Workshop on Anatomical Models

Tuesday 16 June	**Wednesday 17 June**
	Knowledge-driven computational methods for diagnosis support systems - Organized by IMATI 09h30 **Welcome and introduction to the session** **Michela Spagnuolo** (IMATI-CNR, Genova, Italy) **09h35 – 10h15 *An industrial perspective on open issues and challenges of medical data and image analysis*** Sergio Paddeu (Esaote, Genova , Italy)
Registration and welcome coffee	**10h15 - 10h45 -** Coffee break
11h00 - 12h30 Welcome (Pierre Alliez) ***My Corporis Fabrica: ontology for anatomical modeling*** Olivier Palombi (INRIA Rhône-Alpes and Medicine Faculty of Grenoble) in collaboration with François Faure, Guillaume Bousquet, Franck Hétroy, Sahar Hassan and Benjamin Gilles (INRIA) ***The FOCUS K3D project*** Michela Spagnuolo (CNR IMATI)	**10h45 - 12h15 (30 mins per talk)** ***MRI 3D image analysis and processing in orthopaedics*** Fabrizio Ferrando (Esaote, Genova, Italy) Gianni Viano (Softeco/Sismat, Genova, Italy) ***Methods and tools for a collaborative environment supporting experiments in neuroscience*** Andrea Schenone (University of Genova , Italy) ***Shape data modelling and analysis as a support in the diagnosis of vascular diseases*** Michela Mortara, Marco Attene, Giuseppe Patanè (IMATI-CNR, Genova, Italy)
12h30 - 13h45 Lunch	**12h30 - 13h45 Lunch**
14h00 - 15h30 ***Automatic 3D Geometry Reconstruction from Image Data*** Dagmar Kainmueller, Stefan Zachow, Hans-Christian Hege (Zuse Institute Berlin) ***Generating Volumetric Meshes for Therapy Planning*** Hans Lamecker, Herve Delingette, Nicholas Ayache (INRIA Sophia Antipolis - Mediterranee)	**14h00 - 15h30** ***3D Image Reconstruction for Comparison of Algorithm Database: A patient-specific anatomical and medical image database.*** Luc Soler, Alexandre Hostettler, Vincent Agnus, Arnaud Charnoz, Jean-Baptiste Fasquel, Johan Moreau, Anne-Blandine Osswald, Mourad Bouhadjar, Jacques Marescaux (IRCAD Strasbourg). ***Foetuses and pregnant women modelling using a computer graphics approach for dosimetry studies*** Jérémie Anquez, Tamy Boubekeur, Lazar Bibin, Elsa Angelini and Isabelle Bloch (ENST Paris).
15h30 - Coffee break	**15h30 - Coffee break**
16h00 - 19h15 ***Estimation based on vectorized surfaces for craniofacial reconstruction*** Françoise M. Tilotta, Joan Glaunès, Frédéric Richard, Yves Rozenholc (University Paris Descartes) ***Facial modelling for forensic facial reconstruction and identification*** Dirk Vandermeulen (ESAT/PSI K.U.Leuven), Peter Claes (University of Melbourne), Sven De Greef (Forensic Dentistry, K.U.Leuven), Guy Willems (Forensic Dentistry, K.U.Leuven), Paul Suetens (ESAT/PSI K.U.Leuven) **break** (15 minutes) **Craniofacial reconstruction as a prediction problem using a latent root regression model** Maxime Berar, Yves Rozenholc (University Paris Descartes) ***A semantic-driven platform for musculoskeletal simulation*** Caecilia Charbonnier (Miralab)	**16h00 - 16h45** ***Feature preserving Delaunay mesh generation from 3D multi-material images*** Dobrina Boltcheva, Jean-Daniel Boissonnat, Mariette Yvinec (INRIA Sophia Antipolis - Mediterranee)
20h00 **Social event**	

ABSTRACTS

My Corporis Fabrica: ontology for anatomical modelling

Olivier Palombi (INRIA Rhône-Alpes and Medicine Faculty of Grenoble)
in collaboration with François Faure, Guillaume Bousquet, Franck Hétroy, Sahar Hassan and Benjamin Gilles (INRIA)

Foundational Model of Anatomy (FMA) is an anatomical ontology which can be presented as the most elaborated computer-based knowledge source of anatomy. Nevertheless FMA can not be used to create mechanical models of anatomy. My Corporis Fabrica (myCF) extends FMA to provide everything we need to build patient-specific mechanical model.
Ontology modeling principles of FMA has been used in myCF to ensure consistency of the representation. Mechanical parameters (stiffness, density...) and functional informations (stability, motion, mobility...) have been added. The most important contribution of myCF is to link canonical anatomical knowledge to patient-specif data. MyCF adds mechanical parameters to the segmented anatomical entities (medical imaging segmentation) and adds non-visible anatomical entities (as ligaments or fascia) to the generated models . The demonstration is made on the knee joint.

The FOCUS K3D project

Michela Spagnuolo (CNR IMATI)

Automatic 3D Geometry Reconstruction from Image Data

Dagmar Kainmueller, Stefan Zachow, Hans-Christian Hege (Zuse Institute Berlin)

In the Medical Planning group at Zuse Institute Berlin, we developed a general framework for accurate, fully automatic segmentation of anatomical objects from tomographic image data. Firstly, a global initialization procedure roughly places a Statistical Shape Model of the respective object in the image data. After initialization, the Statistical Shape Model is adapted to the image data. Finally, a free form adaptation is performed to achieve fine grain segmentations that are not restricted by the shape space of the Statistical Shape Model. Model adaptation is guided by heuristic intensity models.

We will demonstrate the performance of our fully automatic segmentation framework for various tissues and imaging modalities, including the liver in contrast enhanced CT, the pelvic bones in conventional CT, and the mandibular bone and nerves in Cone-Beam CT. Particularly, we will present a fully automatic method for accurate fine grain segmentation of bones in joint regions, which is a prerequisite for generating patient specific biomechanical models, e.g. of the human lower limb.

Generating Volumetric Meshes for Therapy Planning

Hans Lamecker, Herve Delingette, Nicholas Ayache (INRIA Sophia Antipolis - Mediterranee)

Patient-specific volumetric meshes of anatomical structures are the basis for numerical simulations based on differential equations. There are a number of often competing properties that are desirable in therapy planning applications. Above all, the meshes should reflect the true patient geometry, and yield fast and accurate computational models. To this end meshes of good element quality are required with a mesh size resolution adapted to the specific needs of the application. We will illustrate the problems and present some solutions within applications in electrophysiological and biomechanical cardiac modeling.

Estimation based on vectorized surfaces for craniofacial reconstruction

Françoise M. Tilotta, Joan Glaunès,

Frédéric Richard, Yves Rozenholc
(University Paris Descartes)

In recent years, the development of medical imaging has had a major impact on facial reconstruction. New strategies have been proposed to reconstitute the morphology of a face from the observation of a skull. Our image processing includes 1/ the segmentation of both skull and external skin surface for each slice; 2/ the construction of two 3D surfaces by meshing curves on successive slices. Then 39 landmarks are manually located on each skull mesh. These steps allow computing geodesics on the meshed surface and extract anatomically identified feature from the bone surface (bone patch). Using registration techniques via RKHS for surfaces it is possible to construct a "distance" between individual features on the skull (bone patch) and to compute average of the corresponding skin features in a statistical learning framework. In our work, we choose a local and individual approach based on the used of dense meshes associated to a large collection of landmarks directly extracted from CT-scans. Based on a database containning 85 CT-Scan of the whole head performed on volunteers European, our method allows to reconstruct local features on the skull like the nose with a good accuracy.

Facial modelling for forensic facial reconstruction and identification

Dirk Vandermeulen (ESAT/PSI K.U.Leuven), Peter Claes (University of Melbourne), Sven De Greef (Forensic Dentistry, K.U.Leuven), Guy Willems (Forensic Dentistry, K.U.Leuven), Paul Suetens (ESAT/PSI K.U.Leuven)

We present two automated methods for estimation of the facial outlook from human skeletal skull remains. The first method uses a database of a little less than 400 3D facial surfaces, augmented with soft tissue thicknesses, measured with ultrasound at 52 anatomical landmarks. A standard PCA-model (including also extra individual characteristics such as age, sex and BMI) is constructed from this database using a TPS-based spatial interpolation model for correspondence finding. Reconstruction is cast as a probabilistic estimation problem: given the surface data of a skull, find the most probable model instance such that the associated soft tissue thicknesses at the anatomical landmarks match the distances of the model surface to the skull surface. An EM-approach is followed to deal with outliers. This reconstruction method was tested on a database of 12 subjects for which both a 3D photo and a 3D CT was obtained.

A second reconstruction method is based on a database of volumetric CT images, which are segmented into hard- and soft- tissue volumes. For each of these volumes, Distance Transform (DT) images (implicit descriptions of the associated surfaces) are constructed. Facial reconstruction of a single skull is obtained by (B-spline) warping each skull DT image in the database to the target skull DT image, applying the warp to the corresponding soft tissue DT volumes and (attribute-weighted) averaging of the warped soft tissue DT volumes.

Craniofacial reconstruction as a prediction problem using a latent root regression model

Maxime Berar, Yves Rozenholc
(University Paris Descartes)

We present a computer-assisted method for facial reconstruction: the method provides an estimation of the facial outlook associated with unidentified skelettal remains. Current computer-assisted methods using a statistical framework rely on a common set of extracted points on the bone and soft-tissue surfaces. Facial reconstruction consists then in predicting the position of the soft-tissue surface points knowing the positions of the bone surface points. We proposed to use Latent Root Regression for the prediction and compare the results obtained to those given by Principal Components Analysis linear models. In conjunction, we have evaluated the influence of the number skull landmarks used. Anatomical skull landmarks are completed iteratively by points located upon geodesics linking the anatomical landmarks. It enables us to artificially augment the number of skull points. Facial landmarks are obtain using a mesh-matching algorithm between a common reference mesh and the individual soft-tissue surface meshes. The proposed method is validated in term of accuracy, based on a leave-one-out cross-validation test applied on a homogeneous database. Accuracy measures are obtained by computing the distance between the reconstruction and the ground truth. Finally, these results are discussed in regard to current computer-assisted reconstruction facial techniques.

A semantic-driven platform for musculoskeletal simulation

Caecilia Charbonnier – MIRALab, University of Geneva

The use of 3D techniques is important for orthopaedists wanting to simulate, visualize and navigate through articulations. Nowadays, many multimodal data are available from acquisition (e.g., medical images, motion capture) and modeling (e.g., 3D models). In the course of their work, clinicians are required to analyze large amounts of data related to musculoskeletal anatomy, kinematics, dynamics, mechanics and physiology. They must therefore manage and visualize information at increasing levels of complexity. To reduce this complexity and to exploit the information effectively, we developed a semantic-driven platform able to centralize and structure the multimodal data inputs and the medical knowledge in a coherent and unified manner. Our system integrates conventional diagnostic support (MRI), visualization and simulation tools (in 3D) and the ontology constitutes the interface between the application and the medical interpretation of data. The aim is to provide orthopaedists with an interactive visualization framework for patient-specific musculoskeletal examination.

Morning session: Knowledge-driven computational methods for diagnosis support systems - Organized by IMATI

An industrial perspective on open issues and challenges of Medical data and image analysis

Sergio Paddeu (Esaote, Genova, Italy)

Biomedical advanced imaging platform based on different technologies require to accomplish the extremely pressing need to manage, visualize, elaborate and report the very large dataset of images generated within a distributed healthcare system, starting from 2D up to 4D, including advanced man-machine interface for volume visualization, CAD and modelling-simulations tools at different degree of complexity. The existing medical images management infrastructures will not satisfy in the near future the more and more complex and strict performances resulting from the large dataset size, geographic distribution of users, resources, institutions and computational intensive analysis. These integrated and distributed healthcare systems will determine new clinical workflows which will consequently affect the overall clinical practice. The development and availability of advanced and specialized clinical tools, such as Computer Assisted Diagnosis (CAD) modules or 3D-4D Visual Volume Workstations will be more and more demanded by healthcare providers. In order to address this upcoming complexity, the research will focus on providing advance to improve the quality of patient care through the development of a platform able to provide more accurate diagnosis, therapy and treatment, by leveraging the benefits of emerging and challenging technologies concerning both imaging modalities, secured access to databases of medical images and related data as well as on new computing paradigms which include virtual environments, simulation tools and predictive health systems. This challenging framework will be considered and analysed by taking into account the industrial perspective as well as the impact on clinical practice.

MRI 3D image analysis and processing in orthopaedics

Fabrizio Ferrando (Esaote, Genova, Italy), Gianni Viano and Loris Vosilla (Softeco/Sismat, Genova, Italy) ESAOTE

is producer of low field MRI system which find large application in musculoskeletal examinations including, but not limited to, knee, shoulders, spine, wrist, hip and ankle.

Specific 3D image analysis techniques have been developed to provide radiologists and orthopaedist with advanced visualisation tools suitable to support diagnostic and surgery planning. These approaches are evolving toward objective parameter measurement to support Computed Aided Detection and Diagnosis in several fields including orthopaedics and rheumatology. To tackle this goal, ESAOTE is coordinating a joint public-private laboratory based in Naples, with the participation of academics, research institutes, medical centres and SMEs, for the identification, development and validation of dedicated CAD tools. This initiative exploits ESAOTE most innovative MRI products, G-SCAN, a tilting device allowing supine and weight bearing examinations. This feature enables the development of a new family of parameters obtained by comparing the differences between supine and weight bearing acquisitions, with the aim at defining new disease indicators and to support clinical follow up with quantitative data.

Within the several CAD tools under development, the "supine/weight bearing spine analysis" has a special interest for the 3D image analysis and visualization techniques involved. When changing from supine to weight bearing position, the spine of the patient under examination, which is a 3D physical object, has a movement comprising rotation and bending around the tree coordinate axes. The measurement of the variation from the two positions is the main objective of the CAD tool to provide indicator of the effect of weight on the spine and thus to provide objective parameters for pathological situation scoring and clinical evolution over time follow up. This measurement is a full 3D problem and requires spine components 3D movement reconstruction, matching and registration to achieve accurate parameter computation.

The CAD tool developed starts from classical image analysis step: segmentation of body part of concern and 3D registration of images from different patient position The output is couple of registered 3D models of the spine which allow parameter measurement and comparison as well as direct visualisation of the difference to the user. Segmentation is based on customised level-set algorithms applied according to a set of heuristic rules which try to convey the a-priori knowledge about the anatomical districts considered. Relationships between body parts and their typical appearance on the image are used to impose segmentation constraints and to guide the process. A minimal support from the user is still requested, but a fully automated approach can be envisaged. 3D surface model is reconstructed from segmented image by using a "marching cube" approach. The parameters computed address the relationships among vertebrae and the shape and size of spinal cord. The comparison of parameter values in the supine and weight bearing position is supported as well.

3D model is used to provide realistic visualisation of the difference between the spine in the two attitudes. At this end 3D registration is carried out and a "merged" model is produced which allow to show the two models together and their relationships. A realistic virtual navigation environment is available as well to allow the user to explore the two models.

Methods and tools for a collaborative environment supporting experiments in neuroscience

Andrea Schenone (DIST, University of Genova, Italy)

Current trends in modern e-Science require the adoption of advanced tools in order to collect, organize, annotate and access data. This is evident in life science and especially in neuroinformatics. Nowadays, more and more, common issues like storage and sharing of large amounts of produced data, as well as availability of dedicated computational resources have to be faced within these contexts.

Another key aspect is multimodal and multiscale data integration. There is need for software platforms able to manage data from different modalities on a variety of scales (organ/body image and signals, tissue/sub-organ images, molecular and genomic data). Moreover, data and resources should be accessible through a unified Web interface, and studies (collection of data about a patient) from different domains (structural and functional neuroradiology, oncology, psychology, and psychiatry) should be available for a given patient.

The XTENS (eXTensible Environment for NeuroScience) platform consists in an highly extensible environment for collaborative work that improve repeatability of experiment and provides data storage and analysis capabilities. The platform is divided in repository and application domains, branched in services with different purpose. The first domain is the central component of the platform and consists in a multimodal repository with a client-server architecture. The second one provides remote tools for image and signal visualization and analysis. The main issue for such a platform is not only to provide an extensible collaborative environment, but also to build a development platform for testing models and algorithms in neuroscience. For these reasons a Grid approach has been considered. because of the added value provided by the possibility of exploiting both computational (also taking advantage of dedicated HPC nodes) and data Grids infrastructures to analyze large datasets of distributed data.

The most important improvements of XTENS in comparison with other solutions are:

- as regards functions, it is designed to fully support clinical practice during neuroinformatics multidisciplinary studies, not just managing a Grid based radiology information system, but also providing integrated services and tools;
- as regards data, it is designed to handle not only radiological data, and thus its metadata support has to be fully multimodal, enabling the injection in the repository of several different data types according to structured schemas;
- as regards extensibility, it has been designed in a very general way in order to be able to fit different requirements coming from a large variety of applications simply through a custom configuration.

According to these requirements, our collaborative environment has been designed to fully support diagnostic and therapeutic paths by using hierarchical structures defining all the different events (visits, acquisitions, data manipulations, data analysis steps) in the experimental sequence. Two different scenarios have been considered as references in the development of the Xtens platform. In the first scenario, the architecture has been deployed to support surgical planning for patients affected by drug resistant epilepsy. In that scenario, a complex analysis for a fully multimodal dataset including different image modalities, EEG and video is required to localize the origin of the ictal discharge and critical brain areas.

The second scenario concerns the identification of biomarkers in the development of Mild Cognitive Impairment (MCI) to Alzheimer's Disease (AD) through the correlation between quantitative results of morphological and functional neuroimaging studies, and genetic data related to biological markers.

Shape data modelling and analysis as a support in the diagnosis of vascular diseases

Michela Mortara, Marco Attene, Giuseppe Patanè (IMATI-CNR, Genova, Italy)

Understanding shapes has been a challenging issue for many years. In the last decade, thanks to the advances in technology, the ease of producing and/or collecting data in digital form has caused a gradual shift of paradigm in various applied and scientific fields: from physical prototypes and experience to virtual prototypes and simulation. This shift has an enormous impact on a number of industrial and scientific sectors, such as Design and Manufacturing, Serious Gaming and Simulation, Cultural Heritage and Archaeology, Medical Applications, Bioinformatics and Pharmaceutical Science, where 3D data are essential knowledge carriers.

Therefore, the problem of characterizing a digital shape in terms of its relevant parts, or features, is becoming key to support analysis and processing tasks in diverse fields, and especially in medical imaging where shape analysis can provide an automated support to the screening of 3D imaging data.

During the talk, we will present an overview of the research done in the field of shape understanding with focus on methods developed at IMATI-CNR. In particular, techniques suitable to the analysis of structures with tubular shapes will be described and methods to model and measure their key features will be discussed.

3D Image Reconstruction for Comparison of Algorithm Database: A patient-specific anatomical and medical image database

Luc Soler, Alexandre Hostettler, Vincent Agnus, Arnaud Charnoz, Jean-Baptiste Fasquel
Johan Moreau, Anne-Blandine Osswald, Mourad Bouhadjar, Jacques Marescaux
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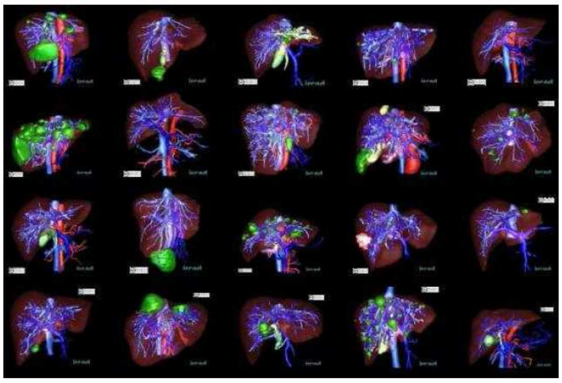
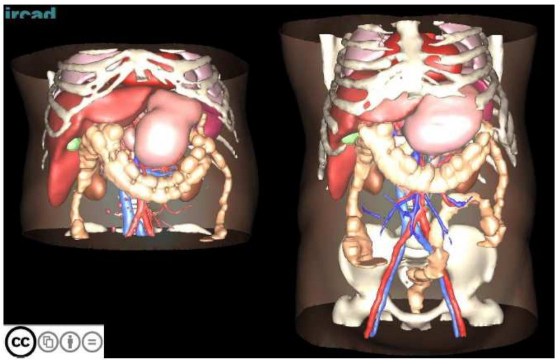
The medical world has known at the end of the last century a real revolution translated by several Nobel Prizes in physics or medicine: 3D medical imaging. By extracting the medical information contained in images into a set of 3D models, it is today possible to obtain a pre-operative 3D model of the patient, a kind of digital clone of the real patient. The visible human project initially limited to cadaveric model can thus be replaced by a visible patient with medical images of living patients. Such data can be used preoperatively to plan surgery, intraoperatively to guide the surgeon or postoperatively within the framework of anatomical education or medical simulation. It can also be used to compare various segmentation, mesh generation or simulation algorithms.

In this aim, we have developed an open database called 3D-IRCADb (3D Image Reconstruction for Comparison of Algorithm Database) that includes several sets of anonymized medical images of patients and the manual segmentation of the various structures of interest performed by clinical experts. The 3D medical images and masks of segmented structures of interest are available as DICOM files. The representation of segmented zones is also provided as surface meshes in VTK format. Each model can be visualized using known freeware such as Osirix or 3D Slicer, or our freeware VR-Render combining DICOM image 2D slice viewer, Direct volume rendering and 3D mesh surface rendering visualisation techniques.

The first two databases have been created within the framework of the European project PASSPORT. The 3D-IRCADb-01 database is composed of the enhanced 3D CT-scans of 10 women and 10 men with hepatic tumours in 75% of cases. The 3D-IRCADb-02 database is composed of two anonymized thoraco-abdominal enhanced 3D CT-scans. The first one has been realized during the arterial phase in inhaled position, whereas the second one has been realized during the portal phase in exhaled position. The patient has a hepatic focal nodular hyperplasia in segment VII according to Couinaud's description.

The first benefit of this work was to validate a new anatomical segmentation of the liver modifying the current anatomical segmentation of Couinaud by removing its topological mistake. In the future, this database will be completed by many other cases including databases dedicated to adrenal tumours, parathyroid tumours and paediatric cases. We also plan to increase the current first two databases with new clinical cases.





The two first 3D IRCADb offer 3D models of 20 livers and 2 abdominal breath positions.

Foetuses and pregnant women modelling using a computer graphics approach for dosimetry studies
Jérémie Anquez, Tamy Boubekeur, Lazar Bibin, Elsa Angelini and Isabelle Bloch (ENST Paris)

Potential sanitary effects related to electromagnetic fields exposure raise public concerns, especially for fetuses during pregnancy. Human fetus exposure can only be assessed through simulated dosimetry studies, performed on anthropomorphic models of pregnant women. Only few pregnant women models have been previously proposed, representing multiple stages of pregnancy. In this presentation, we propose a new methodology to generate a set of detailed utero-fetal unit (UFU) 3D models during the first and third trimesters of pregnancy, based on segmented 3D ultrasound and MRI data. UFU models are built using recent geometry processing methods derived from mesh-based computer graphics techniques and embedded in a synthetic woman body. The generated models are validated by obstetricians, for anatomical accuracy and representativeness and enable, for the first time, the study of the influence of pregnancy stage, fetus position and morphology on dosimetry.

Feature preserving Delaunay mesh generation from 3D multi-material images
Dobrina Boltcheva, Jean-Daniel Boissonnat, Mariette Yvinec, INRIA Sophia Antipolis - Méditerranée

Generating realistic geometric models from 3D segmented images is an important task in many biomedical applications. Segmented 3D images impose particular challenges for meshing algorithms because they contain multi-material junctions forming features such as surface patches, edges and corners. The resulting meshes should preserve these features to ensure the visual quality and the mechanical soundness of the models. We present a feature preserving Delaunay refinement algorithm which can be used to generate high-quality tetrahedral meshes from segmented images. The idea is to explicitly sample corners and edges from the input image and to constrain the Delaunay refinement algorithm to preserve these features in addition to the surface patches. Our experimental results on segmented medical images have shown that, within a few seconds, the algorithm outputs a tetrahedral mesh in which each material is represented as a consistent submesh without gaps and overlaps. The optimization properties of the Delaunay triangulation make these meshes suitable for the purpose of realistic visualization or finite element simulations.