Computational Design Framework to Assist Subject-Specific Urological Evaluation and Intervention

Stratford-Upon-Avon, UK

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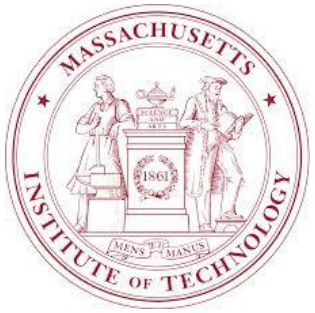
Virginia Monteiro, PhD Engineer, PUC-Rio

Kevin Matheus Moerman, PhD Engineer, MIT



Introduction

Trauma in Urological Structures

Using Gibbon

Kidney segmentation

Bladder geometry smoothing

FE organ level analysis

Final remarks

Trauma in Urological Structures

The urological system encompasses many organs, among them kidneys, bladder and urethra. Traumatic injuries to these organs may require patient specific treatment.

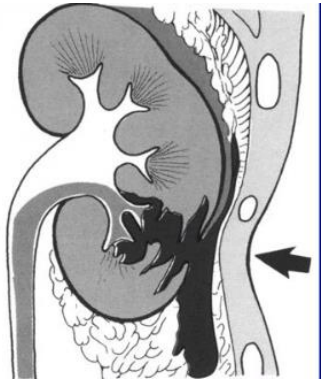
These organs can be damaged along with other internal organs when patients have suffered a blunt force trauma, like a high-speed car accident. Severe injury of kidneys often involves the immediate life saving operation followed by additional post accident medical procedure, like insertion of drains, or urinary stent.

Pelvic fracture also can compromise the urethra and reconstruction may be necessary. Damage to the bladder can occur during an automobile accident due to the impact of the steering wheel or seatbelt to the organ. The subject-specific intervention may be analyzed prior to reconstruction and healing of these organs

Trauma in Urological Structures

Renal trauma:

- Renal injuries are the most common injuries of the urinary system.
- Blunt trauma directly to the abdomen, flank, or back is the most common mechanism, accounting for 80-85% of all renal injuries. Trauma may result from motor vehicle accidents, fights, falls, and contact sports.
- Fractured ribs and transverse vertebral processes may penetrate the renal parenchyma or vasculature.
- Staging begins with an abdominal CT scan. the operation should be maximum savings and directed on the decision of stopping of bleeding and normalization of urine outflow.

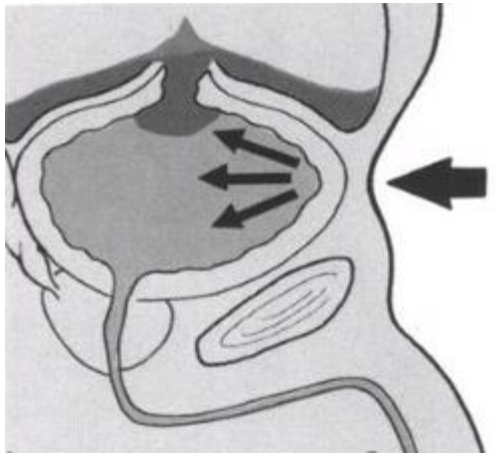


Trauma in Urological Structures

Injuries of the urinary bladder:

- Bladder injuries occur most often from external force and are often associated with pelvic fractures. About 15% of all pelvic fractures are associated with concomitant bladder or urethral injuries.

- Blunt trauma in filled bladder



Blunt trauma in filled bladder

Rising of intravesical pressure

Hydraulic impact

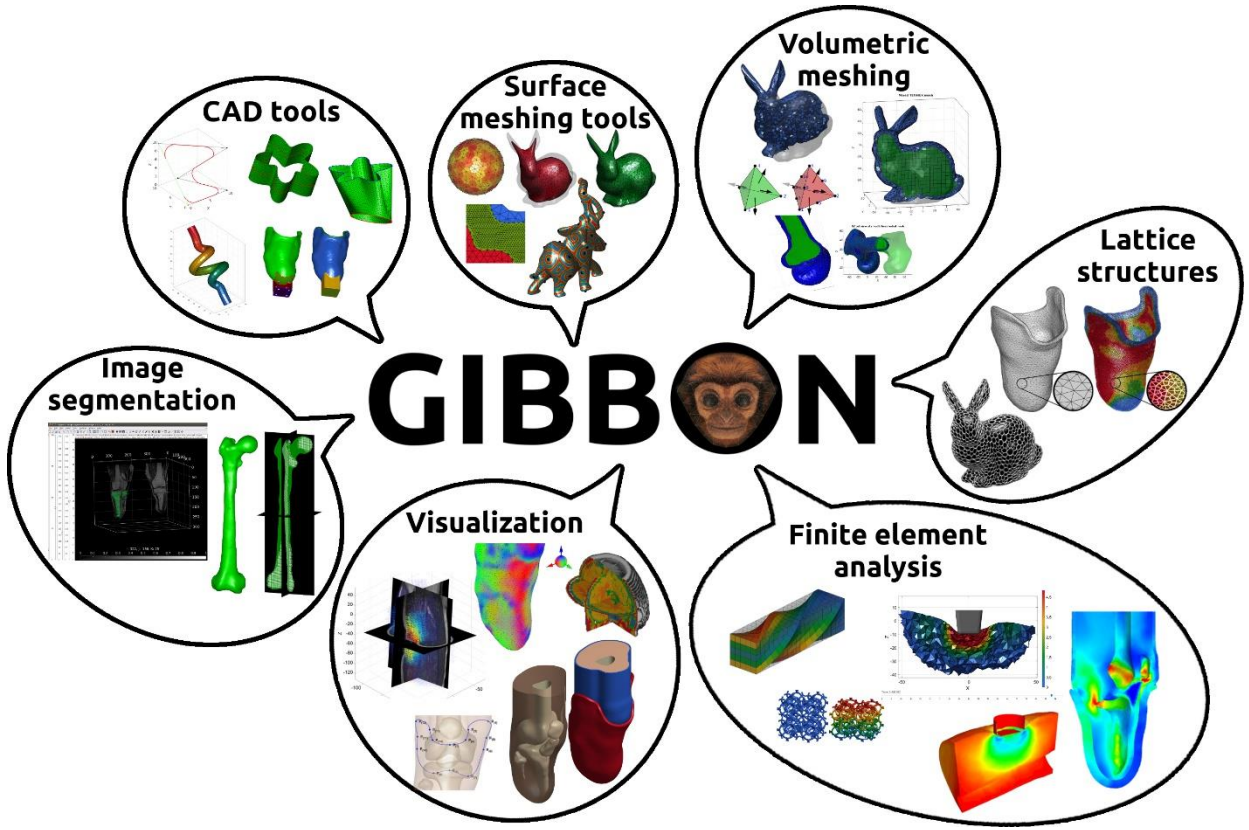
Intraperitonial bladder rupture

Trauma Images Ref.: http://slideplayer.com/slide/8461207/xx

Computer-aided design framework

The use of an integrated framework for image reconstruction and Finite Element analysis can be useful to assist the procedure of patient specific intervention. In this work we explore the use of the open source code Gibbon (The Geometry and Image-Based Bioengineering add-On).

We present a reconstruction of kidney with Percutaneous Access from TC images, and the smoothing of bladder geometry for FE analysis.



Kidney Segmentation

- Kidney images were kindly provided by Clinica Urologica do Calculo.

Convert all DICOM files inside a folder (including its subfolders) to the IMDAT format.

The function |dcmFolder2MATobject| converts the DICOM data to a matlab MAT object and saves it under the name IMDAT.mat inside a subfolder called IMDAT.

A |waitbar| appears showing the process of the data conversion for the DICOM information and image data. Multiple types of image data (e.g. phase, real, imaginary, magnitude data) is stored seperately. Also several DICOM info fields are harvested and stored.

Kidney Segmentation

IMDAT.mat object contains:

G: The geometry parameters

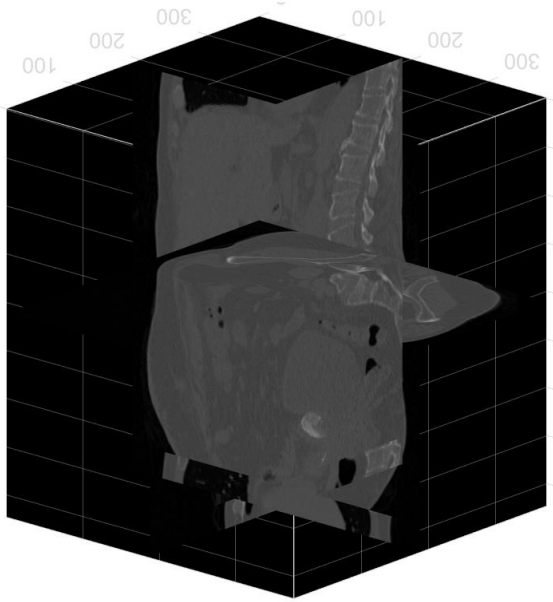
ImageSize: [128 128 17 20] % The image size

ImageTypesUni: {'ORIGINAL\PRIMARY\M_FFE\M\FFE'}

The geometry set G contains:
- v: [3x1 double] - The voxel size
- OR: [3x1 double] - The location of the origin
- r: [3x1 double] - Direction vector for rows
- c: [3x1 double] - Direction vector for Columns

Kidney Segmentation

- dcmFolder2MATobject_UROLOGY
- Converting to Matlab format



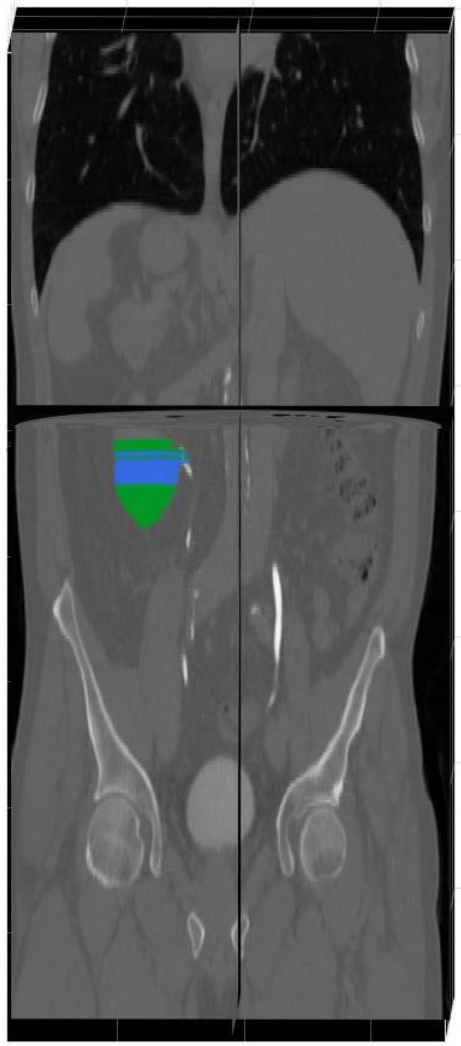
Abdominal TC
Nefrography 2.0
Slice thickness 2mm

Kidney Segmentation

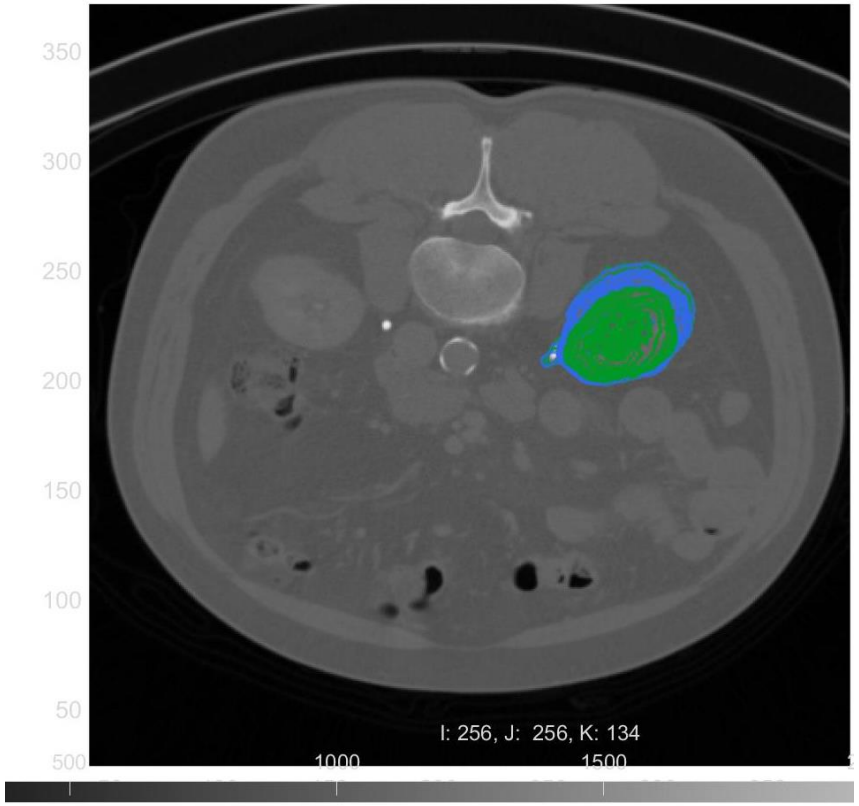
CT Abdomen , Contrast ; Adult
Slice Thickness 12
Pixel Spacing 0.9752

The |imx| function provides a figure window based GUI for 3D image segmentation

Kidney Segmentation



CT Abdomen , Contrast ; Adult
Slice Thickness 12
Pixel Spacing 0.9752



Kidney Segmentation

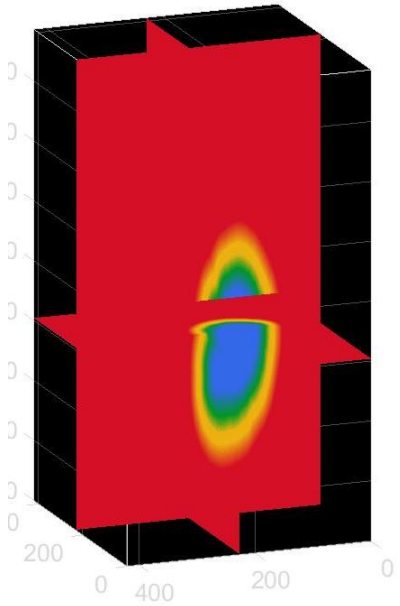
The paradigm of the level set is that it is a numerical method for tracking the evolution of contours and surfaces.

Instead of manipulating the contour directly, the contour is embedded as the zero level set of a higher dimensional function called the level-set function, $\psi(X,t)$.

The level-set function is then evolved under the control of a differential equation. At any time, the evolving contour can be obtained by extracting the zero level-set $\Gamma(X,t) = \{\psi(X,t) = 0\}$ from the output.

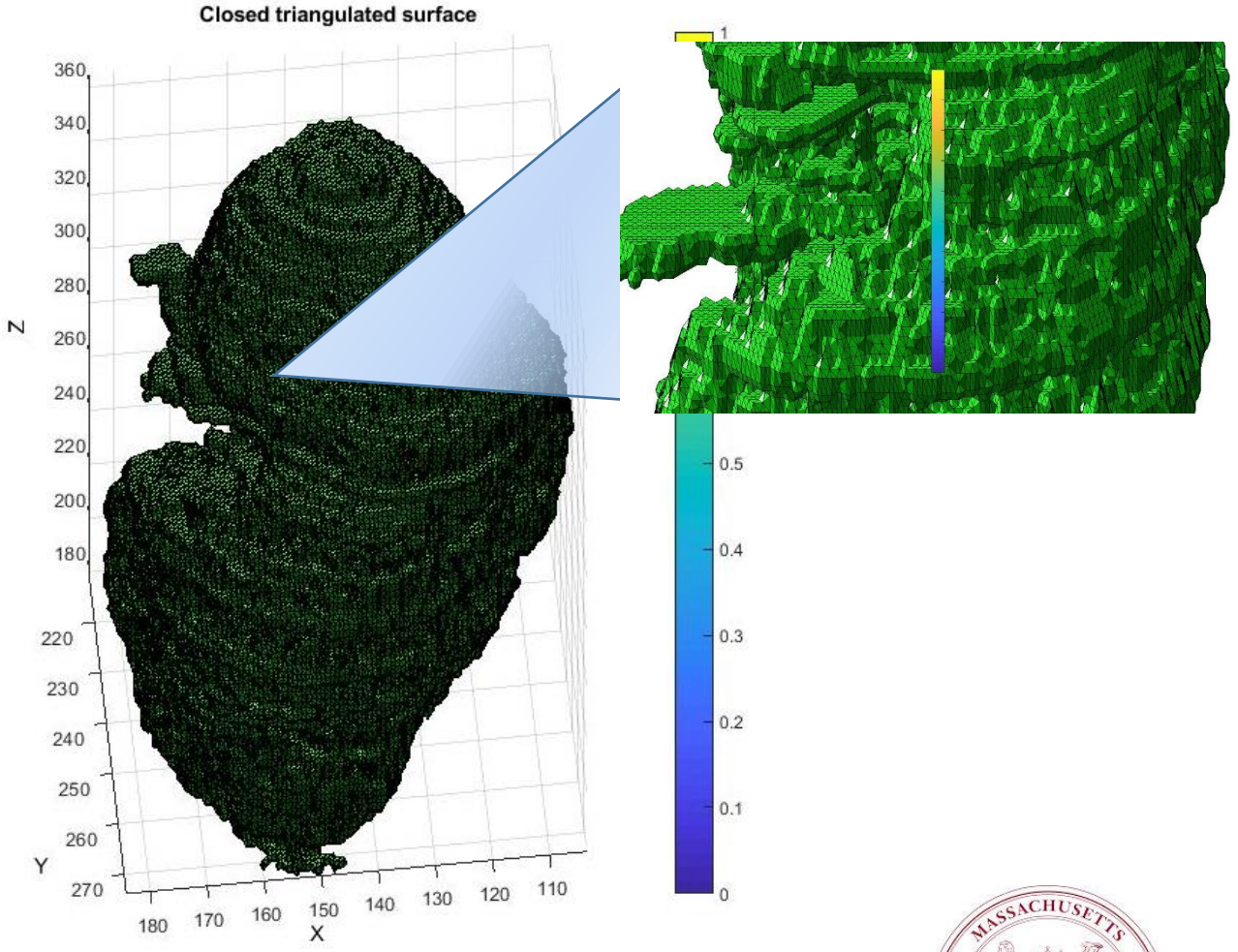
The main advantages of using level sets is that arbitrarily complex shapes can be modeled and topological changes such as merging and splitting are handled implicitly.

Kidney Segmentation



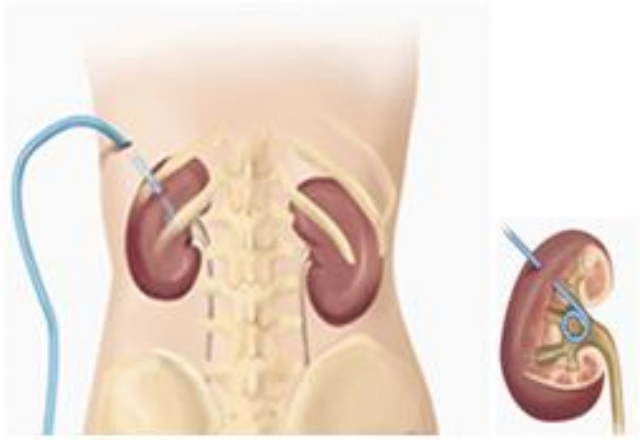
Slice viewer

Closed triangulated surface



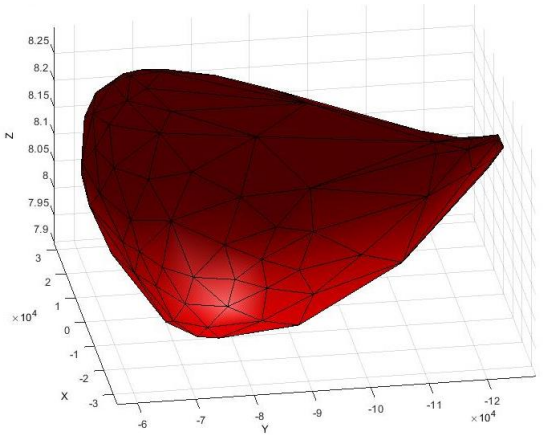
Kidney FEA analysis

- In percutaneous nephrostomy and PCNL high precision access is fundamental to surgery success.
- Multiple pintching lead to increase in edema and hemorragia.
- Subject-Specific kidney percuntaneous access analysis may contribute to improve treatement success in percutaneous intervention.

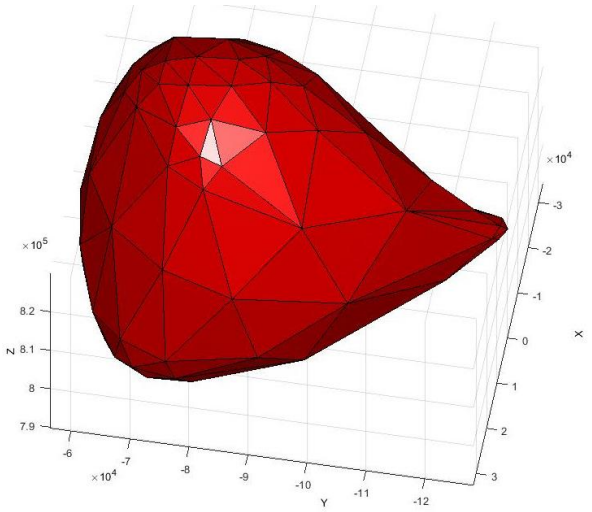


Bladder geometrical model

- TC images used for geometry reconstruction were kindly provided by Hospital Clinic of Barcelona.



Imported patch data from multi-solid STL



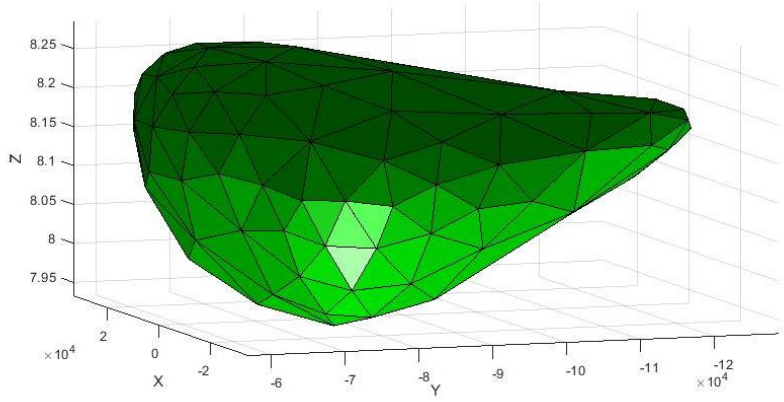
Bladder smoothing

Merging nodes

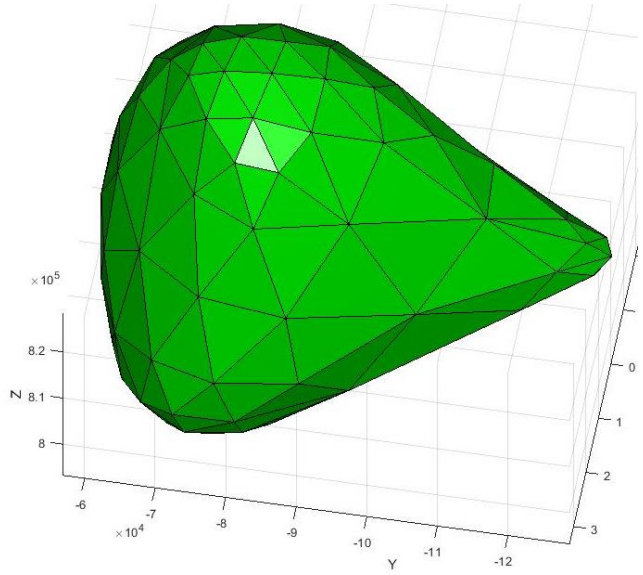
STL imported surfaces suffer from non-unique points since each face is defined with its own coordinate set, even if it shares nodes with an adjacent face.

Hence in order to generate a closed surface these nodes need to be merged. Here the |unique| function is used combined with |pround| to achieve this. So effectively points are deemed the same if they are the same after rounding to the 5th decimal place.

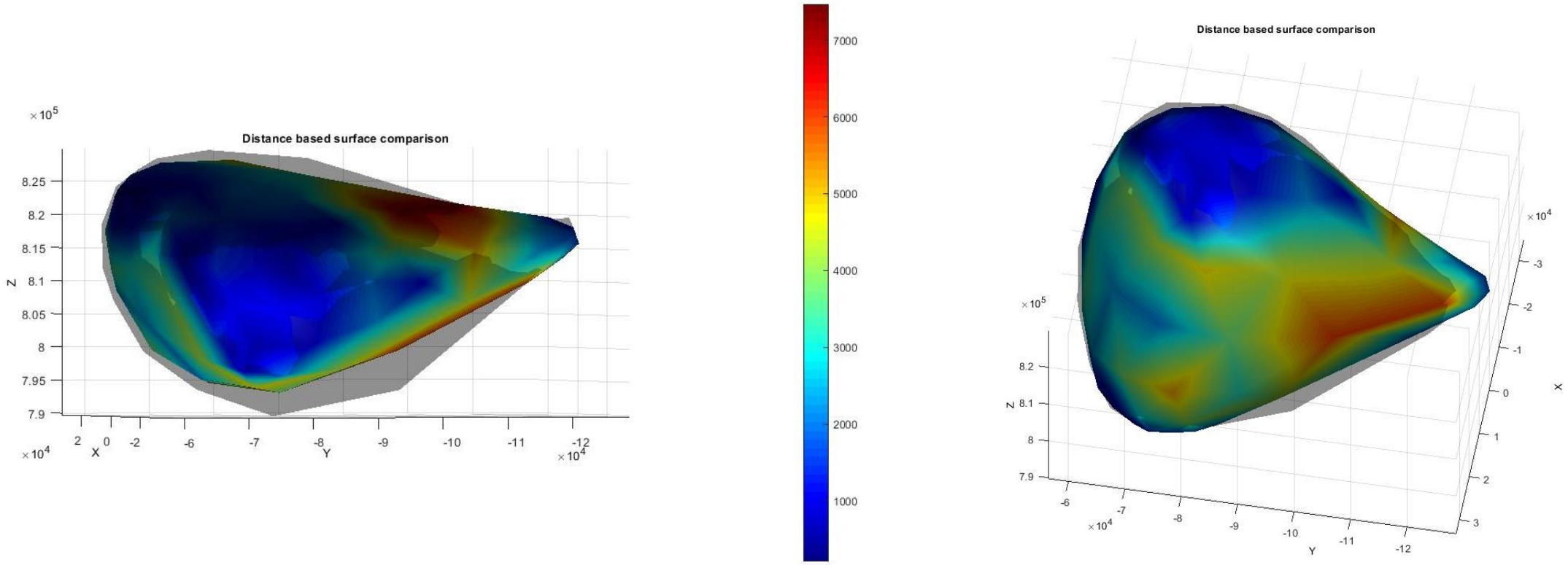
Bladder smoothing



Smoothed surface



Bladder smoothing



FE Organ Level Analysis

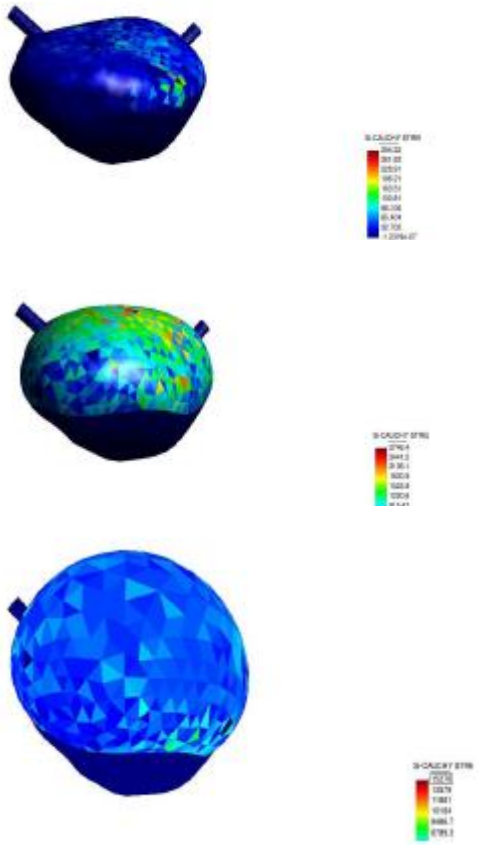
Here a FEM analysis of the urinary bladder is presented. Geometry of the organ was generated from the Visible Human Project, of the US National Library of Science.

The CT data consist of axial CT scans of the entire body taken at 1mm intervals at a pixel resolution of 512 by 512 with each pixel made up of 12 bits of gray tone.

Laplace smoothing of bladder geometry was conducted prior to FEM.

FE Organ Level Analysis

- We intend to replicate stress distribution for patient specific analysis.
- Structural analysis give organ-level response and material parameters
- Fluid analysis account for urodynamic response



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TECGRAF PUC-RIO

GIBBON

open source initiative

THANK YOU !

ENGINEERING engrχiv ARCHIVE

Obrigada!

Dank je wel !

Virginia Monteiro

virginiamonteiro@puc-rio.br

Kevin Mattheus Moerman

kmoerman@mit.edu

PUC RIO

SIMBIO-M

MASSACHUSETTS INSTITUTE OF TECHNOLOGY