IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2013

Team MORPHEO

Capture and Analysis of Shapes in Motion

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Vision, perception and multimedia interpretation

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Team MORPHEO

Keywords: Computer Vision, Computer Graphics, 3d Modeling, Geometry Processing, Video

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

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2. Overall Objectives

2.1. Introduction

Morpheo's main objective is the ability to perceive and to interpret moving shapes using systems of multiple cameras for the analysis of animal motion, animation synthesis and immersive and interactive environments. Multiple camera systems allow dense information on both shapes and their motion to be recovered from visual cues. Such ability to perceive shapes in motion brings a rich domain for research investigations on how to model, understand and animate real dynamic shapes. In order to reach this objective, several scientific and technological challenges must be faced:

A first challenge is to be able to recover shape information from videos. Multiple camera setups allow to acquire shapes as well as their appearances with a reasonable level of precision. However most effective current approaches estimate static 3D shapes and the recovery of temporal information, such as motion, remains a challenging task. Another challenge in the acquisition process is the ability to handle heterogeneous sensors with different modalities as available nowadays: color cameras, time of flight cameras, stereo cameras and structured light scanners, etc.

A second challenge is the analysis of shapes. Few tools have been proposed for that purpose and recovering the intrinsic nature of shapes is an actual and active research domain. Of particular interest is the study of animal shapes and of their associated articulated structures. An important task is to automatically infer such properties from temporal sequences of 3D models as obtained with the previously mentioned acquisition systems. Another task is to build models for classes of shapes, such as animal species, that allow for both shape and pose variations.

A third challenge concerns the analysis of the motion of shapes that move and evolve, typically humans. This has been an area of interest for decades and the challenging innovation is to consider for this purpose dense motion fields, obtained from temporally consistent 3D models, instead of traditional sparse point trajectories obtained by tracking particular features on shapes, e.g. motion capture systems. The interest is to provide full information on both motions and shapes and the ability to correlate these information.The main tasks that arise in this context are first to find relevant indices to describe the dynamic evolutions of shapes and second to build compact representations for classes of movements.

A fourth challenge tackled by Morpheo is immersive and interactive systems. Such systems rely on real time modeling, either for shapes, motion or actions. Most methods of shape and motion retrieval turn out to be fairly complex, and quickly topple hardware processing or bandwidth limitations, even with a limited number of cameras. Achieving interactivity thus calls for scalable methods and research of specific distribution and parallelization strategies.

2.2. Highlights of the Year

The work on human motion capture, done in collaboration with the technical university of Munich, received the best paper runner up award at the 3DV conference for the article: This work contributes to the field with an approach that recovers both the shape and the articulated pose of a human body over time sequences and using multiple videos.

BEST PAPER AWARD :

[7] **Robust Human Body Shape and Pose Tracking in 3DV - International Conference on 3D Vision - 2013**. C.-H. HUANG, E. BOYER, S. ILIC.

3. Research Program

3.1. Shape Acquisition

Recovering shapes from images is a fundamental task in computer vision. Applications are numerous and include, in particular, 3D modeling applications and mixed reality applications where real shapes are mixed with virtual environments. The problem faced here is to recover shape information such as surfaces from image information. A tremendous research effort has been made in the past to solve this problem in the static case and a number of solutions had been proposed. However, a fundamental issue still to be addressed is the recovery of full shape models with possibly evolving topologies using time sequence information. The main difficulties are precision, robustness of computed shapes as well as consistency of these models over time. Additional difficulties include the integration of multi-modality sensors as well as real-time applications.

3.2. Bayesian Inference

Acquisition of 4D Models can often be conveniently formulated as a Bayesian estimation or learning problem. Various generative and graphical models can be proposed for the problems of occupancy estimation, 3D surface tracking in a time sequence, and motion segmentation. The idea of these generative models is to predict the noisy measurements (e.g. pixel values, measured 3D points or speed quantities) from a set of parameters describing the unobserved scene state, which in turn can be estimated using Bayes' rule to solve the inverse problem. The advantages of this type of modeling are numerous, as they enable to model the noisy relationships between observed and unknown quantities specific to the problem, deal with outliers, and allow to efficiently account for various types of priors about the scene and its semantics. Sensor models for different modalities can also easily be seamlessly integrated and jointly used, which remains central to our goals.

Since the acquisition problems often involve a large number of variables, a key challenge is to exhibit models which correctly account for the observed phenoma, while keeping reasonable estimation times, sometimes with a real-time objective. Maximum likelihood / maximum a posteriori estimation and approximate inference techniques, such as Expectation Maximization, Variational Bayesian inference, or Belief Propagation, are useful tools to keep the estimation tractable. While 3D acquisition has been extensively explored, the research community faces many open challenges in how to model and specify more efficient priors for 4D acquisition and temporal evolution.

3.3. Spectral Geometry

Spectral geometry processing consists of designing methods to process and transform geometric objects that operate in frequency space. This is similar to what is done in signal processing and image processing where signals are transposed into an alternative frequency space. The main interest is that a 3D shape is mapped into a spectral space in a pose-independent way. In other words, if the deformations undergone by the shape are metric preserving, all the meshes are mapped to a similar place in spectral space. Recovering the coherence between shapes is then simplified, and the spectral space acts as a “common language” for all shapes that facilitates the computation of a one-to-one mapping between pairs of meshes and hence their comparisons. However, several difficulties arise when trying to develop a spectral processing framework. The main difficulty is to define a spectral function basis on a domain which is a 2D (resp. 3D for moving objects) manifold embedded in 3D (resp. 4D) space and thus has an arbitrary topology and a possibly complicated geometry.

3.4. Surface Deformation

Recovering the temporal evolution of a deformable surface is a fundamental task in computer vision, with a large variety of applications ranging from the motion capture of articulated shapes, such as human bodies, to the deformation of complex surfaces such as clothes. Methods that solve for this problem usually infer surface evolutions from motion or geometric cues. This information can be provided by motion capture systems or one of the numerous available static 3D acquisition modalities. In this inference, methods are faced with the challenging estimation of the time-consistent deformation of a surface from cues that can be sparse and noisy. Such an estimation is an ill posed problem that requires prior knowledge on the deformation to be introduced in order to limit the range of possible solutions.

3.5. Manifold Learning

The goal of motion analysis is to understand the movement in terms of movement coordination and corresponding neuromotor and biomechanical principles. Most existing tools for motion analysis consider as input rotational parameters obtained through an articulated body model, e.g. a skeleton. Such model is tracked using markers or estimated from shape information. Articulated motion is then traditionally represented by trajectories of rotational data, each rotation in space being associated to the orientation of one limb segment in the body model. This offers a high dimensional parameterization of all possible poses. Typically, using a standard set of articulated segments for a 3D skeleton, this parameterization offers a number of degrees of freedom (DOF) that ranges from 30 to 40. However, it is well known that for a given motion performance, the trajectories of these DOF span a much reduced space. Manifold learning techniques on rotational data have proven their relevance to represent various motions into subspaces of high-level parameters. However, rotational data encode motion information only, independently of morphology, thus hiding the influence of shapes over motion parameters. One of the objectives is to investigate how motions of human and animal bodies, i.e. dense surface data, span manifolds in higher dimensional spaces and how these manifolds can be characterized. The main motivation is to propose morpho-dynamic indices of motion that account for both shape and motion. Dimensionality reduction will be applied on these data and used to characterize the manifolds associated to human motions. To this purpose, the raw mesh structure cannot be statistically processed directly and appropriate features extraction as well as innovative multidimensional methods must be investigated.

4. Application Domains

4.1. 4D modeling

Modeling shapes that evolve over time, analyzing and interpreting their motion has been a subject of increasing interest of many research communities including the computer vision, the computer graphics and the medical imaging communities. Recent evolutions in acquisition technologies including 3D depth cameras (Time-of-Light and Kinect), multi-camera systems, marker based motion capture systems, ultrasound and CT scans have made those communities consider capturing the real scene and their dynamics, create 4D spatio-temporal models, analyze and interpret them. A number of applications including dense motion capture, dynamic shape modeling and animation, temporally consistent 3D reconstruction, motion analyses and interpretation have therefore emerged.

4.2. Shape analysis

Most existing shape analysis tools are local, in the sense that they give local insight about an object's geometry or purpose. The use of both geometry and motion clues makes it possible to recover more global information, in order to get extensive knowledge about a shape. For instance, motion can help to decompose a 3D model of a character into semantically significant parts, such as legs, arms, torso and head. Possible applications of such high-level shape understanding include accurate feature computation, comparison between models to detect defects or medical pathologies, and the design of new biometric models or new anthropometric datasets.

4.3. Human motion analysis

The recovery of dense motion information enables the combined analyses of shapes and their motions. Typical examples include the estimation of mean shapes given a set of 3D models or the identification of abnormal deformations of a shape given its typical evolutions. The interest arises in several application domains where temporal surface deformations need to be captured and analysed. It includes human body analyses for which potential applications with are anyway numerous and important, from the identification of pathologies to the design of new prostheses.

4.4. Interaction

The ability to build models of humans in real time allows to develop interactive applications where users interact with virtual worlds. The recent Kinect proposed by Microsoft illustrates this principle with game applications using human inputs perceived with a depth camera. Other examples include gesture interfaces using visual inputs. A challenging issue in this domain is the ability to capture complex scenes in natural environments. Multi-modal visual perception, e.g. depth and color cameras, is one objective in that respect.

5. Software and Platforms

5.1. Platforms

5.1.1. The Grimage platform

The Grimage platform is an experimental multi-camera platform dedicated to spatio-temporal modeling including immersive and interactive applications. It hosts a multiple-camera system connected to a PC cluster, as well as visualization facilities including head mounted displays. This platform is shared by several research groups, most proeminently Moais, Morpheo and Perception. In particular, Grimage allows challenging real-time immersive applications based on computer vision and interactions between real and virtual objects, Figure 1. Note that the Grimage platform will be replaced by the Kinovis platform that will exhibit a larger acquisition space and better acquisition facilities.

Figure 1. Platform: the Grimage acquisition.

5.1.2. Kinovis

Kinovis (http://kinovis.inrialpes.fr/) is a new multi-camera acquisition project that was was selected within the call for proposals ”Equipements d’Excellence” of the program “Investissement d’Avenir˝ funded by the French government. The project involves 2 institutes: the Inria Grenoble Rhône-Alpes, the université Joseph Fourier and 4 laboratories: the LJK(laboratoire Jean Kuntzmann - applied mathematics), the LIG (laboratoire d’informatique de Grenoble - Computer Science), the Gipsa lab (Signal, Speech and Image processing) and the LADAF (Grenoble Hospitals - Anatomy). The Kinovis environment will be composed of 2 complementary platforms. A first platform located at the Inria Grenoble will have a 10mx10m acquisition surface and will be equipped with 60 cameras. It is the evolution of the Grimage platform previously described towards the production of better models of more complex dynamic scenes. A second platforms located at Grenoble Hospitals, within the LADAF anatomy laboratory, will be equipped with both color and X-ray cameras to enable combined analysis of internal and external shape structures, typically skeleton and bodies of animals. Installation works of both platforms started in 2013 and should be finished in 2014. Members of Morpheo are highly involved in this project. Edmond Boyer is coordinating this project and Lionel Reveret is in charge of the LADAF platform.

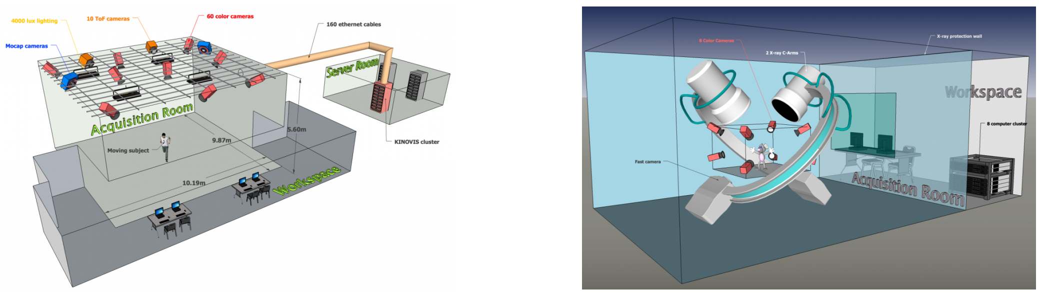

Figure 2. Kinovis platforms: on the left the Inria platform; on the right Grenoble Hospital platform.

5.1.3. Multicamera platform for video analysis of mice behavior

This project is a follow-up of the experimental set-up developed for a CNES project with Mathieu Beraneck from the CESeM laboratory (centre for the study of sensorimotor control, CNRS UMR 8194) at the Paris-

Descartes University. The goal of this project was to analyze the 3D body postures of mice with various vestibular deficiencies in low gravity condition (3D posturography) during a parabolic flight campaign. The set-up has been now adapted for new experiments on motor-control disorders for other mice models. This experimental platform is currently under development for a broader deployment for high throughput phenotyping with the technology transfer project ETHOMICE. This project involves a close relationship with the CESeM laboratory and the European Mouse Clinical Institute in Strasbourg (Institut Clinique de la Souris, ICS).

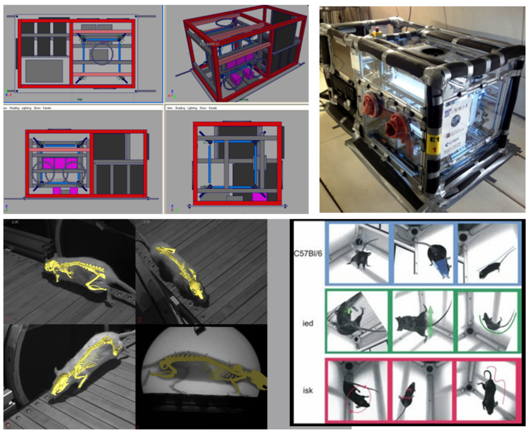

Figure 3. Ethomice: Experimental platform for video analysis of mice behavior.

5.2. Software packages

5.2.1. LucyViewer

Lucy Viewer http://4drepository.inrialpes.fr/lucy_viewer/ is an interactive viewing software for 4D models, i.e, dynamic three-dimensional scenes that evolve over time. Each 4D model is a sequence of meshes with associated texture information, in terms of images captured from multiple cameras at each frame. Such data is available from various websites over the world including the 4D repository website hosted by Inria Grenoble http://4drepository.inrialpes.fr/. The software was developed in the context of the European project iGlance, it is available as an open source software under the GNU LGP Licence.

5.2.2. Ethomice

Ethomice http://morpheo.inrialpes.fr/people/reveret/ethomice/ is a motion analysis software to characterize motor behavior of small vertebrates such as mice or rats. From a multiple views video input, a biomechanical model of the skeleton is registered. Study on animal model is the first important step in Biology and Clinical research. In this context, the analysis of the neuro-motor behaviour is a frequent cue to test the effect of a gene or a drug. Ethomice is a platform for simulation and analysis of the small laboratory animal, such as rat or mouse. This platform links the internal skeletal structure with 3D measurements of the external appearance of the animal under study. From a stream of multiple views video, the platform aims at delivering a three dimensional analysis of the body posture and the behaviour of the animal. The software was developed by Lionel Reveret and Estelle Duveau. An official APP repository has been issued this year.

5.3. Databases

5.3.1. 4D repository (http://4drepository.inrialpes.fr/)

This website hosts dynamic mesh sequences reconstructed from images captured using a multi-camera set up. Such mesh-sequences offer a new promising vision of virtual reality, by capturing real actors and their interactions. The texture information is trivially mapped to the reconstructed geometry, by back-projecting from the images. These sequences can be seen from arbitrary viewing angles as the user navigates in 4D (3D geometry + time) . Different sequences of human / non-human interaction can be browsed and downloaded from the data section. A software to visualize and navigate these sequences is also available for download.

6. New Results

6.1. Robust human body shape and pose tracking

This work considers markerless human performance capture from multiple camera videos and, in particular, the recovery of both shape and parametric motion information, as often required in applications that produce and manipulate animated 3D contents using multiple videos. To this aim, an approach is proposed that jointly estimates skeleton joint positions and surface deformations by fitting a reference surface model to 3D point reconstructions. The approach is based on a probabilistic deformable surface registration framework coupled with a bone binding energy. The former makes soft assignments between the model and the observations while the latter guides the skeleton fitting. The main benefit of this strategy lies in its ability to handle outliers and erroneous observations frequently present in multi view data. For the same purpose, we also introduce a learning based method that partitions the point cloud observations into different rigid body parts that further discriminate input data into classes in addition to reducing the complexity of the association between the model and the observations. We argue that such combination of a learning based matching and of a probabilistic fitting framework efficiently handle unreliable observations with fake geometries or missing data and hence, it reduces the need for tedious manual interventions. The work was presented at the 3DV conference [7] where it received the best paper runner up award.

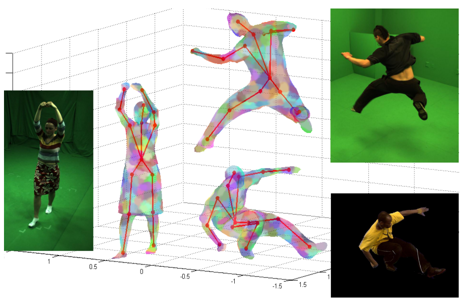

Figure 4. Human pose recovery with 3 different standard datasets.

6.2. Inverse dynamics on rock climbing with and without measurement of contact forces

Rock climbing involves complex interactions of the body with the environment (Figure 5). It represents an interesting problem in biomechanics as multiple contacts in the locomotion task make it an underconstrained problem. In this study we are interested in evaluating how a climber transfers weight through the holds. The motivation of this study is also technical as we are developing an inverse dynamics method that automatically estimates in 3D, not only the usual torques at joint angles, but also the wrenches at contacts [9].

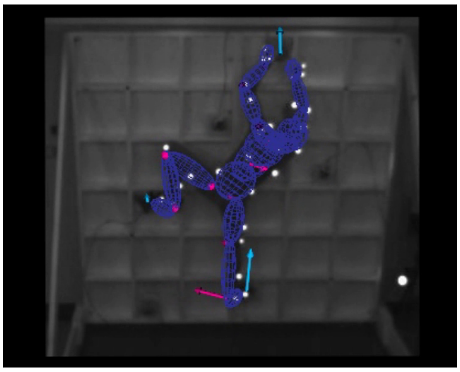

Figure 5. Inverse dynamics on rock climbing with and without measurement of contact forces.

6.3. Video-based methodology for markerless human motion analysis

This study presents a video-based experiment for the study of markerless human motion. Silhouettes are extracted from a multi-camera video system to reconstruct a 3D mesh for each frame using a reconstruction method based on visual hull. For comparison with traditional motion analysis results, we set up an experiment integrating video recordings from 8 video cameras and a Vicon™ marker-based motion capture system (Figure 6). Our preliminary data provided distances between the 3D trajectories from the Vicon system and the 3D mesh extracted from the video cameras. In the long term, the main ambition of this method is to provide measurement of skeleton motion for human motion analyses while eliminating markers [8].

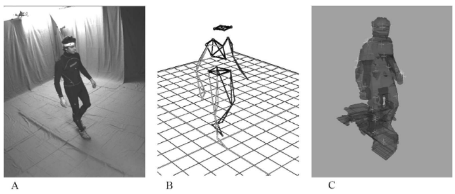

Figure 6. Video-based methodology for markerless human motion analysis.

6.4. 3D shape cropping

We introduce shape cropping as the segmentation of a bounding geometry of an object as observed by sensors with different modalities. Segmenting a bounding volume is a preliminary step in many multi-view vision applications that consider or require the recovery of 3D information, in particular in multi-camera environments. Recent vision systems used to acquire such information often combine sensors of different types, usually color and depth sensors. Given depth and color images we present an efficient geometric algorithm to compute a polyhedral bounding surface that delimits the region in space where the object lies. The resulting cropped geometry eliminates unwanted space regions and enables the initialization of further processes including surface refinements. Our approach exploits the fact that such a region can be defined as the intersection of 3D regions identified as non empty in color or depth images. To this purpose, we propose a novel polyhedron combination algorithm that overcomes computational and robustness issues exhibited by traditional intersection tools in our context. We show the correction and effectiveness of the approach on various combination of inputs. This work was presented at the Vision Modeling and Visualization workshop 2013 [6].

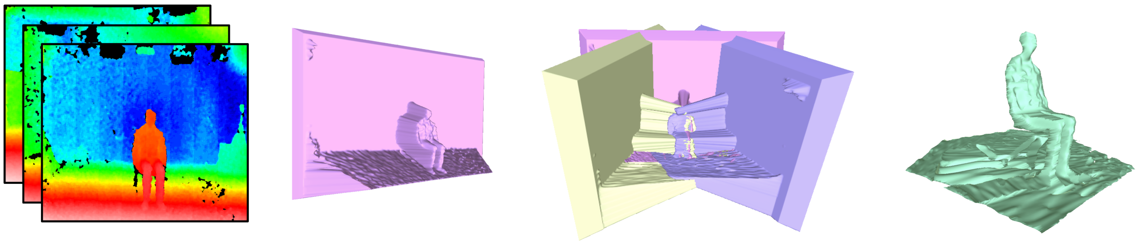

Figure 7. Result of shape cropping using three input depth maps for polyhedral reconstruction.

6.5. Multi-view object segmentation in space and time

In this work, we address the problem of object segmentation in multiple views or videos when two or more viewpoints of the same scene are available. We propose a new approach that propagates segmentation coherence information in both space and time, hence allowing evidences in one image to be shared over the complete set. To this aim the segmentation is cast as a single efficient labeling problem over space and time with graph cuts. In contrast to most existing multi-view segmentation methods that rely on some form of dense reconstruction, ours only requires a sparse 3D sampling to propagate information between viewpoints. The approach is thoroughly evaluated on standard multi-view datasets, as well as on videos. With static views, results compete with state of the art methods but they are achieved with significantly fewer viewpoints. With multiple videos, we report results that demonstrate the benefit of segmentation propagation through temporal cues, in ICCV 2013 [5].

6.6. Segmentation of temporal mesh sequences into rigidly moving components

This work considers the segmentation of meshes into rigid components given temporal sequences of deforming meshes (Figure 9). We have proposed a fully automatic approach that identifies model parts that consistently move rigidly over time. This approach can handle meshes independently reconstructed at each time instant. It allows therefore for sequences of meshes with varying connectivities as well as varying topology. It incrementally adapts, merges and splits segments along a sequence based on the coherence of motion information within each segment. In order to provide tools for the evaluation of the approach, we also introduce new criteria to quantify a mesh segmentation. Results on both synthetic and real data as well as comparisons are provided in the paper [1].

6.7. Segmentation of plant point cloud models into elementary units

High-resolution terrestrial Light Detection And Ranging (tLiDAR), a 3-D remote sensing technique, has recently been applied for measuring the 3-D characteristics of vegetation from grass to forest plant species. The resulting data are known as a point cloud which shows the 3-D position of all the hits by the laser beam giving a raw sketch of the spatial distribution of plant elements in 3-D, but without explicit information on their geometry and connectivity. In this study we propose a new approach based on a delineation algorithm that clusters a point cloud into elementary plant units. The algorithm creates a graph (points + edges) to recover plausible neighbouring relationships between the points and embed this graph in a spectral space in order to segment the point-cloud into meaningful elementary plant units. Our approach is robust to inherent geometric outliers and/or noisy points and only considers the x, y, z coordinate tLiDAR data as an input. It has been presented at the FSPM conference [4].

Figure 8. Multi-view object segmentation using our method with the 3 wide-baseline views shown only, with no photo-consistency hypothesis and no user interaction.

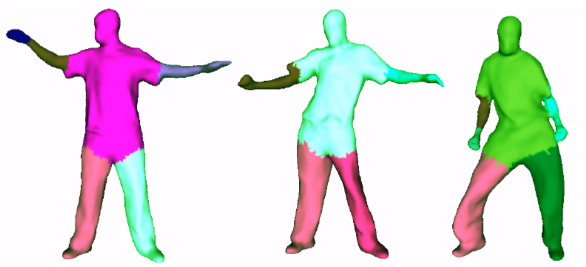

Figure 9. Segmentation of temporal mesh sequences into rigidly moving components.

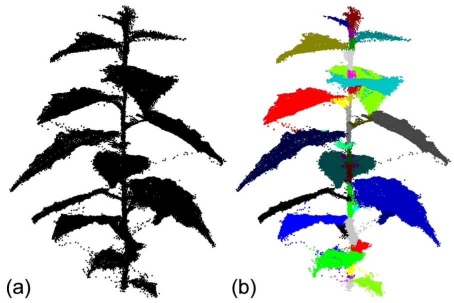

Figure 10. Segmentation of a plant point cloud model into elementary units.

7. Bilateral Contracts and Grants with Industry

7.1. Contract with Technicolor

A three year collaboration with Technicolor has started in 2011. The objective of this collaboration is to consider the capture and the interpretation of complex dynamic scenes in uncontrolled environments. A co-supervised PhD student (Abdelaziz Djelouah) is currently active on this topic [5] [10].

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. ARC6 project PADME – Perceptual quality Assessment of Dynamic MEshes and its applications

In this project, we propose to use a new and experimental "bottom-up" approach to study an interdisciplinary problem, namely the objective perceptual quality assessment of 3D dynamic meshes (i.e., shapes in motion with temporal coherence). The objectives of the proposed project are threefold:

1. to understand the HVS (human visual system) features when observing 3D animated meshes, through a series of psychophysical experiments;
2. to develop an efficient and open-source objective quality metric for dynamic meshes based on the results of the above experiments;
3. to apply the learned HVS features and the derived metric to the application of compression and/or watermarking of animated meshes.

This work is funded by the Rhône-Alpes région through an ARC6 grant for the period 2013-2016. The three partners are LIRIS (University Lyon 1, Florent Dupont), GIPSA-Lab (CNRS, Kai Wang) and LJK (University of Grenoble, Franck Hétroy). The PhD thesis of Georges Nader is part of the project.

8.2. National Initiatives

8.2.1. Motion analysis of laboratory rodents

In order to evaluate the scalabililty of previous work on motion analysis of laboratory rodents, a collaboration has been initiated with the Institut Clinique de la Souris (ICS), in Institut de Génétique et de Biologie Moléculaire et Cellulaire (IGBMC). This institute is dedicated to phenotypying of mice and requires reliable motion analysis tools. A multicamera plateform has been deployed at ICS and will be exploited next year for tests ranging from one to two hundreds mice.

8.2.2. ANR

8.2.2.1. ANR project Morpho – Analysis of Human Shapes and Motions

Morpho is aimed at designing new technologies for the measure and for the analysis of dynamic surface evolutions using visual data. Optical systems and digital cameras provide a simple and non invasive mean to observe shapes that evolve and deform and we propose to study the associated computing tools that allow for the combined analysis of shapes and motions. Typical examples include the estimation of mean shapes given a set of 3D models or the identification of abnormal deformations of a shape given its typical evolutions. Therefore this does not only include static shape models but also the way they deform with respect to typical motions. It brings a new research area on how motions relate to shapes where the relationships can be represented through various models that include traditional underlying structures, such as parametric shape models, but are not limited to them. The interest arises in several application domains where temporal surface deformations need to be captured and analyzed. It includes human body analyses but also extends to other deforming objects, sails for instance. Potential applications with human bodies are anyway numerous and important, from the identification of pathologies to the design of new prostheses. The project focus is therefore on human body shapes and their motions and on how to characterize them through new biometric models for analysis purposes. 3 academic partners will collaborate on this project: the Inria Rhône-Alpes with the Morpheo team, the GIPSA-lab Grenoble and the Inria Lorraine with the Alice team. Website: http://morpho.inrialpes.fr/.

8.2.3. Competitivity Clusters

8.2.3.1. FUI project Creamove

Creamove is a collaboration between the Morpheo team of the Inria Grenoble Rhône-Alpes, the 4D View Solution company specialised in multi-camera acquisition systems, the SIP company specialised in multi-media and interactive applications and a choreographer. The objective is to develop new interactive and artistic applications where humans can interact in 3D with virtual characters built from real videos. Dancer performances will be pre-recorded in 3D and used on-line to design new movement sequences based on inputs coming from human bodies captured in real time.

8.3. European Initiatives

8.3.1. FP7 Projects

8.3.1.1. Re@ct

Type: COOPERATION

Challenge: IMMERSIVE PRODUCTION AND DELIVERY OF INTERACTIVE 3D CONTENT

Instrument: Specific Targeted Research Project

Objective: Networked Media and Search Systems

Duration: December 2011 - November 2014

Coordinator: BBC (UK)

Partner: BBC (UK), Fraunhofer HHI (Germany), University of Surrey (UK), Artefacto (France), OMG (UK).

Inria contact: Jean-Sébastien Franco, Edmond Boyer

Abstract: RE@CT will introduce a new production methodology to create film-quality interactive characters from 3D video capture of actor performance. Recent advances in graphics hardware have produced interactive video games with photo-realistic scenes. However, interactive characters still lack the visual appeal and subtle details of real actor performance as captured on film. In addition, existing production pipelines for authoring animated characters are highly labour intensive. RE@CT aims to revolutionise the production of realistic characters and significantly reduce costs by developing an automated process to extract and represent animated characters from actor performance capture in a multiple camera studio. The key innovation is the development of methods for analysis and representation of 3D video to allow reuse for real-time interactive animation. This will enable efficient authoring of interactive characters with video quality appearance and motion. The project builds on the latest advances in 3D and free-viewpoint video from the contributing project partners. For interactive applications, the technical challenges are to achieve another step change in visual quality and to transform captured 3D video data into a representation that can be used to synthesise new actions and is compatible with current gaming technology.

8.4. International Initiatives

8.4.1. Inria Associate Teams

The Morpheo team is associated with the Matsuyama lab. at the University of Kyoto (http://morpheo.inrialpes.fr/Kyoto/). Both entities are working on the capture of evolving shapes using multiple videos and the objective of the collaboration is to make progress on the modeling of dynamic events using visual cues with a particular emphasize on human gesture modeling for analysis purposes. To this aim, the collaboration fosters exchanges between researchers in this domain, in particular young researchers, through visits between the two teams. In the frame of this collaboration, a workshop was organized in November 2013 at the Inria Grenoble (http://morpheo.inrialpes.fr/kyoto/inria-kyoto-workshop-on-4d-modeling/).

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

8.4.2.1.1. Collaboration with Forest Research, UK

A common work with an ecophysiologist from Forest Research, Eric Casella, is currently carried out to recover useful geometric information from unorganized point clouds of plants and trees, obtained with a terrestrial laser scanning device. Preliminary results have been presented this year at the FSPM conference [4].

8.4.2.1.2. Collaboration with TU Munich

The long term collaboration with TU Munich and Slobodan Ilic on human motion capture is ongoing with the work of Paul Huang [7] that was published at 3DV this year and received a best paper award. The work contributes with an approach that recovers both the shape and the articulated pose of a human body, over time sequences, using multiple videos.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Prof. Matsuyama, Kyoto University, Matsuyama Lab, Japan.
- Associate Prof. Shohei Nobuhara, Kyoto University, Matsuyama Lab, Japan
- Assistant prof. Tony Tung, Kyoto University, Matsuyama Lab, Japan.

9. Dissemination

9.1. Scientific Animation

- Edmond Boyer was co-organizer of the ICCV 2013 workshop 4DMOD on 4D Modeling.
- Edmond Boyer was an area chair for BMVC 2013.
- Edmond Boyer was a member of the program committees of: CVPR2013, ICCV2013, 3DV2013, CVMP2013, HAU3D2013 (CVRP Workshop), ORASIS2013.
- Edmond Boyer has reviewed for the journals: IEEE PAMI, springer IJCV and Elsevier CVIU.
- Edmond Boyer gave invited talks at Kyoto University and Dagsthul seminar.

- Jean-Sébastien Franco has reviewed for the following conferences: CVPR 2013, ICCV 2013, 3DV 2013.
- Jean-Sébastien Franco has reviewed for the following journal: Robotics and Autonomous Systems.
- Franck Hétroy has reviewed for the journal: ReFIG.
- Franck Hétroy has reviewed for the conferences: ACM SIGGRAPH 2013 and Joint Virtual Reality Conference 2013.
- Lionel Reveret has reviewed for the journals: ACM Transactions on Graphics, Computer Graphics Forum.
- Lionel Reveret has reviewed for the conferences in 2013: ACM SIGGRAPH, Eurographics, BMVC, Pacific Graphics (committee member), Motion in Games (committee member).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: J.S. Franco, Algorithmics, 70h, Grenoble INP - Ensimag, France.

License: J.S. Franco, C Project, 58h, Grenoble INP - Ensimag, France.

Licence: J.S. Franco, Introduction to Computer Vision, 27h, Grenoble INP - Ensimag, France.

Licence: Franck Hétroy, algorithmique et structures de données, 45h, Grenoble INP - Ensimag, France.

Master: Edmond Boyer, 3D Modeling, 9h, M2R GVR, Université Joseph Fourier Grenoble, France.

Master: Edmond Boyer, projet de programmation, 30h, M1 informatique - M1 MoSig, Université Joseph Fourier Grenoble, France.

Master: Edmond Boyer, Introduction to Image Analysis, 15h, M1 MoSig, Université Joseph Fourier Grenoble, France.

Master: J.S. Franco, End of study project (PFE) Project Tutoring, 9h, Grenoble INP - Ensimag, France.

Master: J.S. Franco, Projet de Specialité - Project Tutoring, 9h, Grenoble INP - Ensimag, France.

Master: J.S. Franco, 3D Graphics, 50h, Grenoble INP - Ensimag, France.

Master: J.S. Franco, Modelisation et programmation C++, 9h, Ensimag 2nd year, Grenoble INP

Master: Franck Hétroy, modélisation et programmation C++, 18h, Grenoble INP - Ensimag, France.

Master: Franck Hétroy, géométrie algorithmique, 9h, Grenoble INP - Ensimag, France.

Master: Franck Hétroy, introduction a la recherche en laboratoire, 6h, Grenoble INP - Ensimag, France.

Master: Franck Hétroy, projets de spécialité image, 45h, Grenoble INP - Ensimag, France.

Master: Franck Hétroy, responsible for Grenoble INP - Ensimag 2nd year, France.

Master: Lionel Reveret, Synthèse d'Image Avancée, 22h, Grenoble INP - Ensimag, France.

Master: Lionel Reveret, Ingénierie de l'Animation 3D, 18h, Grenoble INP - Ensimag, France.

Master: Lionel Reveret, Anatomie Numérique, 4h, Ecole de Médecine, La Tronche, France.

9.2.2. Supervision

PhD in progress : Benjamin Allain, *Geometry and Appearance Analysis of Deformable 3D shapes*, Université de Grenoble, started 01/10/2012, supervised by J.S. Franco and E. Boyer.

PhD in progress: Benjamin Aupetit, *Raffinement de forme avec photo-consistance spatio-temporelle*, Université de Grenoble, started 01/10/2011, supervised by Edmond Boyer and Franck Hétroy.

PhD in progress: Adnane Boukhayma, *4D model synthesis*, Université de Grenoble, started 01/10/2013, supervised by Edmond Boyer.

PhD in progress: Simon Courtemanche, *Analyse et modélisation des gestes d'escalade*, Université de Grenoble, started 01/10/2010, supervised by Edmond Boyer and Lionel Reveret.

PhD in progress : Abdelaziz Djelouah, *Gesture Interfaces*, Technicolor-Université de Grenoble, started 01/04/2011, supervised by J.S. Franco, E. Boyer, F. Leclerc et P. Perez.

PhD in progress: Georges Nader, *Evaluation de la qualité perceptuelle de maillages dynamiques et ses applications*, Université Claude Bernard - Lyon 1, started 01/10/2013, supervised by Florent Dupont, Kai Wang and Franck Hétroy.

PhD in progress: Li Wang, *Transport optimal pour l'analyse de formes en mouvement, Université de Grenoble*, started 01/10/2013, supervised by Edmond Boyer and Franck Hétroy.

PhD in progress : Vagia Tsiminaki, *Appearance Modelling and Time Refinement in 3D Videos*, Université de Grenoble, started 01/10/2012, supervised by J.S. Franco and E. Boyer.

9.2.3. Juries

- Edmond Boyer was reviewer of one PhD thesis (Youssef Alj - Université de Rennes) and was examiner of one PhD thesis (Mathieu Barnachon - Université de Lyon 1).
- Franck Hétroy was examiner of one PhD thesis (Thibaut Le Naour - Université de Bretagne Sud).

10. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] R. ARCILA, C. CAGNIART, F. HÉTROY, E. BOYER, F. DUPONT. *Segmentation of temporal mesh sequences into rigidly moving components*, in "Graphical Models", January 2013, vol. 75, n^{o} 1, pp. 10-22 [*DOI :* 10.1016/J.GMOD.2012.10.004], http://hal.inria.fr/hal-00749302

[2] A. BARBACCI, J. DIENER, P. HÉMON, A. ADAM, N. DONÈS, L. REVERET, B. MOULIA. *A robust videogrametric method for the velocimetry of wind-induced motion in trees*, in "Agricultural and Forest Meteorology", January 2014, vol. 184, pp. 220-229 [*DOI :* 10.1016/J.AGRFORMET.2013.10.003], http://hal.inria.fr/hal-00915106

[3] M. ROUHANI, A. D. SAPPA. *The Richer Representation the Better Registration*, in "IEEE Transactions on Image Processing", December 2013, vol. 22, n^{o} 12, pp. 5036-5049 [*DOI :* 10.1109/TIP.2013.2281427], http://hal.inria.fr/hal-00916505

International Conferences with Proceedings

[4] D. BOLTCHEVA, E. CASELLA, R. CUMONT, F. HÉTROY. *A spectral clustering approach of vegetation components for describing plant topology and geometry from terrestrial waveform LiDAR data*, in "FSPM2013 - 7th International Conference on Functional-Structural Plant Models", Saariselkä, Finland, A. LINTUNEN (editor), June 2013, Poster, http://hal.inria.fr/hal-00817508

[5] A. DJELOUAH, J.-S. FRANCO, E. BOYER, F. LE CLERC, P. PÉREZ. *Multi-View Object Segmentation in Space and Time*, in "ICCV 2013 - International conference on computer vision", Syndey, Australia, December 2013, http://hal.inria.fr/hal-00873544

[6] J.-S. FRANCO, B. PETIT, E. BOYER. *3D Shape Cropping*, in "Vision, Modeling and Visualization", Lugano, Switzerland, Eurographics Association, September 2013, pp. 65-72 [*DOI :* 10.2312/PE.VMV.VMV13.065-072], http://hal.inria.fr/hal-00904661

[7] *Best Paper*
C.-H. HUANG, E. BOYER, S. ILIC. *Robust Human Body Shape and Pose Tracking*, in "3DV - International Conference on 3D Vision - 2013", Seattle, United States, June 2013, http://hal.inria.fr/hal-00922934.

[8] P. PROVINI, J. PANSIOT, L. REVERET, O. MARTIN. *Video-based methodology for markerless human motion analysis*, in "15ème Congrès international de l'Association des Chercheurs en Activités Physiques et Sportives (ACAPS)", Grenoble, France, October 2013, http://hal.inria.fr/hal-00915093

Conferences without Proceedings

[9] S. COURTEMANCHE, P. PROVINI, P. KRY, O. MARTIN, L. REVERET. *Inverse dynamics on rock climbing with and without measurement of contact forces*, in "ICVM 2013 - 10th International Congress of Vertebrate Morphology", Barcelona, Spain, July 2013, http://hal.inria.fr/hal-00915082

[10] A. DJELOUAH, J.-S. FRANCO, E. BOYER, F. LE CLERC, P. PÉREZ. *Modélisation probabiliste pour la segmentation multi-vues*, in "ORASIS - Congrès des jeunes chercheurs en vision par ordinateur", Cluny, France, June 2013, http://hal.inria.fr/hal-00830762