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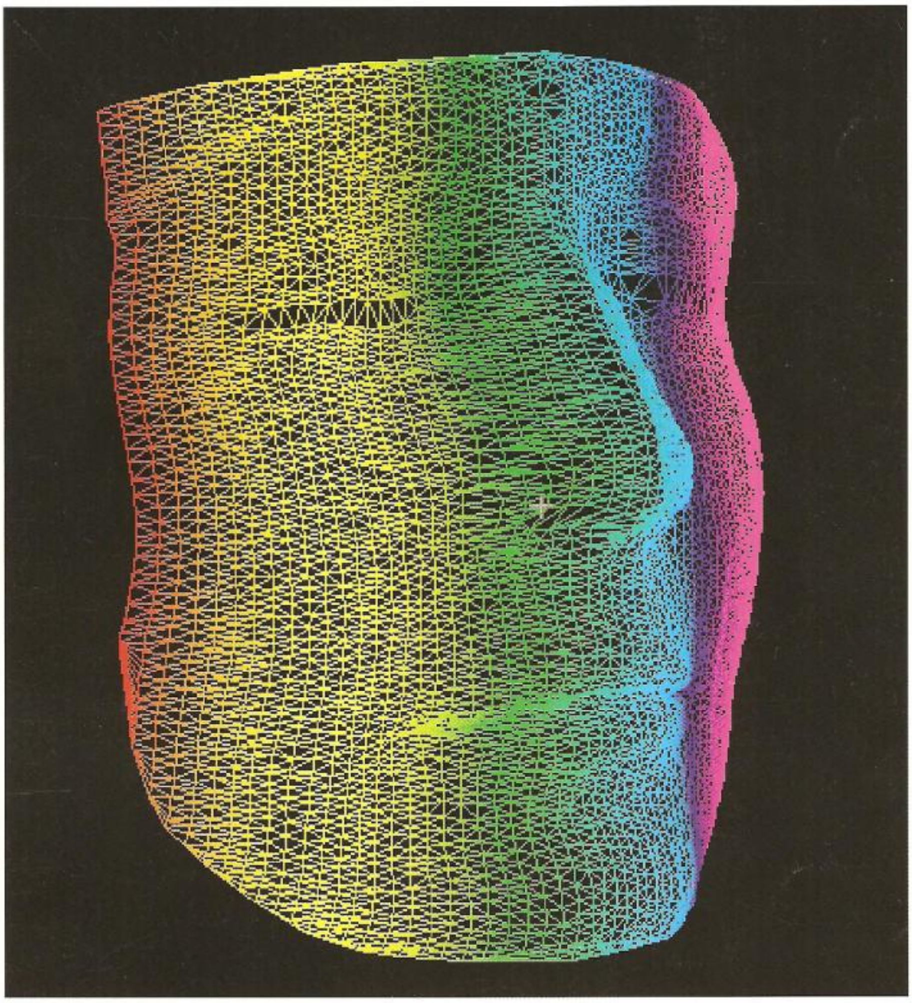

Image produced by Explorer for an application involving real-time 3D scanning for reconstructive surgery (Nouri & Roche p 30)

SUPERCOMPUTERS, VISUALIZATION AND DISTRIBUTED COMPUTING

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Le calcul distribué est en voie de banalisation, permettant aux informaticiens et ingénieurs de tirer parti des meilleures caractéristiques de chaque ordinateur sur un réseau: pendant que de gros calculs sont effectués sur un superordinateur, les utilisateurs peuvent travailler sur leur station de travail et visualiser leurs résultats en 3 dimensions.

En faisant usage de l'environnement distribué Explorer, nous avons construit une application scanner 3D utilisée en chirurgie plastique reconstructive, en distribuant les tâches entre un superordinateur Cray Y-MP et une station de travail SGI.

Distributed computing is becoming increasingly more common, allowing computational scientists and engineers to take advantage of what each computer in a network does best: while the large scale calculations are being performed on a supercomputer, users can work on their workstation and examine their results in 3-D visual form.

Using the *Explorer Distributed Environment*, we have built a Real Time 3-D Scanner application used for Reconstruction Surgery, by distributing it between a Cray Y-MP supercomputer and a SGI workstation.

INTRODUCTION

The ability to develop custom scientific and engineering applications is critical when people are faced with solving complicated and challenging problems. Developing these custom applications, however, is usually a time-consuming task, often too complex for anyone but full-time computer programmers. To make the task easier, several visualization software packages, for example *Explorer, AVS, Khoros, apE*, have been delivered recently on the market. This next-generation technology exploits distributed computing - combining the strengths of supercomputers and graphics workstations to solve problems.

In this paper we describe one of these products, the Explorer Distributed Environment, and show how it has been successfully applied in the area of Real Time 3-D Scanner for reconstructive surgery.

THE EXPLORER DISTRIBUTED ENVIRONMENT

Cray Research IRIS Explorer and Silicon Graphics Inc. IRIS Explorer are visually-based, object-oriented application building software that operate together to form the *Explorer Distributed Environment*. Creating applications in this environment is relatively easy: users select modules with a mouse and drag them into position. With a few clicks of the mouse, the modules are connected into an intuitive, easy-to-read data flow diagram, as shown in Figure 1.

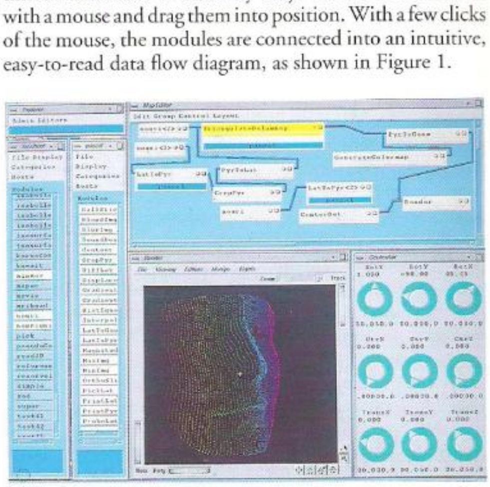

Figure 1 – Explorer map containing some modules running on the Cray Y-MP (pascal) and displaying the woman's face in point mode

The seamless distributed processing inherent in this environment automatically takes care of establishing network connections, logging into the Cray Research system, and transferring data and program control between the SGI workstation and the Cray Research supercomputer as necessary. In other words this distributed environment frees users from the intricacies of working and solving problems across a network: accessing the Cray Research system or the SGI workstation is as easy as choosing a module icon from a palette.

Explorer is a system for creating powerful visualization maps, each of which comprises a series of small software tools, called modules. Modules are equivalent to stand-alone subroutines or «objects». Explorer tools incorporate FORTRAN, C or C++ subroutines and functions into the environment as modules. Applications can be saved and reused as stand-alone applications, or incorporated into other applications, letting people build on the work of others. Users can thus create a new module based on their own code, based on an existing Explorer application, or by adapting third-party modules. Modules can be obtained from a public domain «Explorer» forum, a software service where Explorer users exchange information and modules in various research or engineering areas, e.g. Computational Fluid Dynamics, Computational Geometry, Computer and Graphics, Animation, etc..

Modules have parameters that allow the user to set and change values, as displayed in Figure 3 by the *CropPyr* module. Parameters are controlled through widgets on the module control panel, see Figure 1 and Figure 2. Widgets include buttons, sliders, dials, text slots, scrolled lists, radio buttons, options menus and file browers as well as drawing areas. Explorer has a very interactive user interface and a powerful renderer. For people having little or no experience with computers, such a nice user interface simplifies their work considerably.

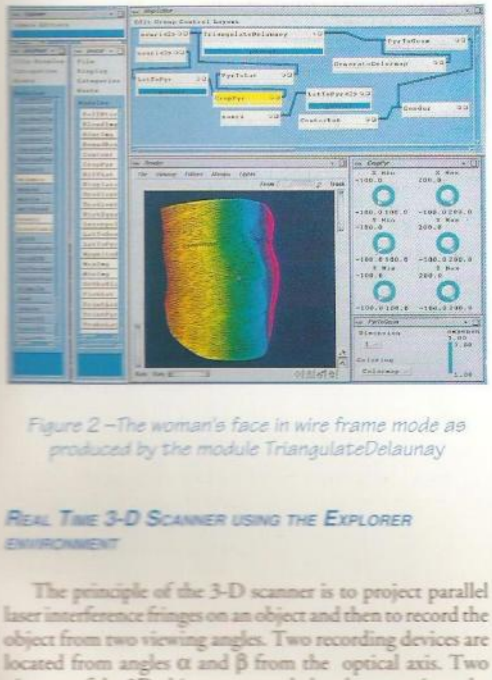

Figure 2 – The woman's face in wire frame mode as produced by the module TriangulateDelaunay

Real Time 3-D Scanner using the Explorer environment

The principle of the 3-D scanner is to project parallel laser interference fringes on an object and then to record the object from two viewing angles. Two recording devices are located from angles α and β from the optical axis. Two pictures of the 3D object are recorded at the same time, the first picture at the angle α and the second at the angle β. These two pictures are then digitized and the coordinates x, y and z (the order or the number of the fringe) of every point are extracted. According to an appropriate transformation one reconstructs the 3-D object even if there is no symmetrical plane. The viewing angle, the fringe intensity as well as the resolution (number of fringes/mm) are controlled by the user. After reconstruction, the digitized 3-D object can be rendered and visualized in different modes such as point, wire frame or solid mode with different textures. Certain operations such as cutting slices, examining samples of surfaces, contour lines and shapes of the reconstructed 3-D object are also available. This 3-D scanner is described elsewhere in further detail [1][2].

We have used the Explorer Distributed Environment software, presented in the previous section, to visualize our reconstructed 3-D object as shown in Figure 1. This figure is a snapshot of the SGI workstation screen, displaying the Explorer *map* used for our Real Time 3-D Scanner application and several windows of interest. A *map* is a collection of modules that carries out a series of related operations on a data set and produces a visual representation of the results. The Explorer screen displayed in Figure 1 is composed of 6 windows, which are described briefly below:

- *Explorer*: Administration window (Librarian, quit Explorer, etc.).
- *Map Editor*: Applications, or maps, are assembled in the Map Editor work area by using a mouse to place and connect modules icons, in order to create and to modify maps.
- *localhost* : Palette of modules residing on the SGI workstation.
- *pascal*: Palette of modules residing on the Cray Y-MP (named «pascal» at the EPFL).
- *Render*: Visualization window obtained by clicking on the «render» module in the Map Editor.
- *CenterRot*: Allows the user to rotate the 3-D object in the *Render* module. It measures the rotation angle (Rotz, Roty, Rotx) and the distance (Transx, Transy, Transz) between any two points of the 3-D object.

Other modules of interest are displayed in the map editor, for instance:

- *CropPyr*: Interactive module which allows the user to cut isolines, slices and shapes through the face.
- *GenerateColormap* : Interactive module which lets the user adjust the colours assigned to various values in the application.
- *PyrToGeom*: Interactive module which transforms data from Explorer pyramid to Explorer geometry output. The following formats are available: vertices, vectors, polygons and external faces.

Three modules in the Map Editor of Figure 1 are labelled «pascal». This means that they have been dragged from the «pascal» palette and thus run on the Cray Y-MP, whereas all other modules run on the SGI workstation. The most time-consuming module of the application is the *TriangulateDelaunay* module. The whole application runs 2.5 times faster by placing this module on the Cray rather than on the SGI. This speed-up factor improves interactive work productivity considerably, since each simulation now runs in less than 100 seconds instead of several minutes when it ran on the workstation only.

The *TriangulateDelaunay* module, which takes as input a 3-D lattice of points and generates a Delaunay triangulation from 2 dimensional data, implements a very computationally intensive algorithm. This algorithm transforms a set of *n* points into a triangulation that produces the maximum of the angles' infima of the triangles. Its complexity is n^2 [3][4].

The woman's face displayed by the *Render* module is composed of 8000 points. These points are introduced in Explorer's 3-D lattice format (Figure 1), then triangulated using the *TriangulateDelaunay* module to produce a mesh in pyramid form as rendered in Figure 2. Finally, modifying the «dimension» parameter in the *PyrToGeom* module, allows the display of the full face in solid mode, and by using the radio button in the module *CropPyr* one can cut lateral and vertical slices as displayed in Figure 3. The «transform sliders» on the right hand side of Figure 3 allows us to measure angles and distances on the woman's face. Such slices and shapes contain precious information, such as deformation measurement or volume calculation, for the reconstructive/cosmetic surgeons.

OUTLOOK

The Distributed Explorer application described above has been used successfully for reconstructive surgery. It is very easy to use and has a highly user-friendly interface. Although the 3-D scanner has principally been used to study nasal forms, it has a wide application for studying other body surfaces or for the examination of breast surgery procedures. In general it is a helpful tool for CAD/CAM and product designers. Some companies have recently shown interest in acquiring the techniques we have developed.

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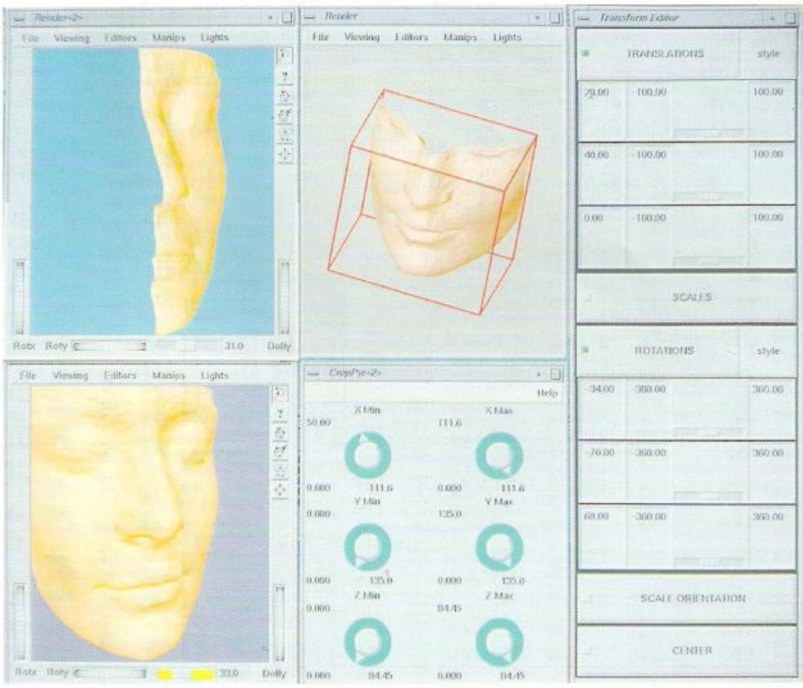

Figure 3 – Three renderings containing lateral and vertical slices for treatment and the complete woman's face as reference in solid mode