INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team artis

Acquisition, Representation and Transformations for Image Synthesis

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THEME 3B

Activity Report

2003

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1. Team

ARTIS is both an INRIA project-team and a subset of the GRAVIR joint research lab of CNRS, Institut National Polytechnique de Grenoble (INPG), INRIA and Université Joseph Fourier Grenoble-I (UJF). The GRAVIR laboratory is part of the IMAG federation (Institut d'Informatique et de Mathématiques appliquées de Grenoble).

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2. Overall Objectives

ARTIS was created in January, 2003, based on the observation that current image synthesis methods appear to provide limited solutions for the variety of current applications. The classical approach to image synthesis consists of separately modeling a 3D geometry and a set of photometric properties (reflectance, lighting conditions), and then computing their interaction to produce a picture. This approach severely limits the ability to adapt to particular constraints or freedoms allowed in each application (such as precision, real-time, interactivity, uncertainty about input data...). Furthermore, it restricts the classes of possible images and does not easily lend itself to new uses such as illustration, where where a form of hierarchy of image constituents must be constructed.

One of the goals of the project is the definition of a more generic framework for the creation of synthetic images, integrating elements of 3D geometry, of 2D geometry (built from 3D geometry), of appearance (photometry, textures...), of rendering style, and of importance or relevance for a given application. The ARTIS project-team therefore deals with multiple aspects of image synthesis: model creation from various sources of data, transformations between these models, rendering and imaging algorithms, and the adaptation of the models and algorithms to various constraints or application contexts.

The main research directions in ARTIS address:

- Analysis and simulation of lighting effects. Development of hierarchical simulation techniques integrating the most general and realistic effects, fast rendering, inverse lighting, relighting, data acquisition based on lighting analysis.
- Expressive ("non-photorealistic") rendering. Definition and identification of rendering styles. Style extraction from existing documents. Development of new view models (mixture of 3D and 2D) and new rendering techniques.
- Model simplification and transformation. Simplification of geometry and appearance, image-based representations, model transformation for various applications, detail creation and creation of virtual models from real data.

Our target applications include:

- 3D image synthesis;
- illustration (animation, technical illustration);
- virtual and augmented reality;
- virtual archeology;
- radiative transfer simulation.

3. Scientific Foundations

3.1. Introduction

The objectives of ARTIS combine the resolution of "classical", but difficult, issues in Computer Graphics, with the development of new approaches for emerging applications. A transverse objective is to develop a new approach to synthetic image creation that combines notions of geometry, appearance, style and priority.

3.2. Lighting and rendering

Participants: François Sillion, Cyril Soler, Nicolas Holzschuch, Jean-Marc Hasenfratz, Jean-Christophe Roche, Sylvain Paris.

Glossary

global illumination complete set of lighting effects in a scene, including shadows and multiple reflections or scattering

inverse rendering Calculation process in which an image formation model is inverted to recover scene parameters from a set of images

The classical approach to rendering images of three-dimensional environments is based on modeling the interaction of light with a geometric object model. . Such models can be entirely empirical or based on true physical behavior when actual simulations are desired. Models are needed for the geometry of objects, the appearance characteristics of the scene (including light sources, reflectance models, detail and texture models...) and the types of representations used (for instance wavelet functions to represent the lighting distribution on a surface). Research on lighting and rendering within ARTIS is focused on the following two main problems: lighting simulation and inverse rendering.

3.2.1. Lighting simulation

Although great progress has been made in the past ten years in terms of lighting simulation algorithms, the application of a general global illumination simulation technique to a very complex scene remains difficult. The main challenge in this direction lies in the complexity of light transport, and the difficulty of identifying the relevant phenomena on which the effort should be focused.

The scientific goals of ARTIS include the development of efficient (and "usable") multiresolution simulation techniques for light transport, the control of the approximations incurred (and accepted) at all stages of the processing pipeline (from data acquisition through data representation, to calculation), as well as the validation of results against both real world cases and analytical models.

3.2.1.1. Image realism

There are two distinct aspects to realism in lighting simulation: first the physical fidelity of the computed results to the actual solution of the lighting configuration; and the visual quality of the results. These two aspects serve two different application types: physical simulation and visually realistic rendering.

For the first case, ARTIS' goal is to study and develop lighting simulation techniques that allow incorporation of complex optical and appearance data while controlling the level of approximation. This requires, among other things, the ability to compress appearance data, as well as the representation of lighting distributions, while ensuring an acceptable balance between the access time to these functions (decompression) which has a direct impact on total computation times, and memory consumption.

Obtaining a *visually* realistic rendering is a drastically different problem which requires an understanding of human visual perception. One of our research directions in this area is the calculation of shadows for very complex objects. In the case of a tree, for example, computing a visually satisfactory shadow does not generally require an exact solution for the shadow of each leaf, and an appropriately constrained statistical distribution is sufficient in most cases.

3.2.1.2. Computation efficiency

Computation efficiency practically limits the maximum size of scenes to which lighting simulation can be applied. Developing hierarchical and instantiation techniques allows us to treat scenes of great complexity (several millions of primitives). In general the approach consists in choosing among the large amount of detail representing the scene, those sites, or configurations, that are most important for the application at hand. Computing resources can be concentrated in these areas, while a coarser approximation may be used elsewhere.

Our research effort in this area is mainly focused on light transfer simulation in scenes containing vegetation, for which we develop efficient instantiation-based hierarchical simulation algorithms.

3.2.1.3. Characterization of lighting phenomena

One of the fundamental goals of ARTIS is to improve our understanding of the mathematical properties of lighting distributions (i.e. the functions describing light "intensity" everywhere). Some of these properties are currently "known" as conjectures, for instance the unimodality (existence of a single maximum) of the light distribution created by a convex light source on a receiving surface. This conjecture is useful for computing error bounds and thus guiding hierarchical techniques. Other interesting properties can be studied by representing irradiance as convolution splines, or by considering the frequency content of lighting distributions. We also note that better knowledge and characterization of lighting distributions is beneficial for inverse rendering applications as explained below.

3.2.2. Inverse rendering

Considering the synthetic image creation model as a calculation operating on scene characteristics (viewing conditions, geometry, light sources and appearance data), we observe that it may be possible to invert the process and compute some of the scene characteristics from a set of images.

This can only be attempted when this image calculation process is well understood, both at the theoretical level and at a more practical level with efficient software tools. We hope that the collective experience of lighting simulation and analysis accumulated by members of the project will guide us to develop afficient and accurate inverse rendering techniques: instead of aiming for the most general tool, we recognize that particular application cases involve specific properties or constraints that should be used in the modeling and inversion process.

Example applications include the reconstruction of 3D geometry by analyzing the variations of lighting and/or shadows, or the characterization of a light source from photographs of a known object.

Key words: *Global illumination*, *multiresolution*, *inverse rendering*.

3.3. Expressive rendering

Participants: François Sillion, Gilles Debunne, Jean-Dominique Gascuel, Joëlle Thollot, Stéphane Grabli, Sylvain Paris, Pascal Barla.

There is no reason to restrict the use of computers for the creation and display of images to the simulation of real lighting. Indeed it has been recognized in recent years that computer processing opens fascinating new avenues for rendering images that convey particular views, emphasis, or style. These approaches are often referred to as "non-photorealistic rendering", although we prefer the term "expressive rendering" to this negative definition.

A fundamental goal of ARTIS is to propose new image creation techniques that facilitate the generation of a great variety of images from a given scene, notably by adapting rendering to the current application. This involves, in particular, significant work on the notion of *relevance*, which is necessarily application-dependent. It is necessary to define relevance both qualitatively and quantitatively. , Relevance is the relative importance of various scene elements, or their treatment, for the desired result. Examples of specific situations may include rendering specular effects, night-time imagery, technical illustration, computer-assisted drawing or sketching, etc. The notion of relevance will also have to be validated for real applications, including virtual reality settings.

Another research direction for expressive rendering concerns *rendering styles*: in many cases it should be possible to define the constitutive elements of styles, allowing the application of a given rendering style to diffferent scenes, or in the long term the capture of style elements from collections of images.

Finally, since the application of expressive rendering techniques generally amounts to a visual simplification, or abstraction, of the scene, particular care must be taken to make the resulting images consistent over time, for interactive or animated imagery.

3.4. Geometric calculation and model transformation

Participants: François Sillion, Cyril Soler, Nicolas Holzschuch, Gilles Debunne, Xavier Décoret, Hector Briceño, Yannick Le Goc, Samuel Hornus, Aurélien Martinet.

Creating images from three-dimensional models is a computationally -intensive task. A particularly difficult issue has long been the calculation of visibility information in 3D scenes. We are working on several issues related to visibility, such as the decomposition of a scene into appropriate regions (or cells) to assist in the precalculation of visibility relationships, or the precalculation of object sets visible from a particular view point or region of space.

More generally, we are interested in all aspects of geometric calculation that lead to the creation, simplification or transformation of 3D models. Complex scenes for virtual environments are typically assembled using data from very different sources, therefore coming in very different resolutions or amounts of detail. It is often a requirement to suppress unneeded detail in some parts of the scene, or to generate detail where it is missing. Given the very high cost of manual modeling, fully or semi-automated techniques are essential.

Furthermore, the apparent complexity and the amount of detail should also be adapted to the particular usage in the application, and we advocate that this can be realized by choosing appropriate data representations. We are therefore working on innovative data representations for 3D scenes, notably involving many image-based techniques.

3.5. Virtual and mixed realities

Participants: François Sillion, Jean-Marc Hasenfratz, Jean-Dominique Gascuel, Marc Lapierre, Raphaël Grasset.

Glossary

mixed reality set of techniques involving the addition of real elements to a virtual world, or virtual elements to the real world

The evolution of technology, with high-quality 3D graphics becoming available on consumer-grade computers, while image and video acquisition has become fully digital, has made the convergence of real and synthetic imagery a real possibility. Applications of mixed realities are blooming and we are interested in providing appropriate tools for these new uses of graphics. One fundamental issue in mixing real and synthetic imagery lies in the proper combination of the two image sources. 3D visibility is, of course, a difficulty, requiring some form of 3D reconstruction from real imagery. However our focus is more on the lighting and shadow consistency: Making sure that lighting effects are consistent between the synthetic and real parts of the image remains a challenge, especially for real-time applications.

The notion of relevance-guided rendering, as described above, is also inspiring us to investigate possible constraints placed on the rendering process by virtual reality applications. In this spirit we are studying the effects of virtual reality immersion for performing a given task.

On the other side of the virtual/real continuum defined by Milgram [25], augmented reality can provide the possibility to manipulate 3D virtual objects in the real world (while keeping easy eye contact and visibility of real artefacts, as opposed to what happpens with virtual reality). This introduces new issues. Registering (visual and spatially) the two worlds remains a major difficulty: efficient calibration algorithms are required. Providing natural, simple and intuitive new interaction metaphors requires user studies and new explorating solutions (coupled with dedicated input and output devices). Also, we must define a formal frame for the possible interactions with the real world (e.g modify the appearance of the real world).

3.6. Guiding principles

We base our research on the following principles:

3.6.1. Mathematical and geometrical characterization of models and algorithms

In all our target applications, it is crucial to control the level of approximation, for instance through reliable error bounds. Thus, all simplification techniques, either concerning geometry or lighting, require a precise mathematical analysis of the solution properties.

3.6.2. Balance between speed and fidelity

We seek to develop representations affording a controllable balance between these conflicting goals. In particular this applies to multiresolution techniques, where an appropriate generic process is defined, that can then be applied to “well chosen” levels of the hierarchy. This aspect is of course key to an optimal adaptation to the chosen application context, both for lighting simulations of geometric transformations and for simplification.

3.6.3. Model and parameter extraction from real data

Modeling geometric shapes, appearance data and various phenomena is the most tedious task in the creation process for virtual scenes. In many cases it can be beneficial to analyse real documents or scenes to recover relevant parameters. These parameters can then be used to model objects, their properties (light sources, reflectance data...) or even more abstract characteristics such as rendering styles. Thus this idea of parameter extraction is present in most of our activities.

4. Application Domains

4.1. Illustration

Although it has long been recognized that the visual channel is one of the most effective means for communicating information, the use of computer processing to generate effective visual content has been mostly limited to very specific image types: realistic rendering, computer-aided cell animation etc.

The ever-increasing complexity of available 3d models is creating a demand for improved image creation techniques for general illustration purposes. Recent examples in the literature include computer systems to generate road maps, or assembly instructions, where a simplified visual representation is a necessity.

Our work in expressive rendering and in relevance-guided rendering aims at providing effective tools for all illustration needs that work from complex 3d models. We also plan to apply our knowledge of lighting simulation, together with expressive rendering techniques, to the difficult problem of sketching illustrations for architectural applications.

4.2. Video games and visualization

Video games represent a particularly challenging domain of application since they require both real-time interaction and high levels of visual quality. Moreover, video games are developed on a variety of platforms with completely different capacities. Automatic generation of appropriate data structures and runtime selection of optimal rendering algorithms can save companies a huge amount of development (e.g the EAGL library used by Electronic Arts [24]).

More generally, interactive visualization of complex data (e.g. in scientific engineering) can be achieved only by combining various rendering accelerations (e.g. visibility culling, LOD, etc.), an optimization task that is hard to perform “by hand” and highly data dependent. One of ARTIS’ goals is to understand this dependence and automate the optimization.

4.3. Virtual heritage

Virtual heritage is a recent area which has seen spectacular growth over the past few years. Archeology and heritage exhibits are natural application areas for virtual environments and computer graphics, since they provide the ability to navigate 3D models of environments that no longer exist and can not be recorded on a videotape. Moreover, digital models and 3D rendering give the ability to enrich the navigation with annotations.

Our work on style has proved very interesting to architects who have a long habit of using hand-drawn schemas and wooden models to work and communicate. Wooden models can advantageously be replaced by 3D models inside a computer. Drawing, on the other hand, offers a higher level of interpretation and a richness of expression that are really needed by architects, for example to emphasize that such model is an hypothesis.

By investigating style analysis and expressive rendering, we could “sample” drawing styles used by architects and “apply” them to the rendering of 3D models . The computationnal power made available by computer assisted drawing can also lead to the development of new styles with a desired expressiveness, which would be harder to produce by hand. In particular, this approach offers the ability to navigate a 3d model while offering an expressive rendering style, raising fundamental questions on how to “animate” a style.

4.4. Collaborative work

Collaborative Work is an essential activity in the worflow of many companies to coordinate and share information among employees. Groupware have largely emerged during these last years for colocated or distant meeting (e.g. Microsoft NetMeeting). In this context, few results have been etablished for the support of colocated activities for 3D tasks (manipulation and visualization of 3D content). Solutions provided by virtual reality setups (CAVE, Responsive Workbench) seem too limited in terms of intuitive interaction metaphors, good working conditions and collaborative support.

In the continuity of previous years research, ARTIS proposed a new vision-based augmented reality, dedicated to tabletop meeting. Augmented reality delivers a large support for keeping natural metaphors of communication (verbal or gesture), and support for simple and intuitive 3D interaction metaphors. This approach has applications in a large variety of domains related to collaborative work: Architecture, Scientific Visualization, Game, Design etc.

4.5. Mixed Reality

A system that allows to seamlessly blend virtual images generated by a computer and a video stream recorded by a digital camera (e.g. a live footage) would have many applications amongst which we foresee:

- Virtual studio: The speaker of a TV show can be included and interact within a virtual world in real-time. As there is no apparatus, even spectators can come at any moment to play or navigate within the virtual set.
- Teaching/Training: this platform may also be used for teaching or training application. A teacher could manipulate in coordination with students for example molecules or any virtual object, interact with it and see in real-time its behavior. For training applications, it can be used for example to train people with a simulation of intervention in nuclear plants or other sites where real conditions are critical.
- Virtual prototyping: in industry it is common to have one model on which engineers from different fields want to collaborate. With this platform it is possible for them to share and view the same model, for example a car (1:1 scale), so that they can manipulate and expose to others any specific part or behavior.
- Multi-sites: Its possible to imagine communicating platforms like this: it would allow persons from different sites to navigate in the same virtual world, manipulate objects or even interact with each other.
- Virtual Archaeology: for archaeologist it is hard to recreate and imagine how was a ancient site. With this platform you can navigate within a virtual world, and have a realistic idea of the specific lighting of a monument (as you cast shadows on the virtual world).
- Virtual Homes: Virtual worlds can be ancient sites, but also future places: it is now possible to make a customer visit his new kitchen or her home before it is build. He can interact and manipulate any furniture and estimate this configuration in real-time.

5. Software

5.1. X3DToolKit: a 3D model processing library

Participants: Gilles Debunne, Xavier Décoret, Yannick Le Goc [contact].

One of the annoying problems in Computer Graphics is 3D file format manipulation. There are many proprietary file formats, making conversion or even loading a tedious task. In this context, X3D, a new open file format developed by the W3C consortium, based on an XML representation and hence extensible, appears as a promising future standard.

Another common need is for a set of tools that process 3D models and meshes in order to make them suitable for the application (removal of degeneracies, simplification, API to access the topological structure...).

Yannick Le Goc was hired by INRIA as a junior engineer to develop the X3DToolKit library, which addresses these requirements by providing a complete loading mechanism for X3D data, as well as a scene graph representation and clear processing mechanisms. X3DToolKit has become a standard software component in our group, facilitating the adoption of X3D as a standard data format, and has recently been released on the web[1].

Prior to the development of X3DToolKit, Xavier Décoret developed a library to parse VRML2, the ancestor of X3D. This work will be obsolete when X3D is largely accepted but is currently useful since commercial modelling applications still use VMRL as a common import/export format.

5.2. libQGLViewer: a 3D visualization library

Participant: Gilles Debunne [contact].

libQGLViewer is a library that provides tools to efficiently create new 3D viewers. Simple and common actions such as moving the camera with the mouse, saving snapshots or selecting objects are *not* available in standard APIs, and libQGLViewer fills this gap. It merges in a unified and complete framework the tools that every one used to develop individually. Creating a new 3D viewer now requires 20 lines of cut-pasted code and 5 minutes. libQGLViewer is distributed under the GPL licence since January 2003, and several hundreds of downloads are recorded each month

5.3. PlantRad

Participants: Cyril Soler [contact], François Sillion.

PlantRad is a software program for computing solutions to the equation of light equilibrium in a complex scene including vegetation. The technology used is hierarchical radiosity with clustering and instantiation. Thanks to the latter, PlantRad is capable of treating scenes with a very high geometric complexity (up to millions of polygons) such as plants or any kind of vegetation scene where a high degree of approximate self-similarity permits a significant gain in memory requirements. Its main domains of applications are urban simulation, remote sensing simulation (See the collaboration with Noveltis, Toulouse) and plant growth simulation (in collaboration with the LIAMA, Beijing).

5.4. High Quality Renderer

Participants: Cyril Soler, Jean-Christophe Roche [contact], François Sillion.

In the context of the European RealReflect project, the ARTIS team has developed the HQR software based on the photon mapping method which is capable of solving the light balance equation and of giving a high quality solution. Through a graphical user interface, it reads X3D scenes using the X3DToolKit package developed at ARTIS, it allows the user to tune several parameters, computes photon maps, and reconstructs information to obtain a high quality solution.

5.5. MobiNet

Participants: Samuel Hornus, Joëlle Thollot.

The MobiNet software allows creation of simple applications such as video games or pedagogic illustrations relying on intuitive graphical interface and language allowing to program a set of mobile objects (possibly through a network). This software is available in public domain for Linux and Windows at `http://www-imagis.imag.fr/mobinet/` The main aim is pedagogical: MobiNet allows young students at high school level with no programming skills to experiment with the notions they learn in math and physics by creating simple video games. This platform was massively used during the INPG "engineer weeks": 150 senior high school pupils per year, doing a 3h practice. This work is partly funded by INPG. Various contacts are currently developed in the teaching world.

[1] http://www-artis.imag.fr/Members/Yannick.Legoc/X3D/index.html

6. New Results

6.1. Lighting and rendering

Participants: François Sillion, Cyril Soler, Nicolas Holzschuch, Jean-Marc Hasenfratz, Jean-Christophe Roche, Sylvain Paris.

6.1.1. Lighting simulation in complex environments

We have developed a technique for computing solutions to the problem of light equilibrium in complex scenes that include plants. Our technique is based on hierarchical radiosity with clustering and instantiation. While this technique may be applied to any kind of scene, instantiation benefits highly from the multi-level approximate self-similarity of plants. Self similarity save memory and thus the program to treat large scenes. On Figure 1 the image at *left* shows a scene involving many plants from various species. Hierachical radiosity has been used in conjunction with a physiological plant growth simulator (*i.e* a simulator that enables plants to react to light and grow accordingly) to produce unique vegetal models adapted to their lighting environment. The image at *right* shows such a plant, on which the odd balance of incoming light energy has produced a dissymmetry in shape and foliage density.

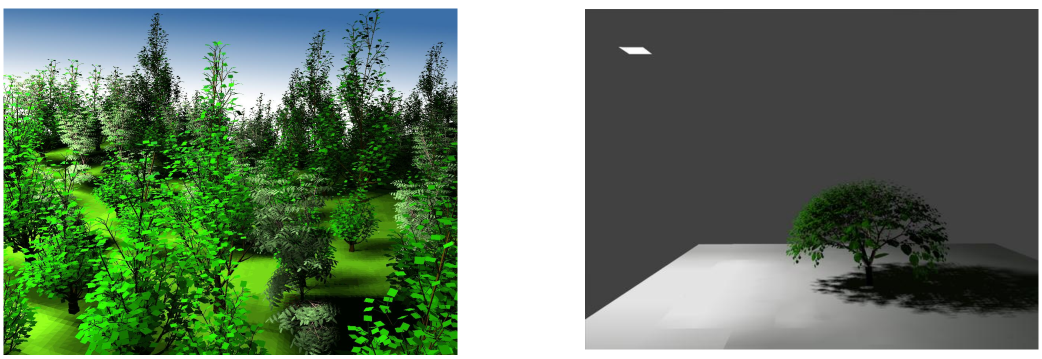


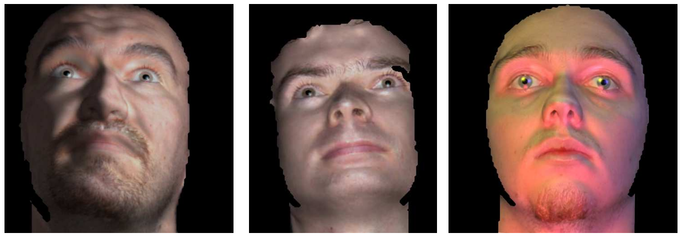
Figure 1. Lighting simulation in complex environments.

6.1.2. Face relighting

Our goal here is to provide an efficient technique to relight faces using commonly available graphics cards. Such relighting may be used in games and similar applications that require real-time rendering and potentially involve complex lighting environments. We aim for an efficient acquisition setup that does not require any specific (and expensive) system such as a robotic gantry. Our work is focused on reaching a very high visual quality using only a parametric reflectance model and a texture correction. Input data needed to render the face are:

- a photograph of the face taken with a flash in a dark room;
- a photograph in the same condition of a mirror ball;
- a 3D model of the face obtained with a standard 3D scanner.

The developed technique first analyzes the lighting environment using the image of the ball mirror . It then determines the best set of parameters for the Phong model that matches the skin appearance. It also computes a texture that adds face details (eyes, mouth, etc). Using this data, the rendering engine has only to compute a Phong model and to apply a texture. Nowadays, this is supported by all the graphics cards.



(a) (b) (c)

Figure 2. Various relighted faces. (a) Our technique can reproduce difficult features such as a short beard that mixes both skin and facial hairs. (b) It acquires various skin conditions, even a wet skin as shown here. (c) The system can render faces under complex lighting conditions.

Our method supports a wide range of faces and skin conditions and can render them under various lighting conditions as illustrated by Figure 2. It can reach a frame rate up to 95Hz on a NVIDIA TNT2 which was out in 1999. This work has been presented at the Pacific Graphics 2003 Conference[17].

6.1.3. Image-based surface reconstruction

Glossary

Lambertian A surface is said to be Lambertian if the image intensity depends only on its normal N and on the light direction L with the law $(N\dot{L})$. A Lambertian model may be extended to any law depending only on N and L; it is then equivalent to saying that the surface image is view-independent.

Our work focuses on reconstructing the surface of a Lambertian object seen in an image sequence. It applies to the scenario of a short video that does not go all around the object and that may suffer of strong occlusions in some of the images.

We state this problem in an optimization framework. We therefore introduce a functional that maps a potential object surface to a value. This functional is expressed with purely geometric measures and is independent of any discretization step used to minimize it. We employ a graph cut to find a global minimum of the functional up to an arbitrary discretization. This process is supported by several theoretical statements that characterize how to determine the surface boundaries, how to localize potential discontinuities and how to ensure surface regularity in smooth areas.

As illustrated in Figure 3, the method is both precise and robust. Future work may concentrate on broadening the supported materials and on accelerating the computation time (more than 10 minutes for the presented results). This work has been published in [4][23] and will be presented at the Asian Conference on Computer Vision 2004 [18].

6.1.4. Soft shadows

The paper “A Survey of Real-time Soft Shadows Algorithms” covers all current methods for real-time shadow rendering, without venturing into slower, high quality techniques based on ray casting or radiosity. Shadows are useful for a variety of reasons: first, they help understand relative object placement in a 3D scene by providing visual cues. Second, they dramatically improve image realism and allow the creation of complex lighting ambiances. Depending on the application, the emphasis is placed on a guaranteed frame-rate, or on the visual quality of the shadows including penumbra effects or “soft shadows”. Obviously no single method can render physically correct soft shadows in real time for any dynamic scene!

However our survey aims at providing an exhaustive study allowing a programmer to choose the best compromise for her needs. In particular we discuss the advantages, limitations, rendering quality and cost of each algorithm. Recommendations are included based on simple characteristics of the application such as

Figure 3. Several reconstructed surfaces illustrating the properties of the method. (a) Surface discontinuties are detected and correctly handled. (b) Fine geometric details are recovered. (c) Strong occlusions are detected and overcome.

static/moving lights, single or multiple light sources, static/dynamic geometry, geometric complexity, directed or omnidirectional lights, etc. Finally we indicate which methods can efficiently exploit the most recent graphics hardware facilities.

6.2. Visibility

Participants: François Sillion, Gilles Debunne, Xavier Décoret, Denis Haumont, Samuel Hornus.

Glossary

Visibility complex Partition of the set of rays according to the equivalence relation: two rays are equivalent if they intersect the same object.

Visibility polyhedron Region of space that is visible from an observer's position. Because the scene is modelled by polygons, it is a polyhedron.

6.2.1. Erosion-based Visibility

Visibility computations aim at finding which objects of a 3D scene are visible from a given viewpoint, in order to speed up the scene rendering in walk-through applications. Urban environment walkthroughs are the typical application of these computations, since the street geometry occludes a large part of the scene.

Visibility computations are usually complex and slow and to be useful in pratice, one must compute an *extended visibility* that is valid from a *region* of space and not only from a point. The result then has to be *conservative*: the list of objects declared visible may be over-estimated, but no visible object should be forgotten. One of the difficulites of extended visibility is to limit this over-conservativeness as much as possible.

A known method to compute extended visibility is to compute the visibility from a *point*, using a transformed scene where objects have been *eroded*. The result is then valid in a spherical region around

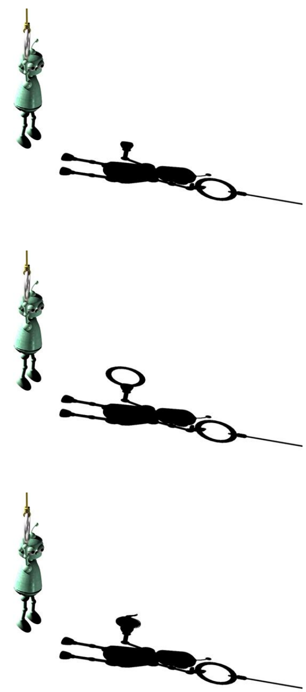


Figure 4. Shadows provide information about the geometry of the occluder. Here we see that the robot holds nothing in his left hand, a ring and a teapot.

the point, whose radius is the amount of erosion applied to the scene (Fig. 6a). In our recent work, a more formalized formulation has allowed us to extend and to better understand this result. We extended isotropic object erosion to erosion by an arbitrary convex shape. An other important result is that *both* occluders and occludees could be eroded. The application of these two results allowed us to drastically limit the over-conservativeness of extended visibility (Fig. 6b).

Exact erosion computation is a complex task and there is no general algorithm to do it. Our mathematical analysis allowed us to exhibit the properties that eroded objects had to satisfy so that the algorithm remains conservative. We could then propose a method to quickly compute an approximation of these erosions.

This research has been published at the 2003 *Eurographics Symposium on Rendering*[9].

6.2.2. Cell-and-Portal Generation

Very efficient visibility culling can be achieved if a decomposition of the 3D model into *Cells and Portals* is given. Such a decomposition might be present if the person who modeled the scene included it somehow in the scene's description (e.g. by explicitely labelling parts of the scene as cells or portals). But in many cases, this information is lost and it is very hard to retrieve it only from the scene's geometrical description.

6.2.2.1. Volumetric approach

Denis Haumont from the "Université Libre de Belgique" developed in collaboration with François Sillion, an algorithm to generate a cell-and-portal decomposition of general indoor scenes.

The method is an adaptation of the 3D watershed transform, computed on a distance-to-geometry sampled field. The watershed is processed using a flooding analogy in the distance field space. Flooding originates from local minima, each minimum producing a region. Portals are built as needed to avoid the merging of regions during their growth. The method is very general since all that is needed is the ability to compute a distance to

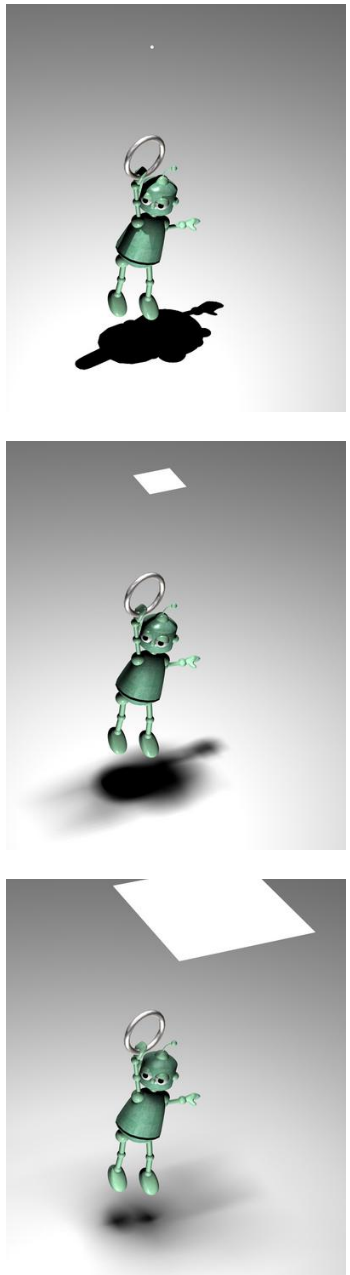


Figure 5. When the light source is significantly larger than the occluder, the shape of the shadow is very different from the shape computed using a single sample; the sides of the object are playing a part in the shadowing.

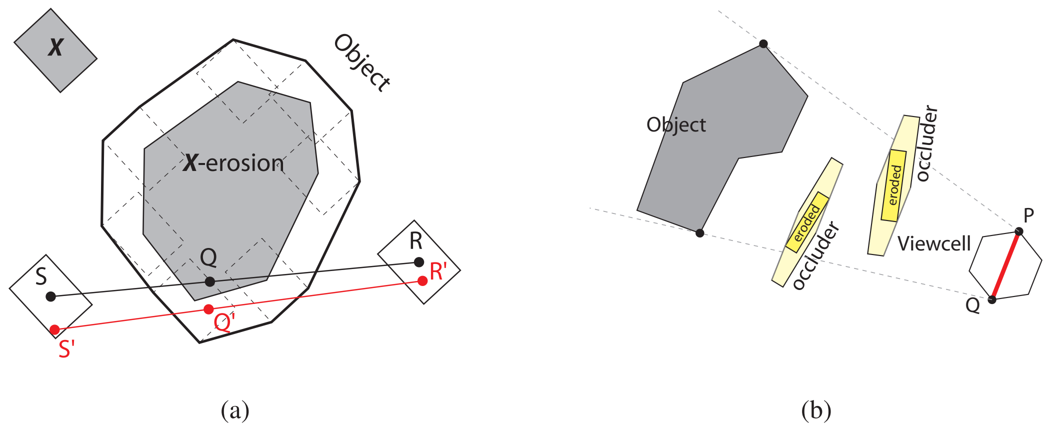


Figure 6. (a) If a ray $[SR]$ is blocked by the $\mathbf{X}$-erosion of an object, then any ray $[S'R']$ joigning two points in a convex region of shape $\mathbf{X}$ around S and R is also blocked by the object. (b) Computing visibility from the region (viewcell) is equivalent to a computation from segment $[PQ]$. But during the erosion by the segment occluders do not disappear as they do during erosion by the full hexagonal viewcell (hexagon).

the model: therefore it deals with parametric curves, implicit surfaces, volumetric data and polygon soups in an unified way.

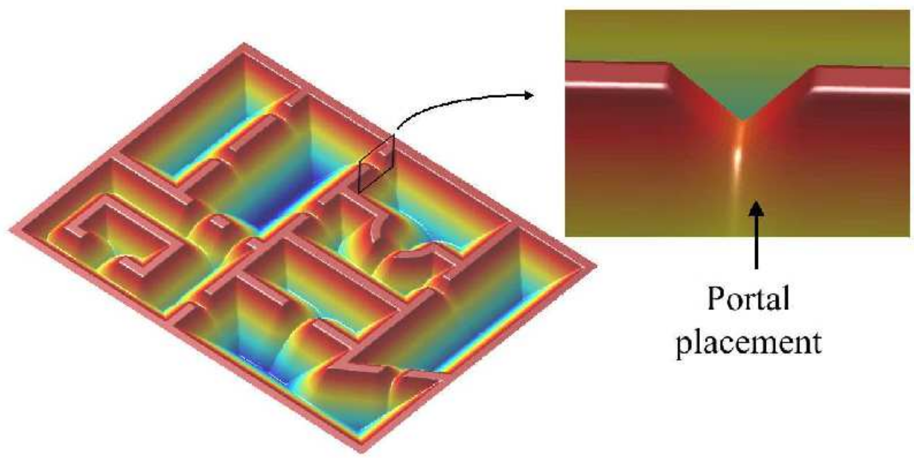


Figure 7. Distance field used as a topographic surface. A saddle point corresponding to a portal is highlighted.

6.2.2.2. BSP-based approach

Sylvain Lefebvre and Samuel Hornus developed another method to automatically compute a decomposition of a polygonal scene into a simple cell-and-portal graph. The resulting cell-and-portal graph satisfies the following user-defined constraints: an upper bound on the rendering cost of each cell, and lower or upper bounds on the size of each cell. This is useful to achieve real-time rendering of large indoor models, and is especially suited to architectural walk-throughs and game engines. The method relies on a binary space-subdivision preprocessing step, then on a portal grouping algorithm that selects or rejects portals generated by the subdivision. Finally the cell-and-portal graph (CPG) is built and post-processed to satisfy the constraints on the cells. They propose a metrics for measuring the quality of portals, which is used to guide the post-processing. Furthermore, the simplification algorithm can be used on any CPG in order to reduce its complexity according to a user threshold.

A general algorithm has been devised together with a complete implementation including relevant practical details. Results show that portals created by the method have good geometrical properties (e.g. they often lie on doors and windows).

6.3. Expressive Rendering

Participants: François Sillion, Jean-Dominique Gascuel, Gilles Debunne, Joëlle Thollot, Sylvain Paris, Stéphane Grabli, Pascal Barla.

6.3.1. Dynamic Canvas

The field of *Non-Photorealistic Rendering* not only captures the qualities of traditional media, but also permits their animation. Media that were inherently static come to life and can be animated and used for interactive walkthrough.

This raises a number of challenges: how should the elements of the picture such as strokes (marks) or background paper be animated, and how can we ensure *temporal coherence*? Two basic strategies are possible, and neither of them is perfect. One can either attach the marks to the 2D space of the picture, or attach them to the 3D objects. In the first case, the scene appears to be viewed through a shower door, and in the second, the 3D objects seem to be textured with, or carved in, artistic strokes. The problem boils down to the tension caused by the dualism of pictures, both 2D compositions and representations of 3D scenes.

In previous work, much attention has been paid to strokes and their temporal coherence, but the temporal behavior of the background canvas or paper has been mostly ignored. As a result, most NPR animations or walkthroughs seem to be projected on a paper or canvas texture using a slide projector, and the background does not participate in the animation or walkthrough experience. The strokes slide on the paper, which not only reduces the "immersion" and motion cues, but also impedes the sense of the picture as a whole, because paper and strokes do not interact and seem to lie in two different dimensions.

We have developed a *dynamic canvas* where the background texture is animated to provide strong motion cues and bind the background and moving strokes. It dramatically improves the "immersive" impression and motion cues for non-photorealistic walkthroughs, and dramatically reduces the effect of strokes that slide on the background. Our method presents a careful balance between the 2D qualities of the background texture and the 3D motion of the observer. This is achieved by panning around and zooming in a 2D background paper texture in order to approximate 3D motion. The problem can be stated as follows: The motion of the observer is three-dimensional and results in a complex optical flow, including parallax effects. In contrast, the canvas or paper of a picture is characterized by its flat and rigid 2D quality. Our goal is to use a rigid 2D motion for the paper in picture space that provides a perceptual impression of motion as close as possible to the 3D displacement in object space. This work has been published in GI'03 [8], where it received the best student paper award.

6.3.2. Procedural manipulation of style for line drawings

Non-Photorealistic styles are usually hard-coded in integrated software with access to a limited number of parameters, but they lack a flexible and formal specification framework. In contrast, the shading languages available in photorealistic renderers such as Pixar's RenderMan permit the design of an infinite variety of rich and complex appearances.

We are developing a flexible procedural approach to non-photorealistic style specification, focusing on pure line drawing as a first step. In our approach, style can be specified by implementing procedures that describe how the silhouettes and other feature lines from the 3D model should be turned into strokes. This allows for a great variety of styles, including local stylistic variations within the drawing. The system we are developing will then be used to explore depiction styles. We borrow inspiration from the visual art, and we implement

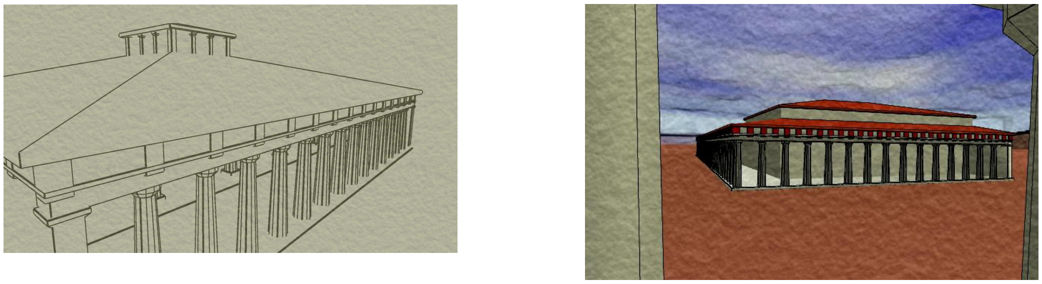


Figure 8. Dynamic Canvas: when animated, the paper is appropriately moved to reduce the feeling that the drawn model “slide” over the paper.

in our systems procedures that imitate given example images. This work has been published as an INRIA Research Report [21].

6.3.3. Crowd animation

In collaboration with the ICA laboratory in Grenoble, we have worked on the modeling of a crowd. The goal was to make the reconstruction of cities more lively. The chosen case concerns an archeological site, the agora of Argos. This place was a social arena in which people came to wander, discuss, negotiate, and participate in collective events such as sporting competitions or theatrical performances. Among all the possible dynamic structures of crowd evolutions, we did not focus on those that are symbolic or cooperative, such as negotiation, discussion, cultural or social interaction, etc. but rather on those that are non-deliberative: flowing, avoiding, jamming, collapsing, etc.

The methodology we used was first to specify precisely the main relevant features for these types of crowd evolutions, and second to define the simplest generic model able to meet all these specifications. The results prove that a physically-based particle approach is particularly appropriate in this case.

To evaluate perceptively the obtained simulations with the minimal bias in interpretation, we created multiple visualizations: evolutions of parts of trajectories for flowing and whirling effects, points for jamming effects, etc. Finally a 3D visualization was built, coating each person of the crowd by means of a non-photorealistic representation in order to obtain an interactive and symbolic rendering of the crowd. This work has been published in Graphicon’03 [16].

6.3.4. Virtual immersion in the ancient Greek city of Argos

ARTIS is working with ERGA (Stendhal and Mendes-France universities) which is specialised in ancient Greece. The goal of this collaboration is to study the use of computer graphics, especially expressive rendering, in archaelogy. This collaboration is funded in part by the ARCHEOS investigation grant.

We have created a 3D reconstruction of the ancient city of Argos. Our goal is then to develop some rendering algorithms to allow a user to walk in real-time into the city. According to our discussions with architects and archaeologists, we have chosen a style of visualization that imitates watercolor. This allows the user to understand that the proposed reconstruction is hypothetic and to keep the traditional media used by the archaeologists to communicate their research results.

This work has been published in an international meeting on archaeology [19]. Some other experiments of the use of virtual reality tools are also being studied in collaboration with the INRIA project-team REVES.

6.4. Virtual Reality

Participants: Jean-Marc Hasenfratz, Jean-dominique Gascuel Lapierre, Marc Lapierre, Jean-dominique Gascuel, Raphaël Grasset.

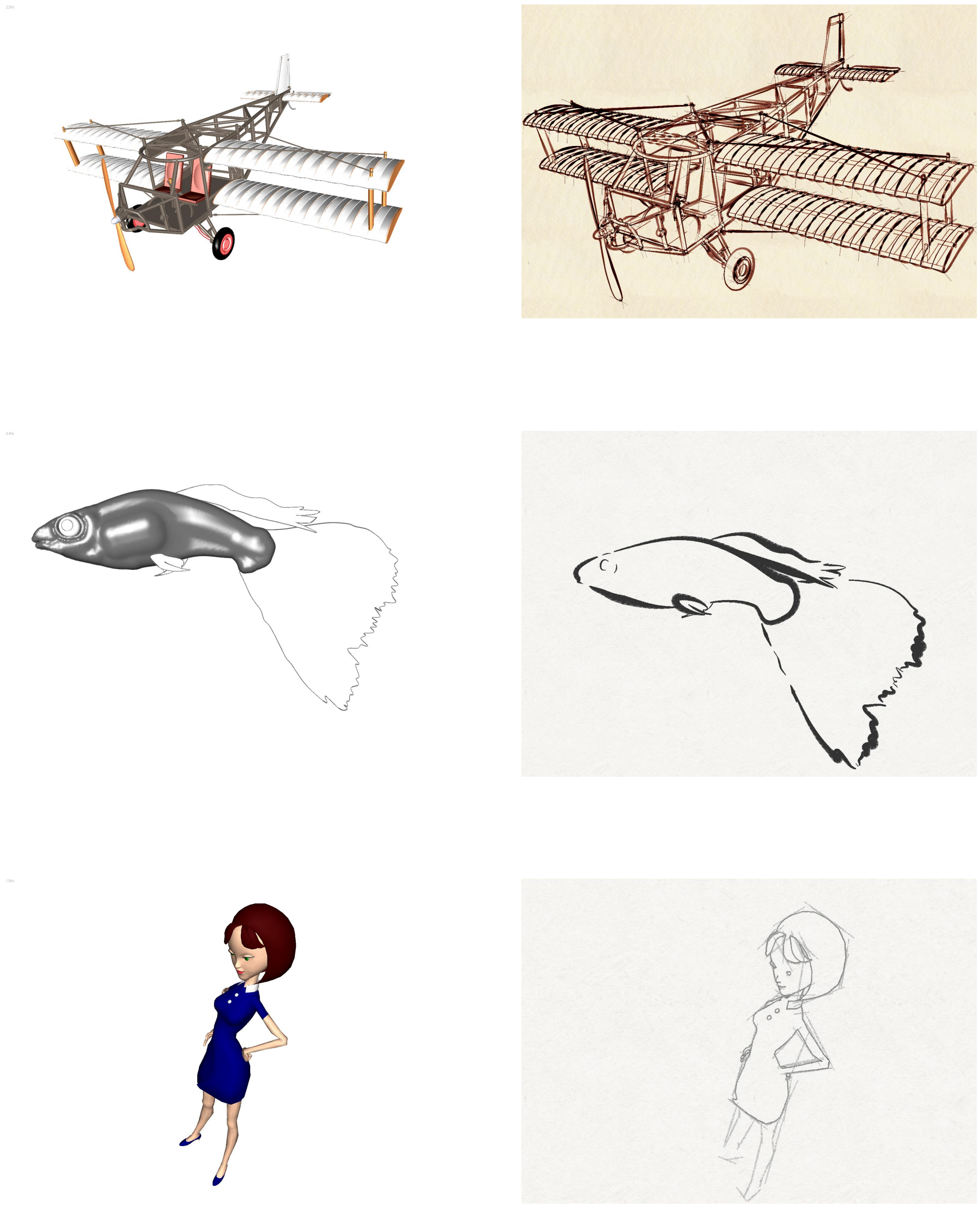


Figure 9. Three different style examples implemented within our system. For each example, we show on the left the Phong-shaded 3D model that was used, and the drawing made by our system on the right. (top row) Pen and Ink technical drawing, (middle row) Japanese Style, (bottom row) Sketching Style showing the guide lines and part of the final lines.

Figure 10. A crowd is animated using a particle system and rendered in real-time. We used a style inspired by the comic book "Alix" in order to emphasize the Ancient Greek nature of the environment.

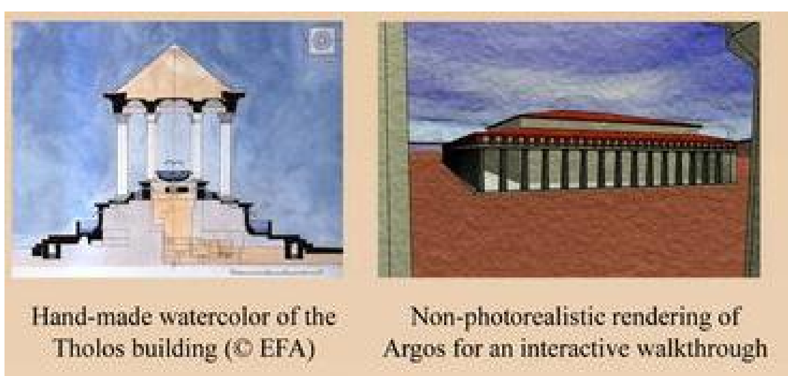


Figure 11.

Key words: *augmented reality*, *mixed reality*, *mediated reality*, *3D interaction*, *painting*.

6.4.1. CYBER

In the context of Augmented Reality applications, our goal is to simulate, in real-time, the presence of a person (e.g. a TV anchorperson or a teacher) in a virtual environment. This simulation consists mainly in visualizing the combined scenario, and possibly in providing tools for interaction between the real person (Figure 12), the virtual environment, and the observer (e.g. TV spectator or pupil).

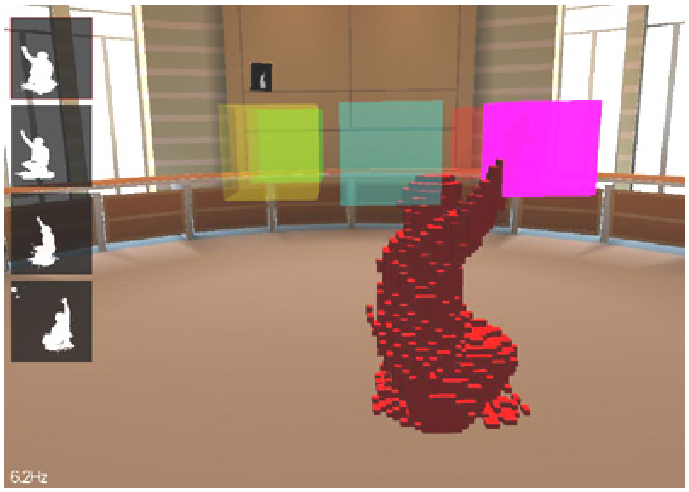


Figure 12. Interaction with the virtual world: actions can be triggered by appropriate gestures by detecting when the actor's arm enters a region of space.

The main overall technical requirements are thus a highly realistic visualization, which works in real time. We have proposed new methods to capture an actor with no intrusive trackers and without any special environment such as a blue-screen set, to estimate its 3D-geometry and to insert this geometry into a virtual world in real-time. We use several cameras in conjunction with background subtraction to produce silhouettes of the actor as observed from the different camera viewpoints. These silhouettes allow the 3D-geometry of the actor to be estimated by a voxel based method. This geometry is rendered with a marching cube algorithm and inserted into a virtual world. Shadows of the actor corresponding to virtual lights are then added and interactions with objects of the virtual world are proposed (Figure 13).

The main originality of this work is to propose a complete and scalable pipeline that can compute up to 30 frames per second. It has been published in the "Vision, Video and Graphics" workshop [13].

6.4.2. Evaluation of immersion

In 2001 a "local" INRIA investigation grant was created in order to conduct studies in cooperation with Olivier Martin (MCU UJF/UFRAPS/SPM Grenoble) and Claude Prabanc (DR INSERM U534 Lyon). The goal is to use the immersive environment of the Platform for Virtual Reality (PRV) at INRIA Rhône-Alpes to understand the coordination between vision, movement and balance for the human.

The goal is twofold: benefit from the ease of use and versatility of numerical 3D models in conducting behavioral and neuromotor studies, and find objective criteria to evaluate the quality of a stereoscopic immersion in a virtual world.

In continuation of the 2002 work by Benjamin Julian, a team of 5 persons: H. Darnet and L. Fribault (internship), L. Boissieux (engineer SED/INRIA), O. Martin (UFR APS) et J.D. Gascuel (ARTIS) worked on the development of this experimental framework. A more friendly user interface, designed to allow a broader diffusion to medical teams that are not familiar with virtual reality is almost completely developed.

Figure 13. Shadow due to a virtual light. Left: the actor seems to be "flying" above the floor. Right: shadows remove this impression

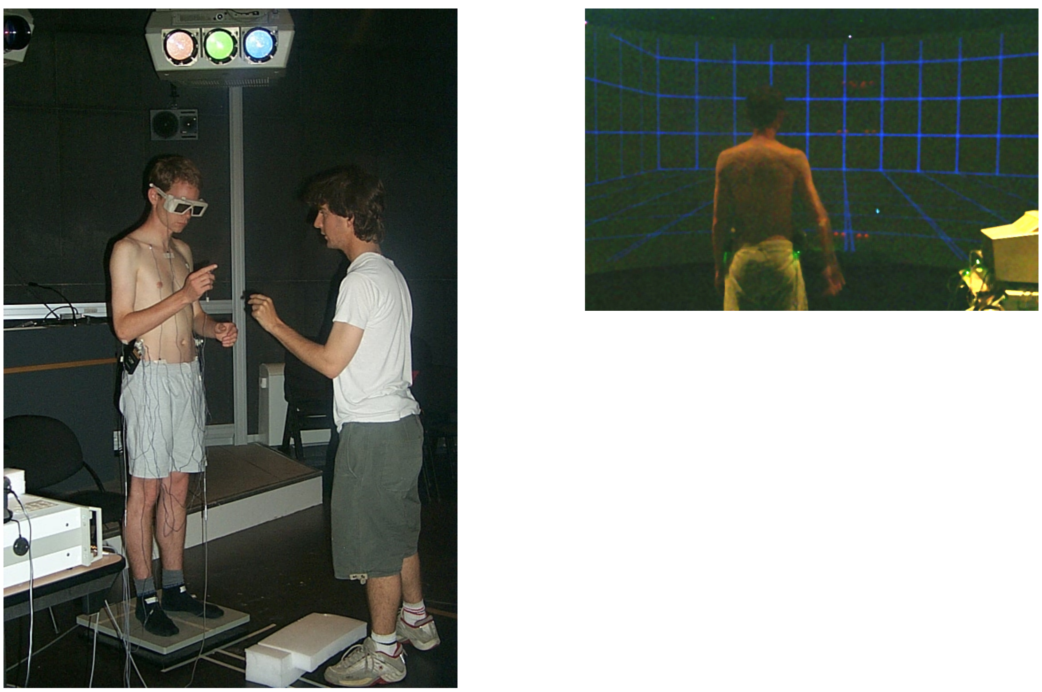


Figure 14. Evaluating on-line control of goal-directed arm movement while standing in virtual visual environment

Experiences have been conducted in June to evaluate the influence of the background (egocentric visual viewpoint) on the perception of movement, the accuracy of gestures and the control of balance. Part of this research has been published in the *Journal of Visualisation and Computer Animation*[2].

6.4.3. *Interactive Mediated Reality*

Virtual Reality researchers have largely demonstrated new working methods during the last years with "proof-of concept" prototypes in the context of virtual prototyping, interactive sculpting or painting tools. Nevertheless, these tools remain inadequate in terms of usability, with lack of proprioperception, sufficient haptic feedback and good stability of 3D devices.

In this context we proposed a new approach based on augmented reality, where a user can interactively and easily modify a simple real mockup. Our approach is based on *Mediated Reality*, which refer to the concept of filtering our vision of reality, typically using a head-worn video mixing display (as opposed to a projection approach). A large panel of domains can benefit from this concept: architecture, cosmetic, packaging, prototyping etc. For this we introduced a general framework of interactively mediated reality, and realized a first prototype that proposes new tools for modifying appearance or geometry of real mockups (i.e. painting, grabbing and glueing together real and virtual elements). Following a preliminary user experience (published in [12]), a new enhanced prototype and a completed formal evaluation have been concluded during November (this work will be submitted for publication in the next few months).

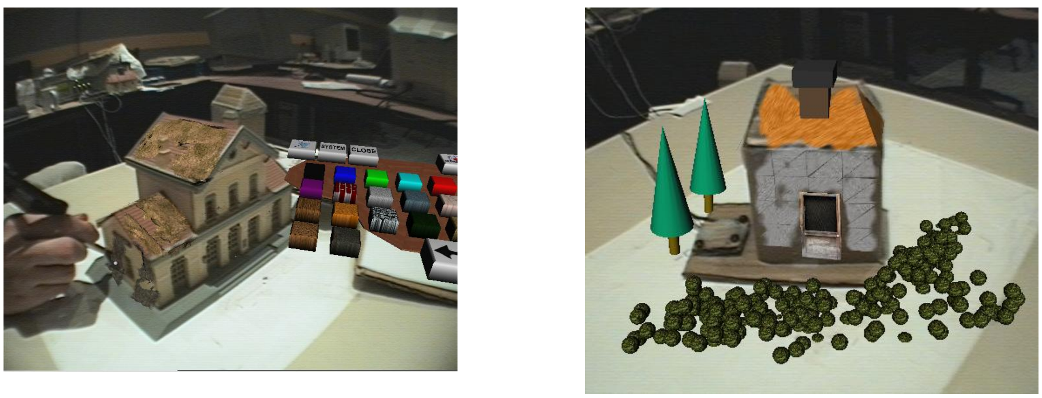


Figure 15. Interactive Mediated Reality

6.4.4. *Survey*

In order to get a better understanding and overview of the numerous and multidisciplinary research on augmented reality and its collaborative aspect, we decided to conduct a large literature study under the prism of user-centered design. The knowledge and experience we have collected during the past three years led us to the publication of a survey [11], and the creation of a new reference website on augmented reality, focused on multimedia and research aspects[2].

6.5. Model transformation

Participant: Xavier Décoret, François Sillion .

Glossary

Image Based Refers to a broad range of methods in Computer Graphics that use images as a modelling/rendering primitive as opposed for example to polygon or point based approaches.

[2] http://www-artis.imag.fr/Members/Raphael.Grasset/AR/

6.5.1. Billboard Clouds for Extreme Simplification

Our investigations on optimal representation of complex models for efficient rendering led us to the design of *billboard clouds* – a new approach for extreme simplification in the context of real-time rendering[10].

Complex 3D models are simplified onto a set of planes with texture and transparency maps. We use an optimization approach to build a billboard cloud given a geometric error threshold. After computing an appropriate density function in plane space, a greedy approach is used to select suitable representative planes. A good surface approximation is ensured by favoring planes that are "nearly tangent" to the model. This method does not require connectivity information, but instead avoids cracks by projecting primitives onto multiple planes when needed. For extreme simplification, our approach combines the strengths of mesh decimation and *image-based* impostors. Our technique has been demonstrated on a large class of models, including smooth manifolds and composite objects.

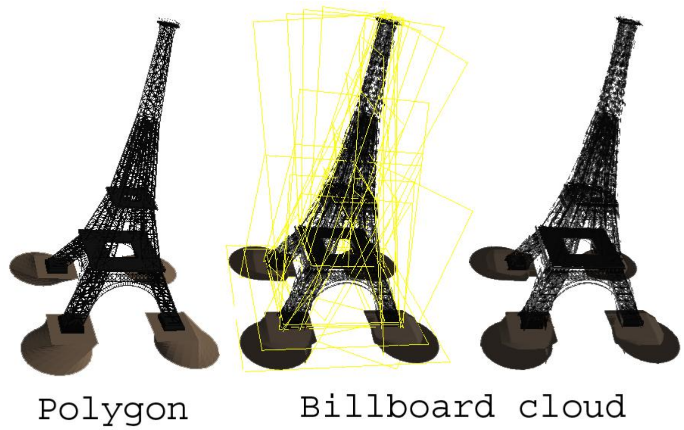


Figure 16. Billboard clouds use a small number of rectangles (here 32, emphasized in yellow) to approximate the global shape of an object and textures with transparency to represent the small scale details, such as the wireframe sillouhette nature of the Eiffel Tower.

7. Contracts and Grants with Industry

7.1. Noveltis

Noveltis is a company established in Toulouse (France) and its main activity is to perform studies of applicability and to provide usable solutions to clients in various scientific application domains such as atmospheric physics and chemistry, oceanography, land surfaces and astrophysics. The technology itself is obtained through consolidation and promotion of scientific work as a tool for analysing and managing environmental problems. Noveltis is developing a partnership with INRIA for using the PlantRad software developed by ARTIS into a framework for simulating embeded sensors on satellites. In this context PlantRad serves for the computation of the reflectance of mixed forest and urban regions of the earth surface.

8. Other Grants and Activities

8.1. National grants

8.1.1. Grants supporting the CYBER research project

The project CYBER-I was supported by the "ACI Jeunes Chercheurs" of the Department of the Research (2001-2003). The continuation of this project is CYBER-II which is supported by the "ACI Masse de

Données" of the Department of the Research (2003-2006). In this second step, we will improve the realism by augmenting the number of cameras (approximatively 20), by using a grid of PC and by visualizing the augmented scenes at very high resolutions, using a multi-projector setup.

8.1.2. INRIA investigation grant: ARCHEOS

ARTIS is participating to the ARC ARCHEOS in collaboration with REVES (INRIA-Sophia), The Foundation of the Hellenic World (Athens), ERGA (Stendhal and Pierre Mendès France Univerisities in Grenoble) and ARIA (Ecole d'architecture de Lyon). The ARCHEOS research initiative set out to meet a number of goals. The first was to establish a working relationship between archeologists, historians and architects on the one side, and computer graphics/VR researchers on the other. The second goal was to investigate issues relating to rendering styles, and notably non-photorealistic rendering, and in particular in relationship with archeological applications. The context of this second goal was concentrated in immersive or semi-immersive virtual reality systems, such as the workbench at INRIA Sophia-Antipolis, or the RealityCenter in Grenoble.

8.1.3. CNRS research action: real-time rendering

Nicolas Holzschuch is co-chair, with Pascal Guitton, of the CNRS Research and Prospective Group on Real-Time Rendering[3]. The Real-Time Rendering Group brings together the GRAVIR research laboratory (CNRS UMR 5527), the LIL research laboratory (CNRS UPRES-JE 2335) in Calais, the IRIT research laboratory (CNRS UMR 5505) in Toulouse), the LABRI research laboratory (CNRS UMR 5800) in Bordeaux, the LIRIS research laboratory (CNRS FRE 2672) in Lyon, the LSIIT research laboratory (CNRS UMR 7005) in Strasbourg and the REVES project-team at INRIA Sophia-Antipolis.

The Real-Time Rendering group was charged by the CNRS to identify ways and means to achieve real-time rendering, promising new directions of research and scientific hard points. We had four regular meetings during the year 2003. Each meeting was focused on a specific way of achieving real-time rendering, such as parallelism, using human perception to guide rendering or using programmable graphics hardware. At each meeting, we invited world renommed experts: Mark Segal (ATI Technologies) and David Kirk (NVIDIA) on programmable graphics hardware, Karol Myzskowski (Max-Planck Insitut fur Informatik) on human perception metrics, Philipp Slusallek (Universitat der Saarlandes) and Bruno Raffin (ID-IMAG) on parallel computations for Real-Time Rendering.

8.1.4. Research Ministry grant: SHOW

At the beginning of 2003, the French Ministry of Research launched a call for proposals for collaborative research actions on "Mass of Data". The call for proposals included processing, management and visualization of very large datasets. ARTIS has a project accepted within this call for proposals, the SHOW research project.

SHOW is a collaborative research action with the INRIA projects: Reves of INRIA Sophia, ISA of LORIA and Iparla of UR-Futurs (in Bordeaux). The goal is to work on a very large dataset that represents an architectural model, including walls, windows, doors, furnitures, and small objects. The model is unstructured, as it often happens in industrial applications, usually as the consequence of applying an automatic translator on the 3D data.

The ARTIS project will be working on the automatic generation of a spatial and semantic structure out of this unstructured dataset, using geometrical tools and techniques from Computer Vision. The goal is to separate and identify in the database the walls, furniture and other objects. The other research projects will be using the generated structure for simulation, parameterization and visualization of the architectural dataset.

8.1.5. Region Rhône-Alpes investigation grant: DEREVE

The Region Rhone-Alpes is funding the Dereve research project. The project has been going on for three years in its first phase (Dereve, 1999-2002) and is now in its second phase (Dereve II, 2003-2006). The Dereve research project is grouping together the ARTIS and EVASION research teams of the GRAVIR research laboratory, the LIRIS research laboratory in Lyon and the ICA research laboratory in Grenoble. The goals of

[3] http://artis.imag.fr/ Nicolas.Holzschuch/asrtr.fr.html

the Dereve project are to render large and animated virtual environments in real time, using either photorealistic rendering or non-photorealistic rendering.

In the Dereve project, we are also working in collaboration with the ARIA research laboratory of the Lyon school of Architecture, who is producing a 3D model of the "Ideal City" by the famous Lyon architect, Tony Garnier. As the city has never been built, the architects are seeing fit to have a non-photorealistic rendering of the city, to underline its virtual status.

8.2. Association with MIT CSAIL graphics group

INRIA's office of international relations has set up in 2001 a program for "associated teams" that bring together an INRIA project-team and a foreign research team, providing a form of institutional recognition to stable scientific collaborations involving several researchers on each side.

An "associated team" was created in for the 2003-2005 period between ARTIS and the MIT graphics group (CSAIL Lab) on the subject of *Flexible Rendering*. After one year of existence, this association has already proven to be extremely positive: several research actions (described above in the results sections) have been performed jointly with MIT researchers, notably the work on simplified representation based on billboard clouds, and the development of a programmable system for stylized rendering.

The associated team has helped this collaboration on a practical level by providing funding for researcher exchanges. The two teams know each other very well and frequent visits and conference calls make actual cooperation a reality (for instance publications [8][10][9][21] are co-signed by researchers from the two groups). 2003 saw four visits of MIT researchers at ARTIS, and six visits of ARTIS researchers at MIT. Furthermore, Hector Briceño was hired by ARTIS as a post doc after graduating from MIT, and Xavier Décoret was hired as research scientist (CR2) after his post-doc at MIT.

8.3. International grants

8.3.1. RealReflect

The european RealReflect project (http://realreflect.org/) is a part of the IST-2001-34744 program (http://www.cordis.lu/ist/). This is a research and developement project planned over three years. The goals of RealReflect are:

- developing new simulation and visualization methods in the context of Virtual Prototyping (VR);
- the new techniques, standards and interfaces for data exchange developed in this project must be an engine for economic development.

On the technical level it combines aspects of data acquisition for materials and ligth sources, light simulation, and realistic and physically correct visualization in VR-displays. Academic partners of the project are

- VUT (Vienna University of Technology, Institute of Computer Graphics and Algorithms, Austria);
- UBO (University of Bonn, Institut fur Informatik II, Germany);
- MPI (Max Planck Institut, Computer Graphics Group, Germany);
- UTIA (Czech Academy of Sciences, Institute of Information Theory and Automation, Czech);
- INRIA (Institut National de Recherche en Informatique et Automatique, ARTIS project, France).

Industrial partners are:

- DC (Daimler Chrysler, automotive industry, Germany);
- ICIDO (integration in VR-systems, Germany);
- FAURECIA (supplier for car interiors in Europe, France);

- VRA (VR-Architecs, architecs, Austria).

The role of the ARTIS team in this project are (1) transferring its scientific knowledge in the domain of simulation of the light equilibrium in complex environments and (2) developing new methods for obtaining a realistic solution in accordance with the physical data. The main result of the first year of work has led us to a first version of the High Quality Renderer (HQR) software (C++), based on the photon mapping method.

8.3.2. Eurodoc grants

The Region Rhône-Alpes has established a grant program to help PhD students in starting actual international cooperation during their PhD years. The following actions have been supported by the program:

8.3.2.1. Hong Kong University of Science and Technology

Sylvain Paris has visited Long Quan at Hong Kong University of Science and Technology (HKUST) twice in 2003: in February-March and in August-September. These visits have been supported by a grant from the Eurodoc program of Region Rhone-Alpes. This collaboration has been mainly centered on developing a new method for face relighting [17] and on formulating the surface-from-images technique [23][18]. During these visits Sylvain Paris has also participated in Gang Zeng PhD work about volumetric recontruction from images [20].

8.3.2.2. MIT

Stéphane Grabli has been visiting Frédo Durand at MIT for four months in 2003, from May 15 to September 15. This visit was supported by a grant from the Eurodoc program of Region Rhone-Alpes. During this collaboration, Frédo Durand and Stéphane Grabli have introduced a model for Style modeling in computer generated Line-Drawings and implemented this model within a flexible programmable system [21].

8.3.2.3. UIUC

From May to July 2003, Samuel Hornus visited prof. John C. Hart, associate professor at University of Illinois, Urbana Champaign, with a grant from a collaboration between CNRS and UIUC. We worked on the “Practical visibility project” (NSF grant CCR-0219594). More precisely, we tried to highlight the usability of the 3D visibility complex in some problems such as the continuous maintenance of the visibility polyhedron of a moving observer, or the description of an efficient data-structure for image-based rendering.

9. Dissemination

9.1. Scientific diffusion and Education

The proper diffusion of scientific results is an important part of their value. Since most of this diffusion is done using the web, a new bibliography server has been developed to ease this diffusion[4]. A search engine browses all the publications: download is made easy, and all associated documents (images, videos, abstract, bibTex...) are also available. This kind of local bibliographic tool is not widely spread in the academic community, and we tried to make our system easy to distribute, so that it can be shared.

Most of the members of the team (faculty members as well as Ph. D. students) give courses. This educational effort is also present in the distribution of libraries such as libQGLViewer, which have a real pedagogical interest since they simplify and explain the creation of computer graphics images. The project is also involved in the animation of the “fete de la science” (scientific vulgarization event), and is often consulted for its scientific expertise.

9.2. Code on the Web

9.2.1. Dynamic Canvas

The simplified and documented code of the *Dynamic Canvas* paper [8] has been released on the web. Since it involves complex geometric and openGL code, this diffusion will facilitate the evaluation and the comparison of our method.

[4] http://artis.imag.fr/Publications

9.2.2. Graph Cuts

The implementation of the graph-cut algorithm supporting the surface-from-images technique [23][5] can be found on this web page: http://www-artis.imag.fr/Members/Sylvain.Paris/PhD/index.html. It handles huge graphs with millions of nodes and edges.

9.3. Collaborations

9.3.1. LIAMA (Beijing)

The French-Chinese Laboratory for Automation and Computer Processing in Beijing (China) has a long history of collaboration with iMAGIS and now ARTIS, through the use of the lighting simulation technology developed at INRIA for the simulation of plant growth. In this context, multiple successful attempts have been done for constructing plant growth simulators capable of producing plants that react to light physically and physiologically. The collaboration is still strong, thanks to the joint efforts of Jean-Francois Barzci at LIAMA, Philippe Dereffye at INRIA Rocquencourt and Cyril Soler at INRIA Rhone Alpes. A new paradigm of structure-based plants is now being developed and experiments are being conducted in order to calibrate growth parameters related to light.

9.3.2. Technical University of Wien

Raphaël Grasset was invited for two months by Dieter Schmalstieg, at the *Technical University of Wien*. During his stay, he started a collaboration on Augmented Reality, with a first common publication [12].

9.4. Eurographics 2004

Jean-Dominique Gascuel is co-chair of the 25th *EuroGraphics 2004 Conference*, that will take place in September, at Grenoble. This international annual conference is back to France for the fourth time only, after a round trip of prestigious sites throughout Europe. This is one of the topmost important events for the Computer Graphics research all over the world. One of the aims of this edition is to involve the Game and Media industry, quite present in the Rhône-Alpes district, and to promote a meeting between these and the research community. The whole ARTIS project is involved in the conference organization, and more that 350 participants are waited for this event.

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