Gesture Vocabulary for Natural Interaction with Virtual Museums
Case Study: A Process Created and Tested Within a Bilingual Deaf Children School

Lucineide Rodrigues da Silva, Laura Sánchez Garcia and Luciano Silva
Department of Computer Science, Federal University of Paraná, Curitiba, Paraná, Brazil

Keywords: Gesture Vocabulary, Virtual Museum, Natural Interaction.

Abstract: The research described in this paper aimed at creating a gesture interface for a 3D virtual museum developed by a research group of Image Processing. Faced to the challenge of using sound methodologies in order to create a genuine natural interface, the group joined to a Computer Human Interaction group that has worked for seven years focusing the social inclusion and development of Deaf Communities. In this context, the research investigated the state-of-the-art of Natural Interaction and gestures vocabulary creation in related literature and placed the case study at a bilingual school (Brazilian Sign Language and written Portuguese) for deaf children. The paper reports the results of some specially relevant works from literature and describes the process of developing the vocabulary together with its validation. As the main contributions of this research, we can mention the addition of a previous state – the observation of potential users interacting with the physical scenario that motivates the innovative virtual uses in order to investigate the actions and gestures used n the physical environment – to a well known author's process that has as its starting point the set of expected functions and the exemplification of a more active way of bringing potential users to the stage of defining the right gestures vocabulary, which brings more help than just interacting with users to get their opinion (asking them to match a feature to the gesture they would like to use to employ it or demonstrating a gesture and seeing what feature users would expect that gesture to trigger). Finally, the paper establishes the limitations of the results and proposes future research.

1 INTRODUCTION

The great challenge in gestural interaction is the creation of the gesture vocabulary to be used in the application (Nielsen et al., 2004). In many cases, this task is done arbitrarily, considering only technical aspects for the recognition of the gestures, which is not adequate from the point of view of the user, who first has to learn a vocabulary and only then get to use it.

The Natural User Interface - NUI (Wigdor and Wixon, 2011) is a concept built in recent decades that has gained great momentum due to new technologies which have begun to allow interaction through gestures, touch and voice. NUIs purse to make the interaction between the user and the system easier and more intuitive, and can take advantage of various devices to reach this objective.

The research described in this paper aimed at creating a gestures interface for a 3D virtual museum project of IMAGO research group. Faced to the challenge of using sound methodologies in order to create a genuine natural interface, the group joined to a Computer Human Interaction group that has worked for seven years focusing the social inclusion and development of Deaf Communities. In this context, the research investigated the state-of-the-art of Natural Interaction in literature and placed the case study at a bilingual school (Brazilian Sign Language and written Portuguese) for deaf children.

Deaf people relate to the world in a gestural-visual manner, and most are not fully proficient in written Portuguese; this makes them one of the main beneficiaries of gestural interaction, along with illiterate people.

A virtual exhibition has several benefits. First, it benefits the exhibitor, who keeps the objects safe during the exhibitions, even when transport is necessary. It also makes it possible to disseminate the project in various physical locations. It also allows the user to see works from different countries and cultures in an easier and often more enabling

Rodrigues da Silva L., Garcia L. and Silva L..
Gesture Vocabulary for Natural Interaction with Virtual Museums - Case Study: A Process Created and Tested Within a Bilingual Deaf Children School.
DOI: 10.5220/0004886700050013
In *Proceedings of the 16th International Conference on Enterprise Information Systems* (ICEIS-2014), pages 5-13
ISBN: 978-989-758-029-1

way.

Additionally, the visitors are presented with a new form of interacting with the exhibited objects they cannot not experience in the real world.

While developing a gestural interface, the objective should not be to make it generic, since gestures are not universally interpreted, but rather to develop specially an interface and interaction environment for a given application (Nielsen et al., 2004). In order to reach this objective, this research utilized a user-centered approach to define the gesture vocabulary.

The present paper is subdivided as follows: A bibliographic review is presented in Section 2. The proposed methodology is presented in Section 3. Next, Section 4 discusses the planning and execution of the experiments. Section 5 presents the conclusion and future work.

2 REVISION OF LITERATURE

According to Nielsen (1993), "usability" refers to how easily accessing the interface seems to the user and is associated to five quality components: learning curve, efficiency in executing tasks, memorization, few mistakes, and satisfaction.

Norman and Nielsen (2010) think that gestural interfaces led to a step backwards in usability, and affirm that gestural systems need to follow basic rules of interaction design to be properly called "natural".

Conducting tests with users is the most basic and useful method to assess a system's usability (Nielsen, 1993). The test consists of locating representative users, asking them to execute representative tasks with the prototype, and noticing what they manage to execute and what difficulties they encounter.

Defining which gestures will be used, in other words, composing the gesture vocabulary of a system, is considered to be one of the most difficult stages in the development of a gestural interaction system (Nielsen et al., 2004).

Grandhi et al. (2011) affirm that very often the gesture vocabulary is defined arbitrarily, considering the ease of implementation, which forces the user to first learn the vocabulary in order to utilize the system afterwards.

In Boulos et al. (2011) a gesture-based navigation system was developed for Google Earth. The gestures it used were also defined arbitrarily, taking the existing functionalities of the application into account to create the gesture vocabulary.

On the way to a better product, Chino et al. (2013) developed a georeferenced gestural interaction application that uses gestures selected from the addressed functionality but still without the users participation, and they realized that the quality of their prototype had been partially compromised by that methodological decision.

Nielsen et al. (2004) propose a user-based approach in four steps to define the gesture vocabulary. The first step consists of identifying the application's functions, using existing applications as parameters.

The second step refers to finding the gestures that represent the functions identified in the first step. With this objective, experiments with users are conducted in scenarios that implement the functions necessary for the application. In these scenarios, the users are told about the functions they must request from the test operator through gestures. All of the experiments in this step must be recorded.

In the third step, the videos are evaluated in order to extract the gestures used for the interaction.

The author emphasizes that the selection of gestures must not be restricted to those identified in the test, but rather that they should only be an inspiration for defining the gesture vocabulary.

The last step consists of testing the resulting gesture vocabulary, which could even lead to changes in the vocabulary. This stage is composed of three tests. In this step, a score should be calculated and attributed to each test. At the end of the tests, the lower the score, the better. Test 1 evaluates the semantic interpretation of the gestures. It is necessary to give a list of the functions and to present the gestures, asking the user to identify the corresponding functions. The score is equal to the number of mistakes divided by the number of gestures in the list.

Test 2 evaluates the memorization of the gestures. The user is shown the test vocabulary in order for him or her to try it and understand it. The names of the functions are presented in their logical order of application. The user must execute the gesture related to the function shown. Upon each mistake, the presentation must be restarted, presenting the vocabulary to the user at every attempt. The scoring corresponds to the number of times the presentation had to be restarted.

Test 3 is a subjective evaluation of the ergonomics of the gestures. The gesture vocabulary is presented and the user is asked to execute the sequence x times.

Between the execution of each gesture, use the following list to score each one: 1) Easy. 2) Slightly tiring. 3) Tiring. 4) Very troublesome. 5) Impossible.

Saffer (2009) states that “simple, basic tasks should have equally simple, basic gestures to trigger or complete them” and, also, that good interactive gestures are simple and elegant.

This author also says (2009) that since human beings are physical creatures, they prefer to interact with physical things. I this sense, the author characterizes interactive gestures as the style that allows for a natural interaction with digital objects in a physical way. He comments about the product designer Naoto Fukasawa´s observation that the best designs are those that “dissolve in behaviour”, adding that the promise of interactive gestures is in the fact that we will empower “the gestures that we already do and give them more further influence and meaning”. He concludes, then, that “the most natural designs are those that match the behaviour of the system to the gestures humans might already do to enable that behaviour”.

In order to involve the user into the process of determining the appropriate gestures for the system, Saffer proposes doing it along with the users, either by asking them to match a feature to the gesture they would like to use to employ it or demonstrating a gesture and seeing what feature users would expect it to trigger.

Based on Nielsen et al. (2004) procedure, we proposed a methodology to define the gesture vocabulary for a system for visiting a virtual museum. In this process the authors share Saffer’s characterization of natural gestural interfaces and propose and alternative to bring users to the vocabulary creation process. The experiment was conducted with the participation of a deaf community. This methodology is presented in the next section.

3 METHODOLOGY FOR THE CONSTRUCTION OF THE GESTURE VOCABULARY

The analysis of similar work showed that, in general, the methodologies for creating a gesture vocabulary begin after defining the actions which the application will use. Consequently, the process is based only on defining the gestures according to the desired actions. In our case, we began the process of creating the vocabulary in the previous step, starting with the following research question: “What actions would the users execute in the physical environment if they were allowed to handle objects in order to learn about them?”

Considering the context of a museum environment, as in the case of this project, we concluded that, since in the real world we can only observe the object from a distance, we did not foresee the ways in which the users of the virtual museum would take advantage of the possibilities opened up by virtual innovative interaction. Therefore, in this research we attempted to propose a methodology that allows for the creation of a gesture vocabulary even when there are no actions defined for the application.

A three-dimensional visualization system makes many contributions in this direction. Mendes (2010) emphasizes that in this way, the objects can “be accessed and explored virtually, with a high level of detail, reducing the risk of irreversible damages due to transport or physical handling”.

Besides the advantages obtained from the point of view of the digitized object made available for visualization, there are also other benefits to a user who interacts with this system, such as more interaction with the exhibited objects, or creating greater interest among the public, which now has another incentive to visit the exhibition.

Van Beurden et al. (2011) conducted research comparing the use of gestural interaction with the use of physical interaction devices. The result demonstrated that, for the users, gestural interaction is easier, more enjoyable, and natural, allowing for intuitive and more engaging learning.

This analogy, similar to Saffer’s conception of gestural interaction, together with the space to provide innovative experiences in visiting virtual museums if compared to the limited possibilities of common visits to physical museums in general, led us to explore the physical scenario as the one to inform the designer of the capabilities needed.

The proposed methodology consists of three stages with the objective of solving a given task regarding the museums. 1) Identification of the set of actions from the analysis of videos of users behavior in the real scenario; 2) Creation of the gesture vocabulary from the data collected in step 1 modulated by theoretical bases of Computer Vision and Computer Human Interaction; 3) Validation of the appropriateness of the vocabulary created.

The first stage defines the actions and gestures that represent such actions from user observations in a real environment. According to the objective of the application to be developed, a scenario should be prepared where the user can interact, in a natural and unlimited manner, with physical objects similar to those used in the application. This scenario should be planned in such a way that the user is led to execute a task that is sufficient to identifying the necessary set of actions. The task must allow for exploration of all the possible actions thought for the application. All user interactions in this scenario should be recorded using images, sounds and/or other relevant means according to the context of the experiment.

The analysis of the data produced in the real scenario will help identify the actions and the ways in which they were executed by the user. This analysis is critical for defining the actions and gestures. It is necessary to evaluate, from data, which actions are relevant in the goal seeking and, for such actions, which gestures were more used and are therefore more likely to be recognized. After this stage, the gesture vocabulary produced must be validated.

The validation of the gesture vocabulary must also take place with the user participation. The steps that make up this stage are:

1. Validation of the set of actions defined related to the fulfillment of the actions needed to execute the application together with the evaluation of the need to insert/modify any functions and/or gestures in the application;
2. Validation of the set of gestures regarding the adequacy of their use in fulfilling the actions of the application;
3. Evaluation of user satisfaction while using the application;
4. Evaluation of the sufficiency of information about the actions/gestures supplied by the application;

This validation stage can be carried out from different approaches. We propose the development of an application prototype so the user can interact and ultimately evaluate it. This prototype does not necessarily need to have all its gesture recognition capabilities funcional. It is possible to simulate gesture recognition, or even use images to represent gestures.

Additionally, we propose the use of a questionnaire for evaluation on the part of the user, and another to be filled out by the person in charge of the experiment after observing users' interaction with the application interface.

To validate the proposed methodology, a case study of the virtual museum was conducted with the cooperation of a deaf community, and is described in the following section.

4 DESCRIPTION OF THE CASE-STUDY

This section presents the planning and the execution of the physical scenario experiment, the analysis of the information registered in that scenario that allowed the creation of the gesture vocabulary for the application, and the planning and the execution of the experiment with the prototype for its final validation.

4.1 Experiment of Interaction of Deaf Children with Physical Objects in the Real World - Planning and Execution

While planning our experiment, we came across the following question: What type of object can, simultaneously, motivate the participant to carry out the proposed task and represent 3D objects common in virtual museums?

While considering the type of object to be used, context was identified as absolutely essential when handling objects of personal use (and/or which are part of people's routine). This dependence on context refers, on one hand, to the shape of the object, especially in the case of objects supported artificially in the museum, and on the other hand the usefulness of the object, since it determines focuses of observation. The dimensions and weight may also influence the manners of handling.

In response to this issue, the following objects were defined (see Figure 1 from left to right): a vase made of paper, a box with decorative candles, a sculpture with a support, a decorative ball and a ceramic vase with a wavy shape. The sculpture and the vases were chosen because they are objects frequently found in museums and exhibitions.

The box and the decorative ball were selected to verify the behavior of participants upon viewing small objects with no clear use. It was also possible to verify the difference, if any, in viewing a larger object, such as the paper vase, and smaller ones, such as the decorative ball. According to the objects chosen, it was also possible to determine if it was more natural for the participant to use one or two hands during the visualization, as well as whether the object's size would influence this choice.

As soon as the objects were defined, it was necessary to determine a task for the participant that demanded viewing of the object from all perspectives. The potential users wee asked to describe the objects precisely and allowed to

Figure 1: Objects used during the experiments.

As soon as the objects were defined, it was necessary to determine a task for the participant that demanded viewing of the object from all perspectives. The potential users wee asked to describe the objects precisely and allowed to manipulate them anyway they wanted to.

The entire experiment was recorded for subsequent analysis. The setting was defined to use three cameras, which would provide top, lateral and frontal views of all the gestures executed by each participant.

The experiments were conducted along with students and teachers from the Prof. Ilza de Souza Santos Municipal School of Special Education for the Deaf. The experiment involved 15 people divided into four groups. The groups were classified according to each participant's degree of proficiency in Brazilian Sign language (*Língua Brasileira de Sinais*, LIBRAS).

Throughout the text, identification of the participants will be done using the group in which the participant was located.

- Student proficient in LIBRAS. Group A, composed of five participants;
- Student not proficient in LIBRAS. Group B, composed of five participants;
- Student not proficient in LIBRAS and with motor impairment. Group C, composed of two participants;
- Teacher proficient in LIBRAS. Group D, composed of three participants.

Each participant, with the exception of those in Group C, was individually taken to a room where there was a table supporting the objects to be viewed. For the participants in Group C, the experiment had to be assembled in a separate location due to the need for space for the wheelchairs to maneuver, which prevented this group's accessing the original experiment room.

Immediately at the beginning of the experiment, it was perceived that the planned instructions were somewhat unnecessary, since most participants entered the room and began to interact with the objects spontaneously.

Participants freely interacted with the objects. The participants observed, commented on the objects, and questioned the interpreter about them.

The importance of communication was noted during the experiment. While participants from Groups A and D talked about the characteristics of each object during the interaction, and gave their opinions about them, participants from Group B barely exchanged words. In this group, there were some cases where there was a blatant lack of understanding regarding what needed to be done, as well as a certain reluctance to visualize and manipulate each object. With Group C, with younger participants, their enthusiasm for participating was clear. However, due to motor difficulty, not all the signs could be interpreted, a fact that hindered communication.

The recorded videos were analyzed for the segmentation of the gestures and actions performed by the participants. The following section presents the analysis of the videos from the experiment in detail.

4.2 Theoretically Supported Analysis of the Videos for the Creation of the Gestures Vocabulary

The videos of the experiment were personally analyzed by the first author of this paper. Each action performed by the participants was identified and classified, except for the actions used for communication between the participants and the interpreter. Each user action was evaluated according to the objective and the way in which each gesture was performed, and a list with the actions/objectives of all the participants was produced.

From this list, the most recurrent actions and the objectives that were applicable to the museum context were selected to be used in the application. The emerged recurrent actions were the following, organized by the authors by semantic categories:

- Pick up the object (from the table) – "Pegar" (Figure 2);
- Let the object go (from the hands to the table) – "Soltar";
- Move the object closer (to the user) - "Aproximar";
- Move the object away (from the user). "Afastar"
- Turn the object (in several directions, along different axes) – "Girar";

- Observe the object (corresponding to none action at all).

There were some isolated actions that were dependent on specific characteristics of the object, for example, throwing the decorative ball upwards. In these cases, the actions were context-dependent and were disconsidered for the application, as the objective was to identify gestures applicable to the majority types of objects present in museums.

From the characteristics of the gestures it was possible to address the question raised during the experiment planning. As for the existence of differences between the visualization of large or small objects, the experiment showed that bigger objects elicited users to automatically use two hands to pick them up or let them go. To turn and view occluded parts of the object, even for smaller objects, the students preferred to use both hands.

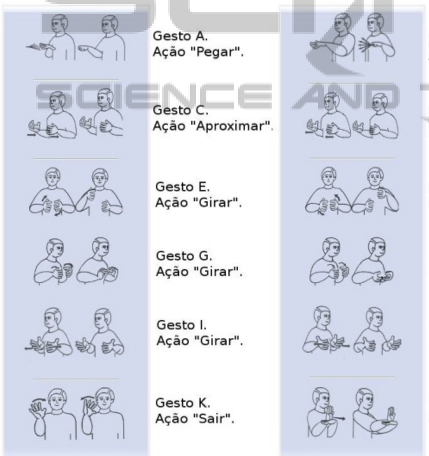

Figure 2: List of gestures and respective actions used in the interface.

Although this stage was clearly based on data analysis, established knowledge from Image Processing and from Computer Human Interaction, respectively for segmentation and semantic completeness. In this way, the x,y,z axes were adopted for objects movements to cover the objects views within the 3D space, determining 6 basic turning actions. Also, gestures and corresponding actions were organized in subsets - by opposite pairs and by semantic in general - to make their perception and interpretation clearer and actions of exit – "Sair" and help menu – "Menu Ajuda" were added.

After defining the actions and gestures which should compose our vocabulary, we went to the validation stage.

4.3 Experiment for Validation of the Constructed Vocabulary - Planning and Execution

The validation must be carried out with the same target public and objective (task) defined in the experiment with the physical objects whose handling generated the vocabulary.

The viewer developed by Vrubel et al. (2009) for the visualization of 3D models used in the experiment was developed within a project called 3D Virtual Museum (IMAGO) which encompasses the process of digital preservation from the acquisition of object data to their availability on the Internet (Mendes, 2010). The 3D objects used in our prototype came also from this project.

Buttons with images representing the gestures were inserted in the viewer. The images were created following the standards in Capovilla and Raphael's LIBRAS dictionary (2001). In this lexicon, LIBRAS signs are represented by images composed by two states and a symbol describing some movement. The objective was for the participants to press the buttons that represented the gestures they wanted to use. The buttons used and their respective actions are shown in Figure 2. The action "turning" was subdivided, due to the necessity of expressing the rotation of an object on the 3D space. It is important to notice that this would have been unnecessary if the prototype's images interpretation had worked out (i.e., if it had been already implemented).

Initially the participants received instructions about the objective of the experiment. The instructions were composed of a video, a textual description, and an image for each gesture. These instructions were available in the program's "help" menu and could be accessed by the participant as many times as necessary.

The interface and interaction environment developed for the viewer initially showed a screen for the participants to choose which object they wanted to view (See Figure 3). On this screen, all the available gestures were shown in order to not influence the participant's selection. As for clarification, the buttons on the right side of the screen of Figure 3 correspond exactly to the set of buttons showed in Figure 2.

After selecting the object to be viewed, a screen showed the participants the buttons they could use to see the object from all points of view. (See Figure 4, whose buttons also correspond exactly to the ones showed in Figure 2).

The validation of the chosen gestures was carried out with the same target public. This stage followed the same execution parameters of the previous stage. In this stage a group of five people was formed, composed of three participants from Group A, one from Group B, and one from Group D.

The first point observed during the validation was how difficult it was to understand the task to be executed. Each participant was shown the instructions present in the "help" menu with the mediation of the interpreter, who conducted the interpretation in real time. In many cases, the participant only fully understood how to use the program after interacting with it for a few moments. After the interaction with the objects, a written questionnaire was utilized to evaluate the gestures and the selected actions.

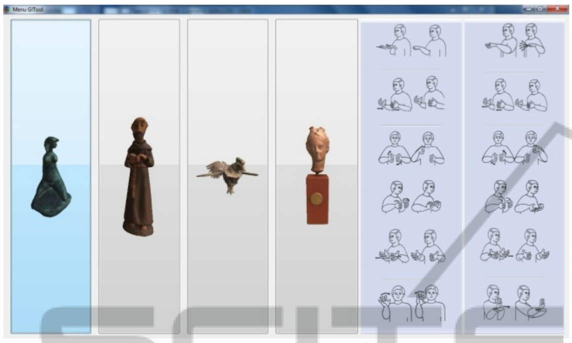

Figure 3: Snapshot of the interface for selecting the object.

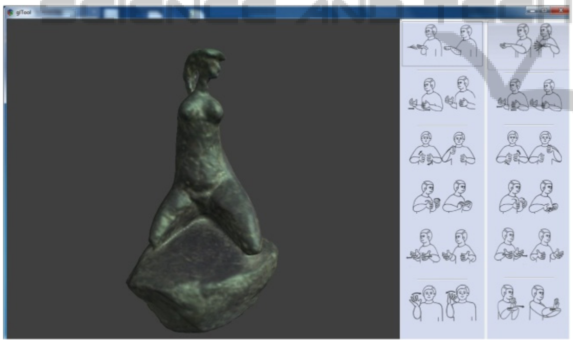

Figure 4: Snapshot of the interface for manipulating the selected object.

All five participants were able to carry out the required task and considered the available gestures adequate for the action performed. However, four of them had some difficulty in identifying the gestures required to execute the task. In these cases, many of the difficulties were related to the fact that they had difficulties in understanding the interaction environment, a difficulty external to what was being evaluated, i.e. designed from the working hypotheses that the prototype could not be implemented in time. After some clicks they were able to maintain interaction normally, which was noted by the fact that all were able to view the objects they wanted to.

To pick up an object on the screen, the participant first had to select it and then click the button associated to the gesture corresponding to "pick up". This dynamic was a complicating factor for three of the participants, and understanding it took them some time. Some participants thought that the gestures defined for the actions "pick up" and "let go" were very similar, which ended up causing confusion in the use of the corresponding buttons.

As for the actions selected for the application, four of the five participants judged them to be sufficient for the interaction. Four of the five participants thought that the selected gestures were easy to recognize. Many users associated the gestures selected for the interaction to its LIBRAS sign. This attribution occurs due to the fact that many LIBRAS signs are iconic, especially those related to spacial actions. In the case of the action "pick up", the selected gesture corresponds to the verb "to pick up" in LIBRAS.

The videos used in the "help" menu were considered relevant by the five participants and they all enjoyed participating in the experiment. When asked if there was anything that could be improved to enable deaf people to use virtual museums on the Internet, their only point regarded the problem of the similarity of the gestures corresponding to "picking up" an object and "letting it go". After a better evaluation of these gestures, we noticed that even in the real world these gestures are very similar, and what usually differentiates them is the context - whether the person has the object in hand or not. This is a question which needs to be studied more deeply for gestural interaction applications in virtual museums.

5 CONCLUSIONS

This paper presented a methodology for creating gesture vocabularies for computational systems in general. A case of a virtual museum was used to validate the methodology with a focus on the deaf community.

The tests demonstrated that the proposed method was effective for creating the gesture vocabulary, as proved by the validation experiment. The gestures identified from the participant observation were easily recognizable, understandable, and were compatible with the actions performed, essential prerequisites for a gestural system to be truly natural for the user.

Readers should note that the number of users involved does not allow for results generalization. However, our proposal was concentrated on getting indicatives of the processes' difficulties. For this kind of experiment, Nielsen (2000) recommends the participation of 5 users. This is because he points out that the test with one user can find approximately 30% of the problems and, also, that each new test brings less new problems and more known ones, being 5 the number to respond for 85% of the problems and the best cost/benefit.

A graphic interface and interaction environment was used for the representation of the gestures to validate the vocabulary. According to the experiment, this was a valid strategy for the participant to view and handle the virtual object. Of the five participants, all managed to carry out the required task and thought that the available gestures were adequate for the action performed.

From the experiments it was possible to notice that it is easier to understand the activity when the system is shown in use. Therefore, instead of presenting textual content, image, and video as a help, it would be more appropriate to produce a video showing it in typical interactions. After using the program for a time, the user adapted to the environment.

As the main contributions of present work we can see the following:

a) as for movements representation: the extension of the graphical 2D language to represent some movements not present in Brazilian Sign Language (LIBRAS) though, as we argued before, this would be of no use in "real virtual museums" (where the image interpretation capacities were implemented);
b) the extension of Nielsen et al's process with a previous state – the observation of potential users interacting with the physical scenario that motivates the innovative virtual uses. This stage is specially critical when there is space for innovation in the transposition of physical tasks to virtual environments, as it is the case of virtual museums;
c) the exemplification of an alternative and more active way of bringing potential users to the stage of defining the right gestures vocabulary suggested by Saffer (2009) through the planning and execution of a physical scenario to bring insights about the innovative virtual space when compared to the physical real one.

The use of new gesture recognition technologies such as the Kinect can make the experience of visiting virtual museums more pleasant. We propose the application of this gesture vocabulary using this device for its interpretation. This would avoid the problems introduced in the experiments by the necessity of using an intermediate 2D representation of the 3D movements.

One critical experiment planned is the one involving deaf and non deaf users in order to make a comparative analysis of results. This will prove or refute the hypotheses that results are extensible to non deaf users and, additionally, allow us to see whether the deaf culture – that sees the World from a gestural-visual prism – brings any special feature to our scene.

Still for future work we propose the planning and execution of the experiments of creating and validating the gestures vocabulary in an statistical manner - crossing exhaustively objects different variables (high, weight,…) and taking an statistic sample.

We also propose the application of the methodology for the creation of gesture vocabularies proposed by the present paper for other types of natural interactive applications to verify its degree of generality related to application domains and, also, to identify if the set of gestures and actions proposed here can be seen as the "core" set of gestures and actions for gestural interaction interfaces environments in general.

REFERENCES

Moore, R., Lopes, J., 1999. Paper templates. In *TEMPLATE'06, 1st International Conference on Template Production*. SCITEPRESS.

Beurden, M. V., IJsselsteijn, W., and de Kort, Y. 2011. User experience of gesture-based interfaces: A comparison with traditional interaction methods on pragmatic and hedonic qualities. *In the 9th International Gesture Workshop: Gesture in Embodied Communication and Human-Computer Interaction*, Athens, Greece.

Boulos, M. N. K., Blanchard, B. J.,Walker, C., Montero, J., Tripathy, A., and Gutierrez-Osuna, R. 2011. Web gis in practice x: a microsoft kinect natural user interface for google earth navigation. *International Journal of Health Geographics*, 10.

Capovilla, F. C. and Raphael, W. D. 2001. *Dicionário Enciclopédico Ilustrado Trilíngue da Língua de Sinais Brasileira*. EdUSP - Editora da Universidade de São Paulo, 2 edition.

Chino, D. Y. T., Romani, L. A. S., Avalhais, L. P. S., Oliveira, W. D., do Valle Gonçalves, R. R., Jr., C. T., and Traina, A. J. M. 2013. The nina framework - using gesture to improve interaction and collaboration in geographical information systems. *In International Conference on Enterprise Information Systems - ICEIS*, pages 58–66.

Grandhi, S. A., Joue, G., and Mittelberg, I. 2011. Understanding naturalness and intuitiveness in gesture production: insights for touchless gestural interfaces. *In Proceedings of the 2011 annual conference on Human factors in computing systems, CHI*, pages 821–824, New York, NY, USA. ACM.

Imago, G. Museu virtual 3D: Preservação digital de acervos culturais e naturais. http://www.imago.ufpr.br/museu3d/.

Mendes, C. M. 2010. Visualização 3D interativa aplicada à preservação digital de acervos naturais e culturais. Master's thesis, Universidade Federal do Paraná.

Nielsen, J. 1993. *Usability Engineering*. Morgan Kaufmann, 1 edition.

Nielsen, J. 2000. "Test with 5 Users", Alertbox. http://www.useit.com/alertbox/20000319.html [Picked up in May,2003].

Nielsen, J. 2003. Introduction to usability. http://www.useit.com/alertbox/20030825.html.

Nielsen, M., St¨orring, M., Moeslund, T. B., and Granum, E. 2004. A procedure for developing intuitive and ergonomic gesture interfaces for hci. In Camurri, A. and Volpe, G., editors, *Gesture-Based Communication in Human-Computer Interaction*, volume 2915 of Lecture Notes in Computer Science, chapter 38, pages 105–106. Springer Berlin / Heidelberg, Berlin, Heidelberg.

Norman, D. A. and Nielsen, J. 2010. Gestural interfaces: a step backward in usability. *Interactions*, 17(5):46–49.

Saffer, D. 2009. *Designing Gestural Interfaces*, O'Reilly Media, Inc. Canada.

Vrubel, A., Bellon, O. R. P., and Silva, L. 2009. A 3D reconstruction pipeline for digital preservation. *IEEE Conference on Computer Vision and Pattern Recognition*, 0:2687–2694.

Wigdor, D. and Wixon, D. 2011. *Brave NUI World: Designing Natural User Interfaces for Touch and Gesture*. Morgan Kaufmann, 1 edition.