The Volume Slicing Display

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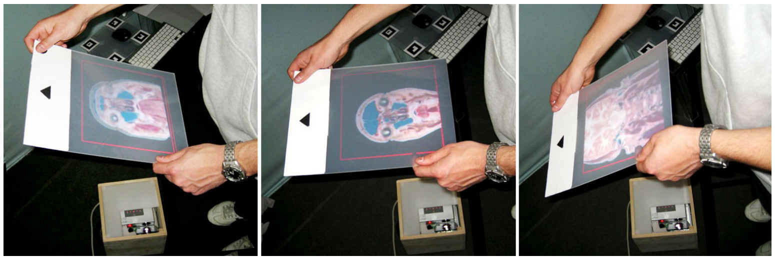

Abstract

The Volume Slicing Display is a device enabling the interactive exploration of volumetric data (e.g. medical images) using a piece of Plexiglass or paper that functions both as a control interface and as a passive, untethered projection screen. With the VSD, radiologists would be able to retrieve a certain amount of three-dimensionality from a flat X-ray plate at any time, by just touching certain portions of the screen, orientating and manipulating it freely above a calibrated projector. It is interesting to note that such interface could solve another important issue, that of the confidentiality of the patient data, since without the machine the piece of paper will only show an undecipherable 2d-barcode identifying the patient.

1 Introduction

This experimental visualization interface may one day enable a team of experts (surgeons, geologists, designers, architects) to explore 3D virtual objects as if these co-exist in the physical space, as well as to explore them interactively a piece of paper or plastic that will function both as a control interface (through the addition of physical widgets) and as a passive, untethered projection screen. An interesting possibility currently being explored is to make these widgets an integral part of the screen (for instance, bendable corners) or use an erasable marker to directly write commands on the screen.

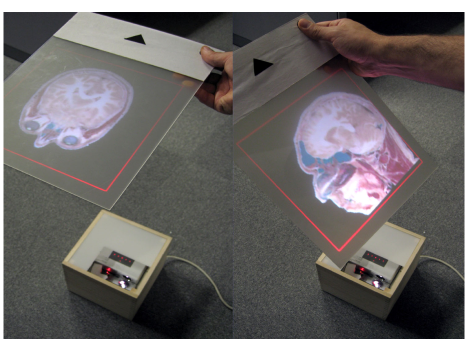

Figure 1: *Horizontal and saggital cuts with locked volume*

This is a second prototype conceived with portability and cost constraints in mind, and can be deployed over off-the-shelf hardware. A first prototype used a custom-made vision chip for pose estimation by tracking four infrared LEDs situated at the corners of a plexiglass screen (P4P algorithm) [1]. Each corner was identified through a different temporal code sequence. The new prototype presented here uses instead retro-reflective ARToolkit markers to track position and orientation of a piece of Plexiglass or translucent paper. A small computer (mac Mini) calculates the corresponding slice of a virtual volume hovering in mid-air above the projector, and prepares the image to be displayed by correctly anamorphosing the slice in real time.

Secondary markers are used either as discrete switches to toggle modes or operation (such as locking and dragging the position of the virtual volume on space, or taking a snapshot of the current slice for printing purposes) or as continuous rotating knobs (to set the zooming factor, change the contrast, etc - Fig. 2). All the hardware (a small LED-based projector, a webcam, some infrared LED and a Mac mini) is integrated in a small box (35x35x35cm).

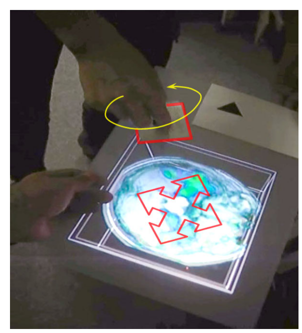

Figure 2: *Zooming using a rotating physical widget*

This system represents a logical evolution of our previous research on the 'Khronos Projector' interface [2], which is a tangible interface with which one is capable to 'sculpting' a volume of data (in particular stacked video frames). Although the screen was deformable, its borders were fixed and it was impossible to rotate the screen with respect to the volume being sliced. The Volume Slicing Display enables this, but the screen is rigid. Although we have been working towards a screen that is both orientable *and* deformable using structured laser light to compute the deformation in real time [3], we feel that this complex mode of interaction is only necessary in a limited number of applications.

2 Preliminary results and discussion

We demonstrated a procedure to rotate the volume of data without relying on a secondary input device: a marker on a corner can be

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partially covered to lock or unlock the volume on space. Then the screen motion will either affect the position and orientation of the virtual volume (unlock mode), or serve to control slicing place (lock mode). This way, one can smoothly and intuitively pass from a saggital/coronal/horizontal slice, while obtaining an observed slice that is always horizontal at the end (Fig. 1). The unlock mode can also serve to freeze a slice and pass to another person for scrutiny (check video here [5]). We also demonstrated a way to alter these markers in order to generate new commands or record information pertaining to the history of the manipulation (by folding some parts, or altering specific markers by superimposing figures or filling blanks with an erasable marker).

Camera/projector calibration is performed off-line. Intrinsic projector matrix is obtained manually or using synthetic imaging: a point of light generated by the projector automatically follows the contours of a custom designed calibration pattern (Fig. 3). The contour following algorithm is similar to the one developped in our 'Sticky Light' project [4]. Intrinsic and extrinsic parameters are estimated using Matlab Calibration Toolbox. Extrinsics are obtained by considering the projector as a secondary camera, and proceeding with the stereo-calibration toolbox.

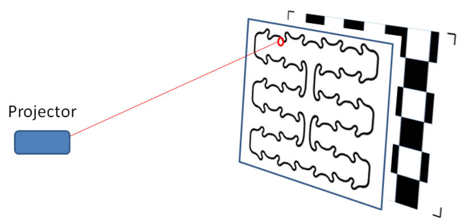

Figure 3: *Calibration contour for syntethic image formation*

Finally, it is interesting to note that the software can run on a desktop computer with a commercial webcam and without a projector; although the images are not projected on space, the computer generated slice is superimposed to the live video on the computer monitor; this may still be helpful when one does not have access to the VSD machine, and can be sufficient to identify the "patient file" as well as rapidly browse the image database (Fig. 4).

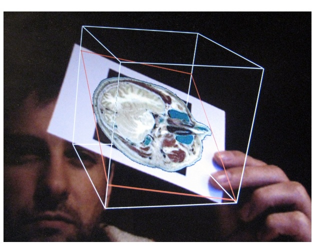

Figure 4: *Running without a projector*

Although there has been related research and similar prototypes (see in particular [6],[7] and [8]), the prototype we propose here is particularly compact, can be built with off the shelf hardware parts, and presents the advantage that the screen is a simple sheet of paper with a set of printed markers that serve for pose estimation but that can also be used to identify the patient in a confidential manner.

3 Improvements and Future research

The present prototype uses a single projector; this reduces the working space as well as the maximum possible inclination of the screen. We are know considering the use of multiple projectors to make the workable space as large as a whole room. Another goal is to make the markers invisible to the naked eye (we have tried using infrared ink, but the contrast is not sufficient). This will allow for a clear and large projection surface. Related to this is the need for a simple auto-calibration procedure for multiple projectors and cameras. This could be done by active marker tracking as in [11], using stable markers or feature points on the projection screen. Since the present prototype uses an infrared source collinear with the projector, an interesting possibility is to use a sanded plastic semi-transparent sheet which will couple light into the screen. Markers can then be engraved on the surface, and will appear as more bright than the rest of the screen. Interestingly, this configuration will permit FTIR-based tracking of fingers over the surface, as done in [9]. This will enable zoom and rotation of images using bare finger and gestures, as well as annotate and draw trajectories (such as surgical paths) in space. Among the interesting directions that this project highlights, is the development of an "origami"-like user interface, in which different shapes and folds of the flexible screen are interpreted by the machine as specific displaying commands; also of interest is the possibility of tracking the user head so as to represent volumes through the screen (as has been done in the "Deskrama" project [7] and in our previous research on the 'Parallax Augmented Desktop' [10]). Finally, we would like to extend the applications of this technology in the domain of Media Arts (interective architectures, dance performances) and 3d spatial games.

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