

# MIRO : Methods for the legible and Interactive Rendering Of 3D complex data

December 2, 2004

## 1 Motivation

For a long time, computer graphics has privileged photo-realistic rendering where the challenge lies in producing an image which can not be distinguished from a photograph. However, the realism of the rendering does not provide any guarantee of legibility, that is, the images are not always easy-to-understand.

An alternative approach, named Non-Photorealistic Rendering (NPR) has emerging these recent years [SS02]. Most NPR techniques consists in the proposal of novel algorithms based on traditional artistic techniques (watercolor, pen and ink illustration, sketching, ...). An important issue in NPR is depiction, that is, the extraction of characteristic features from 3D complex data. In this project, **we are interested in using NPR for the interactive and legible rendering of complex 3D scenes**. The complexity is related to the massive amount of data and to the intrinsic nature of information (images, texts, illustrations...). Many examples in scientific visualization prove that photorealism does not always offer meaningful images. For example in medical books, the representation of organs is more frequently based on sketches and annotations than on photographs. Some various illustration examples are shown Figure 1.

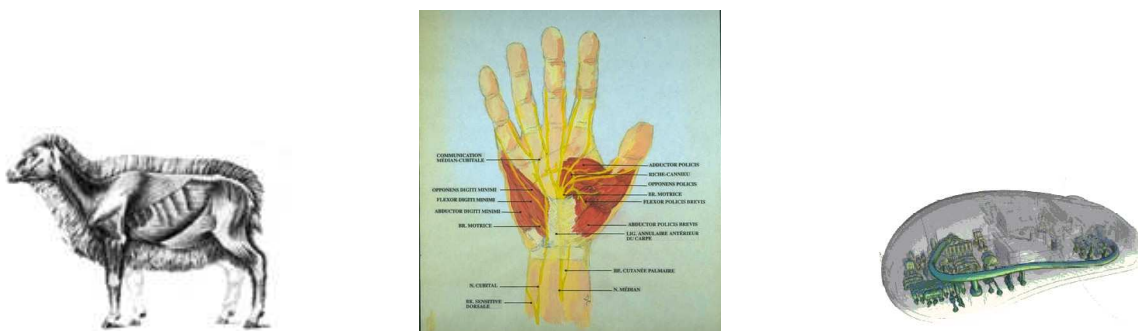


Figure 1: Multi-levels view of a sheep. Annotated medical illustration of an hand. Perceptually effective scientific visualization, SIGGRAPH 2002 course [HIL02].

State of the art rendering techniques do not offer suited tools for perceptually effective, legible rendering of complex data. Researchers in the ARTIS and IPARLA projects are working on these topics, in the context of archeology, museography, medical simulation, all applications that require specialized visualizations. 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 who will help us to define the type of validation needed for our methods.

In the rest of this document, we present our research program based on three inter-related main topics:

- **Extension of Level-of-Detail techniques for legible rendering:** When it comes to the rendering of complex scenes with large numbers of features, primitives, and rendering styles, 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 will experiment this notion of Legible

Level of Details for the different visualizations and criteria developed during this project, as explained in Section 3.

- **Expressive rendering for legibility.** Two main domains will be considered: (i) 3D rendering of objets characterized with feature lines and (ii) volume visualization using NPR techniques. For the feature lines, we will develop a geometric and photometric characterization of lines (Section 4). For volume rendering, based for instance on data extracted with an X-ray scanner, complexity comes from the superposition of information. We will propose some algorithms for the extraction of interesting features inside those volumes (see Section 4).
- **Simplification techniques for NPR.** Visualizing a very complex scene (city, forest) or an object with many features, such as a tree, in a line drawing or hatching style produces too many lines. The result becomes soon incomprehensible due to line clutter. We will develop simplification techniques (see Section 5) of the sets of lines to produce legible and interactive rendering. The reduction of density for strokes-based rendering will also be considered.

## 2 Partners

### **IPARLA project, INRIA Futurs, LABRI, Bordeaux (<http://iparla.labri.fr/>)**

The main goal of this project is to allow the visualization of complex data and their manipulation on mobile and connected devices (MCD), like PDA and cell phones. To be sufficiently small and autonomous, they have some limited resources: a restricted computational power and storage capability, a limited bandwidth, a small display size. These limitations raise some specific problems that we want to address.

- Gwenola Thomas, assistant professor, main coordinator of this proposed ARC
- Xavier Granier, INRIA researcher
- Pascal Guitton, professor, head of IPARLA INRIA project
- Post-doc

### **ARTIS project, INRIA Rhône-Alpes, Grenoble (<http://artis.imag.fr/>)**

- Joëlle Thollot, assistant professor, coordinator of this proposed ARC
- Pascal Barla, PhD student
- Jean-Dominique Gascuel, CNRS researcher
- François Sillion, DR INRIA, head of ARTIS INRIA project
- Post-doc

In these two lists of participants a post-doc is mentioned. We plan to use the budget for the funding of an 18-month post-doc (see Section 6). This post-doc will be shared part-time between IPARLA and ARTIS.

### **Associate partners**

- Roberto Scopigno, senior researcher, Istituto CNUCE, Pisa, Italia
- Robert Vergnien, CNRS researcher, AUSONIA, Institut de recherche sur l'antiquité et le moyen âge, Bordeaux
- Bernard N'kaoua, assistant professor, Cognitive Science Group, Bordeaux 2
- Digisens SA, Annecy, France. This startup company (created in october 2002) just received the prestigious 2004 IST Prize from the EC for its VMGS *Virtual Museum Global Solution* concept.

This project is organized in several sub-projects that are now presented. The list of participants (alphabetically sorted) is indicated above each title. The leader of each sub-project is mentioned in italics.

### 3 Extension of Level of Detail for legible rendering

**Participants** : J.D Gascuel, X.Granier, P.Guitton, J.Thollot, G.Thomas, F. Sillion, X (Post-doc)

We aim to extend the notion of Level-of-Detail (LOD) [LRC<sup>+</sup>03] for legible rendering. The classical LOD issues are (i) the simplification of the 3D representations (1D–features, 2D–surfaces and 3D–volumes, textures, all mixed together in the same scene) and (ii) the criteria for selecting the different levels. For NPR, some solutions exist for a multi-level style [PHWF01, KMM<sup>+</sup>02]. In our case, each representation can also have different rendering styles. For a legible rendering, we have to select the appropriate style that will allow the visualization of most features without being masked by the features of the surrounding styles. We also have to be able to classify the important features hierarchically.

The main issues are then the combination of different rendering styles and the extension of criteria used for classical LOD [LRC<sup>+</sup>03] by developing new legibility criteria (see Section 4). We will develop a platform for the experimentation of these criteria. We will use different simplification approaches (such as line simplification, NPR impostors, mark densities, see Section 5), and different style combinations for different 3D representations (2D surfaces and 3D volumes).

We strongly believe that such NPR approaches will allow a more legible visualization of **augmented 3D scenes**. An augmented 3D scene contains not only its geometry and the description of the material properties, but also related information. This information can consist for instance of labels [BFH01] (see Figure 2), pipe or wire locations for architecture, the construction date of a building in urban planning, or some identifying tags (status of an object: existing, prospective, extracted from documents, ...). Non-photorealistic styles can create visual guides for an easier navigation, since they remove the realistic-looking constraint, and focus on the legibility. As an other example for archeology, multi-style rendering helps to clearly identify which parts of a 3D reconstructed site are pure speculation, assumptions based on existing documents, or actual remaining objects.

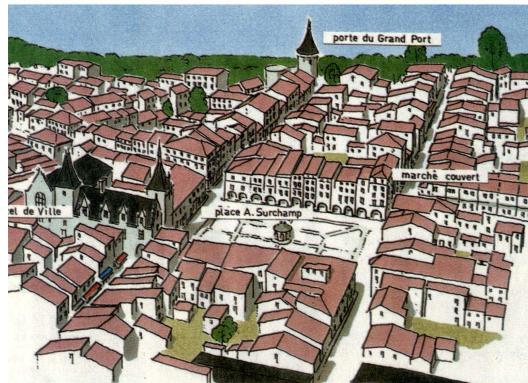


Figure 2: NPR rendering of a city augmented with labels. Note the different styles for the building and the square.

### 4 Expressive rendering for legibility

Producing a legible image is one of the goal of the NPR community. However, the problem of characterization of the important features of a scene is not usually addressed. In this project, we want to study this notion of importance in two cases: line drawing and volumetric visualization. In both cases, we will propose algorithms for a quasi-automatic extraction of features.

The expressiveness of extracted features is not easy to measure. The proposed rendering styles will be tested and validated on real and complex examples (3D virtual cities, medical volumes, archeological data). Cognitive scientists from Bordeaux-II university will participate in the project and help us to set up the tests and measures of user’s satisfaction. More formal validation criteria based on psycho-visual human processes will also be used.

## 4.1 Geometric and photometric characterization of feature lines

**Participants :** P.Barla, J.Thollot, G.Thomas, X (Post-doc)

Non photorealistic rendering based on strokes can be obtained with the automatic extraction of feature lines from photographs or 3D models. There are different kinds of extracted features ; silhouette and contours which are dependent of the viewpoint, creases and principal directions of curvature which are intrinsic to the model, and therefore independent of the viewpoint [SS02]. The set of automatically extracted lines does not always efficiently depict the original model. Some recent work has introduced new types of feature lines. In particular, De Carlo et al [DFR04] introduce the suggestive contours (see Figure 3) that enhance the rendering quality.

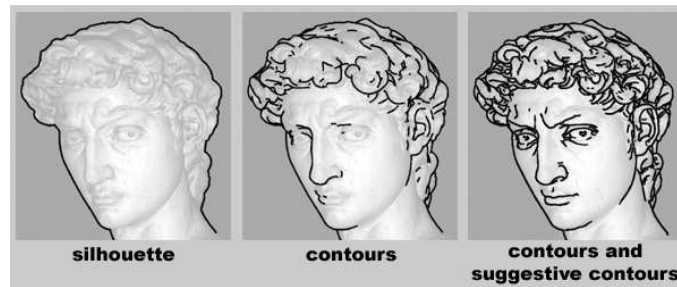


Figure 3: Different kinds of feature lines automatically extracted from a 3D model. [DFR04]

Following this idea of extracting richer lines from the models, we want to better understand the nature of the feature lines created by an artist. We propose to characterize the strokes created by an artist from a photograph or a 3D model. Psychologists from the University of Bordeaux will help us in this process that involves human choices. Various interfaces can be used for the creation of lines. The artist, using a pen tablet can draw strokes on a photograph or on a 3D model. The use of a 3D device like a Phantom can also be considered for the input of 3D strokes. Strokes can also be scanned from a drawing. Whatever the interface, some photographs and a 3D model that inspired the creation of the strokes will be available. Each stroke will be characterized with photometric and geometric properties.

Both ARTIS and IPARLA projects will participate in this study. A dichotomy between characterization of lines in image space and object space will be performed. ARTIS project will mostly work on the characterization of lines in object space, whereas IPARLA project will concentrate on image space. Those two studies are not independent and a matching between 2D lines extracted from photographs and 3D lines extracted from 3D objects will be necessary. A close collaboration will therefore be settled between the two teams for this study. This fundamental study will lead to the formal definition of features lines. Our better understanding of feature lines will be used for the automatic extraction of feature lines and the creation of levels of details, that is which feature lines have to be kept for each level.

## 4.2 Volumetric rendering

**Participants :** J.D Gascuel, X.Granier, J.Thollot, G.Thomas

Modern graphic cards are now able to display huge volumes in real-time (128 MVoxels on standard game level cards), with transparencies and animated colors [KMM<sup>+</sup>01][BHH]. Large 3D data (eg. 3D scalar field of opacities, reconstructed from X-Ray scanners) are already widely used by medicine, and industrial applications [BC03] (see in Figure 4.2). They permit to see not only the surface of objects, but also to have an insight of what lies inside. For those good reasons, museums now want to use those technics to enhance the experience they propose to their visitors. But brut force volume visualization add a great deal on complexity to what is shown on screen. And non-professionals visitors have a definitive need for legibility.

To those respects, ligibility is most needed. And the problem is complex: rendering volumic data will not be enough. Because we need to stress out some particular aspects of the model, we will have to add features like special lighting, surfaces, and line drawings. Hence to mix together in 3D very differente types of graphic primitives. This enrich further the LOD for legible rendering testing-ground.

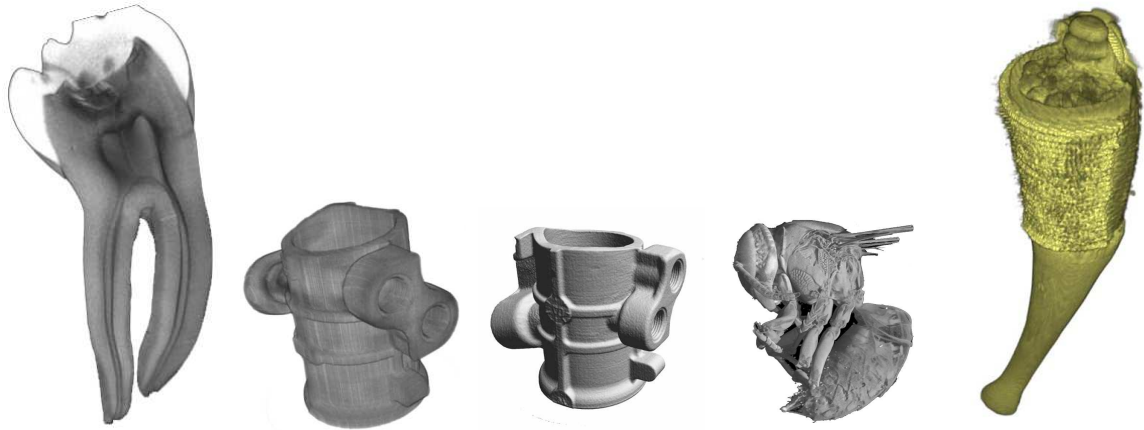


Figure 4: A cut in a tooth, with its internal structure. Non destructive control of aluminium cast using, X-Ray reconstruction: direct volume rendering, and extracted surface. An hornet (voxels of  $3\mu$ ). A talisman, Madagascar, Lyon's museum collection.

We will develop pre-processing tools to filter and classify 3D data, designed to produce optimised representation featuring several levels of complexity of the scene to display.

In a first approach, we will use low-pass filtering to produce low complexity levels, and multi-channels (gradient, laplacian, multi-spectral, fiber-detection) to enrich classification. Then, running features extraction will drop dimension of data from 3D (volumes), to 2D (iso-surfaces), 1D (gradient lines, contours, points). All those features will then be good candidates for Enhanced LOD for legible rendering.

In a longer run, we would like to explore real-time 3D shaders that generate on the fly similar features. It will enable us to interactively change what is displayed, in addition to how it is rendered.

## 5 Simplification techniques for NPR

Here we will develop new algorithms to construct the level of details of a scene rendered in an expressive style. Different approaches either in image space or in object space will be used. Indeed, if we want a simplified version of a drawing or a painting, we can either simplify the geometry, or decrease the number of lines or strokes we want to draw in the final picture, depending on their size or coverage of the image.

### 5.1 Line drawing simplification

**Participants :** P.Barla, *J.Thollot*, G.Thomas, F.Sillion, X (Post-doc)

In the case of line drawings, a complex 3D scene such as a city or a crowd will generate too many lines when rendered with a standard algorithm. The same problem arises if we try to extract feature lines in photographs. For a legible visualization of a line drawing we need to decrease the number of lines. Decreasing this number and organizing the lines into a hierarchy of importance is also useful to reduce the amount of data. This reduction is crucial for limited memory devices or distributed applications. Those hardware constraints are strongly present when the rendering platform is a small device (phone, PDA) which is the main target platform in the IPARLA project.

ARTIS has begun to work on this topic in the case of line drawing without regular structure [BTS04], shown in Figure 5. The simplification algorithm iteratively aggregates neighbors lines based on a scale criterion.

ARTIS and IPARLA will work together on a specialized version in the case of feature lines extracted from photographs of building façades (see Figure 6). We will propose some criteria for the organization of the feature lines of buildings. We will also develop some perception-based techniques in order to determine the levels of details. The resulting application will be a real-time rendering of virtual cities using dynamic levels of details for line drawings.



Figure 5: Preliminary results of a line simplification algorithm [BTS04]



Figure 6: Feature lines extracted from photographs of building façades

## 5.2 Density of the strokes in a painting rendering algorithm

Participants : P.Barla, J.Thollot

When rendering a scene in an expressive style we often also want to add some color information to a line drawing. That is we would like to fill the resulting images with some matter, like in classical painting.

ARTIS has already worked on this topic by adding a paper background on which the scene seems to be drawn and ensuring a coherent motion of this paper during a walkthrough session [CTP<sup>+</sup>03] (see Figure7).



Figure 7: Left: Dynamic canvas [CTP<sup>+</sup>03] - Right: Stroke based rendering [Mei96]

This time we want to address the problem in the case of a painting style. This field of NPR is known as stroke based rendering, (see Figure 7) and consists in filling an image, or some regions of an image, with 2D regions, called strokes, that can be viewed as paint brush strokes. When the goal is to offer an interactive rendering of a 3D scene, we need of course to have fast computation of the strokes but also to address the temporal coherence problem: the strokes have to remain stable from one image to the next. Moreover, the strokes are drawn in 2D and have to keep a nearly constant size in image space: Indeed, we do not want to see the brush strokes becoming larger when we move forward in a scene. However if their size remains bounded, the strokes will separate from each other and new strokes will be needed to fill the image. We thus have to deal with a stroke density problem.

We plan to address this problem in object space, following Meier's work [Mei96], by attaching the strokes to particules on the objects surface. By adding a hierarchy on the particules and a covering test in image space

we will be able to insure a correct strokes density.

Such an algorithm can be viewed as a particular case of LOD because it produces some simplified versions of a painting in terms of number of strokes. The covering criterion will be integrated in the more general LOD hierarchy as stated in section 3.

## 6 Budget

	Travel	Post-doc	Internship	Equipment	Total
Year 1	8k€	18k€	9.6k€	10k€	45.6k€
Year 2	8k€	36k€	9.6k€		53.6k€
Total	16k€	54k€	19.2k€	10k€	99.2k€

Here are some more precise indications of estimated costs :

- **Travel:** 1k€ for travel per year and per person. The interdisciplinary nature of our proposed goal (creating more legible images) leads us to envision regular discussions with our associate partners, requiring a significant travel budget.
- **Post-doc:** 18 months, 3k€ per month. The candidate will concentrate on lines rendering (see Section 4.1, 5.1). He will also participate to the development of non-photorealist techniques in order to test heterogeneous rendering (lines + watercolor + ...) (see Section 3).
- **Internship:** 2 internships of 4 months per year and per participant, 1.2k€ per month
- **Equipment:** 2 PCs per site, 2k€ per PC. Specific material (pen tablet, scanner) for line and painting acquisition.

## 7 Budget of participating INRIA project

	2004-05
ARTIS	176k€(of which 24 k€of INRIA funds)
IPARLA	47.5k€(of which 20.8 k€of INRIA funds)

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