The NInA Framework
Using Gesture to Improve Interaction and Collaboration in Geographical Information Systems

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Abstract: Nowadays, Geographical Information Systems (GIS) have expanded their functionalities including larger interactive displays exploration of spatiotemporal data with several views. These systems maintain a traditional navigation method based on keyboard and mouse, interaction devices not well suited for large screens nor for collaborative work. This paper aims at showing the applicability of new devices to fill the usability gap for the scenario of large screens presentation, interaction and collaboration. New gesture-based devices have been proposed and adopted in games and medical applications, for example. This paper presents the NInA Framework, which allows an integration of natural user interface (NUI) on GIS, with the advantage of being expandable, as new demands are posed to that systems. The validation process of our NInA Kinect-based framework was made through user experiments involving specialists and non-specialists in TerrainViewer, a geographical information system, as well as experts and non-experts in the Kinect technology. The results showed that a NUI approach demands a short learning time, with just a couple of interactions and instructions, and the user is ready to go. Moreover, the users demonstrated greater satisfaction, leading to their productivity improvement.

1 INTRODUCTION

Advances in several knowledge areas, such as electronics, physics, computer science, mathematics, and others have led to the increasing volume of data collected and stored that are employed for analysis and decision making. One of the areas that had benefited from those advances are the sensor technology, obtaining better images from satellites for Earth observation. Orbital sensors aboard polar and stationary satellites capture images of the Earth's surface every day, generating a huge volume of data in different spatial and temporal resolutions and in different light spectra.

Data provided by these sensors can be used in different scientific areas, such as Geography, Meteorology and more recently Agriculture. The large amount of data and their higher resolution are better viewed on large screens that allow specialists to spot fine details with less effort. Therefore, the interaction devices would allow easy and natural ways to display and to manipulate the views. This is the main motivation of this paper: to present a framework that allows the specialists to easily manipulate large amount of data in big screens, with natural and intuitive interaction devices, as well as to do collaborative work and analysis.

This paper also presents a case study applied to a remote sensing images system, which improves the process of decision making in agrometeorological and Geographical Information Systems (GIS). Specialists in remote sensing increasingly depend on computational systems to deal with satellite images. As a consequence, there is an increasing demand for technology (software and hardware) suitable to receive, distribute and manipulate data recorded by orbital sensors. However, the majority of such technology available today is intended for commercial use, such as Er-

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das[1], Idrisi[2] and ArcGIS[3], which are not open source. These applications include functionalities to open images, extract values, visualize layers, create algebra of maps, project images in 3D among others.

GIS have expanded their functionalities including geovisualization that studies interactive display and exploration of spatiotemporal data (Stannus et al., 2011). Recently, GIS have become popular especially due to software such as Google Earth. However, these systems are based on the same traditional navigation method based on keyboard and mouse. New gesture-based devices have been recently proposed and adopted for games and medical areas, for example, making the interaction much more practical and simple.

Basically, the interaction with a software tool is provided by the keyboard and mouse, which is suitable for the majority of interface options. However, layers in 3D view are not just for display, but are being used to describe surface aspects and can be observed at oblique angles. Thus, images in 3D views must be handled in a different manner from the traditional approach employed for 2D views.

Our focus is on how to take advantage of new interaction possibilities provided by natural user interfaces, such as gesture and body movement interpretation to improve the user/computer interaction. New devices, such as the Microsoft Kinect, have been widely used in games to track the players' movements, enabling the game to become much more realistic. Additionally, these games allow more than one player acting together. Natural movements associated to the collaboration aspects can also strongly contribute to improve the interaction in systems from other areas such as geographical information systems and satellite imagery systems.

In this context, this paper proposes an innovative interaction approach for satellite imagery systems based on gestures. Our focus is on how to take advantage of new interaction possibilities provided by natural user interfaces, such as gesture and body movement interpretation to improve the user/computer interaction. Our framework uses the Kinect technology to improve the interaction when handling 3D visualizations. The validation process of our Kinect-based framework was made through experiments including specialists and non-specialists in geographical information systems, as well as experts and non-experts in the Kinect device. The experiments results showed that at the very first interactions, beginners not trained on this device found more difficult to manipulate the interface, but after a while everyone reported this model of interaction much more intuitive and enjoyable than using the keyboard and mouse.

This paper is organized as follows. In the next section we present the background needed to follow the ideas of this paper. The framework proposed is detailed in Section 3. The user experiments are reported in Section 4 and finally we conclude the work in Section 5.

2 BACKGROUND

One of the most troublesome problems to develop a computer system is the design of its user interface. This is an important issue, because technologies with complex interfaces can become useless. Interactive graphical interfaces offer the advantage of allowing users with different computer skills to easily interact with the systems.

Researchers in Human Computer Interaction have proposed innumerous methods and techniques in order to contribute to the improvement of user interface design processes. The majority of these methods consider users as the center of the design process. In this sense, several works have investigated different aspects related to human beings such as cognition, perception, motor system, memory, among others.

All of those aspects must be considered, but one of foremost importance is the time that users take to complete a task, as shorter times imply more intuitive designs. According to the Fitts's law, the time to perform a task is proportional to the size and the distance of the target (Fitts, 1954). Thus, the designer must know about the capacity of the human's motor system to accurately control movements in order to better place the interface elements in the screen (Fitts, 1954). In addition, the learning curve should also be considered when a new design is proposed to a system, taking into account both the beginners and the experts.

The time to perform a task and the learning curve become more important when the user interface is designed to be manipulated through new interaction modalities such as touch and gesture. When users employ their hands in three-dimensional spaces to interact with the interface instead of moving a device we call this type of interaction "gestural user interface". In gestural interfaces, the learning curve tends to shrink, since the user reproduces the same movements performed in the real world, thus they probably spend less time learning new interaction metaphors (Rizzo et al., 2005; Stannus et al., 2011). Although gestures are a powerful mode of interaction, cultural

[1] http://www.erdas.com/

[2] http://www.clarklabs.org/

[3] http://www.arcgis.com

differences/conventions can make it difficult to interact with such interfaces (Norman, 2010), leading to an adaptation process.

Gestural user interfaces are called natural user interfaces (NUI). They are defined as interfaces in which the users are able to interact with computers as they interact with the world (Jain et al., 2011). According to Malizia et al. (Malizia and Bellucci, 2012), the term natural in NUI is mainly used to differentiate them from classical user interfaces, which use artificial devices whose operation has to be learned. However, the current gesture interfaces are based on a set of gestures that also must be learned. According to Norman (Norman, 2010), the gestures are a valuable contribution as interaction technique, but still requires more research involving the use of this form of interaction in different systems, so that we can better understand how to use them. Moreover, conventions for standards should be developed, so that the same gestures mean the same things in different systems. In other words, researchers need to conduct research to assess the feedback, guides, correction of errors and other issues related to the use of gestures and the benefits of this form of interaction.

Malizia et al. (Malizia and Bellucci, 2012) affirm that the way to go for natural interfaces is still very long, since only using natural gestures are not enough for computer systems. They are still artificial because the designer of the system still requires a set of gestures to be used.

The Microsoft Kinect is one of the recent devices that aims at supporting gestural interfaces. The Kinect sensor is available to the community since November 2010. It contains a color sensor, an infrared emitter, an infrared depth sensor and a multi-array microphone. Combining these sensors, Kinect provides a stream of color images, depth images and audio. Through the infrared sensor, Kinect is also able to track people actions, simultaneously recognizing up to six users. From these users, up to two users can be tracked in detail, given spatial information about the joints of the tracked users over time. The Kinect API [4] enables the application to access and manipulate the data collected by the sensor (Microsoft, 2013).

Recently, several works have explored natural user interfaces in different contexts. Stannus et al. (Stannus et al., 2011) developed a gesture-based system to the Google Earth application. Boulos et al. (Boulos et al., 2011) applied depth sensors such as Microsoft Kinect and ASUS Xtion to control 3-D virtual globes such as Google Earth (including its Street View mode), Bing Maps 3D, and NASA World Wind. Richards-Rissetto et al. (Richards-Rissetto et al., 2012) explore the Microsoft's Kinect to create a system to virtually navigate, through a prototype 3D GIS, the digitally reconstructed ancient Maya city.

[4] Kinect for Windows. Available at http://www.microsoft.com/en-us/kinectforwindows. Accessed date January 16, 2013.

3 OUR PROPOSED FRAMEWORK

In this section we present the NInA framework (Natural Interaction for Agrometeorological Data). This framework provides a complete set of functionalities for natural interactions on GIS. We also present a case study named TerrainViewer, a tool to visualize remote sensing images. After a brief introduction to TerrainViewer, the next sections highlights the NInA gesture module.

3.1 TerrainViewer

TerrainViewer is a tool capable of presenting agrometeorological data through three-dimensional rendered models including altitude data. This tool combines topographic data with remote sensing images from different sources, as AVHRR/NOAA[5] and SRTM[6] images. The rendered models assist agrometeorological specialists in finding relationships between remote sensing data and their respective geographic position and elevation. Thus, specialists can analyze huge amounts of data in a short period of time and focus on a region of interest.

The TerrainViewer tool was originally developed using a simple and robust manipulation scheme, based on just keyboard and mouse. With these devices it is possible to rotate, translate and scale the model, meeting the basic specialists needs to perform image and data analyses. However, the sophisticated and highly detailed handling of a 3D scenery pressed for a more flexible and natural interface. The answer for those needs was the NInA Framework.

3.2 The NInA Framework

Many studies regarding more natural computer interfaces, as well as the increasing number of different domain systems using these interfaces, show that there are effective gains in allowing users to interact with tools in the most intuitive way. Based on this

[5] Advanced Very High Resolution Radiometer sensors aboard National Oceanic and Atmospheric Administration satellites.

[6] NASA's Shuttle Radar Topography Mission.

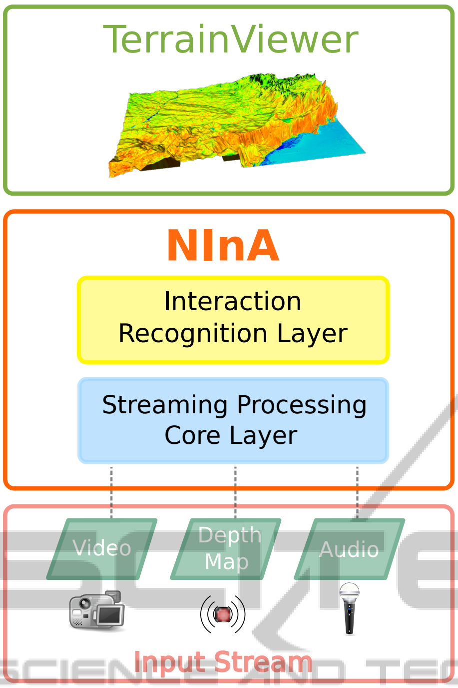

Figure 1: NInA framework architecture.

premise, the NInA Framework was developed aimed at providing natural interactions for GIS.

The NInA framework is a novel approach that brings the natural interactions advantages for the several visual analysis requirements on satellite imagery systems. It is structured using a two layer architecture. The *Streaming Processing Core Layer* (SPCL) receives data from several devices. The data is processed and sent to the *Interaction Recognition Layer* (IRL), which is responsible to detect the user actions. The actions generate events that are sent to the applications, where they will be acknowledge processing the visualizations. Figure 1 shows an overview of the NInA framework and its dataflow.

The SPCL receives data streams of video, audio and depth maps that can be captured by several devices, including video cameras, microphones, motion sensing controllers and multi-touch gadgets. SPCL was designed as a modular architecture. Each module receives a set of raw input streams and outputs the processed data stream required for the second layer. For instance, the skeleton module receives raw depth data and outputs a stream containing 3D positions of body joints. Eventually, a module may receive the output of another module. A summarization of all modules is shown in Table 1.

The first module, *Audio*, has been designed to process input audio stream data, i.e., filtering noise and detecting speech directly from the frequency domain. In this module, text stream is also extracted for further use on IRL. The *Depth* module is used to compute a matrix with depth values from the signals provided by the infrared (IR) sensor. In the *Hand* module, video and depth data are used to segment user's hands position and contour. The segmentation is used to detect the fingers' positions and to determine the hand state (opened/closed). With the depth values, the module *Skeleton* is able to compute the 3D position of user's body joints.

The current version of NInA focuses on the Kinect device, because its range of sensors can provide a pretty complete experience on natural interaction. The Kinect streams are received by SPCL using Microsoft Kinect for Windows API and drivers and the SPCL modules process the streams aided by Kinect API. However, the SPCL modules improve their outputs with focus in GIS and produce other outputs that Kinect API doesn't provide, such as fingers positions, which are very useful on natural interaction (gesture) over maps.

Table 1: Requirements and outputs of the SPCL modules.

Module	Input Data	Output Stream
Audio	– Audio Stream	– Audio –Text
Depth	– IR signals	– Depth Matrix
Hand	– Depth Matrix – Video Stream	– Fingers Position – Hand State (opened/closed)
Skeleton	– Depth Matrix	– 3D Position of Body Joints

On the next step, the SPCL output is sent as input stream to the IRL, where it is processed into an interactive control scheme. Table 3 shows the input and output event of each module in IRL. In the current version there are two main modules in IRL, *Gesture* and *Voice Control*. The Gesture module receives the output of the *Hand* and *Skeleton* modules of the previous layer and triggers the detected events. All detected events are processed, as the visualization target is a real object in front of the user. The voice control receives only the *Audio* module output and the triggered event brings the detected voice as audio and text to be used in the action decision.

In both modules we manipulate the input streams using a time-based sliding window approach. The capture rate is 30 frames per second and the window size is 15 frames. For each window slide, the modules process their input and detect a specific action, triggering their respective events.

Figure 2 presents the flowchart of how the Gesture module triggers events. The IRL receives video, depth and skeleton streams from the Kinect device, combining them to detect the main user by choosing

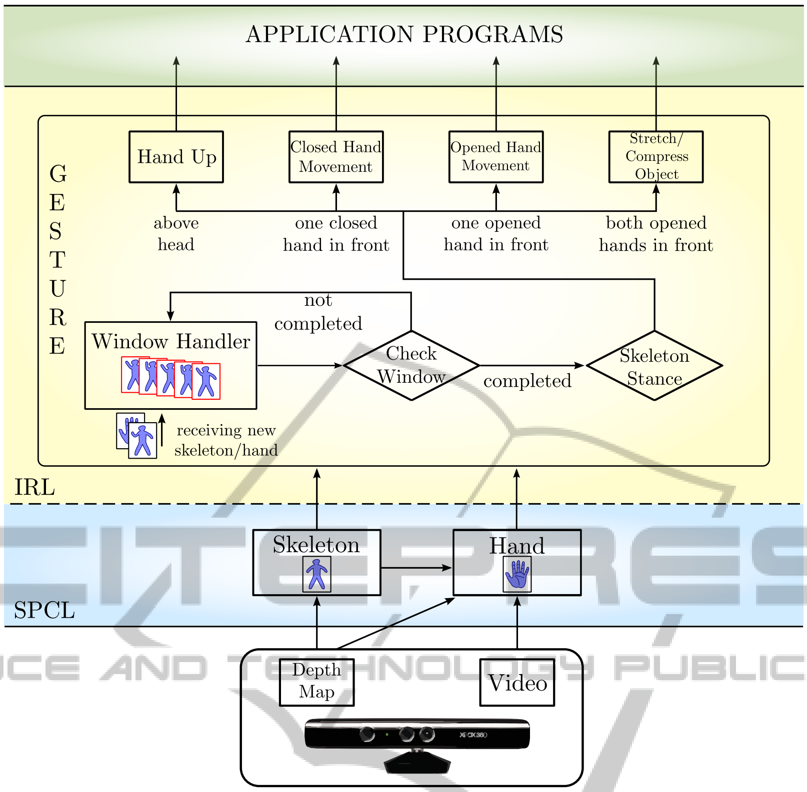

Figure 2: Processing streams and events in the Gesture module from NInA.

Table 2: Requirements and outputs of the IRL modules.

Module	SPCL	Output Event
Gesture	– Hand – Skeleton	– Stretch/Compress Object – Closed Hand Movement – Opened Hand Movement – Hand Up
Voice Control	– Audio	– Voice Command

the nearest one. With the main user chosen, the skeleton positions, the hand status and fingers positions are computed.

The Skeleton and Hand streams are sent as input to the Window Handler in the *Gesture* module in the IRL. The Window Handler receives the stream until the sliding window is full. Thereafter, it is processed generating the IRL output events, e.g., if the user moves both opened hands before his/her body, the Gesture module triggers a Stretch/Compress Object event.

3.3 TerrainViewer and NInA

Since the release of Kinect, TerrainViewer users were enthusiastic with the new possibilities that this technology could provide, based on the later results presented in the literature about NUI. The NInA framework has been developed with an incremental approach, based on the requests of specialists over the TerrainViewer functionalities. This section contains the explanations about how NInA was built to meet the proposed requirements and these natural interactions.

The set of actions was defined by the specialists and their natural gestures were chosen between the proposed events for the NInA Framework. Table 3 presents the association between actions and gestures that results in the NUI version of TerrainViewer.

Table 3: Gestures and the respectives actions on NInA Framework + TerrainViewer.

Actions	Gestures
Zoom In/Out	– Stretch/Compress Object
Rotation	– Closed Hand Movement
Translation	– Opened Hand Movement
Initial State	– Hand Up

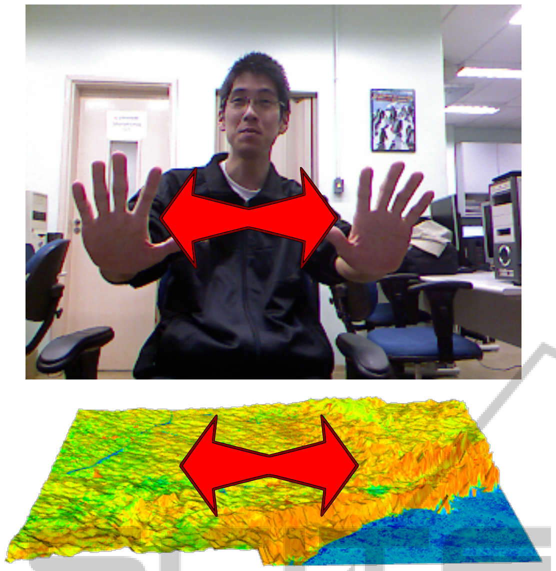

Figure 3: Scaling a map visualization using the NInA Framework.

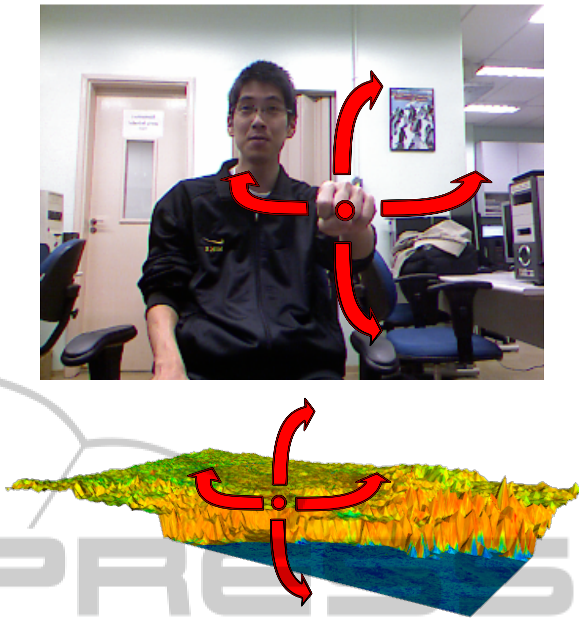

Figure 4: Rotation of a map visualization using the NInA Framework.

All gestures were implemented considering the rendered model being shown in front of the user. For instance, if the user puts both hands in front of his/her body and move away one hand from the other, which describes the stretching object gesture, the Stretch Object gesture is triggered and the model view zooms in as the result action. As the model gets larger, the user feels like he/she is stretching the model, as shown in Figure 3. The zoom out action is analogous, and it is recognized by the Compress Object gesture when both hands move toward each other. Another gesture recognized by the NInA framework is when the user moves one closed hand in front of his/her body. With this gesture, the user feels like he/she is grabbing one part of the rendered model and changing its angulation, as shown in Figure 4. This results in the rotation action on the model being displayed. The same gesture executed with an opened hand results in the translation action, where the position of the model changes depending on the hand position (Figure 5). Finally, although it is not quite a natural interaction, by raising one or both hands above his/her head (Hand Up gesture) for at least two seconds the user resets the visualization to its initial state.

It is important to highlight that all the interaction movements provided by NinA are the ones a user does when pointing to an image during discussion or analyzes in a collaborative work. Moreover, when the user is standing up for a plenary presentation employing large screens, the use of this kind of interaction makes the whole process natural, simple and easy.

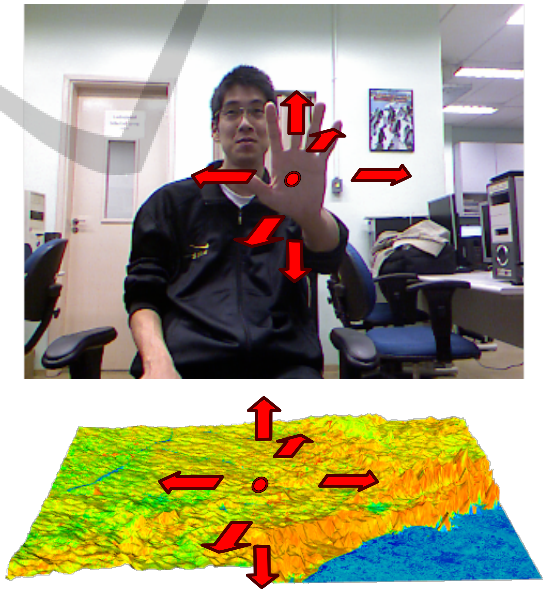

Figure 5: Translation of a map visualization using the NInA Framework.

4 ANALISYS WITH USERS

In order to evaluate the NInA framework incorporated in the TerrainViewer system, we conducted a user experiment involving six subjects with different profiles. Although the number of users in the test had been small, they were a representative part of potential users. Furthermore, the GIS application involves a specific group of users becoming more difficult to find an expressive number of testers to be involved in the experiment. The main objectives of this user-based experiment aimed at assessing:

1. facilities and difficulties of using Kinect-based interaction;
2. users' satisfaction;
3. robustness and performance of the system;
4. usability of the system.

The group of participants was composed of specialits in cartography, forest engineering, agricultural engineering and computer engineering with different knowledge about GIS (experts and non-experts). According to their levels of ability in the manipulation of the Kinect device, the users were classified as:

a) beginners: two of them had never used it before;

b) intermediaries: two users had used it once or twice;

c) upper-intermediary: one user had already used it with games more than 10 hours;

d) expert: one of them had used it with games more than 100 hours.

The user test was conducted in a usability laboratory, where the Kinect sensor was installed and the system was projected in a large screen as showed in Figure 6. Although the best way of observing users was in their own work environment, we were not able to install the Kinect sensor in the users' office because of the distance required to perform the test (more than one meter from the device).

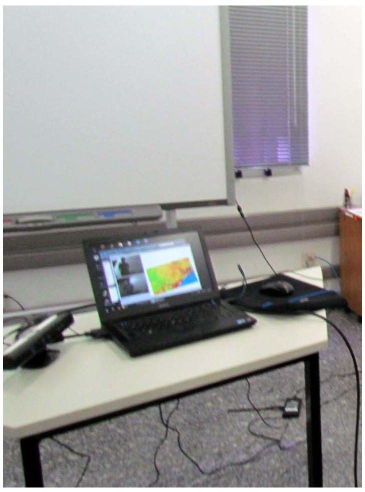

Figure 6: Devices used in the users' test.

The experiment was registered by two cameras, one positioned in front of the users and another by their side to capture users' facial expressions as well as their gestures during each interaction (Figure 7). Audio was also recorded to allow assessing expressions, interjections and comments during the experience. Also, two observers took notes during the test.

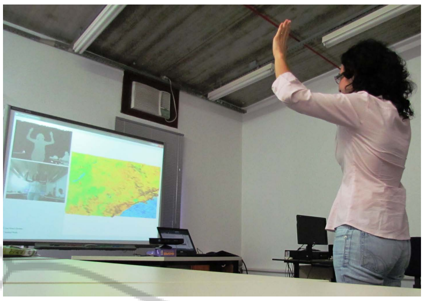

Figure 7: User's interaction recorded by cameras as well as the user's representation and the Terrain Viewer system projected in the screen.

The whole test took around four hours and was organized in four different steps:

1. Interaction through Kinect. First, the users were invited to freely explore the system using NInA for some minutes. After that, one observer asked them to perform three tasks with the 3D satellite image presented in the screen: rotation/translation, zoom in/out and restart the map to the initial position. No instruction was provided to users during this step. In the end, one of the observers explained all commands to perform the suggested tasks. Then, all users redid the tasks.

2. Interaction using Mouse. After all users finished the tests using Kinect with NInA, the observer invited them to manipulate the TerrainViewer system through mouse. First they could explore the system without previously defined tasks. After a few minutes, users should execute the same sequence of tasks performed with Kinect and NInA.

3. Answering a Survey. After their interaction with the Kinect/NInA and keyboard/mouse, the users reported their experience in a survey about difficulties/facility met during the interaction, satisfaction / frustration, and adoption of the Kinect/NInA technology.

4. Brainstorm and Discussion. When all users have finished the test, they have participated in a brainstorming session with two observers. They talked about their impressions, doubts and commands to interact with the system.

As expected, during the exploratory phase, the beginners demonstrated more difficulties to interact with the Kinect sensor than experts. They moved their arms and hands without discretion, with broad and quick movements. Moreover, they also moved along the body without focusing the sensor. The hands were pointed to the screen instead of being directed to the sensor. Although they initially could not totally control the object, their expression was relaxed, enjoying with the activity, regardless of they were making mistakes or not. They laughed, made funny comments, as when the map screen became out of focus and they joked saying “come on, come on!”.

Only one of them was frustrated when was unable to zoom out the map saying, “Why does it not listen to me? And now, what do I do?” (talking to the map that had disappeared with too much zoom from the screen). The less experienced users not positioned the body in front of the sensor to be recognized neither looked at windows with the skeleton of the body drawn. The focus of their attention was just over the display system.

On the contrary, the experts positioned their hands in front of their body, expecting to be recognized by the sensor. They made slow and precise movements. Their face demonstrated concentration attempting to associate the system response to each gesture. In general, they spoke little throughout the exploratory phase. The focus of the experts was not just on the system’s windows, but also on what the sensor was picking up. Their looks went from one window to another in the screen trying to capture every movement as well as the system responses.

During the next phases, in which users should perform a sequence of tasks, their attention became greater. All of them tried to accomplish the tasks in the best way, but they had difficulties with the zoom task. All of them successfully rotated the object. However, only the most experienced managed to zoom in, and only two were able to zoom out the object. The last task corresponding to place the map back to its initial state has not been satisfactorily performed by any of the subjects. Several users have commented on the difficulty with the zoom out considering that the problem occurred due to the distance from the sensor, the delay in response or system calibration for closed hand movements.

After the first two steps (free exploration and sequence of tasks), the developer showed to all subjects which were the movements programmed to be performed in each activity. After the explanations, everyone wanted to repeat the script to make sure they would be able to perform all tasks. Many of them agreed that it seemed much easier after the tips, especially the command to return to the initial state, raising one or both hands. Several users commented that this last task (back to initial state) was the most fun and were raising their arms at various times laughing.

The next step on the achievement of the same sequence of tasks by using the mouse was performed satisfactorily for all. Although the activity with the mouse seemed simple, they also showed no enthusiasm.

Apart from the cameras that captured users’ gestures and speech, observers took notes and users answered a questionnaire with the following questions:

- What is your academic formation?
- What is your level of experience with Kinect?
- What was the difficulty level with the system employing Kinect/NInA?
- Is the use of the system intuitive?
- What was the level of satisfaction? The experience was fun?
- Would you adopt this technology for interacting with a GIS?

The answers are summarized in Table 4. According to the answers, also confirmed by the recordings, they had more initial difficulties by not knowing the new interaction technology (Kinect). Although one of the users is an expert in GIS, as this user was not familiar with the gestural interaction, the performance of activities was impacted, which did not occur when using the mouse, because of previous training in using it. However, after receiving instructions from the system developer, the user interacted with the system without difficulty. This allows us to acknowledge the need of presenting basic instructions on the screen (similar to those presented in various videogames) and/or training user before the interaction. However, it was confirmed that, the learning time is very short, what is a plus of this technique.

Despite some initial difficulties, only one user felt that this form of interaction is non-intuitive. On the other hand, all users stated that the hand movement approaching or moving away to do the zoom command was the first movement that occurred to them. Some of them commented that the scroll ball on the mouse to accomplish the same task is far less intuitive, for example.

The degree of satisfaction was high as we could see by the expressions of each one during the experiment. They smiled, made jokes, grimaced when wandered or were unsure about what to do, commented something funny and no one wanted to stop using the system. When asked about the possibility of adoption of the technology in his/her work, all subjects were in favour of it.

During the brainstorming session, each user had the opportunity to report their experiences and feelings beyond making suggestions. They commented

Table 4: Information about users and their answers of the questionnaire applied to them after the interaction through Kinect.

User	Profession	Kinect experience	Difficulty	Intuitive	Satisfaction degree	Adopt technology?
User1	Cartography	beginner	high	yes	high	yes
User2	Forest engineering	intermediary	medium	yes	high	yes
User3	Agricultural engineering	upper-intermediary	low	yes	high	yes
User4	Agricultural engineering	beginner	high	yes	high	yes
User5	Computer engineering	intermediary	medium	no	high	yes
User6	Computer engineering	expert	low	yes	high	yes

on the difficulty of making subtle movements to zoom and asked if this command could be calibrated less rigid. Several of the subjects suggested different movements to rotate the object instead of making a fist. They requested a movement to stop interacting with the possibility of returning later. They commented that it would be very interesting to use the tool for collaborative use, which is hard to do with the mouse. Furthermore, they suggested that the system with this type of interaction would be appropriate for use in teaching and presentations, since the gestures are natural movements that they usually do.

5 CONCLUSIONS

This paper presented the NInA framework aimed at providing resources to easily add a natural user interface (NUI) based on the Kinect technology on geographical information systems. The modules of NInA make it a simple, but powerful basis to build natural interfaces based on gestures, with the advantage of being expandable, as new needs arrive at the system, and is easily portable to other devices.

The need of NUI became more urgent as the volume of data to be analyzed as well as the size of the maps and presentations grow, demanding the use of very large displays to allow comfortable interaction. Therefore, the use of mouse and keyboard was clearly regarded as being not convenient anymore, since they limit the users' movements. In this scenario, NInA is the natural choice, since the user is not limited by holding a device. Moreover, when the analysis involves collaborative work, the other analysts easily recognize the users' movements, and can participate as a group.

The analyses performed with the users, in the case study with the TerrainViewer system, showed that the learning time is quite short, just a couple of interactions and instructions and the user is ready to go. Beyond that, the users felt greater satisfaction employing the Kinect/NInA framework to interact with the system, what can lead to improve their productivity.

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