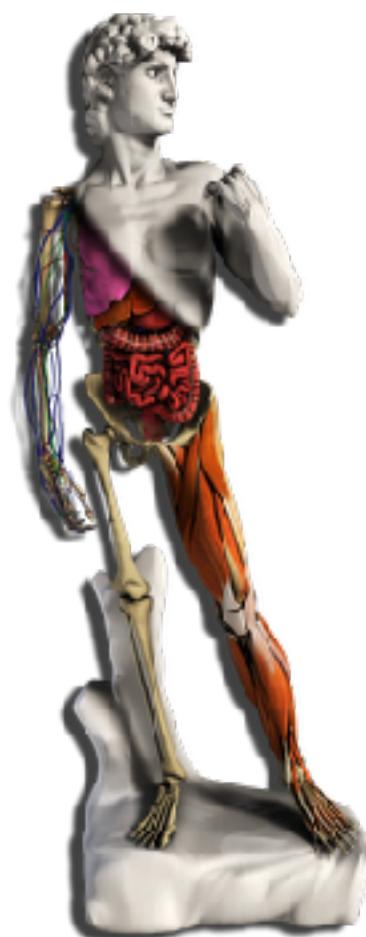


Modèles 3D pour l'analyse d'images et la simulation biomécanique



Benjamin GILLES

gilles@anatoscope.com

CNRS, LIRMM
AnatoScope SA



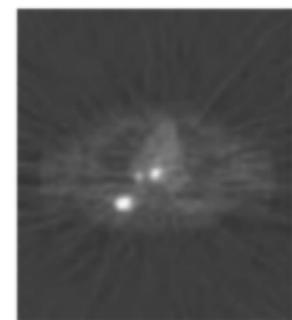
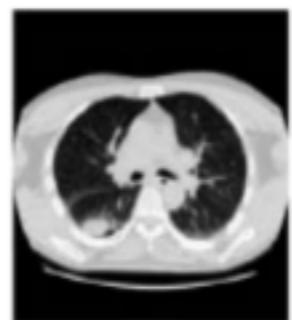
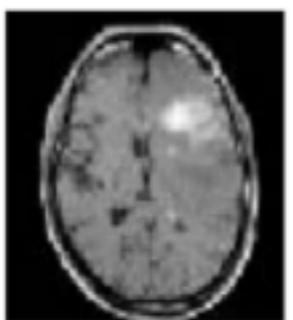
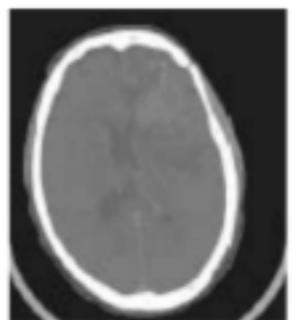
LIRMM



Inria
INVENTEURS DU MONDE NUMÉRIQUE

Contexte

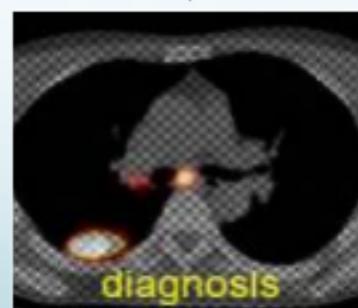
- Aujourd'hui, l'imagerie est une pratique standard .. mais on mesure beaucoup plus que ce que l'on peut comprendre..
- l'analyse et la fusion d'image sont nécessaires



images 3D numériques



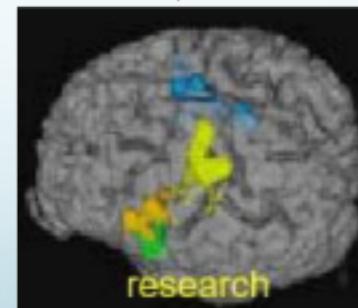
Extraction d'information clinique par traitement d'images



Detection de
cancer :
localisation



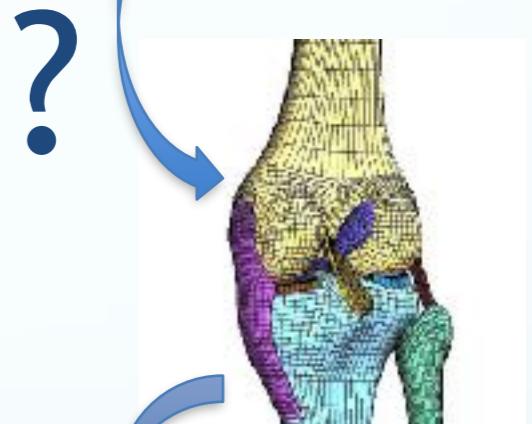
radiothérapie,
chirurgie :
planning



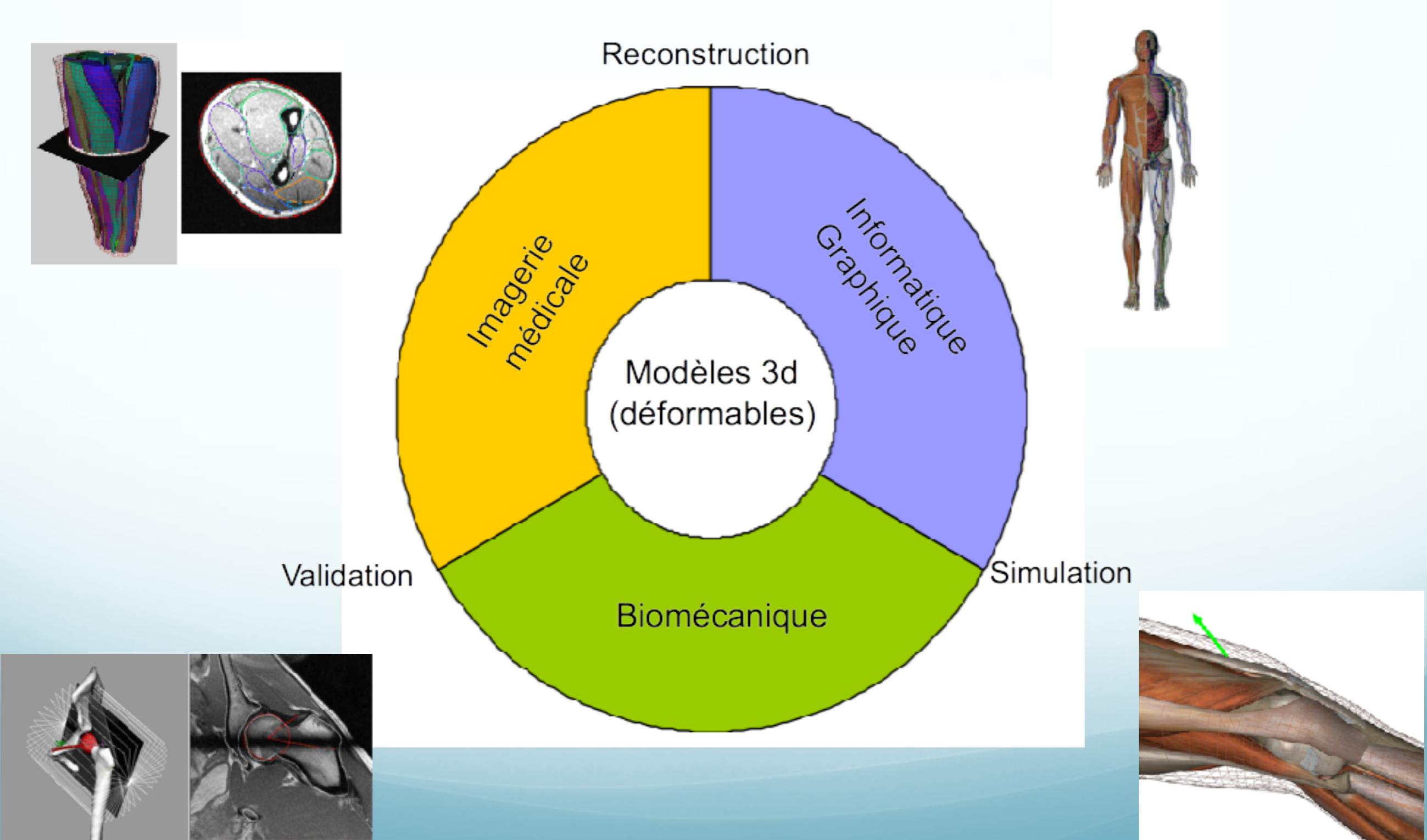
Cerveau : études
longitudinales,
différences inter-
sujets

Médecine personnalisée

- 20% des prothèses génèrent des complications
(source: HAS, nytimes, wikipedia)
- Surcoût > 2 milliards €
- Nécessité de traitements sur-mesure, mais:
 - imagerie: statique
 - conception: long, coûteux
 - fabrication inadaptée
 - flux clinique trop tendu



Modèles anatomiques 3D

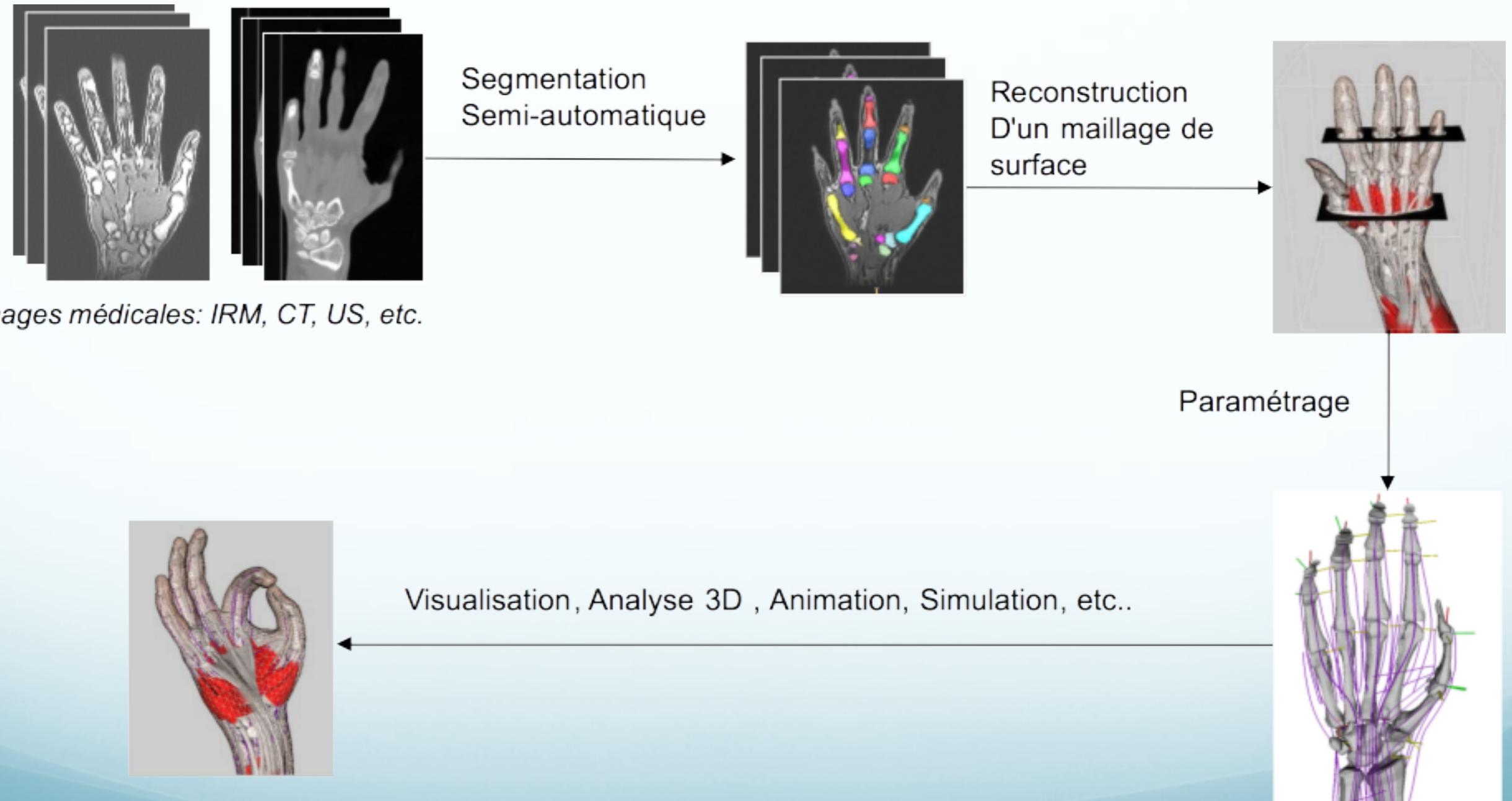


Des Images aux Modèles, à la Simulation



- Diagnostic
- Visualisation
- fusion de données
- Communication
- Indexation
- Anatomie comparée
- Animation d'avatar
- Biomécanique
- Plans de traitement
- fabrication sur mesure

Approche par segmentation



Problèmes

Segmentation :

Un organe = plusieurs intensités

→ seuillage + opérations morphologiques + corrections manuelles

Un type de tissu = même intensités

→ Séparation manuelle + labelisation

Paramétrage :

Systèmes de coordonnées

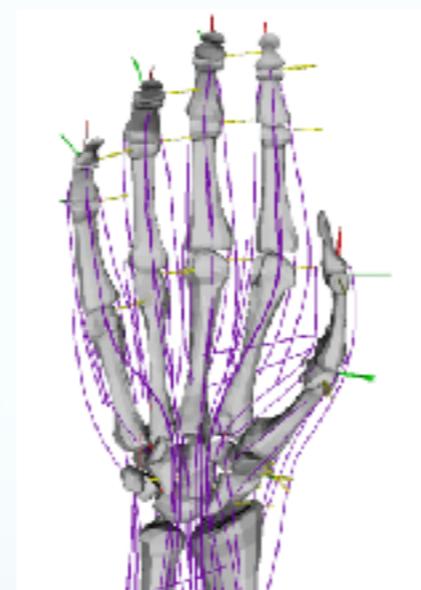
Attaches tissus mous / os

Propriétés matérielles

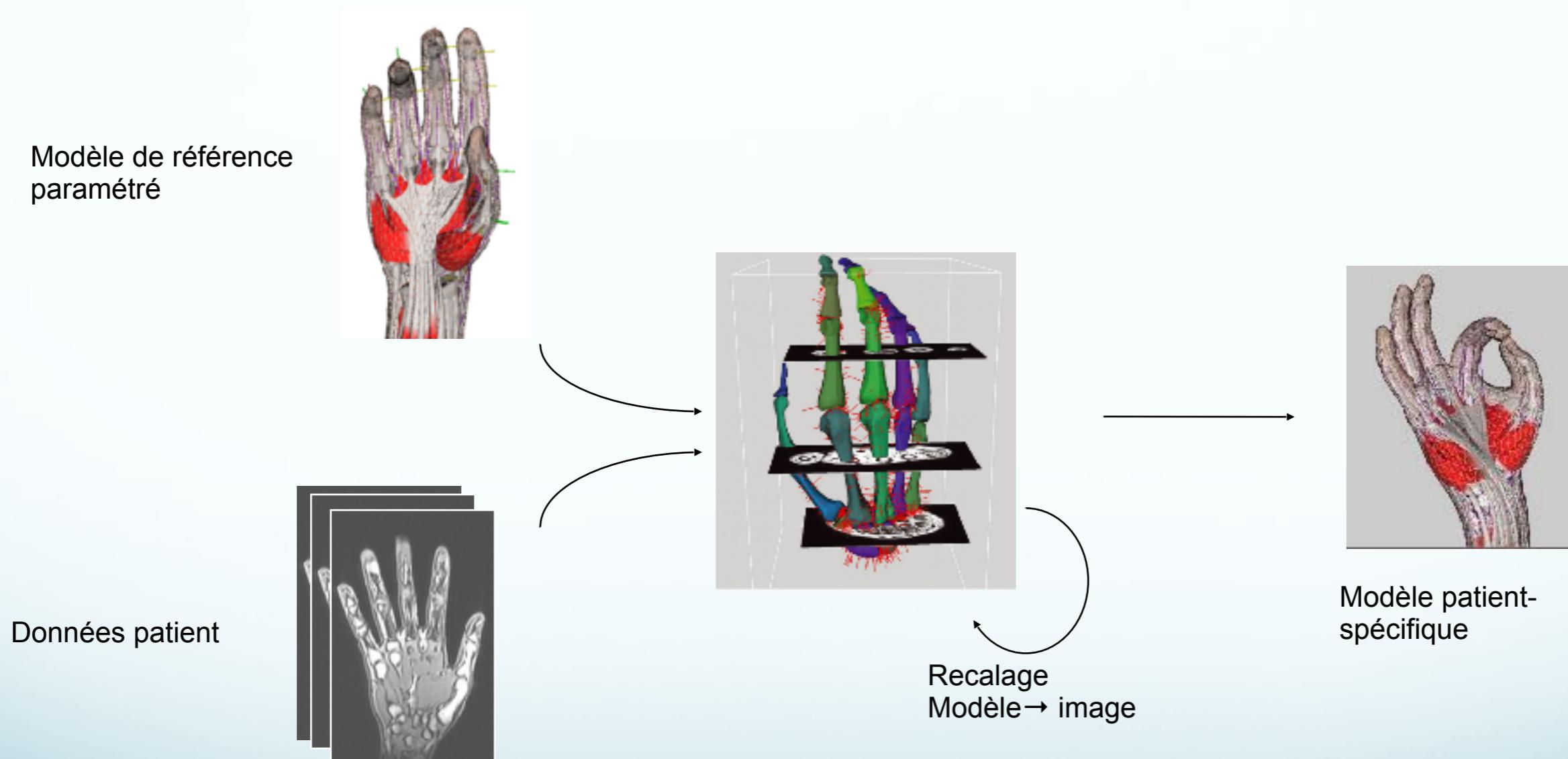
...

→ très long

→ demande beaucoup de connaissances anatomiques



Approche par recalage d'une maquette de référence

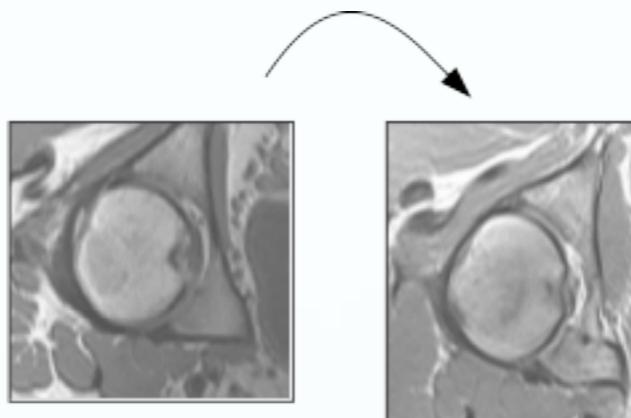


Les différents types de recalage

Recalage Inter-sujet

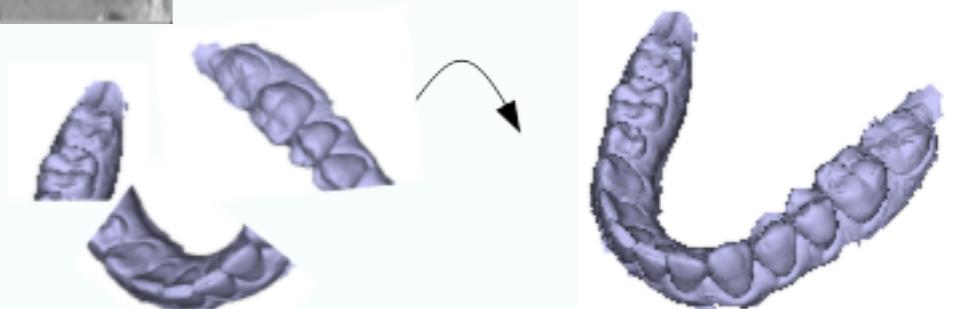
Segmentation

Anatomie comparée



Recalage de multi-vues

Mosaique, reconstruction

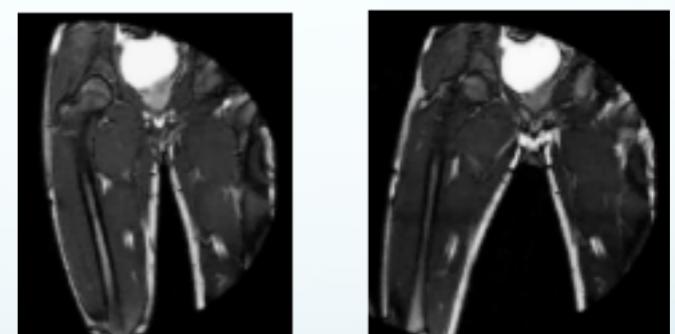


Recalage temporel

Tracking pour navigation peropératoire

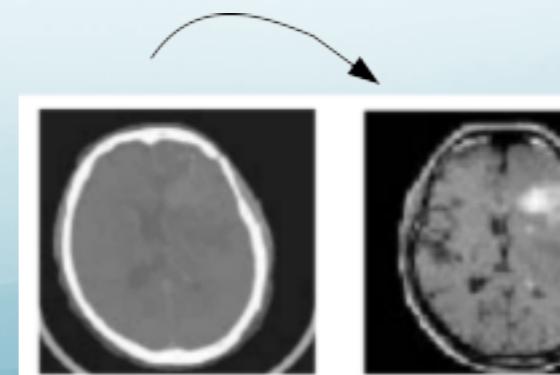
Analyse des déformations

Monitoring des évolutions (analyses longitudinales)



Recalage Multi-modal

Fusion d'information complémentaire

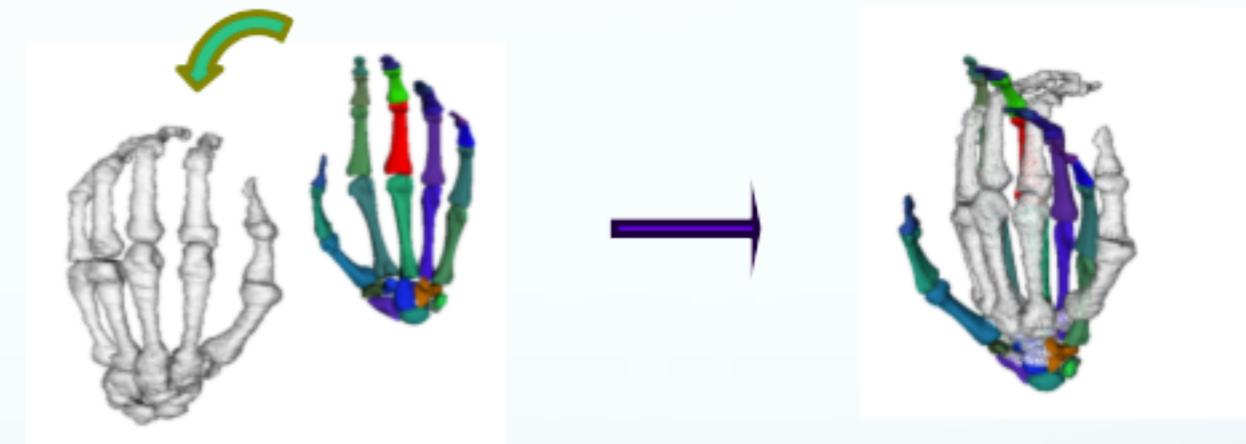
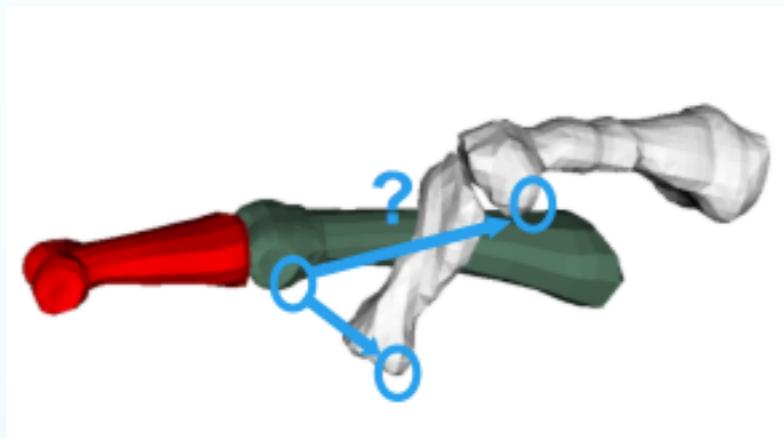


Problèmes

Bruit



Solutions locales, initialisation

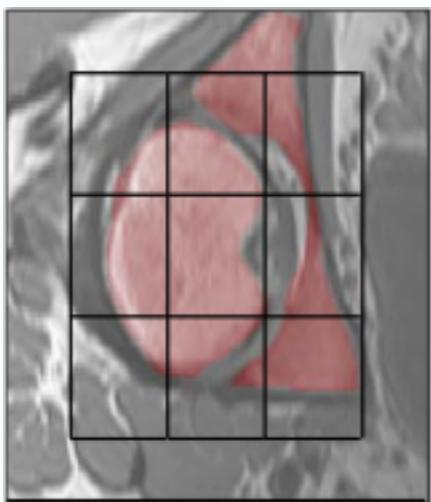


Champs de déformations complexe

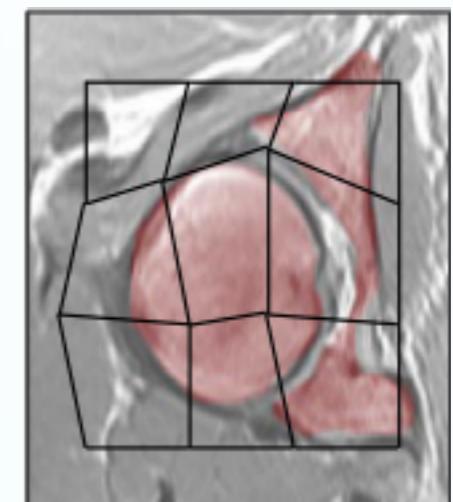
déformations continues + discontinuités

Variabilité de forme et d'apparence

Définition du recalage



Source J



Cible I

Trouver une transformation T qui

- maximise la similarité entre $T(J)$ et I
- est réaliste dans le contexte d'application

← **Modèle**
← **Critère**
← **Régularisation**

Optimisation

Algorithme ICP

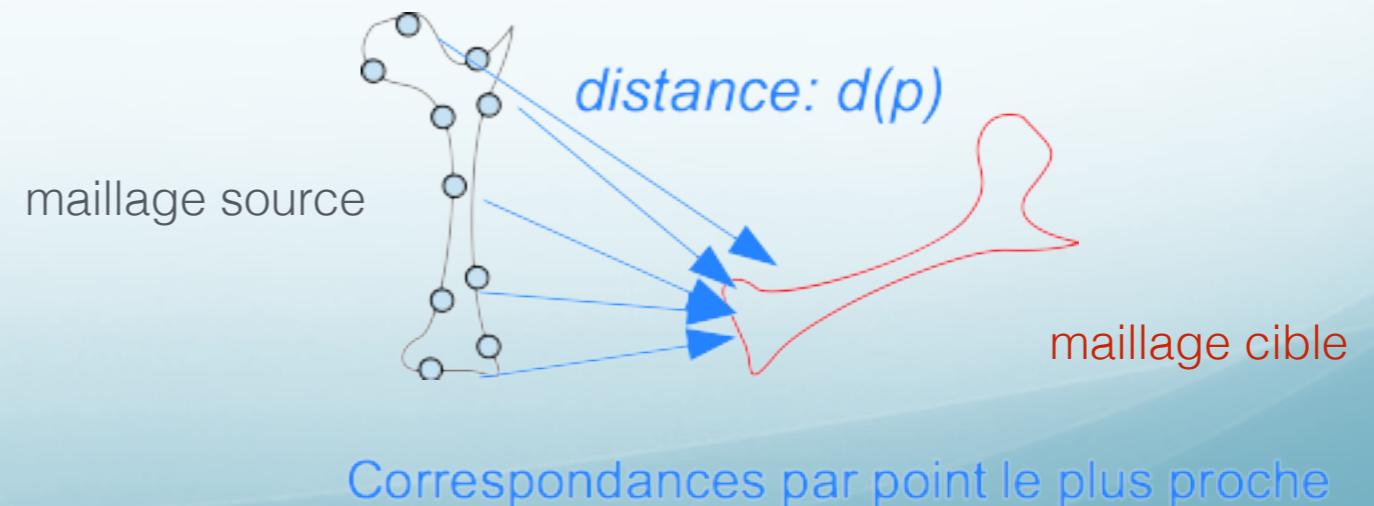
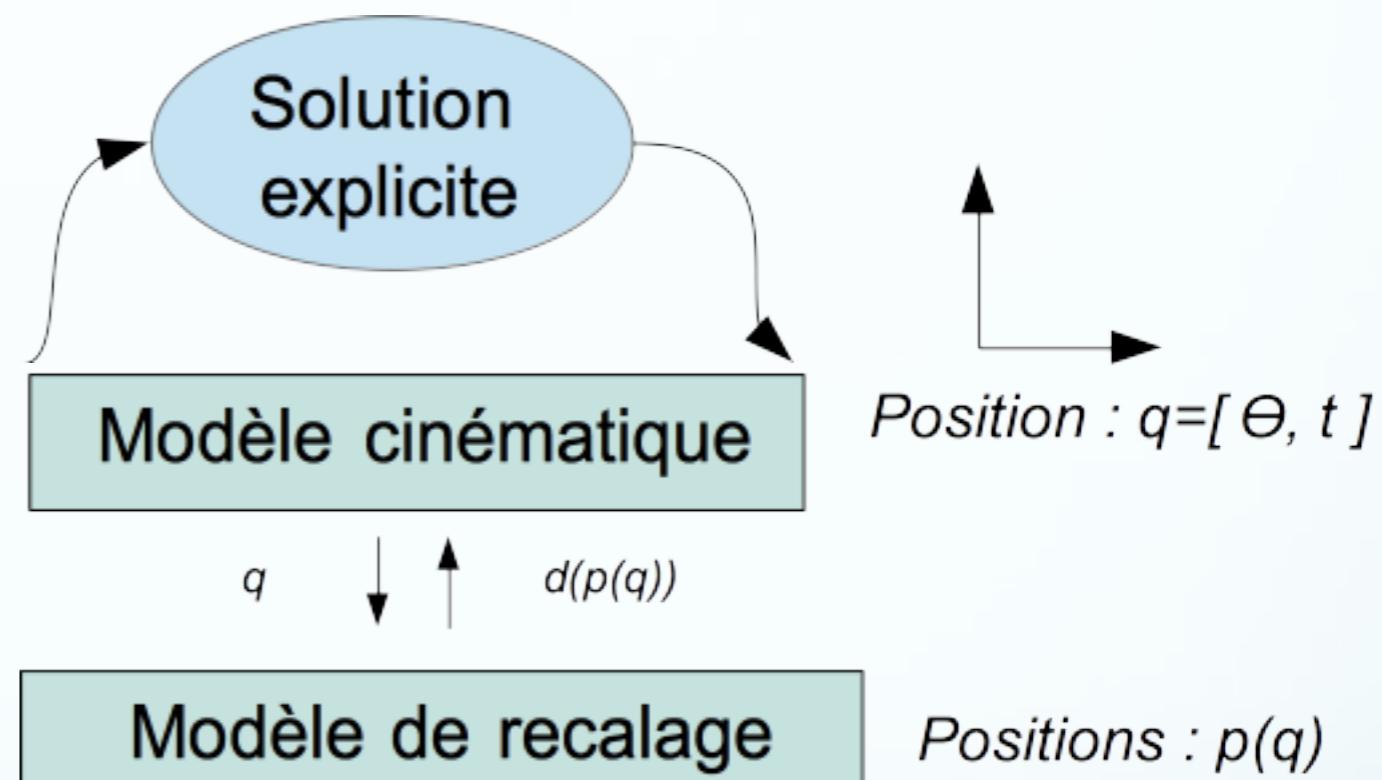
[Besl & Mc Kay 92]

Critère: minimiser la distance entre maillages

Modèle: global (rigide, affine)

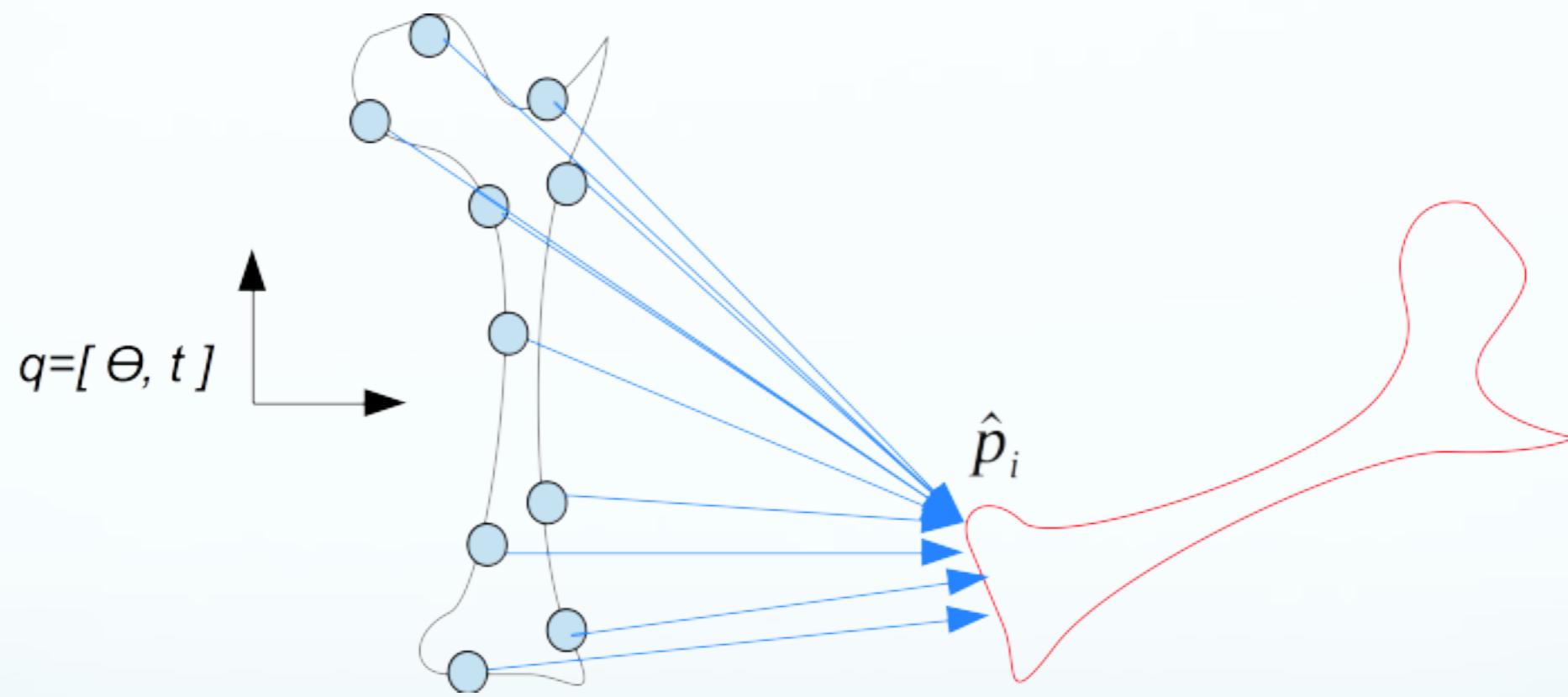
Régularisation: aucune

Optimisation: solutions explicites successives



Algorithme ICP

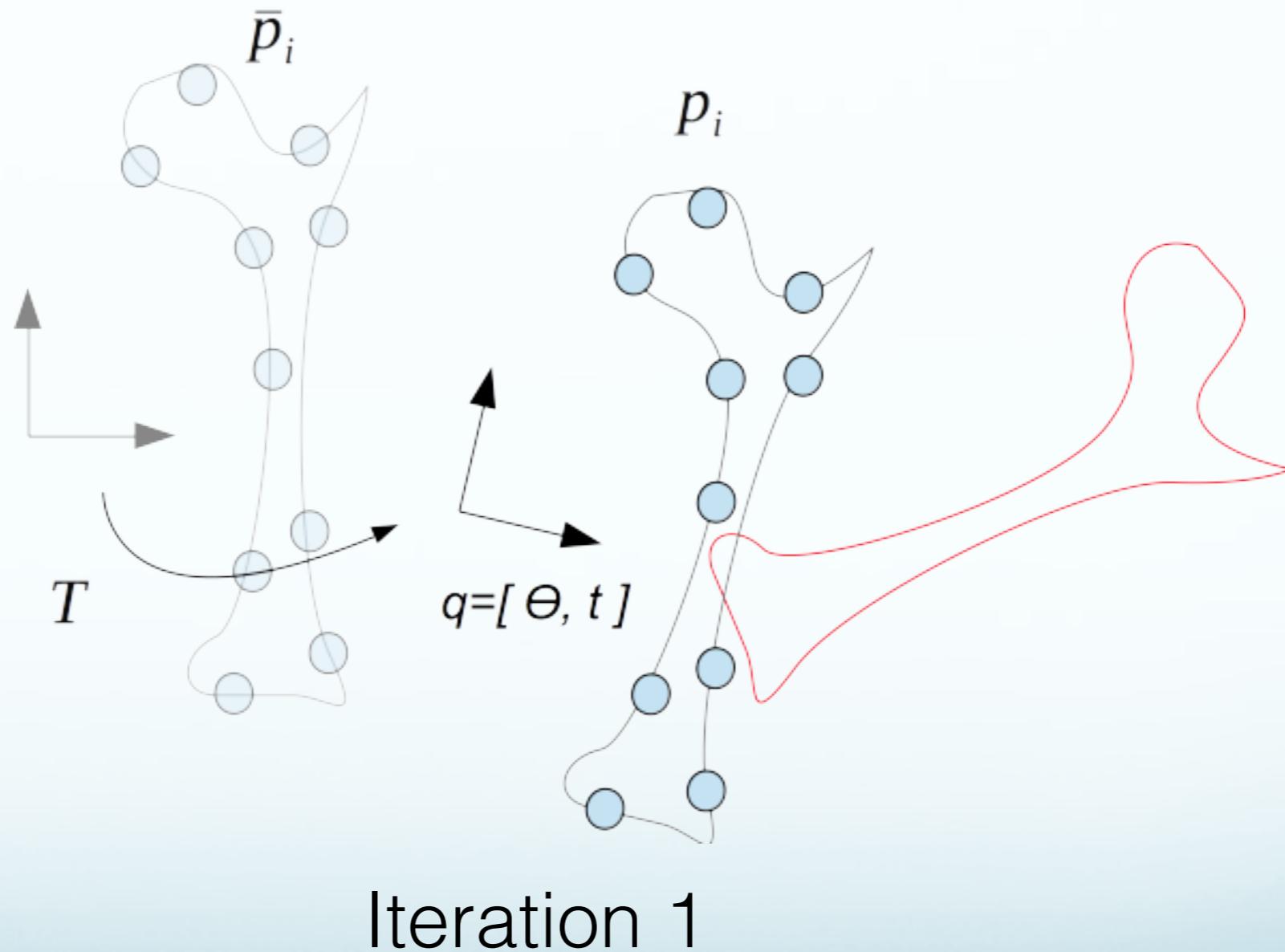
[Besl & Mc Kay 92]



Iteration 1

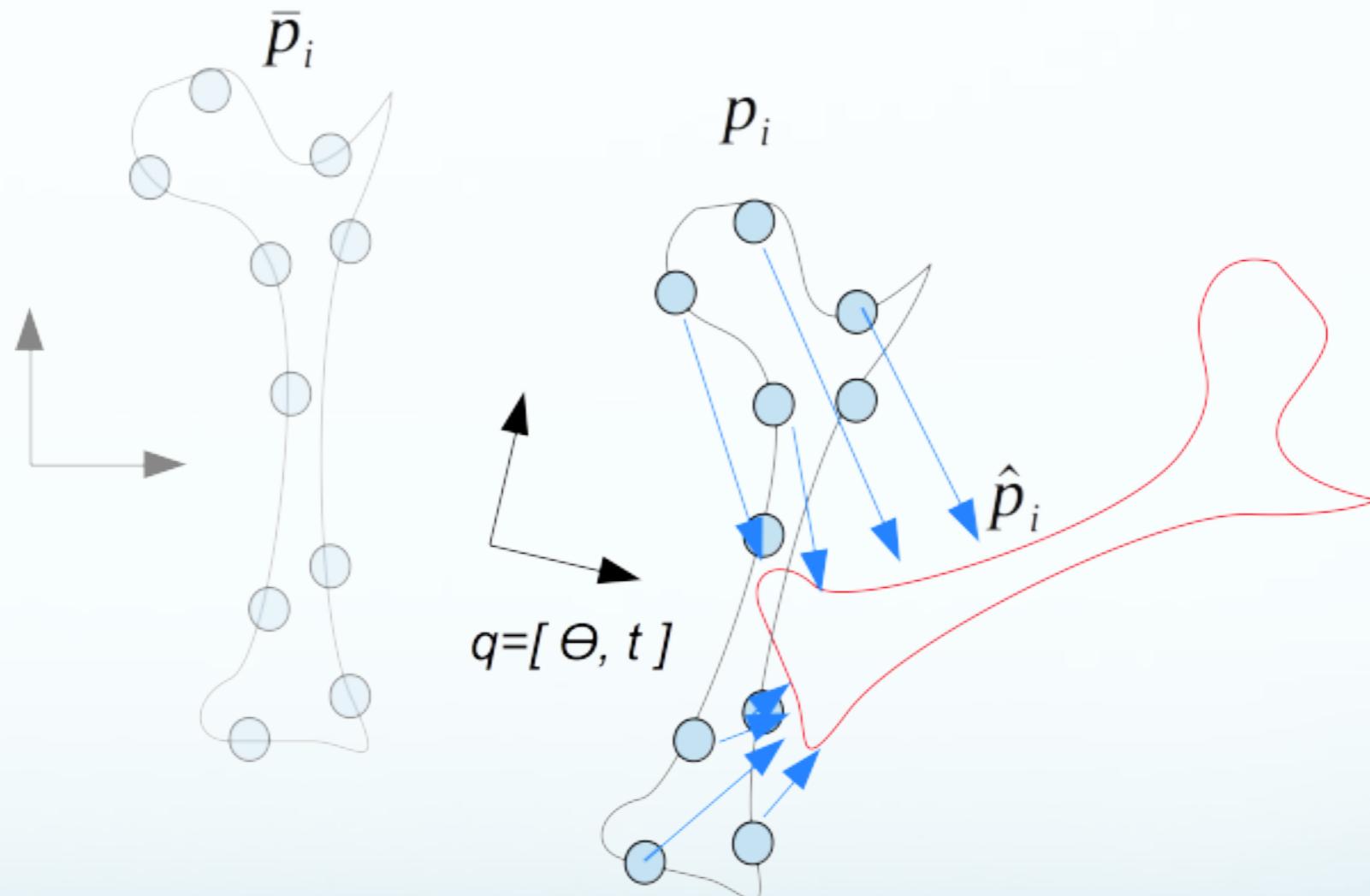
Algorithme ICP

[Besl & Mc Kay 92]



Algorithme ICP

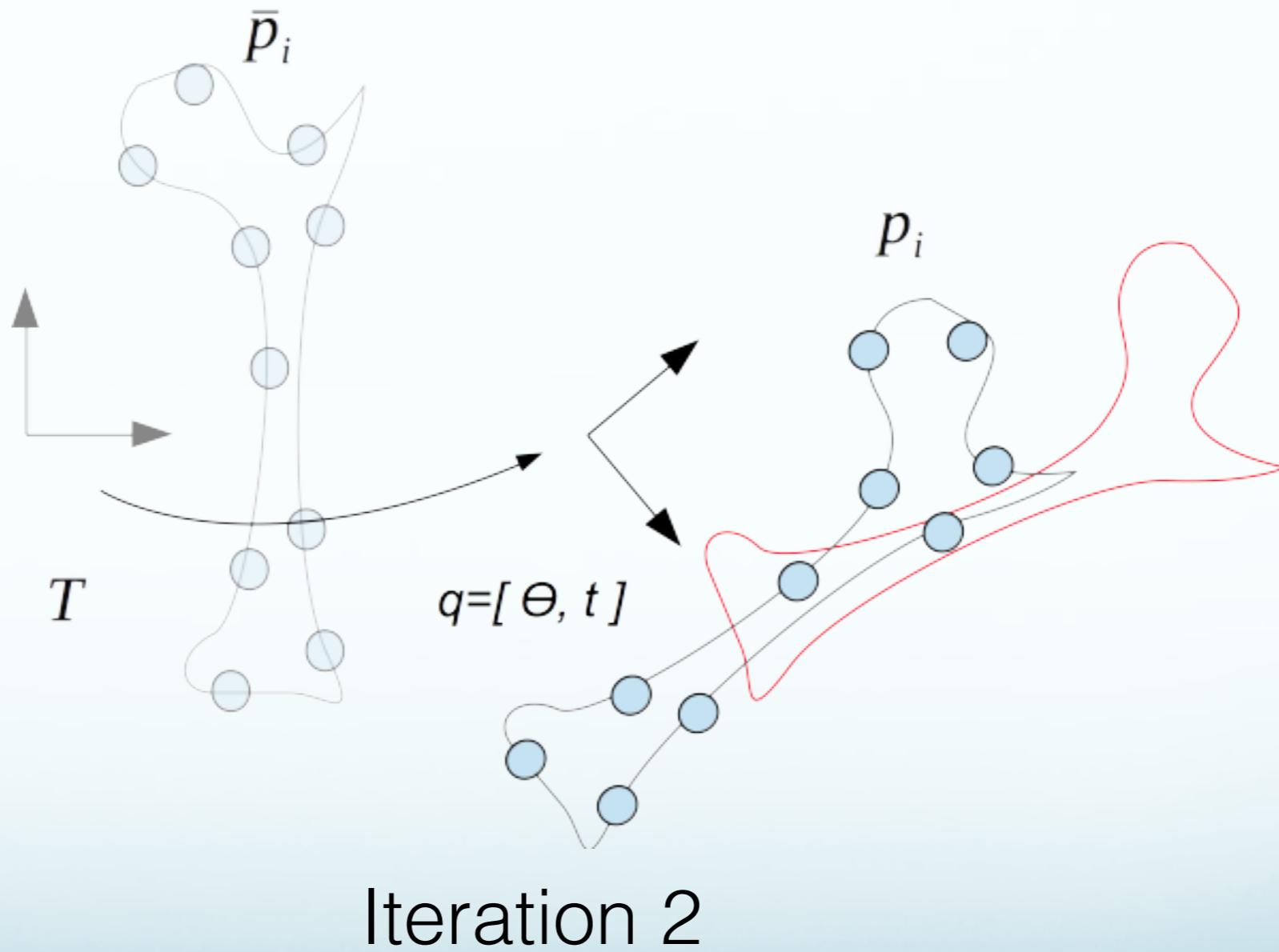
[Besl & Mc Kay 92]



Iteration 2

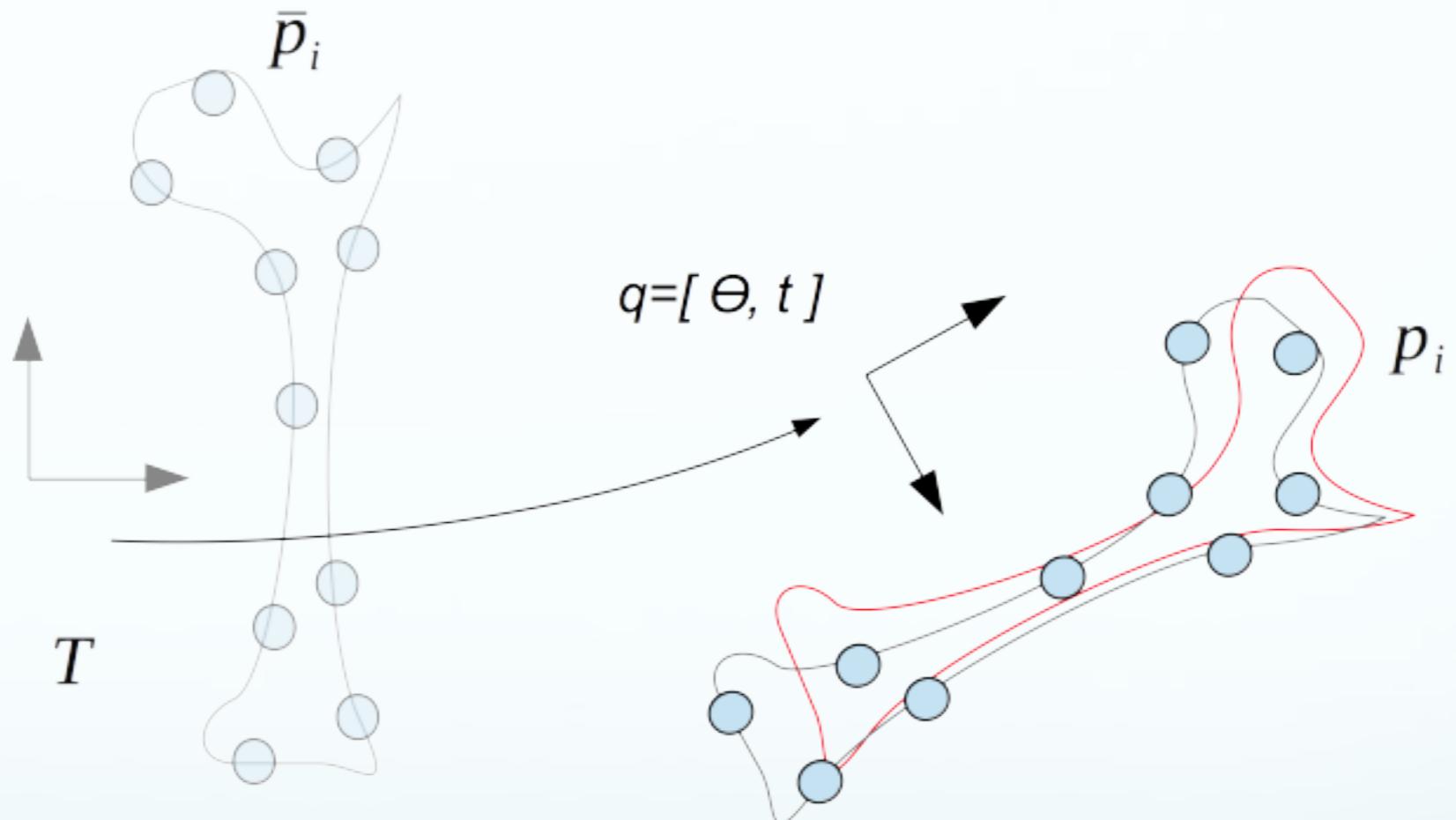
Algorithme ICP

[Besl & Mc Kay 92]



Algorithme ICP

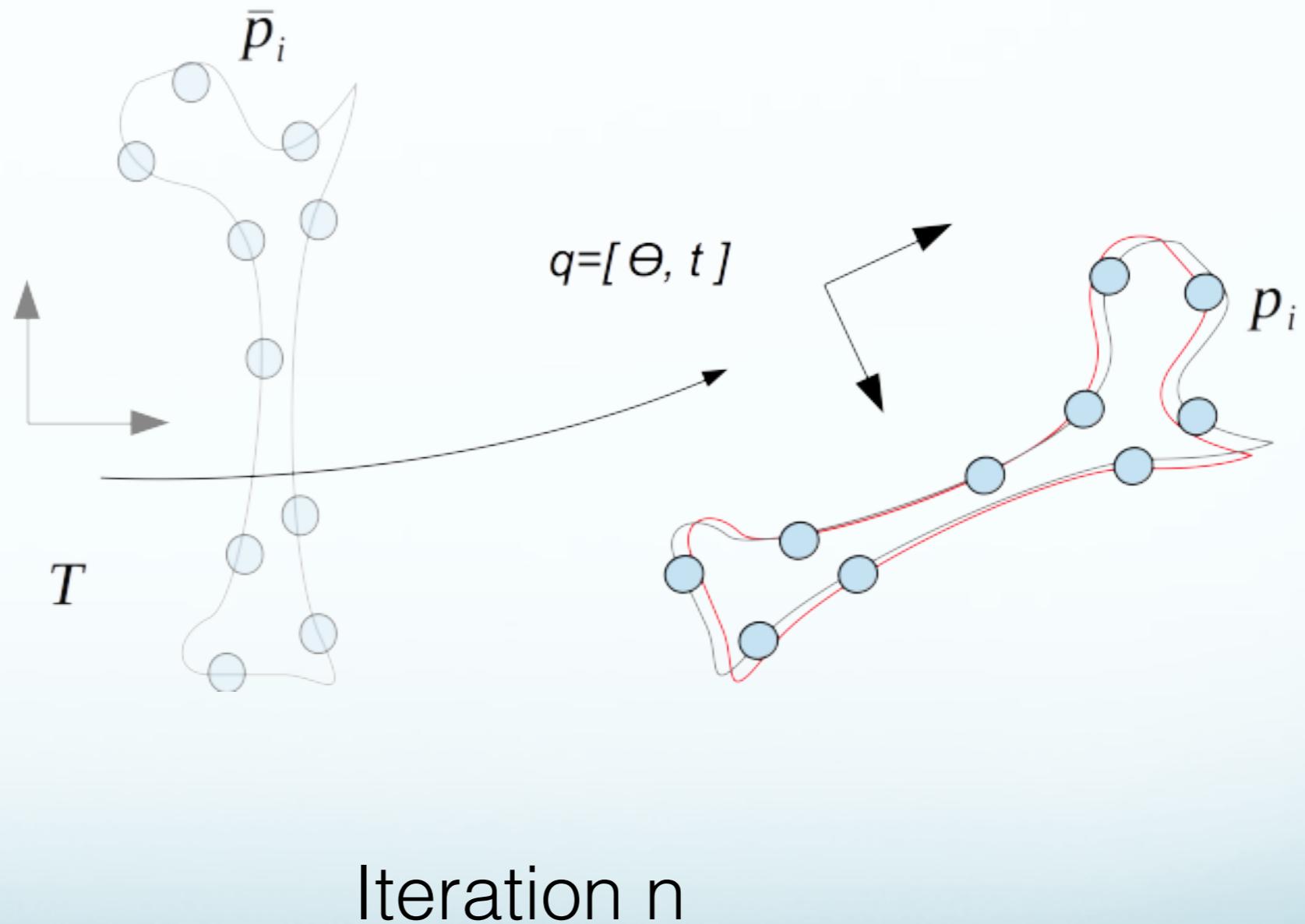
[Besl & Mc Kay 92]



Iteration 3

Algorithme ICP

[Besl & Mc Kay 92]



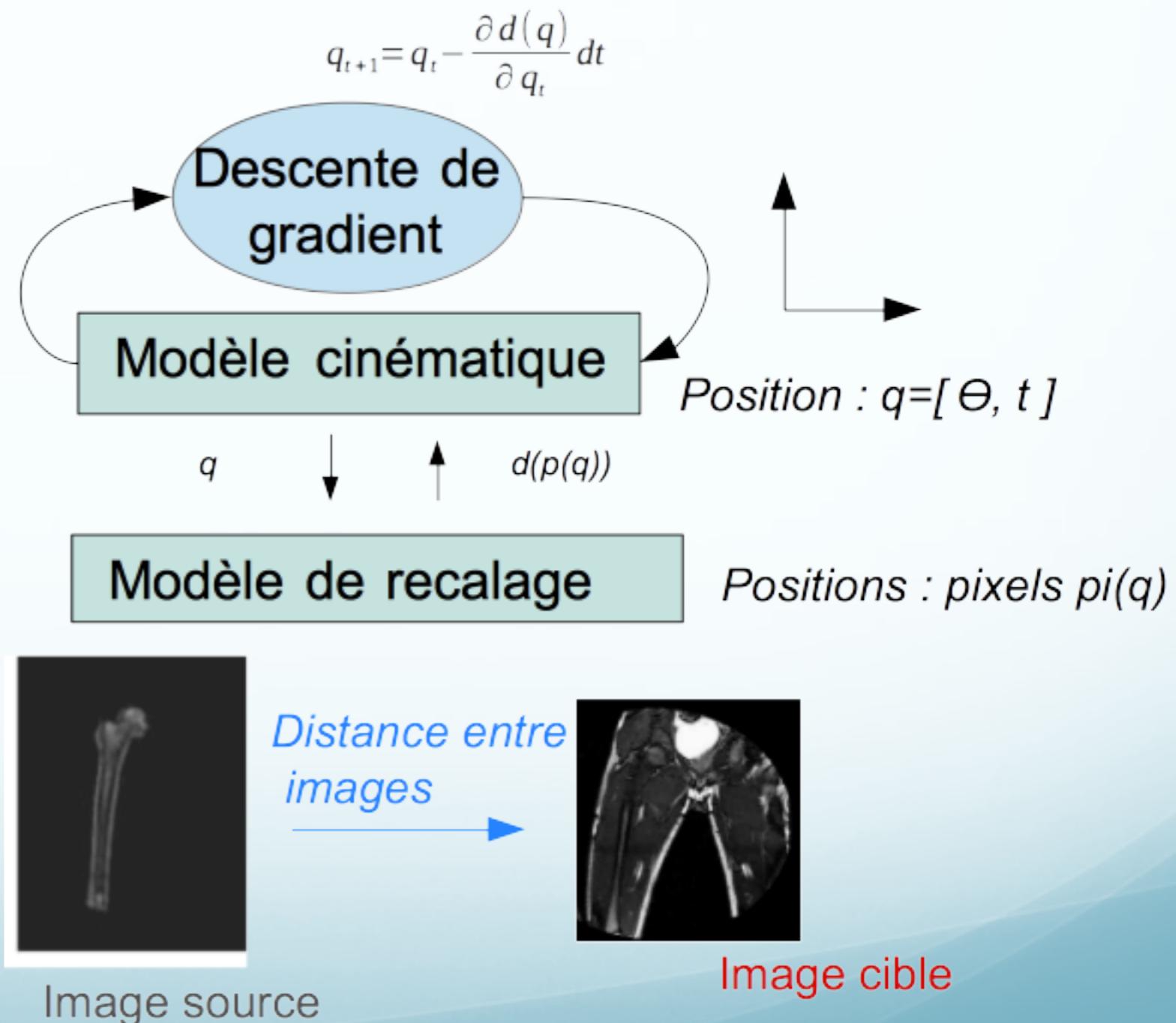
Algorithme: recalage modèle image variationnel

Critère: minimiser la distance entre images (corrélation, différence d'intensité...)

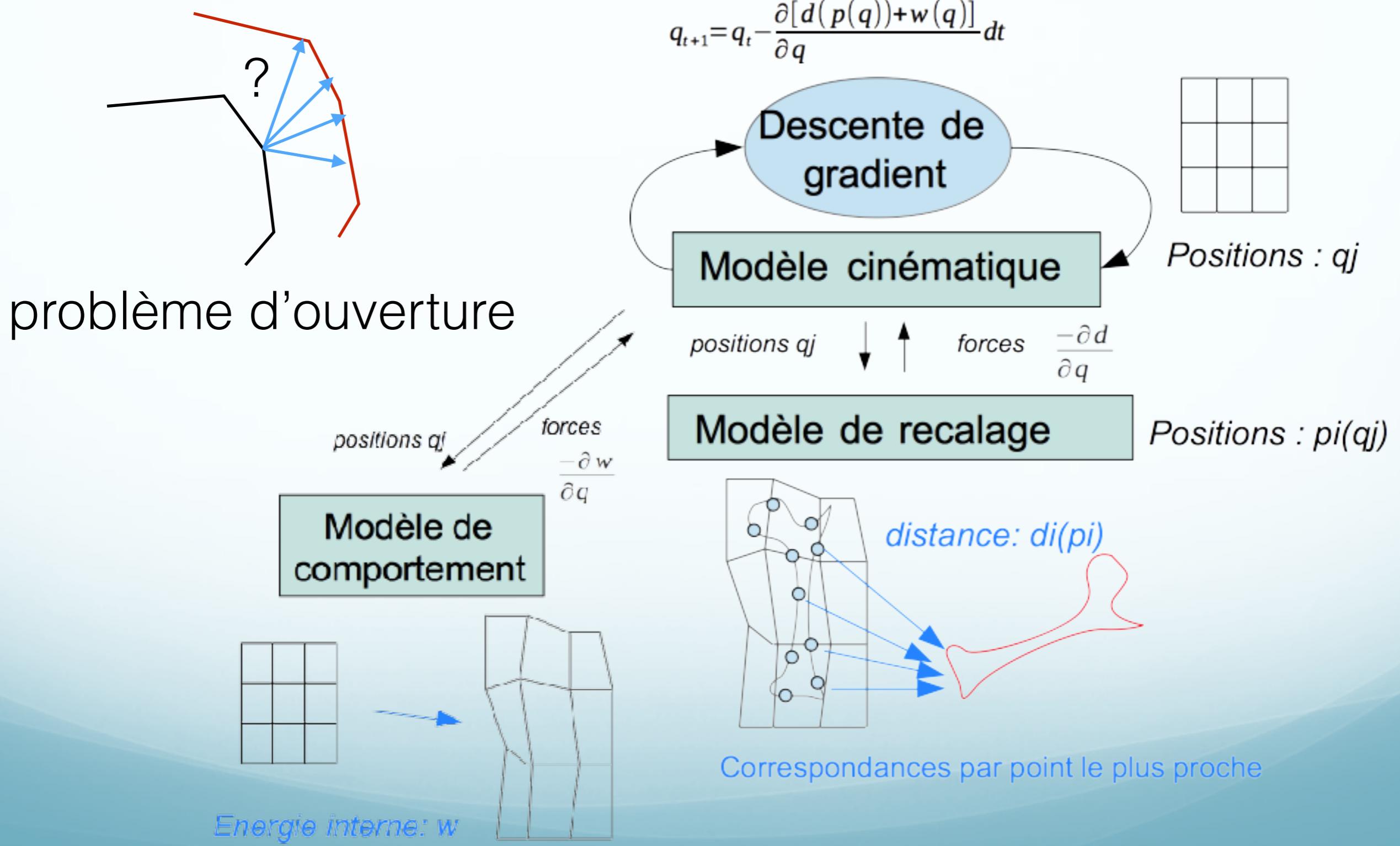
Modèle: global (rigide, affine)

Régularisation: aucune

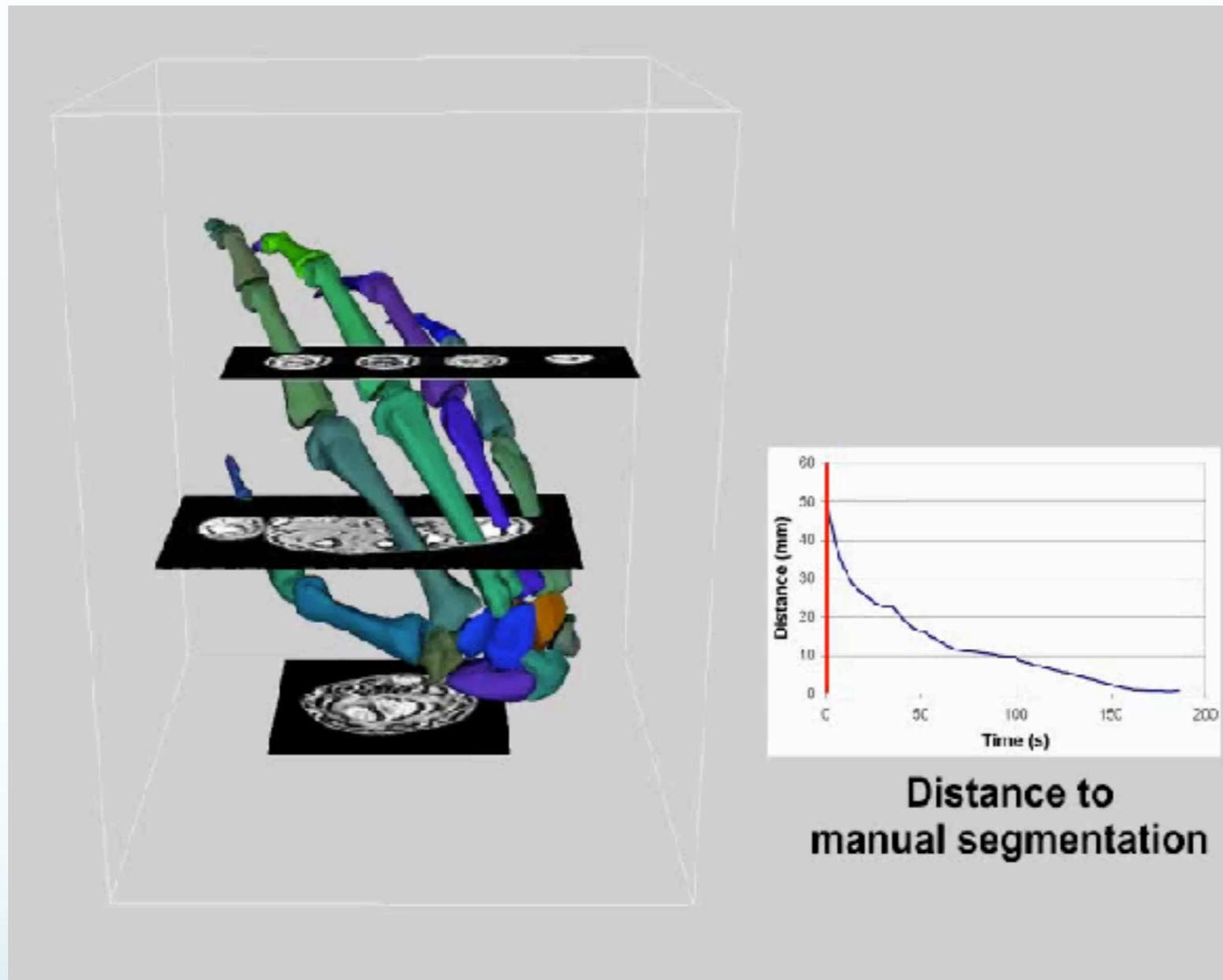
Optimisation: descente de gradient



Recalage Déformable

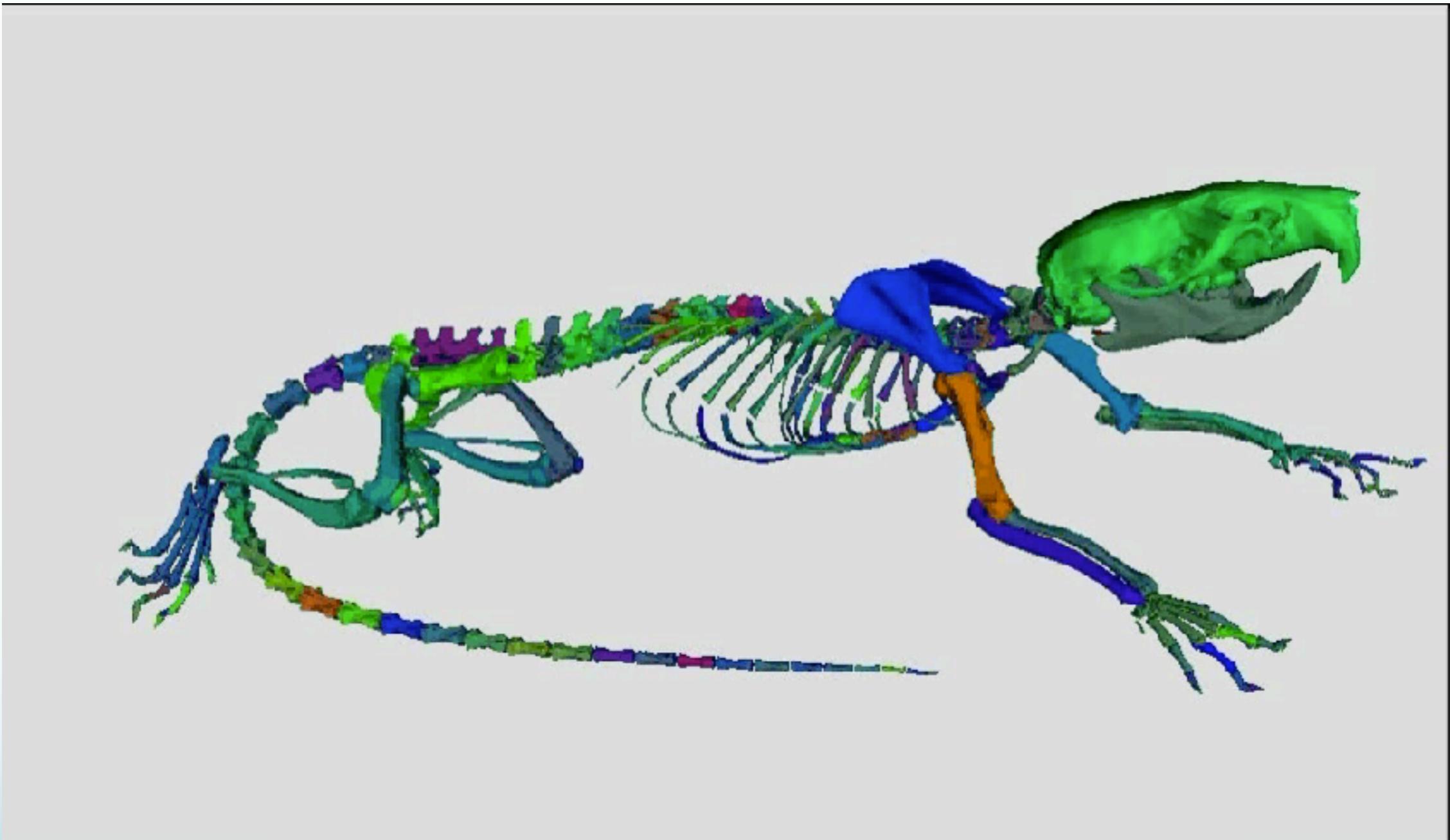


Exemple: recalage de squelettes



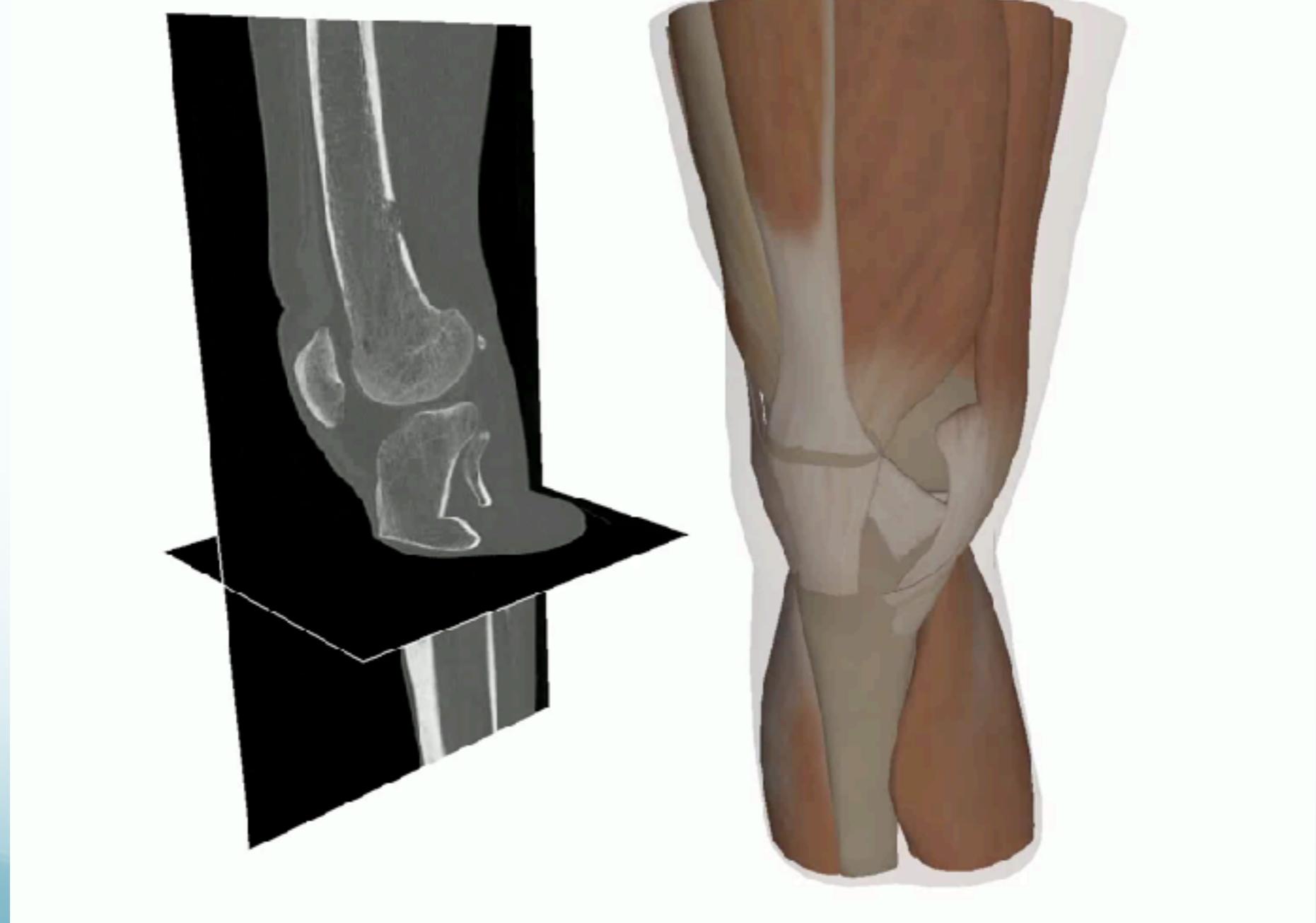
B. Gilles, L. Revéret, D.K. Pai,
Creating and animating subject-specific anatomical models,
Computer Graphics Forum, presented at Eurographics'11, 29(8), pp 2340-2351, 2010.

Exemple: recalage de squelettes

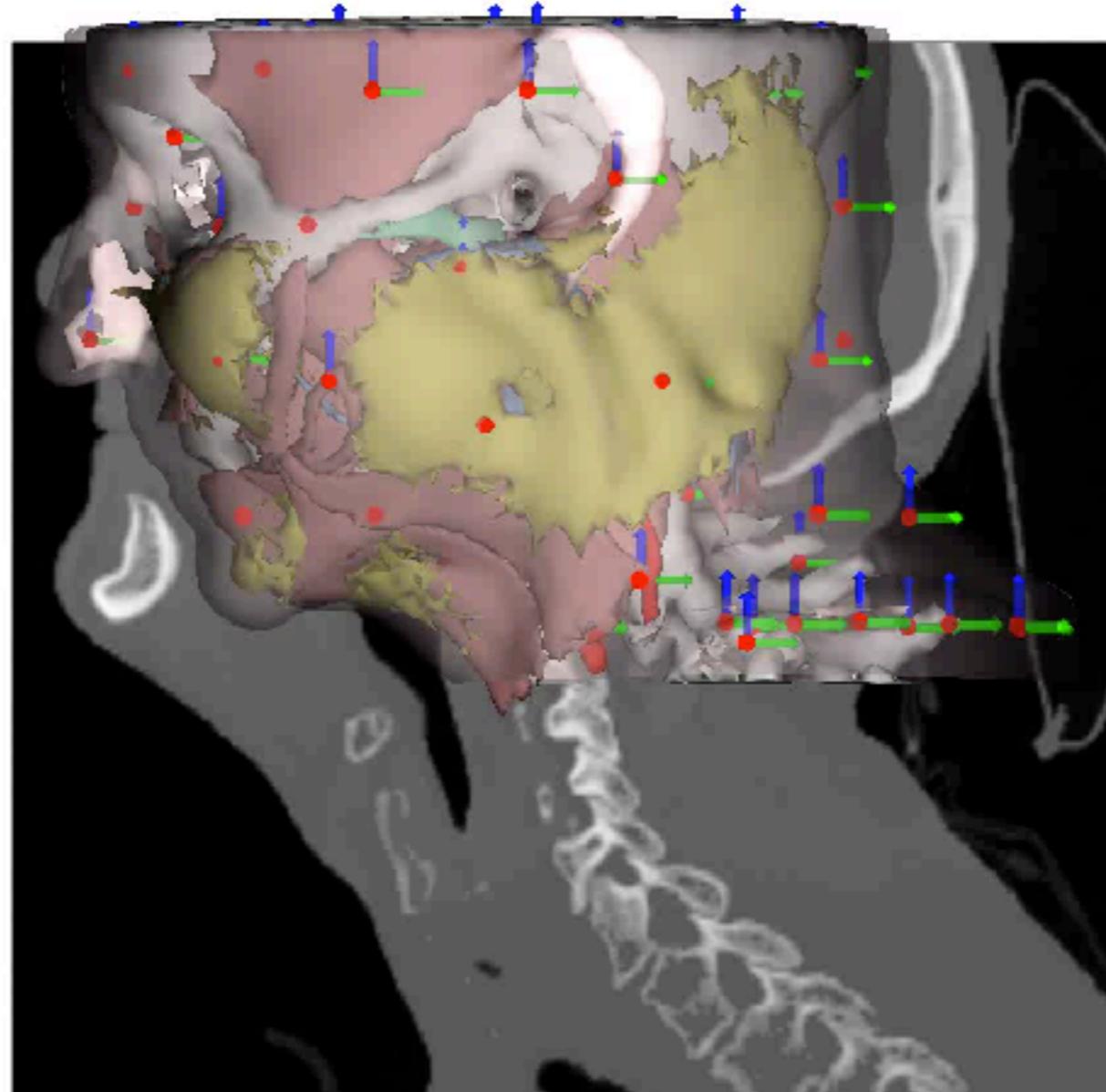


B. Gilles, L. Revéret, D.K. Pai,
Creating and animating subject-specific anatomical models,
Computer Graphics Forum, presented at Eurographics'11, 29(8), pp 2340-2351, 2010.

Exemple: recalage du genou

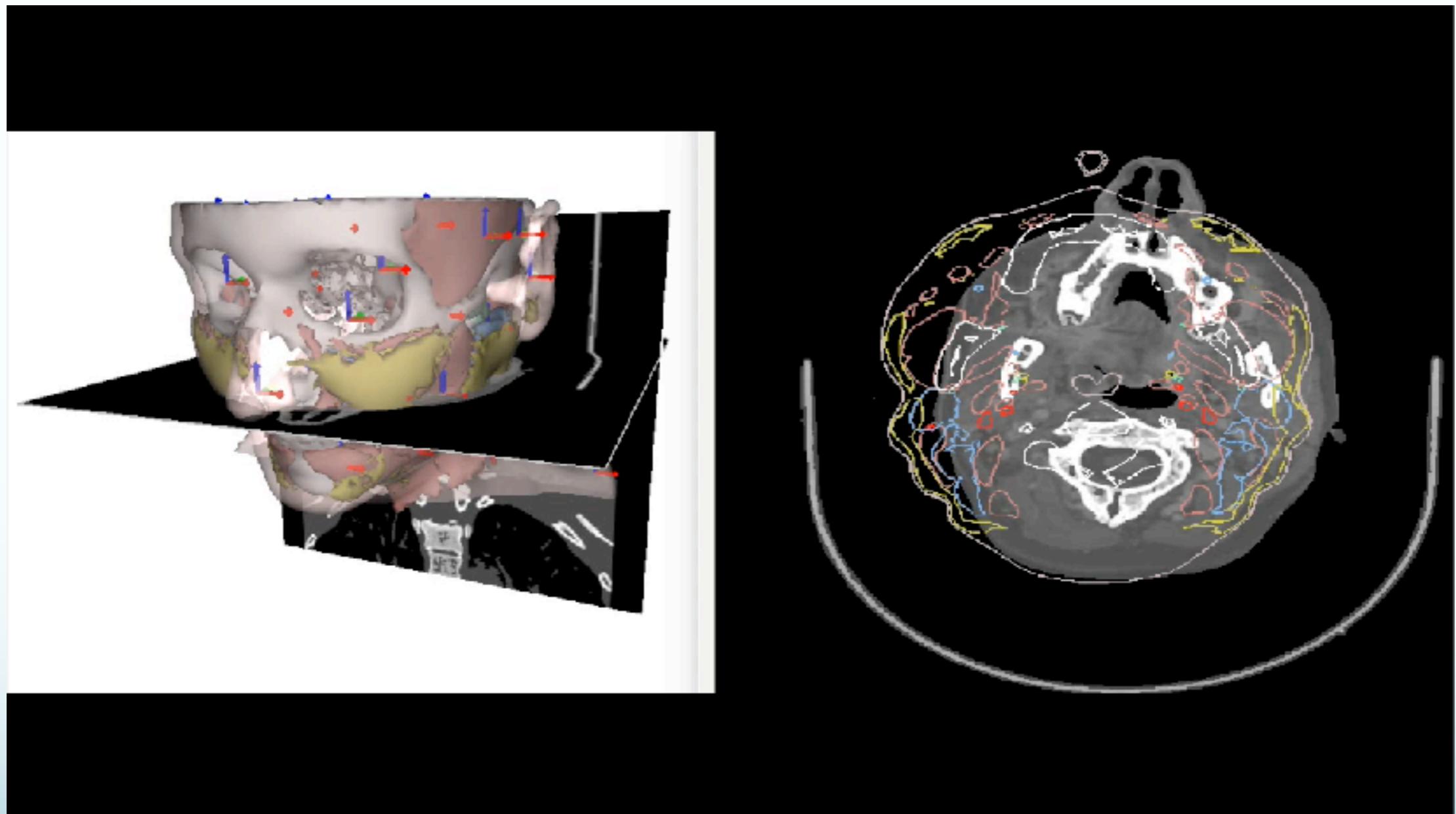


Exemple: identification des espaces ORL profonds pour la radiothérapie



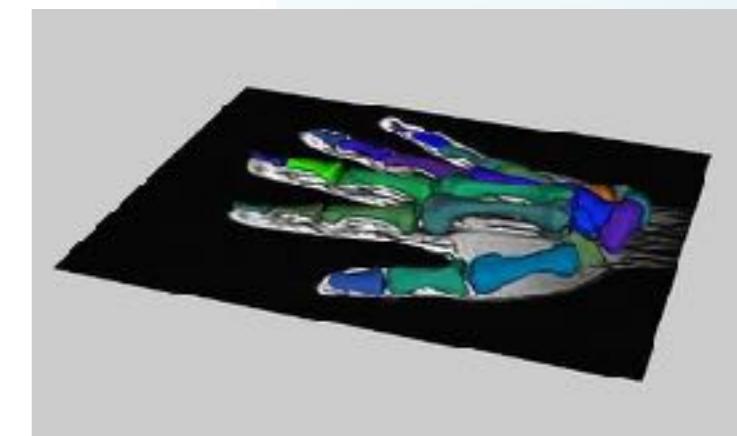
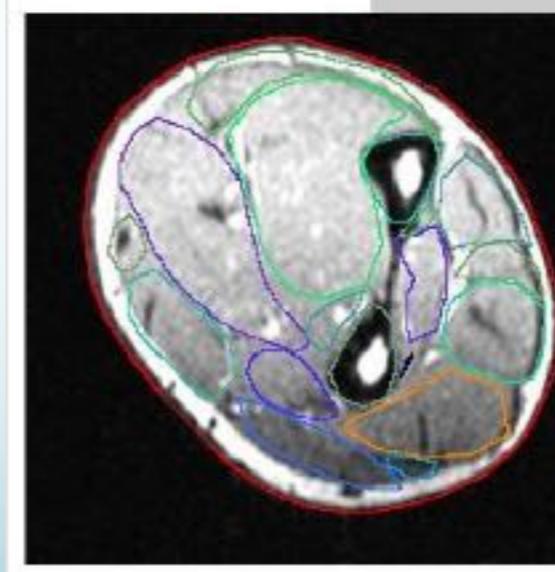
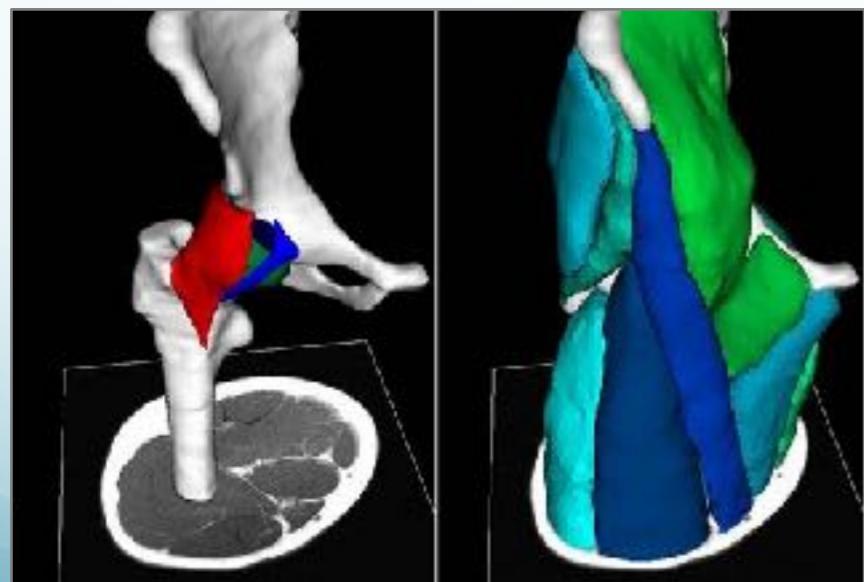
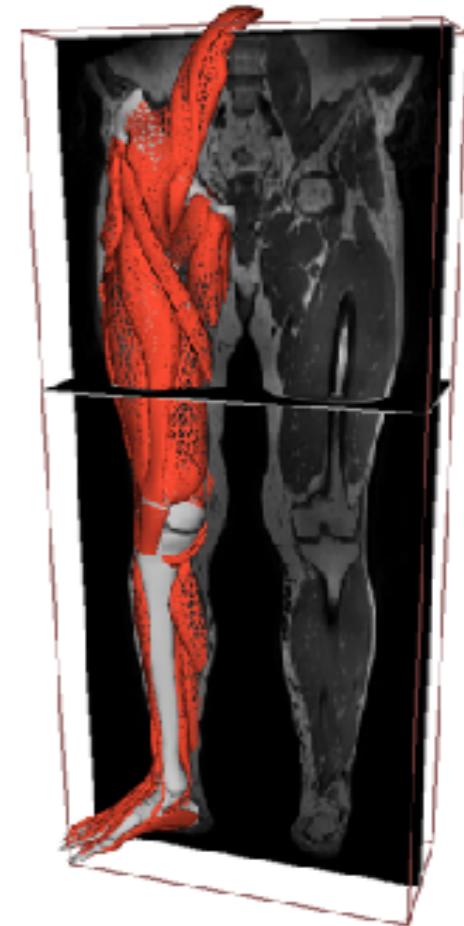
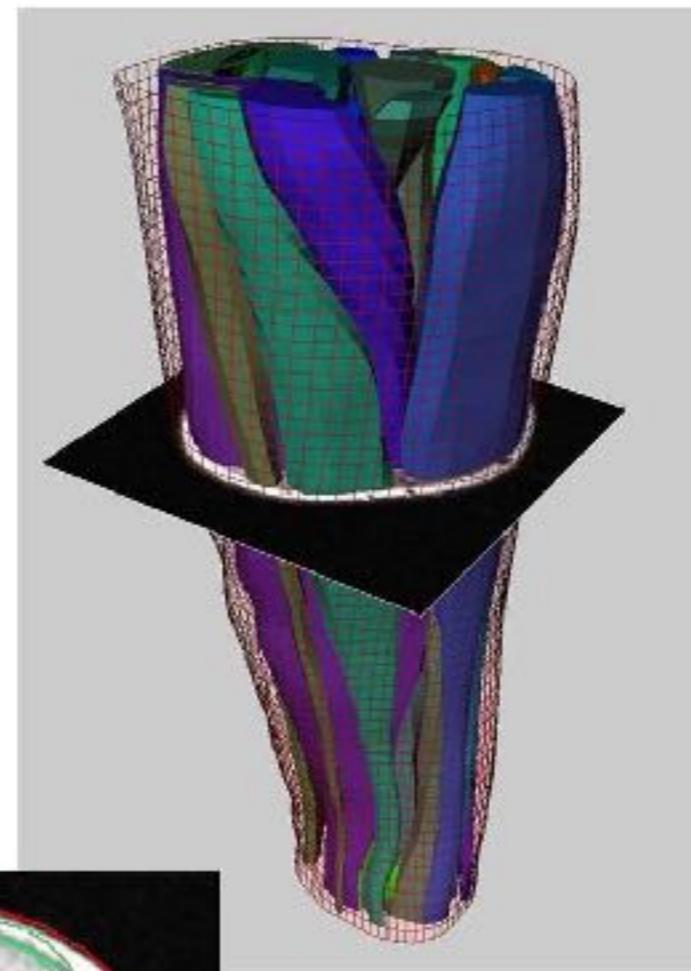
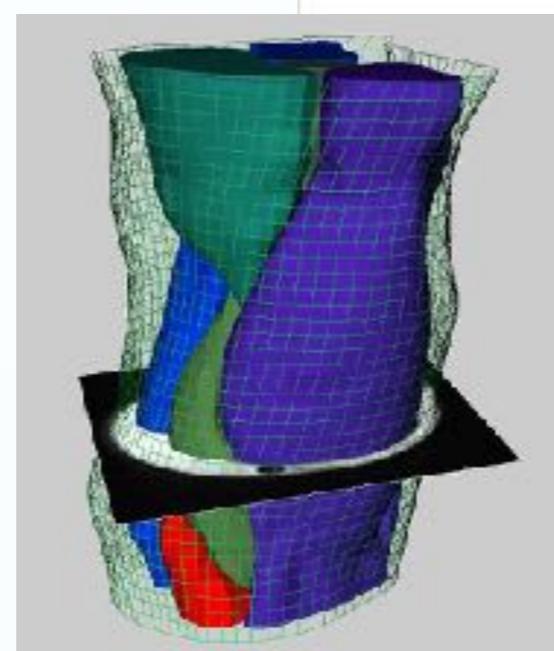
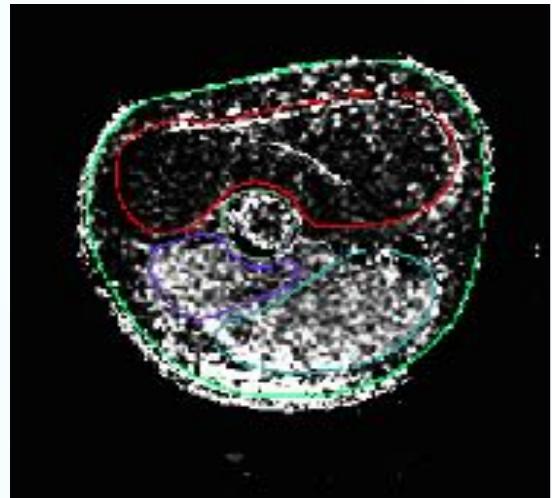
S Boussouar, O Bouhelal, B Gilles, F Faure, C Vaniet, D Balvay, R Douard, J-M Chevallier, P Halimi, CA Cuénod, Segmentation automatique des espaces profonds de la tête et du cou par des techniques de morphing, **Morphologie**, 99 (326): 109, 2015.

Exemple: identification des espaces ORL profonds pour la radiothérapie

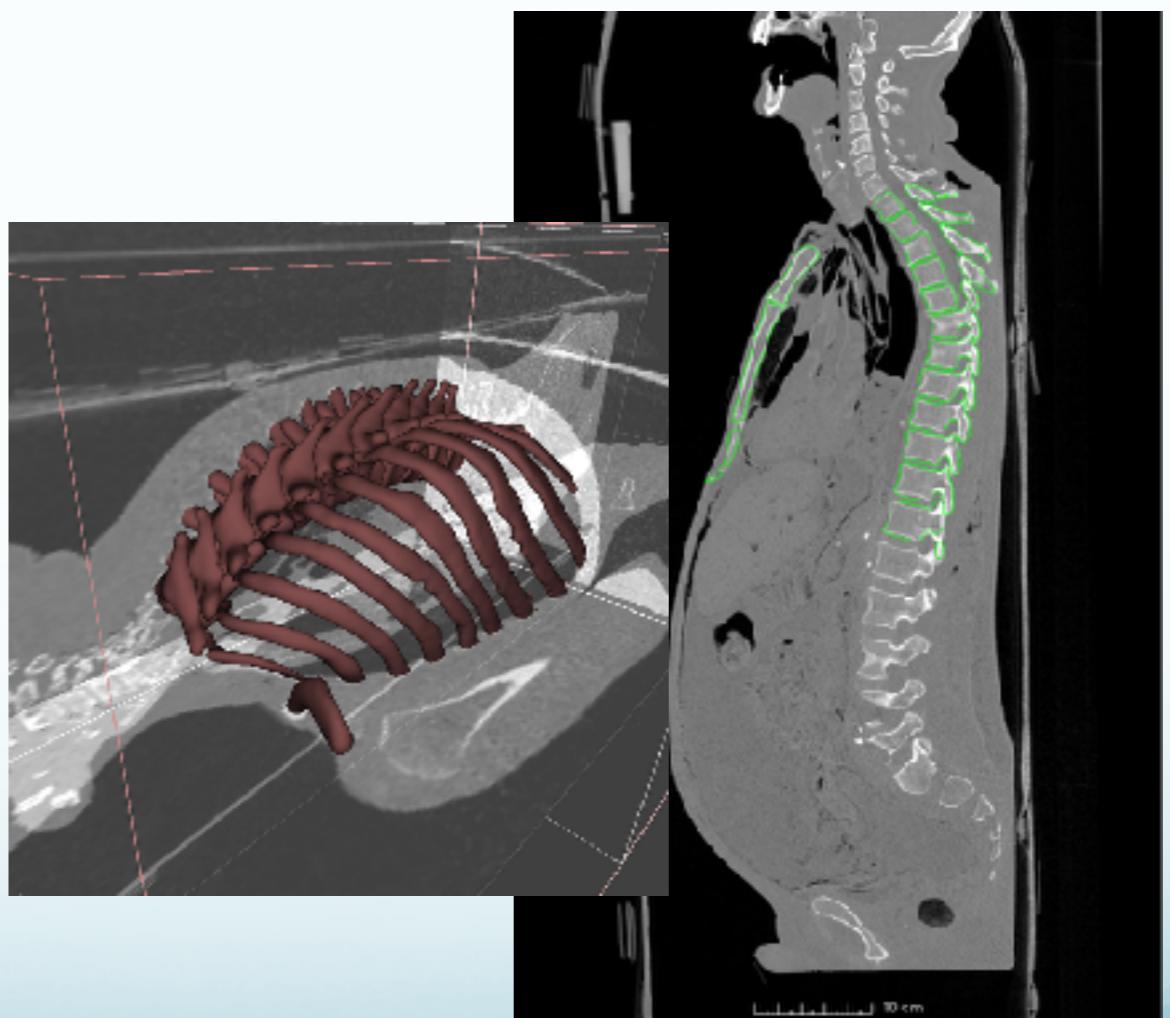
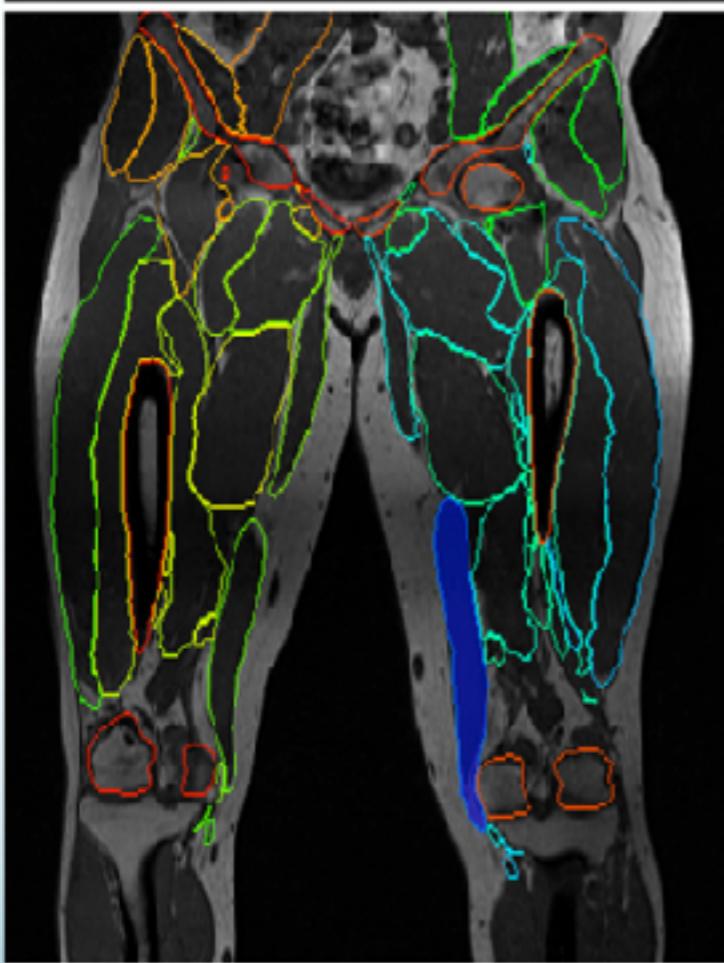
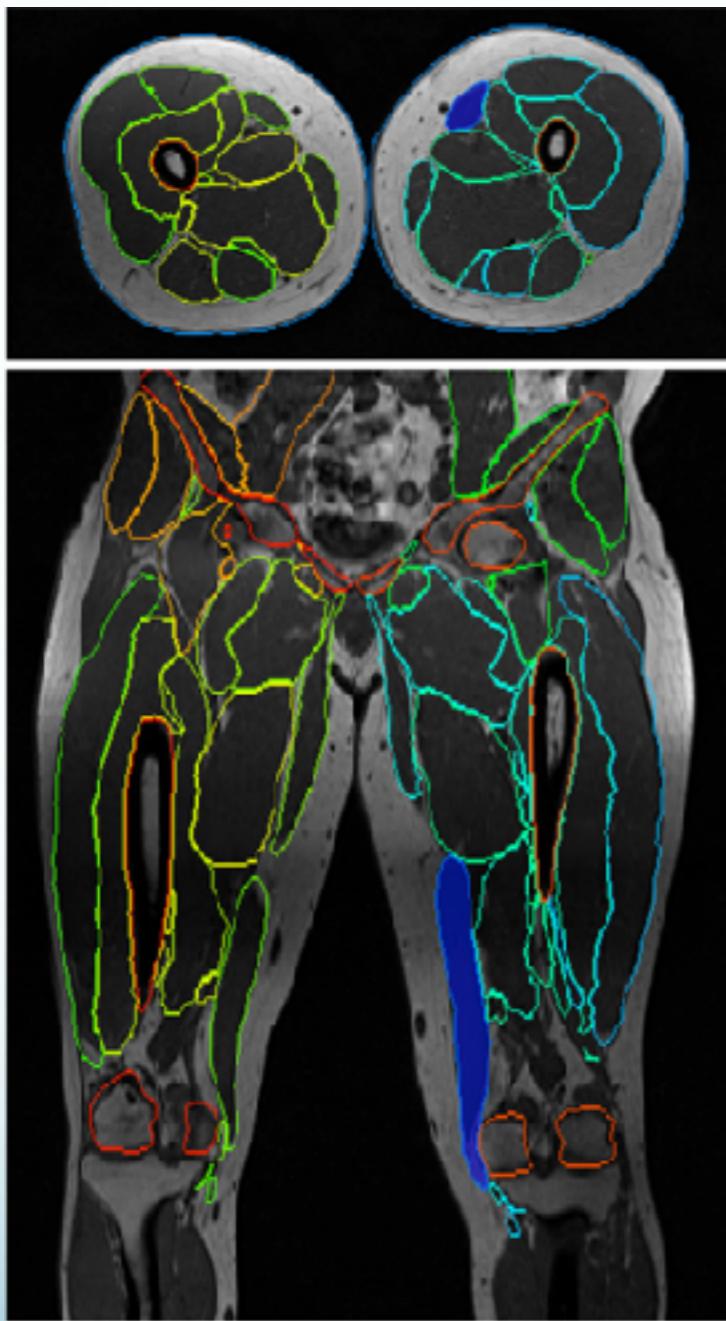


S Boussouar, O Bouhelal, B Gilles, F Faure, C Vaniet, D Balvay, R Douard, J-M Chevallier, P Halimi, CA Cuénod, Segmentation automatique des espaces profonds de la tête et du cou par des techniques de morphing, **Morphologie**, 99 (326): 109, 2015.

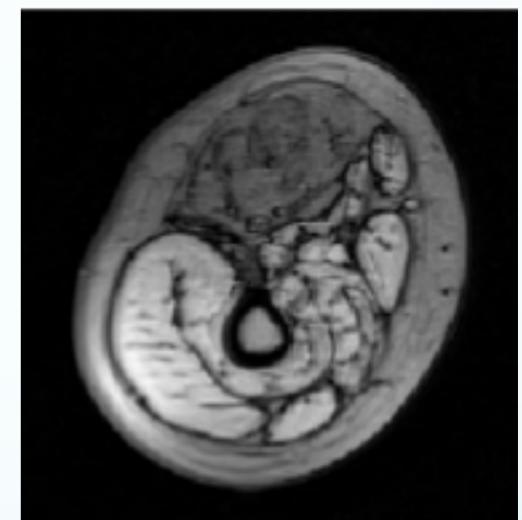
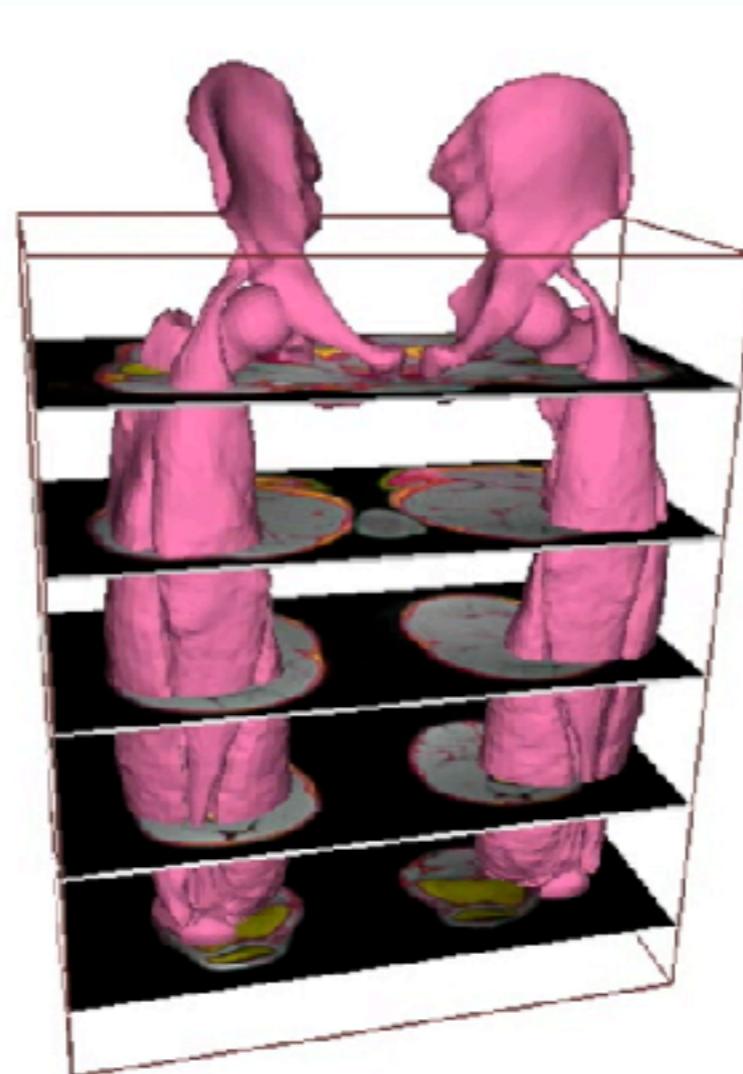
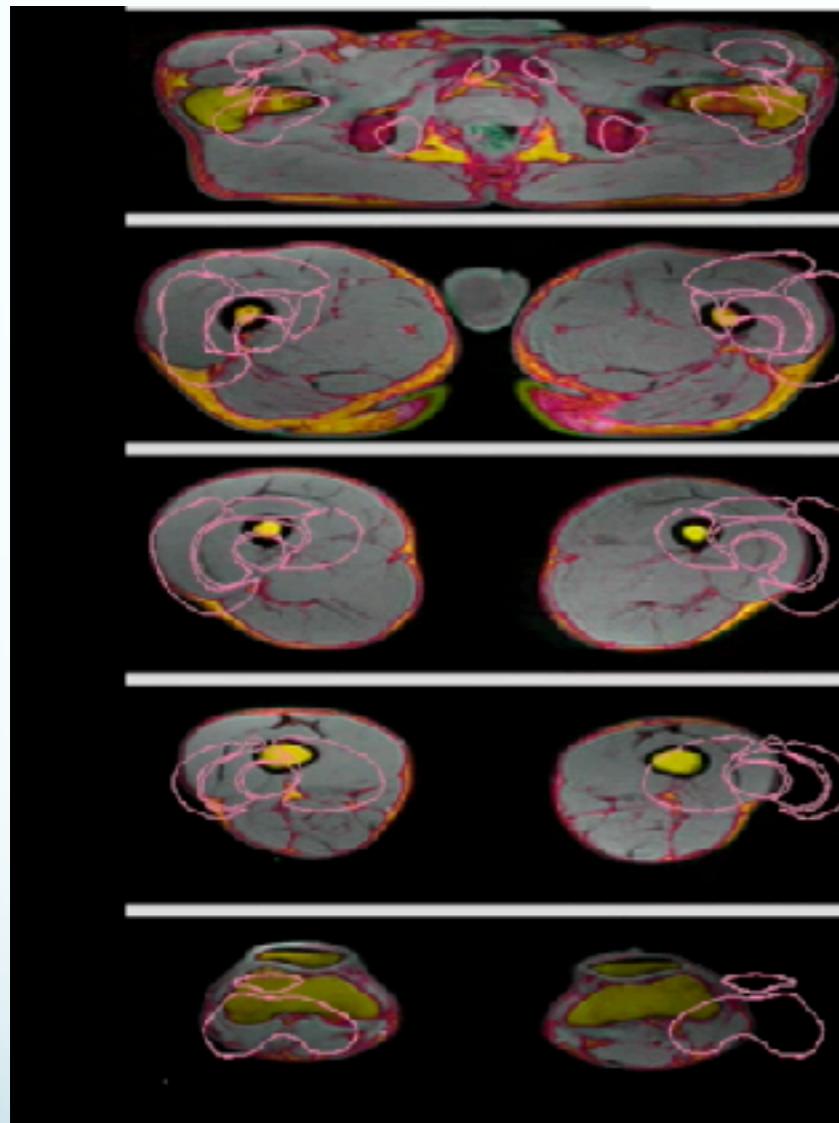
Résultats de Segmentation



Résultats de Segmentation



Exemple: volumetrie de muscles



Pathologies ?

B. Gilles, C. de Bourguignon, P. Croisille, G. Millet, M. Viallon, O. Beuf,
Automatic segmentation for volume quantification of quadriceps muscle head in
athletes during an extreme mountain ultra-marathon,
proc. of ISMRM, 766: 2016.

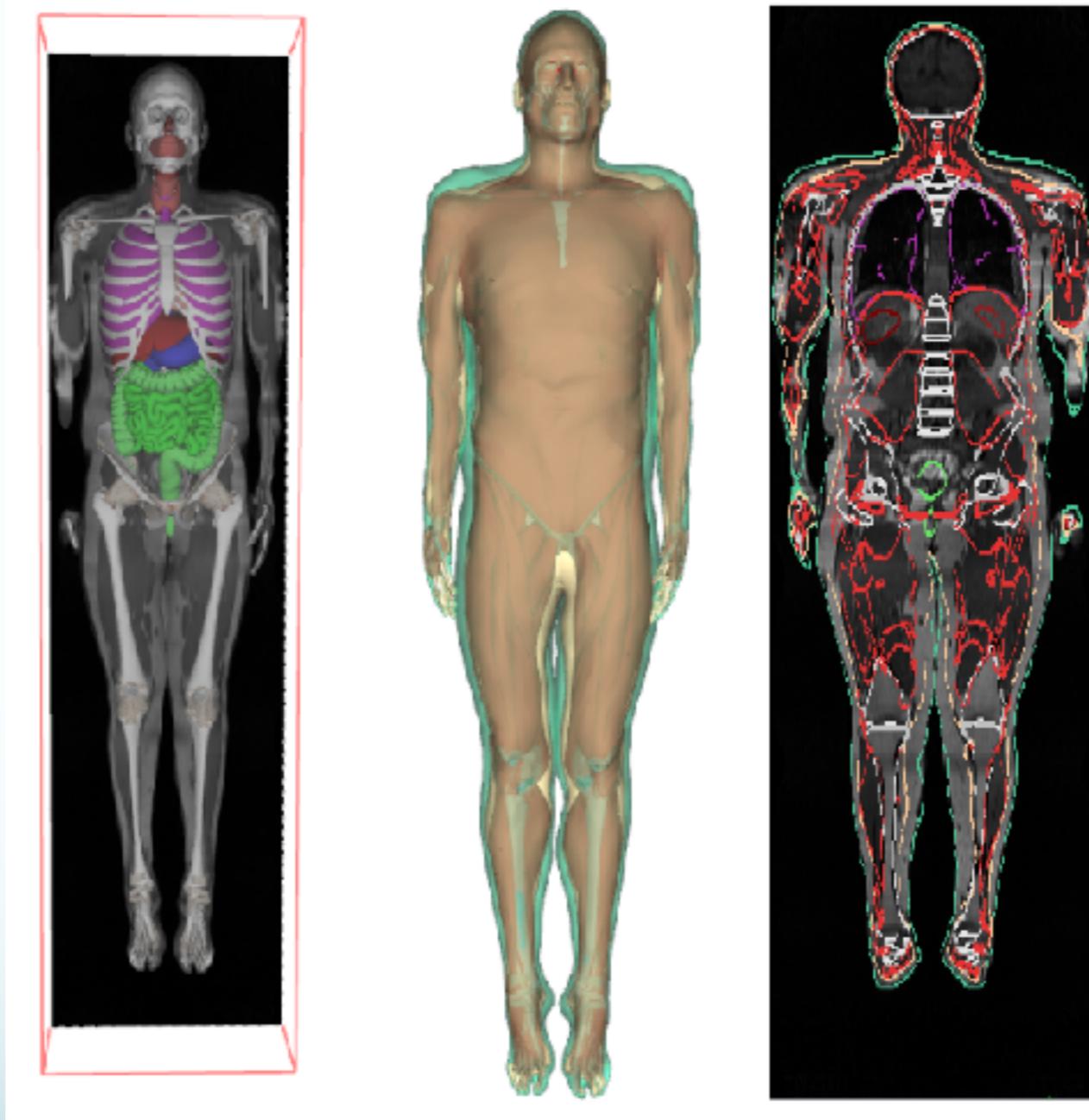
Transfert d'Anatomie

- Recalage de peaux + interpolation des organes sous contraintes anatomiques
- Maquette de référence complète, transférée dans la cible



A. Dicko, T. Liu, B. Gilles, O. Palombi, L. Kavan, M-P Cani, F. Faure
Anatomy transfer
ACM Transactions on Graphics, proc. of SIGGRAPH Asia, 32 (6), 2013.

Transfert d'Anatomie



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Anatomy transfer
ACM Transactions on Graphics, proc. of SIGGRAPH Asia, 32 (6), 2013.

Visualisation du corps en mouvement

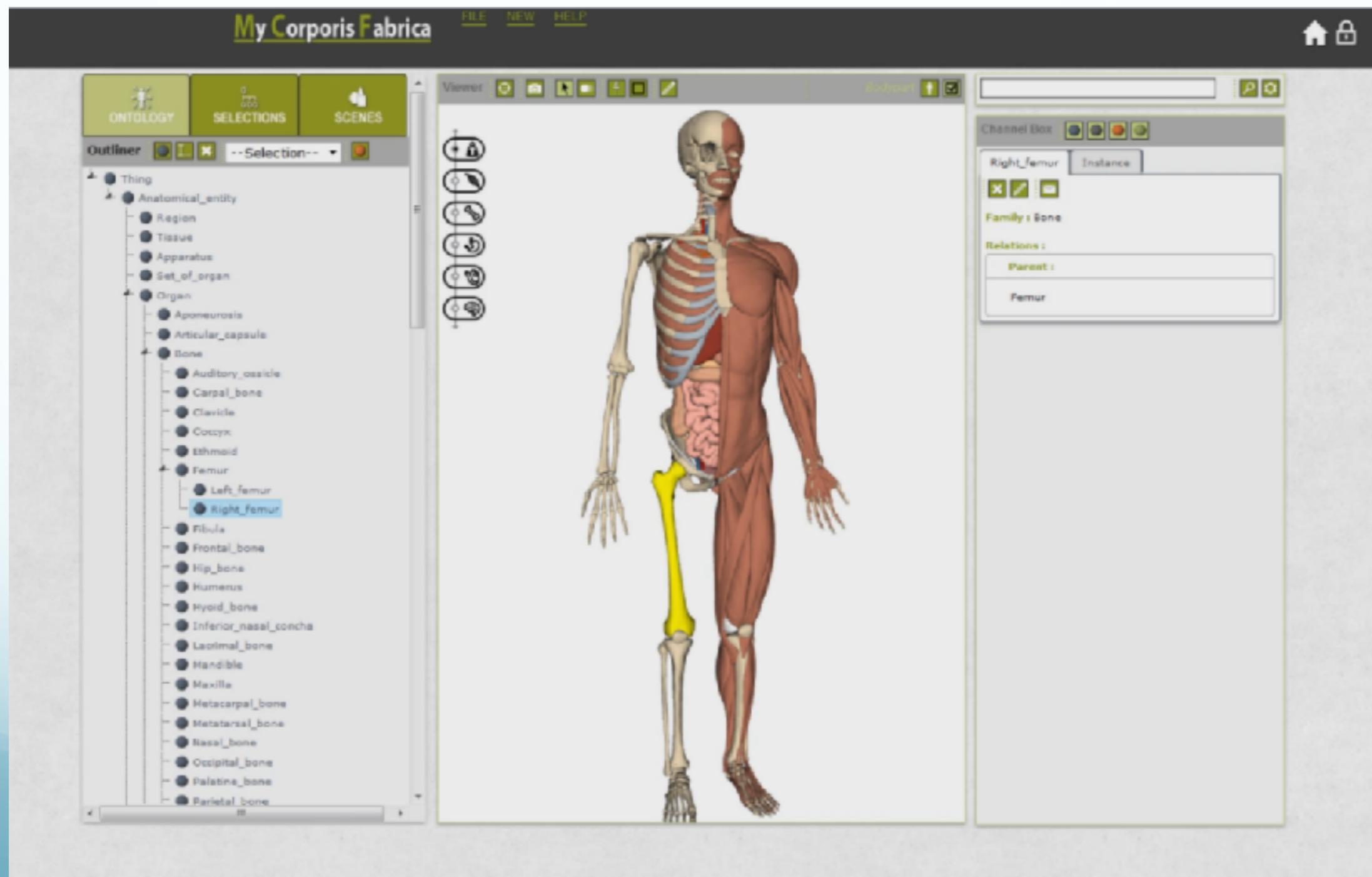
Full Body Anatomy Animation
with Motion Capture



ANATOSCOPE

Indexation dans une ontologie anatomique

- MyCF: entités anatomiques + fonctions physiologiques [Palombi 09]



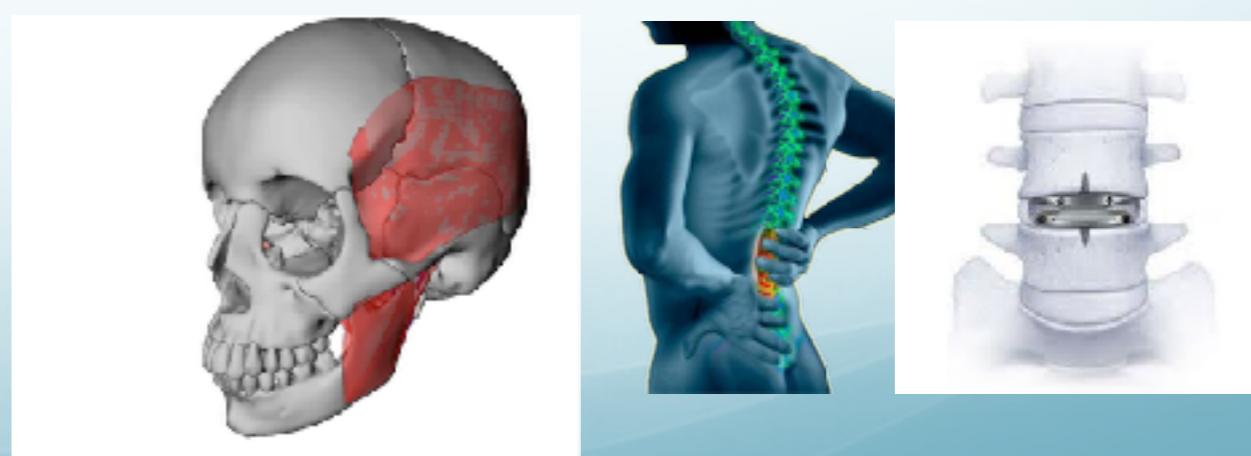
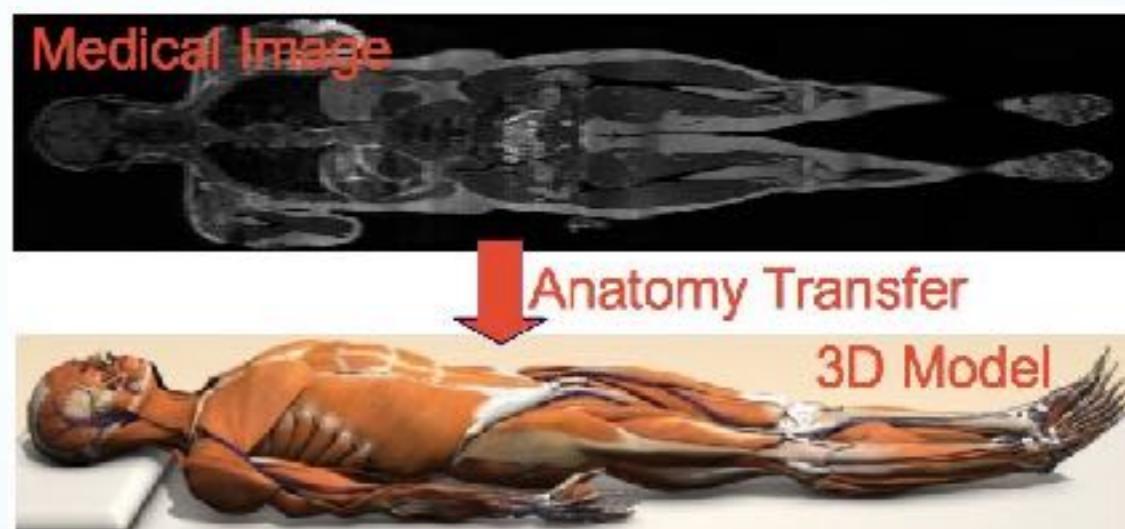
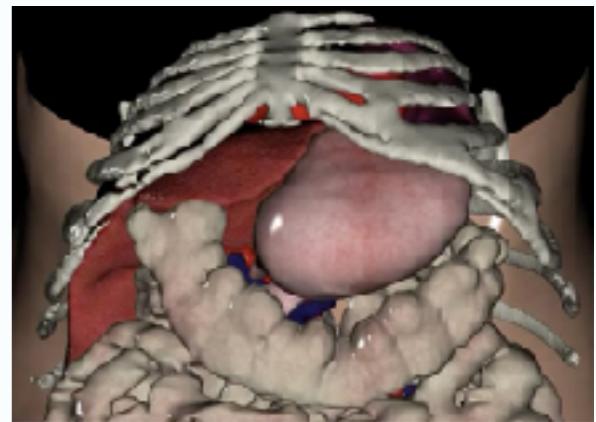
Conclusion: recalage de maquettes anatomiques 3D

- Points forts
 - interactif <-> automatique
 - rapide
 - contient toute la connaissance
- Limitations
 - parties manquantes/supplémentaires (eg. tumeurs)
 - variabilité topologique (eg. système vasculaire)

Applications

personnalisation, prédition, efficacité, maitrise des coûts

- Médecine personnalisée
 - Communication : personnel médical (dossier patient)
 - Communication : médecin – patient – entourage (modèle unifié Cloud)
 - Suivi – rééducation : Objets connectés (Acc, force...), kinect...
- Planification et simulation
 - Dentaire, orthopédie, maxillo-facial, plastique
 - Appareillage personnalisé par impression 3D
- Formation
 - Visualisation et navigation anatomique
 - Simulation interactive



Technologie

Patient data



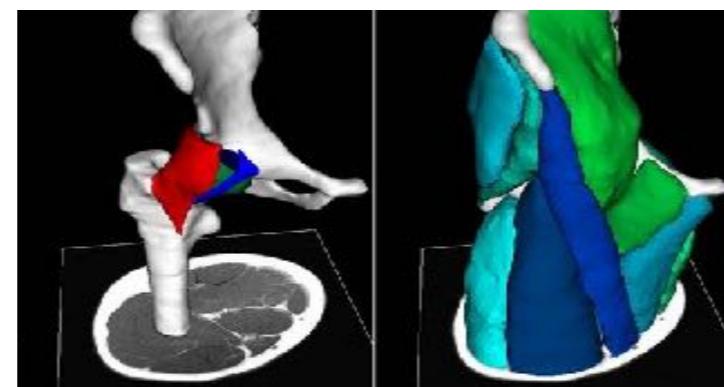
3D surfaces



imaging

Silhouettes,
images, videos...

Automatic integration



Anatomy Transfer

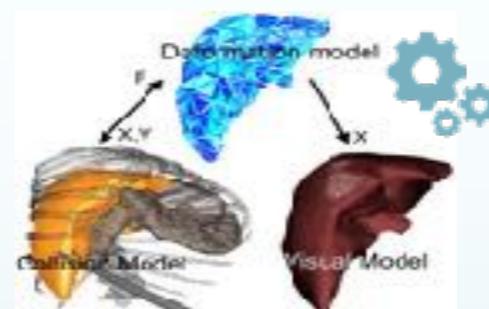


Anatomy
data base



Generic
model

Personalized
model



Simulation software

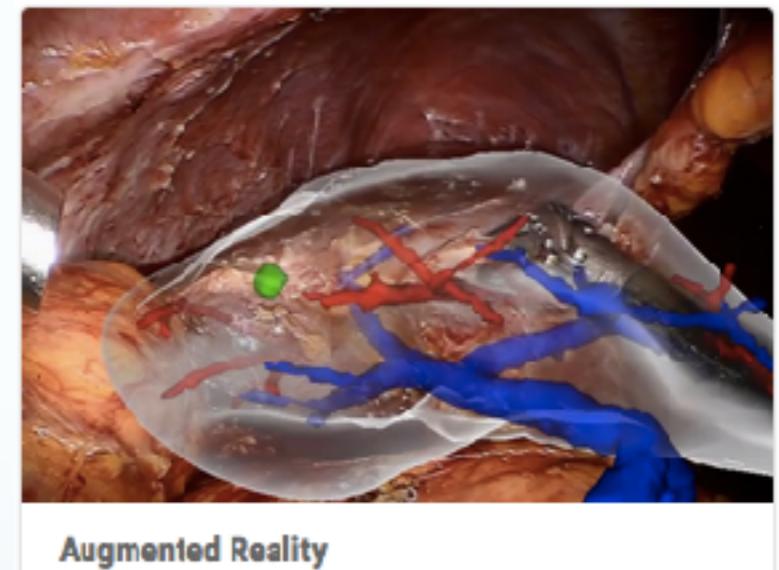
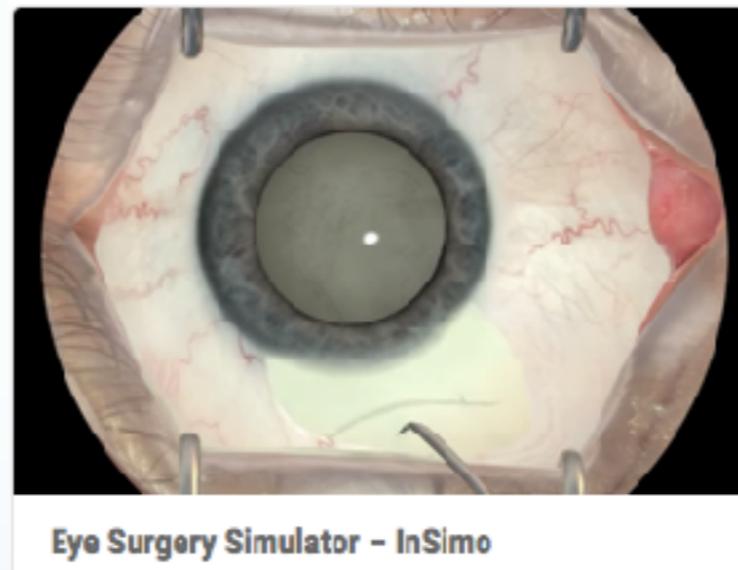
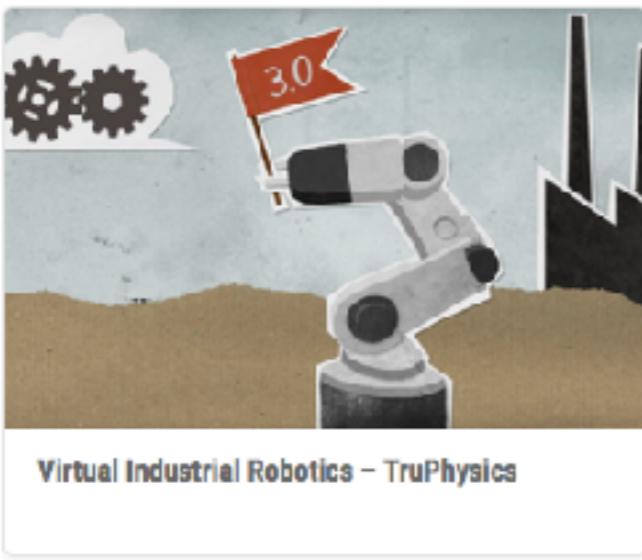
Personalized
devices



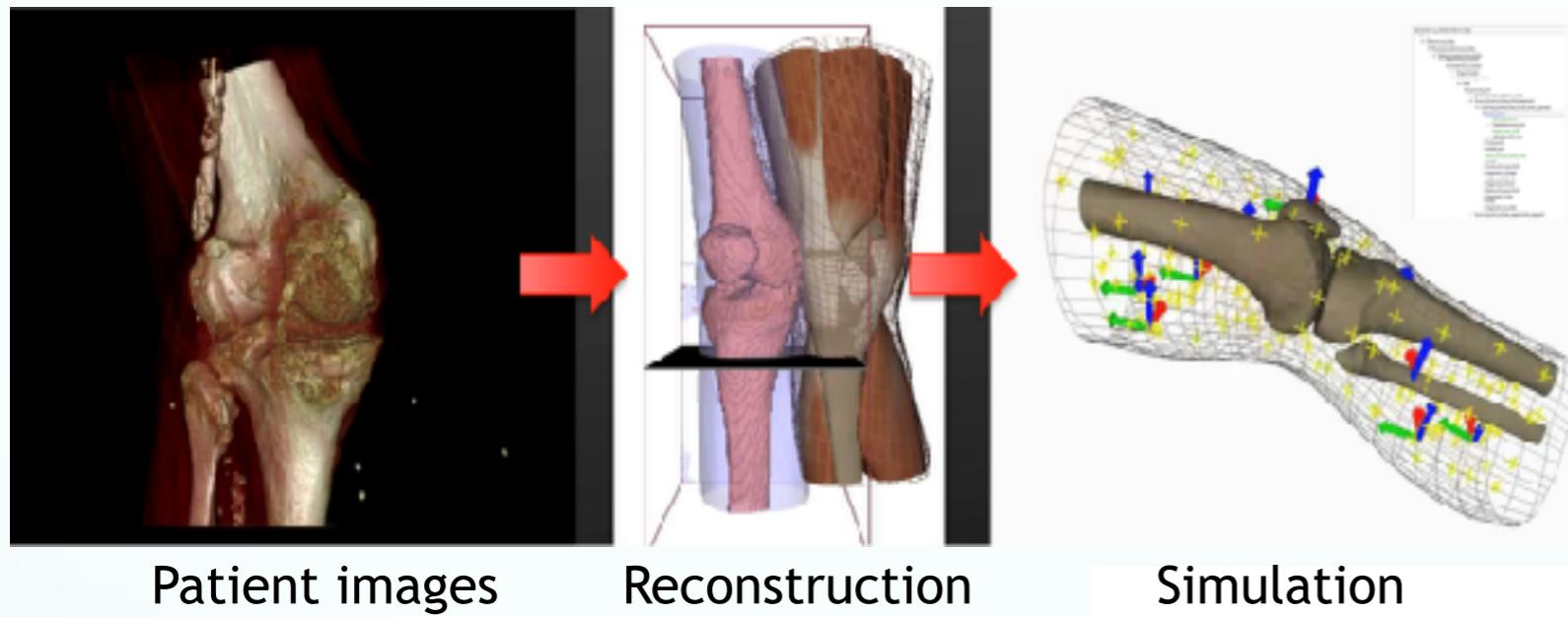
SOFA simulation library

www.sofa-framework.org

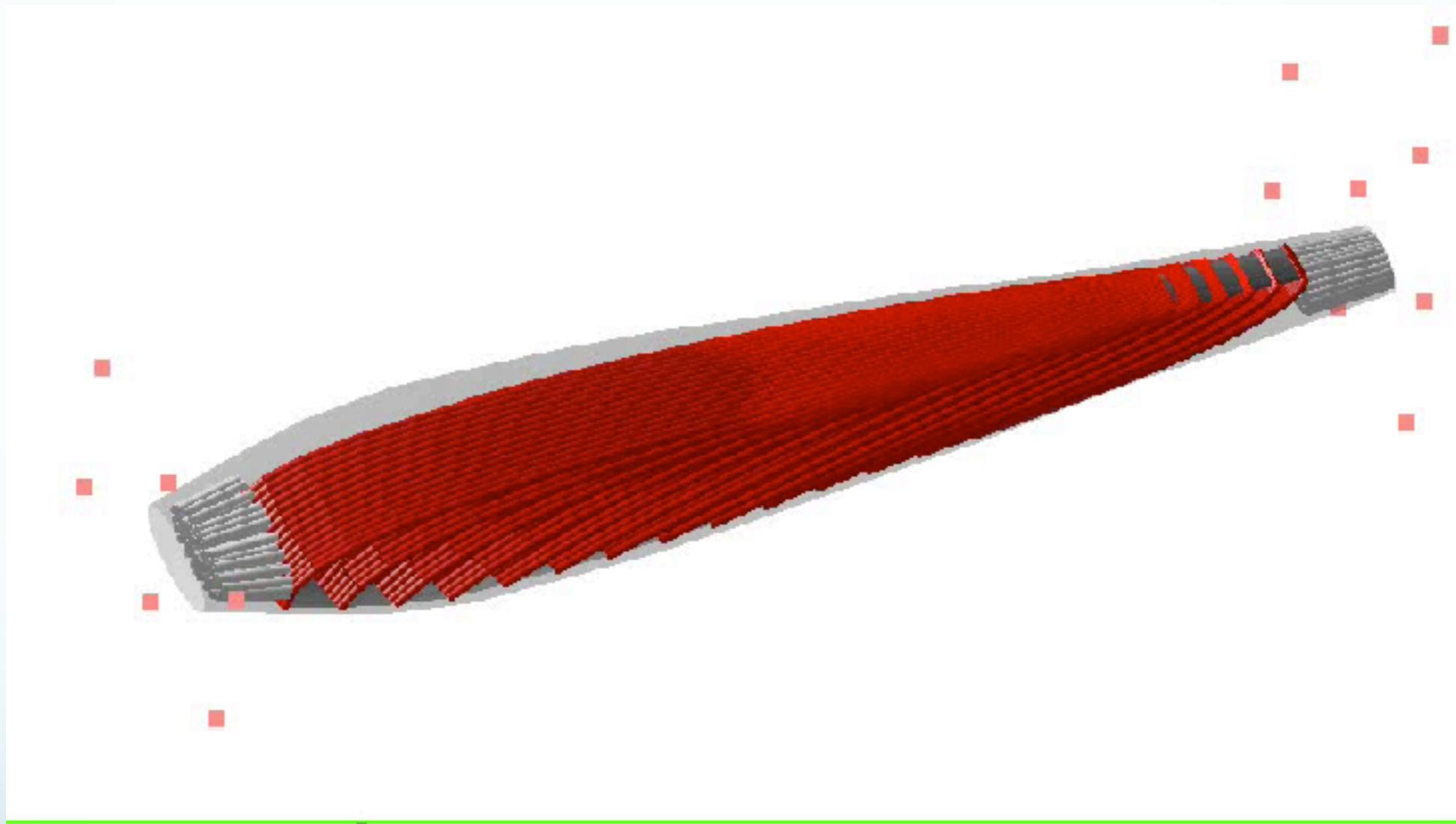
- Open-source C++ depuis 2007
- Solides déformables, rigides, fluides



Exemple: simulation d'un genou personnalisé



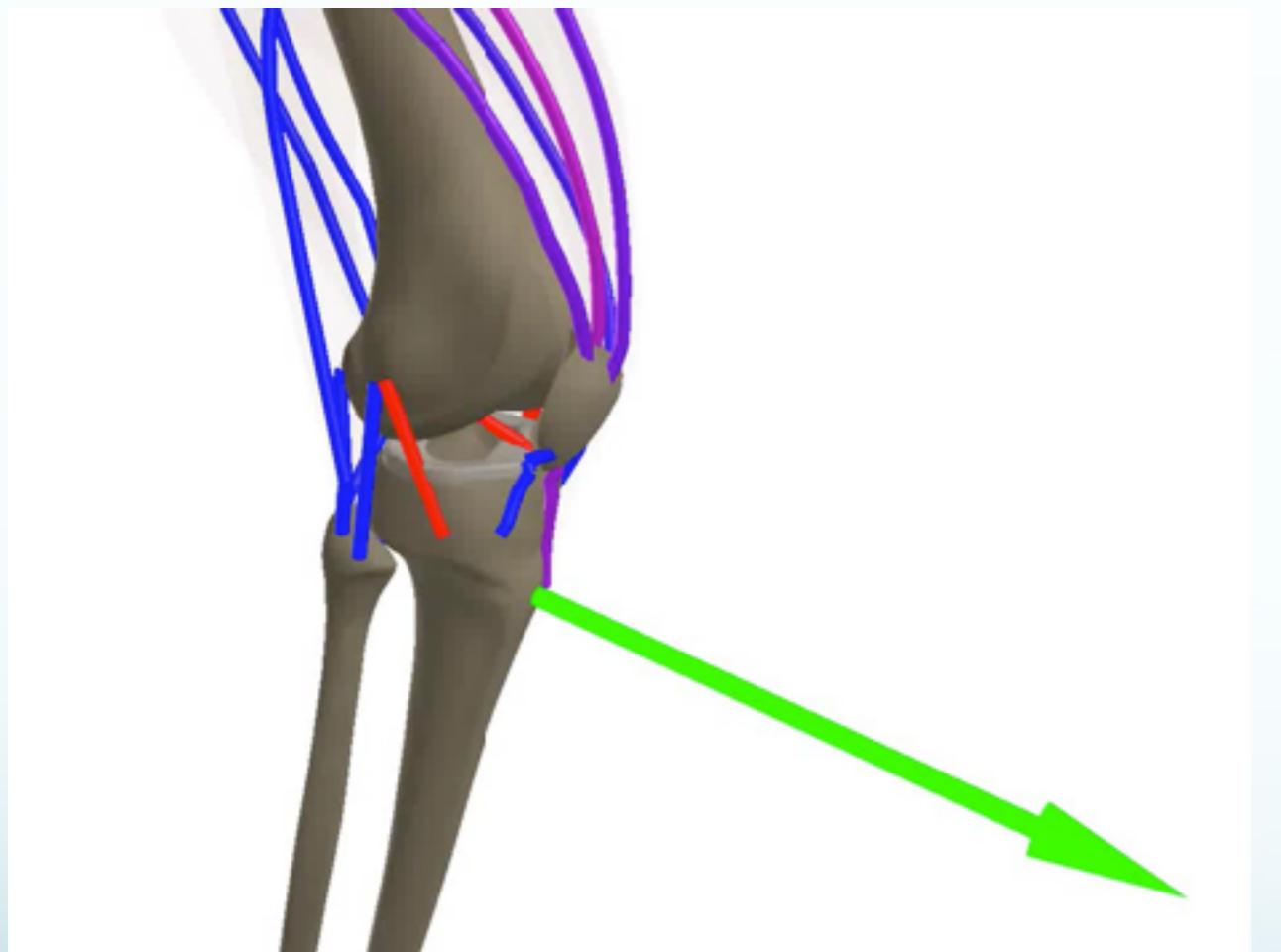
Exemple: Simulation du muscle squelettique



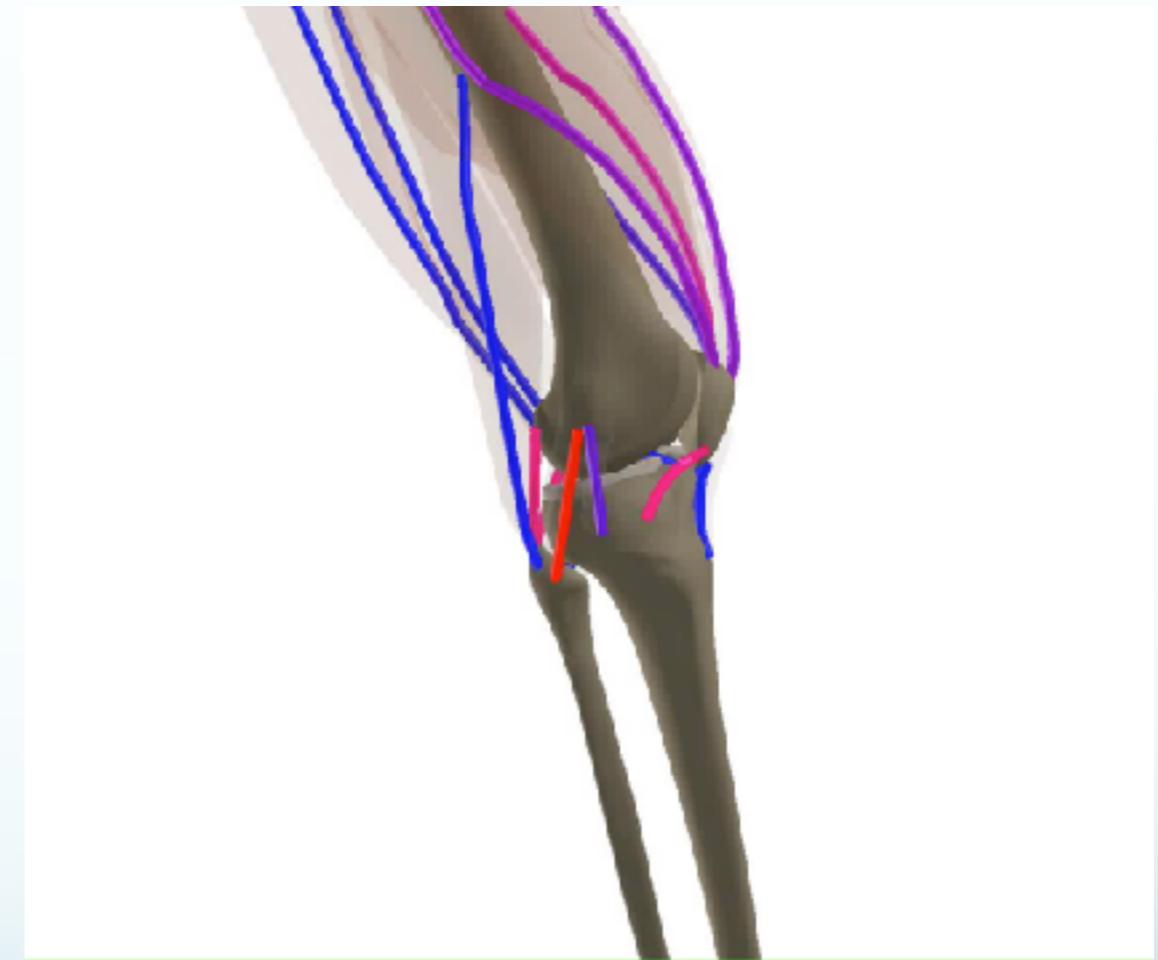
Y. Berranen, M. Hayashibe, D. Guiraud, B. Gilles,
Real-time Muscle Deformation via Decoupled Modeling of Solid and Muscle Fiber Mechanics,
Medical Image Computing and Computer Assisted Intervention, MICCAI, vol. 8674, pp 65-72,
2014.

Exemple: Simulation du membre inférieur

Test de Lachmann



Flexion

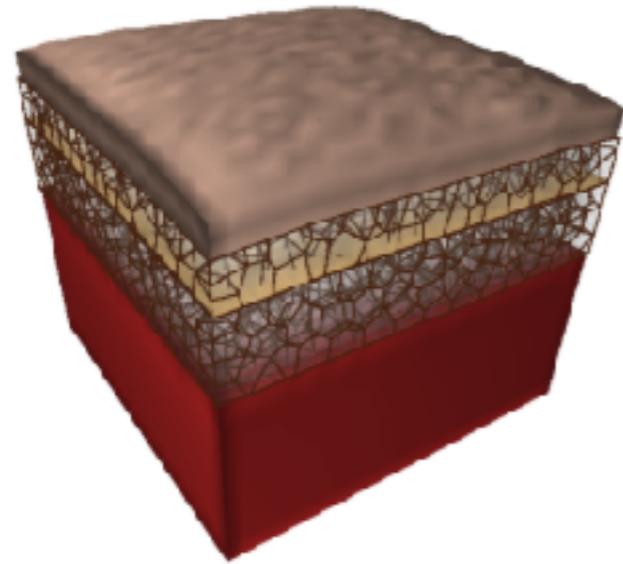
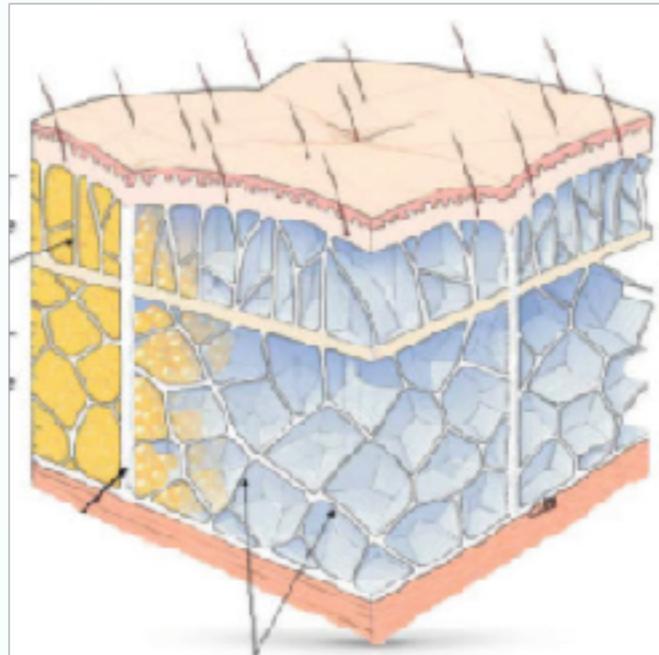


M. Tournier, M. Nesme, B. Gilles, F. Faure,

Stable Constrained Dynamics,

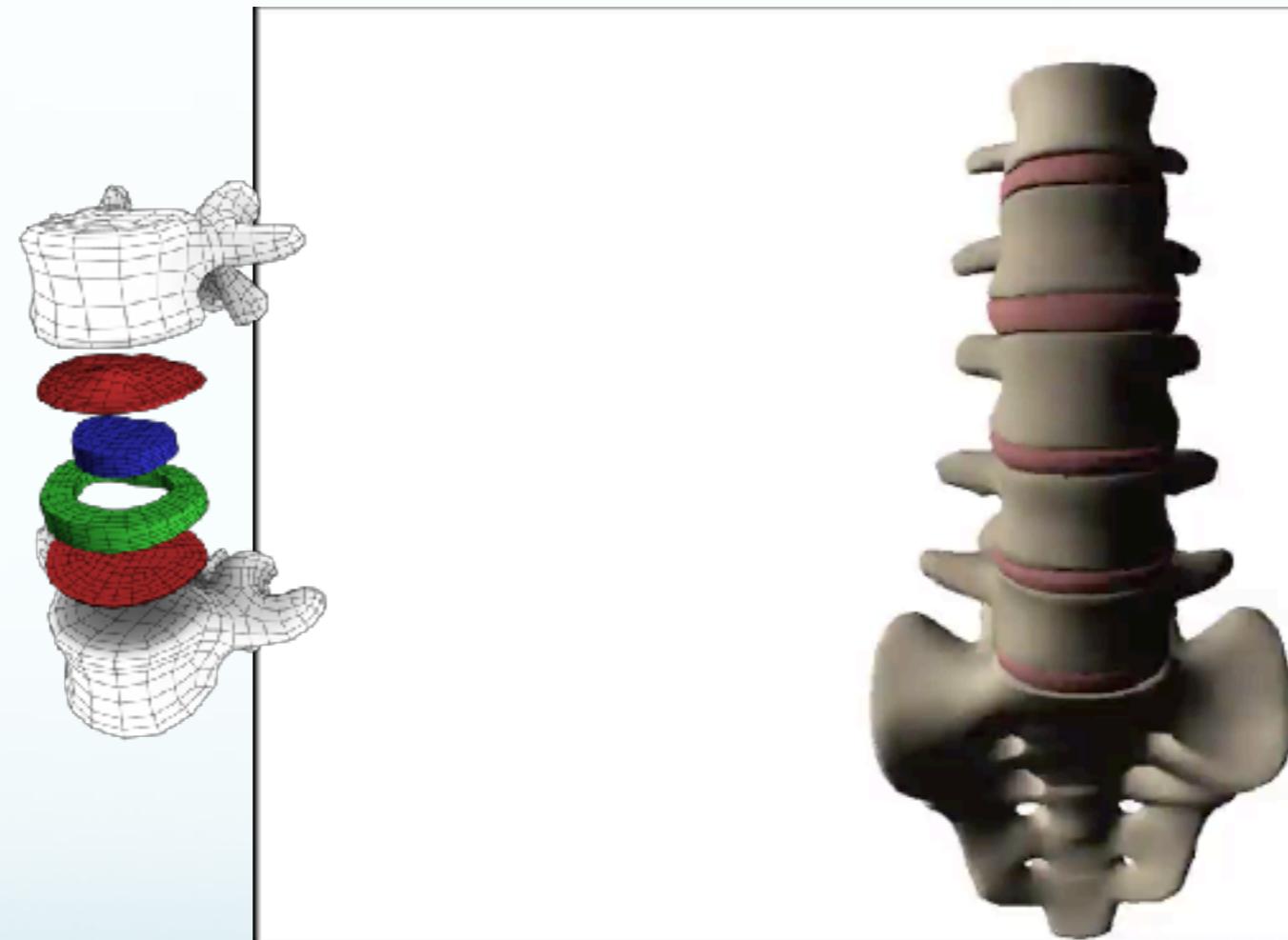
ACM Transactions on Graphics, proc. of SIGGRAPH, 34(4):132, 2015.

Exemple: simulation des tissus sous-cutanés



C. Herlin, B. Gilles, G. Subsol, G. Captier,
Generic 3D Geometrical and Mechanical Modeling of the Skin/Subcutaneous
Complex by a Procedural Hybrid Method,
Int. Symposium on Biomedical Simulation, ISBMS, vol. 8789, p173, 2014.

Exemple: Simulation du rachis



A-H. Dicko, N. Tong-Yette, B. Gilles, F. Faure, O. Palombi,

Construction and Validation of a Hybrid Lumbar Spine Model For the Fast Evaluation of Intradiscal Pressure and Mobility,

Int. Conf. on Orthopaedic Surgery, Biomechanics and Clinical Applications; World Academy of Science, Engineering and Technology (WASET), 9(2), 134-145, 2015.

Simulation du contact

- Articulated bones
- Deformable muscle, skin
- Articulated+deformable exoskeleton
- Skin-exoskeleton contact
- Inverse dynamics

ANR Sohusim



Simulation du contact

- Articulated bones
- Deformable muscle, skin
- Articulated+deformable exoskeleton
- Skin-exoskeleton contact
- Inverse dynamics



Device Customization

Fast & Automatic Personalization of
Sports Equipment
(Shoes examples)



A N A T O S C O P E

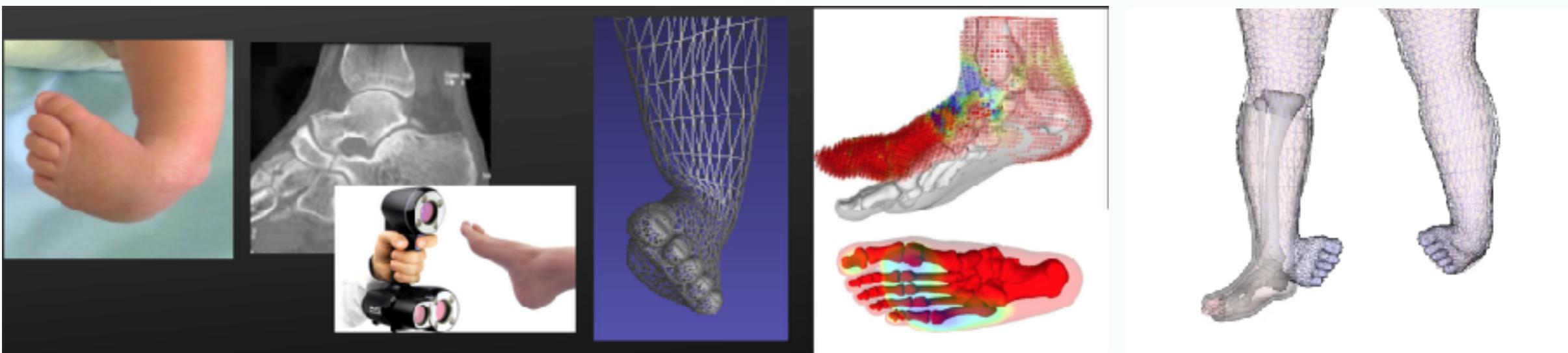
Modélisation personnalisée d'une orthèse de genou



Orthèses

Exemple: Pied Bot avec Institut Saint-Pierre, Montpellier

- Modèle personnalisé de l'anatomie du pied

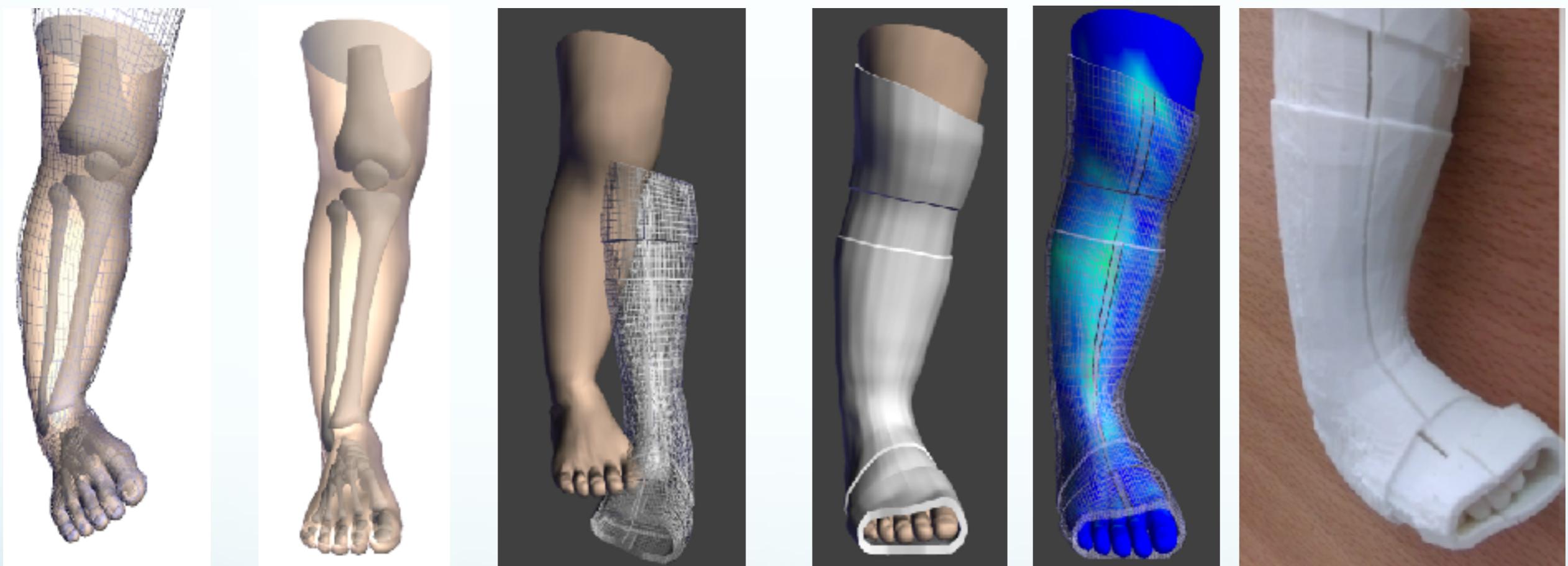


- Conception CAO auto-adaptable et impression 3D



Orthèses

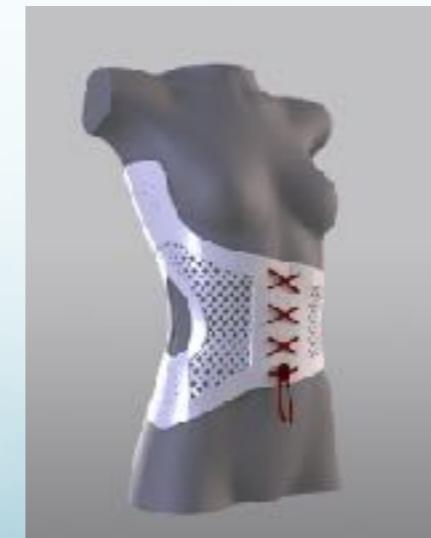
Exemple: Pied Bot avec Institut Saint-Pierre, Montpellier



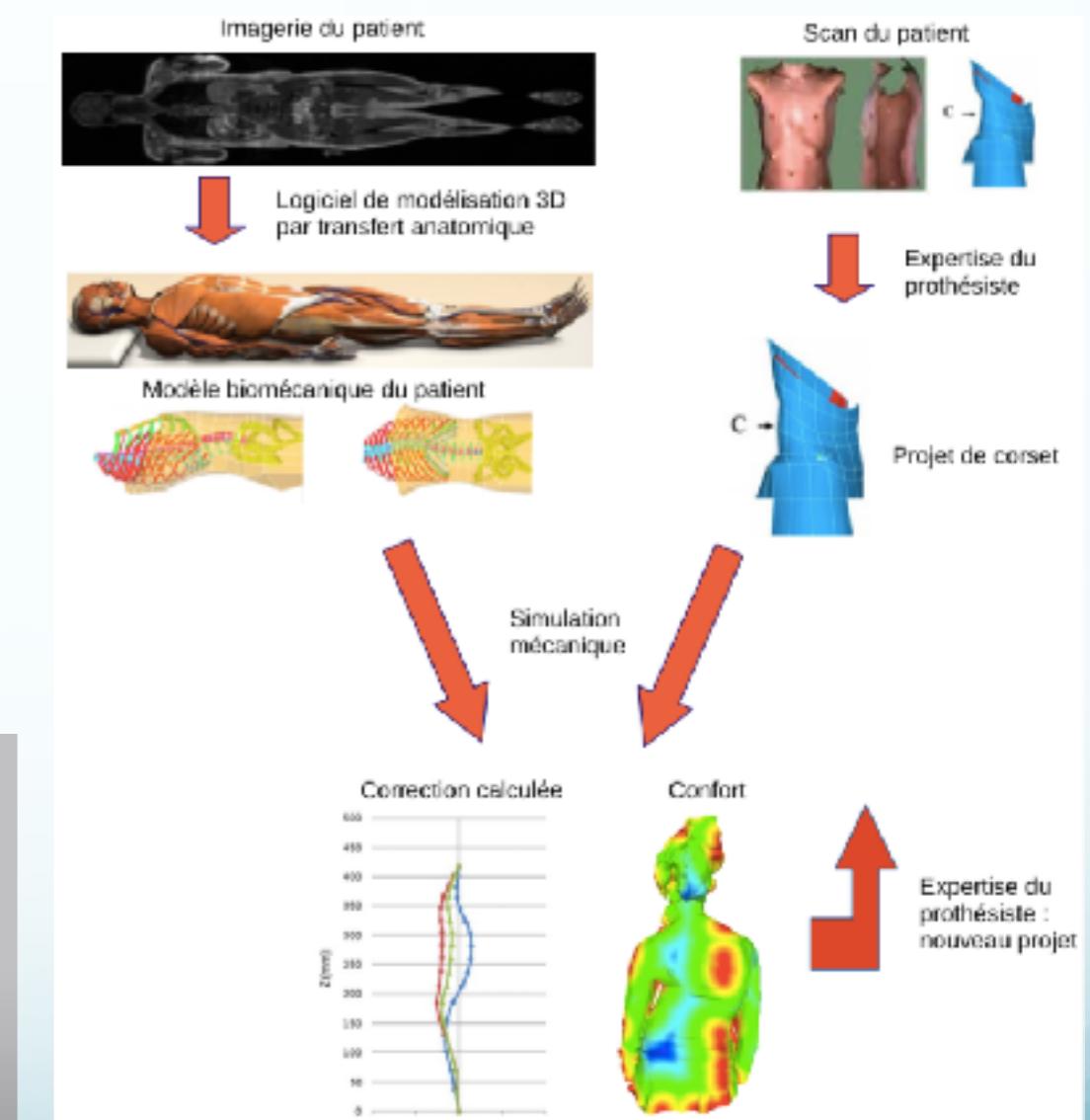
Production automatisée de corsets et d'orthèses

Collaboration hôpital Universitaire de Grenoble

- Corset pour la scoliose
 - Simulation anatomique et validation avec le CHU de Grenoble
 - Auto-adaptation du corset et impression 3D

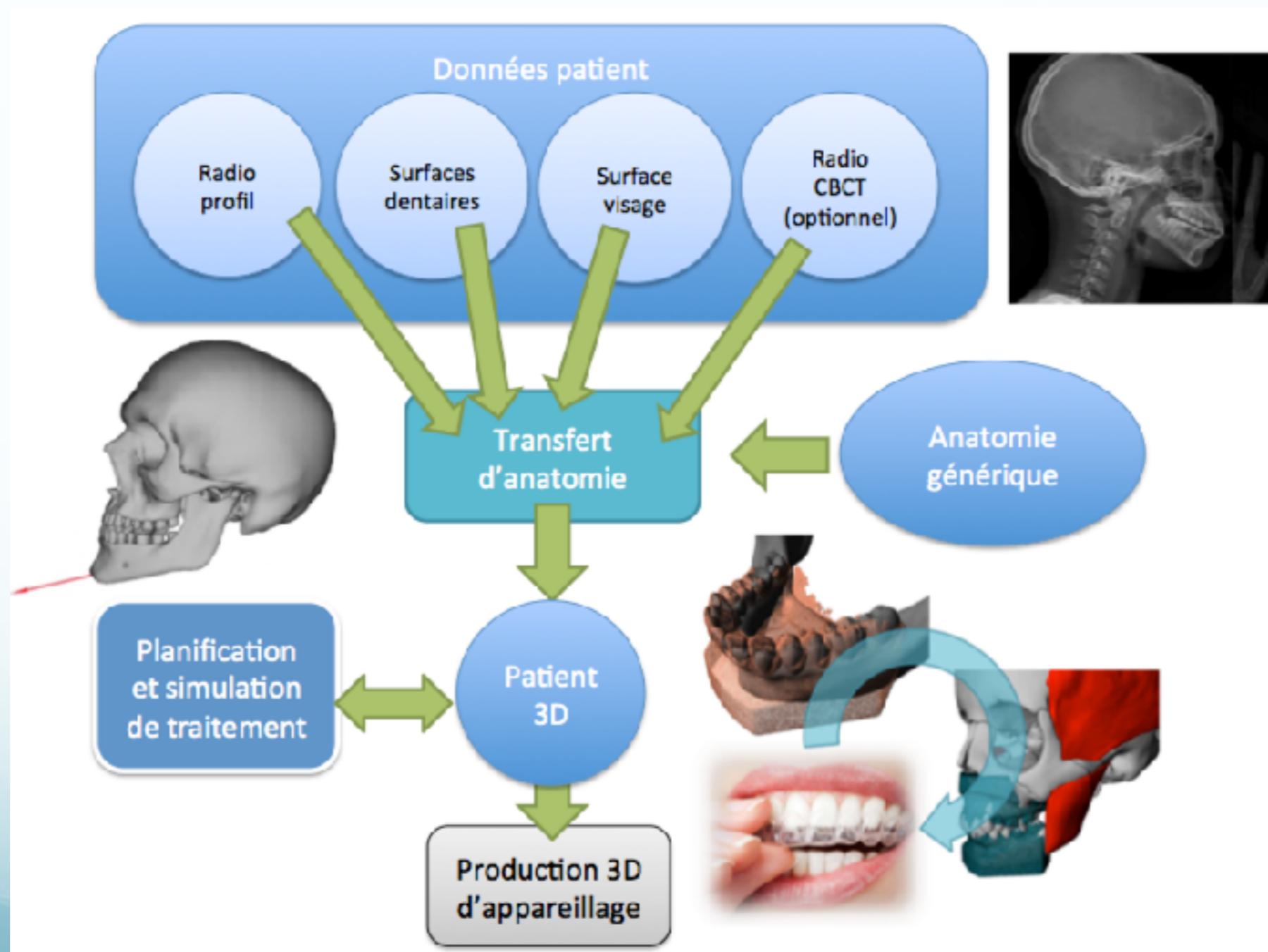


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Simulation Maxillo-faciale et Dentaire

- Modélisation complète du visage
- Plan de traitement et simulation du visage avant/après
- Production d'appareillage personnalisé



Simulation Maxillo-faciale et Dentaire



ANATOSCOPE

DENTAL OCCLUSION

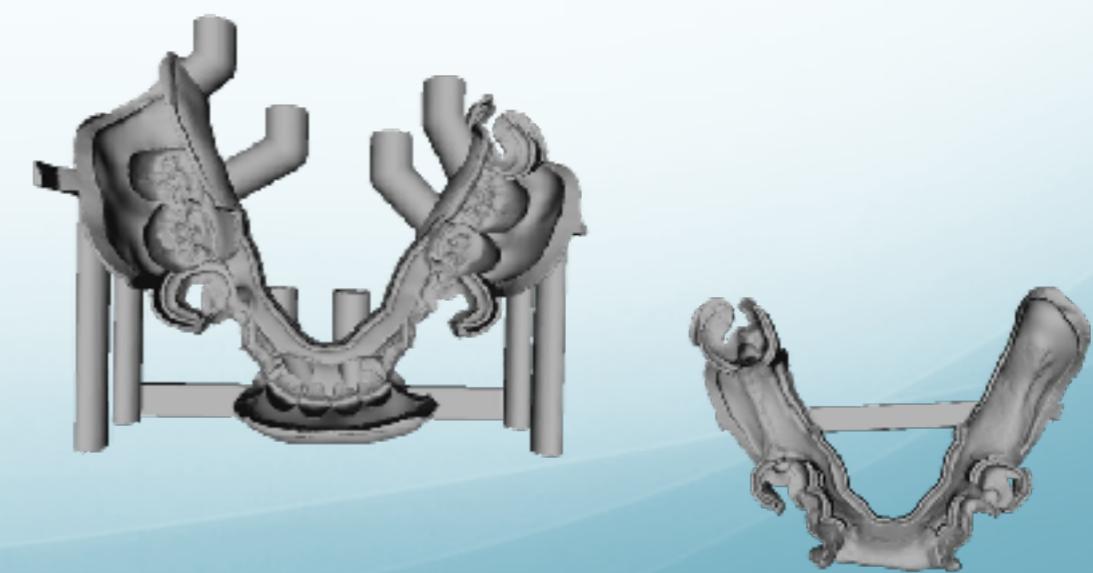
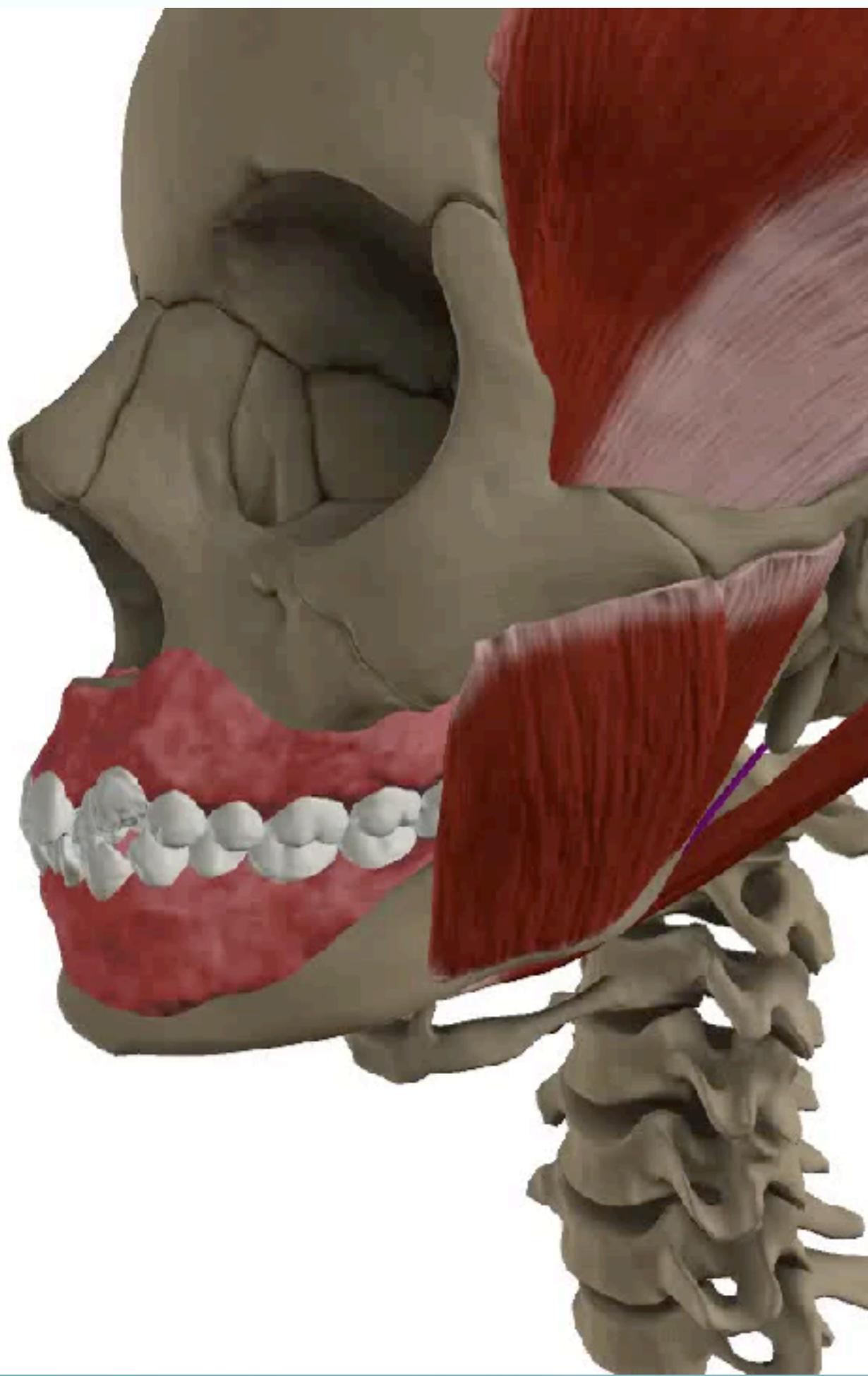
MARCH 2015 - WWW.ANATOSCOPE.COM



BIOTECH DENTAL

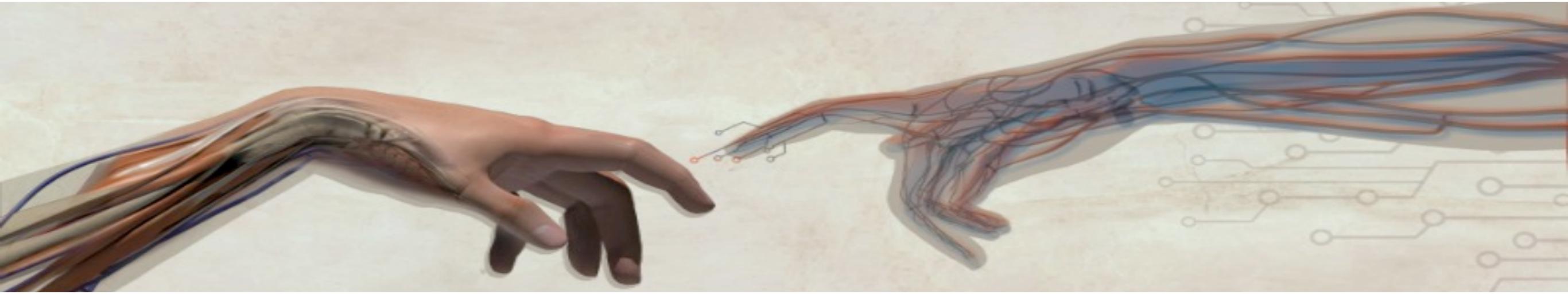
Informations confidentielles - Propriété de AnatoScope SA - 2016

Simulation du contact occlusal



Integration de données multimodales





Modèles 3D pour l'analyse d'images et la simulation biomécanique



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INVENTEURS DU MONDE NUMÉRIQUE