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Collaborative immersive visualization without goggles -- experiences in developing a holographic display system for medical applications

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ABSTRACT

In this contribution, we report on the development of a novel holographic display techology that targets multiple freely moving naked eye viewers and of a collaborative medical application prototype that aims at exploiting this technology to provide medical specialists with a truly interactive 3D collaborative environment for diagnostic discussions and/or pre-operative planning.

1. Background and Motivation

Modern clinical practice often requires a multi-specialty decision process that is heavily dependent on the collaborative analysis of complex 3D datasets derived from medical imaging. This process would therefore benefit from fully 3D immersive visualization. However, at present, the only general purpose computer displays able to provide all the depth cues processed by the human brain to reconstruct a three-dimensional scene are unfortunately limited to single user configurations. In this contribution, we report on the development of a novel holographic display techology that targets multiple freely moving naked eye viewers and of a collaborative medical application prototype that exploits this technology to provide medical specialists with a truly interactive 3D collaborative environment for diagnostic discussions and/or pre-operative planning.

2. Holographic Display Technology Overview

Our display is based on projection technology and uses a specially arranged array of micro-display projectors and a holographic screen. The projectors are used to generate an array of pixels at controlled intensity and color onto the holographic screen. Each point of the holographic screen then transmits different colored light beams into different directions in front of the screen. Similarly to what happens with holograms, each point of the holographic screen thus emits light beams of different color and intensity to the various directions, but in a controlled manner. The display is thus capable of reproducing an appropriate light fields for a given displayed scene.

The light beams that compose the light field are generated by optical modules arranged in a specific geometry. Each module contains a micro-display and special aspheric optics. A high-pressure discharge lamp illuminates all the displays, leading to a brightness comparable to normal CRT displays. The display system concept makes it possible to produce high pixel-count 3D images by optimizing the optical arrangement to the capabilities of the technology and the components applied. The prototype's overall 7.4M pixels originate from the resolution of the 96 LCD micro-displays, each of 320x240. The optical modules are densely arranged behind the holographic screen, and all of them project their specific image onto the holographic screen to build up the 3D image.

In the current prototype, 96 optical modules project 240 pixels horizontally and 320 vertically. Each pixel on the screen is illuminated by 60 different LCDs, and the optical modules can be seen under different angles by looking from the pixel's point of view. This means that 60 different views are generated, and each view has 384x320 resolution. The imaging optics of the modules have a wide angle, which results in a 50 degrees field-of-view. Since 60 independent light beams originate from each pixel in this field of view, the angular resolution of the display is 0.8 degrees.

The holographic screen transforms the incident light beams into an asymmetrical pyramidal form. The horizontal light diffusion characteristic of the screen is the critical parameter influencing the angular resolution of the system, which is very precisely set in accordance with the system geometry. In that sense, it acts as a special asymmetrical diffuser.

With proper software control, the light beams leaving the various pixels can be made to propagate in specific directions, as if they were emitted from physical objects at fixed spatial locations. In our prototype, a custom parallel implementation of OpenGL generates the module images required for holographic viewing by appropriately interpreting the standard OpenGL stream.

3. Medical Data Analysis Demonstrator

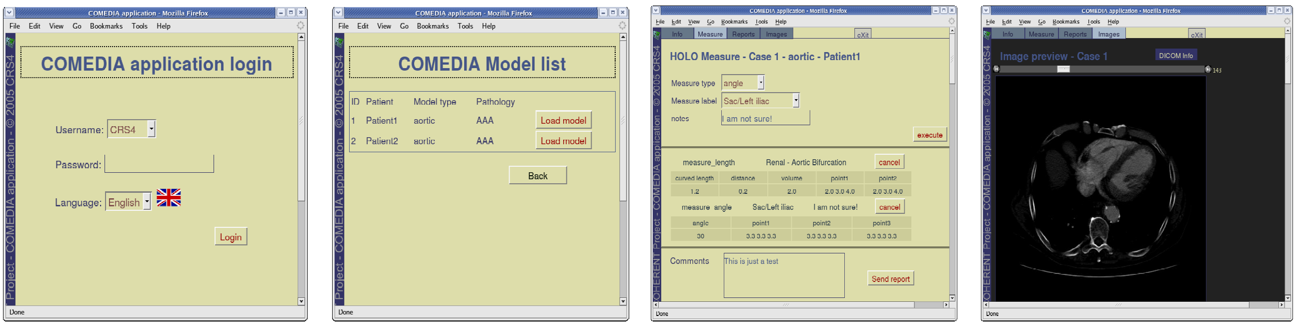
The current display prototype is already sufficient for developing compelling prototype 3D applications that exploit its truly multi-user aspects.We are currently developing demonstrators, which act as driving forces for the development of the display. For the medical market, we are focusing on a system for supporting diagnostic discussions and/or pre-operative planning of Abdominal Aortic Aneurisms.

The overall application is distributed using a client-server approach, with a Data Grid layer for archiving/serving the data, 2D clients for medical data reporting (textual/2D image browsing), and 3D clients for interacting with 3D reconstructions.

The 2D user interface for model measurement and reporting has been developed as a web application that can be executed on a tablet PC or a palmtop computer. The application has been developed in PHP/Javascript and is based on the use of the Javascript XMLHTTPRequest object to send and receive XML messages to/from the Holo application (that includes an HTTP server). HTML is dynamically updated according to the values parsed from the XML responses, and XML measurement reports are automatically generated.

The archive of models with related DICOM images and XML description files is stored in a distributed Data Grid archive based on San Diego Supercomputing Center's Storage Request Broker (SRB). The web interface is based on server scripts that can be executed on a Apache web server with mod_php. Scripts can perform queries to the SRB archive, transfer metafiles and data used to build the client interface (if not cached) and update the archive with the newly created reports. The user tablet/palmtop has, as only requirement, the ability to run a lightweight javascript-enabled web browser, like Firefox. The interface display can be adapted to the screen resolution through the use of different stylesheets. Being based on the use of XML and stylesheets, the interface is also easily modified. It now implements user authentication, authorized 3D models search, analysis of metadata, images and other reports on the selected case and can drive the loading and measurement of the 3D model on the Holo display through the use of dedicated HTTP transactions.

The measurement interface allows the user to select a measurement procedure (typical of the model type), label and comment it and activate the corresponding thread in the holographic application, putting itself in waiting status. Once the measurement result is sent back (as XML), the interface returns active and the measurement results are added to the dynamic page representing the current report. When the report is complete it can be sent to the SRB archive.



The 3D application interacts with the SRB archive for data loading, and with the measurement interface for communicating anatomical measures.

The library and application have been developed on the Linux platform on top of the holographic OpenGL wrapper, that has been concurrently refined to support most of the relevant OpenGL calls. The current prototype of the system is able to provide all the originally defined features (segmented surface based display, highlight, rotate, scale, clip, DICOM slicing). All the features are fully tested on regular 2D/3D display, while on the holographic display there is currently no possibility to access the raw DICOM data since there are currently no texturing capabilities, which should be available at the end of 2005. On a dual GeForce6800 system, the currently achieved frame-rate is about 10Hz, which proved sufficient to provide the illusion of continuous motion in animation and 3D interaction tasks.

Since objects rendered on the holographic display appear floating in fixed positions, it is possible to naturally manipulate them with a 3D user interface that support direct interaction in the display space. In our application, operations are made by selecting a current tool and then operating it with hand motions. Both mono-manual and bi-manual tools have been tested. In the case of mono-manual tools, each hand is attached to its own tool (e.g. for model motion, and right for model sectioning). In the case of bi-manual tools, the joint motion of both hands controls the tool behavior (e.g. rotation using the left hand to specify a center and the right to specify axis and angle). A generic interface for controlling the 3D cursors has been developed. In the final application, it is planned to employ a markerless camera-based hand tracking and posture recognition system, that is currently being developed. Gestures would be used to select tools, and hand motion to control cursors. Alternate cursor control interfaces have been developed, using both commercial 3D trackers (Logitech 3D mouse) and custom-made wireless solutions (camera based tracking of pointers, using wireless USB interface for buttons).

4. Conclusions

We have presented a design and prototype implementation of a scalable holographic system design, that targets multi-user interactive computer graphics applications. The current display prototype is already sufficient for developing compelling prototype 3D applications that exploit its truly multi-user aspects. We have described a particular application, targeting Abdominal Aaortic Aneurisms, that uses starndard 2D displays for accessing medical data records and the holographic display to present and directly interact with reconstructed 3D models. The application is in the early stages of development, but already demonstrates the possibility of sharing a fully 3D synthetic workspace in a local multiuser setting. Our current work focuses on improving the display drivers, completing the application prototype, and assessing its benefits and limitations.

5. Acknowledgments

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References

More information on this research is available on the web at the following URL

- http://www.crs4.it/vic/ - CRS4 Visual Computing Group
- http://www.holografika.com/ - Holografika Home Page
- http://www.coherentproject.org/ - COHERENT Project Home Page