VMAG 3D – An approach for supporting the comprehension of software system models using motion control in a multiuser 3D visualization environment

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Abstract. *This paper presents an approach for Model Visualization Assisted by Gestures in 3D, called VMAG 3D, to support the three-dimensional visualization of system models. It is inspired by the VisAr3D approach, a teaching and learning environment that provides the exploration and interaction of UML models with the use of 3D visualization, and aims to support the visualization of computer systems models, using gesture control, favoring a better usability and opening the possibility for a greater accessibility, while encouraging collaboration and communication among users. A prototype based on this approach was developed and a study was done to evaluate its usability, finding positive evidences from user experience.*

1. Introduction

System modeling is fundamental in learning and understanding of computing systems [Cian *et al.* 2017]. However, as technology progresses, these systems become increasingly larger and more complex, involving a greater number of components and working with a larger amount of data. This, in turn, makes the modeling such systems more demanding, having to represent much more elements and relationships, not only requiring a large amount of documentation, but also the means to organize it [Hamunen 2016]. This increase in the amount of data being presented leads to more difficulties when viewing and comprehending said models and the systems they represent. In order to support the comprehension of system models, applications have been developed to provide support, usually by offering different methods of visualizing the models and filtering the data shown, reducing sensorial overload [Chi 2000].

Applications that support the comprehension of abstract concepts like system modeling, be it through visualization or other means like setting frameworks, have shown to benefit from non-conventional approaches, such as Virtual Reality [Rodrigues 2016] or Multimodal Interfaces [Narayan 2017], to name a few. These approaches in particular offer more natural forms of interaction, visualization and collaboration among multiple users [Cohen *et al.* 2015], including allowing different forms of interaction at the same time [Greenwald *et al.* 2017]. With these, it's possible to support the visualization of software and its components, from different viewpoints, in a more natural manner, favoring its comprehension.

This paper presents the VMAG 3D Approach: Visualization of system Models Assisted by Gestures in 3D. Based on the VisAR3D approach described in [Rodrigues

2016], VMAG 3D has as its main objective to support the understanding of systems models with a large number of elements. This is done by providing the user with the ability to interact with diagrams displayed on the computer screen. A Kinect sensor is used to track the gestures of users, allowing a non-traditional way of interaction, as well as increasing the user's interest in the subject provided by the novelty of motion controls. Audio capturing also allows students to recall their observations about the diagrams, encouraging communication between them.

This paper is organized in 5 sections. Besides this introductory section, Section 2 presents some fundamental concepts that are relevant to the approach. Section 3 describes in detail the VMAG 3D approach, and Section 4 describes the evaluation of usability conducted. Section 5 ends this paper with the conclusion.

2. Fundamental Concepts

2.1. Virtual Reality

Virtual Reality (VR) can be defined as an "advanced user interface" for accessing applications running on the computer, allowing real-time visualization, movement and user interaction in three-dimensional computer generated environments [Kirner & Siscoutto 2007].

In order to allow this interaction, a system that employs VR needs to use various types of devices that provide the user with means to interact and visualize the virtual environment [Huang *et al.* 2010]. An example of such devices would be Motion Capture sensors, like the Kinect sensor developed by Microsoft [Alves *et al.* 2012], which particularly allows the capture of sound, as well as tracking up to 6 users simultaneously.

Due to the possibility of immersion and interaction with an environment that can be adapted to several situations, many of which simulate risk situations while keeping the user safe, VR has found its use for applications in several areas [Sherman & Craig 2002], such as education and entertainment, among others.

2.2. Multimodal Interfaces

Multimodal can be understood as having "multiple modes" or "multiple modalities" of interaction, with each mode being associated with at least one of the senses of perception: hearing, sight, touch, smell and taste [Inacio Júnior 2007]. Thus, one can understand multimodal interfaces as interaction interfaces between one or more users and a computer system that allows a varied number of data inputs [Reeves *et al.* 2004].

One of the advantages of using multimodal interfaces is user adaptability: the user can choose the method that is most practical in a given situation, such as operating a telephone by voice commands [Laput *et al.* 2013] and switch to touchscreen controls when convenient. Another important aspect of systems that use multimodal interfaces is the potential for greater accessibility [Oviatt & Cohen 2000].

However, when developing applications that use this technology, it is important to take into consideration how information is presented to the user, in order to avoid overloading information [Moreno & Mayer 2002]. Other points that require special care during development are the necessity of system feedback to users, data consistency, and adaptability [Reeves *et al.* 2004].

2.3. Collaboration

Collaboration can be defined as an activity where members of the same group work together and mutually support each other to achieve a common goal. This collaborative work occurs without the existence of hierarchical forms of division of tasks. There are no "managers" or "administrators" [Carlone & Webb 2006].

A development environment can be said to be a Collaborative Environment if it provides means for its members to interact with one another, favoring communication and coordination of activities, which can be done with the aid of specialized software supporting group work, a Groupware [Kan *et al.* 2001].

2.4. VisAr3D

VisAr3D - 3D Software Architecture Visualization approach represents a teaching and learning environment that uses Virtual Reality and Augmented Reality (AR) technologies to provide the exploration and interaction of UML models through 3D visualization. This approach was proposed in [Rodrigues 2012] and several of its concepts serve as the basis for the VMAG 3D approach.

Its main objectives are: support students' development and participation in complex projects, reduce the distance between theory and practice, support the assimilation of knowledge and skills, be attractive to students, simplicity and ease of use, the 3D diagrams used look similar to the original 2D models, visual enhancement and hide details and information when not requested.

The VisAr3D architecture is divided into three modules: an Architectural Module, where diagrams are created, documented, and exported in XMI[1] format; an Augmented Reality Module, which recognizes the 2D projection of the diagram and allows access to the related XMI file; and a Virtual Reality Module, responsible for automatically displaying a 3D model based on a 2D projection.

3. VMAG 3D

VMAG 3D - Visualization of system Models Assisted by Gestures in 3D - approach offers a way to encourage and assist computer students in understanding complex models in a collaborative way. In order to offer a different form of control, it uses a Kinect sensor to capture gestures and audio, offering a multimodal interface for interaction. An application of the same name was developed in order to better showcase this approach, as well as to allow a study of its usability, which will be detailed in the next section.

The main objectives of this approach are: supporting the comprehension of System Models, encourage collaborative work within System Modelling and promote greater student interest in that area.

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[1] http://www.omg.org/spec/XMI/

To achieve these objectives, the following functionalities were developed: Exploring the models using either gestures or the mouse, in a 3D environment; Exhibition of multiple models, allowing a better understanding of components of a system and its interactions; Data Filtering, reducing the amount of data that are displayed, allowing users to select what they want to see; Audio recordings, which can store user commentaries regarding specific models; System Feedback, which helps users to better understand details of the application's operation; Multimodal Interface, allowing users to choose their favorite method of control; and collaboration support, using the Kinect's capability to track up to 6 people, simultaneously.

The application was developed using Unity3D[2], with its coding made using the C# language. Data regarding the models are stored in XMI files, which can be created and edited using third-party software, such as Spark's Enterprise Architect[3].

The application's interface (Figure 1) allows the users to select 1 out of 7 data filters, showing the element's name, which diagrams contain these elements, their attributes, their operators, any documentation related to that element, in which package they are contained, and the author's name, respectively. Once the desired filter is selected through the arrow buttons, the user just needs to hover over the desired element with either the mouse cursor, or the hand cursors that are tracked to each user's right hand. The top-right button displays and hides the Audio Interface. It is possible to see a list of messages already recorded associated with the diagram, if any, and new messages are automatically added to the list.

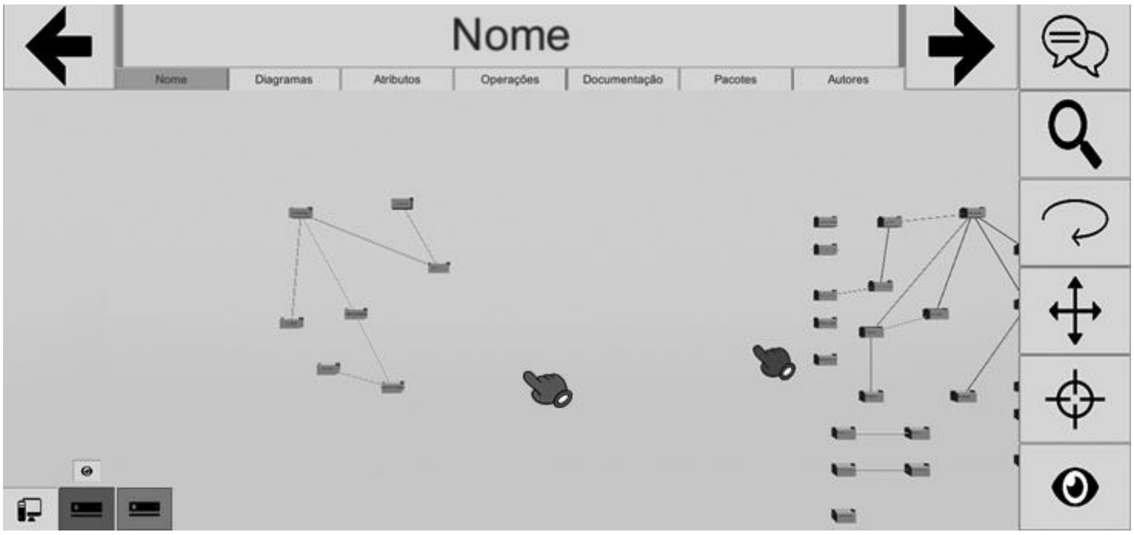

Figure 1. VMAG 3D's Interface

Also on the right side of the main interface, below the Audio Interface button, there are five buttons used to control de visualization. They allow the users to, respectively, from top to bottom: zoom in and out, orbit around a point in the view, move the view perpendicularly to the direction that the view is pointing at, reset the view to its original position, and request control of the view. These controls allow users

[2] https://unity3d.com/

[3] http://sparxsystems.com/products/ea/

to explore complex diagrams, by giving the possibility to view those in more detail, focusing in specific parts, and so on.

Given that multiple users can operate the application at the same time, in order to avoid conflicts for controlling the view, only one user can operate it at a given time. Any user can request control of the view by interacting with the Request Control button (at the bottom). If no user already has the control, he/she will be able to interact with the other four buttons and move the view around. To release control, all that is required is to interact with the Request Control button again.

Since keeping track of which user is controlling the view can become somewhat hectic, a display located at the bottom-left corner of the screen shows which users are being tracked, as well as which one, if any, has control over the view. These icons match the colors of the cursors, for the users being tracked by the Kinect sensor: Blue, Red, Green, Yellow, Purple and Orange.

4. Evaluation

According to [Juristo & Moreno 2010], Experimental Software Engineering states that the validity of any knowledge must be evaluated so that it can be considered scientific. With this in mind, a study to evaluate the application of VMAG 3D tool was planned and conducted in July and August 2017, respectively.

Following GQM – Goal/Question/Metric [Basili *et al.* 1994], the objective of the evaluation was to analyze the use of the VMAG 3D prototype, for the purpose of characterizing, with respect to usability, satisfaction and user perception in using gesture control when operating a visualization tool of three-dimensional UML models, from the point of view of researchers, in the context of execution of tasks by students, similar to those applied in a Systems Modeling discipline, using a system with many modeling elements. The study placed participants as users of the application, who should operate it to obtain data within a model. All participants were exposed to the same model and the same tasks in order to maintain a standardization of the results obtained. This model was based on the Odyssey tool model [Werner *et al.* 1999], presenting four diagrams belonging to the tool, and containing 91 classes.

Bearing in mind the cooperative nature of VMAG 3D, some of the tasks were conducted in pairs, with one researcher serving as the participant's assistant, being careful not to influence the outcome. It was decided to assign eight tasks, out of which five were done by the participant alone, and three done as a team.

A pilot study was performed with a master's degree student in Software Engineering. This pilot helped to adjust some of the questions for the evaluation. After that, ten participants were selected, through convenience by the indication of third parties and advertisements spread throughout the Technology Center building, at the Federal University of Rio de Janeiro (UFRJ). All participants were students, but of distinct academic levels (ranging from graduation, master's degree and doctorate's degree) of areas related to computing and with some level of knowledge about UML models.

Each participant received basic training through a presentation, showing the features and controls of VMAG 3D. This training was followed by a brief interval for the user to freely interact with the tool, in order to avoid the possibility of any kind of bias caused by the lack of familiarity with the provided controls. These activities lasted 10 minutes, approximately. After the training, each participant received the tasks which involved using the tool to identify specific information within the model and make use of the tool's functionalities. Some examples of those tasks would be making an audio recording stating what was the attribute of a specific class, or finding which class was part of another diagram. With the completion of all tasks, each participant received the evaluation questionnaire. Each run took 60 minutes, approximately.

4.1. Results

All 10 participants managed to accomplish the tasks and answer the questions correctly. Regarding their experience using VMAG3D, only 10% of the volunteers said they had difficulties operating it. Participants also stated that the simplified models helped visualize the diagrams and better comprehend the relationship between classes.

Participants who stated that they were comfortable interacting with the interface (40%) were also those who affirmed being more familiar with gesture controls, which implies that the source of this difficulty is not exclusively the application itself, but the level of the user's experience with gesture controls also played a part on it. This is reinforced by some comments from the participants. Furthermore, while some users had trouble interacting with the interface, the Kinect's capture seemed to work properly for more wide and open movements, which according to users, provided a better experience for exploring the diagram.

Furthermore, 90% of the participants affirmed that the tool was adequate to multiple users at the same time, with 60% of users verbally expressing the ease in doing the tasks in a team, in comparison with the individual tasks. It is also important to consider that both types of tasks had the same type of format in order to avoid bias.

Comparing users' satisfaction with the two control methods, gesture control versus mouse and keyboard, it is possible to note that there was a greater affinity for mouse control. This can be justified by the fact that controlling with the mouse is more common and, by being more familiar, presents less difficulty. However, it is important to note that more than 80% of users reported being "Satisfied" or "Very Satisfied" with gesture controls, with one volunteer commenting: "It seems to be an interesting tool for viewing diagrams. Zoom and camera movement are very useful for this".

5. Conclusions

The purpose of the VMAG 3D approach was to allow the user to manipulate 3D visualization of models of a software system by gestures, facilitating the understanding of the model and the user's learning, as well as encouraging other important practices for the understanding of models: collaboration and communication between users.

The evaluation showed that users could use the prototype to view the data and acquire the information contained therein and that its operation occurred in a comfortable way, with little training required and little difficulty in use.

The main contributions of this work as a whole are: insertion of multimodal interface in the VisAr3D approach, exploration of the possibility of using audio recordings as a way to encourage communication between users, and evaluation of the contribution of 3D visualization by more than one user.

From a critical analysis of the approach, as well as some comments made during the evaluation of its implementation, some limitations could be identified. Among them, those related to decisions taken during the development of the approach are: it is currently restricted to the understanding of UML models, the Kinect sensor has considerable serious accuracy problems. Other limitations pertain to the evaluation performed, like the amount of participants used and the difficulty of some of the tasks.

This approach opens up new research perspectives that can be explored in future works, such as: improving the interaction between the user and the interface, promoting a greater interaction among users and encouraging collaboration, inserting other forms of application control, and conducting a new evaluation.

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