Activity Report 2013

Project-Team MAGRIT

Visual Augmentation of Complex Environments

IN COLLABORATION WITH: Laboratoire lorrain de recherche en informatique et ses applications (LORIA)

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Project-Team MAGRIT

Keywords: Computer Vision, Tracking, Modeling, Augmented Reality, Medical Images

Creation of the Project-Team: 2006 April 03.

1. Members

Research Scientists
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Erwan Kerrien [Inria, Researcher]

Faculty Members
Gilles Simon [Univ. Lorraine, Associate Professor]
Frédéric Sur [Univ. Lorraine, Associate Professor]
Pierre-Frédéric Villard [Univ. Lorraine, Associate Professor]
Brigitte Wrobel-Dautcourt [Univ. Lorraine, Associate Professor]

External Collaborator
René Anxionnat [Medical Doctor, PhD, Professor CHRU Nancy]

PhD Students
Charlotte Delmas [Univ. Lorraine, CIFRE GE Healthcare, from Apr 2013]
Nazim Haouchine [Inria, CORDI-C granted by AEN SOFA, co-supervised by M.-O. Berger and S. Cotin (EPI Shacra)]
Pierre Rolin [Univ. Lorraine, Contrat Doctoral, since Oct 2013]
Srikrishna Bhat [Univ. Lorraine, until Feb 2013]
Ahmed Yureidini [Univ. Lorraine]

Post-Doctoral Fellow
Matthieu Loosvelt [CNRS]

Administrative Assistant
Hélène Zganic [Inria]

Others
Nicolas Koenig [Univ. Lorraine, Internship, from Jun 2013 until Aug 2013]
Naoma Oishi [Inria, Internship, from Jun 2013 until Sep 2013]
Guillaume Vandeneeckhoutte [Inria, Internship, from Jun 2013 until Jul 2013]

2. Overall Objectives

2.1. Augmented Reality

Augmented reality (AR) is a field of computer research which deals with the combination of real world and computer generated data in order to provide the user with a better understanding of his surrounding environment. Usually this refers to a system in which computer graphics are overlaid onto a live video picture or projected onto a transparent screen as in a head-up display.

Though there exist a few commercial examples demonstrating the effectiveness of the AR concept for certain applications, the state of the art in AR today is comparable to the early years of Virtual Reality. Many research ideas have been demonstrated but few have matured beyond lab-based prototypes.

Computer vision plays an important role in AR applications. Indeed, the seamless integration of computer generated objects at the right place according to the motion of the user needs automatic real-time detection and tracking. In addition, 3D reconstruction of the scene is needed to solve occlusions and light inter-reflexion between objects and to ease the interactions of the user with the augmented scene. For fifteen years, much work has been successfully devoted to the problem of structure and motion, but these works are often formulated as off-line algorithms and require batch processing of several images acquired in a sequence. The challenge is now to design robust solutions to these problems with the aim to let the user free of his motion during AR applications and to widen the range of AR application to large and/or unstructured environments. More specifically, the Magrit team aims at addressing the following problems:

- On-line pose computation for structured and non structured environments: this problem is the cornerstone of AR systems and must be achieved in real time with a good accuracy.

- Long term management of AR applications: a key problem of numerous algorithms is the gradual drifting of the localization over time. One of our aims is to develop methods that improve the accuracy and the repeatability of the pose during arbitrarily long periods of motion.

- 3D modeling for AR applications: this problem is fundamental to manage light interactions between real and virtual objects, to solve occlusions and to obtain realistic fused images.

The aim of the Magrit project is to develop vision based methods which allow significant progress of AR technologies in terms of ease of implementation, usability, reliability and robustness in order to widen the current application field of AR and to improve the freedom of the user during applications. Our main research directions concern two crucial issues, camera tracking and scene modeling. Methods are developed with a view to meet the expected robustness and to provide the user with a good perception of the augmented scene.

2.2. Highlights of the Year

- Several members of the team received the *best paper-honourable mention* at ISMAR 2013 for the paper : *Image-guided Simulation of Heterogeneous Tissue Deformation For Augmented Reality during Hepatic Surgery, by by Nazim Haouchine, Jeremie Dequidt, Igor Peterlik, Erwan Kerrien, Marie-Odile Berger, Stéphane Cotin.*

- Gilles Simon received the *Lasting Impact Award* at ISMAR 2013 for the paper: *Markerless Tracking using Planar Structures in the Scene by Simon Gilles, Andrew W. Fitzgibbon, Andrew Zisserman in Proceedings of the IEEE and ACM International Symposium on Augmented Reality, 2000 (ISAR), pages 120-128 .*

BEST PAPER AWARD :

[18] **Image-guided Simulation of Heterogeneous Tissue Deformation For Augmented Reality during Hepatic Surgery in ISMAR - IEEE International Symposium on Mixed and Augmented Reality 2013**. N. HAOUCHINE, J. DEQUIDT, I. PETERLIK, E. KERRIEN, M.-O. BERGER, S. COTIN.

3. Research Program

3.1. Camera Calibration and Registration

One of the most basic problems currently limiting Augmented Reality applications is the registration problem. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised.

As a large number of potential AR applications are interactive, real time pose computation is required. Although the registration problem has received a lot of attention in the computer vision community, the problem of real-time registration is still far from being a solved problem, especially for unstructured environments. Ideally, an AR system should work in all environments, without the need to prepare the scene ahead of time, and the user should walk anywhere he pleases.

For several years, the Magrit project has been aiming at developing on-line and marker-less methods for camera pose computation. In particular, we have proposed a real-time system for camera tracking designed for indoor scenes [1]. The main difficulty with on-line tracking is to ensure robustness of the process. For off-line processes, robustness is achieved by using spatial and temporal coherence of the considered sequence through move-matching techniques. To get robustness for open-loop systems, we have developed a method which combines the advantage of move-matching methods and model-based methods by using a piecewise-planar model of the environment. This methodology can be used in a wide variety of environments: indoor scenes, urban scenes .... We are also concerned with the development of methods for camera stabilization. Indeed, statistical fluctuations in the viewpoint computations lead to unpleasant jittering or sliding effects, especially when the camera motion is small. We have proved that the use of model selection allows us to noticeably improve the visual impression and to reduce drift over time.

The success of pose computation largely depends on the quality of the matching stage over the sequence. Research are conducted in the team on the use of probabilistic methods to establish robust correspondences of features over time. The use of *a contrario* decision is under investigation to achieve this aim [7]. We especially address the complex case of matching in scenes with repeated patterns which are common in urban scenes. We also consider learning based techniques to improve the robustness of the matching stage.

Another way to improve the reliability and the robustness of pose algorithms is to combine the camera with another form of sensor in order to compensate for the shortcomings of each technology. Each technology approach has limitations: on the one hand, rapid head motions cause image features to undergo large motion between frames that may cause visual tracking to fail. On the other hand, inertial sensors response is largely independent from the user's motion but their accuracy is bad and their response is sensitive to metallic objects in the scene. In past works [1], we have proposed a system that makes an inertial sensor cooperate with the camera-based system in order to improve the robustness of the AR system to abrupt motions of the users, especially head motions. This work contributes to the reduction of the constraints on the users and the need to carefully control the environment during an AR application. Ongoing research on such hybrid systems are under consideration in our team with the aim to improve the accuracy of reconstruction techniques as well as to obtain dynamic models of organs in medical applications.

Finally, it must be noted that the registration problem must be addressed from the specific point of view of augmented reality: the success and the acceptance of an AR application does not only depend on the accuracy of the pose computation but also on the visual impression of the augmented scene. The search for the best compromise between accuracy and perception is therefore an important issue in this project. This research topic has been addressed in our project both in classical AR and in medical imaging in order to choose the camera model, including intrinsic parameters, which describes at best the considered camera.

3.2. Scene Modeling

Modeling the scene is a fundamental issue in AR for many reasons. First, pose computation algorithms often use a model of the scene or at least some 3D knowledge on the scene. Second, effective AR systems require a model of the scene to support occlusion and to compute light reflexions between the real and the virtual objects. Unlike pose computation which has to be computed in a sequential way, scene modeling can be considered as an off-line or an on-line problem according to the application. Within the team we have developed interactive in-situ modeling techniques dedicated to classical AR applications. We also developed off-line multimodal techniques dedicated to AR medical applications.

In-situ modeling
Most automatic techniques aim at reconstructing a sparse and thus unstructured set of points of the scene. Such models are obviously not appropriate to perform interaction with the scene. In addition, they are incomplete in the sense that they may omit features which are important for the accuracy of the pose recovered from 2D/3D correspondences. We have thus investigated interactive techniques with the aim of obtaining reliable and structured models of the scene. The goal of our approach is to develop immersive and intuitive interaction techniques which allow for scene modeling during the application [5].

Multimodal modeling With respect to classical AR applications, AR in medical context differs in the nature and the size of the data which are available: A large amount of multimodal data are acquired on the patient or possibly on the operating room through sensing technologies or various image acquisitions. The challenge is to analyze these data, to extract interesting features, to fuse and to visualize this information in a proper way. Within the Magrit team, we address several key problems related to medical augmented environments. Being able to acquire multimodal data which are temporally synchronized and spatially registered is the first difficulty we face when considering medical AR. Another key requirement of AR medical systems is the availability of 3D (+t) models of the organ/patient built from images, to be overlaid onto the users's view of the environment.

Methods for multimodal modeling are strongly dependent on the image modalities and the organ specificities. We thus only address a restricted number of medical applications –interventional neuro-radiology and the Augmented Head project– for which we have a strong expertise and close relationships with motivated clinicians. In these applications, our aim is to produce realistic models and then realistic simulations of the patient to be used for surgeon's training or patient's re-education/learning.

One of our main applications is about neuroradiology. For the last 20 years, we have been working in close collaboration with the neuroradiology laboratory (CHU-University Hospital of Nancy) and GE Healthcare. As several imaging modalities are now available in a intraoperative context (2D and 3D angiography, MRI, ...), our aim is to develop a multi-modality framework to help therapeutic decision and treatment.

We have mainly been interested in the effective use of a multimodality framework in the treatment of arteriovenous malformations (AVM) and aneurysms in the context of interventional neuroradiology. The goal of interventional gestures is to guide endoscopic tools towards the pathology with the aim to perform embolization of the AVM or to fill the aneurysmal cavity by placing coils. An accurate definition of the target is a parameter of great importance for the success of the treatment. We have proposed and developed multimodality and augmented reality tools which make various image modalities (2D and 3D angiography, fluoroscopic images, MRI, ...) cooperate in order to help physicians in clinical routine. One of the successes of this collaboration is the implementation of the concept of *augmented fluoroscopy*, which helps the surgeon to guide endoscopic tools towards the pathology. Lately, in cooperation with the Shacra EPI, we have proposed new methods for implicit modeling of the aneurysms with the aim of obtaining near real time simulation of the coil deployment in the aneurysm [8]. Multi-modality techniques for reconstruction have been also considered within the european ASPI project, the aim of which is to build a dynamic model of the vocal tract from various images modalities (MRI, ultrasound, video) and magnetic sensors.

4. Application Domains

4.1. Augmented Reality

We have a significant experience in the AR field especially through the European project ARIS (2001–2004) which aimed at developing effective and realistic AR systems for e-commerce and especially for interior design. Beyond this restrictive application field, this project allowed us to develop nearly real time camera tracking methods for multi-planar environments. Since then, we have amplified our research on multi-planar environments in order to obtain effective and robust AR systems in such environments. We currently investigate both automatic and interactive techniques for scene reconstruction/structure from motion methods in order to be able to consider large and unknown environments. For some time, we are investigating AR for deformable objects in the context of medical applications.

4.2. Medical Imaging

For 15 years, we have been working in close collaboration with University Hospital of Nancy and GE Healthcare in interventional neuroradiology. Our common aim is to develop a multimodality framework to help therapeutic decisions and interventional gestures. In particular, we aim at developing methods and

tools allowing the physicians to take advantage of the various existing imaging modalities on the brain in their clinical practice: 2D subtracted angiography (2DSA), 3D rotational angiography (3DRA), fluoroscopy, MRI,.... Recent works concern the use of AR tools for neuronavigation and laparoscopy as well as the development of simulation tools of the interventional act for training or planning. Some of these projects are developed in collaboration with the EPI Shacra.

5. Software and Platforms

5.1. Software and Platforms

Our software efforts are integrated in a library called RAlib which contains our research development on image processing, registration (2D and 3D) and visualization. This library is licensed by the APP (French agency for software protection).

The visualization module is called QGLSG: it enables the visualization of images, 2D and 3D objects under a consistent perspective projection. It is based on Qt [1] and OpenScenegraph [2] libraries. The QGLSG library integrates innovative features such as online camera distortion correction, and invisible objects that can be incorporated in a scene so that virtual objects can cast shadows on real objects, and occlusion between virtual and real objects are easier to handle. The library was also ported to Mac OS and Windows and a full doxygen documentation was written.

6. New Results

6.1. Motion, Scene and Camera Reconstruction

Participants: Marie-Odile Berger, Srikrishna Bhat, Pierre Rolin, Gilles Simon, Frédéric Sur.

- **Metrological performance enhancement and resolution assessment for experimental solid mechanics**
  This work is motivated by image processing problems from experimental solid mechanics. One of the problem in this field is to measure heterogeneous strains on the surface of specimens subjected to mechanical tests, through an imaging device. Among full-field measurement techniques, the grid method consists in transferring a regular grid on the surface of the specimen and in taking images of the grid before and after deformation. Windowed Fourier analysis then gives an estimation of the surface displacement and strain components. In a collaboration with Institut Pascal (Université Blaise Pascal, Clermont Ferrand), we have shown that the estimations obtained by this technique are a first-order approximation of the convolution of the actual values with the analysis window. We have also characterized how the noise in the grid image impairs the displacement and strain maps [3]. This study has allowed us to improve the metrological performance of the grid method with deconvolution algorithms. A numerical and experimental study can be found in [10], [16], [21]. As any contactless measurement method, the resolution of the grid method is limited by the noise impairing the sensor. We have also characterized this resolution within a Poisson-Gaussian noise model, which is known to be realistic for CCD or CMOS sensors [4].

- **Matching in difficult conditions**

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[1] http://qt.digia.com

[2] http://www.openscenegraph.org/projects/osg

[3] F. Sur, M. Grédiac. Towards deconvolution to enhance the grid method for in-plane strain measurement. To appear in AIMS Inverse Problems and Imaging, American Institute of Mathematical Sciences, 2014.

[4] M. Grédiac, F. Sur. Effect of sensor noise on the resolution and spatial resolution of displacement and strain maps estimated with the grid method. To appear in Strain, Wiley, 2014.

Visual vocabularies are emerging as a new tool for building point correspondences for pose estimation. Within S. Bhat's PhD thesis [9] we have proposed several methods for visual word construction dedicated to point matching, with structure from motion and pose estimation applications in view. The three dimensional geometry of a scene is first extracted with bundle adjustment techniques based on keypoint correspondences. These correspondences are obtained by grouping the set of all SIFT descriptors from the training images into visual words. We obtain a more accurate 3D geometry than with classical image-to-image point matching. In a second on-line step, these visual words serve as 3D point descriptors that are robust to viewpoint change, and are used for building 2D-3D correspondences on-line during application, yielding the pose of the camera by solving the PnP problem. Several visual word formation techniques have been compared with respect to robustness to viewpoint change between learning and the test images.

The PhD thesis of P. Rolin comes within the scope of camera pose estimation from an unstructured 3D point dataset, endowed with image descriptors. His work focuses on improving pose estimation with respect to strong viewpoint changes. 2D-3D correspondences are actually difficult to establish if there are too large viewpoint changes between the image whose pose is sought and the images that gave the 3D point dataset. P. Rolin currently assesses viewpoint simulation techniques in order to enhance the description of the 3D points with information from different viewpoints.

- **Acquisition of 3D calibrated data**

  In situ modeling is generating increasing interest in the community as it makes it possible to build AR applications in unprepared environments. In [19], we present a new method for interactive modeling of polygonal scenes, using a tablet PC, a laser rangefinder, an inertial measurement unit (IMU) and a camera. A well-founded calibration method is used to determine the orientation of the IMU and the origin and direction of the laser beam in the camera coordinate system. A new hybrid, driftless orientation tracking method is proposed, inspired by the tracking-by-synthesis algorithm adapted to 3-degree-of-freedom camera motions. Visual hints are provided during the tracking-and-modeling process in order to help the user get the best possible accuracy. These visual hints are based on a PCA analysis of the reconstructed laser point clouds and statistical measurements of the camera tracking accuracy.

6.2. Medical Imaging

Participants: René Anxionnat, Marie-Odile Berger, Nazim Haouchine, Erwan Kerrien, Matthieu Loosvelt, Pierre-Frédéric Villard, Brigitte Wrobel-Dautcourt, Ahmed Yureidini.

- **Interventional neuro radiology**

  Minimally invasive techniques impact surgery in such ways that, in particular, an imaging modality is required to maintain a visual feedback. Live X-ray imaging, called fluoroscopy, is used in interventional neuroradiology. Such images are very noisy, and cannot show but the vasculature and no other brain tissue. Most of all, and despite recent progress on the sensors, X-rays are bad for the patient's health and X-ray images are 2D projections deprived of any depth hint such as occlusions or shading. To quote a fellow physician: "it is rather uncanny to use 2D images to perform a gesture that is, by nature, 3D". Two of our long term aims in interventional neuroradiology are to reduce the operation time, and provide the interventional radiologists with a real-time visual feedback in 3D.

  All our research activity in this field is led in collaboration with the Department of Interventional Neuroradiology from Nancy University Hospital. This year was pivotal in this activity where some projects ended and other new projects started.

  We've been collaborating with Shacra Inria project-team (Lille-Nord Europe) in the context of the SOFA-InterMedS Inria Large-Scale Initiative for 4 years. Ahmed Yureidini is on the verge of defending his PhD thesis and the last step of his work consisted in validating the model he devised for the blood vasculature as a tree of local implicit surfaces [8]. Comparisons were made against simulations using triangular meshes against our implicit model and they showed a reduction by

2 orders of magnitude in computing time while numerical instabilities encountered with meshes (jaggy motions, unrealistic sticking of the catheter tip on the vessel surface, ...) were not observed with our implicit model. Publication of these results is under way.

We also collaborate with Shacra team within the ANR IDeaS project. Computer simulations are very sensitive to inaccuracies in the various mechanical parameters or geometrical boundary conditions. Such inaccuracies are ubiquitous when dealing with patient-based data. We aim at developing Image-Driven Simulation to add the live X-ray images as new constraints to make the simulated surgical tool virtual visualization fit their position seen in the actual images. This year, a sensor was designed and tested to capture the motion of the line-shaped micro-tools (catheters, guidewires, etc...) and progress was made to design Kalman-like filters compliant with Sofa simulation platform.

Our long-term collaboration with GE Healthcare took a new step this year with the arrival of Charlotte Delmas as a PhD student. She will work towards devising algorithms to reconstruct the micro-tools in 3D from fluoroscopy images.

- **Designing respiration models for patient based simulators**
  Respiration models are useful in many ways. They can be used in: 1) pulmonary radiotherapy, where the tumor displacement should be accurately known to be targeted by ionizing radiation, 2) thoracic surgery simulators, where breathing motion increases the realism of virtual patients, 3) interventional radiology, where augmented medical imaging that incorporates breathing motion can be used during treatment.

  However building and parameterizing a fast and accurate respiration model is still an open problem. We continue this year to work on evolutionary methods to estimate the parameters of a complex 15-D respiration model on 5 patients [23]. A compound fitness function has been designed to take into account various quantities that have to be minimized.

  The optimized parameters have been applied to an interventional radiology simulator that takes into account the respiration [14]. It also includes: segmentation, physically based modeling, haptics rendering, pseudo-ultrasound generation and the concept of a physical mannequin. It is the result of a close collaboration between different universities (Liverpool, Manchester, Imperial College, Banghor, Leeds, Hull) involving computer scientists, clinicians, clinical engineers and occupational psychologists.

- **Realistic simulation of organ dissection** Whilst laparoscopic surgical simulators are becoming increasingly realistic they can not, as yet, fully replicate the experience of live surgery. In particular tissue dissection is one task that is particularly challenging to replicate. Limitation of current attempts to simulate tissue dissection include: poor visual rendering; over simplification of the task and; unrealistic tissue properties. In an effort to generate a more realistic model of tissue dissection in laparoscopic surgery we worked on a novel method based on task analysis. Initially we have chosen to model only the basic geometrics of this task rather than a whole laparoscopic procedure. This year preliminary work has led to the development of a real time simulator performing organ dissection with a haptic thread at 1000Hz. 2D soft-tissue models replicate the process of tissue cutting.

- **Physics-based augmented reality**
  The development of AR systems for use in the medical field faces one major challenge: the correct superposition of pre-operative data onto intraoperative images. This task is especially difficult when laparospic surgery is considered since superposition must be achieved on deformable organs. Most existing AR systems only consider rigid registration between the pre and intraoperative data and the transformation is often computed interactively or from markers attached to the patient's body.

  In cooperation with the Shacra team, we have proposed in [17], [18] a framework for real-time augmentation of the vascular network and tumors during minimally invasive liver surgery. Internal structures computed from pre-operative CT scans can be overlaid onto the laparoscopic view for surgery guidance. Compared to state-of-the-art methods, our method uses a real-time biomechanical model to compute a volumetric displacement field from partial three-dimensional liver surface motion.

The main contributions of this work are threefold: a) the use of a biomechanical model of liver deformation allows us to account for heterogeneity and anisotropy due to veins and arteries. In addition, the physical model is used as regularizer for the unreliable measurement of the visual tracking and as motion compensation in poorly textured areas; b) a real-time implementation of this virtual liver model has been proposed c) appropriate boundary conditions and external force have been defined which guide the biomechanical model using partial 3D motion estimated at the liver surface from a stereo video stream.

Thanks to this framework, we are able to estimate, in real-time, relevant positions of internal structures of the liver (vessels and tumors) taking into account liver deformations and tissue heterogeneity.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

The partnership with GE Healthcare started in 1993. In the past few years, it bore on the supervision of CIFRE PhD fellows on the topic of using a multi-modal framework and augmented reality in interventional neuroradiology. A new PhD thesis -Charlotte Delmas- started in April 2013 with the aim to perform 3D reconstruction of tools in interventional neuroradiology. Our goal is to help clinical gesture by providing the physician with a better understanding of the relative positions of the tools and of the pathology.

8. Partnerships and Cooperations

8.1. Regional Initiatives

P. F Villard received fundings from the regional council to develop research about realistic simulation of organ dissection. The internship of Nicolas Koenig dealt with this subject and the results will be published in a communication at MMVR 2014.

8.2. National Initiatives

8.2.1. ANR

- ANR ARTIS (2009-2013)
  Participants: M.-O. Berger, M. Loosvelt, P.-F. Villard.
  The main objective of this fundamental research project is to develop inversion tools and to design and implement methods that allow for the production of augmented speech from the speech sound signal alone or with video images of the speaker's face. The Magrit team is especially concerned with the development of procedures allowing for the automatic construction of a speaker's model from various imaging modalities.

- ANR Visac (2009-2013)
  Participants: M.-O. Berger, B. Wrobel-Dautcourt.
  The ANR Visac is about acoustic-visual speech synthesis by bimodal concatenation. The major challenge of this project is to perform speech synthesis with its acoustic and visible components simultaneously. Within this project, the role of the Magrit team is to build a stereovision system able to record synchronized audio-visual sequences at a high frame rate [12].

- ANR IDeaS (2012-2016)
  Participants: R. Anxionnat, M.-O. Berger, E. Kerrien.
  The IDeaS Young Researcher ANR grant explores the potential of Image Driven Simulation (IDS) applied to interventional neuroradiology. IDS recognizes the current, and maybe essential, incapacity of interactive simulations to exactly superimpose onto actual data. Reasons are various: physical models are often inherently approximations of reality, simplifications must be made to reach interactive rates of computation, (bio-)mechanical parameters of the organs and surgical devices cannot but be known with uncertainty, data are noisy. This project investigates filtering techniques to fuse simulated and real data. Magrit team is in particular responsible for image processing and filtering techniques development, as well as validation.

8.2.2. Collaboration with the Shacra team and AEN SOFA

Participants: R. Anxionnat, M.-O. Berger, E. Kerrien, A. Yureidini.
The SOFA-InterMedS large-scale Inria initiative is a research-oriented collaboration across several Inria project-teams, international research groups and clinical partners. Its main objective is to leverage specific competences available in each team to further develop the multidisciplinary field of Medical Simulation research. Our action within the initiative takes place in close collaboration with both Shacra Inria project-team in Lille and the Department of diagnostic and therapeutic interventional neuroradiology of Nancy University Hospital. We aim at providing in-vivo models of the patient's organs, and in particular a precise geometric model of the arterial wall. Such a model is used by Shacra team to simulate the coil deployment within an intracranial aneurysm. The associated medical team in Nancy, and in particular our external collaborator René Anxionnat, is in charge of validating our results. For two years, we have also been collaborating with the Shacra team about real time augmentation of deformable organs

8.2.3. Institut Pascal, Université de Clermont-Ferrand

Participants: F. Sur.
Since June 2012, we have been engaged in a collaboration with Pr. Michel Grédiac. The aim is to give a mathematical analysis and to help improving the image processing tools used in experimental mechanics at Institut Pascal.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Informal International Partners

Pierre-Frédéric Villard has a Honorary Research Fellow contract with Imperial College. The collaboration has involved 1 research visit in London in summer to mainly discuss about the writing of a common article [14]. He also participated as an activity leader in two one-week summer schools on Haptic Technology (to give the basics of computer haptics, including visual and haptics rendering, force feedback, haptic interfaces, collision detection, collision response and deformation modeling).

8.4. International Research Visitors

8.4.1. Visits to International Teams

Pierre-Frédéric Villard spent one month at Bangor University as a visiting researcher. This visiting fellowship was supported by the Wales Research Institute for Visual Computing (RIVIC). The aim was to improve existing solutions of respiration models based on optimization-driven models. Four parts have been studied: the meshing method, the deformation method, the boundary condition choice and the optimization method. A M.Sc. student was working on this subject and he has been remotely supervised by Pierre-Frédéric Villard until end of August.

9. Dissemination

9.1. Scientific Animation

- The members of the team reviewed articles for IEEE Transactions on Vizualisation and Computer Graphics, IEEE Transactions on Pattern Analysis and Machine Intelligence, Elsevier Optics and Lasers in Engineering, Computer & Graphics, the Journal of Computer Science and Technology.

- M.-O. Berger was a member of the program committee of the following conferences: IEEE International Symposium on Mixed and Augmented Reality (ISMAR 2013), International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI 2013), the IEEE International Symposium on Biomedical Imaging (ISBI) 2013 and of the french conference on computer vision ORASIS 2013.

- Gilles Simon was a member of the program committee of ISMAR 2013 and Eurographics 2013.

- P.-F. Villard was a member of the program committee of MICCAI 2013 and ISBI 2013.

- E. Kerrien was a member of the program committee of MICCAI 2013.

- Members of the team are members of local management committees (Conseil de Laboratoire, Comité de Centre and Pôle Scientifique AM2i).

- Pierre-Frédéric Villard gave a seminar on "Respiration Simulation : Application in Treatment Planning and Training Simulators" for the Visualization and Medical Graphics Group of the School of Computer Science, Bangor University, UK, on the Wednesday 5 June 2013. This talk was also given for the Computer Vision And Medical Image Analysis Group of the School of Computer Science, Swansea University, UK, on the Friday 14 June 2013

- Frédéric Sur gave a talk within the GDR ISIS day dedicated to *mesure dimensionnelle*, IUT Auxerre. He also gave a talk entitled *dérivation et intégration de mesures de champ* within GDR 2519 day (Mesures de Champs et Identification en Mécanique des Solides), ENSAM Paris.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: Graphic and haptic rendering, 30h, IUT Saint-Dié des Vosges, France

Licence: Image processing, 30h, IUT Saint-Dié des Vosges, France

Licence: 3D programming, 30h, IUT Saint-Dié des Vosges, France

Licence: Object oriented programming, 110h, IUT Saint-Dié des Vosges, France

Licence: Outils informatiques et internet, 14 h, L1, Université de Lorraine, France

Licence: Algorithmique et programmation (python), 48h, L1, Université de Lorraine, France

Licence: Introduction à la programmation objet (java); conception d'interfaces graphiques, 50 h, L2, Université de Lorraine, France

Licence: Système : synchronisation et communication de processus sous Linux, 48 h, L3, Université de Lorraine, France

Licence: Modélisation 3D, 40 h, LP, Université de Lorraine, France

Master: Perception et raisonnement, 50 h, M1, Université de Lorraine, France

ENSAN : Géométrie, 30h, 1A, École Nationale Supérieure d'Architecture de Nancy, France

Licence : Informatique graphique, 10h, L1, Université de Lorraine, France

Master: Réalite augmentée, 24 h, M2, Université de Lorraine, France

Master : Vision par ordinateur, 12h, M1, Université de Lorraine, France

Master: Reconnaissance des formes statistiques, 15 h, M2, Université de Lorraine, France

Master: Outils pour le traitement et l'analyse d'images, 21 h, 2A, École des Mines de Nancy, France

Master: Recherche opérationnelle, 59 h, École des Mines de Nancy, France

Master: Méthodes et outils pour la conception informatique, 34 h, 2A, Télécom-Nancy, Université de Lorraine, France

SUPELEC: Réalite augmentée, 3 h, 3A, SUPELEC Metz, France

DIU: Robotique chirurgicale, 1 h, CHU Nancy Univ. Hospital, France.

Primary and secondary school teacher training: 3h, Maison pour la Science de Lorraine, Nancy, France.

9.2.2. *Supervision*

PhD in progress: Ahmed Yureidini, Modélisation implicite des vaisseaux sanguins pour la simulation interactive d'actes de radiologie interventionnelle, janvier 2010, Erwan Kerrien, Stéphane Cotin (Shacra, Lille).

PhD in progress: Nazim Haouchine, Modèles physiques pour la réalité augmentée des organes déformables, janvier 2012, Marie-Odile Berger, Stéphane Cotin (Shacra, Lille).

PhD in progress: Pierre Rolin, Calcul de pose par simulation de points de vue pour la réalité augmentée, octobre 2013, Marie-Odile Berger et Frédéric Sur.

PhD in progress: Charlotte Delmas, Reconstruction 3D des outils chirurgicaux en radiologie interventionnelle, avril 2013, Marie-Odile Berger, Erwan Kerrien.

9.2.3. *Juries*

- Marie-Odile Berger was external reviewer of the PhD of A. Dufour, G. Gaullier and M. Tamaazousti.

9.3. Popularization

Members of the team participate on a regular basis, to scientific awareness and mediation actions:

- Erwan Kerrien heads the local Scientific Mediation Committee. Among other activites, he was invited to last Didapro5-DidaSTIC conference (didactics of computer science) as a panelist and was an associate researcher to a MATh.en.JEANS workshop.

- Pierre-Frédéric Villard participated to various activities in the IUT of Saint-Dié des Vosges: open days, science festival, science café, Film screening following by a debate and computer science presentations to schoolgirls to promote science.

- In an exploratory experiment conducted in collaboration with the IUFM de Lorraine (teacher training institute), we investigated the use, the usefulness and the impact of an innovative Augmented Reality Environment for teaching/learning astronomy at primary school [15]. An AR learning environment has been designed whose aim is to show augmented views of some celestial bodies and support the pupils' investigations using spatial visual guides and views from a terrestrial observer. Each child was asked to solve problems related to astronomy in two different conditions in which they had to use and manipulate: (1) the traditional learning environment (i.e., with physical models), or (2) the Augmented Reality environment. Preliminary results show that the declarative knowledge related to astronomy was higher with the AR Environment. Only AR users have developed scientific conceptions of the explored astronomical phenomena and learnings have been significantly improved. Furthermore, we presented some arguments in order to support the assumption that the AR model assists the process of scaffolding, promotes collaborative learning by reducing cognitive load, and takes part to the motivation dynamic by enhancing task controllability.

- We have designed and developed a software whose aim is to support students with learning computer programming. This software, named artEoz, enables a pedagogical view of the computer memory, dynamically changing while the user program is running [26]. Using a nice visualization helps to understand the behavior on an object oriented program. This software concerns beginners as well experimented students thanks to its facilities to draw complex data structures. artEoz can be freely downloaded for academic use only from http://arteoz.loria.fr. This software is licensed by the APP (French agency for software protection).

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