INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team IGIT

Interactive Graphics and Image Technology

Liama - Beijing - Chine

THEME NUM

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Our objectives are to define some new methods for interactive graphics and image technology. This work is at the edge of several research areas: image processing, computer graphics, and virtual reality (VR). On one hand, we hope to apply some approaches well-developed in image processing to computer graphics, for example, recently, by analyzing the optical-flow theory typical of computer vision, we find the migration of mesh vertices during fairing process is the essential cause for such volume shrinkage. This leads to our flexible framework which completely avoids degeneracy of local/global structures and produces so called intrinsic scale space with better perceptual effects. On the other hand, we hope to apply some well-developed methods in computer graphics to image processing. For example, we attempt to extend the idea about the consistent correspondence between arbitrary manifold surfaces to image registration. http://liama.ia.ac.cn/wiki/doku.php?id=public.

1. Team

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2. Overall Objectives

2.1. Overall Objectives

Our project aims at defining new methods for interactive graphics and image technology. This work is at the edge of several research areas: image processing, computer graphics, and virtual reality (VR).

- Our current research mainly focuses on meshing processing in computer graphics domain and image editing and video processing in image processing domain. Some advanced graphics and image technology will be exploited for the two specific research topics. On one hand, we hope to apply some approaches well-developed in image processing to computer graphics, for example, recently, by analyzing the optical-flow theory typical of computer vision, we find the migration of mesh vertices during fairing process is the essential cause for such volume shrinkage. This leads to our flexible framework which completely avoids degeneracy of local/global structures and produces so-called intrinsic scale space with better perceptual effects(see section 6.1 for more details). On the other hand, we also apply some well-developed methods in computer graphics to image processing. For example, recently we attempt to extend the idea about the consistent correspondence between arbitrary manifold surfaces to image registration.

- We hope to find some common applications by using the methods related to our research work in image processing and computer graphics. By collaboration with Inria-Alcove, we define two new research works. Both image processing and computer graphics techniques are applied in the two projects. One is A new human representation mixing avatar and video. Firstly, we aim at motion information extraction such as gesture, facial expression from video sequence. The motion information is then used to drive the 3D representation of human in collaborative virtual environment. The other collaboration research is Virtual reality based planning technology for hand-eye coordinated surgical operation. We want to firstly model generalized human's tooth geometrically and physically by using 3D reconstruction of hard/soft tissues within tooth based on patient medical images such as CT or MRI images. Then personalized teeth model is obtained by defining the adaptable capability between the generalized model and some specific medical images of a certain patient. Since the performance of surface models used for simulation and force feedback, cannot satisfy our demands, we refer to volumetric models. The work can therefore benefit the surface deformable methods related to our current mesh processing research .

Our current research mainly focuses on three subjects: image editing, mesh processing and their applications such as collaboration virtual environment and medical simulation.

2.2. Highlights

- A new collaboration with Franck Davoine, CNRS researcher, is opened since September 2008 on computer vision for human behavior analysis. Franck Davoine and Chunhong PAN are co-advisor of Jixia ZHANG, a second year master-PhD jointed student in the LIAMA. A very first project aims at evaluating a new derivative free optimization method-a trust-region interpolation-based method-in the framework of 2D Active Appearance Model matching. In future work, we wish to extend these results to varying 3D pose and structure deformations. We will go towards richer statistical models, considering global and local features as well as temporal patterns.
- Thanks to successful collaborations with ALCOVE-Inria leaded by Prof. Christophe Chaillou and School of Mechanical Engineering and Automation, Beihang University leaded by Prof. ZHANG Yuru, in Dec. 2008 since 2006, we applied for international associate team of Inria. This project is divided into three parts, and they are respectively. A New Human Representation Mixing Avatar and Video, Virtual reality based planning technology for hand-eye coordinated surgical operation, and Coupling of kinaesthetic and tactile feedback devices for touch simulation 7 researchers and professors and more than ten students from China and France will be involved in this cooperation.
- One paper is published in the good conference (Pacific graphics 2008) in the field of computer graphics. Our work attempts to deal with volume shrinkage problem during mesh smoothing, and can completely avoid degeneracy of local/global structures and produces so-called intrinsic scale space with better perceptual effects. It contains three steps: migration field computation, tracking within initial scale space and finally a simple pull-back.

3. Scientific Foundations

3.1. A new human representation mixing avatar and video

Keywords: *Avatar representation*, *Gesture*, *Motion extraction*, *Semantic communication*, *Video processing*.

Participants: Chunhong PAN, Christophe CHAILLOU, Haibo WANG, Li DING, Wanping LU.

Traditionally, virtual environments are used in teaching domains, to simulate physical phenomena or to represent objects taken from the natural environment, notably in such domains as medicine, industry, transport industry. Their goal is to reproduce the environment and the objects as they are in reality, by integrating the natural properties of the objects, physical behaviors and environmental constraints. When we want to consider the virtual representation of cooperative activities of small groups of actors around 3D objects, the solution is usually very expensive, and meanwhile real-time process cannot be guaranteed. Video conference usually emphases the speed and quality of image transferred and 3D virtual environment and actors are not considered at this point. Our proposal is appreciably different. We hope to integrate the advantages from both virtual reality and video conference. From video, we can obtain motion information of body and head, which will be transfer to the virtual model and to express the communication and collaboration in the virtual world. By virtual reality techniques we are able to realistically represent objects from the natural environment.

Here, we want to provide a simple and efficient solution to collaborative virtual environment, which could be considered as an extension of the current work at INRIA-Aclove in the broad sense. Some methods about motion information extraction and a new software platform will be exploited, which is able to make several people (between 2 and 5), each one in front of his computer with a webcam, to work together around a 3D model. We make the assumption that all the participants have the same presentation of the model. In the interface, each user can see the 3D model and the representation for another person who participate at the common work. Therefore, we firstly need to choose an efficient representation for distant users. Then we want to extract motion information and facial expression of users from video stream by employing image processing techniques. Taking the extracted information as input of 3D model, we can animate distant representations. It was divided into two research actions as follows. Currently three students are involved in this project.

1. To extract motion information by making use of image processing techniques.
   - **Gaze** is able to forecast focus of attention, indicate turn-taking of head as well. We estimate gaze from video sequence, then present it by rotating avatar head within 2 DOF.
   - **Facial Expression** is helpful to understand our emotion and attitude. In our model, we will map our face image extracted from video into 3D face directly. Head pose estimation and face contour extraction is referred.
   - **Gestures**: our interest of gestures focuses on deictic, iconic, metaphoric and interactive/beats. Kinematics parameters will be estimated from video, and are used to drive 3D arm models. Common hand gestures will also be displayed by our avatar. Besides, head gestures will be shown in the form of online head movements.
2. To animate avatar and develop collaborative communication platform.
   - **3D representation of head movement and gesture.** It consists of head movements to represent gaze, real-time face mapping and real-time animation for arm and hand.
   - **Network based collaborative platform.** To provide a complete software environment to ease the development of collaborative applications and network communication.

3.2. Mesh processing

Keywords: *Compatible mesh*, *Convex hull*, *Cross-parameterization*, *Mesh processing*, *Sketch-based segmentation*.

Participants: Chunhong PAN, Huaiyu WU, Jia PAN, Binwen MA.

Existing cross-parameterization approaches suffer from several problems: low robustness, slow speed, hard to balance compatible mesh's detail and complexity. These difficulties reduce its usefulness. Here we first want to propose a new scheme to give solution to these problems. Then some application such as 3D face editing and face aging based on the new scheme will be exploited.

It is well known that correspondence of feature is necessary for cross-parameterization, which is usually finished manually. For the model with moderate complex, more than 50 pairs of features are needed to achieve a good cross-parameterization. However, the procedure for selection of features from two models is very tedious and time-consuming. Furthermore, the quality of cross-parameterization is greatly dependent on the selection of features. Therefore, based on the scale-independent feature sensitive metrics, we hope to present an easy-to-use tool to produce meaningful mesh segmentation as cross-parameterization's prerequisite. By sketch-based interaction, we hope to obtain automatically the correspondence of features, meanwhile to segment the object into different parts. Convex hull will be constructed for each part of segmented meshes, and then convex hull cross-parameterization algorithm will be designed to generate compatible meshes. The scheme is able to exploit the excellent properties of convex hull, e.g. good approximating ability and linear convex representation for interior vertices. In addition, utilizing the inherent relationship between patch-generation and cross parameterization, we compute compatible triangle patch layouts on input models. Three stages will be considered in this scheme as follows.

- Sketch-based interactive mesh segmentation and automatic correspondence of feature points. First, the user draws a few sketches on the screen, and then our system produces the segmentation result in real time, based on our angle-based feature sensitive metrics. For cross parameterization usage, two meshes' segmentations need to be compatible, i.e. their decompositions are isomorphic.
- Convex hull cross-parameterization. We want to construct convex hull for each part of source and target meshes, and map every part onto its convex-hull respectively, using the Laplacian convex approximating technique. Then, we will map the source parts, which have already been mapped onto their own convex-hulls, onto target parts' convex-hulls. The method will use the boundaries of compatible parts as continuity constraints to avoid distortions along the part boundaries.
- Reconstructing compatible mesh. After source parts have been approximated onto the target parts' convex-hulls, we will directly reconstruct the compatible mesh by vertices' convex-hull coordinates.

3.3. Image processing

Keywords: *Active appearance model*, *Image segmentation*, *Image understanding*, *Object recognition*, *Poisson editing*.

Participants: Chunhong PAN, Hongxia WANG, Ying WANG, Zongying SONG, Binwen MA.

On the domain of image processing, our current research focuses on the image editing and image understanding, it means that we hope to use some image processing techniques to edit and understand the image so that we are able to detect the image contents. It mainly consists of:

- Based on Active Appearance Model(AAM), we present an easy-to-use system for facial image composition[10]. Fig. 1 gives the procedure of our framework. Given two facial images and the semantic information of ROI(region of interest), such as mouth, eyes or face, etc, the system can automatically exchange the source image's ROI onto the target image. The difference between the traditional methods of image composition and our method is that, we use the facial model to interpret each face image and obtain the boundary of ROI automatically. Then a visually pleasing result is generated by solving Poisson equation with the boundary condition [15]. Furthermore, we also propose a solution to eliminate the artifacts when part of the target face is occluded by hair, glasses, etc. The satisfactory results demonstrate the effectiveness of our facial image composition system.
- Traditional dimension reduction approaches always consider the samples in a class are uni-modal. In real world, samples in a class are always multi-modal, for instance, it is likely that the manifold of the facial appearance of a person under different illumination, expression, and poses is multimodal. So traditional dimension reduction approaches exist a over-fitting problem. Recently dimension reduction approaches based on manifold learning are presented[11], the main purpose is to preserve the manifold structure on low dimensional space. Combining the manifold learning approaches and the traditional dimension reduction LDA, we show that most of these methods can be summarized

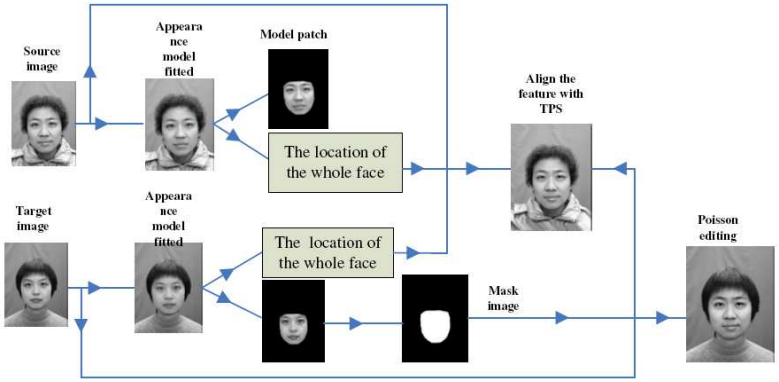

Figure 1. The procedure of the framework

into a general framework. Based on this framework and utilize path-based similarity measure, we proposed a novel dimension reduction approach, called multi-modal preserving embedding (MPE). We also describe two useful extensions: Kernel MPE and Tensor MPE. Fig. 2 gives the graph representation of our multi-modal preserving embedding. Comprehensive comparisons and extensive experiments on face recognition are included to demonstrate the effectiveness of our method.

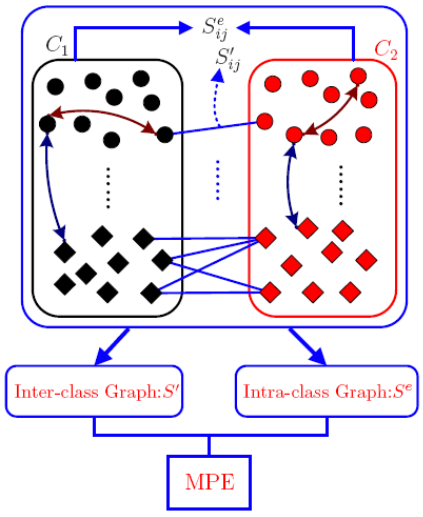

Figure 2. The graph representation of MPE which has two graphs. The S^e is the intra-class graph similarity, it is based on path-based similarity measure. And S^o is the inter-class graph similarity, it is measured with neighboring samples of different classes.

3.4. Virtual reality based planning technology for hand-eye coordinated surgical operation

Keywords: *Deformation*, *Haptic Simulation*, *Physical modeling*, *Virtual surgery*, *Volumetric Model*.

Participants: Stephane COTIN, Chunhong PAN, Dangxiao WANG, Yuru ZHANG, Yiyi WEI, Ge XU.

Due to the development of computer technology, the techniques of computer graphics and haptic interaction are increasingly used to virtual surgeries. This work is designed to help dentists preparing dental surgeries, and as well, to train dental students to get acquainted with teeth anatomy, handling instruments and challenges in surgery procedure. The system features a generalized model that can be adapted to the characteristics of a specific person, so that dentists can have more specific detail plans for each patient. The procedure of drilling and cutting is simulated on the personalized teeth model, using a haptic device to feedback. Results and intermediate steps of the procedure can be saved for future use, such as evaluating and modifying. The research focus is as follows.

- **Volumetric Model.** Volumetric dataset is much larger than a surface dataset, as it concludes all the geometric and physical information inside tooth, but not just on the surface as a surface model. As a result, rendering and deforming this model is time and memory costing. Currently, we represent volume elements as parallelepipeds , but more cutting and drilling experiments should be done on this model to test whether this model is efficient for deformation after each step of operation.
- **Model Adaptation.** We hope to get personal information from patient's X-ray images, which are more expedient than CT or other medical images in terms of easiness to obtain and lower radiation to patient. On the other hand, an X-ray image is 2D projection of 3D objects, using gray scales to distinguish different tissues, and reflect the thickness of the object in the direction of orthogonal image plane. The knowledge of reconstruction and pattern recognition is necessary to adapt general model to personal model, as the patient's tooth may be geometrically different from general models, or pathological changes may exist.
- **Haptic Simulation.** Operating on a patient's teeth in the oral cavity is quite different on the sole teeth model. In order to simulate actually, instruments moving space should be limited, in addition, different tissues would feedback to the haptic device differently.

4. Application Domains

4.1. Collaborative virtual environment from video

Keywords: *Virtual reality*, *avatar*, *interaction*, *network communication*, *semantic gesture*.

We started this year some research on collaborative virtual environment from video. This activity is motivated by cooperating with Inria-Alcove. We hope to integrate the advantages from both virtual reality and video conference. From video, we are interested in obtaining motion information of body and head, which will be transferred to the virtual model and to express the communication and collaboration in the virtual world. By virtual reality techniques we are able to realistically represent avatars from the natural environment. We also plan to study the relationship between movement of head and gaze of eyes in the HCI so that we are able to evaluate the semantic meaning of movement head. Finally our focus is about software architecture. We aim at studying and providing an innovative web-based software framework which is enable to easily create complex collaborative communication around a small of group of people, through the definition of dynamically adaptable interaction components.

5. New Results

5.1. Intrinsic scale space on manifold

Keywords: IDiffusion, Scale space, Vertex migration, Pull-back, Optical flow.

Participants: Jia PAN, Chunhong PAN, Haifeng GONG, Qing YANG

Scale space obtained by diffusion processes suffers from notorious volume shrinkage and unnatural smoothing result. We find that these drawbacks come from the mis-match of vertices between adjacent scales, which are caused by the incomplete catch of vertex migration during diffusion. We use generalized optical flow tracking technique, borrowed from computer vision, to correct such mis-match. Our new framework completely avoids degeneracy of local/global structures and produces so-called intrinsic scale space with better perceptual effects. It contains three steps: migration field computation, tracking within initial scale space and finally a simple pull-back. Our method can handle all flow fairing processes and allows for convenient parameter selection.

5.2. Multisource Data Registration Based on NURBS Description of Contours

Keywords: Multisource image registration, Parametric contour, Non-Uniform Rational BSplines (NURBS), Perspective transformations
Participants: Chunhong PAN, Zhaohui ZHANG, Gang WU, Songde MA

This paper presents a novel contour-based approach for multisource image registration. The contours are parameterized with Non-Uniform Rational BSplines (NURBS). The control points of parametric contours are used as contour descriptor for image registration due to their invariance under affine and perspective transformations. The distance of control points, and the curvature and orientation similarity of the corresponding segments induced by the control points are considered as the matching criteria, and mismatching of control points can be avoided effectively because of the local controllability of NURBS. Therefore, the method is able to deal with the case in which the corresponding contours are locally distorted. Additionally, the NURBS description of contours has the strong global property; the method is therefore robust to image noise. In order to improve robustness, we perform the extraction and labelling of contours interactively. The experiments on both single-sensor and multisource data registration demonstrate the effectiveness and robustness of the presented method.

5.3. Model Transduction with Mean-value Shape Representation

Keywords: Mesh deformation, Mean-value manifold operator, Model transduction, Cross-parameterization.
Participants: Huaiyu WU, Chunhong PAN, Hongxia WANG, Qing YANG, Songde MA

This paper proposes a novel method, called model transduction, to directly transfer pose between different meshes, without the need of building the skeleton configurations for meshes. Different from previous retargetting methods, such as deformation transfer, model transduction does not require a reference source mesh to obtain source deformation, thus effectively avoids unsatisfying results when the source and target have different reference poses. Model transduction is based on two components: model deformation and model correspondence. Specifically, based on mean-value manifold operator, our mesh deformation method produces visually pleasing deformation results under large angle rotations or big-scale translations of handles. We also propose a novel scheme for shape preserving correspondence between manifold meshes. Then, with the above two components, we present the model transduction technique to directly transfer pose between different mesh models. Moreover, we show that the transduction method also can be used for pose correction after various mesh editing operations. Our method fits nicely in a unified framework, where the similar type of operator is applied in all phases. The resulting quadratic formulation can be efficiently minimized by fast solving the sparse linear system. Experimental results show that model transduction can successfully transfer both complex skeletal structures and subtle skin deformations.

5.4. An Online Face Avatar under Natural Head Movement

Keywords: Online Face Avatar, Facial animation, Head Pose, Texture mapping, Video sequences
Participants: Haibo WANG, Chunhong PAN, Christophe CHAILLOU, Jeremy RINGARDR

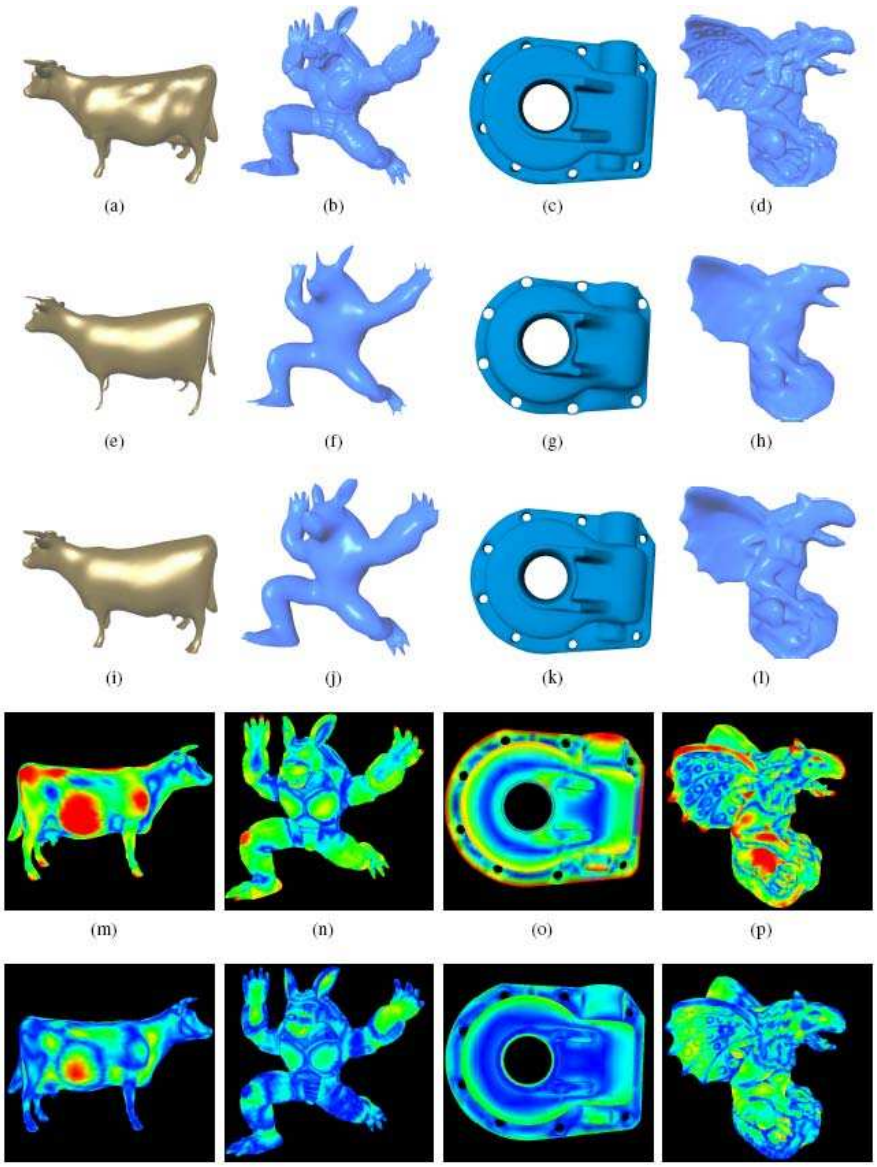

Figure 3. Comparison of basic fairing result and intrinsic representations of cow, armadillo, casting, gargo (provided by AIM@SHAPE Shape Repository). Original meshes are in 1st row and meshes in 2nd row are basic fairing result of 1st row. Meshes in 3rd row are intrinsic representations of our method, which have comparable degree of smoothness with 2nd row but with much better perceptual effects. 4th row is color-coded Hausdorff distances (blue = smallest, red = largest) between original meshes (1st row) and basic fairing results (2nd row). 5th row shows Hausdorff distances between original meshes and intrinsic representations (3rd row). Hausdorff distances are measured by the EPFL MESH tool.

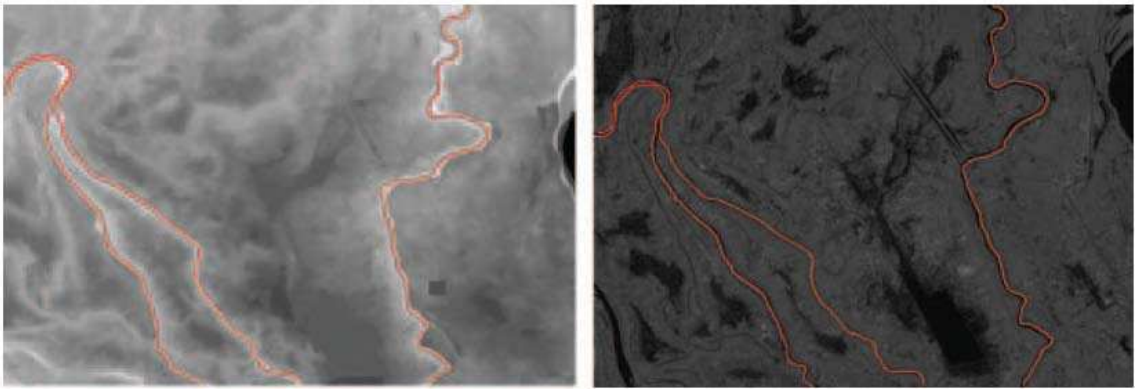

Figure 4. DEM (left) and Landsat images (right) with contours overlaid.

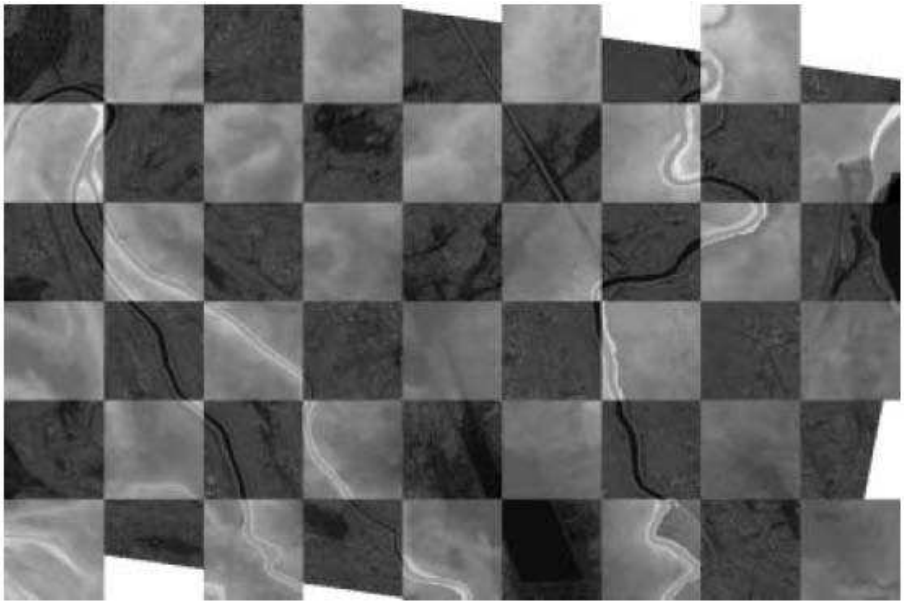

Figure 5. Chess image with alternate patches from DEM and Landsat image

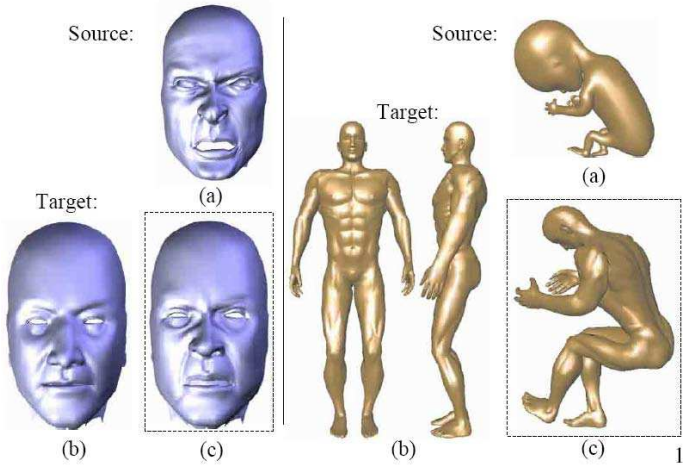

Figure 6. With the model transduction method, (a) an old man directly imitates a young man's expression; (b) the muscular man model directly imitates the fetus model's pose.

Creating a realistic face avatar is still a challenging problem. In the paper, we propose a new video-based technique for synthesizing such an online avatar that is capable of replicating facial expressions under natural head movements. Our approach is to track 3D head pose, simultaneously extract video face textures from monocular video sequences and then map them onto a static head model. In contrast to most of the current facial animation solutions, our approach can avoid the procedures to track highdimensional facial features, warp face textures and deform face model. In addition, the method allows independent control of head pose and facial textures that are separated from videos. The demonstrations of our method in real video scenarios validate its efficiency.

6. Other Grants and Activities

6.1. Grants

1. Project of National Science Foundation of China (**NSFC**) (Duration: 2007-2009).
   Participants: Chunhong PAN, Wei LI, Hongxia WANG, Ying WANG, Haifeng GONG.
2. Project of National Science Foundation of China (**NSFC**) (Duration: 2009-2011).
   Participants: Chunhong PAN, Ying WANG, Jiangyong DUAN, Haibo WANG, Haifeng GONG.
3. Projects of 863 Hi-Tech Research and Development Program of China (**863 Hi-tech**) (Duration: 2008-2010).
   Participants: Chunhong PAN, Yiyi WEI, Wei LI, Jixia ZHANG.

6.2. Collaboration

6.2.1. Collaboration with INRIA-ALCOVE

We continue the close collaboration about communication in collaborative 3D environment with INRIA-Alcove, Christophe Chaillou and Stephane Cotin. Currently, 4 Chinese students (2 for PhD, 2 for Master) are working on the subject, and one of them is the China-France jointed PhD, which is supported by both

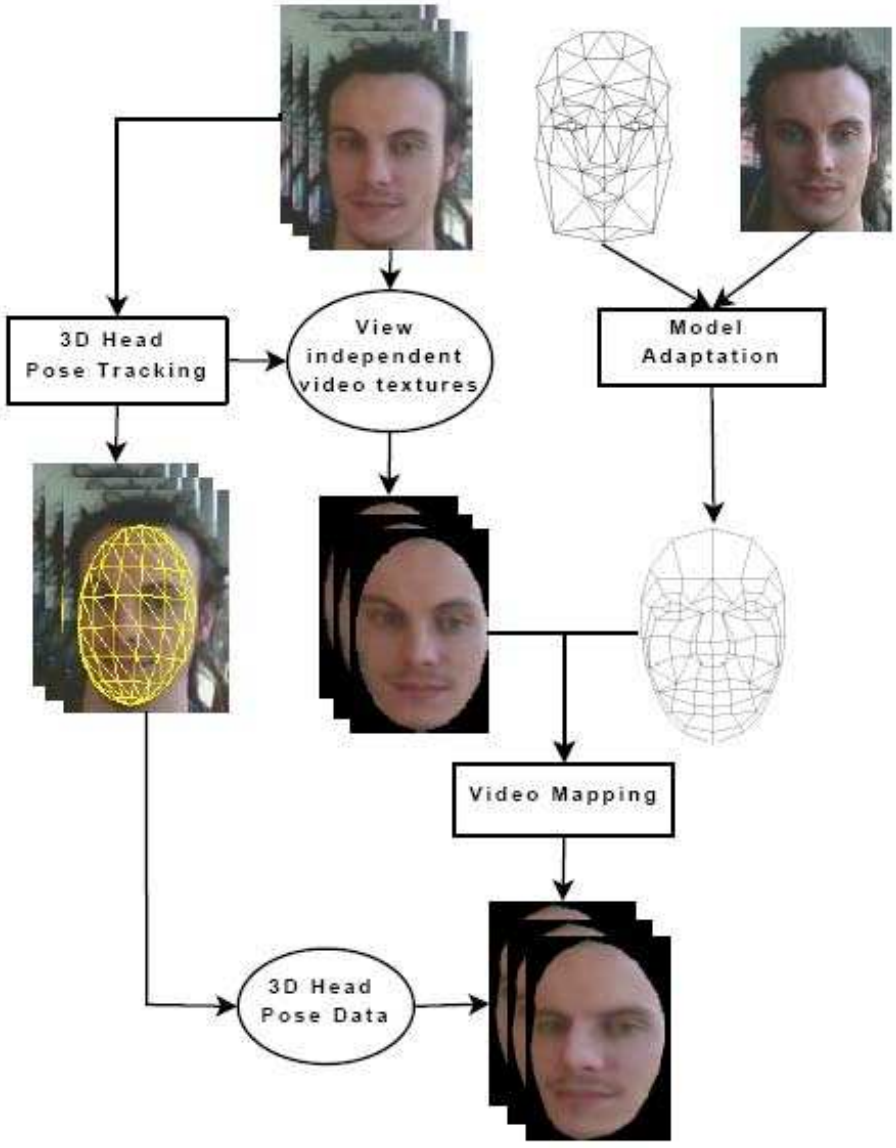

Figure 7. The diagram of creating online face avatar under natural head movements.

French Embassy in China and Liama, and another PhD student is currently working in Inria-Alcove, which is funding supported by Inria. He will stay there for one year since Dec. 2008. In addition, three French internship students finished their research works in Liama on this project. They worked on gaze estimation, 3D representation of gesture, and network based platform building respectively. Currently some research results are achieved. Two papers were accepted by international conference (see Section Year publications), and another one is submitted to the International conference on Computer Vision and Pattern Recognition, which is one of the top conference on computer vision. The first demonstration of virtual communication environment with multiple users by using these techniques developed by ourselves has been presented despite of the rough 3D presentation of face and gesture.

6.2.2. Collaboration with Beihang university and INRIA-ALCOVE

In September 2007, we started another new collaborative project titled Virtual reality based planning technology for hand-eye coordinated surgical operation with Stephane Cotin in Inria-Alcove and Yuru Zhang in School of Mechanical Engineering and Automation, Beihang University. The main objective of the research project is to develop a high performance virtual reality surgical assistant system, which supports realistic simulation of surgical process with hard and deformable tissue manipulation, haptic display, hand-eye coordination, and skill evaluation. The system can not only be used for surgical planning and rehearsal, but also can be used for surgical training. Dental surgical operation is adopted as an example to validate our idea and typical operation including drilling-burring-probing will be studied. Currently, three students (one PhD, two Masters) are involved in this project, and one of them is the China-France jointed PhD, which is supported by the French Embassy in China. Currently she is working together with Stephane Cotin at INRIA-ALCOVE. In addition, on Dec. 2008, Prof. Yuru Zhang and Dangxiao Wang will visit INRIA-ALCOVE with funding support from Liama. They will stay there for 10 days, and during visiting, they will take some activities such as discussion and working together toward the closer cooperation.

7. Dissemination

7.1. Teaching

Prof. Chunhong PAN gives course (one chapter of Computer Vision) in the graduate school of Chinese Academy of Sciences.

7.2. Participation to conferences and workshops

See Publications: Papers in International Conferences

8. Bibliography

Major publications by the team in recent years

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[2] H. GONG, C. PAN, Q. YANG, H. LU, S. MA. *Generalized Optical Flow in the Scale Space*, in "Computer Vision and Image Understanding", vol. 105, 2007, p. 86-92.

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Year Publications

Articles in International Peer-Reviewed Journal

[5] C. PAN, Z. ZHANG, H. YAN, G. WU, S. MA. *Multisource Data Registration Based on NURBS Description of Contours*, in "International Journal of Remote Sensing", vol. 29, 2008, p. 569-591.

International Peer-Reviewed Conference/Proceedings

[6] L. DING, C. PAN, C. CHAILLOU, J. WANG. *Real-Time Upper Body Detection for Visual Interaction Applications*, in "International Conference on Image Processing, Computer Vision, and Pattern Recognition", 2008.

[7] J. PAN, C. PAN, H. GONG, Q. YANG. *Intrinsic scale space on manifold*, in "The Pacific Conference on Computer Graphics and Applications (PG)", 2008.

[8] Z. SONG, C. PAN, Q. YANG, F. LI, W. LI. *Building Roof Detection from a Single High-resolution Satellite Image in Dense Urban Areas*, in "International Society for Photogrammetry and Remote Sensing (ISPRS)", 2008.

[9] H. WANG, C. PAN, C. CHAILLOU, J. RINGARD. *An Online Face Avatar under Natural Head Movement*, in "The Workshop on Facial and Bodily Expressions for Control and Adaptation of Games (ECAG'08)", 2008.

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