IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2012

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 Understanding

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Team MORPHEO

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

Creation of the Team: March 01, 2011 .

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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

2.2.1. Equipement d'Excellence - Kinovis

The Kinovis project has been granted 2 million Euros by the French government within the "Equipement d'Excellence 2012" call for proposals. Kinovis is a collaboration between Inria Grenoble Rhône-Alpes and the University Joseph Fourier and is lead by the Morpheo team. This equipment project will implement 2 acquisition platforms for the capture and the analysis of moving animals and humans. At Inria Grenoble Rhône-Alpes a large platform equipped with 50 cameras will be set up. This platform will be used to capture large and complex scenes, e.g. multiple moving humans. At the Laboratory of Anatomy of Grenoble Hospital (LADAF - UJF), a dual Xray imaging system will be installed, coupled with a multiple views camera system, with the objective to investigate how the motion of laboratory animals such as mice and complex articulation such as hands, knees or feet for humans, relates to their anatomical structures.

3. Scientific Foundations

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 being 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

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.

5.1.2. Virtualization Gate

Vgate is an immersive environment that allows full-body immersion and interaction with virtual worlds. It is a joint initiative of computer scientists from computer vision, parallel computing and computer graphics from several research groups at Inria Grenoble Rhône-Alpes, and in collaboration with the company 4D View Solutions. The Morpheo team is leading this project.

Figure 1. Platforms: on the left the Grimage acquisition; on the right the vgate immersive environment.

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).

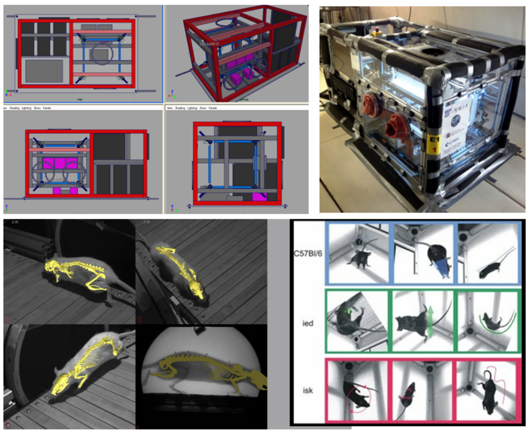

Figure 2. Ethomice: Experimental platform for video analysis of mice behavior.

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.

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. A discrete 3D+t Laplacian framework for mesh animation processing

In this work we extend the discrete 3D Laplacian framework to mesh animations, represented as temporally coherent sequences of meshes (Figure 3). In order to let the user control the motion influence with respect to the geometry, we introduce a parameter for the time dimension. Our discrete 3D+t Laplace operator holds the same properties as the discrete 3D Laplacian, as soon as this parameter is non negative. We demonstrate the usefulness of this framework by extending Laplacian-based mesh editing and fairing techniques to mesh animations [15].

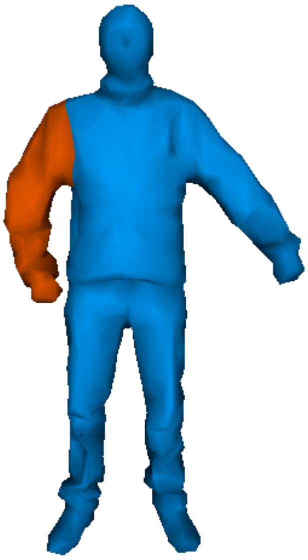

Figure 3. 3D+t Laplacian

6.2. Surface Flow

Recovering dense motion information is a fundamental intermediate step in the image processing chain upon which higher level applications can be built, such as tracking or segmentation. For that purpose, pixel observations in the image provide useful motion cues through temporal variations of the intensity function. We have studied the estimation of dense, instantaneous 3D motion fields over non-rigidly moving surface observed by multi-camera systems. The motivation arises from multi-camera applications that require motion information for arbitrary subjects, in order to perform tasks such as surface tracking or segmentation. To this aim, we have proposed a novel framework that allows to efficiently compute dense 3D displacement fields using low level visual cues and geometric constraints. The main contribution is a unified framework that combines flow constraints for small displacements with temporal feature constraints for large displacements and fuses them over the surface using local rigidity constraints. The resulting linear optimization problem allows for variational solutions and fast implementations. Experiments conducted on synthetic and real data demonstrated the respective interests of flow and feature constraints as well as their efficiency to provide robust surface motion cues when combined.

As an extension of this work, we also studied the situation where a depth camera and one or more color cameras are available, a common situation with recent composite sensors such as the Kinect. In this case, geometric information from depth maps can be combined with intensity variations in color images in order to estimate smooth and dense 3D motion fields. We propose a unified framework for this purpose, that can handle both arbitrary large motions and sub-pixel displacements. The novelty with respect to existing scene flow approaches is that it takes advantage of the geometric information provided by the depth camera to define a surface domain over which photometric constraints can be consistently integrated in 3D. Experiments on real and synthetic data provide both qualitative and quantitative results that demonstrated the interest of the approach[12].

6.3. Progressive Shape Models

In this work we address the problem of recovering both the topology and the geometry of a deformable shape using temporal mesh sequences (Figure 4). The interest arises in multi-camera applications when unknown natural dynamic scenes are captured. While several approaches allow recovery of shape models from static scenes, few consider dynamic scenes with evolving topology and without prior knowledge. In this nonetheless generic situation, a single time observation is not necessarily enough to infer the correct topology of the observed shape and evidences must be accumulated over time in order to learn this topology and to enable temporally consistent modelling. This appears to be a new problem for which no formal solution exists. We have proposed a principled approach based on the assumption that the observed objects have a fixed topology. Under this assumption, the topology can be progressively learned during the capture of a dynamic scene evolutions. The approach has been successfully experimented on several standard 4D datasets and we believe that it paves the way to more general multi-view scene capture and analysis[8].

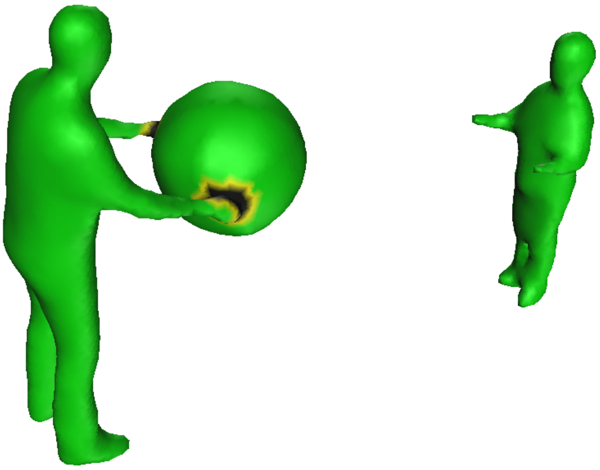

Figure 4. Progressive Shape Models : the balloon can be separated from humans

6.4. Principal Geodesic Dynamics

This work presents a new integration of a data-driven approach using dimension reduction and a physically-based simulation for real-time character animation (Figure 5). We exploit Lie group statistical analysis techniques (Principal Geodesic Analysis, PGA) to approximate the pose manifold of a motion capture sequence by a reduced set of pose geodesics. We integrate this kinematic parametrization into a physically-based animation approach of virtual characters, by using the PGA-reduced parametrization directly as generalized coordinates of a Lagrangian formulation of mechanics. In order to achieve real-time without sacrificing stability, we derive an explicit time integrator by approximating existing variational integrators. Finally, we test our approach in task-space motion control. By formulating both physical simulation and inverse kinematics time stepping schemes as two quadratic programs, we propose a features-based control algorithm that interpolates between the two metrics. This allows for an intuitive trade-off between realistic physical simulation and controllable kinematic manipulation[9].

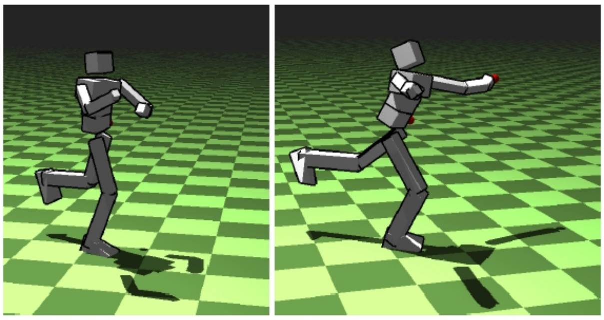

Figure 5. Principal Geodesic Dynamics : test of the balance controller

6.5. A Minimal Solution for Camera Calibration Using Independent Pairwise Correspondences

We have proposed a minimal algorithm for fully calibrating a camera from 11 independent pairwise point correspondences with two other calibrated cameras. Unlike previous approaches, our method neither requires triple correspondences, nor prior knowledge about the viewed scene. This algorithm can be used to insert or re-calibrate a new camera into an existing network, without having to interrupt operation. Its main strength comes from the fact that it is often difficult to find triple correspondences in a camera network. This makes the algorithm, for the specified use cases, probably the most suited calibration solution that does not require a calibration target, and hence can be performed without human interaction [10].

6.6. N-Tuple Color Segmentation for Multi-View Silhouette Extraction

We have presented a new method to extract multiple segmentations of an object viewed by multiple cameras, given only the camera calibration. This method relies on the n-tuple color model to express inter-view consistency when inferring in each view the foreground and background color models permitting the final segmentation. A color n-tuple is a set of pixel colors associated to the n projections of a 3D point. The first goal is set as finding the MAP estimate of background/foreground color models based on an arbitrary sample set of such n-tuples, such that samples are consistently classified, in a soft way, as "empty" if they project in the background of at least one view, or "occupied" if they project to foreground pixels in all views. An Expectation Maximization framework is then used to alternate between color models and soft classifications. In a final step, all views are segmented based on their attached color models. The approach is significantly simpler and faster than previous multi-view segmentation methods, while providing results of equivalent or better quality. [6].

6.7. Cage-based Motion Recovery using Manifold Learning

We have proposed a flexible model-based approach for the recovery of parameterized motion from a sequence of 3D meshes without temporal coherence (Figure 6). Unlike previous model-based approaches using skeletons, we embed the deformation of a reference mesh template within a low polygonal representation of the mesh, namely the cage, using Green Coordinates. The advantage is a less constrained model that more robustly adapts to noisy observations while still providing structured motion information, as required by several applications. The cage is parameterized with a set of 3D features dedicated to the description of human morphology. This allows to formalize a novel representation of 3D meshed and articulated characters, the Oriented Quads Rigging (OQR). To regularize the tracking, the OQR space is subsequently constrained to plausible poses using manifold learning. Results are shown for sequences of meshes, with and without temporal coherence, obtained from multiple view videos preprocessed by visual hull. Motion recovery applications are illustrated with a motion transfer encoding and the extraction of trajectories of anatomical joints. Validation is performed on the HumanEva II database[7].

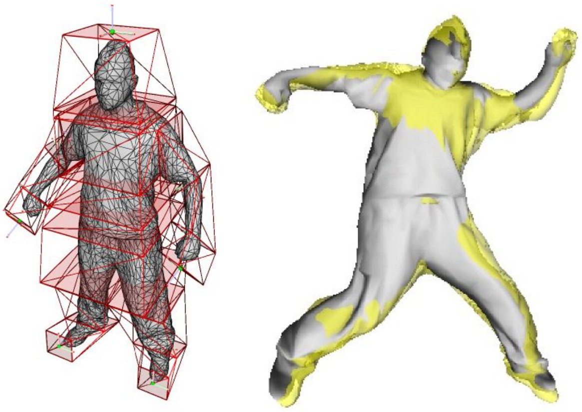

Figure 6. Cage-based Motion Recovery using Manifold Learning

6.8. 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 7). 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[3].

6.9. Keypoints and Local Descriptors of Scalar Functions on 2D Manifolds

This work addresses the problem of describing surfaces using local features and descriptors. While methods for the detection of interest points in images and their description based on local image features are very well understood, their extension to discrete manifolds has not been well investigated. We provide a methodological framework for analyzing real-valued functions defined over a 2D manifold, embedded in the 3D Euclidean space, e.g., photometric information, local curvature, etc. Our work is motivated by recent advancements in multiple-camera reconstruction and image-based rendering of 3D objects: there is a growing need for

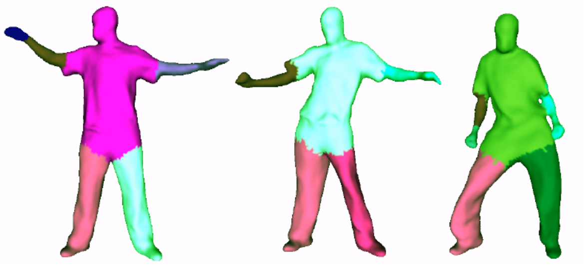

Figure 7. Segmentation of temporal mesh sequences into rigidly moving components

describing object surfaces, matching two surfaces, or tracking them over time. Considering polygonal meshes, we propose a new methodological framework for the scale-space representations of scalar functions defined over such meshes. We propose a local feature detector (MeshDOG) and region descriptor (MeshHOG). Unlike the standard image features, the proposed surface features capture both the local geometry of the underlying manifold and the scale-space differential properties of the real-valued function itself. We provide a thorough experimental evaluation. The repeatability of the feature detector and the robustness of feature descriptor are tested, by applying a large number of deformations to the manifold or to the scalar function[4].

7. Bilateral Contracts and Grants with Industry

7.1. Contracts 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 (Abdelaziz Djelouah) has started on this topic [6].

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

8.1.1.1. 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 analyses 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 Perception team and the Evasion team, the GIPSA-lab Grenoble and the Inria-Lorraine with the Alice team. Website: http://morpho.inrialpes.fr/.

8.1.2. Competitivity Clusters

8.1.2.1. 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 multimedia 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.

8.2. European Initiatives

8.2.1. FP7 Projects

8.2.1.1. project RE@CT

Program: FP7 ICT STREP

Project acronym: RE@CT

Project title: IMMERSIVE PRODUCTION AND DELIVERY OF INTERACTIVE 3D CONTENT

Duration: 12/2011 - 12/2013

Coordinator: BBC (UK)

Other partners: Fraunhofer HHI (Germany), University of Surrey (UK), Artefacto (France), OMG (UK).

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.

8.3. International Initiatives

8.3.1. Inria Associate Teams

The Morpheo team from the Inria Grenoble Rhône-Alpes is associated with the Matsuyama lab. at the University of 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.

8.3.2. Inria International Partners

Simon Courtemanche and Lionel Reveret collaborate with Pr. Kry from University McGill (Montreal) on physical simulation of 3D character. Simon Courtemanche has spent 6 months with Pr Kry at McGill University thanks to an explora'doc regional grant. During this stay, motion capture experiments have been done on specific climbing wall equipped with force and torque sensors.

9. Dissemination

9.1. Scientific Animation

- Edmond Boyer was area chair of BMVC 2012.
- Edmond Boyer was a member of the program committees of: CVPR 2012, ECCV 2012, 3DIMPVT 2012, ACCV 2012, CVMP 2012 and the CDC4CV ECCV 2012 workshop.
- Edmond Boyer has been reviewing for the journals: IEEE PAMI, springer IJCV and elsevier CVIU.
- Edmond Boyer was president of two PhD committees, reviewer of one PhD thesis and he was examiner of three PhD thesis.
- Edmond Boyer gave invited talks at Kyoto university, MPI Sarrebrucken, Hong Kong university and Marseille Luminy.
- Franck Hétroy has been reviewing for the journals: IEEE TVCG, Computer and Graphics, Computer-Aided Design, ReFIG, and for the conferences: Eurographics 2012.
- Jean-Sébastien Franco has reviewed for the following conferences: CVPR 2012, ECCV 2012, VR 2012, 3DIMPVT 2012, BMVC 2012.
- Jean-Sébastien Franco has reviewed for the following journals: CVIU
- Lionel Reveret was a committee member of EUROGRAPHICS 2012.
- Lionel Reveret has reviewed for the conferences: EUROGRAPHICS 2013, SIGGRAPH Asia 2012, Pacific Graphics'12, BMVC'12.
- Lionel Reveret has been reviewing for the journals: IEEE TVCG, Computer Graphics Forum.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

E. Boyer, Master: synthese d'images, 15h, M1 informatique, Université Joseph Fourier Grenoble.

E. Boyer, Master: projet de programmation, 15h, M1 informatique - M1 MoSig, Université Joseph Fourier Grenoble.

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

E. Boyer, Master:Computer Vision, 12h, M2R MoSig, Université Joseph Fourier Grenoble.

F. Hétroy, Master: algorithmique et programmation orientee objets, 36h, Ensimag 2nd year, Grenoble INP.

F. Hétroy, Master: modelisation et programmation C++, 27h, Ensimag 2nd year, Grenoble INP.

F. Hétroy, Master: projets de specialite image, 28h, Ensimag 2nd year, Grenoble INP.

F. Hétroy, Master: introduction a la recherche en laboratoire, 3h, Ensimag 2nd year, Grenoble INP.

F. Hétroy, Master: geometrie algorithmique, 9h, Ensimag 3rd year, Grenoble INP.

F. Hétroy, Licence: algorithmique et structures de donnees, 36h, Ensimag 1st year, Grenoble INP.

F. Hétroy, supervision of ENSIMAG 2A.

J.S. Franco, Licence: Algorithmics, 56h, Ensimag 1st year, Grenoble INP

J.S. Franco, License: C Project, 50h, Ensimag 1st year, Grenoble INP

J.S. Franco, Master: Research Initiation, 3h, Ensimag 2nd year, Grenoble INP

J.S. Franco, Master: End of study project (PFE) Project Tutoring, 6h, Ensimag 2nd year, Grenoble INP

J.S. Franco, Master: 3D Graphics, 40.5h, Ensimag 2nd year, Grenoble INP

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

J.S. Franco, Licence: Introduction to Computer Vision, 27h, Ensimag 1st year, Grenoble INP

L. Reveret, Master: projets image, 30h, Ensimag 2nd year, Grenoble INP

L. Reveret, Master: Multidimensionnal Statistical Analysis, TP, 18h, Ensimag 2nd year, Grenoble INP

L. Reveret, Master: 3D Animation and Maya development, 18h, Ensimag 3rd year, Grenoble INP

L. Reveret, Master: Computer Graphics - Animation, 12h, Ensimag 3rd year, Grenoble INP

9.2.2. Supervision

PhD: Cédric Cagniart, *Motion Capture of Deformable Surfaces in Multi-View Studios*, Université de Grenoble, supervised by Edmond Boyer and Slobodan Ilic, 16/07/12, [1].

PhD: Estelle Duveau, *Motion Measurement of Small Vertebrates*, Université de Grenoble, supervised by Lionel Reveret and Edmond Boyer, 03/12/12, non publically released, patent pending.

PhD: Antoine Letouzey, *Modélisation 4D à partir de plusieurs caméras*, Universitè de Grenoble, supervised by Edmond Boyer, 30/07/12, [2].

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, *Géométrie différentielle discrète et analyse spectrale de maillages spatio-temporels*, Université de Grenoble, started 01/10/2011, supervised by Edmond Boyer and Franck Hètroy.

PhD in progress: Simon Courtemanche, *Caractérisation des Mouvements en Escalade Sportive par Mesure Video*, Université de Grenoble, started 01/10/2010, supervised by Lionel Reveret and Edmond Boyer.

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 : 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.

10. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] C. CAGNIART. *Acquisition de surfaces déformables à partir d'un système multicamera calibré*, Université de Grenoble, July 2012, http://hal.inria.fr/tel-00771536.

[2] A. LETOUZEY. *Modélisation 4D à partir de plusieurs caméras*, Université de Grenoble, July 2012, http://hal.inria.fr/tel-00771531.

Articles in International Peer-Reviewed Journals

[3] R. ARCILA, C. CAGNIART, F. HÉTROY, E. BOYER, F. DUPONT. *Segmentation of temporal mesh sequences into rigidly moving components*, in "Graphical Models", 2012 [*DOI :* 10.1016/J.GMOD.2012.10.004], http://hal.inria.fr/hal-00749302.

[4] A. ZAHARESCU, E. BOYER, R. HORAUD. *Keypoints and Local Descriptors of Scalar Functions on 2D Manifolds*, in "International Journal of Computer Vision", 2012, vol. 100, n^{o} 1, p. 78-98 [*DOI :* 10.1007/S11263-012-0528-5], http://hal.inria.fr/hal-00699620.

Articles in National Peer-Reviewed Journals

[5] A. LETOUZEY, B. PETIT, E. BOYER. *Flot de scène*, in "Traitement du Signal", 2013, Ce travail a été partiellement financé par OSEO, l'agence française pour l'innovation, dans le cadre du programme de recherche QUAERO. A paraître en 2013, http://hal.inria.fr/hal-00746460.

International Conferences with Proceedings

[6] A. DJELOUAH, J.-S. FRANCO, E. BOYER, F. LECLERC, P. PÉREZ. *N-Tuple Color Segmentation for Multi-View Silhouette Extraction*, in "12th European Conference on Computer Vision (ECCV'12)", Firenze, Italy, University of Florence, October 2012, http://hal.inria.fr/hal-00735718.

[7] E. DUVEAU, S. COURTEMANCHE, L. REVERET, E. BOYER. *Cage-based Motion Recovery using Manifold Learning*, in "3DIMPVT", Zurich, Switzerland, October 2012, http://hal.inria.fr/hal-00737329.

[8] A. LETOUZEY, E. BOYER. *Progressive Shape Models*, in "CVPR - Computer Vision and Patern Recognition - 2012", Providence, United States, June 2012, http://hal.inria.fr/hal-00677506.

[9] M. TOURNIER, L. REVERET. *Principal Geodesic Dynamics*, in "EG/SIGGRAPH Symposium on Computer Animation, SCA", Lausanne, Switzerland, P. KRY, J. LEE (editors), Eurographics Association, July 2012 [*DOI :* 10.2312/SCA/SCA12/235-244], http://hal.inria.fr/hal-00727384.

[10] F. VASCONCELOS, J. BARRETO, E. BOYER. *A Minimal Solution for Camera Calibration Using Independent Pairwise Correspondences*, in "12th European Conference on Computer Vision (ECCV'12)", Firenze, Italy, October 2012, http://hal.inria.fr/hal-00735728.

National Conferences with Proceeding

[11] A. LETOUZEY, E. BOYER. *Modèles progressifs de forme*, in "CORESA - COmpression et REprésentation des Signaux Audiovisuels - 2012", Lilles, France, Mohamed Daoudi, May 2012, http://hal.inria.fr/hal-00683549.

[12] A. LETOUZEY, B. PETIT, E. BOYER. *Flot de scène à partir d'images couleur et de cartes de profondeur*, in "RFIA 2012 (Reconnaissance des Formes et Intelligence Artificielle)", Lyon, France, January 2012, p. 978-2-9539515-2-3, Session "Articles", http://hal.inria.fr/hal-00656484.

Scientific Books (or Scientific Book chapters)

[13] G. BAILLY, P. BADIN, L. REVÉRET, A. BEN YOUSSEF. *Sensorimotor characteristics of speech production*, in "Audiovisual Speech Processing", G. BAILLY, P. PERRIER, E. VATIKIOTIS-BATESON (editors), Cambridge University Press, 2012, p. 368-396, http://hal.inria.fr/hal-00694313.

Research Reports

[14] R. ARCILA, C. CAGNIART, F. HÉTROY, E. BOYER, F. DUPONT. *Temporally coherent mesh sequence segmentations*, Inria, January 2012, n^{o} RR-7856, 20, http://hal.inria.fr/hal-00658060.

[15] F. HÉTROY. *A discrete 3D+t Laplacian framework for mesh animation processing*, Inria, June 2012, n^{o} RR-8003, 20, http://hal.inria.fr/hal-00710899.