informatics mathematics

IN PARTNERSHIP WITH:
CNRS

Université de Lorraine

Activity Report 2015

Project-Team MAGRIT

Visual Augmentation of Complex Environments

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

RESEARCH CENTER
Nancy - Grand Est

THEME
Vision, perception and multimedia interpretation

Table of contents

Project-Team MAGRIT

Creation of the Project-Team: 2006 April 03

Keywords:

Computer Science and Digital Science:

5.10.2. - Perception
5.3. - Image processing and analysis
5.4. - Computer vision
5.4.1. - Object recognition
5.4.5. - Object tracking and motion analysis
5.4.6. - Object localization
5.6. - Virtual reality, augmented reality

Other Research Topics and Application Domains:

2.6. - Biological and medical imaging
5.9. - Industrial maintenance
9.4.3. - Physics

1. Members

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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.

The success of pose computation over time largely depends on the quality of the matching 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 [21].

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 [1]. 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 ultrasound 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 addressed are more realistic model representations, 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 reflections, 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 when using AR in unprepared environments or building scenes that either have an ephemeral existence (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 [4] (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 [2]. 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' 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 team MIMESIS, we have proposed new methods for implicit modeling of the vasculature 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 and 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. 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 the 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 on the development 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 team MIMESIS.

4.3. Applied mechanics

In experimental solid mechanics, an important problem is to characterize properties of specimen materials 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. 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. This year we finished developing an application that performs tracking by synthesis using the camera and the sensors of a mobile phone. User tests will start in January 2016 and we expect to submit the application to the Android Market in the middle of 2016.

- Contact: Marie-Odile Berger, Gilles Simon.

5.2. PoLAR

PoLAR (Portable Library for Augmented Reality) is a software library that offers powerful and state of the art visualization solutions under an API that is adapted and easy to use for a computer vision scientist. An ADT, also named PoLAR, started in October, 1st 2014 to sustain its development: a software engineer, Pierre-Jean Petitprez, was hired for two years.

After the code was made independent from our other research codes (RAlib), the library was ported to up-to-date versions of the supporting libraries: OpenSceneGraph 3.2 and Qt5.4. Heavy code refactoring was also carried out to set the core functionalities in conformity with the standards of the supporting libraries.

PoLAR was made available to the public in October 2015, and can be used under Linux or Windows at the moment.

Also this year, a research branch was developed to add the management of physics engines in PoLAR: so far, Bullet and Vega deformation engines were considered, the former being well integrated and the latter still being a work in progress.

- Contact: Erwan Kerrien, Pierre-Frédéric Villard.
- URL: http://polar.inria.fr

5.3. RAlib

RAlib is a library which contains the team's research development on image processing, registration (2D and 3D) and visualization. The library was extended over the period to integrate the Java code developed by Maxime Malgras during his Master's internship. Several applications either used internally or to demonstrate the team's work have been designed with this library.

- Contact: Erwan Kerrien, Gilles Simon

5.4. Reproducible research

Matlab software implementing the algorithms described in published articles is publicly available: NESIF (noise estimation by stacking images affected by illumination flickering) [15], ARPENOS (automated removal of quasi-periodic noise using frequency domain statistics) [14], and AC-ARPENOS (a-contrario automated removal of quasi periodic noise using frequency domain statistics) [22].

6. New Results

6.1. Matching and 3D tracking

Participants: Marie-Odile Berger, Jaime Garcia Guevara, Nazim Haouchine, Gilles Simon, Frédéric Sur.

Pose initialization Automating the camera pose initialization is still a problem in non instrumented environments. Difficulties originate in the possibly large viewpoint changes between the data stored in the model and the current view. In this context, Pierre Rolin's PhD work concerns viewpoint simulation techniques for localization. The idea is to generate keypoint descriptors from simulated views in order to enrich the model and to ease the matching of the current view to the model. We have demonstrated the effectiveness of this technique in several situations, either under an affine or a perspective camera model [17], [21]. The computed pose is more stable when it is difficult to obtain reliable correspondences between the model and the current view. In addition, several examples show that our method successfully computes the camera pose whereas the traditional methods fail. Our recent work concerns a progressive sampling strategy to speed up the search of correspondences when confronted to a large outlier rate, which is inherent to viewpoint simulation. We also currently investigate the localization of the virtual camera from which viewpoints should be simulated.

AR in urban environments

Pose initialization is especially difficult in urban scenes due to the presence of repeated patterns. Another difficulty originates in the fact that a pedestrian is free of his motion in the scene and can therefore adopt uncontrolled viewpoints (close or distant views) with respect to the model. As a result, the set of 2D/3D correspondence hypotheses may contain a high ratio of outliers which may lead to erroneous pose computation. In order to improve the matching / recognition stage, we investigated how facades in calibrated images can be orthorectified and delimited by considering prior information about the scene and the camera relevant to AR in urban context [20]. We provide a Bayesian framework to detect vanishing points in Manhattan worlds, which incorporate priors about the Manhattan frame by imposing a near-vertical direction as well as orthogonality constraints. Second, we propose to detect right-angle corners due to windows or doors using a SVM-based machine learning technique. Rectangular facade hypotheses are then generated through min-cuts techniques with the idea to identify rectangles with high density of right-angle corners. Our algorithm performs better or as well as state-of-the-art techniques and is much faster, mainly as a result of using a suitable prior.

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 MIMESIS 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 [12]. Specific models which best suit the considered organs, such as a vascularized model of the liver, have been introduced in this framework. Experiments conducted on ex-vivo data of a porcine liver show that the localization error of a virtual tumor 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. Shape recovery from a monocular video sequence is an underconstrained problem. State-of-the art solutions enforce smoothness or geometric constraints, consider specific deformation properties such as inextensibility or resort to shading constraints. However, few of them can handle properly large elastic deformations. We have proposed [13] a real-time method that uses a mechanical model and is able to handle highly elastic objects. The problem is formulated as an energy minimization problem accounting for a non-linear elastic model constrained by external image points acquired from a monocular camera. This method prevents us from formulating restrictive assumptions and specific constraint terms in the minimization. In addition, we propose to handle self-occluded regions thanks to the ability of mechanical models to provide appropriate predictions of the shape.

The work conducted during N. Haouchine's PhD thesis allowed us to build a complete framework for the use of AR in liver surgery. We now want to focus on specific points to improve the accuracy and the robustness of the augmented process and to facilitate the clinical use of such AR systems. The PhD thesis of Jaime Garcia Guevara started in October on this topic with the aim to build more realistic mechanical models of organs during the surgery (taking into account liver deformation due to insuflation of air during surgery) and to improve the robustness of visual tracking through the use of multiple visual cues and improved methods for outlier detection.

6.2. Image-based modeling

Participants: Marie-Odile Berger, Charlotte Delmas, Antoine Fond, Erwan Kerrien, Gilles Simon, Pierre-Frédéric Villard, Brigitte Wrobel-Dautcourt.

Finding Manhattan directions in uncalibrated images

Finding orthogonal vanishing points (VPs) in a photography has many potential applications in computer vision and computer graphics, including perspective correction, image-based reconstruction and texture extraction. Surprisingly, while this problem has been extensively studied in the literature, manual solutions are still used in most software. Existing algorithms generally follow two steps. First, lines are grouped into pencils, whose centers are considered as potential VPs. Then, an orthogonality measure is evaluated for every triplet of VPs and the most plausible triplet is used for camera calibration. A drawback of this approach is that complex and time-consuming techniques have to be used to solve the general problem of VP detection, while only three particular VPs are finally used. By contrast, we propose an effective and easy-to-implement algorithm that estimates the zenith and the horizon line before detecting the VPs, using simple properties of the central projection and exploiting accumulations of oriented segments around the horizon. Our method is fast and yields an accuracy comparable, and even better in some cases, to that of state-of-the-art algorithms. This work was submitted to Eurographics 2016.

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 (guidewire, 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. She first devised a solution in a two-view reconstruction context. A paper reporting on this work was published and an oral presentation was made at SPIE Medical Imaging 2015 [19]. The focus was made this year on reconstructing the first coil, a single wire that tangles into a complex pattern when deployed in an aneurysm. The challenge is to produce a 3D reconstruction with as little X-ray dose and acquisition time as possible. Two paths were simultaneously followed this year: 1) design and compare various configurations to rapidly shoot 6 X-ray views from different viewpoints with a biplane (stereo) system; 2) compensate the lack of information (small number of images) with a prior, incorporated in the tomographic reconstruction algorithm, to express the sparsity in space of the shape to be reconstructed. Preliminary work sets forward a simultaneous fast rotation of both planes around the patient's head. A database is currently being acquired for a full validation in a view to submitting this work for publication early next year.

Individual-specific heart valve modeling
Mitral valve surgical repair is a complex procedure where the outcome largely depends on the surgeons' experience. Predicting a good coaptation of the two leaflets post-operatively is one of the most difficult sub-tasks in the procedure. We worked on a biomechanical simulation framework [25] that computes the leaflet deformation and coaptation based on individual-specific microtomography data as an initial step toward patient-based mitral valve surgical repair assistance through simulation. Results from FEM analysis on three explanted porcine hearts showed that it is possible to obtain the real shape of the leaflets during systolic peak. We also measured the influence of the positions of chordae tendineae on the simulation and showed that marginal chordae have a greater influence on the final shape than intermediary chordae.

Quasi-periodic noise removal
Images may be affected by quasi-periodic noise. This undesirable feature manifests itself by spurious repetitive patterns covering the whole image, well localized in the Fourier domain. While notch filtering permits to get rid of this phenomenon, this however requires to first detect the resulting Fourier spikes, and, in particular, to discriminate between noise spikes and spectrum patterns caused by spatially localized textures or repetitive structures. Several approaches have been investigated. First, we have reviewed the available methods, most of them requiring expert tuning, with applications to experimental mechanics in view [11]. We have also proposed two automated patch-based approaches. A parametric approach has been investigated in [14] (more information available in [26]), based on the detection of noise spikes as statistical outliers to the distribution expected from natural non-noisy patches, which is known to follow the inverse of a power of the frequency. A non-parametric approach, based on a-contrario detection, was also proposed in [22].

6.3. Parameter estimation

Participants: Frédéric Sur, Erwan Kerrien, Raffaella Trivisonne.

Metrological performance assessment in experimental mechanics
A problem of interest in experimental solid mechanics is to estimate displacement and strain maps on the surface of a specimen subjected to a load or a tensile test. Two contactless approaches are available in the literature, based on depositing on the surface of the specimen either a pseudo-periodic grid or a random speckle. Analyzing images taken before and after deformation permits to estimate strain maps. While periodicity permits to make use of Fourier analysis in the first case, digital image correlation (DIC) is used in the second case. Concerning pseudo-periodic grids, we have investigated noise reduction techniques. While averaging a series of images is certainly the most basic option to reduce the noise, it is impossible to get rid of residual vibrations carried for instance by concrete floor slabs. We have shown in [16] that, while these

vibrations indeed blur grid images, they still permit to reduce the noise amplitude in the displacement and strain maps. Concerning DIC-based techniques, we have investigated the effect of sensor noise on the measurement resolution. Since displacement of interest are most of the time below one pixel, interpolation plays a major role. We have proposed a new resolution formula which takes interpolation into account. Besides, this formula has been the subject of an experimental assessment on real data, in the presence of signal-dependent noise [24], [18].

Sensor noise measurement
We have investigated in [15] (additional information available in [27]) the problem of sensor parameter estimation from a series of images, under illumination flickering and vibrations. Illumination 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
The IDeaS ANR project targets 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.

Christo Gnonnou was hired as an engineer (located at Inria Lille in Defrost team (ex-Shacra), contract started on January 1st and ended on October 31st). He continued the work to specify which parameters the simulation is sensitive to, in a view to design a reduced parametric model of the device, and associate covariances to its parameters. He also worked on inverting the mechanical parameters of any device, using our experimental setup based on a high speed stereo rig.

Maxime Malgras worked on his Master's thesis in the team. His investigations aimed at designing a particle filter where the transition function is approximated by a polynomial chaos (PC) instead of particles. It appeared that PC is adapted to compute the posterior in a particle filter but it is not clear whether the number of samples required to estimate the PC coefficients is smaller than the number of particles required for the filter to be accurate, which questions the capacity of PC to reduce the computational burden of particle filters in high dimensions. Raffaella Trivisonne started her PhD thesis in November (co-supervised by Stéphane Cotin, from MIMESIS team in Strasbourg) to investigate deeper on this subject and apply data assimilation to image driven simulation of endovascular interventions.

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. The PhD thesis of 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

- Lorraine regional project about AR for liver surgery (2015-2018)
  The MAGRIT and the MIMESIS teams have been working for several years on the use of augmented reality for deformable organs and especially on liver surgery. The PhD of Jaime Garcia Guevara started in October 2015 and is funded by the Région Lorraine. It follows on from our past works and aims at improving the reliability and the robustness of AR-based clinical procedures.

8.2. National Initiatives

8.2.1. ANR

- ANR IDeaS (2012-2015)
  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

- 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 MIMESIS team and AEN SOFA

Participants: R. Anxionnat, M.-O. Berger, E. Kerrien.
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 MIMESIS team 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 MIMESIS 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 MIMESIS team about real-time augmentation of deformable organs.

8.3. International Research Visitors

8.3.1. Visits to International Teams

8.3.1.1. Research stays abroad

Pierre-Frédéric Villard is spending one year and a half as a visiting professor in the Harvard Biorobotics Lab (http://biorobotics.harvard.edu) led by Professor Robert D. Howe in Harvard University, Cambridge (USA). The first year (Sept 2014-Aug 2015) was funded by the CNRS and the last semester (Sept 2015-Jan 2016) is funded by Inria. The research is on individual-specific heart mitral valve simulation with biomechanical models.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events selection

9.1.1.1. Member of the conference program committees

- M.-O. Berger was member of program committee of the following conferences: International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI 2015) and of the International Symposium on mixed and augmented reality (ISMAR 2015).
- Erwan Kerrien was a member of the program committee of MICCAI 2015 and of IPCAI 2016.
- G. Simon was a member of the program committee of ISMAR 2015, of the ISMAR UrbanAR workshop and of the french conference on computer vision ORASIS 2015.
- P.-F. Villard was a member of the program committee of MICCAI 2015 and Eurographics Workshop on Visual Computing for Biology and Medicine 2015.

9.1.2. Journal

9.1.2.1. Reviewer - Reviewing activities

The members of the team reviewed articles for IEEE Transactions on Vizualisation and Computer Graphics, IEEE Transactions on Services Computing, SIAM Journal on Imaging Sciences, The Visual Computer, Experimental Mechanics, Traitement du Signal.

9.1.3. Invited talks

P.-F. Villard gave invited talks at:

- Markey Cancer Center and Radiology Department, September 18th, University of Kentucky
- Department of Mechanical Engineering and Department Of Biomedical Engineering (program of the seminar), William Maxwell Reed Seminar Series, September 18th, University of Kentucky.

9.1.4. Research administration

- Marie-Odile Berger is president of the Association française pour la reconnaissance et l'interprétation des formes (AFRIF).
- Marie-Odile Berger was a member of the jury d'admissibilité for chargé de recherche at Inria Nancy.
- Marie-Odile Berger was a member of the hiring committees for Professor position at Univ. Rouen.

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 science, some of them being accomplished in the field of image processing. Inria researchers have punctual 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 tightly related to image processing and computer vision is detailed below:

- Master: Signal analysis, 50 h, Université de Lorraine.
- Master: Augmented reality, 24 h, Télécom-Nancy, Université de Lorraine.
- Master: Introduction to computer vision, 12 h, 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, 12 h.
- Master : Introduction to signal processing and applications, 21 h, Ecole des Mines de Nancy
- Master: Augmented reality, 24 h, M2 IHM Metz
- Master: Augmented reality, 3 h, SUPELEC Metz.

9.2.2. Supervision

PhD defended in 2015: Nazim Haouchine, Modèles physiques pour la réalité augmentée des organes déformables, Marie-Odile Berger, Stéphane Cotin (MIMESIS).

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.

PhD in progress: Jaime Garcia Guevara, Vers une utilisation clinique de la réalité augmentée pour la chirurgie hépatique, novembre 2015, Marie-Odile Berger, Stéphane Cotin (MIMESIS).

PhD in progress: Raffaella Trivisonne, Image-guided real-time simulation using stochastic filtering. Novembre 2015, Erwan Kerrien, Stéphane Cotin (MIMESIS).

9.2.3. Juries

- Marie-Odile Berger was external reviewer of the PhD thesis of Z. Habibi and a member of the jury for the PhD thesis of F. Chadebecq.
- F. Sur was examinator for the PhD thesis of I. Rey-Otero.

9.3. Popularization

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

- Gilles Simon attended a forum on digital technologies in Lorraine (GEN#3) and gave a talk about the role of augmented reality in the industry 4.0.
- Erwan Kerrien is Chargé de Mission for scientific mediation at Inria Nancy-Grand Est. As such, he is a member of the steering committee of "la Maison pour la Science de Lorraine" [1], and member of the IREM [2] steering council. He also serves as the academic referent of an IREM 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.

[1] "Houses for Science" project, see http://maisons-pour-la-science.org/en

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

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[4] 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

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