Ο Ρόλος της Εξομοίωσης Σύνθετων Συνδεσμικών Κακώσεων του Γόνατος μέσω Ηλεκτρονικού Υπολογιστή

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Επίκουρος Καθηγητής
Τμήμα Φ/Θ ΤΕΙ Δυτικής Ελλάδος

69ο Συνέδριο Ορθοπαιδικής Χειρουργικής & Τραυματολογίας

2 - 5 Οκτωβρίου 2013

Outline

- Introduction
1. Computer simulation
2. Knee Joint Complex Injury
3. *OpenSim* Tool
- Methods
- Results
1. Related work
- Conclusions
- Our team

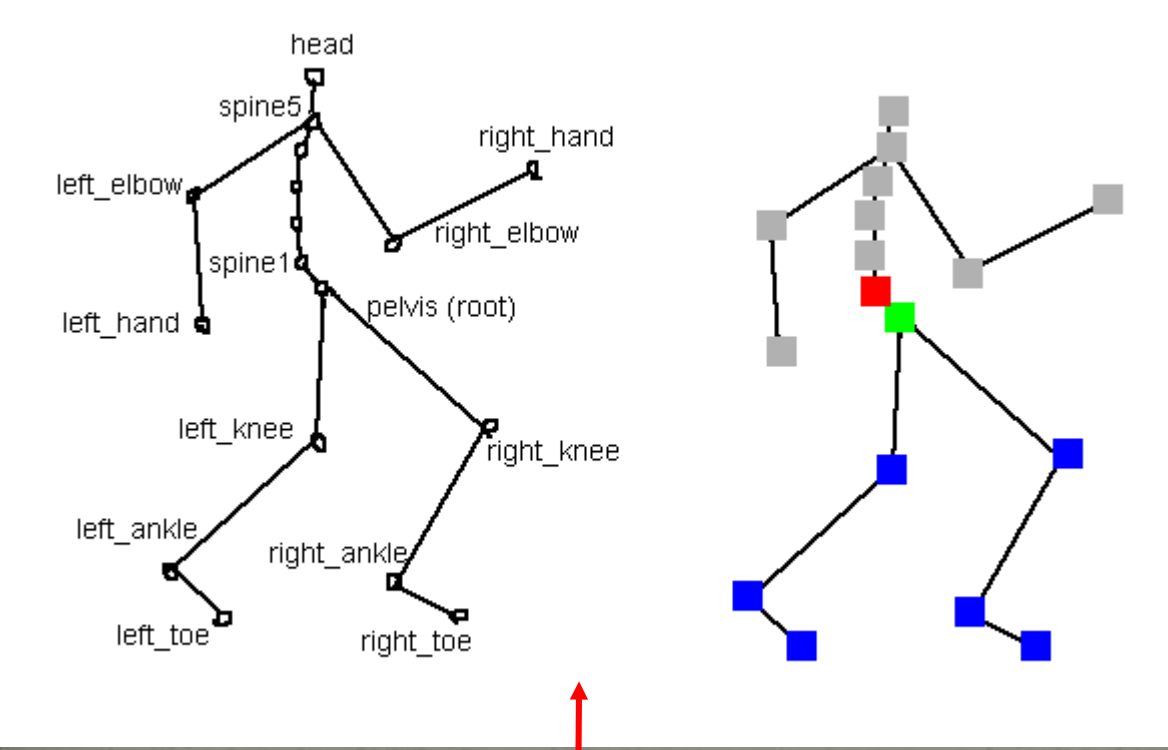
***No Conflict of Interest**

Introduction

1. Computer Simulation:

as Finite Element Analysis are a sum of advanced methods for structural stress analysis

Movement Animation



- Keyframe based animation
- Keyframes manually edited
- Alternative: motion tracking

- Skeletal motion applied to skin

Movement Simulation

- *Definition of physical laws*
  - *Gravity*
  - *…*
- *Definition of physical properties*
  - *Mass*
  - *Elasticity*
  - *…*
- *Definition of simulation-specific quantities*
  - *Viscosity*
  - *Constraints*
  - *…*

$$M\ddot{u} + (\alpha M + \beta K(u) + D)\dot{u} + f_{\text{int}}(u) = f_{\text{ext}}$$

$$M\gamma = \Sigma F$$

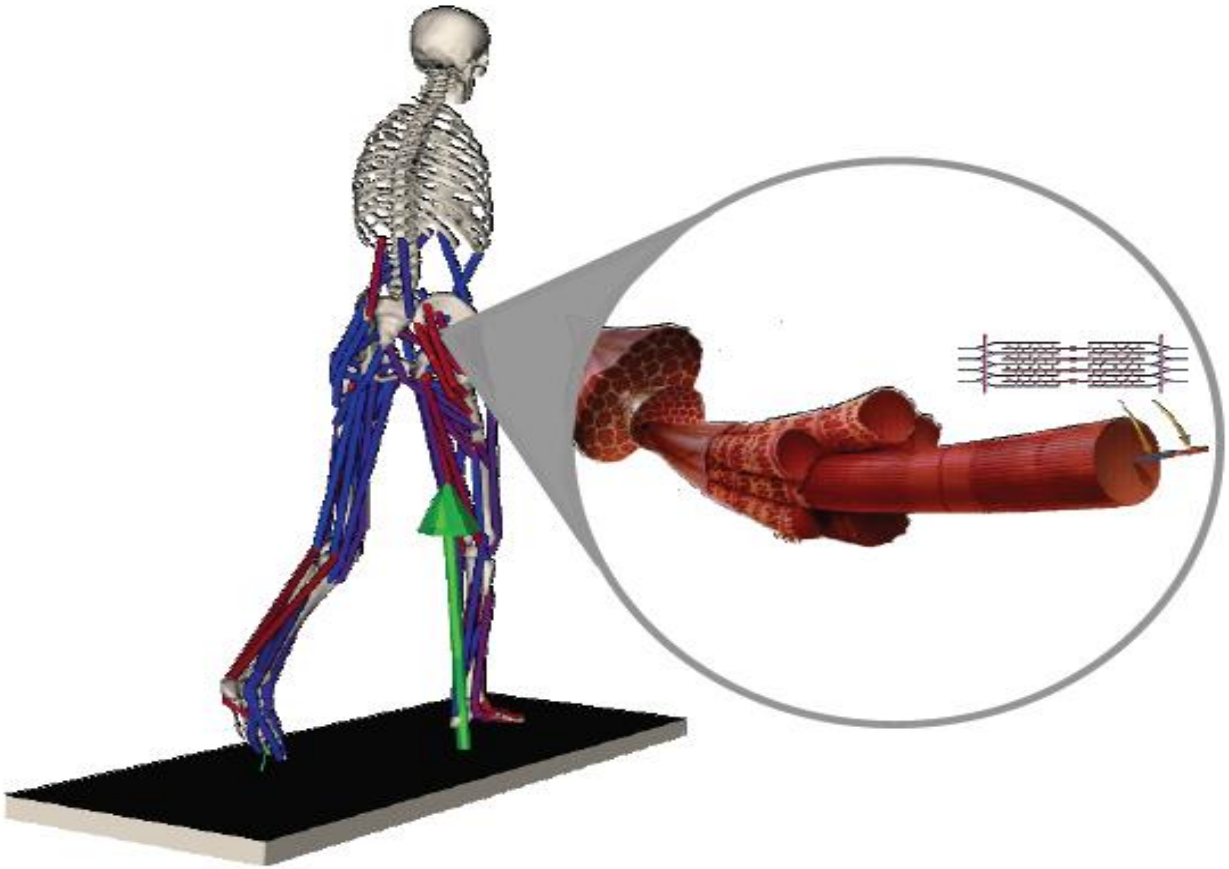
And now what?

$$\dot{\mathbf{u}}_i^{n+1} = \dot{\mathbf{u}}_i^n + \mathbf{F}_i^n \frac{dt}{m_i}$$

$$\mathbf{u}_i^{n+1} = \mathbf{u}_i^n + \dot{\mathbf{u}}_i^{n+1} dt$$

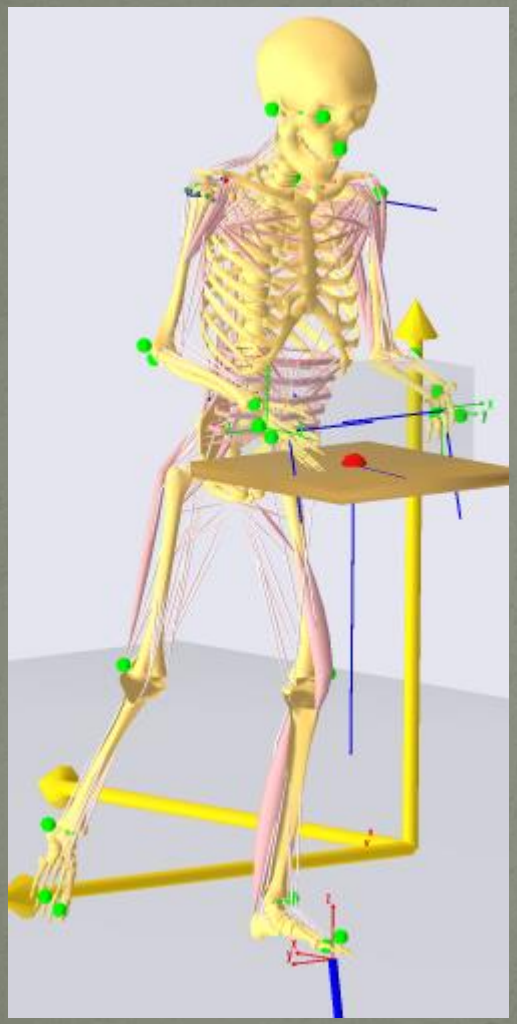
Numerical integration (Timestepping)

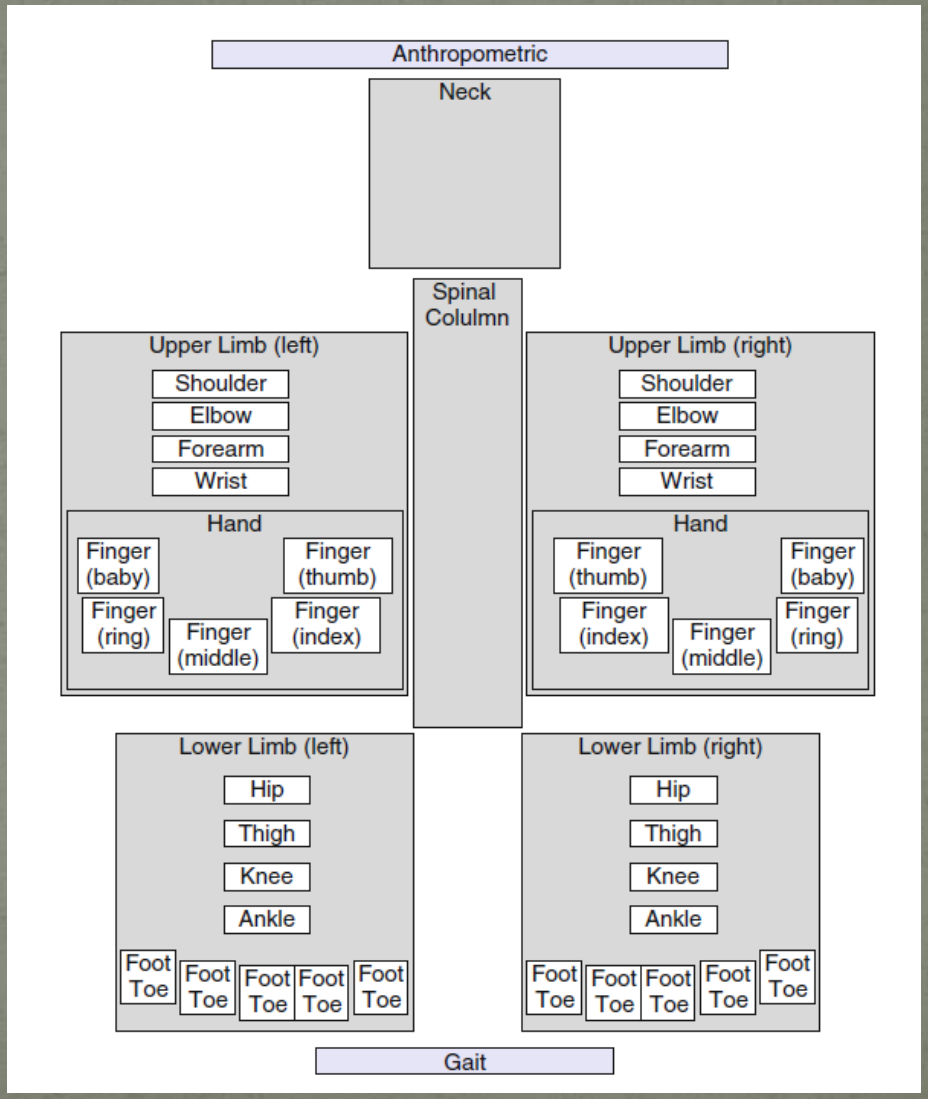
Biological structures and clinical problems concerned are complex



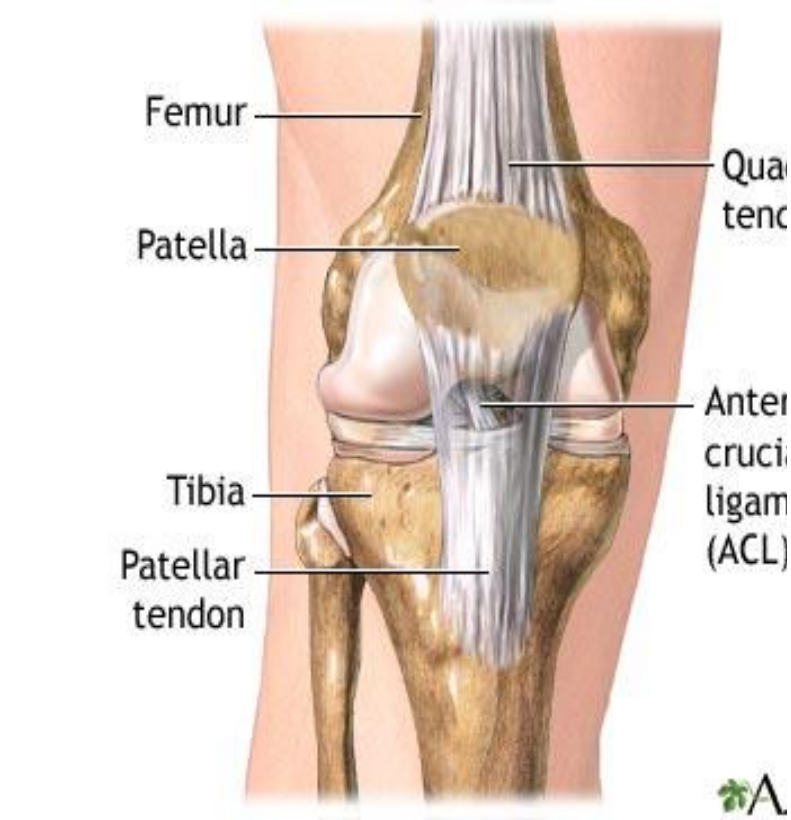
Simulation Analysis: Estimating Joint Loads

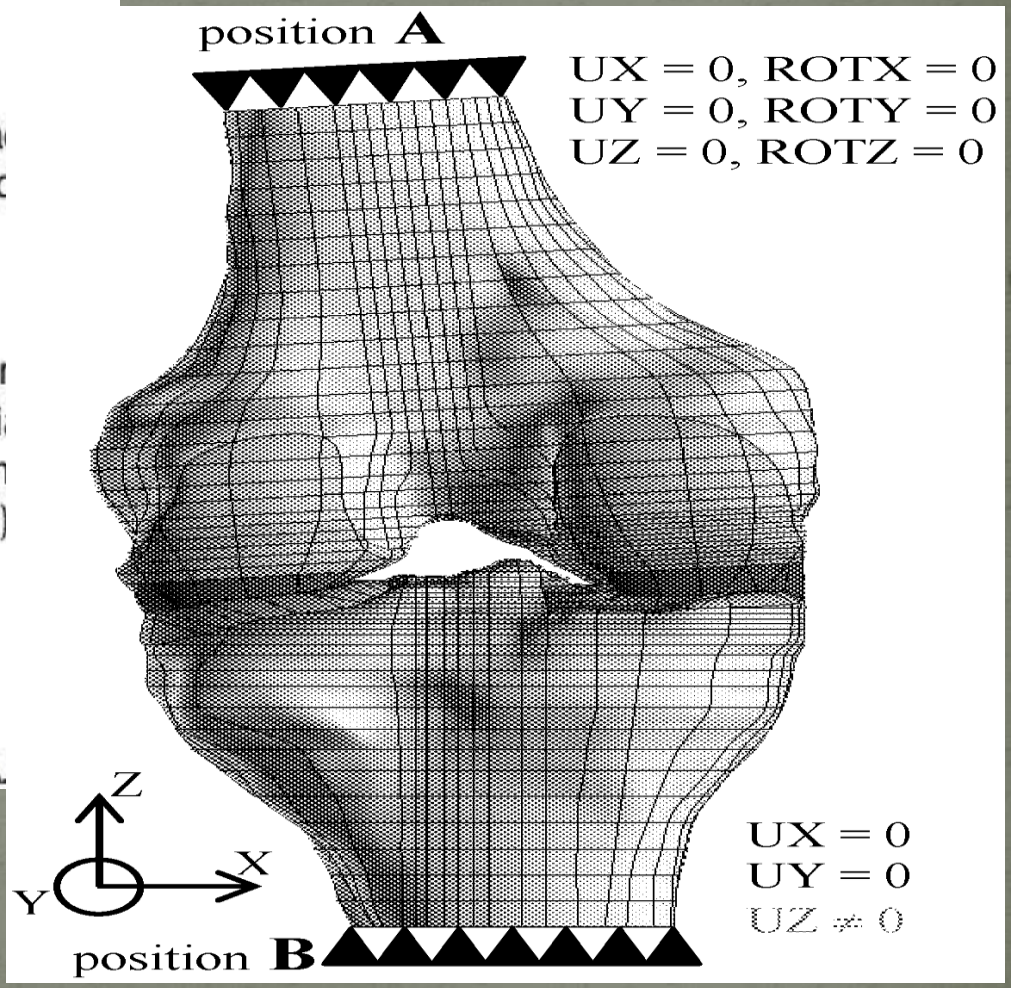
User Model development





2. Knee joint Complex injury

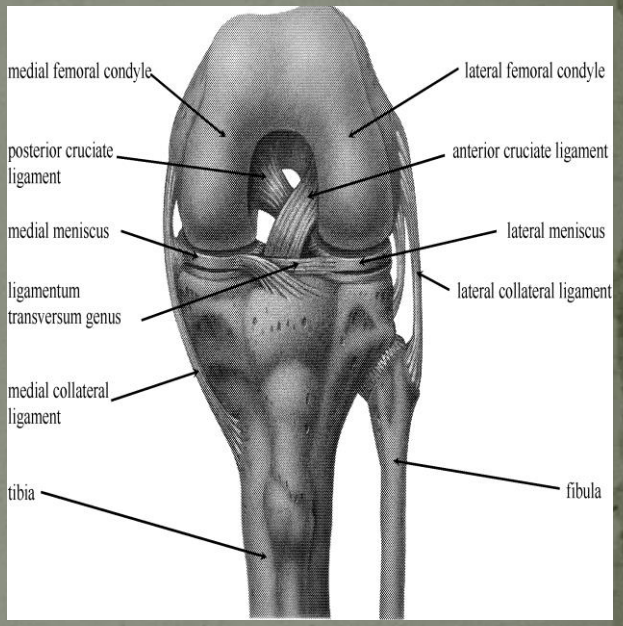




Martin Kubicek,& Zdenek Florian , **Stress Stain Analysis Of Knee joint ,** *Engineering Mechanics, Vol. 16, 2009, No. 5, p. 315–322*

Major ligamentous stabilizers of the knee (MLKI)

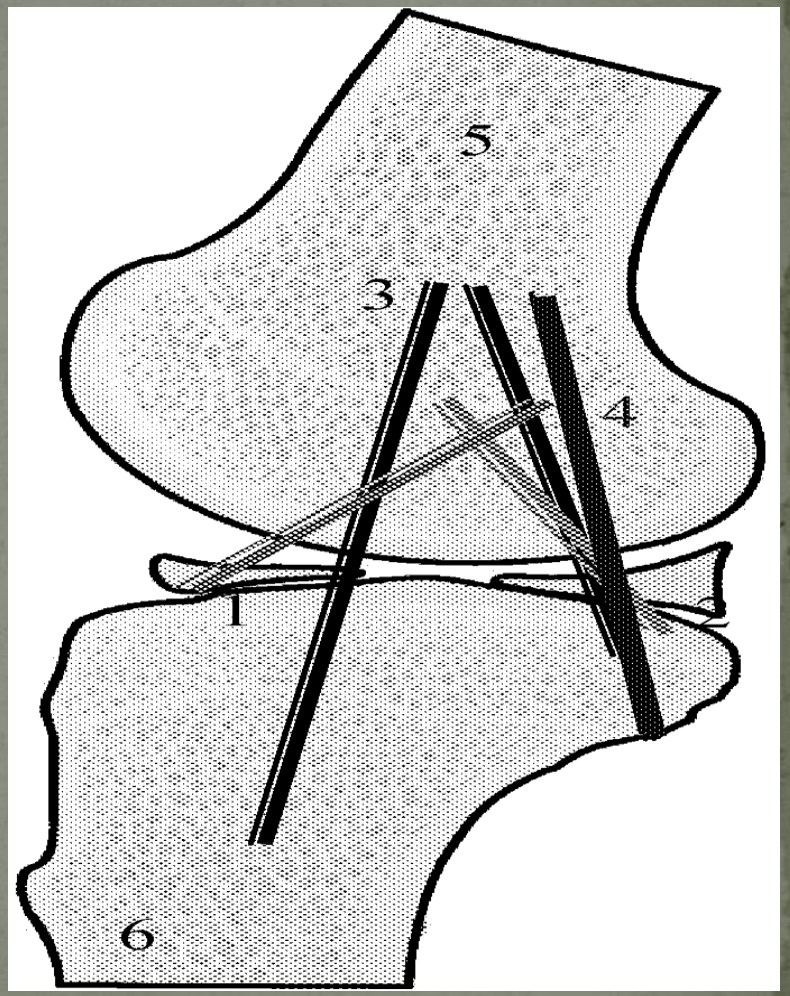
- PCL
- ACL
- MCL - Medial side ligament complex
- LCL - Lateral side ligament complex



Complex Injury of ACL +PCL + PLRI

Central ligamentous axis damage and associated injuries

- PCL
- ACL
- Medial side ligament complex
- Lateral side ligament complex

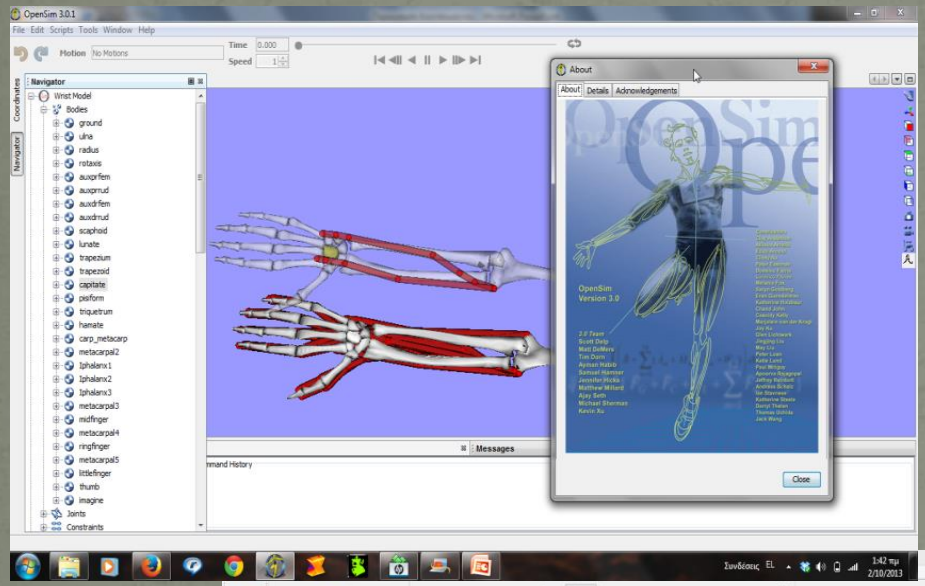


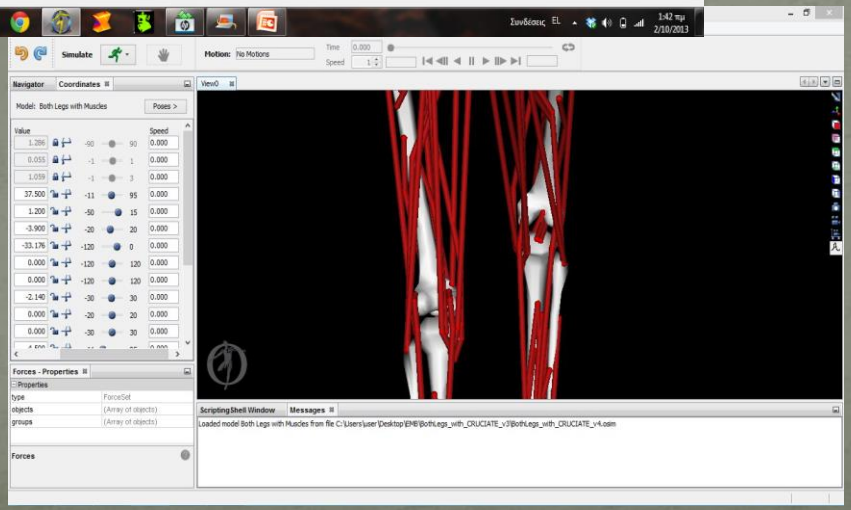
Martin Kubicek,& Zdenek Florian , **Stress Stain Analysis Of Knee joint ,** *Engineering Mechanics, Vol. 16, 2009, No. 5, p. 315–322*

Require sound understanding of engineering mechanics and a profound appreciation of the complex reality

- MLKI will be defined as one complete cruciate tear (grade III) plus a partial or complete collateral tear (grade II or III) or a partial or complete tear of the other cruciate (grade II or III)
- Knee dislocations will be defined as complete tears of both cruciates (grade III) plus a complete collateral tear (grade III)

3. OpenSim Tool: Open Source Simulation Software

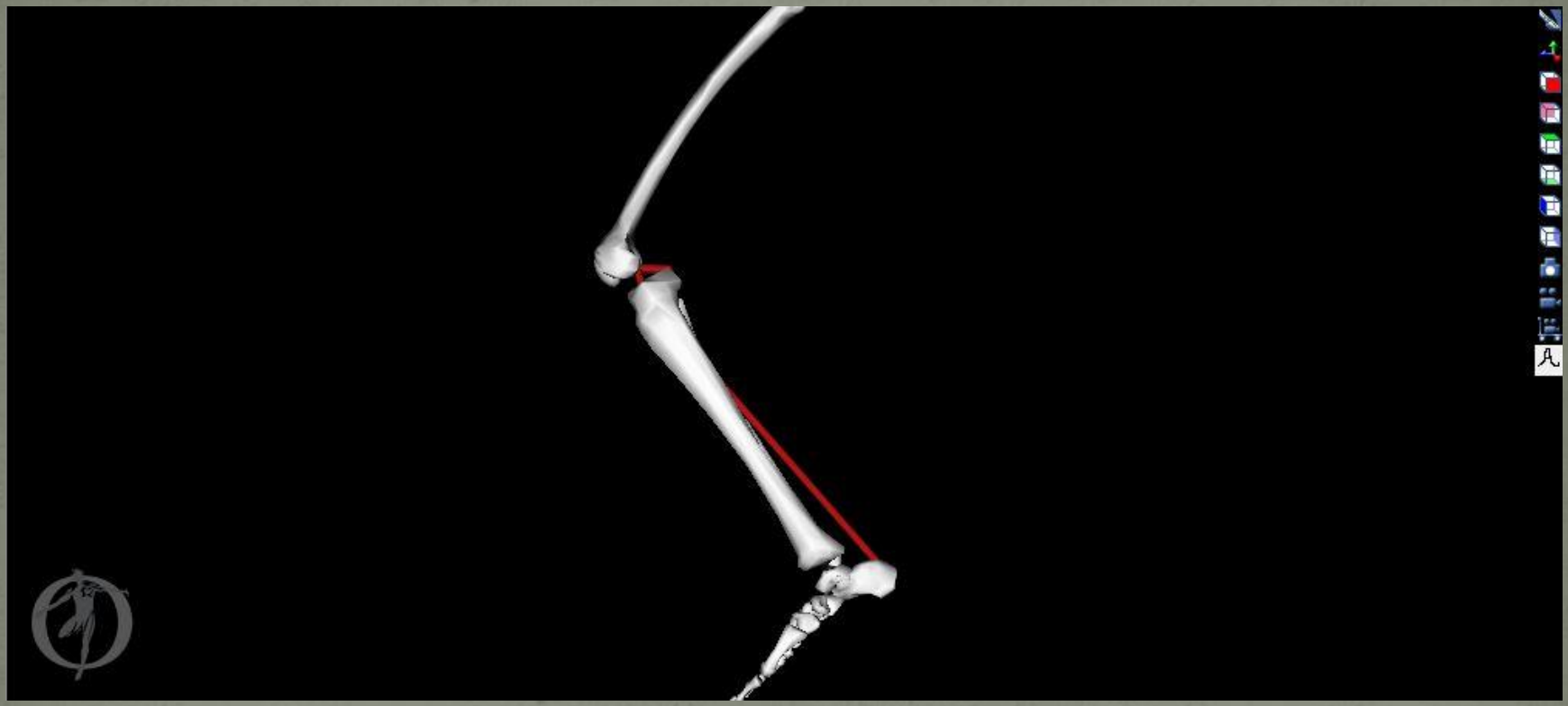




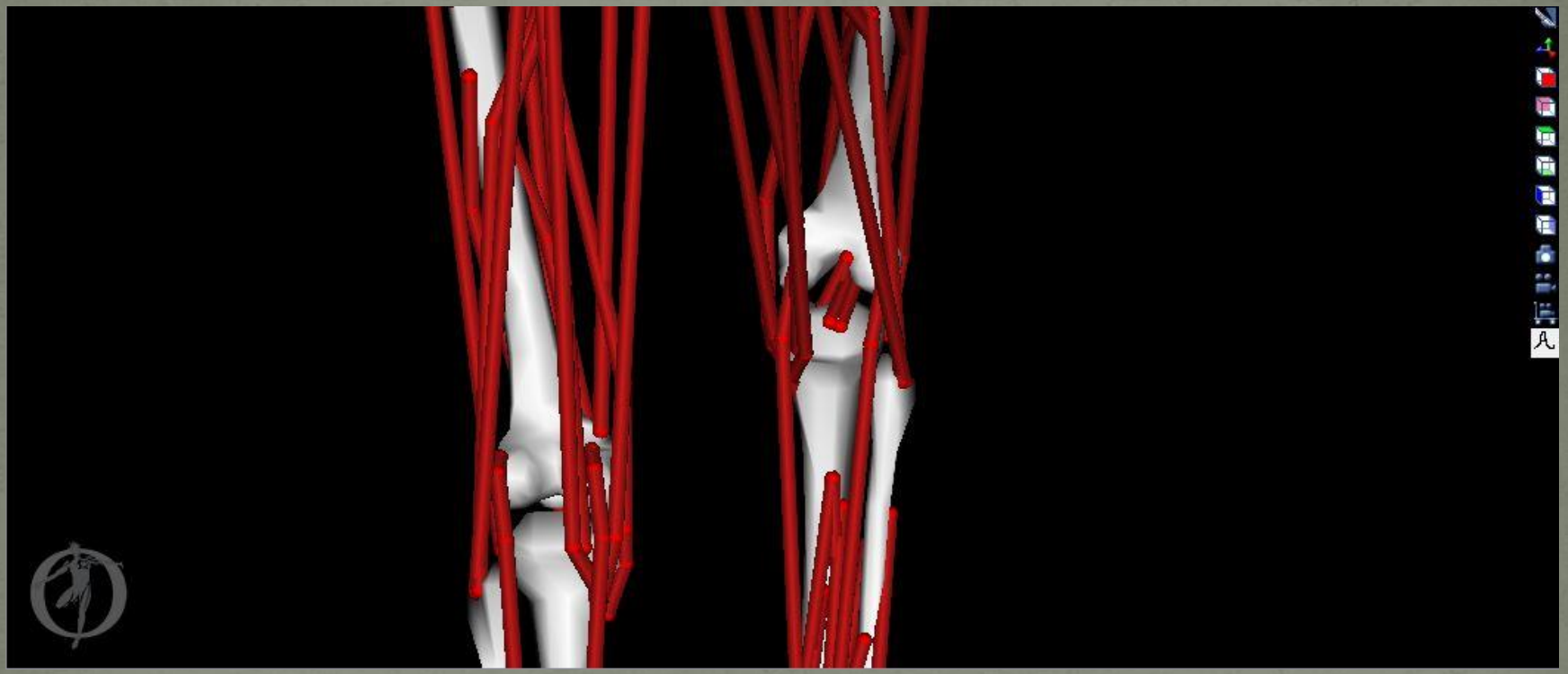
OpenSim is a software platform for modeling **humans, animals, robots, and the environment**, and simulating their interaction and movement.

OpenSim has a graphical user interface (GUI) for visualizing models and generating and analyzing simulations. The open source and extensible software also includes an application programming interface (API) that developers can use to extend the software.

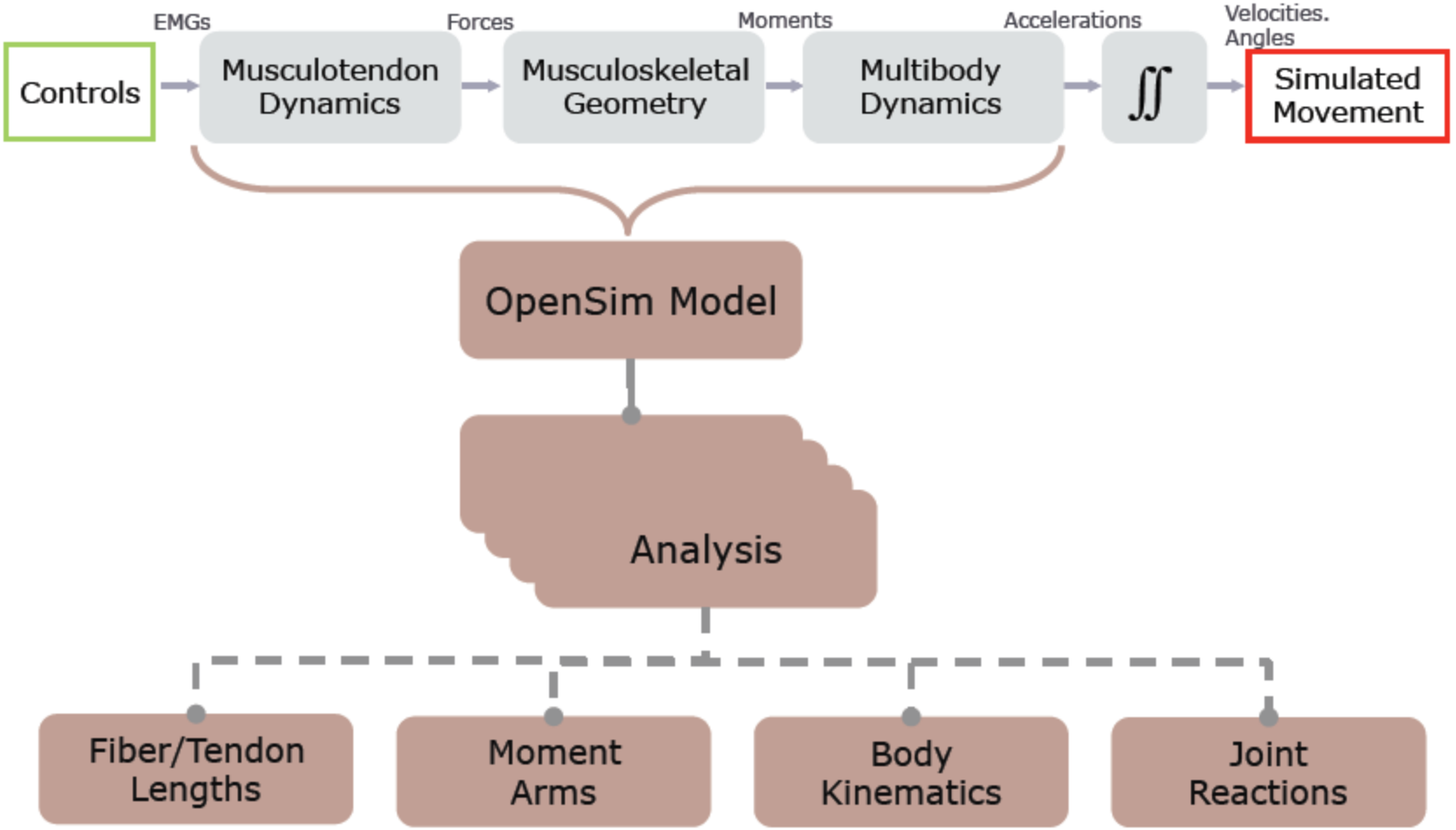
OpenSim: Open Source Simulation Software – Lower limps



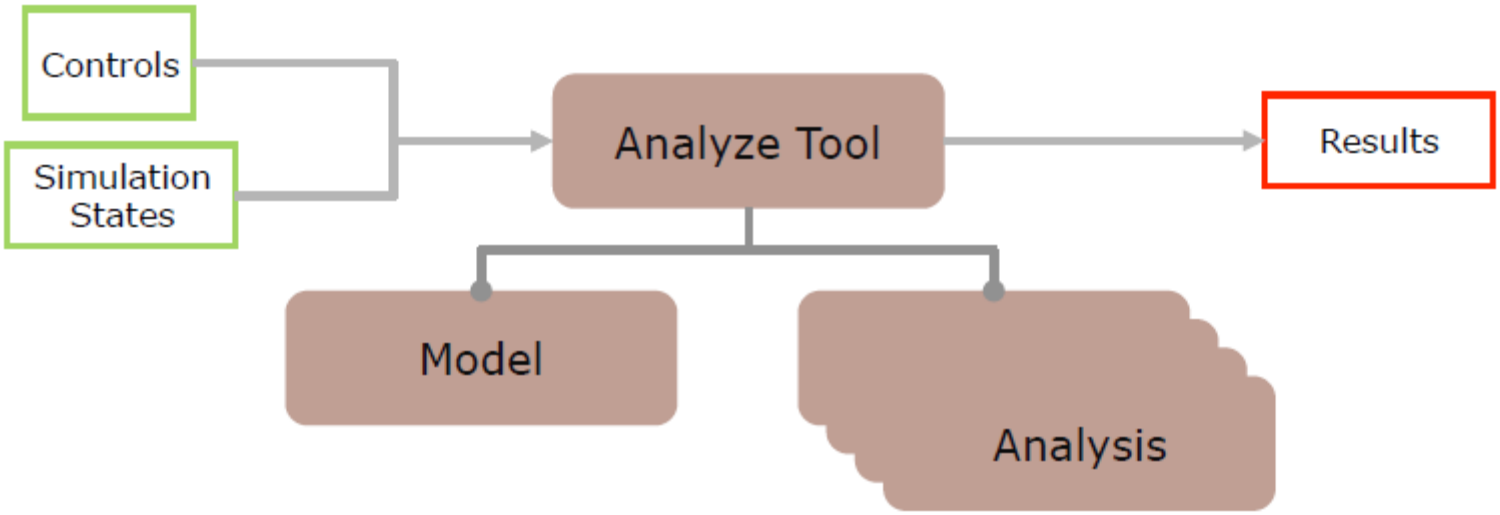
OpenSim: Open Source Simulation Software -Joints



Investigating a Simulation:



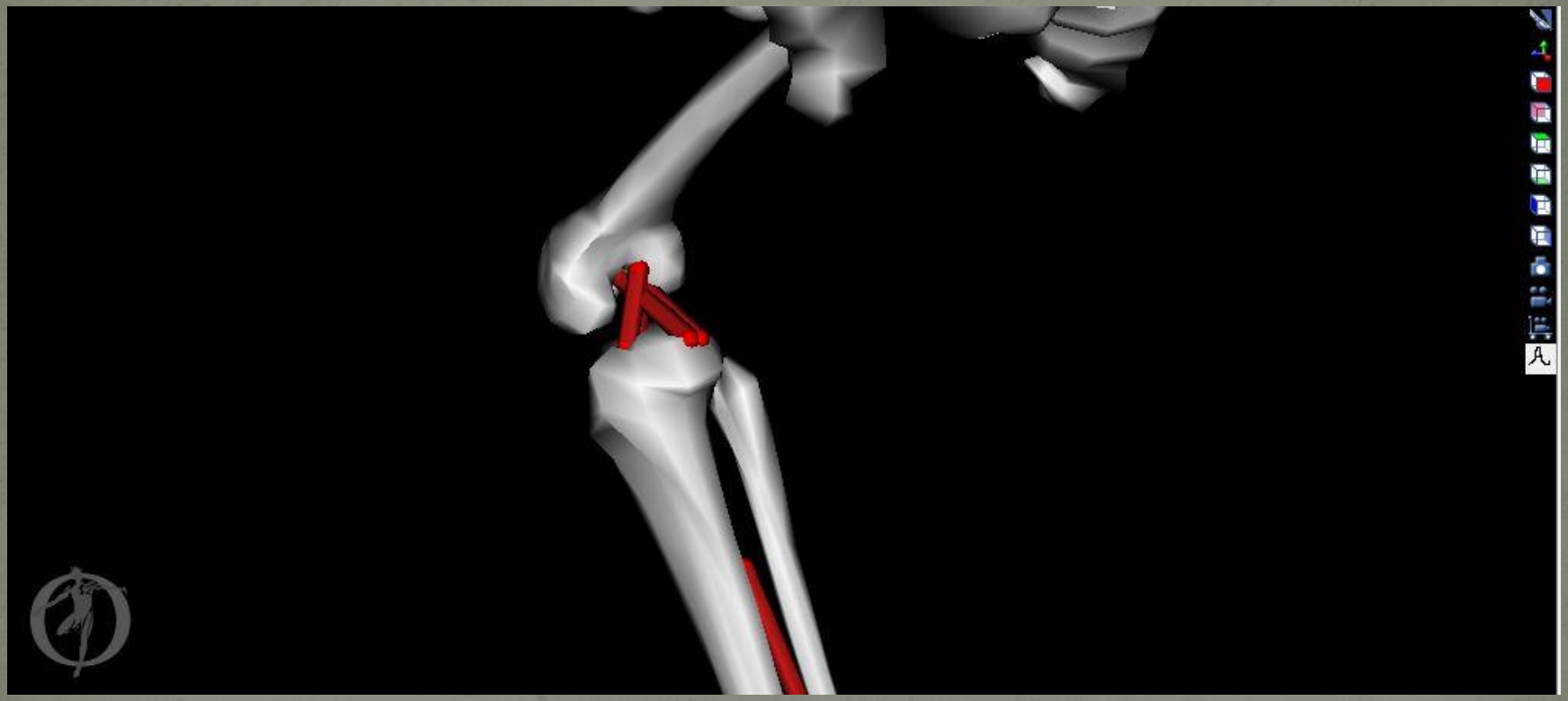
The Analyze Tool:



Scott L. et al, OpenSim: Open-Source Software to Create and Analyze Dynamic Simulations of Movement , IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 54, NO. 11, NOV 2007

Methods:

OpenSim for Knee ligament simulation



Open Source Simulation Software - movement

Scott L. et al, OpenSim: Open-Source Software to Create and Analyze Dynamic Simulations of Movement , IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 54, NO. 11, NOV 2007

Aim: **Central ligamentous axis damage and associated injuries is a special problem area in order to propose the proper surgery approaches in computer environment**

Joint Reaction Analysis: Setting It Up

Inputs from Static Optimization

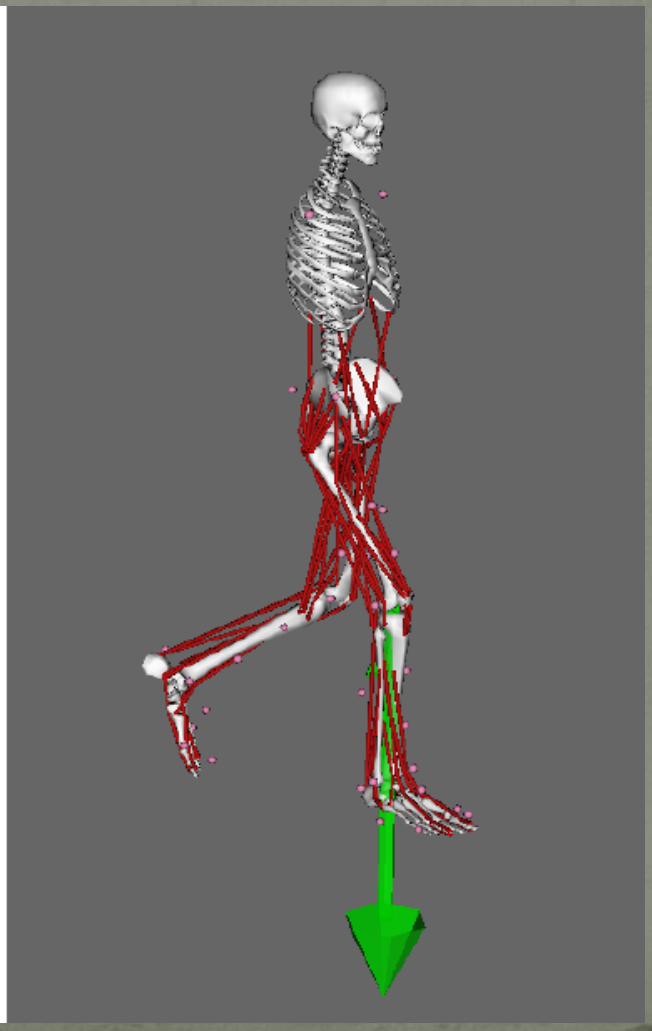
- Model
- Kinematics
- External Loads data
- Residual Actuators

Inputs specific to JointReaction

- Muscle force data
- Joints of interest
- Bodies of interest
- Coordinate reference frames

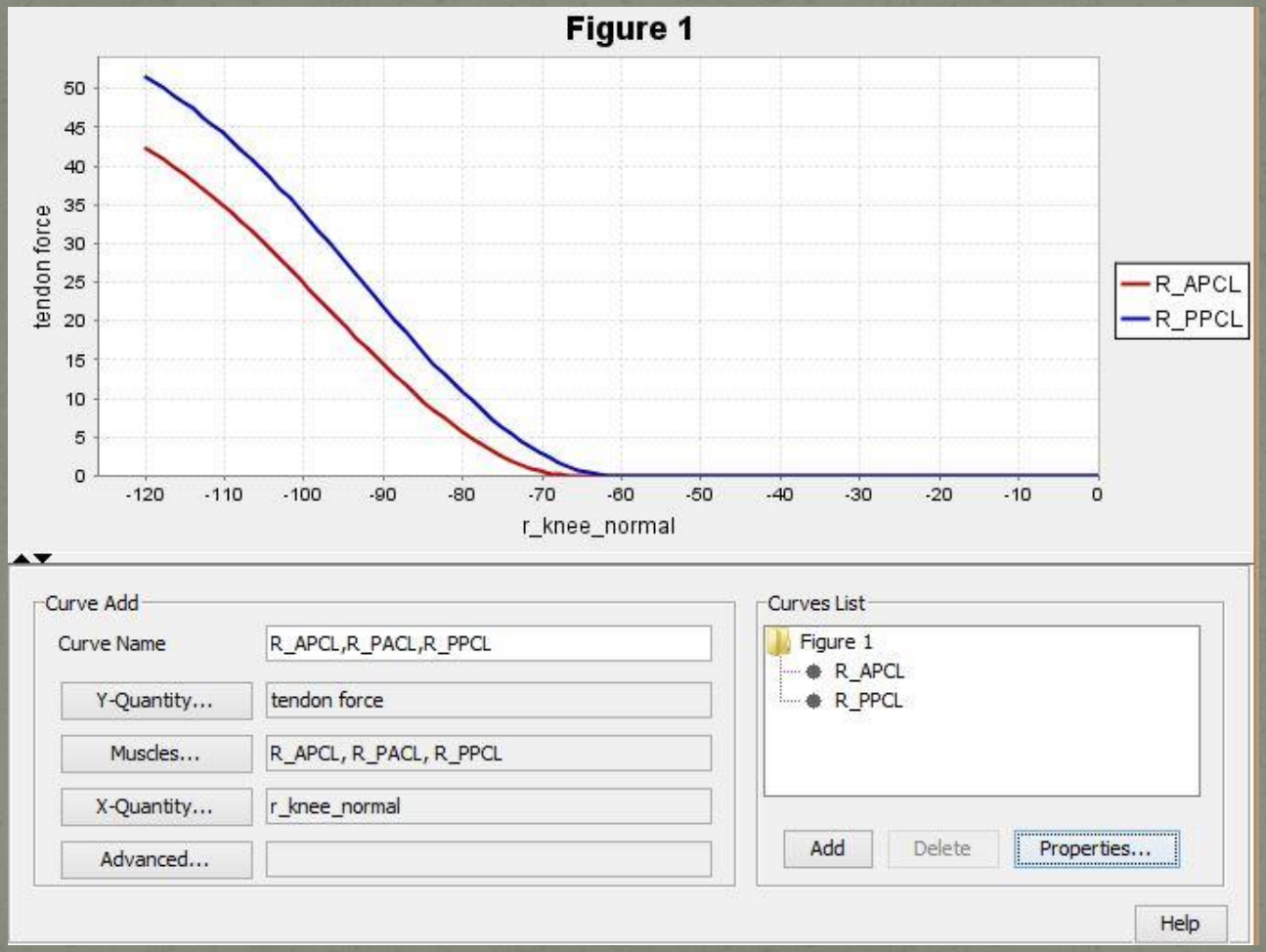
Output

- *_JointReaction_ReactionLoads.sto

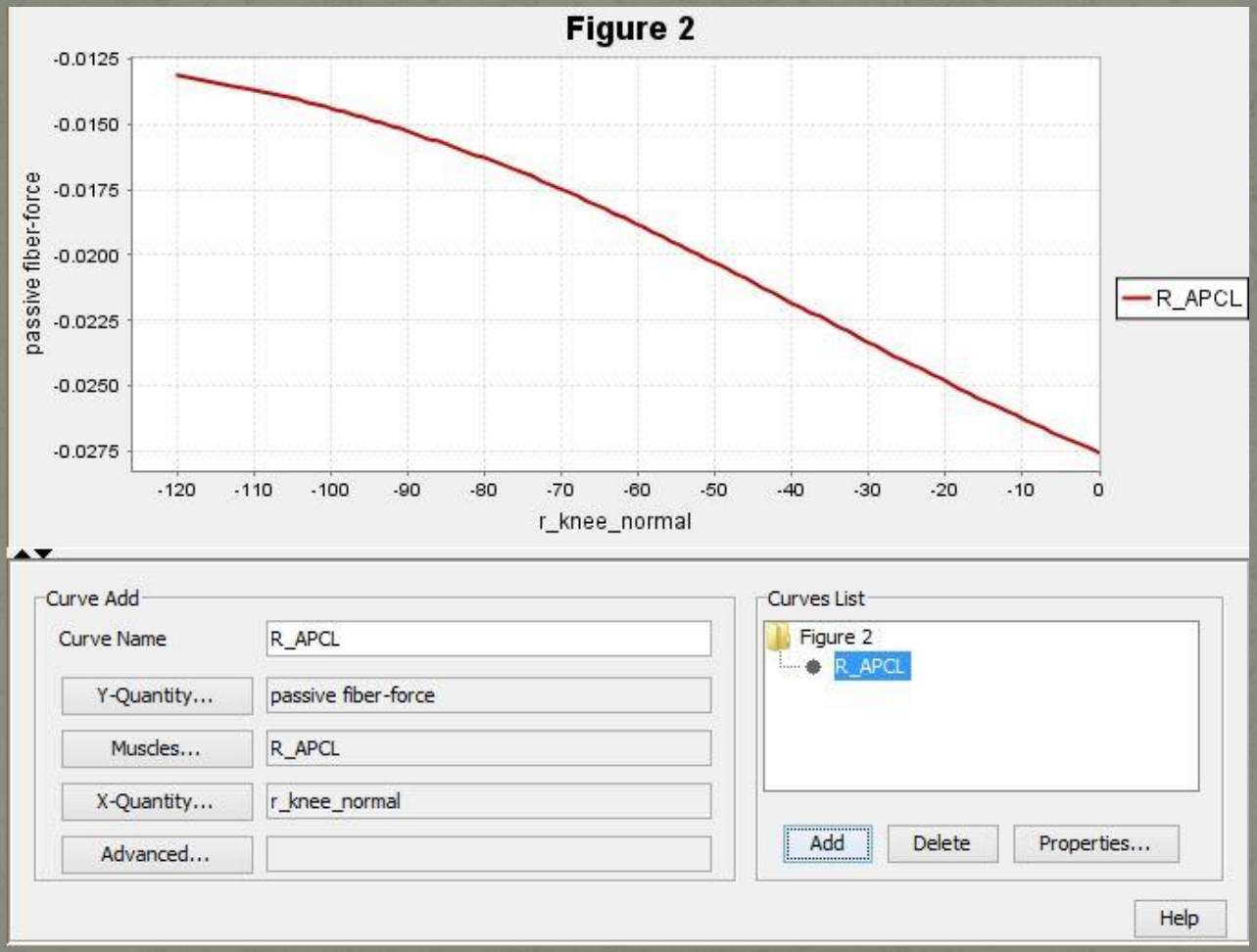


Results

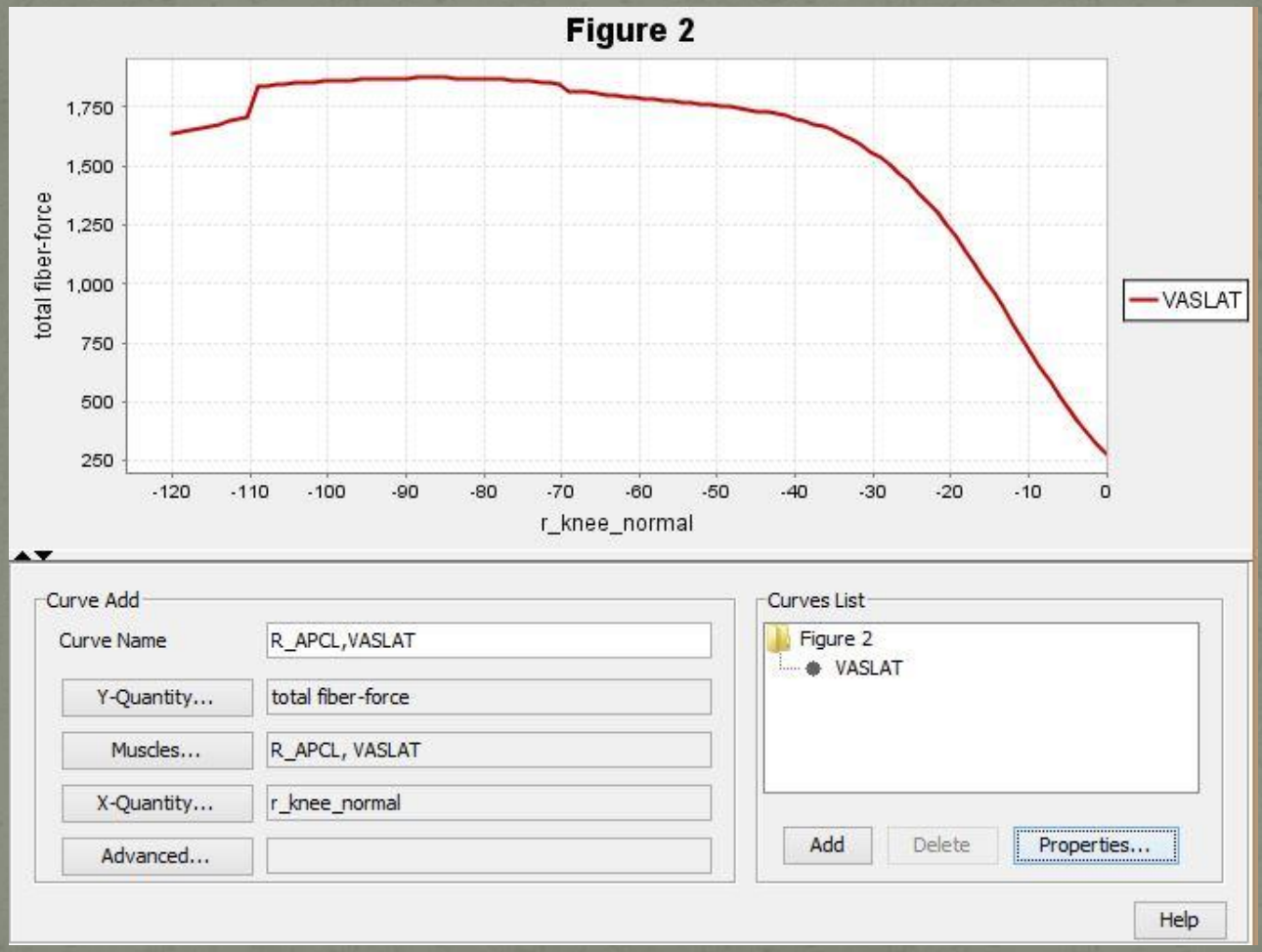
Biomechanic results 1



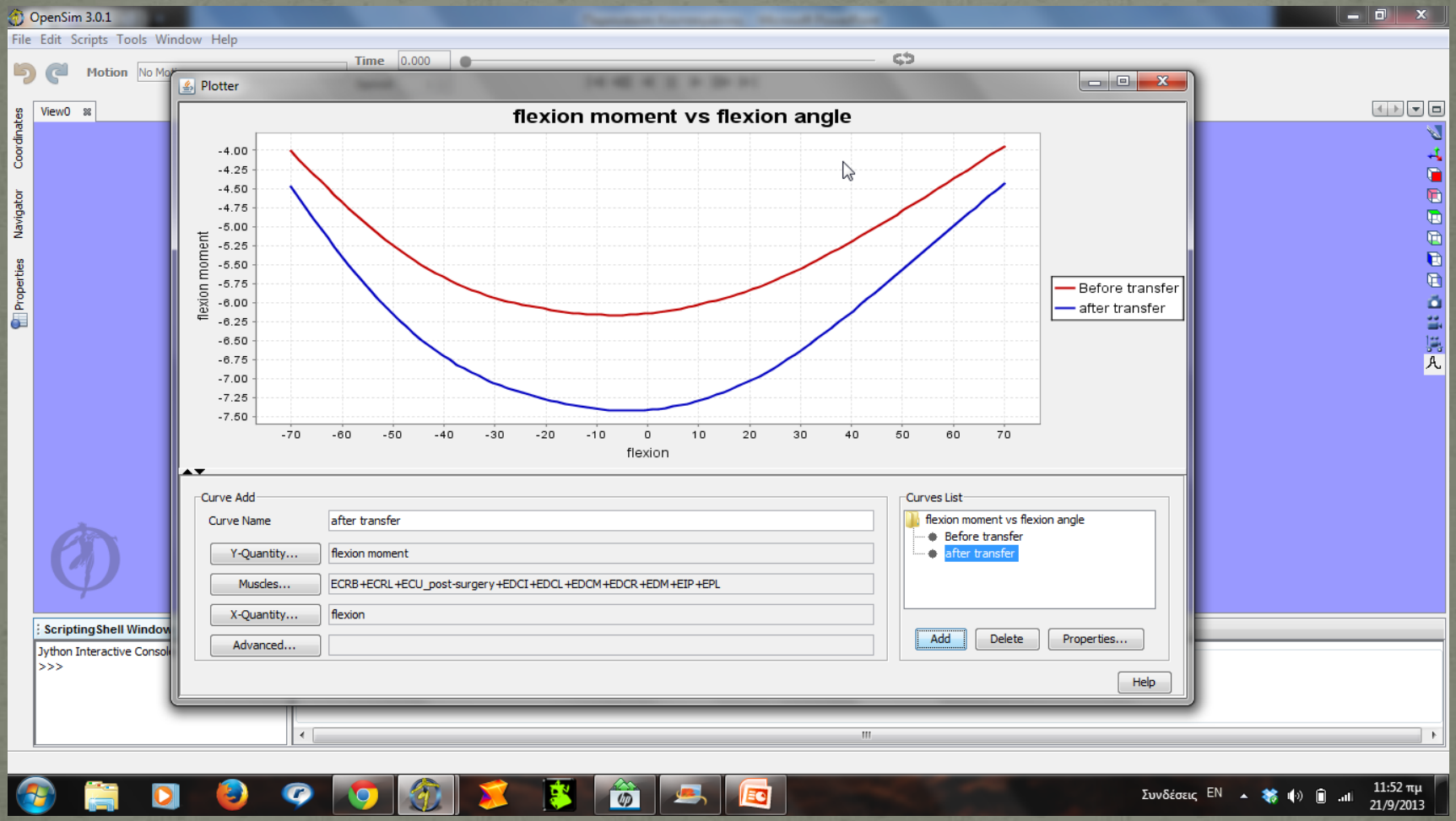
Biomechanic results 2



Biomechanic results 3



Pre- and after Surgery analysis



Related work 1

- Sung-Jae Kim et al, **Femoral Graft-Tunnel Angles in Posterior Cruciate Ligament Reconstruction: Analysis with 3-Dimensional Models and Cadaveric Experiments,** Yonsei Med J. 2013 Jul;54(4):1006-1014: *"The data from both our 3D knee-model analysis and cadaveric experiment indicate that the conventional inside-out technique leads to significantly more acute femoral graft-tunnel angle and higher stress at the intra-articular aperture of the femoral tunnel than the outside-in technique"*
- **M.Kazemi et al, Recent Advances in Computational Mechanics of the Human Knee Joint,** Computational and Mathematical Methods in Medicine Vol 2013, Art 718423: « *A complete model validation at the joint level seems impossible presently, because only simple data can be obtained experimentally. Therefore, model validation may be concentrated on the constitutive laws using multiple mechanical tests of the tissues. Extensive model verifications at the joint level are still crucial for the accuracy of the modeling*"

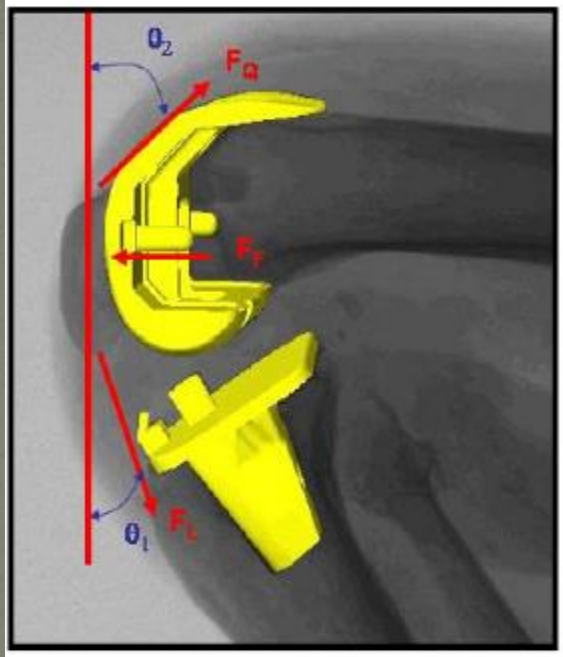
Related work 2

- **Feng Xie et al, A Study on Construction Three-Dimensional Nonlinear Finite Element Model and Stress Distribution Analysis of Anterior Cruciate Ligament Journal of Biomechanical Engineering** Dec 2009, Vol. 131 / **121007-1:** *"The three-dimensional finite element method can be used for the ACL biomechanics research"*
- Martin Kubicek,& Zdenek Florian , **Stress Stain Analysis Of Knee joint ,** *Engineering Mechanics, Vol. 16, 2009, No. 5, p. 315–322: "This review deals with the stress strain analysis of the normal tibio-femoral joint inits basic position (extension). On the basis of the analysis, a contact pressure between a femoral and tibial cartilage and femoral cartilage and meniscus has been obtained"*

OpenSim : Quantifying Joint Loads

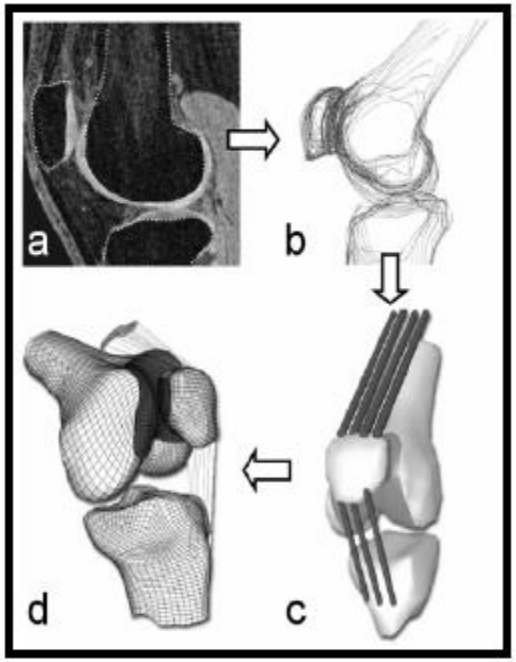
• Scott L. et al, OpenSim: Open-Source Software to Create and Analyze Dynamic Simulations of Movement , IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 54, NO. 11, NOV 2007

Design Biomedical Devices



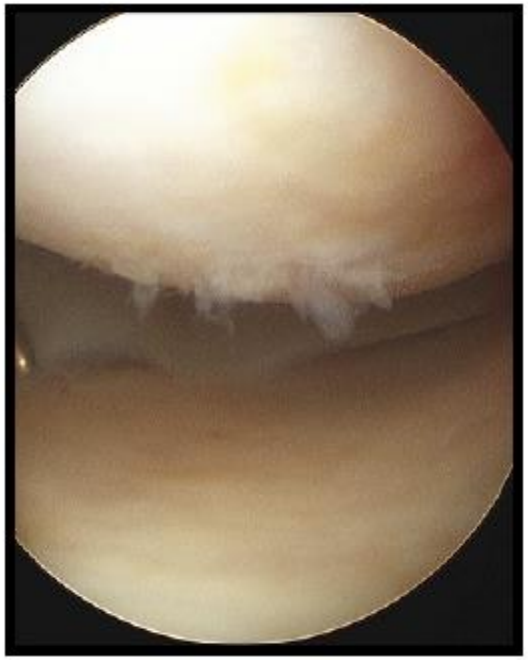
Argenson et al, J. Biomech 2005

Predict Tissue Stress



Besier et al, MED. SCI. SP & EXERCISE, 2006

Study degradation



USC2000, 2009, http://www.flickr.com/photos/usc2000/3189533413/

Conclusions

- Advanced computer methods as Finite Element Analysis is a promising method for structural stress analysis
- Biological structures and clinical problems concerned are complex
- Require sound understanding of engineering mechanics and a profound appreciation of the complex reality
- Central ligamentous axis damage and associated injuries is a special problem area in order to propose the proper surgery approaches in silico
- Real data from GAIT analysis will improve our approach

Scientific and Developing Team

- Ορθοπεδική Κλινική, Ιατρικής Σχολής Πατρών, ΠΠΓΝΠ , Καθ. Ηλίας Παναγιωτόπουλος, **Επ. Καθηγητής Ιωάννης Γκλιάτης, Ορθοπεδικός**

- Εργαστήριο Υγειοφυσικής και Υπολογιστικής Νοημοσύνης Τμήματος Φυσικοθεραπείας ΤΕΙ Δυτικής Ελλάδος, Αίγιο**, Επ. Καθηγητής Κων/νος Κουτσογιάννης, Φυσικός Ιατρικής**

- IEEE EMBS Student Chapter του Πανεπιστημίου Πατρών είναι μία ομάδα προπτυχιακών φοιτητών των τμημάτων Ηλεκτρολόγων Μηχανικών & Τεχνολογίας Υπολογιστών, Μηχανολόγων & Αεροναυπηγών Μηχανικών και της Ιατρικής σχολής, με επιστημονικό ενδιαφέρον στην Βιοϊατρική Τεχνολογία.Στο project "Μελέτης Συμπεριφοράς των Χιαστών σε ασθενείς με μερική ή ολική ρήξη" συμμετέχουν οι: Ανδρέας Τσιπουριάρης, Αλέξανδρος Κόγκας, Χριστίνα Τριανταφύλλου, Λέανδρος Μπούκας, Νίκος Γρέγος, Ειρήνη Καίσαρη, Γεωργία Πιτσάβα, Χρήστος Μπάρτζης, υπό την επίβλεψη του **κ. Κωνσταντίνου Μουστάκα, επίκουρου καθηγητή** του τμήματος Ηλεκτρολόγων Μηχανικών & Τεχνολογίας Υπολογιστών του Πανεπιστημίου Πατρών.

Thank you
for your attention

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