AUGMENTING QUANTUM-GIS FOR COLLABORATIVE AND INTERACTIVE TABLETOPS

VIARD A.(1), BAILLY G.(2), LECOLINET É.(2), FRITSCH E.(1)

(1) ENSG/Paris-Est University - Applied Geomatics Laboratory, MARNE-LA-VALLÉE, FRANCE ;

(2) Télécom ParisTech - CNRS LTCI, PARIS, France

Abstract

This paper presents our QGIS-MT, an extension of Quantum GIS (QGIS) for interactive tabletops. First proposed is an interactive and collaborative environment that allows several users to interact simultaneously on a multi-touch surface. This environment aims at favoring communication among users and at enhancing social awareness and the decision-making process. Next presented are the results of an interview with GIS users, which gives support to the proposed approach. In addition, presented here is a novel interaction technique, called Finger-Count Shortcuts that lets you navigate and activate numerous commands quickly and easily by performing simple finger gestures. Finally, there is a detailed discussion of how Quantum GIS was integrated into this environment and how our QGIS-MT plug-in providing multi-touch capabilities and Finger-Count Shortcuts were implemented in standard GIS menus.

Keywords: Decision making support, GIS Software, User interface, Tabletop, CSCW, Gestural Interaction

Introduction

The complexity of Geographic Information Systems (GIS) has constantly been increasing. Users can now access a huge amount of geographical data (e.g. from satellite imagery or databases), which requires appropriate solutions for storing and visualizing data (Kothuri. et al. 2002, Kraak et al. 1996). Moreover, the number of features keeps increasing, now including not only basic navigation and editing tools, but also numerous specialized tools (e.g., for spatial analysis, hydraulic modeling, etc.) Finally, it is important to make it possible for several users to work together and to facilitate the decision-making process. Improving the usability of GIS through these aspects is important, since GIS are used in various critical contexts such as emergency risk management (e.g. in case of natural disasters, terrorist attacks, etc.).

In this article, we study how novel Human-Computer Interaction (HCI) techniques can improve GIS usability, especially for making command selection easier and for enabling collaborative work. We propose an interactive setup (Figure 1) that enables co-located collaboration around an interactive tabletop. Compared to personal computers, tabletops favor social awareness, facilitate communication among users and make it possible for several users to interact with the same data. Moreover, interactive tabletops, and more especially multi-touch tabletops, provide a way of interacting that is more natural and intuitive than traditional mouse and keyboard interfaces. For instance, the "pinch" gesture, which has been popularized by modern smartphones, allows users to zoom just by expanding two fingers.

While interactive surfaces offer useful advantages for GIS, they also involve some drawbacks. Intuitive gestures can only be used for a limited set of commands (pan, zoom and rotate) while GIS software was designed to provide lots of features. Classical graphical widgets such as menus or tool palettes are not well adapted to interactive surfaces (Bailly et al. 2010) because of insufficient accuracy, occlusion by the user hand, the difficulty to reach them (on large tables) and the lack of keyboard for entering text. New interaction techniques are thus needed to exploit all the potentialities of interactive tabletops for GIS applications.

We propose QGIS-MT, an extension of Quantum GIS (QGIS) for multi-touch tabletops. QGIS-MT makes it possible to use QGIS on multi-touch surfaces and favors collaboration. QGIS-MT also introduces a novel interaction technique, called Finger-Count Shortcuts, which allows users to navigate and activate numerous commands quickly and easily by performing simple finger gestures. QGIS-MT hence improves the usability of QGIS on interactive tabletops.

The article is organized as follows: first, existing collaborative setups used in the context of GIS are presented, as well as the specifications of our interactive and co-located setup. Then, there is a report of the results of an interview with GIS users on their needs and the utility of our setup. Next presented is a novel interaction technique that makes it possible to access the features that were retained from the interview. Finally, there is a detailed discussion of how to implement QGIS-MT.

Fig. 1. A group discusses the implantation of street furniture

Interactive and Collaborative Setup

Collaborative work is often necessary in GIS. For instance, major emergency events like natural disasters, industrial accidents or terrorist attacks require a timely and a coordinated response effort from a number of different experts (e.g. a GIS expert, a cartographer, an urban planner, etc.). Collaborative GIS can also be useful to share skills with less experienced users (such as managers or politicians) or to communicate with the public.

Some studies have proposed to augment GIS by providing remote or co-located collaborative capabilities to overcome the limitations of the classical mono-user paradigm. After presenting them briefly, we will describe our own interactive and collaborative setup.

Remote GIS

With the increase of broadband connectivity and data storage on DMBS, most GIS (such as ArcGIS) allow several users to work on the same data set, but only one user could modify a vector data at a given time by means of a system of locks (Vretanos 2005). GroupArc (Churcher et al. 1996) enables several users to interact on the same vector layer, but only one user can actually edit data, while the others are aware of modifications, but can only leave comments. Shengjun and Yuan's system allows several users to manage different entities on the vector data (Shengjun, Yuan 2008) with a versioning system to keep track of data submission which avoids duplications of work by keeping every participant synced.

Remote groupware GIS (such as ArcGIS Server) is useful for distant users and is increasingly widespread. However, in many cases, collaborative work is performed in a single room by a co-located team. While remote groupware GIS helps users to maintain current and historical GIS data, it does not fully exploit the human ability to communicate and to interact together.

Co-located GIS

Collaborative work on geographic information is quite natural as shown in situations where paper maps are deployed on a table during a meeting. Participants are then located face to face around the paper map. They can communicate, make annotations, take decisions and are constantly aware of other people's actions, While paper maps favor collaboration, they do not offer the high level of interactivity provided by GIS (NB: some attempts have however been made to augment paper maps with digital pens (Yeh et al. 2006)).

The goal of co-located groupware GIS is both to provide a high-level of interactivity with numerous and powerful features but also to allow users to collaborate easily and efficiently. This requires re-thinking the traditional way of interacting, i.e. by using a PC with a relatively small screen, a mouse and a keyboard. Large interactive surfaces are now commercially available (DiamondTouch, Surface, Immersion). They offer several advantages (Gutwin et al. 1996) that are quite useful for GIS (especially for crisis or emergency risk management) such as:

- Informal awareness: knowing who is around and what he/she is doing,
- Social awareness: keeping track of communicational information about others,
- Group structural awareness: information about people’s roles, responsibilities or status,
- Workspace awareness: the perspective of one worker observing/interacting with others.

However, few studies have been carried out in this field. Hofstra et al. performed a theoretical overview, which showed the potential applicability of interactive surfaces to some of the process in disaster risk management in the Netherlands (Hofstra et al. 2008). They only tested pan and zoom features, which are definitively not representative of the complexity of a GIS, but this study was done to design a commercial product (Geodan Eagle 2008) for crisis risk management. The hardware setup is based on the Microsoft Surface and the software reposes on the Microsoft’s Citizen Safety architecture. Users can both visualize and navigate in 2D and 3D scenes, but they cannot add/edit geographical data into the live database. Users can also change modes to get messages from ground operatives in a different window.

Another research project uses an interactive tabletop for Emergency Operation Centers (EOC) for supporting both team and individual work (Bader et al. 2008).

This system provides three main features: a) a second large display is used to provide extra information; b) each participant can use a tablet that can be placed at arbitrary locations on the tabletop to provide personalized perspectives in the information space; c) 16 gestures can be performed on the surface of the tabletop (but the authors do not indicate how they are used, except for navigational gestures). Using these gestures requires an initial learning phase. This may be problematic during a crisis situation as some users may have limited technical experience.

Our interactive and collaborative setup

Hardware setup.

Our setup is based on an Immersion Ilight multi-touch tabletop (Immersion 2008). This technology provides a display of 72x96cm (1400x1050 pixels), which is suitable for the visualization of relatively large amounts of geographical data. The size of the Ilight tabletop is optimal for efficient collaborations (Ryal et al. 2004) because it is not too large (this would make it difficult for participants to communicate), nor too small (participants would not have enough private space). For instance, Figure 1 shows several participants positioned face to face around the table during a meeting where they share information and take decisions.

The Ilight tabletop not only allows oral communications or social awareness. It also allows for several users to interact without the burden of having one person play the role of a moderator in charge of controlling the system (a constraint that would be frustrating and time consuming for teamwork). All participants can thus interact directly with the system by touching the tabletop, a situation that is likely to be more efficient for supporting users' ideas and exploiting their respective skills. Besides, direct touch rather than mouse and keyboard interaction allows users to more easily notice their partner’s actions (Hofstra, et al. 2008).

Finally, this setup supports multi-touch interaction, this making it possible for several users to interact simultaneously with the GIS. For instance, several participants can annotate different elements on the same map (and work on different parts of the map simultaneously) as shown in Figure 2.

From the hardware point of view, our setup differs from Geodan Eagle by its size [the Ilight screen (72x96cm) is larger than the Microsoft Surface (55x69cm) and by its height (Surface is a coffee table while Ilight must be used with participants standing up)]. This larger visualization space and the fact that users do not have to bend down are likely to improve usability. However, the main difference with Geodan Eagle is about interaction. In the next section, we will propose a novel interaction technique to activate numerous GIS commands quickly and easily by performing multi-touch gestures.

Fig. 2. Thoughts and annotations on implanting self-service electric car rental stations in Paris.

Software setup

Our approach did not consist in developing a specific GIS but in adapting an existing one to our hardware setup. We chose to run Quantum GIS on the Immersion Ilight tabletop. Quantum GIS (QGIS) is a multi-platform desktop GIS software that offers numerous features making it one of the most advanced and user-friendly open source GIS.

QGIS supports a wide range of sources and data formats such as Shapefile, WMS, WFS and raster images. Moreover, it provides several “Export” capabilities such as paper outputs. QGIS offers classical visualization and navigation features such as pan, zoom, rotate and various advanced tools for editing data such as the “automatic layer simplification” feature. Users can also analyze data through advanced statistical and geometric functions. Finally, QGIS provides an efficient plug-in system, a feature we used for augmenting it with advanced interaction techniques.

While QGIS provide many features and a user-friendly interface (Figure 3), it was developed for the PC and not for multi-touch tabletops. In particular, traditional graphical widgets (menu bar, docks, palettes, etc.) are not very well suited for direct touch interaction on tabletops because they suffer a number of drawbacks (Bailly et al. 2010):

- Occlusion. The hand and the fingers may hide parts of the display.

- Accuracy. The large surface area of finger-screen contact may induce selection errors when touching graphical objects on the screen.
- Lack of keyboard. In the absence of a keyboard, it may be difficult for users to enter text, while keyboard shortcuts are not available for activating menu items.
- Reachability. The length of the human arm being what it is, the menu bar may be difficult to reach.

We thus propose novel techniques for simplifying the interaction with QGIS on interactive tabletops in order to overcome the abovementioned shortcomings and to allow technical and non-technical users to perform a large set of tasks (including common navigation tasks, but also more complex tasks such as editing, annotation or statistical analyses) by performing simple gestures.

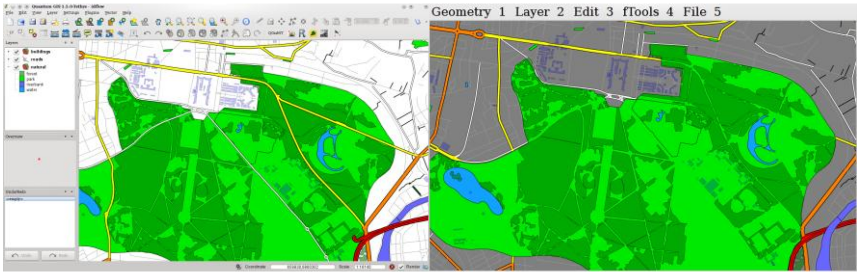

Fig. 3. The Quantum GIS (left) and QGIS-MT (right) main windows

User needs and command selection

QGIS provides a large number of features and all of them are obviously not useful when interacting on a tabletop. For instance, the PC is better suited for writing long documents because of its keyboard. But some tasks such as layer editing are likely to be really useful in collaborative scenarios. We thus conducted an interview to learn which features would be especially valuable when working collaboratively on a tabletop.

Interview

Ten GIS users, 2 being QGIS users, participated in a face-to-face interview about their use of GIS. Nine of them came from spatial data analysis or production. During the first part of the interview, they were asked about features they often use on their desktop GIS software. During the second part, they were asked about their experience with GIS or large paper maps during typical collaborative scenarios such as meetings or presentations. We also asked them to compare GIS and large paper maps, to describe their respective advantages and drawbacks, and to explain which features or behaviors would be helpful for them. Finally, we presented our interactive co-located setup and discussed the usefulness of this environment and how it could be improved. We now report the main results.

Desktop GIS software. All participants first mentioned the need for efficient navigational features (pan, zoom, rotate). They also said they frequently used different kinds of selection tools such as rectangular selection, inverted selection or attribute selection. Finally, they mentioned the importance of data editing (such as cut/copy/paste operations) and the different types of data joining (such as geospatial and attribute joins).

Meetings or presentations. Most participants noticed that paper maps were generally more useful than desktop GIS software during collaborative scenarios, in particular to point at an element or to perform annotations under discussion. For instance, one participant said that “adding information on paper maps by drawing is quite simple”. They also mentioned the navigation problems related to paper maps compared to GIS software. They, for instance, explained that it is necessary to handle several paper maps with different scales to “zoom”, such manipulations being time consuming. Participants underlined that it was sometimes frustrating not to be able to interact with the presenter system. As an example, several participants said “it is difficult to precisely explain to the presenter where he must move the view”. In small groups, it is common to see attendees switching places with the presenter to interact with the system, and repeated moves tend to be awkward and time consuming.

Co-located and interactive GIS. All participants showed interest in this project and insisted on the need for efficient and intuitive navigational tools. Some of them mentioned gestural interaction on the iPhone: e.g., one finger to move the map, two fingers for zooming and rotating, etc. They also explained they would like to add contents to their basemap during the meeting in order to avoid having to enter data afterward from written notes. The capability to draw annotations would be appreciated in the case of complex and time consuming analyses and users would also like to have access to measurement tools (for angles, distances and areas).

These results confirm those obtained in (Hofstra et al. 2008), which reveal the need of co-located GIS for providing the best of paper maps and desktop GIS software, that is to say interactivity and collaboration. This study also highlights the need for numerous features, contrary to what is generally available in existing co-located prototypes and products. According to these results, we will now present a novel interaction technique that addresses the above-mentioned questions.

Finger-Count Shortcuts: a novel interaction technique for QGIS

Gestural interaction is especially relevant for interactive surfaces not only for practical reasons (such as the absence of a mouse and a keyboard), but also because of various advantages such as ability to exploit spatial memory effectively (Wobbrock et al. 2009). Most gesture vocabularies on interactive surfaces are based on straightforward connections with their referents, this making them easy to learn. However, the number of “natural” gestures is limited and too small for selecting the numerous commands that are needed in real applications. Arbitrary gestures (gestures without direct connections with their referents) offer more possibilities, but require guidance to learn. Interaction techniques such as Marking menus (Kurtenbach et al. 1991) or their variants (Bailly et al. 2008), which are based on arbitrary gestures, have been proved very efficient, because they combine circular menus (for guidance) and gestural interaction. This makes it possible to favor a fluid transition from novice to expert usage. However, a common problem with Marking menus on interactive surfaces is that they use drag events. They may thus conflict with gestural interaction techniques based on pan, rotate or pinch gestures.

Finger-Count Shortcuts (Bailly et al. 2010) is an alternate technique, which was recently proposed for avoiding those problems. It makes it possible to use common pan, zoom, rotate gestures together with arbitrary gestures for selecting numerous commands. It is based on a very simple principle: the selected command just depends on the number of fingers that the user places on the interactive surface using his left hand and his right hand. Besides, as explained below, this technique fits well with traditional menu systems, so that it can serve to enhance existing systems without the need to redesign them from scratch. This paper proposes an improvement of Finger-Count Shortcuts that is specifically adapted for the QGIS software.

Finger-Count Shortcuts (FC shortcuts) work as follow. Each N-finger touch with the non-dominant hand is associated with a menu of the menubar, the correspondence being recalled to users by a digit displayed next to each corresponding item (Figure 4). Likewise, the dominant hand is associated with an item in the currently selected menu. Hence, the user simply selects an item by putting N fingers with each hand in contact with the interactive surface. The corresponding command is activated when the user lifts all his fingers. This technique makes it possible to quickly explore the different menus just by adding or removing the appropriate number of fingers. The current operation can be canceled by first releasing the non-dominant hand.

Contrary to classical graphical widgets (the traditional menubar, palettes, docks, etc.), this technique does not force users to point at small elements: interaction can be performed away from the place where the menu is displayed. Occlusion, accuracy and reachability concerns (which were presented above) thus vanish. Moreover, it was shown that users can quickly learn the association between

FC shortcuts and the corresponding features (Bailly et al. 2010), a feature that is useful for non-technical experts and necessary during time crisis.

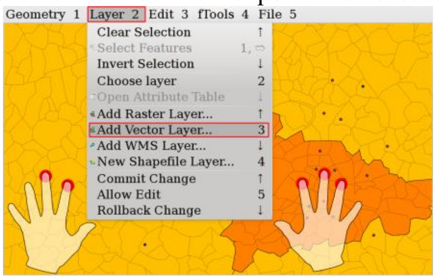

Fig. 4. Performing a simple command

Navigational Tasks. FC shortcuts do not conflict with common panning, zooming and rotating gestures. Panning only requires one finger and zooming/rotating operations in fact corresponds to the specific FC shortcut, where one finger is used for each hand. As a consequence, zooming/rotating corresponds to the first item of the first menu of the menubar, as shown in Figure 5. In other words, FC shortcuts do not break habits and provide a general framework for associating gestures to menu items.

Fig. 5. Zooming in QGIS-MT

Number of commands. As the system just counts the number of fingers in each hand, the technique provides 5x5=25 items in a two-level hierarchical menu (such as a menubar and the associated pull down menus). This number can be increased in two different ways. First, menu items can still be selected in the usual way, just by clicking on them. As for desktop applications, not all commands need to have an associated shortcut. However, as QGIS requires a large number of frequently used commands, we developed a new mechanism called Relative Finger-Counts. It makes it possible to select menus items that do not have a dedicated FC shortcut by first selecting a neighboring item that has a shortcut, then moving the right hand up or down before releasing it from the table surface. This is shown in figure 6 where "Save Project As" is reached by first selecting "Save Project", and then moving fingers to the North.

Another improvement is Contextual Finger-Count shortcuts. By double tapping on an interactive element (e.g. a building on a map), a pop-up window is opened and the user can select its properties such as symbols, by performing FC shortcuts in this window. The pop-up is large enough to contain 10 fingers. Hence, users can not only select up to 75 items of the global menubar system but also change the properties of interactive elements by performing multi-touch gestures.

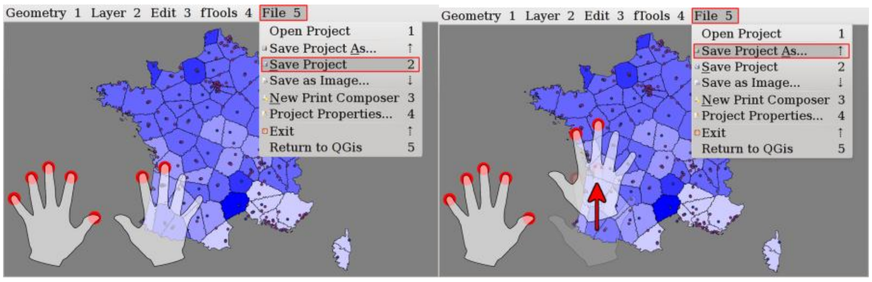

Fig. 6. Saving projects in QGIS-MT

Direct manipulation. Some commands require direct manipulation: the user must not only select a command but also set one or several values interactively. FC shortcuts allow to do both in the same gesture. For instance, the “Select Features” command requires the definition of a selection zone. The user first presses 2 left hand fingers and 1 right hand finger to activate this command (Figure 7), then directly moves his fingers on the screen to set the position of the selection zone corners, and only releases them when the correct position is obtained. This feature avoids using modes and the many errors they tend to provoke (Raskin 2000).

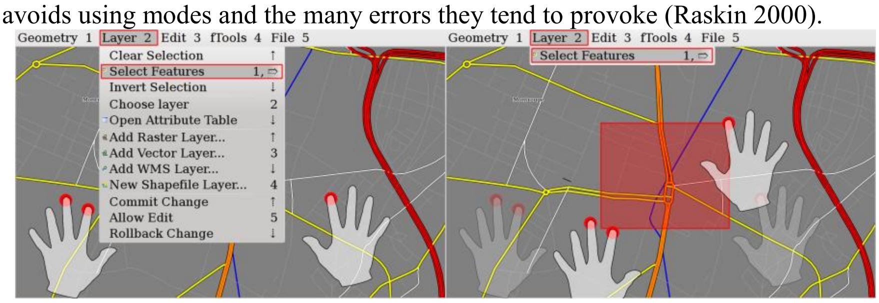

Fig. 7. Selecting features in QGIS-MT

Multi-users. Users can not only interact in turn but also simultaneously. The latter case requires the system to detect which hands belong to the same user. This is done in a simple way in our implementation, just by partitioning the surface into different areas, one for each hand of each participant (typically, 8 areas if 4 users are around the table). More sophisticated schemes could also be used, through vision-based hand recognition or by using dedicated hardware as with Diamond Touch tabletops.

Implementation: QGIS-MT

QGIS uses the Qt framework (qt.nokia.com) and provides a plug-in system in C++ to extend its features. We thus developed a C++/Qt plug-in for QGIS, called QGIS-MT (Figure 8).

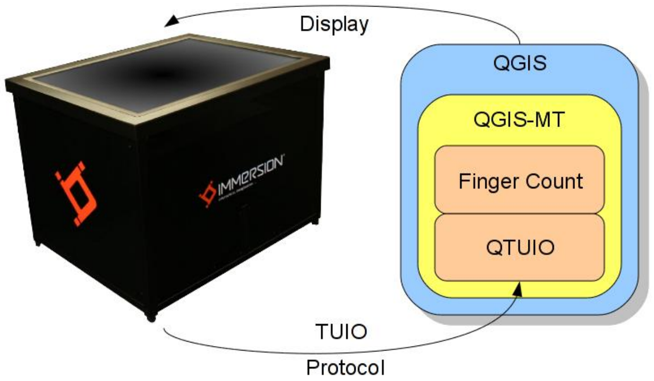

Fig. 8. QGIS-MT environment architecture

TUIO protocol. QGIS and the Ilight tabletop communicate via the TUIO protocol. TUIO is an open protocol for multi-touch surfaces allowing touch events to be sent to the application over the network (Kaltenbrunner et al 2005). TUIO has been adopted by various academic (NUI group) and commercial (Flash) projects and can be used on a wide range of hardware setups.

As Qt provides support for multi-touch input, we developed a library for translating TUIO messages to the Qt native multi-touch events used in our plug-in.

QGIS-MT plug-in. This plug-in creates a full screen window which is displayed on the tabletop and detects the position and the number of finger contacts, which are then used by the menubar of the application.

Finger-Count Shortcuts rely on the application menubar, which was modified according to the needs of our new technique. First, it is able to activate appropriate commands according to finger contacts. Second, item rendition was slightly modified to provide appropriate feedback to users: FC numbers are displayed instead of keyboard shortcuts, horizontal arrows indicate a command that allows direct manipulation and vertical arrows indicate that the item can be selected using *Relative Finger Count.*

Finally, the application provides 57 frequent commands that can be activated by performing gestures. These commands are organized in 5 menus (“Geometry”, “Layer”, “Edit”, “Tools” and “File”) and more commands could be added if needed.

Conclusion

We proposed an environment and a novel interaction technique for augmenting the QGIS software. Using an interactive tabletop, our environment favors communication among users, enhances social awareness and facilitates the decision-making process. Our interaction technique, called Finger-Count shortcuts, facilitates navigation and quickly allows to activate numerous commands by performing simple multi-touch gestures. QGIS-MT, a plug-in that augments QGIS with multi-touch capability via FC shortcuts, was also presented. Finally, an interview was conducted with GIS users to choose a coherent set of commands that are especially well suited for collaborative work on tabletops.

As a next step, we intend to carry out user studies to assess the benefits of this environment with realistic scenarios. We also plan to add on new capabilities, such as the ability to use a smartphone or a tablet that would serve as a private space for interacting with the surface.

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