INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team Mirages

Object Manipulation in Image Sequences for Augmented Reality and Special Effects

Rocquencourt

THEME 3B

Activity Report

2003

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1. Team

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2. Overall Objectives

2.1. presentation

The MIRAGES project research activity is concentrated on the manipulation of 3D objects in images sequences and its application domain is oriented towards new services (related to those 3D objects) which will appear in future communication networks. Research activity is carried out in two directions:

2.1.1. First Research activity: 3D Analysis of image sequences

We are interested in the determination of properties such as structure, mouvement and photometry of 3D objects in image sequences. Our approach differs from traditional methods as we mainly look for feedback model-based methods to guide the analysis. The main problems we are handling are:

- 3D object tracking in image sequences when the geometry of the object is known but its movement has to be determined. Both rigid, articulated and deformable objects are considered: particularly human body and face tracking.
- Automatic and semi-automatic object model renormalization: starting from a generic model of an object(for example a human body or a face) and an image sequence, this task has to construct the specific model which will be used for tracking in image sequences (see above)
- Interactive, semi-automatic and automatic camera calibration: Here, we use 3D object models (very often, generic models) which are used as calibration tools, in order to perform calibration. Calibration is necessary for 3D model renormalization
- Inverse rendering (Computer Graphics denomination corresponding to photometric analysis in Computer Vision): We dispose of input images of a scene and of a 3D model of this scene. The aim is to compute the photometry of the part of the scene available on those images in such a way that the digital synthesis of the scene model corresponds faithfully to the input images. The main application of this specific research is oriented towards the creation of advanced tools for audio-visual productions (advertising, films,...)

Collaboration is carried out with Mikros (a french post-production company) on the PRIAMM VIP3D contract which started in 2001. With VIP3D, we tackle human body tracking and specially facing tracking for 3D rotoscopy in post-production. Golf-STREAM contract started in June 2002 in collaboration with the french Symah Vision production company. The task is to study complete human body tracking and more specifically professional golfers from image sequences in order to allow them to improve their technique and also enrich journalists comments for television broadcasts of professional golf tournements. We hope to extend this work to other types of applications such as video-surveillance, tele-conferencing, video games, while mixing real and synthetic images.

2.1.2. Second Research Activity: 3D Garment Simulation

The second research direction is the creation and deformation of soft objects, particularly non linear and hysteretic ones. Presently, our research activity is limited to the 3D simulation of garments. In this research area, we are mainly studying:

- The control of the mechanical properties of soft 2D structures (like textile materials) modelled by mass/spring systems.
- The automatic construction of garments from 2D patterns around a human body modelled as an articulated mechanical system.

Potential applications are the realistic synthesis of 3D garments on 3D numerical mannequins applied to future e-commerce of garments for the textile industry. This problem was studied within the framework of an EUREKA contract (COMEDIA) where the main contractant was Lectra Systemes.

3. Scientific Foundations

3.1. Augmented reality for TV productions: 3D human tracking

Key words: *anthropometry*, *3D tracking*, *3D human modeling*.

Participants: Philippe Gérard, Eric Nowak, Tung Le Than, André Gagalowicz.

A 3D model-based approach is applied to human body tracking for production and post-production applications.

We are currently developping a 3D tracking system using video cameras able to produce outdoor motion capture without the use of markers. A standard 3D human body and anthropometric measurements give a very first result of morphology adaptation. Then, further body adjustments are made using images. After positionning the puppet on the first frame, the texture is learnt and a tracker has to retrieve the position of the puppet automatically in the rest of the image sequence.

3.2. Face tracking

Key words: *3D Face Tracking*, *Deformable Models*, *Model-Based modeling*, *3D Face Modeling from Images*.

Participants: André Gagalowicz, Richard Roussel.

3D reconstruction of a realistic face model is one of the greatest challenges in the field of audio-visual post-production and special effects generation. Previously manual tracking is more and more automated. We are working on faces, which are one of the most difficult entities to track, because of their deformations. In order to perform a high quality tracking, we developed a technique to model a 3D mesh of face from a set of images taken from a video sequence. This model, first constructed in a neutral expression, will be animated for tracking purposes.

3.3. 3D garment simulation

Key words: *mass-spring systems*, *numerical integration*, *spatial coherence*, *constraints*.

Participants: Hatem Charfi, Jeremy Denise, David Reversat, André Gagalowicz.

3.3.1. Mechanical modeling of textile materials

Usual geometric modeling is not suficient to simulate cloth: an in-depth knowledge of fabrics behaviour is required. Relations between stress and strain have to be delt with, that are not defined by ordinary differential equations. Since analytical solutions are not available, numerical models are used; we have chosen mass-spring systems.

These models have to be fed with correct parameters. The Kawabata Evaluation System is the de-facto industry standard for fabrics measurements (limited to warp/weft textile materials): it operates typical deformations upon cloth samples and evaluates the resulting stress, which is provided as digital data.

3.3.2. Dynamic cloth simulation

Once a numerical model of cloth is stated, our goal is to compute its evolution with respect to time; it relies on the integration of the fondamental equation of dynamics. Several families of algorithms exist, adequations to the underlying problem of which vary, both in terms of stability and computation time.

Handling contact phenomenon between pieces of cloth, and the characters that wear cloth is the other big challenge: large amount of data have to be processed to accurately detect possible collisions, and a realistic model has to be used once an actual collision has been detected.

5. Software

5.1. Emilion

Emilion is the cloth simulation system that was developed by J. Denise during his Ph.D.

This software computes the evolution along time of a set of garments that are represented by mass-spring systems. Both explicit and implicit integration schemes are available. Hysteretic behaviour is taken into account in order to reach a high degree of realism. Contact and inverse kinematics are introduced through the constraints handling method initiated by Baraff [1]. An attractive feature is the spatial partitioning scheme that makes collision detection a low-cost task, even with large scenes (less than 15 % computation time in typical simulations).

Emilion was written in C++ and makes heavy use of Generic Programming concepts (which most famous incarnation is the Standard Template Library [2]). Tcl [3] was chosen as its scripting language to ease both its feeding with external data and the simulation of Kawabata [4] experiments.

A custom version was developped by D. Reversat to allow draping on animated characters.

6. New Results

6.1. 3D Human tracking

During the first year of Golf-Stream, an interactive tool to adjust a 3D squeleton and reconstruct a 3D skin envelope from images has been successfully achieved (see: figures 1, 2 and article [12])

The 3D tracking algorithm is on the edge to give tracking results visible soon on http://www.inria.fr/multimedia/

6.2. Face tracking

At this stage, we developed a model-based approach to construct a 3D human face using only a set of uncalibrated images. The developed technique only requires the operator to determine some correspondances between vertices of a generic face model and of face images in each camera corresponding to different view points. Our camera system, then, calibrates itself by finding the best way to view the model according to given points on the images. (see figure: 3 and article [13]). Once this step is done, we use this calibration to

Figure 1. Squeleton adjusment using several views

Figure 2. Skin reconstruction using several views

reconstruct a set of 3D points taken from the images by triangulation, and use these points to refine calibration, in order to better reconstruct the 3D points. So, this process of calibration/reconstruction works in a cooperative way to converge to a well calibrated system of cameras. At this step, we have a generic model, a calibrated system of cameras, and a set of 3D points calculated from the images. Each feature point of the 3D generic face is sent to its corresponding 3D reconstructed vertex, creating a set of 3D deformation vectors. This set is then interpolated on the rest of the face, using the well known RBF interpolation technique, allowing to obtain a specific face model. This technique is only based on points; we don't have any control on the 3D surface except for the feature points. That is why we added a curve-based deformation that deforms the 3D model by its external contours (see figure 4). In fact, we compute the 2D deformations between each projected limb of the specific model at each image (see figure 5) and the real contour in the corresponding image. This 2D deformation is then transformed in a 3D one added to the previous set of 3D deformation vectors. All of them are interpolated on the rest of the face giving a good 3D reconstructed Face (see figures 6 and 7). Our goal being to produce a good face tracker, we are now developing a deformation model for the face, in order to perform tracking in a model-based approach.

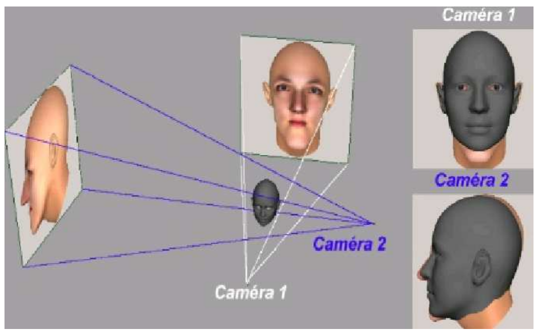

Figure 3. The calibrated system of cameras

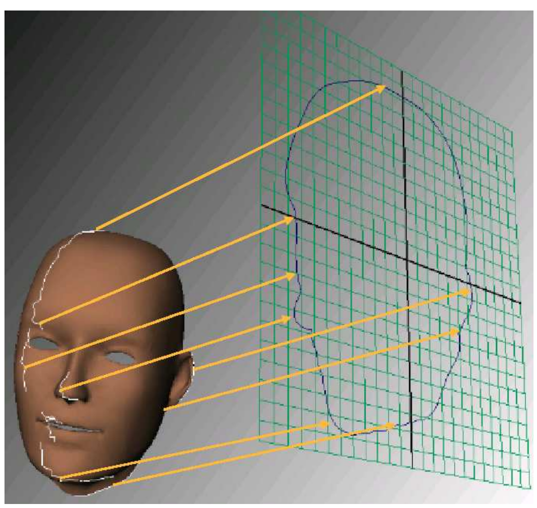

Figure 4. The line of limb of the 3D model, and its projection in the image plane (squared)

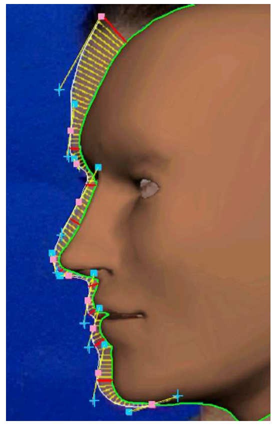

Figure 5. The 2D differences, in yellow, between the projected line of limbs, in green, and the real contour of the face, in white

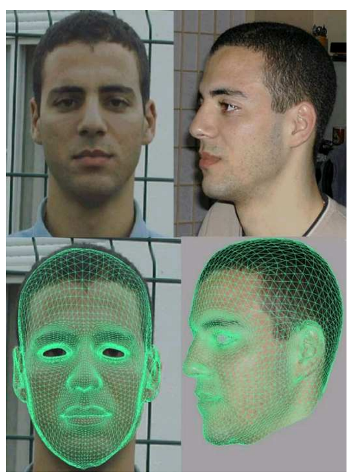

Figure 6. A result of 3D reconstruction

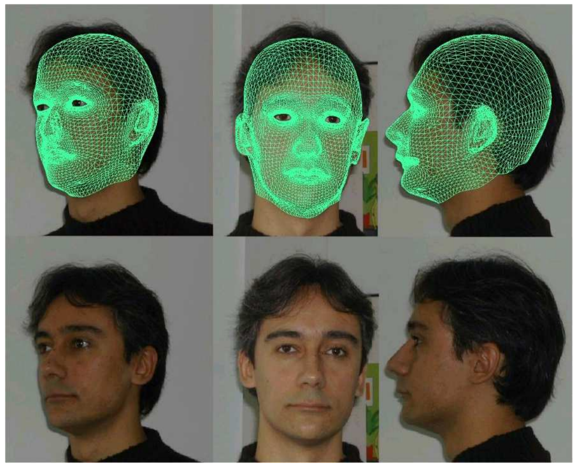

Figure 7. Another result of 3D reconstruction

6.3. Study of fabrics

6.3.1. Analysis of viscous dissipation

Realistic animation of fabrics and clothes is in full development in the world of computer graphics. Its results can be exploited in various fields such as audio-visual productions, video games or e-commerce of garments. However, one of the challenges to reach an acceptable realism in these simulations is to model of the viscous dissipation between fabric and air and between warp and weft of the fabric itself. That is why, we are interested in the study of viscous interactions between fabric and air, then interactions between warp and weft threads of fabric. The goal of this work is to set up experiments and associated techniques which make it possible to measure viscosity forces applied on fabric. Collaboration with the ATTITUDE-STUDIO company has been started to carry out a series of experiments.

6.3.2. Collision processing within an animated environment

6.3.2.1. Input:

The geometry of the garment environment is assumed to be for each frame; we need a way to estimate the garment position for the whole simulation time interval. We have assumed that a linear interpolation would be a good approximation. We can also compute each mass speed at each time step.

Rather than trying to take into account the textile thickness (a minimal distance between environement and cloth) during the detection stage as we do for self-collision, we decided to add the thickness to the environment geometry for all key frames, and then to interpolate between those thickened positions. As the ratio between time step and frame duration is quite important (about 100), computing time spent for this operation is insignificant.

6.3.2.2. Detection:

Collision between a cloth mass P and an external facet $f = ABC$ can occur only when mass P reaches the facet plane f:

$$\left(\overrightarrow{AB(t)} \wedge \overrightarrow{AC(t)}\right) \cdot \overrightarrow{AP(t)} = 0 \tag{1}$$

During the time step between t and $t + \Delta t$, we can assume a linear movement for each mass and we obtain a 3rd degree equation in t. Then we check for each t_i solution if $P(t_i)$ is inside the triangle.

Assuming we have a well-oriented environment, we can remove here "going away collisions": those who decrease the distance defined by (1) i.e those such that the derivative of (1) is negative.

Collision detection leads to a constraint creation, linking P to f.

6.3.2.3. Processing of the constraint:

At the beginning of each step, we **already know** exactly the cloth position at the end of the step. We can thus constrain the linked particle positions in order not to collide. This constraint can be applied on the speed.

The constraint is only on one direction : the facet normal at the end of the current step. Indeed, if we constrain that P will be above f at the end of the step, then all positions in a plane parallel with f with be valid, regarding the collision.

If we suppose the distance between P and F must not change during the time step, we obtain :

$$\begin{aligned} d_{before} &= AP(t) \cdot N(t) \\ &= (P - A) \cdot N(t) \\ d_{after} &= AP(t + \Delta t) \cdot N(t + \Delta t) \\ &= (P + \Delta t \cdot v_P - A - \Delta t \cdot v_A) \cdot N(t + \Delta t) \end{aligned} \tag{2}$$

writing $v_P = z \cdot N(t + \Delta t)$ and $d_{after} = d_{before}$, we obtain :

$$\begin{aligned} (P - A) \cdot N(t) &= (P - A) \cdot N(t + \Delta t) + \Delta t \cdot z - \Delta t \cdot v_A \cdot N(t + \Delta t) \\ z &= (A - P) \cdot \frac{N(t+\Delta t) - N(t)}{\Delta t} + v_A \cdot N(t + \Delta t) \end{aligned}$$

If we constrain P to move along $\overrightarrow{d} = N(t + \Delta t)$ of z, we insure that there are no collision.

6.3.2.4. Simulation:

A model for modeling hysteretic behaviour of cloth was proposed in [10]. Attempts were then made to include contact friction effects. Several approaches to improve both stability and computation time were investigated as well.

Our spatial partitioning scheme dramatically reduces collision detection computation time. Geometrical properties of the simulated scene were investigated; conditions were established so a linear complexity (in terms of geometric primitives) could be achieved.

7. Contracts and Grants with Industry

7.1. Golf-Stream

Participants: Philippe Gérard, Eric Nowak, Tung Le Than, Wei Du, André Gagalowicz.

The Golf-Stream project of the Riam* network is interested in movement capture on a real life character. This is a complex problem that we are solving by adjoining INRIA's skills with those of the Symah Vision production house. PGA (professional Golfer association) and FFG (French Federation of Golf) are part of that project in order to drive the golf analysis.

*National Riam network: Research and Innovation in Audiovisual and Multimedia

MIRAGES develops a tool that makes it possible to capture actual movements on site. In an initial stage, static images of the player are shot from different angles and are used to reconstruct his or her skeleton and body envelope. The virtual character is then superimposed live over the player in action and adjusts itself by learning. It can determine body movements (pelvis rotation, arms position, etc.) as well as the position of the player's center of gravity and direction imposed to the ball with great precision. This method does not require the use of sensors placed on the athlete's body! We needed one night of computations. However to obtain a result on a sequence, we optimized the software to be much faster and usable by TV crews. Standard video cameras are able to provide up to fifty measures per second. It is thus possible to broadcast a slow-motion sequence showing the superimposed skeleton of the player with added visualization tools that support live comments on such and such aspect of the shot, barely a few minutes after the shot. This product should be available for TV broadcasts about twenty months from now.

Golf-Stream is now under the MIRAGES Coordination and got a positive review from the Industry Ministry, in November 2003.

http://www.inria.fr/multimedia/.

7.2. VIP3D

Participants: Richard Roussel, André Gagalowicz.

This contract is an application of our research for post-production and is conducted in collaboration with MIKROS IMAGE. This contract follows two european MULTIMEDIA ESPRIT contracts : NEMESIS I and NEMESIS II where the target was to produce commercial software for the 3D rotoscopy of rigid objects. This software is now available under the name of FROGPLUS. In VIP 3D, we generalize the former technique to the case of deformable objects. Practically, we reduced the study to the study of human face tracking for 3D rotoscopy.

7.3. Attitude Studio Partnership

Participants: David Reversat, Hatem Charfi, André Gagalowicz.

This contract is an application of our research on 3D garment simulation. The idea was to put together ATTITUDE STUDIO expertise on the design of realistic human avatars, and the expertise of MIRAGES on 3D garment simulation in order to produce a realistic avatar (EVE SOLAL) wearing realistic garments. A two-years research position was proposed to David Reversat by INRIA to work for this application.

Attitude Studio's computer graphists provided us with a 200 frames animation of their own virtual "star" : Eve Solal. This allowed us to perform our first test with dynamic environment on our simulator and thus to improve and validate it. Then we prepared several videos of Eve with different clothes that where submitted to Attitude's computer graphists opinion.

During the partership, David Reversat spent one week at Attitude Studio to transfer the MIRAGES software, EMILION (see 5.1). This software was integrated to their internal environment. David Reversat also modified EMILION, originally developed under Unix, so that it could be run under Windows with visual C++.

During summer, we worked in parallel on the case of a gown. Objectives were many : simulator validation, comparison with other commercial software that professionals use to work with, comparative measurement of computing time for the same complexity.

Figure 8. Eve with a dress

Figure 9. Eve with a pant

Figure 10. Eve with a shirt

Figure 11. Eve with a shirt and a pant

8. Other Grants and Activities

8.1. International collaborations

- Collaboration between MIRAGES and NTU (Nanyang Technological University) on the domain of human body tracking. André Gagalowicz spent his sabbatical year from November 2002 to October 2003 for these purposes.
- Collaboration with ID Technologies, a company located in Singapore. André Gagalowicz is scientific advisor for the company.
- A new collaboration with NUS (National University of Singapore) has been initiated.

8.2. Invitation of foreign researchers

Dr Du Wei from China has got a one-year post-doc position in MIRAGES and studied 3D object tracking in the project.

9. Dissemination

9.1. Animation of the scientific community

- André Gagalowicz was scientific advisor at the INSA Lyon Scientific Committee.
- André Gagalowicz was scientific advisor at the University of Bordeaux I Scientific Committee.
- André Gagalowicz was member of the scientific advisory board of "Machine, Graphics and Vision", "Computer Graphics and Geometry" journals as well as of the LCPC journal.

9.2. Conference program committees

André Gagalowicz was a member of the conference program committees of:

- IVCNZ'2003 conference in New Zeland
- MIRAGES 2003 conference in Paris, FRANCE
- GRAPHIKON 2003 conference in Moscou, RUSSIA
- Cyberwords 2003 conference in Singapore
- CAIP 2003 conference in Gröningen, THE NETHERLANDS
- ICIAP 2003 conference in ITALY

9.3. Conference Program Chair

André Gagalowicz was the chairman of MIRAGE 2003 in Paris, France.

9.4. Teaching

André Gagalowicz has taught Advanced Computer Graphics and Mathematics in the last year undergraduate courses at NTU.

Hatem Charfi has taught Data Statistical Analysis in Psychology (ASDP) for Social Sciences DEUG at the university Paris 5.

9.5. Participation to seminars, conferences and invitations

- André Gagalowicz has presented a series of conferences at NTU and NUS in Singapour.
- Jeremy Denise, Wei Du, André Gagalowicz, Philippe Gérard and Richard Roussel have presented a scientific communication at the MIRAGE 2003 conference in Paris.
- Presentation of Golf-Stream by P.Gerard to the new consortium "AS Human Virtual", and participation
- P.Gerard went to the Laval Virtual and Siggraph 2003 conferences.

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