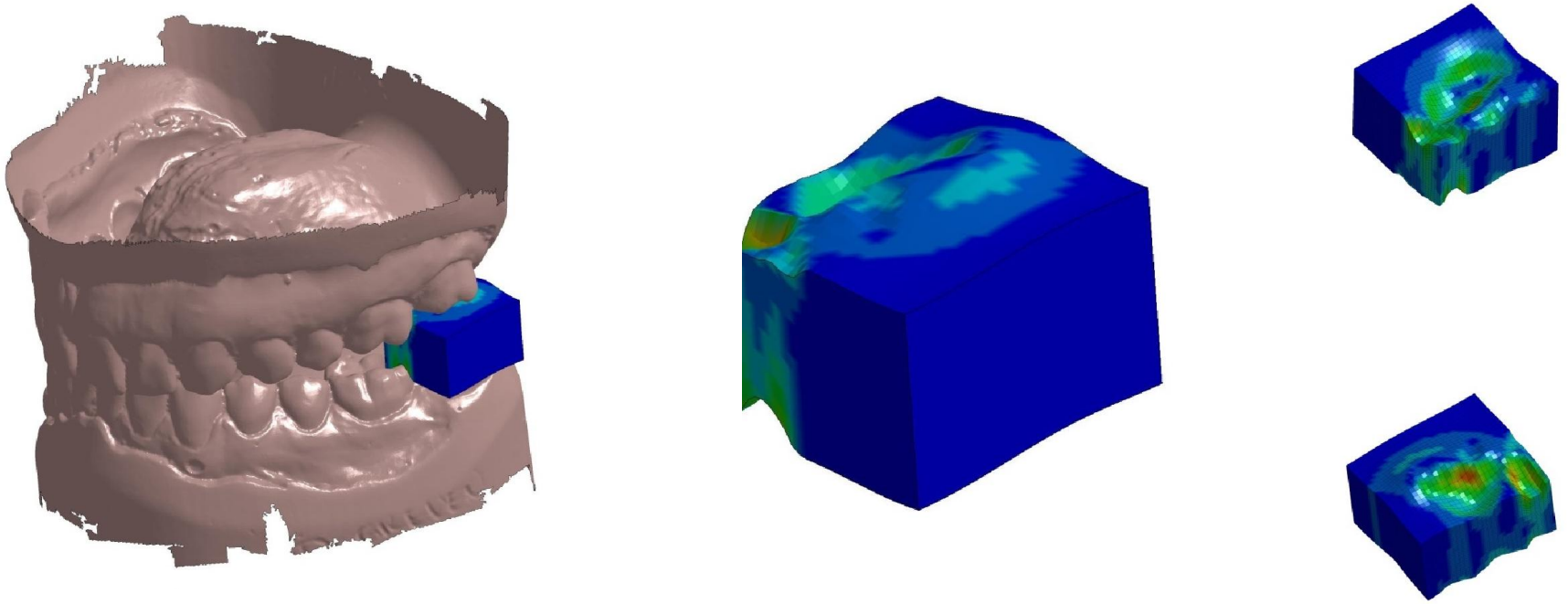
Biting force estimation – Uniaxial jaw motion



Fraunhofer IPA

Biting force estimation

- Interface forces between chewing rubber and teeth
- Contact forces on the teeth are the biting forces
- Pending patent

Next steps:

- Acquire actual jaw motion
- How does scan resolution (mesh density) affect the interface forces?
- Use computed biting forces to design and test dental restorations, dental implants, jaw replacements, mouthguards,…

Contacts

Biomechatronische Systeme

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