Tangible User Interfaces for geosciences

Guillaume Riviere, Nadine Couture, Fabrice Jurado

Tangible User Interfaces for geosciences

Guillaume Rivière and Nadine Couture, LaBRI, ESTIA, Fabrice Jurado, IFP*

Summary

Graphical User Interfaces (GUI) are widely used for interacting with complex geosciences software such as interpretation tools or 3D model visualization programs. Despite their well designed protocol of interaction, through the mouse or the keyboard, the user is absent-minded from the main task of interpretation or visualization when applying the protocol. Furthermore collaborative work of more than two users is difficult with a standard computer configuration.

As an alternate way of interacting with software, Tangible User Interfaces (TUI) are designed to simplify the actions of the user by utilizing common props (*i.e.* physical objects) such as rulers or pucks. Actions take place in front of a camera whose images are interpreted by software and the desired result is rendered on a desk by a projector. The user manipulates props on the projected images in front of the camera to interact with the geosciences software. Finally the collaboration of several users is made very comfortable around the desk.

The GeoTUI system is developed to combine the working practice of geoscientists on desk with the use of graphical workstation. Several experiments on a workplace allowed to evaluate the advantages of TUI over GUI through the manipulation of different props.

Introduction

To get an accurate image of the subsurface, traveltime tomography is one of the most suitable techniques. Jurado *et al.* (1996) proposed to use traveltimes being interpreted in the prestack domain (Figure 1).

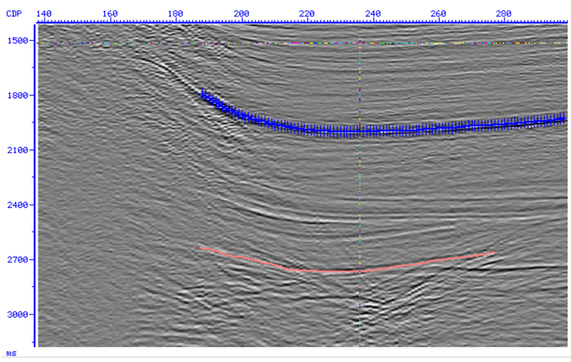

Figure 1: CMP gathers among more than one hundred thousands seismic traces. Colored superimposed curves are prestack traveltimes used as input of the tomographic inverse problem.

The numerical solution of the tomographic inverse problem is based on an iterative Gauss-Newton technique and requires the minimization of a large size least square problem: hundreds of thousands of traveltime data (Figure 1) have to be inverted to determine thousands of model parameters (Figure 2).

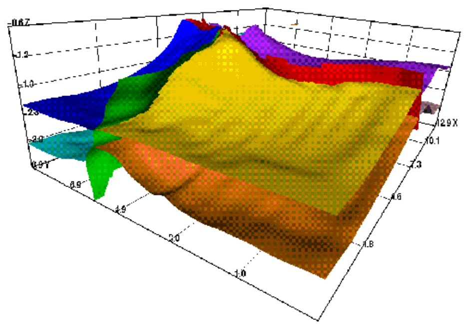

Figure 2: Surfaces of the 3D model retrieved by traveltime tomography. Velocities inside blocks between surfaces are also retrieved by inversion.

Interpreting this huge amount of traveltime data needs efficient user interfacing with the computer for manipulating and visualizing the data. After inversion, the analysis of the calculated model needs easy to manipulate visualization software.

Although well designed, most software has a specific interaction protocol when using the mouse or the keyboard. The user is less concentrated on the (primary) task concerning traveltimes picking or model evaluation. Also collaboration between users in front of a screen during the task seems impractical or exhausting.

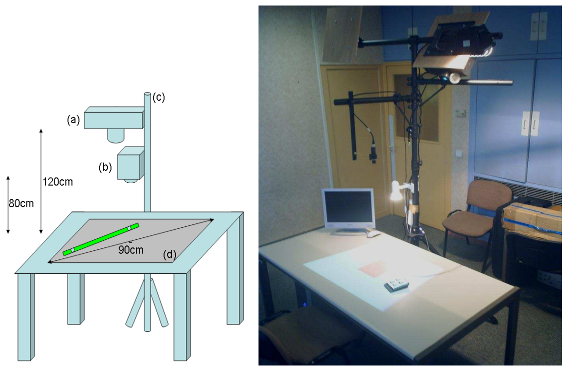

Figure 3: Schematic view (left) and setup (right) of the tangible user interface on tabletop GeoTUI.

Tangible user interfaces for geosciences

In order to simplify the interaction with computers and facilitating the collaboration, Tangible User Interfaces are developed (Couture *et al.* (2009)).

Tangible User Interfaces

The main idea is to use a tabletop vision-projection system and props that can be manipulated directly on a (suitable) desk (Figure 3). The workspace of the TUI combines the collaborative conditions of work around a desk with the use of (powerful) software. In fact the TUI display information on the desk, observe user actions and send instructions to the software, *e.g.* interpretation tool or model display. TUI are in the family of sensing-based interaction tools and they have gained significant attention during recent years. TUI were initially defined by Ishii *et al.* (1997) as user interfaces that "*augment the real physical world by coupling digital information to everyday physical objects and environment"*. Real-world physical objects are essential as representations and controls of digital information for user interaction. Graphical user interfaces and tangible user interfaces can be compared as follows:

- Graphical User Interfaces represent information with intangible pixels on a bit-mapped display and sound. General-purpose input devices allow users to control those representations.
- Tangible User Interfaces make information directly graspable with haptic feedback (technology that interfaces to the user via the sense of touch and kinesthesia), giving tangible (physical) representation to the digital information. Intangible representation, such as video projection for example, may complement tangible representation.

GeoTUI system

In order to integrate the human factors in the design of the computer user interfaces, it is obvious to consider the behavior of the end user of the interfaces. It is also important to take into account experience and know-how in order to develop tools that are adapted to the tasks.
For example while determining the overall structure of a salt dome, the interpreter identifies first its 2D geometry by interpreting slices and combines them in order to get an idea of the geological structure.

Geoscientists have to concentrate on what they observe in slices and what the next position to select. GUI make intensive use of the mouse and the keyboard. The mouse allows simple actions like opening menus. Changing the position of the vertical plane or its orientation is done by a menu reached by two mouse clicks and typing a value with the keyboard. The keyboard can also be used as a shortcut for moving forward or backward along a vertical plane direction.

Nowadays, such manipulations seem very natural on modern computers. However, they require the user to leave reasoning and focus on the computer environment. Thus these repeated different tasks limit the capacity to focus on the main work of exploring the structure and implies an additional cognitive load. We focused on this task in order to develop the GeoTUI prototype and to prove the relevance of a tangible tabletop applied to geosciences.

The goal of our research is twofold: simplifying interaction, and facilitating collaboration. The GeoTUI system is designed such that it combines the horizontal conditions of work (known by the geophysicists when working with paper representation on a desk) with the use of powerful graphical software.

The GeoTUI system controls a geological application (see Jurado *et al.* (1996)) written with the Java language. It is an interactive tool for visualizing and editing 3D geological models compatible with the tomography software. The visualization is made on 2D vertical planes, either (x,z) or (y,z), whose positions can be anywhere inside the model.

The software for the GeoTUI system was developed in C++ using the GTKmm 2.0 graphics library for managing images. We built a communication protocol through a UNIX socket with the Java application. GeoTUI sends instructions resulting from the user manipulations, and the graphical application sends back calculated images. Note that the GeoTUI system only substitutes the GUI of the application while the graphical program remains the same - only the interaction is modified. On the surface of the desk, only maps and cutting planes are displayed as if they were sheets of paper, and all the WIMP components are removed (the borders of the windows, the mouse pointer, and the menus, see Figure 4). We use optical tracking in order to locate the props, the tangible objects on the desk. Green coloured plastic markers glued on the props are tracked on images captured by the video camera. Consequently, the users only dispose of physical tools (the tangible props and a button box) to interact with data.

We implemented four kinds of props for the navigation in the subsurface model in order to evaluate what is the best interaction for the vertical plane selection. The best interaction is the one that improves speed, and more importantly, has the best reliability for the given task.

One interaction is with the mouse (M) as input and the screen as output (classical GUI conditions), and three are with the tabletop as output using the tangible props as input: one puck (1P), two pucks (2P) and a ruler (R), as shown on Figure 4-a,b,c. The mouse and the one puck prop are used to sequentially position two points for the cutting line on a map. The two pucks props are used to simultaneously position two points for the cutting line. With the ruler prop, the graded border immediately represents the cutting line.

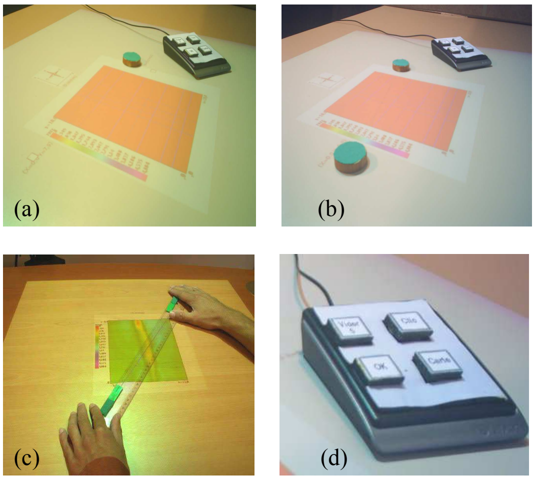

Figure 4: (a) The one-puck prop. (b) The two-puck prop. (c) The ruler prop. (d) The button box.

The 2D cutting planes cannot be calculated on the fly. In the GUI, a graphical button allows to engage the calculation of the 2D cutting plane. After the calculation, this 2D cutting plane is displayed instead of the map. In GeoTUI, we propose to couple the use of the props with an additional device, a physical button box (see Figure 4-d). In the prototype, the button box is composed of four buttons that are labeled exactly the same as the graphical buttons of the GUI. Users disposed of a button to go back to the map view.

Interpretation experiments and results

We conducted successively two on-site studies at the workplace of geophysicists at IFP, over one day each. The order of using the GUI and TUI was counterbalanced. When using the TUI, the order of the props to use was also counterbalanced.

First, a cognitive walkthrough based user study, following recommendations of Polson *et al.* (1992), with 10 participants aged from 23 to 59 years old, 41 in average, in order to study the ability of GeoTUI for the cutting line selection task. Users were in an exploratory learning mode. The subjects received no instructions about the use of the two interfaces to compare, the GUI and GeoTUI. When using GeoTUI, we gave to each subject a box containing a ruler, six pucks, and the button box: the subject had the choice of the props to use. Hence we observed the props they found the most representative of the cutting line selection task.

Second, a formal comparative user study with 12 participants, aged from 23 to 66, 41 in average, in order to evaluate the user performance with respect to the usage of the three tangible props, 1-Puck, 2-Puck and the ruler, for specifying cutting planes.

Three kinds of exercises were tested. The first kind consisted in the selection of a series of six cutting planes at various coordinates given in instructions. A second kind consisted in the selection of cutting planes in order to navigate through a model to find marks hidden in the subsurface at random locations. Hence, there is no relation between the cutting planes. For the third kind of exercise, the user had to locate and identify a 3D geometric form hidden in the model performing various 2D cutting planes. All exercises were time-limited to two minutes.

This third kind of exercise is an illustration of how interpretation can be improved using TUI. We constructed a series of 3D models containing a letter from the alphabet, as shown on Figure 5. The aim of the experiment is to recover the letters by performing vertical cutting planes into the models.

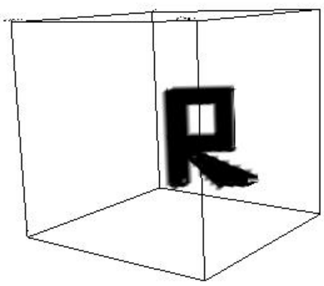

Figure 5: Letter of the alphabet somewhere in a 3D model.

After performing the exercise, subjects filled out a questionnaire. A summary of the subjective ratings depending on the interaction props is reported in Table 1.

The overall results of the exercise are as follows:

- with (M): 105 cutting planes, 9 letters found and 7 well recognized
- with (1P): 69 cutting planes, 5 letters found and 1 well recognized
- with (2P): 119 cutting planes, 3 letters found and 3 well recognized
- with (R): 140 cutting planes, 8 letters found, and 7 well-recognized.

	M	*1P*	*2P*	*R*
Easiness to select a line	4.1	2.6	4.6	5.2
Most precise interaction	3.8	2.8	4.8	5.1
Most rapid interaction	3.8	2.5	4.6	5.3
Most simple interaction	4.2	2.7	4.6	5.2
User preference	3.5	2.7	4.5	5.0
Concentration on recognition	3.8	2.6	4.4	4.8

Table 1: Averages of the subjective ratings of users scaled from 1 to 6 (6 is best) depending of interaction props.

The time allocated to the exercise was very short and the success or failure to recognize a letter was dependant on the position and orientation of the letter. Thus, those results are not exploitable for a statistical analysis in order to compare the rate of recognition of the four interactions. However, we present those figures because they give a good indication of what would be obtained in new experiments with more time and more letters to recognize.

Beyond the final scores of recognition, we are more interested in how users felt during the exercises for solving a problem with the four ways of interaction. All the actions of users were recorded in a log file and we measured the selection time of a cutting plane as follows: the delay past from the time the user presses the button to go back to the map and the time the user validates the next cutting plane. This period corresponds to the sum of the manipulation time of the input devices and the time of reasoning of the user. The selection time was in average 8.5s with (M), 7.6s with (2P) and 5.5s with (R). The ruler is then 1s better in average than (2P) and 3s than the mouse. The mechanical properties of the ruler help the user to accomplish the task and the ruler better represents the problem to solve (Couture *et al.* (2008)).

Subjects' feedback about the use of GeoTUI is that this interaction is "*more concrete*" and they "*rediscover some reflexes*" using the ruler. Using the mouse "*is a habit*", they are used to it, but "*it is slow for some actions*". They also point out they "*sometimes focused on the tool*" and were sometimes more concentrated on the mouse cursor than on the task of recognition of the letter. The ruler is also the most representative tool of the cutting line selection task, 100% of the subjects took it during the pilot study.

Hence, the ruler will be a more appropriated input device for geophysicists. It may also help them to concentrate more on their actual complex working task. Certainly, the fact to work in a coinciding action and perception space, thanks to the tabletop, is also decisive.

Conclusions

In the context of a graphical subsurface model, the GeoTUI system, specifically designed for geophysicists, is the first application that uses tangibles on a tabletop for the specific task of selecting perpendicular cutting planes from a topographic map. It combines the advantages of the spontaneous conditions of work that geophysicists are commonly used to in their classical paper/pen/tools environment, with the advantages of the use of powerful geological software.

We proved the acceptance by geophysicists of the tangible interaction. In the first exercise of the first experiment, in all 50 exercises (5 exercises for each of the 10 subjects), no one refused to use the TUI, but 2 subjects refused to use the GUI. The essential reason was the exercise was too difficult. We have to admit the TUI had the advantage to be innovative, and the subjects were very curious to test it. We concluded from the results on speed and accuracy, from analysis on manipulation time and from analysis on user preference, that the ruler device in the geosciences context is the best choice. But, more important, we show the possible gain and the interest for geoscientists to work with tangible props on a tabletop.

On a perspective point of view, thanks to the software architecture based on client/server model, GeoTUI is extensible and can be adapted to geosciences' software simply defining a communication protocol. Let us notice the hardware cost to build the GeoTUI prototype is low, about 1.5k$. Building a final tabletop vision-projection system is more expensive and could be about 30k$. Moreover, GeoTUI can be integrated in users' environment and duplicated in every office or meeting room.

To end, according to the recommendations of Norman (1988), the GeoTUI system has a perfectly coinciding action and perception space. Consequently, geophysicists can be concentrated as much as possible on the actual working task. Moreover, we strongly believe that tangible interaction for the manipulation of data in the physical world (instead of logical manipulation in the digital world) helps them to concentrate more on their actual trade problems. The development of GeoTUI continues by adding new tangible interfaces for interaction with other important features, such as giving properties on layers, zooming of specific areas, or editing curves and pointing.

Acknowledgments

We thank Jacques Jacobs from IFP for authorizing and supporting this project and sharing his great experience. We also thank all IFP persons involved in the experiments for the time they gratefully spent for this project.