Activity Report 2014

Project-Team MAGRIT

Visual Augmentation of Complex Environments

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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
Marie-Odile Berger [Team leader, Inria, Senior Researcher, HdR]
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]

Engineer
Pierre-Jean Petitprez [Inria, from Oct 2014]

PhD Students
Charlotte Delmas [CIFRE grant, from Apr 2013]
Antoine Fond [Univ. Lorraine, from Oct 2014]
Pierre Rolin [Univ. Lorraine, from Oct 2013]
Nazim Haouchine [Inria, from Jan 2012, co-supervision with EPC SHACRA]

Administrative Assistant
Helene Zganic [Inria]

Others
Guillaume Blanchin [Univ. Lorraine, Internship, from Jun 2014 until Sep 2014]
Nicolas Gaillard [Univ. Lorraine, Internship, from Apr 2014 until Jun 2014]
Clement Jansen [Univ. Lorraine, Internship, from Jun 2014 until Sep 2014]
Ahmed Yureidini Nogales [Univ. Lorraine, ATER, until Aug 2014]

2. Overall Objectives

2.1. Augmented Reality

The basic concept of Augmented Reality (AR) is to place information correctly registered with the environment into the user's perception. What makes AR stand out is that this new technology offers the potential for big changes in many application fields such as industrial maintenance, creative technologies, image guided medical gestures, entertainment...

Augmented reality technologies have made major advancements recently, both in terms of capability, mobile development and integration into current mobile devices. Most applications are dedicated to multimedia and entertainment, games, lifestyle and healthcare and use rough localization information provided by the sensors of the mobile phones. Cutting-edge augmented reality applications which take place in complex environments and require high accuracy in augmentation are less prevalent. There are indeed still technological barriers that prevent applications from reaching the robustness and the accuracy required by such applications.

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, reliability and robustness. An expected consequence is the widening of the current application field of AR.

The team is active in both medical and classical applications of augmented reality for which accurate integration of the virtual objects within the scene is essential. Key requirements of AR systems are the availability of registration techniques, both rigid and elastic, that allow the virtual objects to be correctly aligned with the environment, as well as means to build 3D models which are appropriate for pose computation and for handling interactions between the virtual objects and the real scene. Considering the common needs for tracking, navigation, advanced modeling and visualization technologies in both medical and industrial applications, the team focuses on three main objectives: matching, localization and modeling. Methods are developed with a view to meet the expected robustness and accuracy over time and to provide the user with a realistic perception of the augmented scene, while satisfying the real time achievements required by these procedures.

3. Research Program

3.1. Matching and 3D tracking

One of the most basic problems currently limiting AR 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, independently of the variations in experimental conditions (lighting, weather condition,...) which may exist between the application and the time the model of the scene was acquired.

For several years, the MAGRIT project has been aiming at developing on-line and marker-less methods for camera pose computation. The main difficulty with on-line tracking is to ensure robustness of the process over time. 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 investigated various methods, ranging from statistical methods to the use of hybrid camera/sensor systems. Many of these methods are dedicated to piecewise-planar scenes and combine the advantage of move-matching methods and model-based methods. In order to reduce statistical fluctuations in viewpoint computation, which lead to unpleasant jittering or sliding effects, we have also developed model selection techniques which allow us to noticeably improve the visual impression and to reduce drift over time. Another line of research which has been considered in the team 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 [1].

The success of pose computation over time largely depends on the quality of the matching stage at the initialization stage. Indeed, the current image may be very different from the appearances described in the model both on the geometrical and the photometric sides. Research is thus conducted in the team on the use of probabilistic methods to establish robust correspondences of features. The use of *a contrario* has been investigated to achieve this aim [6]. We especially addressed the complex case of matching in scenes with repeated patterns which are common in urban scenes. We are also investigating the problem of matching images taken from very different viewpoints which is central for the re-localization issue in AR. Within the context of a scene model acquired with structure from motion techniques, we are currently investigating the use of viewpoint simulation in order to allow successful pose computation even if the considered image is far from the positions used to build the model.

Recently, the issue of tracking deformable objects has gained importance in the team. This topic is mainly addressed in the context of medical applications through the design of bio-mechanical models guided by visual features [2]. We have successfully investigated the use of such models in laparoscopy, with a vascularized model of the liver and with an hyper-elastic model for tongue tracking in US images. However, these results have been obtained so far in relatively controlled environments, with non pathological cases. When clinical

routine applications are to be considered, many parameters and considerations need to be taken into account. Among the problems that need to be solved are the model representation, the specification of the range of physical parameters and the need to enforce the robustness of the tracking with respect to outliers, which are common in the interventional context...

3.2. Image-based 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 interactions between the virtual and the real objects such as occlusions, lighting reflexions, contacts...in real time. 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 depending on the requirements of the targeted application. Interactive in-situ modeling techniques have thus been developed with the aim to enable the user to define what is relevant at the time the model is being built during the application. On the other hand, we also proposed off-line multimodal techniques, mainly dedicated to AR medical applications, with the aim to obtain realistic and possibly dynamic models of organs suitable for real time simulation.

In-situ modeling

In situ modeling allows a user to directly build a 3D model of his/her surrounding environment and verify the geometry against the physical world in real time. This is of particular interest in using AR in unprepared environments or building scenes that have an ephemeral existences (e.g. a film set) or cannot be accessed frequently (e.g. a nuclear power plant). We have especially investigated two systems, one based on the image content only and the other based on multiple data coming from different sensors (camera, inertial measurement unit, laser rangefinder). Both systems use the camera-mouse principle [5] (i.e. interactions are performed by aiming at the scene through a video camera) and both systems have been designed to acquire polygonal textured models, which are particularly useful for camera tracking and object insertion in AR.

Multimodal modeling for real time simulation

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 is 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, laparoscopic surgery, 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. 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 EPC SHACRA, 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]. These works open the way towards near real time patient-based simulations of interventional gestures both for training or for planning.

3.3. Parameter estimation

Many problems in computer vision or image analysis can be formulated in terms of parameter estimation from image-based measurements. This is the case of many problems addressed in the team such as pose computation or image-guided estimation of 3D deformable models... Often traditional robust techniques which take into account the covariance on the measurements are sufficient to achieve reliable parameter estimation. However, depending on their number, their spatial distribution and the uncertainty on these measurements, some problems are very sensitive to noise and there is a considerable interest in considering how parameter estimation could be improved if additional information on the noise is available. Another common problem in our field of research is the need to estimate constitutive parameters of the models, such as (bio)-mechanical parameters for instance. Direct measurement methods are destructive and elaborating image based methods is thus highly desirable. Besides designing appropriate estimation algorithms, a fundamental question is to understand what group of parameters under study can be reliably estimated from a given experimental setup.

This line of research is relatively new in the team. One of the challenges is to improve image-based parameter estimation techniques considering sensor noise and specific image formation models. In a collaboration with the Pascal Institute (Clermont Ferrand), metrological performance enhancement for experimental solid mechanics has been addressed through the development of dedicated signal processing methods [12]. In the medical field, specific methods based on an adaptive evolutionary optimization strategy have been designed for estimating respiratory parameters [7]. In the context of designing realistic simulators for neuroradiology, we are now considering how parameters involved in the simulation could be adapted to fit real images.

4. Application Domains

4.1. Augmented reality

We have a significant experience in AR that allowed good progress in building usable, reliable and robust AR systems. Our contributions cover the entire process of AR: matching, pose initialization, 3D tracking, in-situ modeling, handling interaction between real and virtual objects....

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. Contributions of the team focus about the developments of AR tools for neuro-navigation as well as the development of simulation tools of the interventional act for training or planning. Laparoscopic surgery is another field of interest with the development of methods for tracking deformable organs based on bio-mechanical models. Some of these projects are developed in collaboration with the EPC SHACRA.

4.3. Applied mechanics

In experimental solid mechanics, an important problem is to characterize properties of specimen subject to mechanical constraints, which makes it necessary to measure tiny strains. Contactless measurement techniques have emerged in the last few years and are spreading quickly. They are mainly based on images of the surface of the specimen on which a regular grid or a random speckle has been deposited. We are engaged since June 2012 in a transdisciplinary collaboration with Institut Pascal (Clermont-Ferrand Université). The aim is to characterize the metrological performances of these techniques limited by, e.g., the sensor noise, and to improve them by several dedicated image processing tools.

5. New Software and Platforms

5.1. Ralib

Our research 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 library was extended over the period to integrate our new research code on tongue modeling and tracking. Several applications either used internally or to demonstrate our work have been designed with this library.

5.2. PoLAR

The visualization module in RAlib has now reached a level of maturity where we believe it could be proposed to a wider audience. In the context of the ADT PoLAR (which started on October, 1st), a software engineer, Pierre-Jean Petitprez, started working on a new library called PoLAR (Portable Library for Augmented Reality). So far, the code has been cleanly made independent from our other code in RAlib, and in the process of being ported to up-to-date versions of the supporting libraries: OpenSceneGraph 3.2 and Qt5.

5.3. Ltrack

The Inria development action **LTrack** aims at developing an Android platform in order to facilitate the transfer of some of our algorithms onto mobile devices. For the moment, the tracking-by-synthesis algorithm has been implemented (up to our knowledge, for the first time on a mobile device) in order to rigidly track a real object in real time assuming that a CAD model of this object is available. The design and implementation of the platform have been guided by the need to enable easy integration of any tracking algorithm based on combining video data and other sensor information.

6. New Results

6.1. Highlights of the Year

We were invited to present our work on *Impact of Soft Tissue Heterogeneity on Augmented Reality for Liver Surgery* in the TVCG Special Session at SIGGRAPH Asia 2014.

6.2. Matching and 3D tracking

Pose initialization

Automating the camera pose initialization is still a problem in non instrumented environments. Difficulties originate in the possibly large viewpoint changes and lighting variations between the data stored in the model and the current view. One year ago, we began to investigate the use of viewpoint simulation techniques for re-localization within P. Rolin's PhD thesis. We especially consider challenging situations where the current view is distant from the image sequence used for model construction. We here consider scene models built from image sequence using Structure from Motion techniques. A point is then represented by its 3D coordinates and small image patches arising from the images where the point is detected.The underlying idea is to enrich 3D points by descriptors generated from virtual viewpoints chosen away from the learning sequence. For each 3D point of the model, a local image patch is generated from a set of virtual viewpoints, taking into account the local 3D normal and the images of the learning sequence. View synthesis is performed with an affine or an homography model. Though one possible shortcoming of simulation is to generate too many incorrect patches at discontinuities in the scene and thus to degrade the matching step, our preliminary results are very promising [25] and show a noticeable increase of the inlier ratio in the matching stage and an improved stability of the computed pose, especially when homography models are considered. We exhibit many examples where our method successfully computes the camera pose whereas the traditional methods fail.

Current investigations are about the development of scalable solutions for pose computation in large environments with several leverage actions in view. Designing efficient probabilistic techniques for matching and defining strategies based on the geometry of the scene for choosing a reduced set of virtual views are lines of research under investigation for jointly limiting the redundancy and improving the performance of the matching.

Tracking 3D deformable objets

3D augmentation of deformable objects is a challenging problem with many potential applications in computer graphics, augmented reality and medical imaging. Most existing approaches are dedicated to surface augmentation and are based on the inextensibility constraint, for sheet-like materials, or on the use of a model built from representative samples. However, few of them consider in-depth augmentation which is of utmost importance for medical applications. Since the beginning of N. Haouchine's PhD thesis, we have addressed several important limitations that currently hinder the use of augmented reality in the clinical routine of minimally invasive procedures. In collaboration with the SHACRA team, our main contribution is the design and the validation of an augmented reality framework based on a mechanical model of the organ and guided by features extracted and tracked on the video at the surface of the organ [2]. Specific models which best suit the considered organs, such as a vascularized model of the liver, have been introduced in this framework. During this year, we have first performed quantitative evaluation of the method [17]. Promising results were obtained through in-vivo experimentation on a human liver and ex-vivo validation on a porcine liver. In this latter case, artificial tumors were introduced in the liver, thus allowing a quantitative evaluation of the error between the predicted and the actual tumor. These experiments show that localization errors were less than 6mm, and thus below the safety margin required by surgery. To our knowledge, we were the first to produce such evaluation for deformable objects. This work has been extended to augment highly elastic objects in a monocular context [16], whereas previous works were guided by 3D features obtained with a stereo-endoscope. The only parameter involved in the method is the Young's modulus but we show in experiments that a rough estimate of the Young's modulus is sufficient to obtain a good reconstruction. Experiments on computer-generated and real data have shown the effectiveness of the approach. The method is currently restricted to the orthographic projection and its extension to full projective geometry is under investigation.

A bio-mechanical model-based approach has also been considered in the context of tongue tracking in ultrasound images with a view to produce an augmented head for language learning. A crucial issue is the robustness of the tracking due to the strong speckle noise in ultrasound (US) data. Here, a small number of points are used to guide the model. Selection of feature points is based on the uncertainty associated to the tracked points and on spatial constraints. This model has proven to be especially efficient in the case of non uniform and fast movements [19].

Use of AR in educational sciences

In collaboration with the Ecole supérieure du professorat et de l'éducation and the PErSEUs laboratory at Université de Lorraine, we designed an inquiry-based AR learning environment (AIBLE) for teaching and learning astronomy in primary school (children of 8-11 years old). The novelty of this environment is the combination of Inquiry Based Sciences Education principles and didactics principles (here of astronomy) with AR capabilities. In this context, a GPL-licensed software called AIBLE-AstroAR has been developed based on the ARToolkit library. This software basically consists of a tangible user interface, which allows the children to move virtual celestial objects "as for real" and investigate in order to find origins of Moon phases evolution, alternation of day and night, seasons and Moon/Sun eclipses.

Last year, a study has been carried out to compare AIBLE with a physical model traditionally used in primary school. This study indicated that AIBLE significantly enhances learning compared to classical support. During this year, we performed further investigation with a larger panel of children to assess which characteristics of the environment facilitate learning [14]. Analyses of the marker positions as moved by the children indicated that AIBLE really facilitates heuristic investigation, which fosters consciousness of the origin of astronomical phenomena. This work provides new opportunities for teachers to identify solving problem strategies initiated by learners. These results also contribute to the understanding of the ways through which AR can be used in formal teaching curricula in K-12 schools.

6.3. Image-based modeling

Modeling vasculature for real time simulation
One of our objectives to benefit interventional neuroradiology is to offer a patient-based interactive simulator to the interventional radiologists. Our contributions address vasculature modeling from patient data, namely 3D rotational angiography (3DRA) volumes. During Ahmed YUREIDINI's PhD thesis (2010-2014), a new model was developed consisting of a tree of local implicit blobby models.

We've been collaborating with SHACRA Inria project-team (Lille-Nord Europe) and the Department of Interventional Neuroradiology from Nancy University Hospital, in the context of the SOFA-InterMedS Inria Large-Scale Initiative. Ahmed YUREIDINI defended his PhD thesis in May this year with highest honors [9]. In particular, a detailed study was made to compare our tree of local implicits with triangular meshes in a view to model synthetic shapes as well as vasculatures from patient data. Increased performances with regard to processing speed, numerical stability and realism of the behavior were demonstrated.

Tools reconstruction for 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. In particular, since at most only two projective fluoroscopic views are available, containing absolutely no depth hint, the 3D shape of the micro-tool (guidwire, micro-catheter or micro-coil) can be very difficult, if not impossible to infer, which may have an impact on the clinical outcome of the procedure.

In collaboration with GE Healthcare, we aim at devising ways to reconstruct the micro-tools in 3D from fluoroscopy images. Charlotte Delmas has been working as a PhD Cifre student on this subject since April 2013. A solution in a two-view reconstruction context was proposed this year based on the extraction of the guide-wire as a skeleton in the images. The large stereo basis (views are almost orthogonal) and the segmentation errors (such as both missing parts and spurious segments in the skeleton) make the reconstruction especially difficult. The skeletons are subdivided in simple curves that are matched to build all corresponding potential 3D curves. These curves are nodes in a graph whose edge weights express a connection cost that takes into account both distance and orientation at the curves extremities. The solution 3D curve is provided by following the path of minimal cost in the graph. This algorithm demonstrated very good reconstruction results on synthetic and phantom data. A paper on this subject has been accepted for publication at SPIE Medical Imaging 2015.

Patient-specific heart valve modeling
Many pathologies damage heart valve anatomy producing undesired backflow, or regurgitation, decreasing cardiac efficiency and potentially leading to heart failure if left untreated. Such cases could be treated by surgical repair for the valve. However it is technically difficult and outcomes are highly dependent upon the experience of the surgeon: he must essentially predict the displacement and deformation of complex valve leaflets and supporting structures. One way to facilitate the repair is to simulate the mechanical behavior of the pathological valve with patient-specific data. This is the objective of Pierre-Frédéric Villard's one-year CNRS delegation in the Harvard Bio-robotics Laboratory (HBL). During the initial three first months of the sabbatical leave, various tasks have been performed: i) Study of the physiology of pathological valve behavior with medical experts. Following anatomical book reading and medical expert interviews the anatomy and the physiology are now understood. ii) Evaluation of HBL material for 4D ultrasound segmentation. HBL has previously developed a method to extract mitral valve geometry from a home-made high temporal resolution 3D ultrasound and iii) Automatic segmentation of a Mitral Valve microCT to feed a biomechanical model. A method to semi-automatically segment the leaflet-chordae set has been developed.

6.4. Parameter estimation

Metrologic performance assessment in experimental mechanics

A problem of interest in experimental solid mechanics is strain map estimation on the surface of a specimen subjected to a load or a tensile test. One of the available approaches is based on images of a pseudo-periodic grid transfered on the surface of the specimen. Sensor noise is a major source of uncertainty in the strain map, and quantifying the propagation of the sensor noise to the measured strain components is a major problem when metrological performances are in view. We have proposed in [12] a study of the mathematical properties of the popular method based on windowed Fourier analysis, under a Gaussian white noise assumption. In the case of a more realistic signal-dependent, heteroscedastic noise, we have quantified in [10] (see also [15], [26]) the trade-off between the noise amplitude, the measurement resolution and the spatial resolution of the method. We have also investigated image stacking for noise reduction. While averaging a serie of images is certainly the most basic option to reduce the noise, it is not effective for studying grid images under a high magnification factor, because of unavoidable residual vibrations carried for instance by concrete floor slabs. We have shown in [13] that, while these vibrations indeed blur grid images, they still permit to reduce the noise amplitude in the displacement and strain maps.

Sensor noise measurement.
While searching for a low-cost on-the-fly estimation of the sensor parameters based on a serie of grid images (thus with no need of changing the experimental setting), we have proposed in [11] an algorithm which is able to deal with the vibrations biasing the estimations. More generally, we have investigated in [21] the problem of sensor parameter estimation from a series of images, under light flickering and vibrations. Light flickering is indeed a natural assumption for indoor artificial lights. It is also involved by slight variations in the opening time of a mechanical shutter. We have proposed a model of the pixel intensity based on a Cox process, together with an algorithm which, taking benefit of flickering, gives an estimation of every sensor parameter, namely the gain, the readout noise, and the offset.

Image driven simulation
In the IDeaS ANR project we propose to target Image-driven simulation, applied to interventional neuroradiology: a coupled system of interactive computer-based simulation (interventional devices in blood vessels) and on-line medical image acquisitions (X-ray fluoroscopy). The main idea is to use the live X-ray images as references to continuously refine the parameters used to simulate the blood vessels and the interventional devices (micro-guide, micro-catheter, coil).

Our guideline is to follow a sequential statistical filtering approach to fuse such heterogeneous data. This approach first calls for an improved knowledge of the statistical behavior of the simulation, which we addressed in the past year through experimental studies. We described our experimental setup in [20], which, in particular uses high speed stereo reconstruction to be able to study non quasi-static effects. Preliminary measures of the catheter speed during stick and slip transitions back up our conviction that quasi-static mechanical models fail to simulate such rapid motions of the tool. Our on-going analysis of the simulation sensitivity to mechanical parameters also sets forward friction as critical for high-fidelity simulation.

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 plysician with a better understanding of the relative positions of the tools and of the pathology.

8. Partnerships and Cooperations

8.1. Regional Initiatives

Collaboration with Nancy School of Surgery

We are working with Nancy School of Surgery on soft tissue dissection simulation. In an effort to generate a more realistic model of tissue dissection in laparoscopic surgery we started to investigate on a novel method based on a task analysis. Nancy School of Surgery experts have defined the key features of the simulator. Initially we have chosen to model the basic geometry of this task rather than a whole laparoscopic procedure. Preliminary work has led to the development of a real time simulator performing cutting with a haptic thread at 1000Hz on a simple 2D geometry using SOFA Framework [23].

8.2. National Initiatives

8.2.1. ANR

- 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. Project funded by GDR ISIS in collaboration with Institut Pascal, Université de Clermont-Ferrand

- Participant: 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.

  The TIMEX project (2014-2016) is funded by GDR ISIS ("Appel à projet exploratoire, projet interdisciplinaire"). It aims at investigating image processing tools for enhancing the metrological performances of contactless measurement systems in experimental mechanics.

8.2.3. 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 three years, we have also been collaborating with the SHACRA team about real time augmentation of deformable organs

8.2.4. Collaboration with the Parole team

Participants: M.-O. Berger, P. -F. Villard, B. Wrobel-Dautcourt
Our collaboration with the local Inria team Parole is about the augmented head. This project aims at building a realistic head augmented by external and internal articulators with foreseen applications to language learning technologies [18].

8.3. International Research Visitors

8.3.1. Visits to International Teams

8.3.1.1. Research stays abroad

Pierre-Frédéric Villard started a one year full time CNRS delegation in September 2014 in the Harvard Bio-robotics Laboratory.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events selection

9.1.1.1. Organizing committee membership

M.-O. Berger was chair of the French conference on pattern recognition RFIA 2014.

9.1.1.2. Conference program committee membership

- M.-O. Berger was member of the program committee of the following conferences: International Conference on Medical Image Computing and Computer Assisted Intervention: MICCAI 2014, ICPR 2014, ISMAR 2014.
- Erwan Kerrien was a member of the program committee of MICCAI 2014 and of the International Symposium on Biomedical Simulation (ISBMS'14).
- G. Simon was a member of the program committee of ISMAR 2014 and Eurographics 2014.
- P.-F. Villard was a member of the program committee of MICCAI 2014 and of the International Symposium on Biomedical Simulation (ISBMS'14).

9.1.2. Journal

9.1.2.1. reviewer

The members of the team reviewed articles for Computers & Graphics (Elsevier), The Visual Computer (Springer), Medical Images Analysis (Elsevier), IEEE Transactions on Vizualisation and Computer Graphics, Journal on Imaging Sciences (SIAM), Journal of Electronic Imaging (IS&T / SPIE), Axioms (MDPI), Experimental Mechanics (SEM), Transactions on Pattern Analysis and Machine Intelligence (IEEE), Optics and Lasers in Engineering (Elsevier).

9.1.3. Invited Conferences

Pierre-Frédéric Villard was invited to give a talk entitled "Respiration Simulation : Application in Treatment Planning, Training Simulators and On-Line Treatment" during the CIM Workshop on Mathematics and Medicine, November 6-7, 2014, Uppsala, Sweden http://www.math.uu.se/cim/seminarier-och-aktiviteter/cim-workshop-2014/.

9.1.4. Other review

E Kerrien was reviewer for one COFECUB project.

9.2. Teaching - Supervision - Juries

9.2.1. *Teaching*

The four associate professors of the MAGRIT team actively teach at Université de Lorraine with an annual number of around 200 teaching hours in computer sciences, some of them being accomplished in the field of image processing. Inria researchers have ponctual teaching activities in computer vision and shape recognition mainly in the computer science Master of Nancy and in several Engineering Schools near Nancy (ENSMN Nancy, SUPELEC Metz, ENSG). Our goal is to attract Master students with good skills in applied mathematics towards the field of computer vision. The list of courses given by staff members which are tighly related to image processing and computer vision is detailed below:

- Licence: Graphic and haptic rendering, 30h, IUT Saint-Dié des Vosges.
- Licence: Image processing, 30h, IUT Saint-Dié des Vosges.
- Licence: 3D programming, 30h, IUT Saint-Dié des Vosges.
- Licence : Geometry, 30h, École Nationale Supérieure d'Architecture de Nancy.
- Master: Signal analysis, 50 h, Université de Lorraine.
- Master: Augmented reality, 24 h, Télécom-Nancy, Université de Lorraine.
- Master : Introduction to computer vision, 12h, Université de Lorraine.
- Master : Shape recognition, 15 h, Université de Lorraine.
- Master : Computer vision: foundations and applications, 15 h, Université de Lorraine.
- Master : Introduction to image processing, 21 h, École des Mines de Nancy
- Master : Image processing for Geosciences, ENSG, 12h.
- Master : Introduction to signal processing and applications, 21 h, Ecole des Mines de Nancy
- Master : Augmented reality, 3 h, SUPELEC Metz.
- Inter University Degree: Medical robotics, 1 h, CHU Nancy Univ. Hospital.

9.2.2. *Supervision*

PhD: Ahmed Yureidini, Modélisation implicite des vaisseaux sanguins pour la simulation interactive d'actes de radiologie interventionnelle, defended on mai 2014, 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, Frédéric Sur.

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

PhD in progress: Antoine Fond, Introduction de sémantique dans la modélisation urbaine dans un contexte de calcul du point de vue, octobre 2014, Marie-Odile Berger, Gilles Simon.

9.2.3. *Juries*

Marie-Odile Berger was external reviewer of the PhD of D. Larnaout and L. Younes.

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. He also serves as the academic referent of an IREM [1] working group aiming at introducing computer science in secondary and high school curricula. Among other activites, he was also an associate researcher to a MATh.en.JEANS workshop.

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[1] Institut de Recherche sur l'Enseignement des Mathématiques - *Research Institute for Teaching Mathematics*

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Major publications by the team in recent years

[1] M. ARON, G. SIMON, M.-O. BERGER. *Use of Inertial Sensors to Support Video Tracking*, in "Computer Animation and Virtual Worlds", 2007, vol. 18, pp. 57-68, http://hal.inria.fr/inria-00110628/en/

[2] N. HAOUCHINE, J. DEQUIDT, I. PETERLIK, E. KERRIEN, M.-O. BERGER, S. COTIN. *Image-guided Simulation of Heterogeneous Tissue Deformation For Augmented Reality during Hepatic Surgery*, in "ISMAR - IEEE International Symposium on Mixed and Augmented Reality 2013", Adelaide, Australie, October 2013, http://hal.inria.fr/hal-00842855

[3] N. PADOY, T. BLUM, A. AHMADI, H. FEUSSNER, M.-O. BERGER, N. NAVAB. *Statistical Modeling and Recognition of Surgical Workflow*, in "Medical Image Analysis", 2011, http://hal.inria.fr/inria-00526493/en

[4] G. SIMON, M.-O. BERGER. *Interactive Building and Augmentation of Piecewise Planar Environments Using the Intersection Lines*, in "The Visual Computer", February 2011, vol. 27, n⁰ 9, pp. 827-841, http://hal.inria.fr/inria-00565129/en

[5] G. SIMON. *In-Situ 3D Sketching Using a Video Camera as an Interaction and Tracking Device*, in "31st Annual Conference of the European Association for Computer Graphics - Eurographics 2010", Suède Norrkoping, May 2010

[6] F. SUR, N. NOURY, M.-O. BERGER. *An A Contrario Model for Matching Interest Points under Geometric and Photometric Constraints*, in "SIAM Journal on Imaging Sciences", 2013, vol. 6, n⁰ 4, pp. 1956-1978 [*DOI :* 10.1137/120871766], http://hal.inria.fr/hal-00876215

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Doctoral Dissertations and Habilitation Theses

[9] A. YUREIDINI. *Robust blood vessel surface reconstruction for interactive simulations from patient data*, Université des Sciences et Technologie de Lille - Lille I, May 2014, Rédigée au 21 janvier 2014, https://tel.archives-ouvertes.fr/tel-01010973

Articles in International Peer-Reviewed Journals

[10] M. GRÉDIAC, F. SUR. *Effect of Sensor Noise on the Resolution and Spatial Resolution of Displacement and Strain Maps Estimated with the Grid Method*, in "Strain", February 2014, vol. 50, n° 1, pp. 1-27 [*DOI :* 10.1111/STR.12070], https://hal.inria.fr/hal-00937972

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[15] M. GRÉDIAC, F. SUR. *Stabilizing Heteroscedastic Noise With the Generalized Anscombe Transform. Application to Accurate Prediction of the Resolution in Displacement and Strain Maps Obtained With the Grid Method*, in "SEM Annual Conference & Exposition on Experimental and Applied Mechanics - 2014", Greenville, SC, United States, H. JIN, C. SCIAMMARELLA, S. YOSHIDA, L. LAMBERTI (editors), Advancement of Optical Methods in Experimental Mechanics, Springer, June 2014, vol. 3, pp. 225-230 [*DOI :* 10.1007/978-3-319-06986-9_25], https://hal.inria.fr/hal-01001869

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[20] M. SANZ-LOPEZ, J. DEQUIDT, E. KERRIEN, C. DURIEZ, M.-O. BERGER, S. COTIN. *Testbed for assessing the accuracy of interventional radiology simulations*, in "ISBMS - 6th International Symposium on Biomedical Simulation", Strasbourg, France, LNCS, Springer, October 2014, https://hal.inria.fr/hal-01059892

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