IN PARTNERSHIP WITH:
CNRS

Université de Lorraine

Activity Report 2017

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

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Project-Team MAGRIT

Creation of the Project-Team: 2006 April 03

Keywords:

Computer Science and Digital Science:

A5.3. - Image processing and analysis
A5.4. - Computer vision
A5.4.1. - Object recognition
A5.4.5. - Object tracking and motion analysis
A5.4.6. - Object localization
A5.6. - Virtual reality, augmented reality
A5.10.2. - Perception

Other Research Topics and Application Domains:

B2.6. - Biological and medical imaging
B5.9. - Industrial maintenance
B9.4.3. - Physics

1. Personnel

Research Scientists

Marie-Odile Berger [Team leader, Inria, Senior Researcher, HDR]
Erwan Kerrien [Inria, Researcher]

Faculty Members

Fabien Pierre [Univ de Lorraine, Associate Professor, from Sep 2017]
Gilles Simon [Univ de Lorraine, Associate Professor]
Frédéric Sur [Univ de Lorraine, Associate Professor, HDR]
Pierre-Fredéric Villard [Univ de Lorraine, Associate Professor]
Brigitte Wrobel-Dautcourt [Univ de Lorraine, Associate Professor]

Post-Doctoral Fellow

Cong Yang [Univ de Lorraine, until Sep 2017]

PhD Students

Antoine Fond [Univ de Lorraine]
Jaime Garcia Guevara [Inria, co-supervision with EPC MIMESIS]
Vincent Gaudilliere [Inria, DGA Rapid]
Daryna Panicheva [Univ de Lorraine, from Oct 2017]
Raffaella Trivisonne [Inria, co-supervision with EPC MIMESIS]
Charlotte Delmas [Defended on Nov, 10th]
Pierre Rolin [until Mar 2017]

Intern

Daryna Panicheva [Univ de Lorraine, from Mar 2017 until Jul 2017]

Administrative Assistants

Isabelle Blanchard [Inria]
Emmanuelle Deschamps [Inria]
Virginie Priester [CNRS]

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 advances 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,...)

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 robust 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* methods has been investigated to achieve this aim [9]. 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 [4].

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 a 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 performed 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 of obtaining realistic and possibly dynamic models of organs suitable for real-time simulation [14].

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 [7] (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 [3]. 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 imaging modalities and the organ specificities. We thus only address a restricted number of medical applications –interventional neuro-radiology, laparoscopic surgery– 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 the training of surgeons or the re-education of patients.

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 an 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 [2]. 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 were 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 [8]. In the medical field, specific methods based on an adaptive evolutionary optimization strategy have been designed for estimating respiratory parameters [10]. 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 multimodal framework to help therapeutic decisions and interventional gestures. Contributions of the team focus on the developments of AR tools for neuro-navigation as well as the development of simulation tools 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 MIMESIS project team.

4.3. Experimental 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 Auvergne 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. Highlights of the Year

5.1. Highlights of the Year

Our paper entitled "The grid method for in-plane displacement and strain measurement: a review and analysis" [23] has been awarded with the Fylde Best Paper in Strain Prize 2016 by the British Society for Strain Measurement (BSSM).

6. New Software and Platforms

6.1. Ltrack

KEYWORDS: Augmented reality - Visual tracking

FUNCTIONAL DESCRIPTION: 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.

NEWS OF THE YEAR: A recovery procedure based on key-frames has been designed when the number of inliers tracked keypoints is too small.

- Contact: Marie-Odile Berger

6.2. PoLAR

Portable Library for Augmented Reality

Functional Description: PoLAR (Portable Library for Augmented Reality) is a framework which aims to help creating graphical applications for augmented reality, image visualization and medical imaging. PoLAR was designed to offer powerful visualization functionalities without the need to be a specialist in Computer Graphics. The framework provides an API to state-of-the-art libraries: Qt to build GUIs and OpenSceneGraph for high-end visualization, for researchers and engineers with a background in Computer Vision to be able to create beautiful AR applications, with little programming effort. The framework is written in C++ and published under the GNU GPL license

- Contact: Erwan Kerrien
- URL: http://polar.inria.fr

6.3. Fast>VP

Keywords: Vanishing points - Image rectification
Functional Description: Fast>VP is a fast and effective tool to detect vanishing points in uncalibrated images of urban or indoor scenes.

This tool also allows automatic rectification of the vertical planes in the scene, namely generating images where these planes appear as if they were observed from a fronto-parallel view.

It is the Matlab implementation of the algorithm described in [6].

- Contact: Gilles Simon
- URL: https://members.loria.fr/GSimon/fastvp/

6.4. TheGridMethod

The grid method toolbox
Keyword: Experimental mechanics
Functional Description: This Matlab toolbox implements several efficient and state-of-the art algorithms to estimate displacement and strain fields from grid images deposited on the surface of a specimen submitted to mechanical testing.

- Contact: Frédéric Sur
- URL: http://www.thegridmethod.net/

7. New Results

7.1. Matching and localization

Participants: Marie-Odile Berger, Vincent Gaudilliere, Antoine Fond, Pierre Rolin, Gilles Simon, Frédéric Sur.

Pose initialization
Estimating the pose of a camera from a model of the scene is a challenging problem when the camera is in a position not covered by the views used to build the model, because feature matching is difficult in such a situation. Several viewpoint simulation techniques have been recently proposed in this context. They generally come with a high computational cost, are limited to specific scenes such as urban environments or object-centered scenes, or need an initial guess for the pose. In his PhD thesis [12], P. Rolin has proposed a viewpoint simulation method well suited to most scenes and query views. Two major problems have been addressed: the positioning of the virtual viewpoints with respect to the scene, and the synthesis of geometrically consistent patches. Experimental results showed that patch synthesis dramatically improves the accuracy of the pose in case of difficult registration, with a limited additional computational cost.

Vanishing point detection

Accurate detection of *vanishing points* (VPs) is a prerequisite for many computer vision problems such as camera self-calibration, single-view structure recovery, video compass, robot navigation and augmented reality, among many others. we are interested in VP detection from uncalibrated monocular images. As any two parallel lines intersect in a VP, grouping line segments is a difficult problem that often yields a large number of spurious VPs. However, many tasks in computer vision, including the examples mentioned above, only require that the vertical (so-called *zenith*) VP and two or more horizontal VPs are detected. In that case, a lot of spurious VPs can be avoided by first detecting the zenith and the *horizon line* (HL), and then constraining the horizontal VPs on the HL. The zenith is generally easy to detect, as many lines converge towards that point in man-made environments. However, until recently, the HL was detected as an alignment of VPs, which led to a “chicken-and-egg” problem.

Last year, we showed that, assuming that the HL is inside the image boundaries, this line can usually be detected as an alignment of oriented line segments. This comes from the fact that any horizontal line segment at the height of the camera’s optical center projects to the HL regardless of its 3-D direction. In practice, doors, windows, floor separation lines but also man-made objects such as cars, road signs, street furniture, and so on, are often placed at eye level, so that alignments of oriented line segments around the HLs are indeed observed in most images from urban or indoor scenes. This allowed us to propose a new method for VP detection, that was fast in execution and easy to implement. However, it was only middle rank in terms of accuracy. This year, we effectively put the HL detection into an *a contrario* framework. This transposal along with other improvements allows us to obtain top-ranked results in terms of both rapidity of computation and accuracy of the HL, along with more relevant VPs than with the previous top-ranked methods. This work has been submitted to CVPR 2018 (IEEE Conference on Computer Vision and Pattern Recognition).

Facade detection and localization

Planar building facades are semantically meaningful city-scale landmarks. Such landmarks are essential for localization and guidance tasks in GPS-denied areas which are common in urban environments. Detection of facades is also key in augmented reality systems that allow for the annotation of prominent features in the user’s view. We proposed in [19] a novel object proposals method specific to building facades. We define new image cues that measure typical facade characteristics such as semantics, symmetry and repetitions. They are combined to generate a few facade candidates in urban environments fast. We show that our method outperforms state-of-the-art object proposals techniques for this task on the 1000 images of the Zurich Building Database. We demonstrated the interest of this procedure for augmented reality through facade recognition and camera pose initialization. In a very time-efficient pipeline we classify the candidates and match them to a facade references database using CNN-based descriptors. We proved that this approach is more robust to severe changes of viewpoint and occlusions than standard object recognition methods.

We are currently investigating ways to perform registration from this set of facade proposals. As point-based approaches may be inefficient to perform image/model matching due to changes in the illumination conditions, we propose to rely on semantic segmentation to improve the accuracy of this initial registration. Registration is here improved through an Expectation-Maximization framework. We especially introduce a Bayesian model that uses prior semantic segmentation as well as geometric structure of the facade reference modeled by L p Gaussian mixtures. This work has been submitted to CVPR’2018.

AR in industrial environments

As industrial environments are normally inundated with textureless objects and specular surfaces, it is difficult to capture enough features and build accurate 3D models for camera pose estimation using traditional 2D/3D matching-based approaches. Moreover, as people usually check industrial objects with free motions, recent CNN-based approaches could easily fail if the training data is not properly collected (e.g. does not cover enough views around the objects) and augmented (e.g. over-zoomed and over-augmented). For these challenges, we presented a novel protocol for six degrees of freedom (6-DOF) camera pose learning and estimation without any 3D reconstruction and matching processes. In particular, we proposed a visually controllable method to collect sufficient training images and their 6-DOF camera poses from different views and camera-object distances. Building upon this, we proposed a transfer learning scheme to train convolutional neural networks to detect objects and estimate the coarse camera pose from a single RGB image in an end-to-end manner. Experiments show that the trained convolutional network estimates each camera pose in about 5 ms and obtains approximately 13.3mm and 4.8 deg accuracy, which is compatible for training or maintenance tasks in industrial environments.

This work has been submitted to WACV 2018 (IEEE Winter Conf. on Applications of Computer Vision), and an extended version to TVCG (IEEE Transactions on Visualization and Computer Graphics).

7.2. Handling non-rigid deformations

Participants: Marie-Odile Berger, Jaime Garcia Guevara, Daryna Panicheva, Pierre-Frédéric Villard.

Elastic multi-modal registration

Image-guided hepatic surgery is progressively becoming a standard for certain interventions. However, requirements on limited radiation dosis result in lower quality images, making it difficult to localize tumors and other structures of interest. Within J. Guevara's PhD thesis, we have proposed an automatic registration method exploiting the matching of the vascular trees, visible in both pre- and intra-operative images. The graphs are automatically matched using an algorithm combining Gaussian Process Regression and biomechanical model [20]. Indeed, Gaussian Process regression allows for a rigorous and fast error propagation but is extremely versatile. On the contrary, using biomecanical transformations is slower but provides physically correct hypotheses. Integrating the two approaches allows us to dramatically improve the quality of the matching for moderate or large organ deformations while reducing significantly the computational cost.

Individual-specific heart valve modeling

In this work, we focused on the segmentation of the valve cords. As dataset, we used 8 CT images of porcine hearts. Those data were acquired during various times with a microCT scan machine.

Within D. Panicheva's Master thesis, we worked on modeling the mitral valve chordae by applying a RANSAC-based method designed to extract cylinders with elliptical basis from a set of 3D contour points. To limit the search area, the results of segmentation obtained with classical methods for tubular structures extraction were used as initial assumptions of cords location.

The proposed method allows us to significantly improve cords segmentation results compared with classical methods, in particular, the section size and the endpoints of the cords are accurately defined which is important for future mechanical modeling of the mitral valve.

INVIVE: The Individual Virtual Ventilator: Image-based biomechanical simulation of the diaphragm during mechanical ventilation

The motivation for the project is the serious medical condition, called ventilator induced diaphragmatic dysfunction (VIDD). During mechanical ventilation, air is pushed into the lungs resulting in a passive displacement of the diaphragm. This unnatural forcing results in loss of function in the muscle tissue. Our goal is to develop a simulator that allows for an in-silico exploration of the respiratory function with and without mechanical ventilation in combination with intervention measures that can reduce or prevent the risk for VIDD in the patients.

In the first year of the project, we worked on extracting a mesh from the segmented medical data that includes the boundary conditions. This work relies on analyzing the physiological constrains (rib motions, thoracic, abdominal and lung pressures) that can be measured.

We also worked on a method to solve differential equations on a complex geometric domain using the Radial Basis Function Partition of Unity Collocation Method (RBF-PUM). To use RBF-PUM for solving differential equations a covering of the domain has to be formed. The test implemented Poisson's diffusion equation on a domain defined by the diaphragm geometry. The diaphragm is not an easy case due to its thickness and shape.

This work is funded by the Swedish Research Council and realized within a collaboration with Uppsala University.

7.3. Interventional neuroradiology

Participants: Marie-Odile Berger, Charlotte Delmas, Erwan Kerrien, Raffaella Trivisonne.

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 any brain tissue except the vasculature. Moreover only two projective fluoroscopic views are available at most, with absolutely no depth hint. As a consequence, 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, our project aims 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 presented her research and results about fluoroscopic image segmentation, live stereo reconstruction of the guidewire, and fast 3D coil reconstruction, together with in-depth validation, in her PhD manuscript [11].

Image driven simulation
We consider image-driven simulation, applied to interventional neuroradiology as 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).

Raffaella Trivisonne started her PhD thesis in November 2015 (co-supervised by Stéphane Cotin, from MIMESIS team in Strasbourg) to address this research topic. We investigated various image and mechanical constraints, and proposed an efficient constrained shape from template approach where a set of radio-opaque markers on the catheter are tracked in the fluoroscopic images, and the surface of the vessel defines a set of unilateral constraints to prevent the catheter from crossing the vessel wall [22]. In particular, a constraint on the insertion point of the catheter at the groin was necessary to retrieve an accurate 3D shape of the micro-device.

7.4. Assessing metrological performance in experimental mechanics

Participant: Frédéric Sur.

In experimental mechanics, displacement and strain fields are estimated through the analysis of the deformation of patterns deposited on the surface of the tested specimen. Regular patterns such as grids are processed with spectral methods (the so-called "grid method"), and random speckle patterns are processed with digital image correlation (DIC). The scientific contribution obtained in 2017 concerns the comparison of the grid method and DIC. Since neither guidelines nor precise standard are available to perform a fair comparison between them, a methodology must first be defined. In [13], it is proposed to rely on three metrological parameters, namely the displacement resolution, the bias and the spatial resolution, which are not independent but linked.For the value of the bias fixed in the study of [13], the grid method features a better compromise than subset-based local DIC between displacement resolution and spatial resolution, in spite of its additional cost due to grid depositing. Work in progress concerns several aspects of DIC-based methods. In particular, we worked on synthetic speckle image rendering: ground truth databases are indeed crucial to assess the performance of the algorithms estimating displacement fields. It is, however, not straightforward to control any aspect of the rendering algorithm to ensure that performance assessment is not biased by the rendering algorithm. In addition, a popularization paper has been published in ERCIM News [15]. This work is part of a collaboration between Magrit project-team and Institut Pascal (Clermont-Ferrand).

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts 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 and ended in November 2017 and was supervised by M.-O. Berger and E. Kerrien. In her work, C. Delmas developped methods to reconstruct the micro-tools in 3D from fluoroscopy imaging. This will help clinical gesture by providing the physician with a better understanding of the relative positions of the tools and of the pathology.

9. Partnerships and Cooperations

9.1. Regional Initiatives

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 is co-supervised by M.-O. Berger and S. Cotin (MILESIS, Strasbourg). It follows on from our past works and aims at improving the reliability and the robustness of AR-based clinical procedures.

A one year post-doc position was granted by the Region Lorraine and the Université de Lorraine. Cong Yang started this position in November 2016 and ended in October 2017. He developed algorithms for object recognition in large-scale industrial environments (factories, vessels, ...), with the aim to enrich the operator's field of view with digital information and media. The main issues concerned the size of the environment, the nature of the objects (often non textured, highly specular, ...) and the presence of repeated patterns.

9.2. National Initiatives

9.2.1. Projet RAPID EVORA

Participants: M.-O. Berger, V. Gaudillière, G. Simon, C. Yang.
This 3-year project is supported by DGA/DGE and led by the SBS-Interactive company. The objective is to develop a prototype for location and object recognition in large-scale industrial environments (factories, ships...), with the aim to enrich the operator's field of view with digital information and media. The main issues concern the size of the environment, the nature of the objects (often non textured, highly specular...) and the presence of repeated patterns. Use cases will be provided by industrial partners such as DCNS and Areva. A class of officer cadets and professors of the Merchant Marine School will also be associated to judge the pedagogical interest of such a tool. A PhD student, Vincent Gaudillière, has been recruited to work on this project and his contract started in December 2016.

9.2.2. Project funded by GDR ISIS in collaboration with Institut Pascal

Participant: F. Sur.
Between September 2014 and September 2017, we have been engaged in a collaboration with Institut Pascal funded by GDR ISIS. The aim of this project was the investigation of image processing tools for enhancing the metrological performance of contactless measurement systems in experimental mechanics.

9.2.3. AEN Inria SOFA-InterMedS

Participants: R. Anxionnat (CHU Nancy), 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 the MIMESIS team and the Department of diagnostic and therapeutic interventional neuroradiology of Nancy University Hospital. Two PhD students - R. Trivisonne and J. Guarcia Guevara- are currently co-supervised by the Magrit and the MIMESIS teams.

9.3. International Initiatives

9.3.1. Inria Associate Teams Not Involved in an Inria International Lab

9.3.1.1. CURATIVE

Title: CompUteR-based simulAtion Tool for mItral Valve rEpair

International Partner (Institution - Laboratory - Researcher):

Harvard University (United States) - Harvard Biorobotics Lab (HBL) - Robert Howe

Start year: 2017

See also: https://team.inria.fr/curative/

The mitral valve of the heart ensures one-way flow of oxygenated blood from the left atrium to the left ventricle. However, many pathologies damage the 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 of the valve. However, it is technically difficult and outcomes are highly dependent upon the experience of the surgeon.

One way to facilitate the repair is to simulate the mechanical behavior of the pathological valve with subject-specific data. Our main goal is to provide surgeons with a tool to study solutions of mitral valve repairs. This tool would be a computer-based model that can simulate a potential surgical repair procedure in order to evaluate its success. The surgeons would be able to customize the simulation to a patient and to a technique of valve repair. Our methodology will be to realistically simulate valve closure based on segmentation methods faithful enough to capture subject-specific anatomy and based on a biomechanical model that can accurately model the range of properties exhibited by pathological valves.

During the first year, we worked on three aspects of this project: i) developing a fast image-based mitral valve simulation, ii) extracting the mitral valve chordae from a CT scan (see section New Results) and iii) developing a Cosserat model for catheter robot for heart surgical procedures. The work on fast image-based mitral valve simulation has been accepted to the The International Journal of Medical Robotics and Computer Assisted Surgery [17].

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Douglas Perrin, a senior researcher at Harvard University (http://people.seas.harvard.edu/~dperrin), visited the MAGRIT team from 05/29/17 to 06/02/17. He gave a talk to the Department 1 in Loria, he helped out with scientific understanding of the mitral valve anatomy and he provided advice to Daryna Panicheva supervision during one week.

Thomas Waite, an undergrad student at Harvard University, visited the MAGRIT team from 06/05/17 to 06/09/17. He gave a talk to the Department 1 in Loria, he worked with Pierre-Frédéric Villard on modeling a heart surgical catheter robot with Cosserat model and started writing a journal paper on this subject.

9.4.2. Visits to International Teams

9.4.2.1. Research Stays Abroad

Pierre-Frederic Villard spent one month (August 2017) at Uppsala University working on the INVIVE project http://www.it.uu.se/research/scientific_computing/project/rbf/biomech. His work there includes supervising PhD student Igor Tominec, meeting with a physiologist expert in respiration muscles and working on both the mesh and the boundary conditions in the case of a passive diaphragm.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. Member of the Organizing Committees

- M.-O Berger co-organized with E. Marchand (IRISA) a one-day workshop on Augmented Reality in Paris in June 2017.

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

- M.-O. Berger was a member of the program committee of: International Conference on Robotic and automation (ICRA 2016), International Conference on Information Processing in Computer assisted interventions (IPCAI 2017), International Conference on Robotics and Automation (IROS 2017), International Symposium on Mixed and Augmented Reality (ISMAR 2017)
- E. Kerrien was a member of the program committee of the Medical Image Computing and Computer Assisted Interventions Conference (MICCAI 2017).
- G. Simon was a member of the program committee of IEEE Virtual Reality 2018
- P.-F Villard was a member of the program committee of IADIS Computer Graphics, Visualization, Computer Vision and Image Processing 2017, and of the Eurographics Workshop on Visual Computing for Biology and Medicine 2017.

10.1.3. Journal

10.1.3.1. Reviewer - Reviewing Activities

The members of the team reviewed articles in IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Multimedia, Experimental Mechanics, Traitement du Signal, IEEE Transactions on Biomedical Engineering.

10.1.4. Invited Talks

- Marie-Odile Berger was a keynote speaker at ISMAR'2017.
- Pierre-Frederic gave a seminar at the department of information technology of Uppsala University on August 30th. Title: 'Application in treatment planning, training simulators and on-line treatment' http://user.it.uu.se/~maya/seminar_abstracts/sem_fall17/PFVillard.
- Pierre-Frederic Villard gave a talk at the Harvard Biorobotics Lab on October 31st. Title: 'Automatic Reconstruction of Mitral Valve Chordae'.

10.1.5. Scientific Expertise

- Marie-Odile Berger is the president of the Association française pour la reconnaissance et l'interprétation des formes (AFRIF)

10.1.6. Research Administration

- Marie-Odile Berger is a member of the Inria evaluation committee.
- Gilles Simon is Chargé de Mission Loria to take part in an EIT's KIC (Knowledge and Innovation Communities) proposal on the topic of manufacturing (KIC Added-value Manufacturing).
- E. Kerrien and G. Simon were members of selection committees for Assistant Professor hiring.

10.2. Teaching - Supervision - Juries

10.2.1. 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 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:

- Licence: Graphic and haptic rendering, 30h, IUT Saint-Dié des Vosges (P.-F. Villard).
- Licence: Image processing, 30h, IUT Saint-Dié des Vosges (P.-F. Villard).
- Licence: 3D programming, 30h, IUT Saint-Dié des Vosges (P.-F. Villard).
- Game design with Unity3D , 15h, IUT Saint-Dié des Vosges (P.-F. Villard).
- Introduction to augmented reality, 6h, IUT Saint-Dié des Vosges (P.-F. Villard).
- Master: Signal analysis, 50 h, Université de Lorraine (F. Sur).
- Master: Augmented reality, 24 h, Télécom-Nancy, Université de Lorraine (G. Simon).
- Master : Introduction to computer vision, 12h, Université de Lorraine ((M.-O. Berger).
- Master : Shape recognition, 15 h, Université de Lorraine (M.-O. Berger).
- Master : Computer vision: foundations and applications, 15 h, Université de Lorraine (M.-O. Berger).
- Master : Introduction to image processing, 21 h, École des Mines de Nancy (M.-O. Berger, R. Kerrien)
- Master : Image processing for Geosciences, ENSG, 12h (M.-O. Berger).
- Master : Introduction to signal processing and applications, 21 h, Ecole des Mines de Nancy (F. Sur).
- Master : Augmented reality, 24h, M2 IHM Metz (G. Simon).
- Master : Augmented reality, 3 h, SUPELEC Metz (G.simon).
- Master : Virtual worlds, 10h, M2 Cognitive Sciences and Applications, UFR Math-Info, Université de Lorraine (P.-F. Villard).

Frédéric Sur is the head of the Industrial Engineering and Applied Mathematics department at Mines Nancy.

10.2.2. Supervision

PhD: Pierre Rolin, Calcul de pose par simulation de points de vue pour la réalité augmentée, octobre 2013, Marie-Odile Berger, Frédéric Sur. PhD defended in March 2017.

PhD: Charlotte Delmas, Reconstruction 3D des outils chirurgicaux en radiologie interventionnelle, avril 2013, Marie-Odile Berger, Erwan Kerrien. PhD defended in november 2017.

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 agmentée pour la chirurgie hépatique, octobre 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).

PhD in progress: Vincent Gaudillière, Reconnaissance de lieux et d'objets pour la réalité augmentée en milieux complexes, décembre 2016, Marie-Odile Berger, Gilles Simon.

PhD in progress: Daryna Panicheva, Image-based Biomechanical Simulation of Mitral Valve Closure, octobre 2017, Marie-Odile Berger, Pierre-Frédéric Villard.

10.2.3. Juries

Marie-Odile Berger was external reviewer of the PhD of Canseng Jiang (Université de Bourgogne), Angélique Loesch (Université de Clarmont Auvergne) and Shaifali Parashar (Université de Clermont Auvergne).

10.3. Popularization

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

- 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 “Maison pour la Science de Lorraine, and member of the IREM [1] steering council. He also serves as the academic referent of an IREM working group aiming at introducing computer science in middle and high school curricula. Among other activites, he was also an associate researcher to a MATh.en.JEANS workshop, and he participated in the creation of a MOOC for teachers of the new ICN option (Informatique et Création Numérique - *Computer Science and Digital Creation*) at the beginning of high school curriculum.
- Gilles Simon participated to the “Fête de la science 2017” at the Faculté de Sciences et Technologies of the Université de Lorraine. He presented unplugged activities of computer science.
- Pierre-Frédéric Villard participated to open days and science festival in the IUT of Saint-Dié des Vosges. He presented augmented and virtual reality demos and their link to the high school mathematics program.

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Major publications by the team in recent years

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