IN PARTNERSHIP WITH:
Université Haute Bretagne (Rennes 2)

Université Rennes 1

École normale supérieure de Rennes

Activity Report 2015

Project-Team MIMETIC

Analysis-Synthesis Approach for Virtual Human Simulation

IN COLLABORATION WITH: Institut de recherche en informatique et systèmes aléatoires (IRISA)

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Interaction and visualization

Table of contents

Project-Team MIMETIC

Creation of the Team: 2011 January 01, updated into Project-Team: 2014 January 01

Keywords:

Computer Science and Digital Science:

5.1.5. - Body-based interfaces
5.4.2. - Activity recognition
5.5.3. - Computational photography
5.5.4. - Animation
5.6. - Virtual reality, augmented reality

Other Research Topics and Application Domains:

1.3.2. - Cognitive science
2.5. - Handicap and personal assistances
2.8. - Sports, performance, motor skills
5.8. - Learning and training
7.1.1. - Pedestrian traffic and crowds
9.2.2. - Cinema, Television
9.2.3. - Video games
9.3. - Sports

1. Members

Research Scientists

Ludovic Hoyet [Inria, Researcher]
Julien Pettré [Inria, Researcher, HdR]

Faculty Members

Franck Multon [Team leader, Univ. Rennes II, Professor, HdR]
Benoit Bideau [Univ. Rennes II, Associate Professor, HdR]
Nicolas Bideau [Univ. Rennes II, Associate Professor]
Marc Christie [Univ. Rennes I, Associate Professor]
Armel Crétual [Univ. Rennes II, Associate Professor, HdR]
Georges Dumont [Normale Sup Rennes, Professor, HdR]
Coralie Germain [Normale Sup Rennes, until Aug 2015]
Richard Kulpa [Univ. Rennes II, Associate Professor, HdR]
Fabrice Lamarche [Univ. Rennes I, Associate Professor]
Guillaume Nicolas [Univ. Rennes II, Associate Professor]
Anne-Hélène Olivier [Univ. Rennes II, Associate Professor]
Charles Pontonnier [Normale Sup Rennes, Associate Professor]

Engineers

Julian Joseph [Inria, until Sep 2015]
Tristan Le Bouffant [Inria, until Nov 2015, granted by ANR CHROME project]
Ricardo Marques [Inria, until Sep 2015]
Anthony Sorel [Univ. Rennes II, granted by ANR ENTRACTE project]
David Wolinski [Inria]

PhD Students

Julien Bruneau [Univ. Rennes I]
Ana Lucia Cruz Ruiz [Inria, granted by ANR ENTRACTE project]
Kevin Jordao [Inria, granted by ANR CHROME project]
Carl-Johan Jorgensen [Univ. Rennes I, until Jun 2015]
Sean Lynch [Univ. Rennes II, from Sep 2015]
Antoine Muller [Normale Sup Rennes]
Pierre Plantard [Univ. Rennes II, granted by CIFRE]
Sébastien Cordillet [Univ. Rennes II, granted by ARED]
Cunka Sanokho [Univ. Rennes I, granted by ANR CINECITTA project]
Steve Tonneau [INSA Rennes, until Feb 2015]
Hui-Yin Wu [Inria]

Post-Doctoral Fellows
Panayiotis Charalambous [Inria]
Diane Haering [Inria, from Dec 2015]
Christophe Lino [Univ. Rennes I]

Visiting Scientist
Zhiguo Ren [PHD student, until Jun 2015]

Administrative Assistant
Nathalie Denis [Inria]

Others
Felix Demore [Normale Sup Rennes, Internship, from May 2015 until Jul 2015]
Audrey Gilet [Inria, Internship, from Jun 2015 until Aug 2015]
Jonathan Levy [Normale Sup Rennes, Internship, from May 2015 until Jul 2015]
Felix Massy de La Chesneraye [Inria, Internship, from Sep 2015]
Salim Nadour [Univ. Rennes I, Internship, from Jul 2015 until Aug 2015]
Gurvan Priem [Inria, Internship, until Sep 2015]
Mickael Salomez [Univ. Rennes I, Internship, from Jul 2015 until Aug 2015]

2. Overall Objectives

2.1. Presentation

MimeTIC is a multidisciplinary team whose aim is to better understand and model human activity in order to simulate realistic autonomous virtual humans: realistic behavior, realistic motions and realistic interactions with other characters and users. It leads to modeling the complexity of a human body, his environment where he can pick-up information and he can act on it. A specific focus is dedicated to human physical activity and sports as it raises the highest constraints and the highest complexity when addressing these problems. Thus, MimeTIC is composed of experts in computer science whose research interests are computer animation, behavioral simulation, motion simulation, crowds and interaction between real and virtual humans. MimeTIC is also composed of experts in sports science, motion analysis, motion sensing, biomechanics and motion control. Hence, the scientific foundations of MimeTIC are motion sciences (biomechanics, motion control, perception-action coupling, motion analysis), computational geometry (modeling of the 3D environment, motion planning, path planning) and design of protocols in immersive environments (use of virtual reality facilities to analyze human activity).

Thanks to these skills, we wish to reach the following objectives: to make virtual human behave, move and interact in a natural manner in order to increase immersion and to improve knowledge on human motion control. In real situations (see Figure 1), people have to deal with their physiological, biomechanical and neurophysiological capabilities in order to reach a complex goal. Hence MimeTIC addresses the problem of modeling the anatomical, biomechanical and physiological properties of human being. Moreover this character has to deal with his environment. Firstly he has to perceive this environment and pick-up relevant information. MimeTIC thus addresses the problem of modeling the environment including its geometry and associated semantic information. Secondly, he has to act on this environment to reach his goal. It leads to cognivitve processes, motion planning, joint coordination and force production in order to act on this environment.

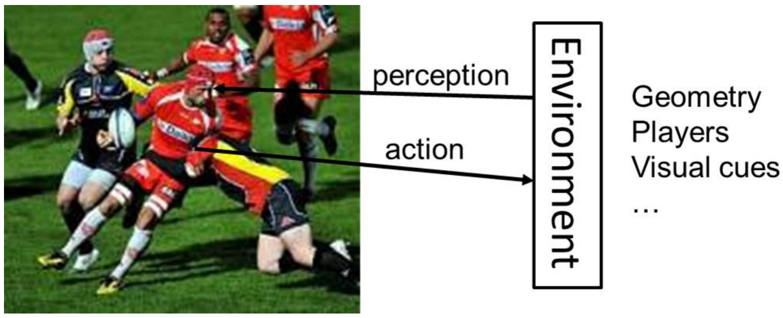

Figure 1. Main objective of MimeTIC: better understand human activity in order to better simulate virtual humans. It leads to modeling the complexity of human body, his environment where he can pick-up information and he can act on it.

In order to reach the above objectives, MimeTIC has to address three main challenges:

- dealing with the intrinsic complexity of human being, especially when addressing the problem of interactions between people for which it is impossible to predict and model all the possible states of the system,
- making the different components of human activity control (such as the biomechanical and physical, the reactive, cognitive, rational and social layers) interact while each of them is modeled with completely different states and time sampling,
- and being able to measure human activity while dealing with the compromise between ecological and controllable protocols, and to be able to extract relevant information in wide databases of information.

Contrary to many classical approaches in computer simulation, which mostly propose simulation without trying to understand how real people do, the team promotes a coupling between human activity analysis and synthesis, as shown in Figure 2.

In this research path, improving knowledge on human activity enables us to highlight fundamental assumptions about natural control of human activities. These contributions can be promoted in e.g. biomechanics, motion sciences, neurosciences. According to these assumptions we propose new algorithms for controlling autonomous virtual humans. The virtual humans can perceive their environment and decide of the most natural action to reach a given goal. This work is promoted in computer animation, virtual reality and has some applications in robotics through collaborations. Once autonomous virtual humans have the ability to act as real humans should do in the same situation, it is possible to make them interact with other autonomous characters (for crowds or group simulations) and with real users. The key idea here is to analyze to what extent the assumptions proposed at the first stage lead to natural interactions with real users. This process enables the validation of both our assumptions and our models.

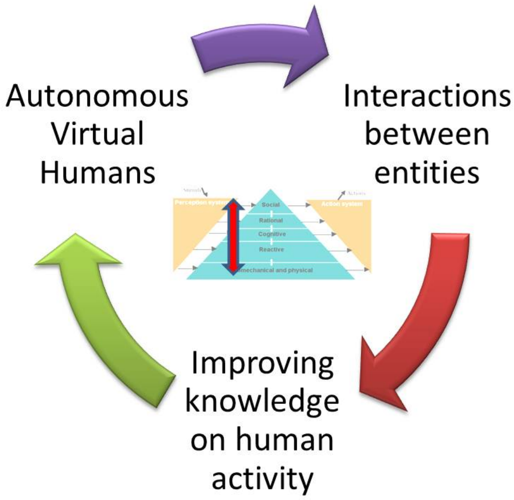

Figure 2. Research path of MimeTIC: coupling analysis and synthesis of human activity. Analysis provides us with more realistic autonomous characters and synthesis enables us to evaluate assumptions about human motion control.

Among all the problems and challenges described above, MimeTIC focuses on the following domains of research:

- motion sensing which is a key issue to extract information from raw motion capture systems and thus to propose assumptions on how people control their activity,
- human activity & virtual reality, which is explored through sports application in MimeTIC. This domain enables the design of new methods for analyzing the perception-action coupling in human activity, and to validate whether the autonomous characters lead to natural interactions with users,
- crowds and groups simulation which is dedicated to model the interactions in small groups of individuals and to see how to extend to larger groups, such as crowds with lot of individual variability,
- virtual storytelling which enables us to design and simulate complex scenarios involving several humans who have to satisfy numerous complex constraints (such as adapting to the real-time environment in order to play an imposed scenario), and to design the coupling with the camera scenario to provide the user with a real cinematographic experience,
- biomechanics which is essential to offer autonomous virtual humans who can react to physical constraints in order to reach high-level goals, such as maintaining balance in dynamic situation or selecting a natural motor behavior among all the theoretical solution space for a given task,
- and autonomous characters which is a transversal domain that can reuse the results of all the other domains to make these heterogeneous assumptions and models provide the character with natural behaviors and autonomy.

3. Research Program

3.1. Biomechanics and Motion Control

Human motion control is a very complex phenomenon that involves several layered systems, as shown in Figure 3. Each layer of this controller is responsible for dealing with perceptual stimuli in order to decide the actions that should be applied to the human body and his environment. Due to the intrinsic complexity of the information (internal representation of the body and mental state, external representation of the environment) used to perform this task, it is almost impossible to model all the possible states of the system. Even for simple problems, there generally exist infinity of solutions. For example, from the biomechanical point of view, there are much more actuators (i.e. muscles) than degrees of freedom leading to infinity of muscle activation patterns for a unique joint rotation. From the reactive point of view there exist infinity of paths to avoid a given obstacle in navigation tasks. At each layer, the key problem is to understand how people select one solution among these infinite state spaces. Several scientific domains have addressed this problem with specific points of view, such as physiology, biomechanics, neurosciences and psychology.

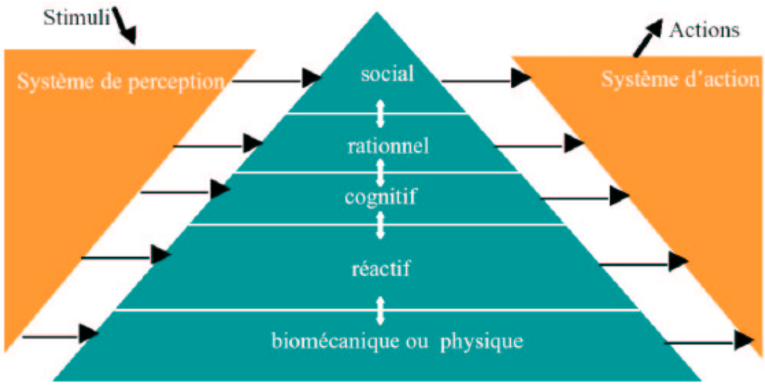

Figure 3. Layers of the motion control natural system in humans.

In biomechanics and physiology, researchers have proposed hypotheses based on accurate joint modeling (to identify the real anatomical rotational axes), energy minimization, force and torques minimization, comfort maximization (i.e. avoiding joint limits), and physiological limitations in muscle force production. All these constraints have been used in optimal controllers to simulate natural motions. The main problem is thus to define how these constraints are composed altogether such as searching the weights used to linearly combine these criteria in order to generate a natural motion. Musculoskeletal models are stereotyped examples for which there exist infinity of muscle activation patterns, especially when dealing with antagonist muscles. An unresolved problem is to define how using the above criteria to retrieve the actual activation patterns while optimization approaches still lead to unrealistic ones. It is still an open problem that will require multidisciplinary skills including computer simulation, constraint solving, biomechanics, optimal control, physiology and neurosciences.

In neuroscience, researchers have proposed other theories, such as coordination patterns between joints driven by simplifications of the variables used to control the motion. The key idea is to assume that instead of controlling all the degrees of freedom, people control higher level variables which correspond to combination of joint angles. In walking, data reduction techniques such as Principal Component Analysis have shown that lower-limb joint angles are generally projected on a unique plan whose angle in the state space is associated with energy expenditure. Although there exist knowledge on specific motion, such as locomotion or grasping, this type of approach is still difficult to generalize. The key problem is that many variables are coupled and it is very difficult to objectivly study the behavior of a unique variable in various motor tasks. Computer simulation is a promising method to evaluate such type of assumptions as it enables to accurately control all the variables and to check if it leads to natural movements.

Neurosciences also address the problem of coupling perception and action by providing control laws based on visual cues (or any other senses), such as determining how the optical flow is used to control direction in navigation tasks, while dealing with collision avoidance or interception. Coupling of the control variables is enhanced in this case as the state of the body is enriched by the big amount of external information that the subject can use. Virtual environments inhabited with autonomous characters whose behavior is driven by motion control assumptions is a promising approach to solve this problem. For example, an interesting problem in this field is navigation in an environment inhabited with other people. Typically, avoiding static obstacles together with other people displacing into the environment is a combinatory problem that strongly relies on the coupling between perception and action.

One of the main objectives of MimeTIC is to enhanche knowledge on human motion control by developing innovative experiments based on computer simulation and immersive environments. To this end, designing experimental protocols is a key point and some of the researchers in MimeTIC have developed this skill in biomechanics and perception-action coupling. Associating these researchers to experts in virtual human simulation, computational geometry and constraints solving enable us to contribute to enhance fundamental knowleged in human motion control.

3.2. Experiments in Virtual Reality

Understanding interaction between humans is very challenging because it addresses many complex phenomena including perception, decision-making, cognition and social behaviors. Moreover, all these phenomena are difficult to isolate in real situations, it is thus very complex to understand the influence of each of them on the interaction. It is then necessary to find an alternative solution that can standardize the experiments and that allows the modification of only one parameter at a time. Video was first used since the displayed experiment is perfectly repeatible and cut-offs (stop the video at a specific time before its end) allow having temporal information. Nevertheless, the absence of adapted viewpoint and stereoscopic vision does not provide depth information that are very meaningful. Moreover, during video recording session, the real human is acting in front of a camera and not an opponent. The interaction is then not a real interaction between humans.

Virtual Reality (VR) systems allow full standardization of the experimental situations and the complete control of the virtual environment. It is then possible to modify only one parameter at a time and observe its influence on the perception of the immersed subject. VR can then be used to understand what information are picked up to make a decision. Moreover, cut-offs can also be used to obtain temporal information about when these information are picked up. When the subject can moreover react as in real situation, his movement (captured in real time) provides information about his reactions to the modified parameter. Not only is the perception studied, but the complete perception-action loop. Perception and action are indeed coupled and influence each other as suggested by Gibson in 1979.

Finally, VR allows the validation of the virtual human models. Some models are indeed based on the interaction between the virtual character and the other humans, such as a walking model. In that case, there are two ways to validate it. First, they can be compared to real data (e.g. real trajectories of pedestrians). But such data are not always available and are difficult to get. The alternative solution is then to use VR. The validation of the realism of the model is then done by immersing a real subject in a virtual environment in which a virtual character is controlled by the model. Its evaluation is then deduced from how the immersed subject reacts when interacting with the model and how realistic he feels the virtual character is.

3.3. Computational Geometry

Computational geometry is a branch of computer science devoted to the study of algorithms which can be stated in terms of geometry. It aims at studying algorithms for combinatorial, topological and metric problems concerning sets of points in Euclidian spaces. Combinatorial computational geometry focuses on three main problem classes: static problems, geometric query problems and dynamic problems.

In static problems, some input is given and the corresponding output needs to be constructed or found. Such problems include linear programming, Delaunay triangulations, and Euclidian shortest paths for instance. In geometric query problems, commonly known as geometric search problems, the input consists of two parts: the search space part and the query part, which varies over the problem instances. The search space typically needs to be preprocessed, in a way that multiple queries can be answered efficiently. Some typical problems are range searching, point location in a portioned space, nearest neighbor queries for instance. In dynamic problems, the goal is to find an efficient algorithm for finding a solution repeatedly after each incremental modification of the input data (addition, deletion or motion of input geometric elements). Algorithms for problems of this type typically involve dynamic data structures. Both of previous problem types can be converted into a dynamic problem, for instance, maintaining a Delaunay triangulation between moving points.

The Mimetic team works on problems such as crowd simulation, spatial analysis, path and motion planning in static and dynamic environments, camera planning with visibility constraints for instance. The core of those problems, by nature, relies on problems and techniques belonging to computational geometry. Proposed models pay attention to algorithms complexity to be compatible with performance constraints imposed by interactive applications.

4. Application Domains

4.1. Autonomous Characters

Autonomous characters are becoming more and more popular has they are used in an increasing number of application domains. In the field of special effects, virtual characters are used to replace secondary actors and generate highly populated scenes that would be hard and costly to produce with real actors. In video games and virtual storytelling, autonomous characters play the role of actors that are driven by a scenario. Their autonomy allows them to react to unpredictable user interactions and adapt their behavior accordingly. In the field of simulation, autonomous characters are used to simulate the behavior of humans in different kind of situations. They enable to study new situations and their possible outcomes.

One of the main challenges in the field of autonomous characters is to provide a unified architecture for the modeling of their behavior. This architecture includes perception, action and decisional parts. This decisional part needs to mix different kinds of models, acting at different time scale and working with different nature of data, ranging from numerical (motion control, reactive behaviors) to symbolic (goal oriented behaviors, reasoning about actions and changes).

In the MimeTIC team, we focus on autonomous virtual humans. Our problem is not to reproduce the human intelligence but to propose an architecture making it possible to model credible behaviors of anthropomorphic virtual actors evolving/moving in real time in virtual worlds. The latter can represent particular situations studied by psychologists of the behavior or to correspond to an imaginary universe described by a scenario writer. The proposed architecture should mimic all the human intellectual and physical functions.

4.2. Biomechanics and Motion Analysis

Biomechanics is obviously a very large domain. This large set can be divided regarding to the scale at which the analysis is performed going from microscopic evaluation of biological tissues' mechanical properties to macroscopic analysis and modeling of whole body motion. Our topics in the domain of biomechanics mainly lie within this last scope.

The first goal of such kind of research projects is a better understanding of human motion. The MimeTic team addresses three different situations: everyday motions of a lambda subject, locomotion of pathological subjects and sports gesture.

In the first set, Mimetic is interested in studying how subjects maintain their balance in highly dynamic conditions. Until now, balance havec nearly always been considered in static or quasi-static conditions. The knowledge of much more dynamic cases still has to be improved. Our approach has demonstrated that first of all, the question of the parameter that will allow to do this is still open. We have also taken interest into collision avoidance between two pedestrian. This topic includes the research of the parameters that are interactively controlled and the study of each one's role within this interaction.

When patients, in particular those suffering from central nervous system affection, cannot have an efficient walking it becomes very useful for practicians to benefit from an objective evaluation of their capacities. To propose such help to patients following, we have developed two complementary indices, one based on kinematics and the other one on muscles activations. One major point of our research is that such indices are usually only developed for children whereas adults with these affections are much more numerous.

Finally, in sports, where gesture can be considered, in some way, as abnormal, the goal is more precisely to understand the determinants of performance. This could then be used to improve training programs or devices. Two different sports have been studied: the tennis serve, where the goal was to understand the contribution of each segments of the body in ball's speed and the influence of the mechanical characteristics of the fin in fin swimming.

After having improved the knowledge of these different gestures a second goal is then to propose modeling solutions that can be used in VR environments for other research topics within MimeTic. This has been the case, for exemple, for the colision avoidance.

4.3. Crowds

Crowd simulation is a very active and concurrent domain. Various disciplines are interested in crowds modeling and simulation: Mathematics, Cognitive Sciences, Physics, Computer Graphics, etc. The reason for this large interest is that crowd simulation raise fascinating challenges.

At first, crowd can be first seen as a complex system: numerous local interactions occur between its elements and results into macroscopic emergent phenomena. Interactions are of various nature and are undergoing various factors as well. Physical factors are crucial as a crowd gathers by definition numerous moving people with a certain level of density. But sociological, cultural and psychological factors are important as well, since crowd behavior is deeply changed from country to country, or depending on the considered situations. On the computational point of view, crowd push traditional simulation algorithms to their limit. An element of a crowd is subject to interact with any other element belonging the same crowd, a naive simulation algorithm has a quadratic complexity. Specific strategies are set to face such a difficulty: level-of-detail techniques enable scaling large crowd simulation and reach real-time solutions.

MimeTIC is an international key contributor in the domain of crowd simulation. Our approach is specific and based on three axis. First, our modeling approach is founded on human movement science: we conducted challenging experiment on the motion of groups. Second: we developed high-performance solutions for crowd simulation. Third, we develop solutions for realistic navigation in virtual world to enable interaction with crowds in Virtual Reality.

4.4. Motion Sensing

Recording human activity is a key point of many applications and fundamental works. Numerous sensors and systems have been proposed to measure positions, angles or accelerations of the user's body parts. Whatever the system is, one of the main problem is to be able to automatically recognize and analyze the user's performance according to poor and noisy signals. Human activity and motion are subject to variability: intra-variability due to space and time variations of a given motion, but also inter-variability due to different styles and anthropometric dimensions. MimeTIC has addressed the above problems in two main directions.

Firstly, we have studied how to recognize and quantify motions performed by a user when using accurate systems such as Vicon (product of Oxford Metrics) or Optitrack (product of Natural Point) motion capture systems. These systems provide large vectors of accurate information. Due to the size of the state vector (all the degrees of freedom) the challenge is to find the compact information (named features) that enables the automatic system to recognize the performance of the user. Whatever the method is used, finding these relevant features that are not sensitive to intra-individual and inter-individual variability is a challenge. Some researchers have proposed to manually edit these features (such as a Boolean value stating if the arm is moving forward or backward) so that the expertise of the designer is directly linked with the success ratio. Many proposals for generic features have been proposed, such as using Laban notation which was introduced to encode dancing motions. Other approaches tend to use machine learning to automatically extract these features. However most of the proposed approaches were used to seek a database for motions which properties correspond to the features of the user's performance (named motion retrieval approaches). This does not ensure the retrieval of the exact performance of the user but a set of motions with similar properties.

Secondly, we wish to find alternatives to the above approach which is based on analyzing accurate and complete knowledge on joint angles and positions. Hence new sensors, such as depth-cameras (Kinect, product of Microsoft) provide us with very noisy joint information but also with the surface of the user. Classical approaches would try to fit a skeleton into the surface in order to compute joint angles which, again, lead to large state vectors. An alternative would be to extract relevant information directly from the raw data, such as the surface provided by depth cameras. The key problem is that the nature of these data may be very different from classical representation of human performance. In MimeTIC, we try to address this problem in specific application domains that require picking specific information, such as gait asymmetry or regularity for clinical analysis of human walking.

4.5. VR and Sports

Sport is characterized by complex displacements and motions. These motions are dependent on visual information that the athlete can pick up in his environment, including the opponent's actions. The perception is thus fundamental to the performance. Indeed, a sportive action, as unique, complex and often limited in time, requires a selective gathering of information. This perception is often seen as a prerogative for action, it then takes the role of a passive collector of information. However, as mentioned by Gibson in 1979, the perception-action relationship should not be considered sequential but rather as a coupling: we perceive to act but we must act to perceive. There would thus be laws of coupling between the informational variables available in the environment and the motor responses of a subject. In other words, athletes have the ability to directly perceive the opportunities of action directly from the environment. Whichever school of thought considered, VR offers new perspectives to address these concepts by complementary using real time motion capture of the immersed athlete.

In addition to better understanding sports and interaction between athletes, VR can also be used as a training environment as it can provide complementary tools to coaches. It is indeed possible to add visual or auditory information to better train an athlete. The knowledge found in perceptual experiments can be for example used to highlight the body parts that are important to look at to correctly anticipate the opponent's action.

4.6. Interactive Digital Storytelling

Interactive digital storytelling, including novel forms of edutainment and serious games, provides access to social and human themes through stories which can take various forms and contains opportunities for massively enhancing the possibilities of interactive entertainment, computer games and digital applications. It provides chances for redefining the experience of narrative through interactive simulations of computer-generated story worlds and opens many challenging questions at the overlap between computational narratives, autonomous behaviours, interactive control, content generation and authoring tools.

Of particular interest for the Mimetic research team, virtual storytelling triggers challenging opportunities in providing effective models for enforcing autonomous behaviours for characters in complex 3D environments. Offering both low-level capacities to characters such as perceiving the environments, interacting with the environment and reacting to changes in the topology, on which to build higher-levels such as modelling abstract representations for efficient reasonning, planning paths and activities, modelling cognitive states and behaviours requires the provision of expressive, multi-level and efficient computational models. Furthermore virtual storytelling requires the seamless control of the balance between the autonomy of characters and the unfolding of the story through the narrative discourse. Virtual storytelling also raises challenging questions on the conveyance of a narrative through interactive or automated control of the cinematography (how to stage the characters, the lights and the cameras). For example, estimating visibility of key subjects, or performing motion planning for cameras and lights are central issues for which have not received satisfactory answers in the litterature.

4.7. VR and Ergonomics

The design of workstations nowadays tends to include assessment steps in a Virtual Environment (VE) to evaluate ergonomic features. This approach is more cost-effective and convenient since working directly on the Digital Mock-Up (DMU) in a VE is preferable to constructing a real physical mock-up in a Real Environment (RE). This is substantiated by thefact that a Virtual Reality (VR) set-up can be easily modified, enabling quick adjustmentsofthe workstation design.Indeed, the aim of integrating ergonomics evaluation tools inVE is to facilitate the design process, enhance the design efficiency, and reduce the costs.

The development of such platforms ask for several improvements in the field of motion analysis and VR: the interactions have to be as fidelistic as possible to properly mimic the motions performed in real environments, the fidelity of the simulator need also to be correctly evaluated, and motion analysis tools have to be able to provide in real-time biomechanics quantities usable by ergonomists to analyse and improve the working conditions.

5. Highlights of the Year

5.1. Highlights of the Year

In March 2015, Ludovic Hoyet arrived in MimeTIC has full-time Inria CR2 researcher. It’s an important event for the team as it will reinforce and push the Virtual Human simulation topic in the team. Ludovic has a unique expertise in both computer animation and perceptual studies which will enable us to tackle original problems, such as developping innovative animation methods while taking the perception of the user into account, contrary to classical approaches based on dynamic simulation.

Our work “Intuitive and Efficient Camera Control with the Toric Space”, co-authored by Christophe Lino and Marc Christie has been selected at SIGGRAPH 2015, the premier and most selective computer graphics scientific event. The paper presents a novel representation to interactively and intuitively manipulate cameras, and to perform interpolations between camera keyframes while maintaining on-screen visual properties. Results of this paper, together with earlier work on automated viewpoint computation (Directors Lens patent), are now available as a plugin in Autodesk’s Motion Builder. This technology is exploited by the french SME Solidanim http://www.solidanim.com through a technological transfer partnership.

Platforms in Immerstar project: Immerstar is the new name of our jointed platforms, namely Immersia on Inria campus and Immermove on ENS Campus. This year, we succeeded to end up the building of the first phase of Immermove platform. Associated with a sport area equipped with a high end motion capture system, an immersive setup has been installed. It is a L-shaped setup with 12m*4m front screen and floor. It allows to perform immersive interaction experiments between real and virtual human. To follow this first phase, and sustained by Inria and our academic institutions, we succeeded to the CPER call that will be implemented from 2016 to 2020. We will have the opportunity to invest and to improve the two immersive platforms (Immersia and Immermove) and their possibilities of distantly collaborate.

5.1.1. Awards

Caroline Martin won the "Jean Vives" Award for her work on the analysis of tennis serves. This price is discerned by the Académie nationale olympique française and given during the 40th congress of the Society of Biomechanics, 2015.

6. New Software and Platforms

6.1. AsymGait

Asymmetry index for clinical gait analysis based on depth images
KEYWORDS: Motion analysis - Kinect - Clinical analysis
SCIENTIFIC DESCRIPTION

The system uses depth images delivered by the Microsoft Kinect to retrieve the gait cycles first. To this end it is based on a analyzing the knees trajectories instead of the feet to obtain more robust gait event detection. Based on these cycles, the system computes a mean gait cycle model to decrease the effect of noise of the system. Asymmetry is then computed at each frame of the gait cycle as the spatial difference between the left and right parts of the body. This information is computed for each frame of the cycle.
FUNCTIONAL DESCRIPTION

AsymGait is a software package that works with Microsoft Kinect data, especially depth images, in order to carry-out clinical gait analysis. First is identifies the main gait events using the depth information (footstrike, toe-off) to isolate gait cycles. Then it computes a continuous asymmetry index within the gait cycle. Asymmetry is viewed as a spatial difference between the two sides of the body.

- Participants: Franck Multon and Edouard Auvinet
- Contact: Franck Multon

6.2. Cinematic Viewpoint Generator

KEYWORDS: Virtual Cinematography - Intelligent Gallery
FUNCTIONAL DESCRIPTION

The software, developed as an API, provides a mean to automatically compute a collection of viewpoints over one or two specified geometric entities, in a given 3D scene, at a given time. These viewpoints satisfy classical cinematographic framing conventions and guidelines including different shot scales (from extreme long shot to extreme close-up), different shot angles (internal, external, parallel, apex), and different screen compositions (thirds,fifths, symmetric of di-symmetric). The viewpoints allow to cover the range of possible framings for the specified entities. The computation of such viewpoints relies on a database of framings that are dynamically adapted to the 3D scene by using a manifold parametric representation and guarantee the visibility of the specified entities. The set of viewpoints is also automatically annotated with cinematographic tags such as shot scales, angles, compositions, relative placement of entities, line of interest.

- Participants: Emmanuel Badier, Christophe Lino and Marc Christie
- Partners: Université d'Udine - Université de Nantes - William Bares
- Contact: Marc Christie

6.3. Directors Lens Motion Builder

KEYWORDS: Previzualisation - Virtual cinematography - 3D animation
FUNCTIONAL DESCRIPTION

Directors Lens Motion Builder is a software plugin for Autodesk's Motion Builder animation tool. This plugin features a novel workflow to rapidly prototype cinematographic sequences in a 3D scene, and is dedicated to the 3D animation and movie previsualization industries. The workflow integrates the automated computation of viewpoints (using the Cinematic Viewpoint Generator) to interactively explore different framings of the scene, proposes means to interactively control framings in the image space, and proposes a technique to automatically retarget a camera trajectory from one scene to another while enforcing visual properties. The tool also proposes to edit the cinematographic sequence and export the animation. The software can be linked to different virtual camera systems available on the market.

- Participants: Emmanuel Badier, Christophe Lino and Marc Christie
- Partner: Université de Rennes 1
- Contact: Marc Christie

6.4. Kimea

Kinect IMprovement for Egronomics Assessment
KEYWORDS: Biomechanics - Motion analysis - Kinect
SCIENTIFIC DESCRIPTION

Kimea consists in correcting skeleton data delivered by a Microsoft Kinect in an ergonomics purpose. Kimea is able to manage most of the occlultations that can occur in real working situation, on workstations. To this end, Kimea relies on a database of examples/poses organized as a graph, in order to replace unreliable body segments reconstruction by poses that have already been measured on real subject. The potential pose candidates are used in an optimization framework.
FUNCTIONAL DESCRIPTION

Kimea gets Kinect data as input data (skeleton data) and correct most of measurement errors to carry-out ergonomic assessment at workstation.

- Participants: Franck Multon, Pierre Plantard and Hubert Shum
- Partner: Faurecia
- Contact: Franck Multon

6.5. Populate

SCIENTIFIC DESCRIPTION

Populate is a toolkit dedicated to task scheduling under time and space constraints in the field of behavioral animation. It is currently used to populate virtual cities with pedestrian performing different kind of activities implying travels between different locations. However the generic aspect of the algorithm and underlying representations enable its use in a wide range of applications that need to link activity, time and space. The main scheduling algorithm relies on the following inputs: an informed environment description, an activity an agent needs to perform and individual characteristics of this agent. The algorithm produces a valid task schedule compatible with time and spatial constraints imposed by the activity description and the environment. In this task schedule, time intervals relating to travel and task fulfilment are identified and locations where tasks should be performed are automatically selected.
FUNCTIONAL DESCRIPTION

The software provides the following functionalities:

- A high level XML dialect that is dedicated to the description of agents activities in terms of tasks and sub activities that can be combined with different kind of operators : sequential, without order, interlaced. This dialect also enables the description of time and location constraints associated to tasks.
- An XML dialect that enables the description of agent's personal characteristics.
- An informed graph describes the topology of the environment as well as the locations where tasks can be performed. A bridge between TopoPlan and Populate has also been designed. It provides an automatic analysis of an informed 3D environment that is used to generate an informed graph compatible with Populate.
- The generation of a valid task schedule based on the previously mentioned descriptions.

With a good configuration of agents characteristics (based on statistics), we demonstrated that tasks schedules produced by Populate are representative of human ones. In conjunction with TopoPlan, it has been used to populate a district of Paris as well as imaginary cities with several thousands of pedestrians navigating in real time.

- Participants: Fabrice Lamarche and Carl-Johan Jorgensen
- Contact: Fabrice Lamarche

6.6. The Theater

SCIENTIFIC DESCRIPTION

The Theater is a software framework to develop interactive scenarios in virtual 3D environements. The framework provides means to author and orchestrate 3D character behaviors and simulate them in real-time. The tools provides a basis to build a range of 3D applications, from simple simulations with reactive behaviors, to complex storytelling applications including narrative mechanisms such as flashbacks.

FUNCTIONAL DESCRIPTION

The Theater is Unity 3D application. XML descriptions are used to specify characters behaviors.

- Contact: Marc Christie

7. New Results

7.1. Biomechanics for motion analysis-synthesis

Participants: Charles Pontonnier, Georges Dumont, Steve Tonneau, Franck Multon, Julien Pettré, Ana Lucia Cruz Ruiz, Antoine Muller.

Ana-Lucia Cruz-Ruiz has been recruited as a PhD student since november 2013. The goal of this thesis is to define and evaluate muscle-based controllers for avatar animation. We developed an original control approach to reduce the redudancy of the musculoskeletal system for motion synthesis, based on the muscle synergy theory. For this purpose we ran an experimental campaign of overhead throwing motions. We recorded the muscle activity of 10 muscles of the arm and the motion of the subjects. Thanks to a synergy extraction algorithm, we extracted a reduced set of activation signals corresponding to the so called muscle synergies and used them as an input in a forward dynamics pipeline . Thanks to a two stage optimization method, we adapted the model's muscle parameters and the synergy signals to be as close as possible of the recorded motion. The results are compelling and ask for further developments [9], [24].

We are also developing an analysis pipeline thanks to the work of Antoine Muller. This pipeline aims at using a modular and multiscale description of the human body to let users be able to analyse human motion. For now, the pipeline is able to assemble different biomechanical models in a convenient descriptive graph [15], Calibrate those models thanks to experimental data [30] and run inverse dynamics to get joint torques from exeperimental motion capture data [14].

7.2. VR and Ergonomics

Participants: Charles Pontonnier, Georges Dumont, Pierre Plantard, Franck Multon.

The use of virtual reality tools for ergonomics applications is a very important challenge in order to genezalize the use of such devices for the design of workstations.

We deeply assessed the propensity of a virtual reality immersive room and classical interaction devices to evaluate properly the physical risk factors associated to assembly tasks. For this purpose, we compared tasks realized in real and virtual environment in terms of shoulder kinematics and muscular activity [20] and in terms of controlled kinematical variables, on the basis of the uncontrolled manifold theory [31]. Results show that there is less difference between real and virtual conditions than between indviduals, that make us think that such a virtual environment can be used to assess this type of task.

7.3. Interactions between walkers

Participants: Anne-Hélène Olivier, Armel Crétual, Julien Bruneau, Richard Kulpa, Sean Lynch, Julien Pettré.

Interaction between people, and especially local interaction between walkers, is a main research topic of MimeTIC. We propose experimental approaches using both real and virtual environments. This year, we developped new experiments in our immersive platform. First, we investigated obstacle avoidance behavior during real walking in a large immersive projection setup [22]. We analyze the walking behavior of users when avoiding real and virtual static obstacles. Indeed, CAVE-like immersive projection environments enable users to see both virtual and real objects, including the user's own body. With recent advances in VR technologies it becomes possible to build large-scale tracked immersive projection environments, which enable users to control their position in a large region of interest by real walking. In such environments virtual and real objects as well as multiple users or avatars may coexist in the same interaction space. Hence, it becomes important to gain an understanding of how the user's behavior is affected by the differences in perception and affordances of such real and virtual obstacles. We consider both anthropomorphic and inanimate objects, each having his virtual and real counterpart. The results showed that users exhibit different locomotion behaviors in the presence of real and virtual obstacles, and in the presence of anthropomorphic and inanimate objects. Precisely, the results showed a decrease of walking speed as well as an increase of the clearance distance (i. e., the minimal distance between the walker and the obstacle) when facing virtual obstacles compared to real ones. Moreover, users act differently due to their perception of the obstacle: users keep more distance when the obstacle is anthropomorphic compared to an inanimate object and when the orientation of anthropomorphic obstacle is from the profile compared to a front position. However, although we observed differences in collision avoidance behavior between real and virtual obstacles, which indicate biases of natural locomotion introduced by the setup, their magnitude seem lower compared to typical results found in HMD environments.This suggests that although the user's behavior in mixed environments varies depending on the nature of the stimulus, the user's locomotion behavior and the management of his/her interaction space is comparable with the ones in real life. Considering these findings, our results open promising vistas for using large CAVE-like setups for socio-physical experiments, in particular in the fields of locomotion and behavioral dynamics.

Second, we studied interactions between an individual and a crowd [7]. When avoiding a group, a walker has two possibilities: either he goes through it or around it. Going through very dense group or around huge one would not seem natural and could break any sense of presence in a virtual environment. The aim of this work was to enable crowd simulators to correctly handle such situations. To this end, we need understanding how real humans decide to go through or around groups. As a first hypothesis, we apply the Principle of Minimum Energy (PME) on different group sizes and density. According to it, a walker should go around small and dense groups while he should go through large and sparse groups. We quantified decision thresholds. However, PME left some inconclusive situations for which the two solutions paths have similar energetic cost. In a second part, we proposed an experiment to corroborate PME decisions thresholds with real observations. We proposed using Virtual Reality to enable accurately controlling experimental factors. We considered as well the role of secondary factors in inconclusive situations. We showed the influence of the group appearance and direction of relative motion in the decision process. Finally, we draw some guidelines to integrate our conclusions to existing crowd simulators and demonstrate that spectators can perceive some improvement in the crowd animation.

This year, we also developed new experiments in real conditions by considering the interaction between a walker and a moving robot. This worked was performed in collaboration with Philippe Souères and Christian Vassallo (LAAS, Toulouse). The development of Robotics accelerated these recent years, it is clear that robots and humans will share the same environment in a near future. In this context, understanding local interactions between humans and robots during locomotion tasks is important to steer robots among humans in a safe manner. Our work is a first step in this direction. Our goal is to describe how, during locomotion, humans avoid collision with a moving robot. We study collision avoidance between participants and a non-reactive robot (we wanted to avoid the effect of a complex loop by a robot reacting to participants' motion). Our objective is to determine whether the main characteristics of such interaction preserve the ones previously observed: accurate estimation of collision risk, anticipated and efficient adaptations. We observed that collision avoidance between a human and a robot has similarities with human-human interactions (estimation of collision risk, anticipation) but also leads to major differences. Humans preferentially give way to the robot, even if this choice is not optimal with regard to motion adaptation to avoid the collision. We proposed to interpret this behavior based on the notion of perceived danger and safety. Given the difficulty to understand how a robot behaves, and the lack of experience of interactions with the robot, humans apply a conservative avoidance strategy and prefer giving way to the robot. However, it is important to note that human participants succeed in perceiving the motion of the robot (anticipation was observed, no aberrant reaction occurred). One main conclusion is that, if we control robots to move like humans, we have a risk facing unexpected situations where robot compensates and cancels humans adaptations to the robot. A robot programmed to be cooperative could be perceived as hostile. The conclusion of this study opens paths for future research. A first direction is to better understand the possible effect of this notion of danger during interactions. We believe that this notion is of even higher importance when studying interactions with vehicles: a risk of collision with a fast vehicle obviously raises higher danger. A second direction is about the design of safe robots moving among human walkers. How the robot should adapt to others? Should it be collaborative with the risk of compensating human avoidance strategies? Should it be passive? We believe that robots should first be equipped with the ability to early detect humans avoidance strategy and adapt to it. In the near future, we want to continue our study of interactions between a robot and a human. In a first step, we plan to equip the robot with collision avoidance system which imitates real human strategies, and investigate how participants adapt to this new situation in comparison with a passive robot.

Finally, Sean Dean Lynch has been recruited as a PhD student since september 2015. This thesis concerns the visual perception of human motion during interactions in locmotor tasks. From the visual perception of someone's motion, we are able to predict the future course of this motion, interpret and anticipate his/her intentions and adapt our own motion to allow interactions. The main objective of the thesis is to identify the underlying perceptual mechanisms, i.e., the human motion cues which are necessary for an accurate understanding of others' intentions. It would allow to make significant progress in the understanding of human social behaviors. To reach these objectives, the thesis will be based on an experimental approach in virtual reality.

7.4. Motion Sensing

Participants: Franck Multon, Pierre Plantard.

Recording human activity is a key point of many applications and fundamental works. Numerous sensors and systems have been proposed to measure positions, angles or accelerations of the user's body parts. Whatever the system is, one of the main is to be able to automatically recognize and analyze the user's performance according to poor and noisy signals. Hence, recognizing and measuring human performance are important scientific challenges especially when using low-cost and noisy motion capture systems. MimeTIC has addressed the above problems in two main application domains.

Firstly, in ergonomics, we explored the use of low-cost mottion capture systems, a Microsoft Kinect, to measure the 3D pose of a subject in natural environments, such as on a workstation, with many occlusions and inappropriate sensor placements. Predicting the potential accuracy of the measurement for such complex 3D poses and sensor placements is challenging with classical experimental setups. To tackle this problem, we propose [16] a new evaluation method based on a virtual mannequin. Thanks to this evaluation method, more than 500,000 configurations have been automatically tested, which is almost impossible to evaluate with classical protocols. The results show that the kinematic information obtained by the Kinect system is generally accurate enough to fill-in ergonomic assessment grids. However inaccuracy strongly increases for some specific poses and sensor positions. Using this evaluation method enabled us to report configurations that could lead to these high inaccuracies. Results obtained with the virtual mannequin are in accordance with those obtained with a real subject for a limited set of poses and sensor configuration. This knowledge can help to anticipate potential problems using a Kinect in given scenarios, and to propose methods to tackle these expected problems.

Secondly, in clinical gait analysis, we proposed a method to overcome the main limitations imposed by the low accuracy of the Kinect measurements in real medical exams. Indeed, inaccuracies in the 3D depth images leads to badly reconstructed poses and inaccurate gait event detection. In the latter case, confusion between the foot and the ground leads to inaccuracies in the foot-strike and toe-off event detection, which are essential information to get in a clinical exam. To tackle this problem we assumed that heel strike events could be indirectly estimated by searching for the extreme values of the distance between the knee joints along the walking longitudinal axis [5] . As Kinect sensor may not accurately locate the knee joint, we used anthropometrical data to select a body point located at a constant height where the knee should be in the reference posture. Compared to previous works using a Kinect, heel strike events and gait cycles are more accurately estimated, which could improve global clinical gait analysis frameworks with such a sensor. Once these events are correctly detected, it is possible to define indexes that enables the clinician to have a rapid state of the quality of the gait. We proposed [4] a new method to asses gait asymmetry based on depth images, to decrease the impact of errors in the Kinect joint tracking system. It is based on the longitudinal spatial difference between lower-limb movements during the gait cycle. The movement of artifically impaired gaits was recorded using both a Kinect placed in front of the subject and a motion capture system. The proposed longitudinal index distinguished asymmetrical gait ($p < 0.001$), while other symmetry indices based on spatiotemporal gait parameters failed using such Kinect skeleton measurements. This gait asymmetry index measured with a Kinect is low cost, easy to use and is a promising development for clinical gait analysis.

7.5. Virtual Human Animation

Participants: Julien Pettré, Franck Multon, Steve Tonneau.

Multiped locomotion in cluttered environments is addressed as the problem of planning acyclic sequences of contacts, that characterize the motion. In order

to overcome the inherent combinatorial difficulty of the problem, we separate it in two subproblems [34]: first, planning a guide trajectory for the root of the robot and then, generating relevant contacts along this trajectory. This paper proposes theoretical contributions to these two subproblems. We propose a theoretical characterization of the guide trajectory, named “true feasibility”, which guarantee that a guide can be mapped into the contact manifold of the robot. As opposed to previous approaches, this property makes it possible to assert the relevance of a guide trajectory without explicitly computing contact configurations, as proposed in our previous works. This property can be efficiently checked by a sample-based planner (e.g. we implemented a visibility PRM). Since the guide trajectories that we characterized are easily mapped to a valid sequence of contacts, we then focused on how to select a particular sequence with desirable properties, such as robustness, efficiency and naturalness, only considered for cyclic locomotion so far. Based on these novel theoretical developments, we implemented a complete acyclic contact planner and demonstrate its efficiency by producing a large variety of movements with three very different robots (humanoid, insectoid, dexterous hand) in five challenging scenarios. The planner is very efficient in quality of the produced movements and in computation time: given a computed RB-PRM, a legged figure or a dexterous hand can generate its motion in real time. This result outperforms any previous acyclic contact planner.

7.6. VR and sports

Participants: Richard Kulpa, Benoit Bideau, Franck Multon, Anne-Hélène Olivier.

Athletes' performances are influenced by internal and external factors, including their psychological state and environmental factors, especially during competition. As a consequence, current training programs include stress management. In this work [3], we explore whether highly immersive systems can be used for such training programs. First, we propose methodological guidelines to design sport training scenarios both on considering the elements that a training routine must have and how external factors might influence the participant. The proposed guidelines are based on Flow and social-evaluative threat theories. Second, to illustrate and validate our methodology, we designed an experimental setup reproducing a 10 m Olympic pistol shooting. We analyzed whether changes in the environment are able to induce changes in user performance, physiological responses, and the subjective perception of the task. The simulation included stressors in order to raise a social-evaluative threat, such as aggressive public behavior or unforced errors, increasing the pressure while performing the task. The results showed significant differences in their subjective impressions, trends in the behavioral and physiological data were also observed. Taken together, our results suggest that highly immersive systems could be further used for training in sports.

Among the stimuli, visual information uptake is a fundamental element of sports involving interceptive tasks. Several methodologies, like video and methods based on virtual environments, are currently employed to analyze visual perception during sport situations. Both techniques have advantages and drawbacks. We made an experiment to determine which of these technologies may be preferentially used to analyze visual information uptake during a sport situation [21]. To this aim, we compared a handball goalkeeper's performance using two standardized methodologies: video clip and virtual environment. We examined this performance for two response tasks: an uncoupled task (goalkeepers show where the ball ends) and a coupled task (goalkeepers try to intercept the virtual ball). Variables investigated in this study were percentage of correct zones, percentage of correct responses, radial error and response time. The results showed that handball goalkeepers were more effective, more accurate and started to intercept earlier when facing a virtual handball thrower than when facing the video clip. These findings suggested that the analysis of visual information uptake for handball goalkeepers was better performed by using a 'virtual reality'-based methodology.

In a previous work, we analyzed the performance of beginners as they shot basketball free throws using various immersive conditions. Our results supported the assumption that natural complex motor behavior is possible in a VE, with little motor adaptation. The ultimate goal of our work is to design a VE training system for basketball free throws, so in this article we compare the performance of beginners making free throws in various visual conditions (first- versus third-person views using a large-screen immersive display) with that of expert players in the real world [8]. The key idea is to analyze how different visual conditions affect the performance of novices and to what extent it enables them to match the experts' performance.

Distance underestimation or any other perceptual disturbance in VR makes people adapt to the task at hand. The users in our study reached the same success rate by finding a new way to throw the ball, despite this incongruity between perception and action. The main observations reported in this article reinforce the conclusions in previous work, stating that 3PP is more efficient for certain tasks, but further work is required to test this result against other types of training conditions.

Finally, we worked on a transportable virtual reality system to analyse sports situations [6]. We proposed an original methodology to study the action of a goalkeeper facing a free kick. This methodology is based on a virtual reality setup in which a real goalkeeper is facing a virtual player and a virtual defensive wall. The setup has been improved to provide a total freedom of movement to the goalkeeper in order to have a realistic interaction between the goalkeeper and the player. The goalkeeper's movements are captured in real-time to accurately analyze his reactions. Such a methodology not only represents a valuable research tool but also provides a relevant training tool. Using this setup, this paper shows that goalkeepers are more performant during free kick with a wall composed of 5 defenders whatever its position.

7.7. Scheduling activities under spatial and temporal constraints

Participants: Fabrice Lamarche, Carl-Johan Jorgensen.

This work focusses on generating statistically consistent behaviors that can be used to pilot crowd simulation models over long periods of time, up to multiple days [1]. In real crowds, people's behaviors mainly depend on the activities they intend to perform. The way this activity is scheduled rely on the close interaction between the environment, space and time constraints associated with the activity and personal characteristics of individuals. Compared to the state of the art, our model better handle this interaction.

Our main contributions lie in the cdomain of activity scheduling and path planning. First, we proposed an individual activity scheduling process and its extension to cooperative activity scheduling. Based on descriptions of the environment, of intended activities and of agents' characteristics, these processes generate a task schedule for each agent. Locations where the tasks should be performed are selected and a relaxed agenda is produced. This task schedule is compatible with spatial and temporal constraints associated with the environment and with the intended activity of the agent and of other cooperating agents. It also takes into account the agents personal characteristics, inducing diversity in produced schedules. We showed that this model produces schedules statistically coherent with the ones produced by humans in the same situations. Second, we proposed a hierarchical path-planning process. It relies on an automatic environment analysis process that produces a semantically coherent hierarchical representation of virtual cities. The hierarchical nature of this representation is used to model different levels of decision making related to path planning. A coarse path is first computed, then refined during navigation when relevant information is available. It enable the agent to seamlessly adapt its path to unexpected events. Finally, those models have been included in a simulation platform that is able to simulate several thousand of pedestrians performing their daily activities in real-time. In order to deal with unexpected events, a process enabling adaptations of the pedestrian behavior have been designed. Those adaptations range from path modification to schedule adaptation according to the observed situation.

The proposed model handles long term rational decisions driving the navigation of agents in virtual cities. It considers the strong relationship between time, space and activity to produce more credible agents' behaviors. It can be used to easily populate virtual cities in which observable crowd phenomena emerge from individual activities.

7.8. Shoulder biomechanics

Participant: Armel Crétual [contact].

Shoulder hyperlaxity (SHL) is considered a main risk factor for shoulder instability and can be associated with different clinical shoulder instability presentations, such a multidirectional instability or unstable painful shoulder. Interestingly, quantification of shoulder laxity and hyperlaxity, particularly during physical examination, still remains an unsolved problem. Indeed, it is still frequently evaluated only through mono-axial amplitude, in particular using external rotation of the arm whilst at the side (ER1). We previously showed that this parameter is sensitive to inter-operator variability.

Therefore, we proposed a novel way to account for global shoulder mobility, the Shoulder Configuration Space Volume (SCSV) corresponding to the reachable volume in the configuration space of the shoulder joint [10]. In mechanics and robotics, the configuration space is the set of all reachable combination of coordinates. Considering the shoulder as the single joint between thorax and humerus instead of a combination of 4 actual joints (gleno-humeral, thoraco-humeral, scapulo-thoracic and sterno-clavicular), these coordinates are based upon the three joint angles defined by the International Society of Biomechanics (ISB) recommendations as plane of elevation orientation, elevation and axial rotation.

Then, this new index was examined through correlation to shoulder signs of hyperlaxity [19] for which we have shown a link with instability in patients who received a surgical procedure [18].

7.9. The Toric Space: a novel representation for camera control applications

Participants: Marc Christie, Christophe Lino, Quentin Galvane.

Many types of computer graphics applications such as data visualization or virtual movie production require users to position and move viewpoints in 3D scenes to effectively convey visual information or tell stories. The desired viewpoints and camera paths need to satisfy a number of visual properties (e.g. size, vantage angle, visibility, and on-screen position of targets). Yet, existing camera manipulation tools only provide limited interaction methods and automated techniques remain computationally expensive.

We introduce the *Toric space*, a novel and compact representation for intuitive and efficient virtual camera control. We first show how visual properties are expressed in this Toric space and propose an efficient interval-based search technique for automated viewpoint computation. We then derive a novel screen-space manipulation technique that provides intuitive and real-time control of visual properties. Finally, we propose an effective viewpoint interpolation technique which ensures the continuity of visual properties along the generated paths. The proposed approach (i) performs better than existing automated viewpoint computation techniques in terms of speed and precision, (ii) provides a screen-space manipulation tool that is more efficient than classical manipulators and easier to use for beginners, and (iii) enables the creation of complex camera motions such as long takes in a very short time and in a controllable way. As a result, the approach should quickly find its place in a number of applications that require interactive or automated camera control such as 3D modelers, navigation tools or games. The paper has been presented at SIGGRAPH 2015 (see [12] for more details).

We then rely on this Toric Space representation to contruct optimal camera paths (optimal in the satisfaction of visual properties along the path). Indeed, when creating real or computer graphics movies, the questions of how to layout elements on the screen, together with how to move the cameras in the scene are crucial to properly conveying the events composing a narrative. Though there is a range of techniques to automatically compute camera paths in virtual environments, none have seriously considered the problem of generating realistic camera motions even for simple scenes. Among possible cinematographic devices, real cinematographers often rely on camera rails to create smooth camera motions which viewers are familiar with. Following this practice, we have proposed a method for generating virtual camera rails and computing smooth camera motions on these rails. Our technique analyzes characters motion and user-defined framing properties to compute rough camera motions which are further refined using constrained-optimization techniques. Comparisons with recent techniques demonstrate the benefits of our approach and opens interesting perspectives in terms of creative support tools for animators and cinematographers. See [25] for more details.

TO address the more general problem of solving contradicting visual properties, novel ways of aggregating functions has also been proposed [33].

7.10. Data-driven Virtual Cinematography

Participant: Marc Christie.

Our propelling motivation here is to rely on existing data from real movies (automatically extracted or manually annotated), to propose better better and better framing techniques.

We first contributed to the problem of automated editing, by reproducing elements of cinematographic style. Automatically computing a cinematographic consistent sequence of shots over a set of actions occurring in a 3D world is a complex task which requires not only the computation of appropriate shots (viewpoints) and appropriate transitions between shots (cuts), but the ability to encode and reproduce elements of cinematographic style. Models proposed in the literature, generally based on finite state machine or idiom-based representations, provide limited functionalities to build sequences of shots. These approaches are not designed in mind to easily learn elements of cinematographic style, nor do they allow to perform significant variations in style over the same sequence of actions. We have proposed a model for automated cinematography that can compute significant variations in terms of cinematographic style, with the ability to control the duration of shots and the possibility to add specific constraints to the desired sequence. The model is parameterized in a way that facilitates the application of learning techniques. By using a Hidden Markov Model representation of the editing process, we have demonstrated the possibility of easily reproducing elements of style extracted from real movies. Results comparing our model with state-of-the-art first order Markovian representations illustrate these features, and robustness of the learning technique is demonstrated through cross-validation. See [13] for more details.

We also proposed a tool to ease the process of annotating cinematographic content, for the purposes of both film analysis, and film synthesis [29]. The work relies on the proposition of a film language that extends previous representations such as PSL (Prose Storyboard Language) by integrating the editing aspects, through the notion of cinematographic "techniques" described as patterns of shots.

The proposed language, named "Patterns", is described in more details in [35]. Our language can express the aesthetic properties of framing and shot sequencing, and of camera techniques used by real directors. Patterns can be seen as the semantics of camera transitions from one frame to another. The language takes an editors view of on-screen aesthetic properties: the size, orientation, relative position, and movement of actors and objects across a number of shots. We have illustrated this language through a number of examples and demonstrations. Combined with camera placement algorithms, we demonstrated the language's capacity to create complex shot sequences in data-driven generative systems for 3D storytelling applications.

7.11. Logic control in interactive storytelling

Participants: Marc Christie, Hui-Yin Wu.

With the rising popularity of engaging storytelling experiences in gaming arises the challenge of designing logic control mechanisms that can adapt to increasingly interactive, immersive, and dynamic 3D gaming environments. Currently, branching story structures are a popular choice for game narratives, but can be rigid, and authoring mistakes may result in dead ends at runtime. This calls for automated tools and algorithms for logic control over flexible story graph structures that can check and maintain authoring logic at a reduced cost while managing user interactions at runtime. In this work we introduce a graph traversal method for logic control over branching story structures which allow embedded plot lines. The mechanisms are designed to assist the author in specifying global authorial goals, evaluating the sequence of events, and automatically managing story logic during runtime. Furthermore, we showed how our method can be easily linked to 3D interactive game environments through a simple example involving a detective story with a flashback. See [36] for more details.

7.12. Automatic Continuity Editing for 3-D Animation

Participants: Marc Christie, Quentin Galvane, Christophe Lino.

We have proposed an optimization-based approach for automatically creating movies from 3-D animation. The method nicely separates the work of the virtual cinematographer (placing cameras and lights to produce nice-looking views of the action) from the work of the virtual film editor (cutting and pasting shots from all available cameras). While previous work has mostly focused on the first problem, the second problem has never been addressed in full details. We have reviewed the main causes of editing errors and built a cost function for minimizing them. We made a plausible semi-Markov assumption, which results in a computationally efficient dynamic programming solution. We showed that our method generates movies that avoid many common errors in film editing, including jump cuts, continuity errors and non-motivated cuts. We also show that our method can generate movies with different pacings. Combined with state-of-the-art cinematography, our approach therefore promises to significantly extend the expressiveness and naturalness of virtual movie-making. The work has been published at AAAI [27]. More details comparisons have been performed in [26].

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Visual Analytics for Cinematographic Data

Participant: Marc Christie [contact].

The contract has two objectives: first developping a film annotation tool that integrates cinematographic image and editing features such as visual composition, shot type, balance, depth, shot transition, etc. While existing annotation tools such as Anvil and Elan are are largely used for film annotation, the specificities of cinematographic and editing features requires the design of dedicated tools which mix automated and manual annotation stages. The work builds on the Insight annotation tool developed in our group (see [29]).

The second objective is to provide means to visualize and interact with the data, following the general trend of Visual Analytics. Different representations are currently explored and developped inside Technicolor's internal tools.

8.2. Bilateral Grants with Industry

8.2.1. Cifre Faurecia

Participant: Franck Multon [contact].

This contract aims at developing new ergonomics assessments based on inaccurate Kinect measurements in manufactures on real workers. The main challenges are:

- being able to improve the Microsoft Kinect measurement in order to extract accurate poses from depth images while occlusions may occur,
- developing new inverse dynamics methods based on such inaccurate kinematic data in order to estimate the joint torques required to perform the observed task,
- and proposing a new assessment tool to translate joint torques and poses into potential musculoskeletal disorders risks.

Faurecia has developed its own assessment tool but it requires tedious and subjective tasks for the user, at specific times in the work cycle. By using Kinect information we aim at providing more objective data over the whole cycle not only for specific times. We also wish to make the user focus on the interpretation and understanding of the operator's tasks instead of taking time estimating joint angles in images.

This work is performed in close collaboration with an ergonomist in Faurecia together with the software development service of the company to design the new version of their assessment tool. This tool will be first evaluated on a selection of manufacture sites and will then be spread worldwide among the 300 Faurecia sites in 33 countries.

This contract enabled us to hire Pierre Plantard as a PhD student to carry-out this work in MimeTIC and M2S Lab. He started in January 2013 and will finish in January 2016.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

9.1.1.1. Cinecitta

Participants: Marc Christie [contact], Cunka Sanokho, Quentin Galvane, Christophe Lino, Hui-Yin Wu.

Cinecitta is a 3-year young researcher project funded by the French Research Agency (ANR) lead by Marc Christie. The project started in October 2012 and will end in March 2016. The main objective of Cinecitta is to propose and evaluate a novel workflow which mixes user interaction using motion-tracked cameras and automated computation aspects for interactive virtual cinematography that will better support user creativity. We propose a novel cinematographic workflow that features a dynamic collaboration of a creative human filmmaker with an automated virtual camera planner. We expect the process to enhance the filmmaker's creative potential by enabling very rapid exploration of a wide range of viewpoint suggestions. The process has the potential to enhance the quality and utility of the automated planner's suggestions by adapting and reacting to the creative choices made by the filmmaker. This requires three advances in the field. First, the ability to generate relevant viewpoint suggestions following classical cinematic conventions. The formalization of these conventions in a computationally efficient and expressive model is a challenging task in order to select and propose the user with a relevant subset of viewpoints among millions of possibilities. Second, the ability to analyze data from real movies in order to formalize some elements of cinematographic style and genre. Third, the integration of motion-tracked cameras in the workflow. Motion- tracked cameras represent a great potential for cinematographic content creation. However given that tracking spaces are of limited size, there is a need to provide novel interaction metaphors to ease the process of content creation with tracked cameras. Finally we will gather feedback on our prototype by involving professionals (during dedicated workshops) and will perform user evaluations with students from cinema schools.

9.1.2. National scientific collaborations

9.1.2.1. Cavaletic

Participant: Franck Multon.

The Cavaletic collaborative project is leaded by University Bretagne Sud and also involves University Rennes2 (CREAD Lab.). It has been funded by the National IFCE (Institut Français du Cheval et de l'Equitation) in order to develop and evaluate technological assistance in horse riding learning, thanks to a user-centered approach. MimeTIC is involved in measuring expert and non-expert horse riders motions in standardized situations in order to develop a metrics to measure the performance of users. It will be used to develop a technological system embedded on users to evaluate his performance and provide him with real-time feedback to correct potential errors.

9.1.3. ADT

9.1.3.1. ManIP

Participants: Franck Multon, Ludovic Hoyet.

The ADT-MAN-IP aims at proposing a common production pipeline for both MimeTIC and Hybrid teams. This pipeline intends to facilitate the production of populated virtual reality environments.

The pipeline starts with the motion capture of an actor, using motion capture devices such as a Vicon (product of Oxford Metrics) system. To do so, we need to design new methods to automatically adapt all motion captures data to an internal skeleton that can be reused to retarget the motion to various types of skeletons and characters. The purpose is then to play this motion capture data on any type of virtual characters used in the demos, regardless their individual skeletons and morphology. The key point here is to make this process be as automatic as possible.

The second step in the pipeline is to design a high level scenario framework to describe a virtual scene and the possible user's interactions with this scene so that he/she can interact with the story directly.

In this ADT we also connect these two opposite parts into a unique framework that can be used by non-experts in computer animation to design new immersive experiments involving autonomous virtual humans. The resulting framework can consequently be used in the Immersia immersive room for various types of application.

9.1.3.2. Immerstar

Participants: Franck Multon, Georges Dumont.

The ADT-Immerstar is drivenby the SED and aims at developping new tools and facilities for the scientific community in order to develop demos and use the two immersive rooms in Rennes: immersia and immermove. The engineer will have to homogeneize the software modules and development facilities in each platform, help installing new upgrades and to develop collaborative applications between the two sites.

9.2. International Initiatives

9.2.1. Inria Associate Teams not involved in an Inria International Labs

9.2.1.1. FORMOSA

Title: Fostering Research on Models for Storytelling Applications

International Partner (Institution - Laboratory - Researcher):

NCCU (Taiwan) - Computer Science Department - Pr. Tsai-yen Li

Start year: 2013

The application context targeted by this proposal is Interactive Virtual Storytelling. The growing importance of this form of media reveals the necessity to re-think and re-assess the way narratives are traditionally structured and authored. In turn, this requires from the research community to address complex scientific and technical challenges at the intersection of literature, robotics, artificial intelligence, and computer graphics. This joint collaboration addresses three key issues in virtual storytelling: (i) delivering better authoring tools for designing interactive narratives based on literary-founded narrative structures, (ii) establishing a bridge between the semantic level of the narrative and the geometric level of the final environment to enable the simulation of complex and realistic interactive scenarios in 3D, and (iii) providing a full integration of the cinematographic dimension through the control of high-level elements of filmic style (pacing, preferred viewpoints, camera motion). The project is founded on a past solid collaboration and will rely on the team's complementarity to achieve the tasks through the development of a joint research prototype.

9.2.1.2. SIMS

Title: REal data against crowd SImulation AlgorithMS

International Partner (Institution - Laboratory - Researcher):

University of North Carolina at Chapel Hill (United States) - GAMMA Research Group (GAMMA) - Ming LIN

Start year: 2015

See also: http://www.irisa.fr/mimetic/GENS/jpettre/EASIMS/easims.html

RE-SIMS aims at gathering the best international research teams working on crowd simulation to allow significant progresses on the level of realism achieved by crowd simulators. To this end, RE-SIMS aims at improving methods for capturing crowd motion data that describe real crowd behaviors, as well as by improving data assimilation techniques.

In this renewal, RE-SIMS extends the previous SIMS partnership and follows a multidiciplinary direction.

9.2.2. Inria International Partners

9.2.2.1. Informal International Partners

Hubert Shum, Northumbria University, Newcastle, UK, collaboration with Franck Multon with joint papers,

Edouard Auvinet, Imperial College London, UK, collaboration with Franck Multon with joint papers,

Alexandra Covaci, Middlesex University of London, collaboration with Franck Multon with joint papers, Jean Meunier, Carl-Eric Aubin, and Maxime Raison, University of Montreal, collaboration with Franck Multon with joint papers,

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

Marc Christie, co-Program Chair, ACM Motion in Games, MIG 2015, Paris

10.1.1.2. Member of the organizing committees

Marc Christie, Steering Committee and Conference Organiser, Smartgraphics 2015, Chengdu, China

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

Marc Christie, ACM Motion in Games MIG 2015, Paris, France, November 2015

Marc Christie, Smartgraphics, Chengdu, China, August 2015

Ludovic Hoyet, ACM Motion in Games MIG 2015, Paris, France, November 2015

Ludovic Hoyet, International Conference on Computer Graphics Theory and Applications (GRAPP), Rome, Italy, February 2016

Richard Kulpa, International Conference on Computer Graphics Theory and Applications (GRAPP), Rome, Italy, February 2016

Franck Multon, member of the International Steering committee of MIG, Interational steering committee of the symposium "From humans and non-humans primates to robots: motion", member of the International Program Committee of MIG, STARs International Program Committee Eurographics

Anne-Hélène Olivier, IEEE VR 2016, Greenville, United-States, March 2016

10.1.2.2. Reviewer

Ludovic Hoyet, Eurographics 2016, Lisbon, Portugal, May 2016

Ludovic Hoyet, IEEE VR 2016, Greenville, United-States, March 2016

Richard Kulpa, IEEE VR 2016, Greenville, United-States, March 2016

Richard Kulpa, VISIGRAPP, Rome, Italy, February 2016

Franck Multon, ICRA2016, IEEE VR 2016, ISBS 2015

Charles Pontonnier, IHM 2015, Toulouse, France, October 2015

Marc Christie, Eurographics, CHI, Smartgraphics, VISIGRAPP, Motion in Games,

10.1.3. Journal

10.1.3.1. Member of the editorial boards

Franck Multon, Editorial board of Presence MIT Press

Marc Christie, Associate Editor, The Visual Computer, Springer

10.1.3.2. Reviewer - Reviewing activities

Ludovic Hoyet, Computer Animation and Virtual Worlds, Computer Graphics Forum, Transactions on Graphics, Transactions on Applied Perception

Richard Kulpa, Journal of Sports Engineering and Technology, Journal of Sports Sciences

Franck Multon, Gait and Posture, Applied Computing and Informatics, Journal of Applied Biomechanics, Sensors, International Journal of Sports and Exercise Medicine

Anne-Hélène Olivier, Gait and Posture, Journal of Experimental Psychology Human Perception and Performance

Charles Pontonnier, Applied Ergonomics

Marc Christie, TVCG, The Visual Computer, Computer Graphics Forum

10.1.4. Invited talks

Ludovic Hoyet, Perception of Biological Human Motion: Towards New Perception-Driven Virtual Character Simulations, Inria Grenoble, Equipe Imagine, France, September 2015

Ludovic Hoyet, Perception of Biological Human Motion: Towards New Perception-Driven Virtual Character Simulations, Northumbria University, United Kingdom, November 2015

Franck Multon, Virtual Reality and Sports, applied session, International Society of Biomechanics in Sports, 2015

Franck Multon, Physical Activity on VR, Invited talk, International Society of Biomechanics in Sports, 2015

Richard Kulpa, Virtual Reality and Sports, applied session, International Society of Biomechanics in Sports, 2015

Charles Pontonnier Muscle based control for avatar animation: a synergy based approach, From Humans and Non-Human Primates to Robots: Motion, International Meeting, CNRS Primatology Station, Rousset sur Arc, France, December 2015

10.1.5. Scientific expertise

- Franck Multon, reviewer for a full-length ANR Proposal
- Franck Multon, reviewer for 12 short ANR proposals

10.1.6. Research administration

- Franck Multon is member of the University Rennes2 Research steering committee "commission recherche", and Academic Council "CAC",
- Franck Multon is member of the M2S Lab steering committee,
- Richard Kulpa is member of the University Rennes2 Research steering committee "commission recherche", and Academic Council "CAC",
- Franck Multon is member of the UFR-APS steering committee in University Rennes2
- Benoit Bideau is director of the M2S Lab
- Georges Dumont is director of mechatronics teaching department at École Normale Supérieure de Rennes
- Georges Dumont is president of the elected group at scientific council of École Normale Supérieure de Rennes, member of the scientific council of École Normale Supérieure de Rennes
- Georges Dumont is scientific head of Media and Interaction Department at IRISA
- Georges Dumont is scientific head of Immerstar platforms (Immersia + Immermove) jointly for Inria and Irisa Partners

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

10.2.1.1. Master level

Master : Franck Multon, "Images et Mouvement - IMO", leader of the module, 20H, Master 2 research in computer sciences, University Rennes1, France

Master : Franck Multon, "Santé et Performance au Travail : étude de cas", leader of the module, 30H, Master 1 M2S, University Rennes2, France

Master : Franck Multon, "Analyse Biomécanique de la Performance Motrice", leader of the module, 30H, Master 1 M2S, University Rennes2, France

Master : Franck Multon, "Modélisation et Simulation du Mouvement", leader of the module, 30H, Master 2 M2S, University Rennes2, France

Master: Marc Christie, "Multimedia Mobile", Master 2, leader of the module, 32h, Computer Science, University of Rennes 1, France

Master: Marc Christie, "Projet Industriel Transverse", Master 2, 32h, leader of the module, Computer Science, University of Rennes 1, France

Master: Marc Christie, "Outils pour la Conception d'IHM", Master 2, 32h, leader of the module, Computer Science, University of Rennes 1, France

Master : Armel Crétual, "Méthodologie", leader of the module, 20H, Master 1 M2S, University Rennes2, France

Master : Armel Crétual, "Biostatstiques", leader of the module, 15H, Master 2 M2S, University Rennes2, France

Master: Charles Pontonnier, "Numerical methods", leader of the module, Mechanics, École Spéciale Militaire de Saint-Cyr Coëtquidan, France

Master: Charles Pontonnier, "Numerical simulation of mechanical systems", leader of the module, Mechanics, École Spéciale Militaire de Saint-Cyr Coëtquidan, France

Master: Charles Pontonnier, "Analytical Mechanics" , Mechanics, École Spéciale Militaire de Saint-Cyr Coëtquidan, France

Master: Charles Pontonnier, "Design and control of mobile robots", leader of the module, Electronics, École Spéciale Militaire de Saint-Cyr Coëtquidan, France

Master: Charles Pontonnier, "Design, simulation and control of mechanical systems", leader of the module, Lecturers training in mechatronics, École Normale Supérieure de Rennes, France

Master : Richard Kulpa, "Contrôle moteur", leader of the module, Master 1 M2S, Université Rennes 2, France

Master : Richard Kulpa, "Boucle analyse-modélisation-simulation du mouvement", leader of the module, Master 2 M2S, Université Rennes 2, France

Master : Richard Kulpa, "Méthodes numériques d'analyse du geste", leader of the module, Master 2 M2S, Université Rennes 2, France

Master : Richard Kulpa, "Cinématique inverse", leader of the module, Master 2 M2S, Université Rennes 2, France

Master: Fabrice Lamarche, "Compilation pour l'image numérique", 29h, Master 1, ESIR, University of Rennes 1, France

Master: Fabrice Lamarche, "Synthèse d'images", 12h, Master 1, ESIR, University of Rennes 1, France

Master: Fabrice Lamarche, "Synthèse d'images avancée", 28h, Master 1, ESIR, University of Rennes 1, France

Master: Fabrice Lamarche, "Modélisation Animation Rendu", 36h, Master 2, ISTIC, University of Rennes 1, France

Master: Fabrice Lamarche, "Jeux vidéo", 26h, Master 2, ESIR, University of Rennes 1, France

Master : Georges Dumont, Mechanical simulation in Virtual reality, 36H, Master Mechatronics, Rennes 1 University and École Normale Supérieure de Rennes, France

Master : Georges Dumont, Responsible of the second year of the master Mechatronics, Rennes 1 University and École Normale Supérieure de Rennes, France

Master : Georges Dumont, Mechanics of deformable systems, 40H, Master FE, École Normale Supérieure de Rennes, France

Master : Georges Dumont, oral preparation to agregation competitive exam, 20H, Master FE, École Normale Supérieure de Rennes, France

Master : Georges Dumont, Vibrations in Mechanics, 10H, Master FE, École Normale Supérieure de Rennes, France

Master : Georges Dumont, Multibody Dynamics, 9H, Master FE, École Normale Supérieure de Rennes, France

Master : Georges Dumont, Finite Element method, 12H, Master FE, École Normale Supérieure de Rennes, France //

Master : Anne-Hélène Olivier, "Biostatstiques", 18H, Master 2 M2S, University Rennes2, France

Master : Anne-Hélène Olivier, "Biostatstiques", 12H, Master 1 2SEP, École Normale Supérieure de Rennes, France

Master : Anne-Hélène Olivier, "Contrôle moteur : loi de contrôle de la locomotion", 3H30, Master 1 M2S, Université Rennes 2, France

Master : Anne-Hélène Olivier, "Contrôle moteur : Boucle perceptivo-motrice", 3H30, Master 1 M2S, Université Rennes 2, France

Master : Anne-Hélène Olivier, "Analyse Biomécanique de la Performance Motrice", 15H, Master 1 M2S, University Rennes2, France

10.2.1.2. Licence level

Licence : Franck Multon, "Ergonomie du poste de travail", Licence STAPS L2 & L3, University Rennes2, France

Licence : Marc Christie, "Système d'information Tactiques", Computer Science, University of Rennes 1, France

Licence : Marc Christie, "Programmation Impérative 1", leader of the module, University of Rennes 1, France

Licence : Armel Crétual, "Analyse cinématique du mouvement", 100H, Licence 1, University Rennes 2, France

Licence: Charles Pontonnier, "Numerical control", leader of the module, Electronics, École Inter-Armes de Saint-Cyr Coëtquidan, France

Licence : Richard Kulpa, "Biomécanique (dynamique en translation et rotation)", Licence 2, Université Rennes 2, France

Licence : Richard Kulpa, "Méthodes numériques d'analyse du geste", Licence 3, Université Rennes 2, France

Licence : Richard Kulpa, "Statistiques et informatique", Licence 3, Université Rennes 2, France

Licence: Fabrice Lamarche, "Initiation à l'algorithmique et à la programmation", 56h, License 3, ESIR, University of Rennes 1, France

License: Fabrice Lamarche, "Programmation en C++", 46h, License 3, ESIR, University of Rennes 1, France

Licence: Fabrice Lamarche, "IMA", 24h, License 3, ENS Rennes, ISTIC, University of Rennes 1, France

Licence : Anne-Hélène Olivier, "Analyse cinématique du mouvement", 100H , Licence 1, University Rennes 2, France

Licence : Anne-Hélène Olivier, "Anatomie fonctionnelle", 8H , Licence 1, University Rennes 2, France

Licence : Anne-Hélène Olivier, "Effort et efficience", 12H , Licence 1, University Rennes 2, France

Licence : Anne-Hélène Olivier, "Locomotion et handicap", 12H , Licence 1, University Rennes 2, France

Licence : Anne-Hélène Olivier, "Biomécanique du viellissement", 12H , Licence 1, University Rennes 2, France

10.2.2. Supervision

PhD: Steve Tonneau, Synthèse et planification de mouvement pour des personnages virtuels en environnements contraints, INSA Rennes, 2011-2015, Franck Multon & Julien Pettré

PhD: Carl-Johan Jorgensen, Peuplement automatisé d'environnements urbains pour l'étude et la validation d'aménagements, University of Rennes 1, Fabrice Lamarche & Kadi Bouatouch

PhD: Kevin Jordao, Peuplement massif de maquettes numériques immenses, University Rennes1, Julien Pettré

PhD: Julien Bruneau, Foules immersives, University Rennes1, Julien Pettré

PhD: Billal Merabti, Style-driven virtual camera control in 3D environments, University of Rennes 1, Kadi Bouatouch & Marc Christie

PhD: Quentin Galvane, Automatic cinematography and editing in virtual environments, University of Grenoble, Rémi Ronfard & Marc Christie

PhD in progress: Marion Morel, Suivi et étude des interactions pour l'analyse des tactiques durant un match de basket-ball, UPMC - University Rennes 2, septembre 2014, Catherine Achard & Séverine Dubuisson & Richard Kulpa

PhD in progress: Sean D. Lynch, Perception visuelle du mouvement humain dans les interactions lors de tâches locomotrices, M2S - University Rennes 2, septembre 2015, Anne-Hélène Olivier & Richard Kulpa

PhD in progress: Pierre Touzard, Suivi longitudinal du service de jeunes joueurs de tennis élite : identification biomécanique des facteurs de performance et de risque de blessures, University Rennes 2, septembre 2014, Benoit Bideau & Richard Kulpa & Caroline Martin

PhD in progress: Yacine Said Bouhalia, Approche transversale pour l'analyse et la reconnaissance de gestes 2D et 3D, INSA of Rennes, septembre 2015, Richard Kulpa & Franck Multon & Eric Anquetil

PhD in progress: Pierre Plantard, Estimation des efforts musculaires à partir de données in situ pour l'évaluation ergonomique d'un poste de travail, 2013-2016, Franck Multon & Anne-Sophie LePierres

PhD in progress: Ana Lucia Cruz Ruiz, Contributions to muscle based control: a synergy based approach, Ecole normale supérieure, Georges Dumont & Charles Pontonnier

PhD in progress: Antoine Muller, Design of a modular and multiscale musculoskeletal model as a support to motion analysis-synthesis, Ecole normale supérieure, Georges Dumont & Charles Pontonnier

PhD in progress: Hui-yin Wu, Validated temporal structures in Interactive Storytelling, University Rennes1, Marc Christie

PhD in progress: Cunka Sanokho, Data-driven Virtual Cinematography, University Rennes1, Marc Christie

10.2.3. Juries

PhD: Eray Molla, Precise and Responsive Performance Animation for Embodied Immersive Interactions, EPFL, September 25th, Richard Kulpa, rapporteur

PhD: Guay Martin, Sketching free-form poses and movements for expressive character animation, Univ. Grenoble, July 2nd, Franck Multon, Examinateur

PhD: Omran Sahab, Génération de trajectoires de marche de robots humanoïdes établies sur les modèles pendulaires bio-inspirés de l'humain, November 30th, Univ. Nantes, Franck Multon, Examinateur

PhD: Vallee Pascal, Estimation du risque de chute suite à une perturbation d'équilibre, November 26th, Univ. Claude Bernard Lyon1,, Franck Multon, Rapporteur

HDR: Watier Bruno, De l'analyse du mouvement in-vitro à la génération de mouvements des systèmes anthropomorphes, November 16th, Univ. Toulouse3, Franck Multon, Rapporteur

HDR: Hayashibe Mitsuhiro, Computational Modeling and Control for Personalized Neuroprosthetics and Rehabilitation, October 12nd, Univ. Montpellier, Franck Multon, Rapporteur

PhD: Fourati Nesrine, Classification et Caractérisation de l'Expression Corporelle des Emotions dans des Actions Quotidiennes, September 9th, Telecom Paristech, Franck Multon, Examinateur

PhD: Maurice Pauline, Virtual ergonomics for the design of collaborative robots, June 16th, Univ. Pierre et Marie Curie, Franck Multon, Rapporteur

PhD: Vigier Toinon, Suggestion et perception des ambiances climatiques dans les environnements virtuels urbains, July 3rd, Ecole Centrale de Nantes, Franck Multon, Président

PhD: Han Yuan, Static and Dynamic Stiffness Analysis of Cable-Driven Parallel Robots, INSA Rennes, March 11th, Georges Dumont, Examinateur

PhD: Brian Ravenet, Modélisation de comportements non-verbaux et d'attitudes sociales dans la simulation de groupes conversationnels, Telecom Paristech, Dec 7, Marc Christie, Examinateur

PhD: Zaynab Habibi, Vers l'assistance à l'exploration pertinente et réaliste d'environnments 3D très denses, Université de Picardie Jules Verne, Dec 8, Marc Christie, Examinateur

11. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] C.-J. J. JORGENSEN. *Scheduling activities under spatial and temporal constraints to populate virtual urban environments*, Université Rennes 1, July 2015, https://tel.archives-ouvertes.fr/tel-01216740

[2] S. TONNEAU. *Motion planning and synthesis for virtual characters in constrained environments*, INSA de Rennes, February 2015, https://tel.archives-ouvertes.fr/tel-01144630

Articles in International Peer-Reviewed Journals

[3] F. ARGELAGUET SANZ, F. MULTON, A. LÉCUYER. *A methodology for introducing competitive anxiety and pressure in VR sports training*, in "Frontiers in Robotics and AI", April 2015, vol. 2, n^o 10, 11 p. [*DOI :* 10.3389/FROBT.2015.00010], https://hal.inria.fr/hal-01140454

[4] E. AUVINET, F. MULTON, J. MEUNIER. *New Lower-Limb Gait Asymmetry Indices Based on a Depth Camera*, in "Sensors", February 2015, vol. 15, n^o 3, pp. 4605-4623 [*DOI :* 10.3390/S150304605], https://hal.inria.fr/hal-01119763

[5] E. AUVINET, F. MULTON, J. MEUNIER, M. RAISON, C.-E. AUBIN. *Detection of gait cycles in treadmill walking using a Kinect*, in "Gait and Posture", 2015, vol. 41, n^o 2, 15 p. [*DOI :* 10.1016/J.GAITPOST.2014.08.006], https://hal.inria.fr/hal-01076393

[6] S. BRAULT, R. KULPA, L. DULISCOUËT, A. MARIN, B. BIDEAU. *Virtual kicker vs. real goalkeeper in soccer: a way to explore goalkeeper's performance*, in "Movement and Sport Sciences – Science and Motricité", October 2015, n^{o} 89, pp. 79-88 [*DOI :* 10.1051/SM/2015026], https://hal.archives-ouvertes.fr/hal-01239468

[7] J. BRUNEAU, A.-H. OLIVIER, J. PETTRÉ. *Going Through, Going Around: A Study on Individual Avoidance of Groups*, in "IEEE Transactions on Visualization and Computer Graphics", April 2015, vol. 21, n^{o} 4, 9 p. [*DOI :* 10.1109/TVCG.2015.2391862], https://hal.inria.fr/hal-01149960

[8] A. COVACI, A.-H. OLIVIER, F. MULTON. *Visual Perspective and Feedback Guidance for VR Free-Throw Training*, in "IEEE Computer Graphics and Applications", September 2015, vol. 35, n^{o} 5, pp. 55 - 65 [*DOI :* 10.1109/MCG.2015.95], https://hal.inria.fr/hal-01205681

[9] A. L. CRUZ RUIZ, C. PONTONNIER, A. SOREL, G. DUMONT. *Identifying representative muscle synergies in overhead football throws*, in "Computer Methods in Biomechanics and Biomedical Engineering", October 2015, 2 p. , https://hal.inria.fr/hal-01174114

[10] A. CRÉTUAL, I. BONAN, M. ROPARS. *Development of a novel index of shoulder's mobility based on the configuration space volume and its link to mono-axial amplitudes*, in "Manual Therapy", June 2015, 7 p. [*DOI :* 10.1016/J.MATH.2014.10.020], https://hal.inria.fr/hal-01090851

[11] A. CRÉTUAL. *Which biomechanical models are currently used in standing posture analysis?*, in "Neurophysiologie Clinique – Clinical Neurophysiology", 2015, vol. 45, n^{o} 4-5, pp. 285–295, Special issue : Balance and Gait [*DOI :* 10.1016/J.NEUCLI.2015.07.004], https://hal-univ-rennes1.archives-ouvertes.fr/hal-01205353

[12] C. LINO, M. CHRISTIE. *Intuitive and Efficient Camera Control with the Toric Space*, in "ACM Transactions on Graphics", July 2015, vol. 34, n^{o} 4, pp. 82:1–82:12 [*DOI :* 10.1145/2766965], https://hal.inria.fr/hal-01142876

[13] B. MERABTI, M. CHRISTIE, K. BOUATOUCH. *A Virtual Director Using Hidden Markov Models*, in "Computer Graphics Forum", 2015 [*DOI :* 10.1111/CGF.12775], https://hal.inria.fr/hal-01244643

[14] A. MULLER, C. GERMAIN, C. PONTONNIER, G. DUMONT. *A Comparative Study of 3 Body Segment Inertial Parameters Scaling Rules*, in "Computer Methods in Biomechanics and Biomedical Engineering", October 2015, 2 p. , https://hal.inria.fr/hal-01174120

[15] A. MULLER, C. PONTONNIER, C. GERMAIN, G. DUMONT. *Dealing with Modularity of Multibody Models*, in "Computer Methods in Biomechanics and Biomedical Engineering", October 2015, 2 p. , https://hal.inria.fr/hal-01174136

[16] P. PLANTARD, E. AUVINET, A.-S. LE PIERRES, F. MULTON. *Pose Estimation with a Kinect for Ergonomic Studies: Evaluation of the Accuracy Using a Virtual Mannequin*, in "Sensors", January 2015, vol. 15, pp. 1785-1803 [*DOI :* 10.3390/S150101785], https://hal.inria.fr/hal-01104045

[17] K. POTHIER, N. BENGUIGUI, R. KULPA, C. CHAVOIX. *Multiple Object Tracking While Walking: Similarities and Differences Between Young, Young-Old, and Old-Old Adults*, in "Journals of Gerontology Series B: Psychological Sciences and Social Sciences", November 2015, vol. 70, n^{o} 6, pp. 840-849 [*DOI :* 10.1093/GERONB/GBU047], https://hal.archives-ouvertes.fr/hal-01239476

[18] M. ROPARS, A. CRÉTUAL, R. KAILA, I. BONAN, H. ANTHONY, H. THOMAZEAU. *Diagnosis and treatment of anteroinferior capsular redundancy associated with anterior shoulder instability using an open Latarjet procedure and capsulorrhaphy*, in "Knee Surgery, Sports Traumatology, Arthroscopy", May 2015 [*DOI :* 10.1007/S00167-015-3621-9], https://hal.inria.fr/hal-01239752

[19] M. ROPARS, A. CRÉTUAL, H. THOMAZEAU, R. KAILA, I. BONAN. *Volumetric definition of shoulder range of motion and its correlation with clinical signs of shoulder hyperlaxity. A motion capture study*, in "Journal of Shoulder and Elbow Surgery", 2015, vol. 24, n^{o} 2, pp. 310-316 [*DOI :* 10.1016/J.JSE.2014.06.040], https://hal.inria.fr/hal-01058988

[20] A. SAMANI, C. PONTONNIER, G. DUMONT, P. MADELEINE. *Shoulder Kinematics and Spatial Pattern of Trapezius Electromyographic Activity in Real and Virtual Environments*, in "PLoS ONE", March 2015, vol. 10, n^{o} 3, e0116211 [*DOI :* 10.1371/JOURNAL.PONE.0116211], https://hal.archives-ouvertes.fr/hal-01133032

[21] N. VIGNAIS, R. KULPA, S. BRAULT, D. PRESSE, B. BIDEAU. *Which technology to investigate visual perception in sport: Video vs. virtual reality*, in "Human Movement Science", February 2015, vol. 39, pp. 12-26 [*DOI :* 10.1016/J.HUMOV.2014.10.006], https://hal.inria.fr/hal-01095548

International Conferences with Proceedings

[22] F. ARGELAGUET SANZ, A.-H. OLIVIER, G. BRUDER, J. PETTRÉ, A. LÉCUYER. *Virtual Proxemics: Locomotion in the Presence of Obstacles in Large Immersive Projection Environments*, in "IEEE Virtual Reality", Arles, France, March 2015, https://hal.inria.fr/hal-01149962

[23] G. BRUDER, F. ARGELAGUET SANZ, A.-H. OLIVIER, A. LÉCUYER. *Distance Estimation in Large Immersive Projection Systems, Revisited*, in "IEEE Virtual Reality", Arles, France, March 2015, https://hal.inria.fr/hal-01149964

[24] A. L. CRUZ RUIZ, C. PONTONNIER, J. LEVY, G. DUMONT. *Motion Control via Muscle Synergies: Application to Throwing*, in "MIG'15 Motion in Games", Paris, France, November 2015, 8 p. [*DOI :* 10.1145/2822013.2822022], https://hal.inria.fr/hal-01205162

[25] Q. GALVANE, M. CHRISTIE, C. LINO, R. RONFARD. *Camera-on-rails: Automated Computation of Constrained Camera Paths*, in "ACM SIGGRAPH Conference on Motion in Games", Paris, France, November 2015, https://hal.inria.fr/hal-01220119

[26] Q. GALVANE, R. RONFARD, M. CHRISTIE. *Comparing film-editing*, in "Eurographics Workshop on Intelligent Cinematography and Editing", Zurich, Switzerland, May 2015, https://hal.inria.fr/hal-01160593

[27] Q. GALVANE, R. RONFARD, C. LINO, M. CHRISTIE. *Continuity Editing for 3D Animation*, in "AAAI Conference on Artificial Intelligence", Austin, Texas, United States, AAAI Press, January 2015, https://hal.inria.fr/hal-01088561

[28] K. JORDAO, P. CHARALAMBOUS, M. CHRISTIE, J. PETTRÉ, M.-P. CANI. *Crowd Art: Density and Flow Based Crowd Motion Design*, in "Motion In Games", Paris, France, November 2015, https://hal.inria.fr/hal-01213887

[29] B. MERABTI, H.-Y. WU, C. B. SANOKHO, Q. GALVANE, C. LINO, M. CHRISTIE. *Insight: An annotation tool and format for film analysis*, in "Eurographics Workshop on Intelligent Cinematography and Editing", Zurich, Switzerland, May 2015, 1 p. [*DOI :* 10.2312/WICED.20151079], https://hal.inria.fr/hal-01240276

[30] A. MULLER, C. GERMAIN, C. PONTONNIER, G. DUMONT. *A Simple Method to Calibrate Kinematical Invariants: Application to Overhead Throwing*, in "33rd International Conference on Biomechanics in Sports (ISBS 2015)", Poitiers, France, ISBS proceedings, June 2015, https://hal.archives-ouvertes.fr/hal-01150814

[31] A. SAMANI, C. PONTONNIER, G. DUMONT, P. MADELEINE. *Kinematic synergy in a real and a virtual simulated assembly task*, in "19th Triennal Congress of the International Ergonomics Association (IEA2015)", Melbourne, Australia, August 2015, https://hal.inria.fr/hal-01174259

Conferences without Proceedings

[32] J. BATEMAN, M. CHRISTIE, R. RANON, R. RONFARD, T. SMITH. *Computer Generation of Filmic Discourse from a Cognitive/Affective Perspective*, in "Eurographics Workshop on Intelligent Cinematography and Editing", Zurich, Switzerland, May 2015, https://hal.inria.fr/hal-01160592

[33] C. LINO. *Toward More Effective Viewpoint Computation Tools*, in "Eurographics Workshop on Intelligent Cinematography and Editing", Zurich, Switzerland, May 2015, 8 p. , https://hal.inria.fr/hal-01152740

[34] S. TONNEAU, N. MANSARD, C. PARK, D. MANOCHA, F. MULTON, J. PETTRÉ. *A Reachability-based planner for sequences of acyclic contacts in cluttered environments*, in "International Symposium on Robotics Research (ISSR 2015)", Sestri Levante, Italy, September 2015, http://hal-lirmm.ccsd.cnrs.fr/lirmm-01149666

[35] H.-Y. WU, M. CHRISTIE. *Stylistic Patterns for Generating Cinematographic Sequences*, in "4th Workshop on Intelligent Cinematography and Editing Co-Located w/ Eurographics 2015", Zurich, Switzerland, May 2015, The definitive version is available at http://diglib.eg.org/ [*DOI :* 10.2312/WICED.20151077], https://hal.inria.fr/hal-01150905

[36] H.-Y. WU, T.-Y. LI, M. CHRISTIE. *Logic Control for Story Graphs in 3D Game Narratives*, in "2015 International Symposium on Smart Graphics", Chengdu, China, August 2015, https://hal.archives-ouvertes.fr/hal-01193141