# High Performance Computing and Visualization for Forestry Applications - Project SILVES

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## *Project SILVES*

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Abstract

Modelling, simulation and visualisation of forest cover is a very important aim for the sylviculture. Now the development of different techniques in tree and forest modelling, in GIS is sufficient to develop specific software used in forest simulation. Now, having a better way to represent and to interact with large models like forests are topics of high interest. After a short presentation of the project SILVES, we resent in this paper the design and implementation of a visualisation program that involves two main features. It is based on the central data model, in order to display in real time the modifications caused by the modeler. Furthermore, it benefits from the different immersive environments which give the user a much more accurate insight of the model than a regular computer screen. Then, we focus on the difficulties that come in the way of performance.

Keywords: visualisation, forest, GIS, immersive environments, multi-pipe rendering.


## 1   Introduction

Integrating information coming from different sources, getting a better understanding of 3D objects' relationships, having a better way to represent and to interact with large models are topics of high interest in many applications. Also the development of a visualisation tool must be based on the central data model, in order to display in real time the modifications caused by the different modelling tools; furthermore, it should benefit from the different immersive environments (like CAVES™, REALITYCENTERS™ or workbenches) which give the user a much more accurate insight of the model than a regular computer screen. These general considerations can be applied to different fields of research, and, in particular, to forestry applications.

In the field of forestry management, the creation of visual tools of high quality represents a very important scientific and technical issue today. Forestry management is disputed by various social movements, and the administrative organisms are ready to their stronger implication in the decisions. For that, the current dialogue tools are defective: in reason for the very slow growth of the forests, it is necessary to rest on realistic visual tools for the discussion of management scenarios taking effect on several decades. Within the framework of a collaboration inter Inria-Cirad-Inra-Engref French institutes, we try to develop tools allowing to help in the management of plantings by using geographic information systems (GIS), the models of forest production of Inra-Engref, the models structure-function of Cirad and the knowledge in high performance computing and visualisation of the Isa project

(applications for Increased Reality in real time) in Inria. This project is called SILVES: *Computer simulations and visualisation software applied to sylviculture*.

In this paper, we will describe the main points of the design and implementation of solutions chosen to adapt the visualisation of huge models (like forests) to immersive environments. Finally, we will present the main ideas of the project SILVES.

## 2    High performance computing and visualisation

The Isa research group was created in 1995 and is part of Inria. The fundamental scientific problems addressed by Isa are geometric (differential, algebraic and projective), numeric (domain decomposition method) and algorithmic (complexity, parallelism). These problems are to be found in the classical research fields of computer vision and computer graphics. The work of Isa centres around three topics : (i) modelling by vision (medical imaging, augmented reality), (ii) geometric computations for rendering complex scenes (meshing and parameterisation, robust computation on quadrics, 3D visibility), and (iii) simulation and high performance visualisation (realistic rendering, volumetric visualisation).

In particular, in the field of high performance visualisation, Isa introduced new software architecture making it possible to combine a multiprocessor and several graphic pipelines environment [1]. This allows very important acceleration of overall geometrical calculations implemented in certain scientific applications, without penalising the acceleration of traditional parallelism. This has been applied to a standard geoscience program (GOCAD) [2] to enable the visualisation of its model within different immersive environments (Fig.1) [3].



Fig. 1 GOCAD: visualisation of  seismic data in a CAVE™.
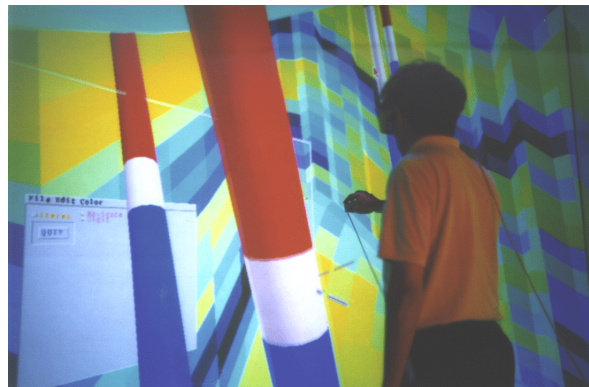
### 2.1    Immersive Environment

An immersive toolkit should be flexible enough to accommodate several environments, ranging from the simple user display (the common computer screen) to immersive VR environments (Fig.2). In these high end configurations, the global representation of the scene is displayed to the user by means of multiple sub-images projected on screens.

The possibility of configuring the software without having to recompile anything is essential. As with the CAVE LIBRARY [4], this goal is achieved by having the hardware part of the virtual environment defined in an external configuration file. This file defines the number of displays, the screen geometries and their relative positions (given by the position of three corners of the screen), as well as the different devices and their specific parameterisations used to drive the visualisation. Thus it is possible to adapt at runtime to any hardware environment.



Fig. 2 Immersive room: broad screen with video-projectors (left) and control screen (right).

Depending on the characteristics of each screen, a specific sub-image must be computed. These images are then displayed together, and are seen by the user as one large image. Synchronizing the display of the sub-images must be specially considered. Our implementation has a barrier that synchronizes the rendering threads just before they swap the frame-buffers. This must be applied throughout the whole rendering process, since nothing guarantees that the sub-images are computed equally fast. This solution avoids some visual artefacts which can occur when the different sub-images are not displayed exactly simultaneously. In this case, the global image would be distorted.

For efficiency, it is better if all the images are computed simultaneously. This is possible with computers having multiple graphics pipes or graphics cards, and implies an obvious parallelism of the visualisation process. In this case, the scene graph traversal must be thread-safe.

## 2.2    Multi-pipe acceleration

In order to accelerate the visualisation process, a solution  is to allow multiple pipes to collaborate on one single image. The goal is to benefit from a graphics hardware parallelism.

Different acceleration designs can be used:
- 2D composition : the image is divided into a number of sub-images computed by separate graphics pipes. Only a part of the scene is sent to each pipe, thus accelerating the rendering time. All the resulting images are then merged into one single frame buffer 3 .

- 3D decomposition: the scene is divided in ordered sub-scenes, sorted in back to front order. Each sub-scene is assigned to one pipe. The first pipe computes the image corresponding to its sub-scene. The resulting frame buffer is then copied to the next pipe, which adds the image corresponding to its sub-scene. This process is repeated for all the pipes to arrive at the final image. Furthermore, once one pipe has passed its frame buffer to the next one, it can simultaneously get the buffer from the preceding pipe and start its local rendering with new viewing parameters before the total image is finished.
- 4D decomposition: this time decomposition assigns to each pipe a different time-frame to be computed. While one pipe is computing the $n^{th}$ frame, the following pipe computes the $(n+1)^{th}$ frame.

## 2.3    Interaction and interface considerations

The immersive visualisation gives the users more freedom to interact with the model. Thus, they are tempted by manipulations they would not try with a window-based interface. For example, a common request is to implement the possibility to pick an object in the scene, to drag it around to have a better view of this particular object (without having the whole scene moving around), and then to drop it so that it automatically snaps to it's original position.

Meanwhile, the main difficulty for the users is to adapt to the new environment. They have to switch from the standard screen/keyboard/mouse scheme, with the Graphical User Interface they are used to, to a new immersive environment without the concept of a frame or a window defining the work area.

A time consuming solution consists in redesigning a brand new 3D interface from scratch. Unfortunately, no standard API exists to help building such interfaces. A better alternative is to use video mapping techniques to display the standard interface on a panel (3D rectangle called laptop)embedded in the 3D world (Fig.3). The implementation is quite easy, and the user is again faced with the interface he is used to. Furthermore, any existing interface can be displayed on the laptop, without writing any new lines of code.



Fig. 3 Standard interface in a panel displayed in a 3D scene.

# 3   Project SILVES

Thus, within the framework of ISA project, the scientific project SILVES would result in an integrated software platform to represent, simulate and visualize forestry spaces in their current state and during their evolution in order to better control the management decisions [5]. The geometrical modelling of forest covers could also be used by others models interested by the structure of forests: simulation of forest fires, simulation of the wind within the covers and resistance to breakage, evaluation of the wood quality according to the forestry constraints, etc.

## 3.1   Acquired competences by Cirad

The competences of the Cirad are in the field of agronomy. More particularly, the Cirad developed virtual plant simulation software which was widely diffused in the worlds of the computer graphics and of agronomy [6], [7]. Thus, the Programme of Plant Modelling of the Cirad developed a range of application software, AMAP™, for the design and landscape visualisation. This range is composed of modular tools (Fig.4) or workshops allowing the simulation of growth and plant visualisation , thus that the design and simulation,  in the space and along the time, of  management project (Fig.5) [8].



Fig. 4 *Genesis* module (AMAP™): tools for simulation pf growth and plant visualisation.



Fig. 5 Management project realized with *Orchestra* module (AMAP™).

The IMAGIS software, also developed by Cirad, aims to represent, in the manner the realistic photos, the information contained in a GIS (Fig.6). The user has an interactive tool allowing him to extract the information contained in the GIS data base, to constitute and handle a

three-dimensional scene, to choose a point of view of this scene and to calculate the image corresponding. The combination of IMAGIS with AMAP can be used to semi-automatically generate 3D scenes from 2D data contained in GIS [9], [10], [11].
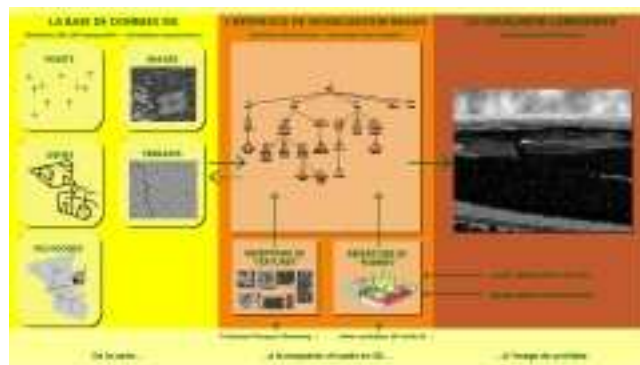


Fig. 6 IMAGIS structure: 3D representation of a GIS.

## 3.2    Acquired competences by Inra and Engref

The models of forest production aim to simulate on the long term, and with a good reliability required by the forest administrative customers, the evolution of the forests on the scale of the plot (10 hectares). They take as inputs the ecological characterization of the environment (fertility of the station, total changes a long the rotation) and the actions of forest managers throughout the life of the plot. They provide as outputs statistics summarizing the state of the plot (number of trees, diameters, heights and volumes). These statistical exits are well adapted to the forester needs, but they remain rather abstract if the goal is to communicate or negotiate with "profane" interlocutors. In this case, taking into account the visual aspect (of a plot, of a path in forest) in management projects would be an invaluable tool.

Within this framework, LERFoB (Laboratory of study of the Resources Forest-Wood, UMR Inra-Engref) develops a whole of quantitative methods to modernize forest management [12], [13]:

- NTM (Numerical Terrain Model), GIS (Geographic Information System) and forest ecology. The goal is to create methods of spatialized treatment for the ecological determinants of the dynamics of forests (relief, climate, grounds, vegetation), by interfacing data bases (NTM and ecological data bases) and simulators (Fig.7).
- Dynamic systems and modelling of forest dynamics: the goal is to develop robust models and simulators to predict the long term evolution of the forests, in an ecological and socio-economic changing environment (software Fagacées, CAPSIS) (Fig.8).
- Simulation of the quality of the forest products (Fig.9): the goal is to build methods to evaluate the wood properties of a given standing forest resource (WinEPIFN, software of resource evaluation).
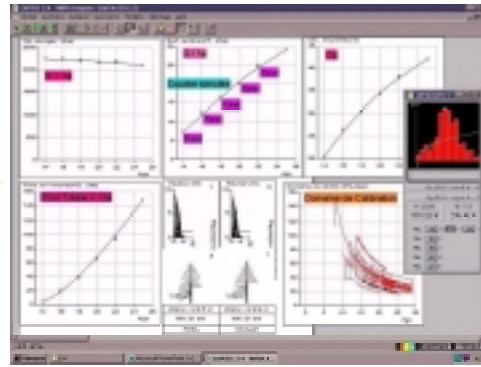
Fig. 7  NTM visualisation.



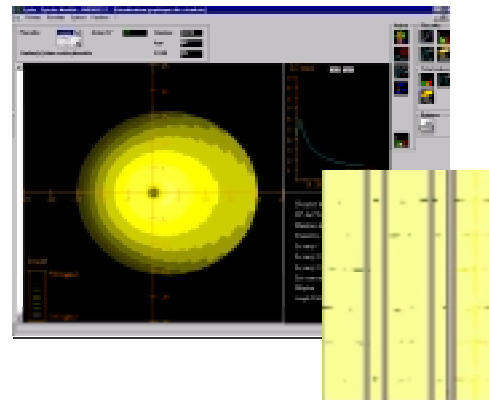Fig. 8 CAPSIS software: statistical outputs.



Fig. 9 Not destructive estimate of the quality of a log: 3D reconstruction from scanned views (left); WinEPIFN® outputs (right).

### 3.3    Research Topics

Scientific objectives of project SILVES can be divided into three principal research topics:

1.  **3D visualisation of GIS data.** Use of the software IMAGIS (visualisation of GIS) and software AMAP (simulation of the growth of the plants) developed in Cirad.

2.  **Coupling structure-function models and forest production models.** The main idea is to develop an interactive relationship between structure-function models and forest production models in order to pull together advantages of each system: in one hand, the tree architecture is well described but the stand structure is not managed, on the other hand, forest production is estimated at broad scales but the tree description is very simplified. Coupling both approaches would then offer realistic simulations on a large area, with a good description at the stand and the tree level (including tree architecture, wood quality etc.).

3. **High performance computing and visualisation**. Simulation in *real time* of forest covers and visualisation in immersed room. Development of an unified interface allowing to modify the characteristics of the simulation (forestry choices for example) with AMAP and IMAGIS supported as back-end.

## 4 Conclusion

The high performance computing and visualisation can be described by: (i) capacity to treat great quantity of data, (ii) high precision and broad display, (iii) real time and interactivity.

But various problems arose from extending a window-based sequential software to a multi-threaded program running in immersive environments with multiple pipes:
- the ability of the visualisation tool to handle very large data models;
- the flexibility to deal with different multi-pipe environments, which implies a parallel rendering process;
- the side effects inherent to this parallelism must be fixed, in particular when both the modelling and rendering processes access the model's data.

Modelling and visualisation of forest covers is a good application to test and to develop these technologies. The integration of a management plan in a GIS and the ability of computer graphic systems to simulate plant mock-ups offers the possibility to predict the evolution of a landscape with time, and to project different scenarios. With the advent of computer graphics and virtual reality techniques, land-use managers have become interested in such tools which help represent rural landscapes. The development and the use of such computer tools show that the representation of geographic data provides by a GIS through virtual computer graphic images can provide a better understanding of the landscape by a non-specialist public. The resulting simulations lead to realistic images, which can become efficient aids to facilitate understanding, communication and decision making by the various stakeholders in a land management project (Fig.10).
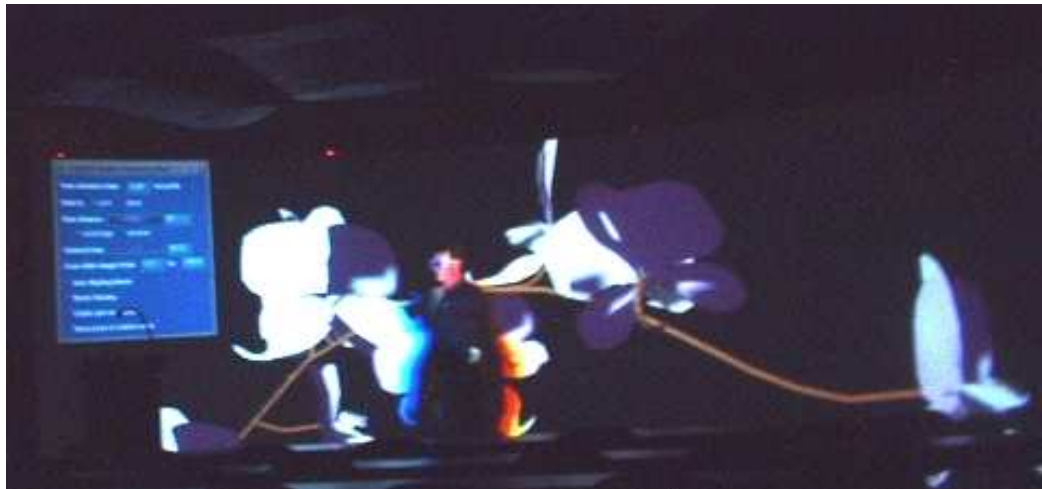


Fig. 10 First realisation of project SILVES: display of a plant generated by AMAP™ software in an immersive environment.

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