INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team IPARLA

Computer Graphics and 3D Interaction for Mobile Users

Futurs

THEME COG

Activity Report

2006

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2. Overall Objectives

2.1. Overall Objectives

Mobility is the major (r)evolution for the current interactive systems. Therefore, one of the biggest challenges for interactive 3D graphics is now to evolve to a mobile context. The main goal of the IPARLA project is to contribute to this evolution.

During the last decade, a large range of consumer electronics devices have been developed, that allow the user to benefit from computing resources in mobile settings. The last generations of cell phones, personal digital assistants, or even portable game devices, combine embedded programmable CPUs (and more recently GPUs) with several flavors of wireless communication capabilities. Such *Mobile and Connected Devices* (MCDs) offer the opportunity to develop a wide variety of end-user software applications over client/server infrastructures.

MCDs induce specific constraints for the incoming data flow (e.g. limited CPU/GPU for real-time computing and small screens) as well as for outgoing data flow (e.g. limited input devices). These technological constraints naturally decrease the cognitive immersion of the user, which affects the performance and the adhesion to the end-user applications. In the IPARLA project, we want to address this issue by jointly developing techno-centered and human-centered techniques for interactive mobile 3D applications.

Although MCDs are an important part of our project, we focus more on the mobility of the user and the involved applications (including the data) than on the device itself. In other words, we do not aim exclusively on the development of applications for MCD, but rather to design flexible solutions that allow easy conversions for the user and the applications between a mobile context and a fixed context. For example, we want to design concepts that enable us to use the same application on a MCD, on a standard PC or in a virtual reality center as illustrated by the image at the end of this text.

In order to reach this goal, our development is strongly oriented to produce **scalable** solutions in **multi-resolution** that are able to **stream** and deal with **large amounts of data** in a **client-server** context. These five keywords recall the main approaches we have selected to reach our objectives.

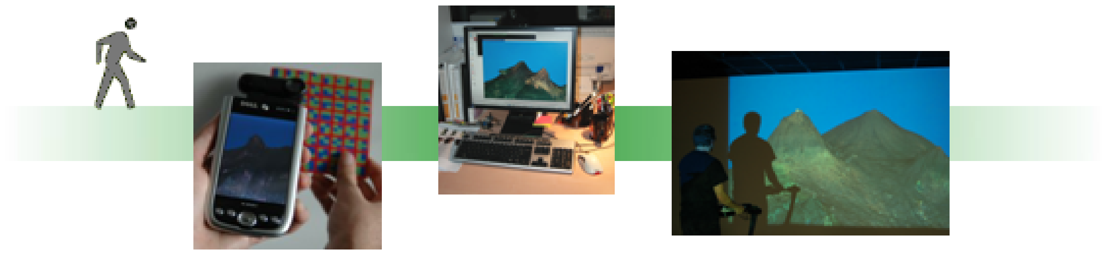

Figure 1. Visualization and Interaction on 3D Content for Mobile Users.

3. Scientific Foundations

3.1. Modeling

In computer graphics, we are primarily concerned with the surfaces of geometric objects since the surfaces are what we actually see, animate, and physically process. In recent years, multiresolution modeling has proved to be valuable in 3D geometric surface modeling and computer graphics. It deals with the generation, representation, visualization, and manipulation of surfaces at various levels of detail or accuracy in a single model. Applications include fast rendering, level of detail editing, collision detection, scientific visualization, as well as compression and progressive transmission. In the context of mobility, the requirement of multiresolution is even indispensable due the enormous differences of hardware capacities.

A widespread example for multiresolution surfaces is the subdivision surface. Starting from very simple primitives, such as cubes or spheres, the user can progressively deform and enrich the surface with tools like, for instance, extrusion, shear or twist. As soon as a coarse level is correctly modeled, the user can refine the model by applying a subdivision pass, and add finer details, tessellate the areas where more features are required, and thus model the shape more and more accurate by using the different levels of refinement of the subdivision surface. Indeed, a major advantage of the subdivision surface is flexibility: the user can modify the shape at any resolution - the deformations at coarser levels are automatically propagated to the finer levels.

Multiresolution is also the link between geometric modeling and rendering, providing for instance an appropriate level of detail for a given viewpoint in order to ensure real-time rendering. A simple example, introduced in the 90s, is the progressive polygonal mesh. Starting from a detailed single model, multiple coarser mesh resolutions can be generated by the successive application of an edge collapse operator. Of course, coarser mesh resolutions can be rendered more efficiently, at the expense of lost fine details. All these multiresolution techniques must now be adapted to acquired surface data, since due to the recent advances in 3D acquisition devices, the surfaces are more and more scanned from the real world rather than modeled.

A challenging task is to handle the modeling and rendering of the large amount of data usually provided by 3D scanners in real-time. For example, the significant overhead of dealing with the connectivity of polygonal meshes has motivated various researchers to seek for alternative multiresolution surface representations, as for example point-based surfaces. In the Iparla project, multiresolution surface modeling is present at different scales, from surface reconstruction to visualization. We use and develop surface definitions that have gained much attention recently as suitable multiresolution representations, such as subdivision surfaces, implicit surfaces, and point-based surfaces. Our special interest focuses on how these surface representations are adapted for multiresolution modeling and rendering in the above-mentioned applications. Several of our algorithms are designed to work “out-of-core” for being able to process large acquired data (e.g. gigantic point clouds from 3D scanners).

3.2. 3D Data Rendering and Visualization

One of the main goals of the Iparla project is the interactive visualization of complex data on heterogeneous platforms. For example, a very rich and realistic visualization stream including shadows and a complete set of light effects is required when a user has to "feel" parts of a virtual world. Realistic rendering is also required when it comes to augmented reality applications. Keeping the coherence between the virtual world and some virtual objects as well as between real objects and the virtual world is a challenging research domain. For the MCD, these technologies can be used for example for virtual visits, virtual presentations or, more generally, when the MCD is used as an interface to the real world.

On the other hand, in order to easily focus on what is really important to visualize, a more legible rendering is more appropriate. As a consequence, non-photorealistic rendering (NPR) techniques have recently become popular in the computer graphics community. We believe that these techniques are helpful for depiction. Based on a cognitive study, we choose the appropriate rendering style in order to provide the user with the desired information for a faster communication.

Despite the progress of MCDs, these client devices which are designed for mobility will always have less computing and storage capacity compared to the server. Consequently, we have to think about distributed approaches by re-investigating the entire pipeline, from storage, over transmission, to visualization. We have to define the correct representation for the data, for transmission and streaming. Moreover, we have to define how to visualize the data when received, both for realistic rendering and NPR rendering. We think that NPR rendering reduces the amount of information to transmit by focusing on what is really important.

In order to achieve an interactive visualization for every device - from cell phones to powerful VR settings - we rely on the use of multiresolution representations as a unified representation for the data for adaptive rendering according to the specific resources. For devices with embedded graphics pipelines, we exploit the mutliresolution representation in order to provide the best possible performance. Since most of the MCDs do not provide this high-end power capacity, we need to investigate alternative rendering techniques, like image-based or point-based rendering techniques, or to simply use 2D approaches.

3.3. 3D User interfaces

The Iparla project aims at improving the development of 3D interactive applications for the mobile user. Consequently, as we have seen above, an essential part of this project consists in adapting the classical 3D graphics pipeline to the mobile context. However, we think that the development of modeling and rendering techniques cannot go without the development of adapted user interfaces. Indeed, the interest of mobile applications where complex data can be visualized in real-time is limited when the interaction with the data is difficult.

We believe that human factors have to be taken into account in the early stage of development. Indeed, the choice of the user interface can influence the modeling and rendering techniques to use. For example, an object-oriented construction of the scene has to be preferred when the main user task of a given application consists in selecting individual objects. In the Iparla project, we want to control the entire process, from the creation of the 3D environments to the interaction with these environments. Each of the components of this process have to be strongly linked and should not be considered independently.

When dealing with mobile devices, the classical user interfaces that have been developed for desktop workstations are not the most appropriate. For example, the lack of keyboards has led to the development of intuitive writing interfaces. The classical side-menus cannot be used for the control of the application without occluding a large amount of the screen and, consequently, without occluding a large part of the data to be visualized. Last but not least, the lack of pointing devices with cell-phones makes the manipulation of the data very difficult. In the Iparla project, we develop interaction techniques that are adapted to the user, to the task, and to the characteristics of mobile devices, for efficient interaction with 3D datasets.
For the success of mobile applications, the efficiency of the interaction techniques is primordial. From previous work in the scope of VR and general Human Computer Interfaces (HCI), we investigate mobile HCI techniques. In particular, our work is based on the following foundations:

- Collaboration. In many cases, the user does not interact alone. Consequently, the issues coming with collaborative work are taken into account.
- Bi-manual interaction. It has been shown that the use of both hands can be more efficient than the use of one single hand.
- Multi-degree of freedom (dof) interaction. It is necessary to adapt the structure of the interface to the structure of the task. Consequently, interaction with 3D data generally requires interfaces with more than 2-dof.
- Gesture recognition. Non-intrusive and easy-to-learn interaction can be obtained from natural gesture recognition.
- Video-based interaction. Modern mobile devices are equipped with embedded cameras. The video stream analysis can be used as input for the development of interaction techniques.

The interaction techniques are developed in concordance with the user and the task. They are evaluated via experiments. Hence, the user performance can be qualitatively and quantitatively measured, which indicates whether a new technique is more or less efficient than another one.

4. Application Domains

4.1. Application Domains

Keywords: *augmented reality*, *interaction*, *modeling*, *multimedia*, *remote applications*, *telecommunications*, *virtual environment*, *visualization*.

We think that is out of the scope of this report to establish an exhaustive list of application domains that could benefit from mobile 3D interactive technologies. Consequently, we only present some key applications here.

Assisted navigation. Mobile and connected devices equipped with GPS are currently used as digital assistants for navigation. Such systems can help car drivers for route planning. They also can assist pedestrians or bike users when exploring cities, or when hiking in countryside. Existing solutions are mainly based on 2D or 2.5D visualization of data, which are generally stored on CD-ROMs or memory-sticks. Our project aims to provide 3D navigation tools where the data can be accessed from an up-to-date database stored on distant servers. Hence, for example, a hiker visualizes on its mobile device a 3D representation of the surrounding landscape that embeds information such as the way to follow, or the direction to the next mountain hut.

Augmented reality. The majority of today's mobile devices is equipped with embedded cameras. Consequently, the use of these setups for augmented reality allows to imagine a wide variety of useful applications in our everyday life. For example, in the domain of cultural heritage, some extra information coming from distant servers can enhance the images coming from the cameras of the mobile devices. More precisely, for example the interest of merging synthetic reconstructions of partially destroyed buildings with the images of the real buildings can easily be understood. The same approach can be useful for many domains such as tourism, maintenance, and so on.

Crisis management and distant assistance. Mobile and immersive technologies can be mixed. In particular, we want to enhance interaction between mobile users that are surrounded by the real environment and distant ”control centres” where high quality visualizations are provided. On the one hand, information such as GPS positions and video streams can be received by control centres from all the mobile units. On the other hand, control centres that have a global knowledge of the situation can send helpful information to the mobile users, such as 3D models of pertinent objects. The interest of such kind of approach can easily be understood for many applications in the scope of crisis management or distant assistance.

Entertainment. Entertainment and especially video games are key applications directly related with our project as well. Some mobile devices have been designed for entertainment, and video games have been specifically developed for such setups. The results of our research in the scope of rendering or interaction can directly contribute to the development of the entertainment industry. Moreover, we are investigating new approaches for entertainment, in particular concerning the continuum between different platforms. For example, we can imagine a user to start a game at home with a PC/console, and to continue later the same game with MCD in public transportation.

5. Software

5.1. GLUT|ES - The OpenGL|ES Utility Toolkit

Keywords: *GLUT*, *OpenGL|ES*, *PocketPC*.

Participants: Joachim Pouderoux [correspondent], Jean-Eudes Marvie.

GLUT|ES is an OpenSource port of the well known OpenGL Utility Toolkit (GLUT) which is a window system independent toolkit for the development of OpenGL applications. GLUT|ES is an implementation of GLUT for WinCE and Win32 systems based on OpenGL|ES that itself is based on the OpenSource freeglut implementation. Most of GLUT API v.3 features are present: window creation, callbacks, menus, timers, etc. Only the functions that cannot exist with OpenGL|ES or that are not pertinent have not been ported (like overlays, joysticks on PocketPC, etc.). An example is given in Figure 2.

GLUT|ES homepage, which is hosted on SourceForge.net since 2006, has been visited by more than 7.000 people all around the world and downloaded about 3.000 times. GLUT|ES has been cited by OpenGL and OpenGL|ES in their respective homepages and by their community, like in the ZeusCMD tutorials or in a 3D-Test.com interview.

Figure 2. A sample application based on GLUT|ES running on a Smartphone and a PocketPC.

5.2. AutoDEM - A software to create digital terrains from scanned topographic maps

Keywords: *DEM*, *GIS*, *contours*, *interpolation*, *map processing*.

Participants: Joachim Pouderoux [correspondent], Jean-Christophe Gonzato, Pascal Guitton.

AutoDEM is a Geographical Information System (GIS) software for the creation of Digital Elevation Models (DEM) from scanned topographic maps. Through different data layers (map, contours, DEM, etc.), AutoDEM provides many tools for topographic map analysis, contour line extraction and reconstruction, DEM interpolation and analysis. Most of the worldwide file formats used in the GIS domain are supported, making AutoDEM a credible software in the GIS community.

AutoDEM development started in 2003. Since the first freeware public version released in August 2004, nearly 7.000 people visited the webpage and we counted about 2.000 downloads. Through an open forum and emails, we established the contact with architects, researchers and many amateurs. Figure 3 shows a screenshot of the software.

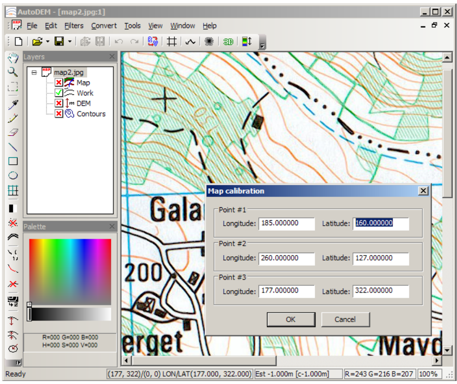

Figure 3. Screenshot of the AutoDEM graphical user interface

5.3. Elkano

Keywords: *3D visualization*, *client-server*, *framework*, *streaming*.

Participants: Mickaël Raynaud [correspondent], Joachim Pouderoux, Jean-Charles Quillet.

Elkano is scene-graph oriented platform based on the Magellan framework developed by Jean Eudes MARVIE during his PhD thesis in the SIAMES project (IRISA). Elkano is a cross platform C++ library and a set of client/server applications for Linux, Win32 and WindowsMobile. Elkano provides schemes for remote visualization of large 3D virtual environments and tools to design adaptive and progressive nodes. Through the VRML97 and X3D formats, one can easily develop new optimized nodes with streaming capabilities to get the best performance on heterogeneous platforms. We also developed modules to support multi-screen rendering through a homogeneous cluster of devices (PCs or MCDs), OpenGL shaders and streamed level of details of lines in the context of NPR rendering. Geo-referenced models (like earth terrains) are now supported.

5.4. Other softwares

5.4.1. CoTeX

Keywords: *Solid texturing*.

Participants: Tamy Boubekeur [correspondent], Patrick Reuter, Christophe Schlick.

Following a previous research result, a plug-in available for download at http://www.labri.fr/~boubek/cotex/ of this new interactive constructive solid texturing approach has been developed for the PointShop3D system. http://graphics.ethz.ch/pointshop3d

5.4.2. Osiris

Participant: Tamy Boubekeur [correspondent].

Osiris provides various surface processing tools and visualization methods for 3D surfaces, either represented by point clouds or polygonal meshes. Osiris focuses on efficient local methods, suitable for large data sets. http://www.labri.fr/~boubek/osiris/

5.4.3. GenRef

Participant: Tamy Boubekeur [correspondent].

GenRef is a GPU framework for Generic Mesh Refinement methods in real-time applications. GenRef is a small module, easy to integrate in existing applications, and efficiently replaces usual on-CPU refinements required in displacement surfaces, Bezier patches, or subdivision surfaces.

5.4.4. ST Mesh Tool

Participant: Tamy Boubekeur [correspondent].

The ST Mesh Tool is a simple 3D modeler for creating and deforming Scalar Tagged Meshes. It takes as input existing meshes, and allows to configure the various scalar tags for controlling the global shape at rendering time.

6. New Results

6.1. Modeling

6.1.1. Volume Surface Tree

Participants: Tamy Boubekeur, Wolfgang heidrich, Xavier Granier, Christophe Schlick.

Many algorithms in computer graphics improve their efficiency by using Hierarchical Space Subdivision Schemes (HS^3), such as octrees, kD-trees or BSP trees. Such HS^3 usually provide an axis-aligned subdivision of the 3D space embedding a scene or an object. However, the purely volume-based behavior of these schemes often leads to strongly imbalanced clustering. In project [14], we introduce the VS-Tree, an alternative HS^3 providing efficient and accurate surface-based hierarchical clustering via a combination of a global 3D decomposition at coarse subdivision levels, and a local 2D decomposition at fine levels near the surface. First, we show how to efficiently construct VS-Trees over meshes and point-based surfaces, and analyze the improvement it offers for cluster-based surface simplification methods. Then we propose a new surface reconstruction algorithm based on the volume-surface classification of the VS-Tree. This new algorithm is faster than state-of-the-art reconstruction methods and provides a final semi-regular mesh comparable to the output of remeshing algorithms (see figure 4).

6.1.2. Interactive Out-Of-Core Texturing

Participants: Tamy Boubekeur, Christophe Schlick.

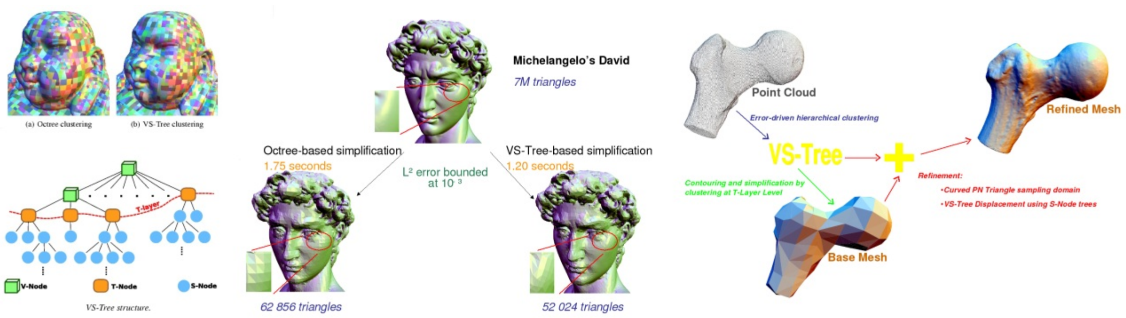

Figure 4. The Volulme Surface Tree. From Left to Right: the VS-tree structure, a comparison with an octree (partitioning and simplification), and the fast surface reconstruction algorithm built upon it.

The visualization of huge 3D objects becomes available on common workstations thanks to highly optimized data-structures and out-of-core frameworks for rendering. However, the editing, and in particular, the texturing of such objects is still a challenging task, since usual methods for optimized rendering are not easily amenable to interactive modification. In this context, we introduce the idea of point-sampled textures [24], and show how to interactively texture such a huge model at various scales, without any parameterization. An adaptive in-core point-based approximated geometry is first created by employing an efficient out-of-core point-sampling algorithm. This simplified geometry is then used for an interactive and multi-scale point-based texturing. Finally, a feature-preserving kernel is used to convert the point-based model into a global 3D texture which can be applied back on the initial huge geometry. Our technique thus provides a flexible tool to generate, edit and apply size-independent textures to a wide range of huge 3D objects thanks to point-based methods (see Figure 5).

The general principle behind this approach can help to design large object editing tools [23] and can optimize the 3D content production pipeline, usually bottlenecked by the size of scanned objects.

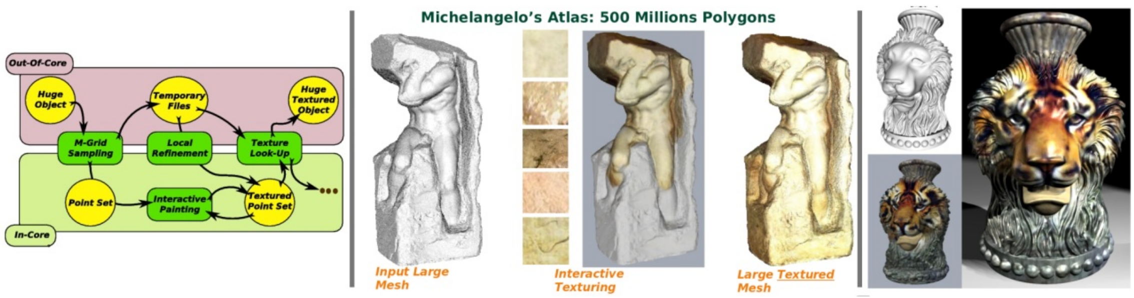

Figure 5. Interactive Out-Of-Core Texturing. From left to right: the system architecture, an example of out-of-core texturing using a set of texture patterns and an high quality offline rendering using several Point-Sample Textures.

6.1.3. A Controllable Adaptive Real-Time Refinement Kernel for Meshes

Participants: Tamy Boubekeur, Christophe Schlick.

This on-going project proposes a flexible GPU kernel for real-time adaptive refinement of meshes with arbitrary topology. By simply reserving a small amount of GPU memory to store a set of adaptive refinement patterns, on-the-fly refinement is performed by the GPU, without any preprocessing nor additional topology data structure. The level of adaptive refinement can be controlled by specifying a per-vertex depth-tag, in addition to usual position, normal, color and texture coordinates. This depth-tag is used by the kernel to choose the correct refinement pattern to instanciate. Finally, the refined patch produced for each triangle can be displaced by the vertex shader, using any kind of geometric refinement, such as subdivision surface, scalar valued displacement, or procedural geometry synthesis. This refinement engine does not require multi-pass rendering nor any use of fragment processing nor special preprocess of the input mesh structure. It can be implemented on any GPU with vertex shading capabilities (see Figure 6).

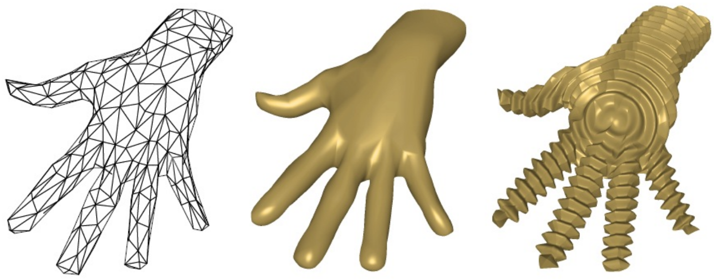

Figure 6. Controllable Adaptive Real-Time Mesh Refinement. From left to right: the on-CPU coarse mesh (576 triangles), an adaptive refinement topology generated in a single pass on the GPU (290000 triangles) and a procedural displacement applied on it (same pass).

6.1.4. Local Reconstruction and Visualization of Point-Based Surfaces Using Subdivision Surfaces

Participants: Tamy Boubekeur, Patrick Reuter, Christophe Schlick.

In 2005, we have designed a multiresolution structure, coupled with a *local geometry synthesis* kernel and an *out-of-core appearance preserving* framework for providing a *polygonal visualization of point-based surfaces*. We complete this study [15], provide more technical details and a better analysis of related work concerning the *lower dimensional meshing* kernel used for generating quickly the surfaces patches carried by the leaves of our *Surfel Stripping* structure (see Figure 7).

6.1.5. On the Fly Quantization for Large Data Transmission

Participants: Julien Hadim, Tamy Boubekeur, Mickaël Raynaud, Xavier Granier, Christophe Schlick.

We are currently working on a new approach for reducing the required bandwidth for the transmission of large 3D objects. Our first goal, is to reduce the size of the data without reducing the complexity. One solution is the compression, and more precisely, the quantization. The client-server system allows a higher availability of this data by the quantization on demand and the use of GPU in order to reduce the CPU load on server side. The quantization process compresses on-the-fly meshes and point clouds during the transmission to the final client.

We have performed some preliminary experiments on the attributes of a mesh or a point cloud that control the final appearance of the object (normal and color) [28]. We are currently investigating some new quantization algorithms that will increase the final quality and that can be extended to other attributes. We are also working on the integration of a simplification process in order to reduce the complexity of the 3D objects.

Figure 7. Local reconstuction for visualization of point-clouds.

6.1.6. Using particle systems in order to sample and add details to implicit surfaces

Participants: Florian Levet, Xavier Granier, Christophe Schlick.

(a) With uniform particles. (b) With non-uniform particles.

Figure 8. Sampled models with either uniform or non-uniform particles.

Particle systems are a powerful way to sample implicit surfaces since they generate almost evenly distributed samples over the surface, thanks to a global minimization of an energy criterion. Nonetheless, due to the computational cost of the relaxation process, the sampling process becomes rather expensive when the number of samples exceeds a few thousands. We have developed [30], [11] a technique that only relies on a pure geometry processing which enables us to rapidly generate the set of final particles (e.g., half a second to generate 5,000 particles for an analytic implicit surface) with near-optimal positions. Because of its characteristics, the technique does not need the usual split-and-death criterion anymore and only about ten relaxation steps are necessary to get a high quality sampling. Either uniform or non-uniform sampling can be performed with our technique (see Figure 8).

Thanks to the extremely regular distribution of uniform particle systems, we have developed a very efficient technique that uses these particle systems in order to rapidly generate a triangular mesh over an implicit surface, where each triangle is almost equilateral. The major advantage of such a triangulation is that it minimizes the deformations between the mesh and the underlying implicit surface. We exploit this property by using few triangular texture samples mapped in a non-periodic fashion as presented by Neyret and Cani. The result is a pattern-based texturing method that maps homogeneous non-periodic textures to arbitrary implicit surfaces, with almost no deformation. Some examples of this technique are shown in Figure 9.

(a) (b)

Figure 9. Pattern-based texturing of two different models.

6.1.7. Light Source Acquisition

Participants: Xavier Granier, Michael Goesele, Wolfgang Heidrich, Hans-Peter Seidel.

Accurately capturing the near field emission of complex luminaires is still very difficult. We have developed [33] a new acquisition pipeline of such luminaires that performs in a two-step procedure an orthogonal projection onto a given basis. In a first step, we use an optical low-pass filter that corresponds to the reconstruction filter and guarantees high precision measurements. The second step is a numerical process on the acquired data that finalizes the projection. Based on this concept, we have developed new experimental setups for automatic acquisition and performed a detailed error analysis of the acquisition process.

6.1.8. Multi-Scale Implicit Surface Reconstruction from Unorganized Point Sets

Participants: Ireneusz Tobor, Patrick Reuter, Christophe Schlick.

In 2004, we have designed a new algorithm that reconstructs multi-scale variational partition of unity implicit surfaces with attributes. In this paper [21], we complete this work and provide further results.

6.2. 3D Data Rendering and Visualization

6.2.1. Terrain visualization and streaming

Participant: Joachim Pouderoux.

Terrain rendering is an important factor in the rendering of virtual scenes. If they are large and detailed, digital terrains can represent a huge amount of data. In a previous work, we developed an efficient technique for out-of-core rendering of pseudo-infinite terrains. The terrain height field is divided into regular tiles which are managed adaptively, and each tile is also rendered in an adaptive way according to an importance metric. Our main approach is a general technique to render terrains on any kind of devices - from slow PDA to recent desktop PC. Thus, it only exploits the device capacity to draw as much triangles as possible (see Figure 10). Since the previous publication, we are now able to manage georeferenced terrains and browse the full earth as in commercial products like Google Earth. Moreover, we are currently studying an enhancement to this approach with a new adaptive step in the transfer of terrain tiles from the server to clients: tiles are now streamed according to the level of details needed by the client. This should allow small clients to display large territories faster. Note that this project is developed using the Elkano platform (see 5.3). [35] [34]

Figure 10. Flying over a terrain on a PDA without hardware acceleration.

6.2.2. Volumic Lighting Representation

Participants: Romain Pacanowski, Xavier Granier, Pierre Poulin, Christophe Schlick.

We are working on a volumetric representation to capture indirect illumination. A 3D grid of irradiance vectors is first constructed via Photon Mapping. The indirect illumination within a voxel is interpolated from its associated irradiance vectors, which can be modified to take into account local occlusions. This volumetric and vectorial representation results in an illumination more robust against local variations of geometric and photometric properties, and captures very well low-varying diffusely inter-reflected light. The efficiency of the approach is therefore well-suited for a high-quality caching scheme, but also for the storage and the transmission of indirect lighting for 3D scenes. The low-cost reconstruction allows an interactive rendering with complex diffuse inter-reflexions. An example is given in Figure 11.

Figure 11. Virtual museum

6.2.3. Tools for the creation of lighting effects

Participants: Romain Pacanowski, Xavier Granier, Pierre Poulin, Christophe Schlick.

Projective textures are commonly used for the creation of shadows. This tool is integrated into current graphic pipeline. We are currently working on a prototype that will allow the edition and the control of the shadow directly into the 3D scene. With this prototype, we want to validate the possibility of displacement, scaling, filtering, rotation, combination for the shadows before the integration of a larger range of lighting effects.

Figure 12. Line-based rendering of a virtual city

6.2.4. Non-Photorealistic Urban Environments Rendering

Participants: Jean-Charles Quillet, Jean-Eudes Marvie, Gwenola Thomas, Xavier Granier, Kadi Bouatouch.

We are particularly interested in the navigation through large virtual urban environments. Usually, 3D urban models contain a set of buildings that are simple blocks on which some realistic textures are mapped. When rendering these environments on a PDA, the cost for texture storage and transmission can be prohibitive. We propose to use a Non-Photorealistic-Rendering (NPR) style based on feature lines for the modeling and rendering of urban environments (see Figure 12). We work in image space because of the richness of information we can extract. The input is the image of a building facade where feature lines are created thanks to the vectorization of contour lines. The initial line set is dense and noisy. Considering some knowledge on the facade structure (majority of horizontal / vertical lines), we post-process this set in order to obtain a minimal set of lines that can be transmitted more rapidly than textures via a network. We are working on a hierarchical classification of lines in order to transmit them progressively on the network [31]. For the final rendering, our future work is to adapt stylization techniques (pen and ink) for a more aesthetic (but still interactive) rendering on the PDA. We will also explore mixed rendering (water-color) for a legible rendering. This work is done in collaboration with France-Télécom (see 7.1).

6.2.5. Cognitive Studies for Non-Photorealism

Participants: Audrey Legeai, Xavier Granier, Gwenola Thomas.

We are leading 2 studies in collaboration with France-Télécom: city NPR and NPR talking faces. These are real applications that require validation and confrontation to users. We are in collaboration with psychologists for the settlement of experiments. For the modeling and rendering of NPR cities we have implemented a pipeline that takes as input photographs of facades and produces 3D VRML stylized streets. The NPR cities should be used for navigation-aid applications. Users have therefore to do the matching between real streets and their virtual representation. We set up a user experiment to measure how far this matching is possible depending on the abstraction. A perspective view of a real street was first shown to the user. Two views of NPR streets or virtual streets with photos were then shown. The user had to determine if one of the synthetic views matched with the first view. Time for response was measured. This experiment was performed by a large set of users (more than 20). A large set of streets have been created to construct this experiment. The results show that matching is possible between the real view and the line-based abstraction we propose.

As for NPR city rendering, NPR talking faces is a real application lead in collaboration with FT. Faces can be seen as templates structured with clearly identified feature lines: eyes, mouth, nose... We will use filters (Gabor, brightness map) for the detection of feature lines.

In order to produce nice expressions during the talk, we will also consider expressive features as wrinkles. Compared to NPR cities, the new challenge here is that the feature lines are animated; we have to take care of temporal coherence. Active Appearance Models are used for the extraction of generic features of a face (eyes, mouth, nose). We also have explored dynamic snakes for the extraction of wrinkles. This work is in progress.

6.2.6. *NPR for exploring 3D data*

Participants: Xavier Granier, Matthew Kaplan, Gwenola Thomas.

State of the art rendering techniques do not offer suited tools for perceptually effective, legible rendering of complex data. We are working on these topics, in collaboration with ARTIS and in the context of archeology. Complex 3D scenes can have a large range of different properties associated to its 3D objects. It can be the classical geometric and material properties, but it can also be extended to more generic properties (purpose of a building, confidence on the 3D reconstruction of archaeological data, ...). We want to use the expressiveness of NPR in order to visualize different attributes at the same time, in order to explore these 3D worlds, choices have to be made in order to produce a legible solution. The issue is here similar to the classical issues of Level Of Detail (LOD) management, but with a focus on legibility. We are experimenting this notion of Legible LOD for the different visualizations and criteria.

6.2.7. *Selection of feature lines for expressive line rendering of 3D objects*

Participants: Gwenola Thomas, Audrey Legeai.

NPR. work suffer from a lack of rating tools that allows evaluating the rendering quality; especially, for now, it is not possible to assess how well a set of lines is able to convey the shape it has been extracted from. Our intuition is that these lines should correspond to what we actually perceive from shape. Visual perception modeling field provides some image processing tools that allow the extraction of relevant feature lines, such as Brightness maps, Logical/Linear operators, or Gabor's energy maps. We have developed a complete stylised-line based NPR tool that integrates some of these tools.

Among the lines it is possible to extract them with Gabor's energy method, some may not be stable onto the surface relative to slight lighting conditions or view position changes. However, image processing tools are generally not real-time. This implies that they should be run in a pre-processing step into the discretized space of possible view-positions and ligthing conditions. The extracted informations may then be analyzed so that steady lines are identified and others are derived on the fly from precomputed ones.

We are currently studying different tracks of merging and deriving extracted lines from varying light sources and view positions [36]. We experimented a method inspired by W. Xu that allows statistical selection of relevant lines extracted over different lighting conditions in order to detect light-independent lines. We are also investigating Shape-From-Shading and Image-Based rendering fields. Indeed, Shape-From-Shading goal is very close to the problem we want to solve, since it consists in deriving a shape description from one or more images, while we would rather derive a set of lines. On the other hand, Image-Based rendering consists, from a set of images of an object, in deriving an image of the same object from a new point of view; while we consider deriving a line-based rendered image from a set of line-based rendered images.

6.3. 3D User interfaces

6.3.1. *Collaborative and immersive interaction*

Participant: Martin Hachet.

This work is done in cooperation with the Human Interface Engineering Lab (University of Osaka). The goal is to develop 3D interfaces for collaborative and immersive interaction. In particular, we have developed an interface for the Illusionhole, a collaborative visualization system. This interface is based on a ring-shaped device that allows the users to easily manipulate virtual objects, as if they were rotating real ones (see Figure 13). In addition, a set of mice associated with adapted UI favors accurate collaborative tasks (eg. pointing and selecting). [27].

6.3.2. *Desktop 6DOF input device*

Participants: Martin Hachet, Pascal Guitton.

Figure 13. Collaborative interaction with the IllusionHole

From the success of the CAT (Control Action Table), we are working on the development of a 6 degree of freedom (DOF) input device for desktop settings [32]. This device is based on the CAT's isotonic/isometric DOF separation. The rotations in the 3D scene are directly controlled by rotating a physical sphere (isotonic). The translations are controlled by the forces applied to the device (isometric). This work is done in collaboration with the Immersion company (http://www.immersion.fr).

6.3.3. *Jump and Refine*

Participants: Martin Hachet, Joachim Pouderoux, Florence Tyndiuk, Pascal Guitton.

Standard mobile phones input devices such as directional keys and discrete thumb-joysticks are dedicated to the current discrete phone GUIs (eg. scroll lists and small icons arrays). Today, new mobile applications are arising and require adapted interfaces. In particular, the development of 3D applications will be favored if users can efficiently interact by pointing on any part of the screen. We proposed a new interaction technique called "Jump and Refine" for selection tasks on mobile phones. This technique is based on two levels of cursor displacement in order to reduce the number of keystrokes. The first level allows fast movements into an underlying grid. The second one can be used for accurate positioning into the selected area (see Figure 14). A user study allows us to show that using a first coarse *jump* level decreases the selection completion times. The study also shows that the technique is widely accepted by the users. [26]

Figure 14. "Jump and Refine" for selection on mobile phones.

6.3.4. *Z-goto for 3D navigation on mobile devices*

Participants: Martin Hachet, Fabrice Dècle, Pascal Guitton.

Z-Goto is a key-based 3D navigation technique. It is an extension of the classical "go to" technique, where the user selects the end-point of the trajectory. Contrary to the "go to" where the selection is done by moving a cursor on the screen frame, Z-Goto directly operates in the 3D space. This is done by sampling the depth axis in a few number of "sections" that the user will select using the keys. This technique is illustrated in figure 15. It favors the cognitive immersion of the user by increasing depth perception. Moreover, the selection of the targets is faster than with the classical "go to" as the number or required keystrokes is reduced [25].

Figure 15. Z-Goto for 3D navigation on a mobile device.

6.3.5. 3D Sketching with profile curves

Participants: Florian Levet, Xavier Granier, Christophe Schlick.

In recent years, 3D sketching has gained popularity as an efficient alternative to conventional 3D geometric modeling for rapid prototyping, as it allows the user to intuitively generate a large range of different shapes. We have developed [29], [11] some sketching interactions for 3D modeling, based on a set of two different bidimensional sketches (profile curves and silhouette curves). By using these two sketches and combining them with a gesture grammar (either by a global selection of the model or by a local selection of a part of it), a very large variety of shapes (including shapes with topological holes) can be easily produced by our interactive modeling environment. For instance, the hammer shown in Figure 16 was created with only five sketches. The user first sketched the silhouette curve. Then, the hammer head was selected (thanks to a second sketch) and a rectangular profile curve was applied on the corresponding selected vertices. Finally, the hammer pommel was selected with the fourth sketch and a new profile curve with a crease was drawn by the user and applied (see Figure 16).

6.3.6. 2D Gesture based Interaction and Navigation

Participants: Martin Hachet, Pascal Guitton, Fabrice Decle, Sebastian Knödel.

We propose to investigate general principles for easy interaction and navigation in Virtual Environments using mobile and immersive projection technologies. The technique is based on simple 2D gestures, which allow easy navigation in 3D virtual environments. It provides a good feedback and control for fast and easy interactive camera positioning. Consequently, it is well suited for a wide variety of modern visualization systems, from small handheld devices to large interactive displays. Figure 17 shows an example with a PDA.

6.3.7. Computer vision for gesture recognition

Participants: Jean-Baptiste de la Rivière, Pascal Guitton.

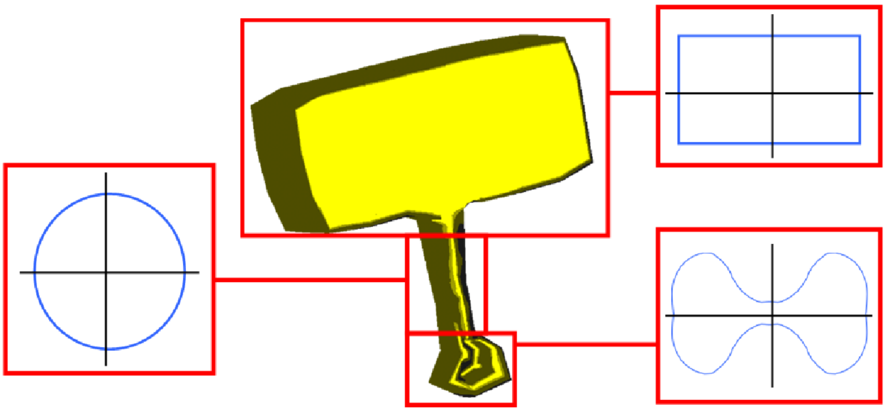

Figure 16. This hammer was created with only five sketches.

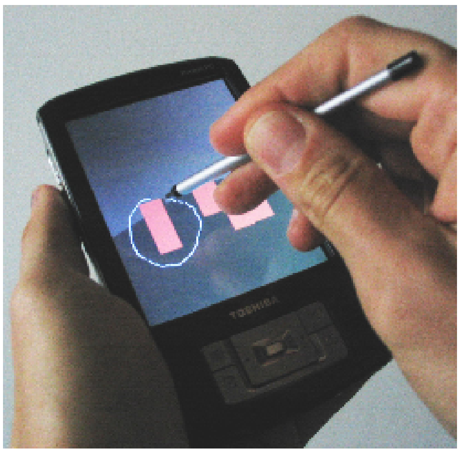

Figure 17. Navigation within 3D Virtual Environments with different technologies

As computer vision enables the robot to be aware of its human counterpart, such algorithms could help machines to achieve human-like interaction. However, many video tracking algorithms are not able to cope with some robot vision requirements. The articulated tracking system we developed solves some of those issues. It relies on model-based algorithms, which we believe are more suitable to robot vision than appearance-based ones. Indeed, as they update all the relevant parameters of a surrounding world model, results include some knowledge of the camera and objects relative positions. Our system relies on 3D model silhouette matching and runs in real-time. We increased the algorithm robustness by introducing a pre-processing step based on image moments. It allows the iteration refinement to start in a better position by roughly estimating the body motion from one frame to the next [22].

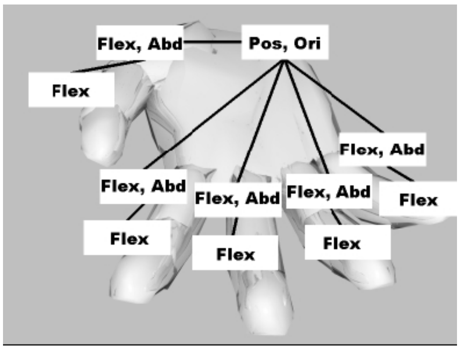

Figure 18. Hand tracking.

6.3.8. Tangible User Interfaces for reassambling fractured objects

Participants: Patrick Reuter, Tamy Boubekeur, Martin Hachet, Pascal Guitton, Xavier Granier.

We started a new collaboration with archeologist from the University Bordeaux 3 - Ausonius/Archeopôle (http://www-ausonius.u-bordeaux3.fr/) in order to virtually reassamble fractured objects that were digitized with a 3D scanner. To do this intuitively, we are currently setting up an environment for reassambling the fractured objects with tangible user interfaces. To each hand of a user, we assign a tangible user interface equipped with an electromagnetic tracker (see Figure 19). The translations and rotations of each tracker are mapped to the virtual fractured objects on the screen. This enables to determine the translations of the fractured objects and to relatively orientate them in an intuitive way. This work is done in collaboration with the LIPSI laboratory of the ESTIA Engineering School.

7. Contracts and Grants with Industry

7.1. France-Télécom

Participants: Audrey Legeai, Xavier Granier, Pascal Guitton, Gwenola Thomas.

Title: Non-photorealistic rendering dedicated to facial animation and city walkthrough.
Dates: 2006-2007

Figure 19. Our prototype for assembling fractured objects with electromagnetic trackers.

Overview: We aim at exploring Non-Photorealistic solutions for two kinds of application : « 3D cities » and « virtual humans ». This study includes three steps: (i) **Feature lines extraction** we propose a stroke-based representation of the objects based on their nature and the templates they are made of (3D cities or faces). This representation has to be minimal in order to save memory and ease transmission. (ii) **Feature lines structuration**. The set of feature lines is structured hierarchically to produce levels of details. (iii) **Validation**. The stroke based representations of cities and faces are efficient if recognition is possible whatever the level of detail used. We have settled some first experiments to measure the quality of matching between the reality and an NPR abstraction.

7.2. France-Télécom

Participants: Jerome Baril, Tamy Boubekeur, Xavier Granier, Patrick Reuter, Christophe Schlick.

Title: Multi-scale techniques for scalable coding of 3D representations and attributes.
Dates: 2005-2008
Overview: The goal of this project is to develop new techniques for progressive representations of point-based surfaces and their appearence properties. These methods are based on wavelet decomposition, a well-known tool to compute a space/frequency representation of a signal. Our first steps deal with the compression and transmission of Bilateral Texture Functions. The results are subject to a patent. Futur work is focused on point-based surfaces and how to find a good wavelet decomposition for them.

7.3. Immersion

Participants: Martin Hachet, Pascal Guitton.

Title: The CAT.
Dates: From 2004
Overview:

The CAT is a 6 degrees of freedom input device that has been developed to favor interaction with virtual environments displayed on large screens (see the 2004 activity report). The success of this new interface lead us to work with a company, Immersion, for the commercialization of the product. The CAT has jointly been presented by INRIA and Immersion at the 2nd European Research and Innovation Exhibition. This collaboration comes from a support by EITICA, a technology transfer organism of the Aquitaine Region.

The design of the CAT has been registred by Inria.
Web: http://www.immersion.fr

8. Other Grants and Activities

8.1. International grants

8.1.1. Associated Team: LIGHT

"Lab for Interactive Graphics on Handheld and Tabletop displays"
Grant: INRIA-DREI
Dates: 2004-2007
Partners: IMAGER Lab - University of British Columbia - Vancouver - Canada
Overview: LIGHT stands for "Laboratory for Interactive Graphics on Handheld and Tabletop Displays". Our goal is to investigate the different possibilities for the acquisition, the rendering and the visualization of specific or adapted representation of mobile and connected devices. We want also to develop some new interaction techniques for such devices.
Web: http://iparla.labri.fr/collaborations/associate/RA2006.html

8.1.2. MIRO

Participants: Gwenola Thomas, Xavier Granier, Audrey Legeai, Jean-Charles Quillet.

Grant: INRIA ARC
Dates: 2005-2006
Partners: INRIA (IPARLA, ARTIS) + ISTI-Pise, AUSONIUS-Bordeaux, LSC-Bordeaux, DIGISENS-Annecy
Overview: MIRO stands for "Methods for the legible and Interactive Rendering Of Complex data". In this project, we are interested in using NPR for the interactive and legible rendering of complex 3D scenes. Many examples of scientific visualization proove that photorealism does not always offer meaningful images. To address the legibility question we will rely (i) on the skills and experience of the IPARLA and ARTIS teams; (ii) on the knowledge of specific users: archeologists, museum curators, industrial users at Digisens (the startup specialized in CTscan reconstruction and dental chirurgy); (iii) on the skills of the Bordeaux lab of cognitive psychology that will help us how to validate our new methods.
Web: http://www.labri.fr/perso/granier/MIRO/

8.1.3. NatSim

Grant: ARA "Masse de données" (Research National Agency)
Dates: 2005 - 2008
Partners: IRIT (Toulouse 2), EVASION (Inria Rhones-Alpes), AMAP (UMR Montpellier), LIAMA (Beijing)
Overview: This project deals with natural simulations (vegetal, watercourses, clouds). It aims to adapt this huge amount of heterogenous data in terms of data structures, techniques and algorithms, in a unified framework to both to the content and navigation context (from mobile phones to display walls).

8.2. National grants

8.2.1. SHOW

Grant: ARA "Masse de données" (Research National Agency)
Dates: 2003-2006
Partners: ARTIS et GRAVIR-IMAG (Inria Rhones-Alpes), ISA-ALICE Loria (Inria Lorraine), REVES (Inria Sophia-Antipolis)
Overview: This project deals with the structuration and hierarchisation for the visualisation of large amounts data. It aims to enable the processing, reconstruction and rendering of large point clouds, the struturation of large meshes, as well as the structuration of large scenes.

8.2.2. DALIA

Grant: ARA "Masse de données" (Research National Agency)
Dates: 2006 - 2009

Partners: MOAIS and PERCEPTION (Inria Rhones-Alpes), University Orléans.
Overview: The Dalia project focuses on visualization, interactivity and collaboration in distributed and heterogeneous environments. The goal is to study 3D collaborative/interactive applications handling large data sets.

8.2.3. Part@ge

Grant: RNTL (Research National Agency)
Dates: 2006 - 2009
Partners: CEA-LIST, Clarte, CNRS, ESIA, France-Telecom, Haption, INRIA, INSA Rennes, Renault SAS, Sogitec, Thales, Virtools.
Overview: This project deals with the human - system interaction with 3D Virtual Environments in a collaborative experiment. We are involved in both visualization and interaction topics for mobility settings.

8.2.4. Raxenv

Grant: RNTL (Research National Agency)
Dates: 2006 - 2009
Partners: BRGM, Lyonaise des eaux, Université d'Evry, Archividéo.
Overview: This project aims at developing an Augmented Reality system for outdoor use. It is based on environmental sciences and techniques (geology, water distribution ...). We are involved in both visualization and interaction topics for mobility settings.

8.2.5. SOUL

Grant: Pôle de compétitivité AESE
Dates: 2006-2009
Partners: Thalès, BeTomorrow, Axyz.
Overview: This project deals with control of autonomous embedded systems. We are involved in the human - system interaction for 3D Virtual Environments.

8.2.6. Pôle de recherche en informatique

Grant: Conseil Régional d'Aquitaine
Dates: 2005-2007
Partners: Sound analysis and synthesis group (LaBRI)
Overview: We collaborate with the sound analysis and synthesis group of our lab for the development of interfaces aiming at enhancing interaction with sounds in virtual reality setups.

9. Dissemination

9.1. Participation to the Scientific Community

9.1.1. Conferences organization

AFIG 2006 http://afig2006.labri.fr took place in Bordeaux. It was organized by the Iparla project. 130 attendees participated at this event.
Sino-French Workshop on digital images http://www-direction.inria.fr/international/ASIE_OCEANIE/chine.html was organised in Nanjing, in cooperation with Stephane Donikian (Siames project, Rennes). During two days the workshop geathers over 30 chinese and french colleagues in order to aim the development of exchanges.

9.1.2. Program committee and reviews

Iparla is involved in the program committee of IEEE 3D User Interfaces Symposium 2007.
The members of Iparla have also participated to the reviewing process for conferences and journals:

TVCG (IEEE Vis. 2006), Computer graphics forum 2006/2007, TSI 2006/2007, IEEE VR 2006/2007, UIST 2006, ACM SIGGRAPH 2006, ACM I3D 2007, Eurographics (Annual Conference) 2006, Eurographics Symposium on Rendering 2006, Web3D 2006, NPAR 2006, International Conference on Visual Information Engineering (VIE) 2006.

9.1.3. Committees

In 2006, the members of Iparla have been involved in the following responsibilities:

- "Chargé de mission" Research by training for INRIA.
- Scientific committee of INRIA Futurs
- Recruitment committee for temporary engineers
- Evaluation committee for Interstices
- Evaluation committee for LIRIS Lab (Lyon)
- Scientific committee of Visitor project (Grenoble, Marie Curie action)
- Scientific committee CAVE Nancy
- Scientific committee for GDR Algorithmique, Langages et Programmation (CNRS)
- Administrating committee of the AFRV
- Administrating committee of the AFIG

9.1.4. Books

Editorial board:

- "Le traité de la réalité virtuelle" (3rd edition) [Pascal Guitton]

The members of Iparla have participated to books editing:

Le traité de la réalité virtuelle

- Les applications de la réalité virtuelle - Présentation des applications de réalité virtuelle, [Pascal Guitton] [12]
- Outils et modèles informatiques des environnements virtuels - Modèles pour le rendu visuel, [Pascal Guitton] [19]
- Interfaçage, immersion et interaction en environnement virtuel - Les techniques d'interaction, [Martin Hachet] [16]

Informatique graphique et rendu

- Couleur - Modèles locaux d'éclairement, Ombres portées, [Xavier Granier] [17]
- Rendu par Points, [Christophe Schlick, Patrick Reuter, Tamy Boubekeur] [20]
- Rendu réaliste - Algorithmes pour l'éclairement global, [Xavier Granier] [18]
- Rendu expressif, [Gwenola Thomas] [13]

9.2. Teaching

The members of our team are implied in teaching computer science at University Bordeaux 1, University Bordeaux 2, University Bordeaux 3, and ENSEIRB Engineering School. General computer science is concerned, as well as the following image related topics:

- Univ. Bx 1 - IUT - Modeling and Image Synthesis (Gwenola Thomas, Xavier Granier)
- Univ. Bx 1 - IUT - Introduction to image analysis and image synthesis (Gwenola Thomas)
- Univ. Bx 1 - Licence 2 - Image and Sound (Tamy Boubekeur)
- Univ. Bx 1 - Master 2 - Image Synthesis (Pascal Guitton, Xavier Granier, Julien Hadim)
- Univ. Bx 1 - Master 2 - Geometric Modeling (Tamy Boubekeur)
- Univ. Bx 1 - Master 2 - Virtual Reality (Pascal Guitton, Martin Hachet)
- Univ. Bx 2 - DESS - Virtual Reality and Image Synthesis (Tamy Boubekeur)
- ENSEIRB - Computer Graphics (Pascal Guitton and Joachim Pouderoux)
- Univ. de Pau et des Pays de l'Adour - Master Computer Science - Graphical User Interfaces (Patrick Reuter)
- ESTIA - Master Ingénierie de Projets - Graphical User Interfaces (Patrick Reuter)

9.3. Participation to Conferences and Seminars, Invitations

The project members have participated to a number of international workshops and conferences (cf bibliography).

They also have been invited to seminars and conferences:

- ”Mobile 3D User Interfaces”, Bauhaus Universität, Weimar (Germany), December 2006 [Martin Hachet]
- ”Out-Of-Core Texturation / Volume-Surface-Trees”, UBC, Vancouver (Canada), July 2006 [Tamy Boubekeur]
- ”3D Sketching with profile curve”, UBC, Vancouver (Canada), July 2006 [Florian Levet]
- ”Real-time Visualization of Large Terrains on Mobile Connected Devices”, University of Tokyo (Japan), 3rd France-Asia VR Workshop. April 2006 [Jean-Christophe Gonzato]
- ”3D Interaction with mobile devices”, University of Nanjing (China), Sino-French Workshop on graphics and image. June 2006 [Pascal Guitton]
- ”Représentations de données 3D surfaciques adaptées pour la visualisation par streaming”, INRIA Sophia Antipolis, Projet Geometrica, September 2006 [Patrick Reuter]

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