Heads Up Displays (HUD) as a Tool to Contextualize the User in 3D Virtual Worlds

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***Abstract*—Virtual Worlds are open 3D environments that can be used to implement virtual laboratories and simulations, improving student interaction. However, it is often seen that their freedom characteristic can cause dispersion for the user, making it difficult to navigate and focus. This paper presents a proposal to reduce the difficulties of this impasse, with a Heads Up Display (HUD) solution that dynamically and constantly senses the locations visited by the avatar, and presents it in the form of a "heat map". An experiment was conducted with 16 individuals that formed the experimental and the control groups (with and without the HUD). The results reveal the usefulness of the HUD, allowing to see that this resource provided a real-time view of the user interaction and places visited, helping him/her navigate the Virtual World.**

Keywords-virtual worlds; heads up display; heat map.

I. INTRODUCTION

Virtual Worlds (VW) are complete 3D environments where virtual laboratories and simulations can be implemented, and users represented by their own avatars can move around, meet and interact with other avatars [1]. According to [2] it opens the possibility for students to perform lab practices at any place, time and at reduced costs and risks of human accidents from eventual problems during experiences. Although the development of these environments is quite a lengthy process, long term benefits of its use may arise, since it can be used several times [3].

VW offers a great level of freedom, as the user not only can chose when to learn, when to enter the environment, but also what to learn and in what order, which is in agreement with active modern pedagogical approaches. Due to the great diversity of didactic materials that can be inserted in this type of environment, such as texts, videos and images, different types of rooms can be created, separated by type of content, so that the user can interact with each topic and their respective educational materials. This opens the possibility for the users to navigate through different locations within the VW.

However, this openness of the environment and freedom received by the users is often seen as a cause of dispersion, leading to several implications, as engagement hindrance or discouragement on the following of their pedagogical trajectory. According to Mayer [4] environments designed to make users discover materials completely on their own are harder to use. Csikszentmihalyi [5] highlights that activities stimulate more flow if they embody certain rules and clearly state what the users should do.

In a complementary way, Sivunen and Nordbäck [6] found that team dispersion could be one of the causes of low social presence among participants. Gütl [7] discovered that if users spend too much time learning to use a complex interface they might leave these environments. In [8], the authors explored how examples of reflective guidance, directive signs, symbols, footprints and notice boards within the environment might be helpful to achieve the learning goals, getting some positive results.

Ubiquitous computing techniques can help overcome these drawbacks. In an educational ubiquitous computing enhanced environment, the fundamental issue is how to provide learners with the right information at the right time in the right way [9]. The so called ubiquitous learning systems aim to provide personalized learning support based on students' preferences, learning status, personal factors as well as the characteristics of the learning contents and learning environments [10].

In this study, we propose the use of ubiquitous computing techniques to provide a context-aware VW, using Heads Up Display (HUD), a device that can be attached to the user's screen for different purposes. Our work dynamically infers user's context, working as a "heat map" that changes the color according to the locations of the 3D environment that the user has visited. It is assumed that this could help with students navigation, decreasing the losing of focus and keeping them aware of the locations they still have to visit. Therefore, the hypothesis of this research is: "using a heat map HUD in 3D VW can facilitate engagement and increase interaction time".

The rest of this paper is organized as follows. Section II presents the related work. Section III explains the research method. Section IV addresses the results analysis and discussion. Section V presents the conclusion.

II. RELATED WORK

Virtual Worlds projected for learning purposes contain a variety of educational resources modelled inside it. In this sense, it is desirable for the user to spend long times navigating it. Users who spend more time in the VW tend to interact more with educational objects [11].

However, one of the most complicated aspects of 3D VW is scaffolding or guidance, since it is very large and flexible [8]. Ubiquitous computing techniques can help overcome this challenge, improving student performance and consequently improving institutional cost effectiveness [12]. One illustrative example of a context-aware 3D VW is an environment for teaching Computer Networks presented by [13], where student's context is used to adapt the materials, tools and information according to their level of expertise.

In consonance with this trend, several researches have benefited from the use of Heads Up Display (HUD) device capabilities to personalize and dynamize VW. Shah, Bell and Sukthankar [14] implemented a recommendation system that suggests places to visit, personalized with the user's destination preferences. To acquire data on users' travel patterns, they developed a custom tracker object using the Linden Scripting Language (LSL), which periodically prompts the user to enter information describing its current location. The tracker object appears as an HUD that can be worn on the right or left of the avatar and monitors the user's current (x, y, z) location.

In the study of [15] participants were each given a HUD that allowed them to indicate up to eight emotional states throughout the presentation (four positive and four negative). The goal of using the device was to identify and analyze which aspects invoked emotional responses and what kinds of information were considered trustworthy or untrustworthy.

One of the promising VW applications that seem to demand such a device is the visit of virtual museums. Sookhanaphibarn and Thawonmas [16] emphasize that personalization can play a key role for increasing the number of return visitors. They have mentioned the idea of using HUD to show personalized recommendations in VW, similarly to what has already been implemented for physical museums, but with the advantages of requesting simple implementation and no additional cost.

Ward and Sonneborn [17] implemented a HUD that provides subtitles of dialogue in many languages, including English, French, German, Spanish, Italian, and Portuguese. Also, the HUD records the avatar's position so users can know where they are in the build and receive audio, pictorial and textual information about what they are seeing on their visit, like a virtual version of the sort of devices used in real life museums.

In the field of displaying locations to situate the user, the Virtual Learning Environment (VLE) MOODLE in more recent versions (2.7 onwards) has a plugin that implements the "heat map" concept to help user navigation, using a color scheme (yellow, orange and red) to represent the "heating". The heat map highlights areas as well as components that highly attracted student's attention by counting the number of mouse clicks [18].

Similarly to the studies presented, in this paper we show the results of the development and application of a context-aware HUD that works as a heat map, "heating" as the locations in the VW are visited more often, allowing the user to be aware of his navigation behavior. The HUD is attached to the user's screen and keeps sensing the places visited, registering into a database and retrieving this information in real time. Our research differs from the ones mentioned because of the heat map characteristic of the HUD, towards investigating an unprecedented hypothesis that this device could help on improving engagement and interaction time. Also, our heat map counts local visitation per user, showing it individually to each one.

III. MATERIALS AND METHOD

This research is an exploratory quasi-experimental study, in which a case study was performed with a convenient sample of university students that had a minimum level of computer skills. To investigate the hypothesis, the sample was separated in two groups: control, who did not use the heat map, just interacted with the VW without this device, and, experimental, who used the VW with the heat map device, and experimental, that used the VW with the heat map device.

A region in a Virtual World from project AVATAR [19] (from the Portuguese of Virtual Learning Environment and Remote Academic Work), on the open source platform Open Simulator was used. Students enrolled in courses at the authors' university and colleagues that work on the project were invited to spontaneously participate in the experiment, which took place on Universidade Federal do Rio Grande do Sul facilities. Singularity [20] and Firestorm [21] viewers were used to enter the VW, because these pieces of software are capable of representing the 3D graphical environment in an appropriate form.

A. *The Virtual World*

Two virtual laboratories were used: Waves and Wireless Networks, which are introduced on [22]. According to the authors, in these virtual labs students from Secondary or Technical education have the opportunity to visualize the practical side of some abstract concepts that are part of their daily life. Figure 1 shows a screenshot of the environment entrance. It can be seen that an instruction manual and a control panel were placed at the beginning of the path, to give the user introductory information about the experiment, for example, on how to move around, use the didactic materials and what is expected in this visitation.

Figure 1 - Waves and Wireless Networks Laboratories entrance.

Due to the comprehensiveness of these two teaching contents it was decided divide them into 12 topics, distributed along 12 specific locations in the two laboratories, which are presented in Table 1.

TABLE I. LOCATIONS AND TOPICS DISTRIBUTION

Location number	Content topic/subject
1	Wave Characteristics
2	AM and FM Radio Waves
3	Wave Phenomena
4	Electromagnetic Spectrum
5	Introduction to Wireless Networks I
6	Introduction to Wireless Networks II
7	Wireless Network Topologies
8	Infrared and Bluetooth
9	Range of Wireless Networks I
10	Range of Wireless Networks II
11	Range of Wireless Networks III
12	Material interference in propagating the wireless network

Didactic materials, such as videos, slides, images, texts, animated digital media, audios, web pages embedded in QR (Quick Response) Code and simulations according to the subjects are available in these locations, each one identified as to their type through luminous plaques.

B. The heat map HUD

In the experimental group, a HUD was attached at the top right of the users screen with a numerical map of the environment. The HUD is composed of 12 prims (primitives – 3D object unit) that are linked. Each prim has its own texture that identifies the number and the topic of the location, and its own scripts to change its color, "heating" according to the frequency of access and time elapsed on avatar visitation. To do this, the classification presented in Table 2 was idealized and adopted.

TABLE II. HEATMAP CLASSIFICATION ON HUD

Color	Tag	Frequency	Time elapsed
Yellow	Weak	Second time	2 minutes
Orange	Medium	Third time	3 minutes
Red	Strong	Fourth time	4 minutes

Besides LSL (Linden Scripting Language) programming language, Open Simulator Scripting Language (OSSL) was used to program the HUD. To capture data from each user in real time, sensors programmed with scripts were inserted in each one of the 12 locations of the VW. These sensors collect data and send it through HTTP requests to PHP (Hypertext Preprocessor) files in the server. These PHP files treat the data and insert them in the table created in a MySQL database.

Data stored in the table "Heat map" of the database were as follows: a) user's name; b) name and identifier of the location visited; c) time user remained in that location; d) the current heat map status for the user at that location; e) time records. When visiting a location for the first time, a new complete record is inserted in this table, and only the current heat map status attribute is subsequently updated, according to an incremental analysis of time elapsed.

In this sense, if the user has remained at one of the 12 locations for more than two minutes, it is assumed the user is visiting this location for the second time, so the prim on the HUD that corresponds to this location turns yellow; after three minutes it turns orange and after four minutes it turns red. A sensor checks every five seconds for the presence of an avatar and consults in the database if this specific avatar has already visited the place, registering it after every minute (60 seconds) in an incremental way. The prim also has the ability, by touching it, to tele transport users avatar to each one of the 12 locations.

Figure 2 shows the heat map following the user avatar at different scenarios of the VW. It can be seen, for example, that this user has visited Location 5 very often (red), but Location 3 lacks visiting, as it is still white (top screen). It also shows in the bottom screen that Location 8 is now red, as the user is currently at this location again and probably has spent more 2 minutes observing a simulation (from yellow – 2 minutes; to red – 4 minutes).

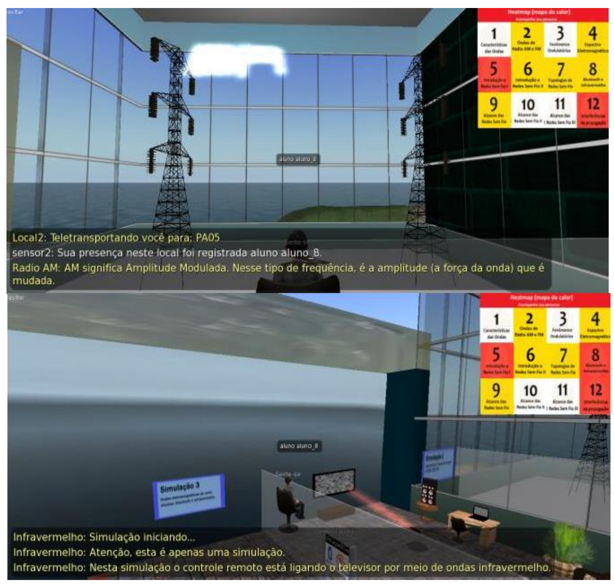

Figure 2 – Heat map HUD under different scenarios.

The locations were signalized with circles on the floor and the sensors are programmed to sense avatars presence in a radius of eight VW meters. Messages are sent to the user about the simulation or educational materials he is currently seeing during this visit.

As mentioned by [21], VWs such as Open Simulator — developed using open-source software — allow developers and teachers to access student logs and retrieve valuable information on learners' in-world behavior and interaction. This possibility, explored in this research, is important not only in terms of assessment: it also facilitates the identification of learner profiles and VW behavior patterns.

C. *The experiment*

Initially, students were informed about the experiment goals, the voluntary aspect of their participation, as well as about the complete confidentiality of any data gathered about them. Each one received an individual login to access the 3D environment. Users were instructed to navigate freely and intuitively in the VW, without any pedagogical path or visitation time previously defined. The purpose of this choice was to provide users with freedom to interact in places they considered appropriate, visiting the desired materials and remaining in a location as long as they were interested.

Immediately after the session, a questionnaire was administered, containing demographic questions about the participants including age, gender, instructional level and VW experience, and items about the navigation in the environment and the impressions regarding the heat map (HUD).

In order to compare the results between control and experimental groups, five questions related to the users impressions concerning the environment characteristics have been evaluated, which can be seen in Table 3.

TABLE III. QUESTIONS RELATED TO THE ENVIRONMENT

Characteristic	Question
Easy and Intuitive Operation	Q1: Was the system operation easy and intuitive?
Easy Navigation	Q2: Were you capable of orienting yourself in the environment?
Provided Information	Q3: Did the system adequately inform you about what was going on?
Provided Instructions	Q4: Did the system clearly indicate what could (or couldn't) be done?
Overall Impression	Q5: Would you like to use virtual labs like these in your area of application?

Additionally to the questions that were administered to both control and experimental groups, a set of questions was answered only by the experimental group, since they were specifically related to the impression about the use of the heat map. These questions can be seen on Table 4.

TABLE IV. QUESTIONS RELATED TO THE HEAT MAP HUD

Characteristic	Question
Localization Support	Q6: Did the heat map help you to orient yourself in the environment?
Information Format	Q7: Did the heat map provide interaction information in an adequate manner?
Timely information	Q8: Did the heat map provide the information in the appropriate time?
Usefulness	Q9: Was the heat map useful?
Design	Q10: Was the heat map design pleasant (colors, format)?
Overall Impression	Q11: Would you prefer to use the environment with or without the heat map?

Except for Question "Q11" that was in multiple choice format, all the others were in the 5-point Likert scale format, with 1 being strongly disagree and 5 strongly agree. The results of the experiment performed are presented as follows.

IV. RESULTS ANALYSIS AND DISCUSSION

A total of 16 individuals participated in this study, as can be seen in Figure 3, which shows the sample's demographic data.

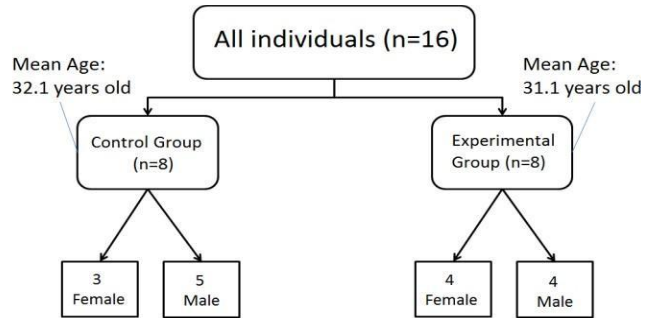

Figure 3 – Sample's demographics.

Regarding the instruction level of the participants, both groups were very similar in this inference: 50% of individuals held Bachelor's or Master's Degree and 50% were Doctoral students. Concerning previous knowledge on VW, individuals of control group had more previous knowledge than the experimental group: while 50% of individuals of control group answered the Likert scale on either levels 4 or 5, only 25% of individuals from the experimental group answered in these levels.

A. *Quantitative Analysis*

The answers related to the evaluation of the experience of exploring the environment (Questions 1 to 5) were positive in general, which can be seen in Figure 4. Out of all responses to the questionnaire, about 78% were positive (levels 4 or 5 of Likert scale), around 13% were neutral (level 3) and only 7.5% were negative (levels 1 or 2). A comparison between control and experimental groups, taking into consideration all responses (Questions 1 to 5), shows a similar result, but there were more responses at level 5 from the experimental group than from the control group (55% versus 40%).

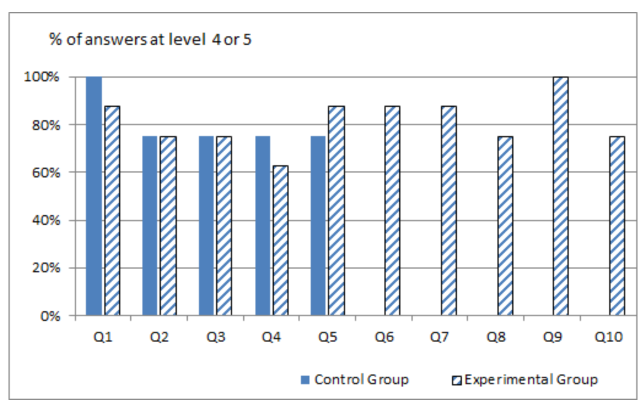

Figure 4 - Summary of questionnaire answers.

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In order to test whether the identified differences in responses were statistically significant and therefore could be extrapolated to the population of users, statistical tests have been performed using nonparametric Mann-Whitney test with 95% confidence level. The test checks whether the two groups come from the same population, that is, test whether the two independent groups are homogeneous and have the same distribution [23].

For all questions the null hypothesis (there are no significant differences) tests of the responses medians have not been rejected, since all *p*-values were above 0.05. However, this must be taken with a proper caution, due to the fact that it was a small sample (only 8 respondents per group).

This result shows that both groups predominantly agreed that: the system operated satisfactorily and its navigation was intuitive (Q1); they were able to locate themselves in the environment autonomously and without major difficulties (Q2); the environment was properly identified, with clear information about the contents and rooms available (Q3); the system has conveniently indicated what should be done and which instructions should be followed (Q4); and finally, users have generally indicated that they would like to use this environment in their domain area (Q5). This reveals an interesting result, showing that both groups well accepted the resources and considered their navigation adequate and that the process of interaction occurred properly.

Concerning the user's impression about the heat map HUD itself, the general responses can also be seen in Figure 4. The experimental group that used the VW with the HUD considered that this device helped them to navigate during their trajectory in the environment (Q6): around 87% of participants gave positive answers (4 or 5 points). The same percentage was obtained for Q7, allowing to infer that experimental group understood that the heat map provided information about their interaction in real time and in an appropriate way. On the other hand, the positivity on answers decrease to 75% on Q8, but reasonably allowing inferring they considered the heat map showed information in an appropriate time. They have unanimously strongly agreed that this device was useful for navigation (Q9). The heat map design characteristic was not so positive according to the answers (Q10). Despite of that, 75% of answers were positive, allowing to conclude that the arrangement of the heat map colors and format was considered adequate. This demonstrates that besides the approval of the environment in both groups, the experimental group indicated a positive tendency regarding the use of heat map HUD, emphasizing that this feature added even more to the quality of interaction in VW.

In addition, all of experimental group participants stated preference on using the Virtual World with the heat map HUD (Q11). The average time spent on visiting the environment was 35 minutes for the experimental group and 32 minutes for the control group.

In this sense, although not statistically proven, some differences between the two groups were identified in the quantitative analysis. There were slightly more positive responses (at levels 4 or 5) from the experimental group than the control group. Considering also that there was a little more time spent in the environment from the experimental group, we can conclude that our hypothesis "using a heat map HUD in 3D VW can facilitate engagement and increase interaction time" is true.

B. Qualitative Analysis

The participants from both groups of the study were invited to add comments about their experience at the end of the questionnaire and 75% of them provided inputs to help clarify their ratings and also some suggestions. Among the positive comments from participants of control group they have mentioned the environment is an interesting and productive way of learning, with potential to be a teaching instrument of the highest quality. According to them it is interesting the proposal to visualize some concepts, helping to make it less abstract. One of the participants teaches the same subject of the labs and mentioned he would like to use the environment in his class.

Among the negative comments in control group, they have mentioned there is some information overload, with many warnings and messages overlapping, disrupting the interaction. Some revealed that although intuitive enough, at times they did not know where to go or what to do, highlighting the need for more tips or indications. In this context, a user feedback is transcribed below:

"There are arrows on the floor that indicate the direction, but after each 'section' ends, there is no indication of where we should go (I believe it to be intentional, giving the student freedom), but it could be suggested to the student."

Among the positive comments from participants of experimental group, some of them mentioned the heat map helped them navigate, being very useful. As mentioned by most of them, the environment is of easy interaction and location, well intuitive, with beautiful and nice design. They revealed that they had a great user experience, finding the labs and the simulations very interesting. One participant has mentioned he wanted to participate in the test of the next version of the VW. A clipping of a participant comments is presented below.

"It was very interesting for a first experience, a very interactive way to learn. I had some difficulty locating myself in a few moments but the heat map helped me."

Among the negative comments, participants from the experimental group mentioned that sometimes the heat map in a specific position covered important parts of the screen, reducing the visibility. In this sense, they have suggested the heat map could be hidden in those cases. Some participants revealed the system does not clearly state what should be done, because the chat box where the instructions and explanations are sent is in a barely visible place in the left

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corner. On the other hand, it was also mentioned by other users that there is information overload when the dialog (information) appears on the whole screen, even if it is transparent. One of the suggestions was to dedicate half of the screen for the chat box.

In this qualitative analysis, the usefulness of the heat map can be seen. While the control group highlighted the need for more indications or suggestions about where to go in the environment, the experimental group pointed out the device helped them navigate, and no comment of this kind (loss of direction) was received from them.

IV. Conclusion And Future Work

The use of context information from user interaction in VW can be useful in different application scenarios, one of them being educational. The access of students' logs facilitates assessment and the identification of learner profiles and patterns [24]. The collecting of information from users behavior in the environment can allow the accomplishment of different types of actions to assist the students during their interaction.

In this way, the study presented in this paper focused on the use of context information of users to present a real-time heat map, in HUD format, of their activities in the environment. The objective was to help user navigation in the environment, highlighting the places visited and how often, working as a tool to contextualize the user in 3D Virtual Worlds.

The results from the experiment demonstrated the acceptance of the hypothesis that using the heat map HUD in 3D VW can facilitate engagement and increase interaction time, as we have collected important indications about the implications of using this device, in which the users emphasized the usefulness of knowing their on navigation pattern to aid in their interaction. On the other hand, the users who did not have the HUD device coupled to their screen complained about loss of directions and the need for more guidance.

The HUD showed to be flexible, as it can be attached to particular users and it functions individually. Flexible guidance (guided and unguided navigation) can also be provided to meet the needs of different students' learning styles and levels of knowledge [8]. The device can be used in other Virtual Worlds, by importing the HUD 3D object. This type of application can benefit especially new users, helping on guidance in this new environment.

As a limitation of this research, it can be mentioned the sample size relatively small, consisting of sixteen respondents, which limits the degree of external validity and generalizability of the results. This study could be reelaborated in the future to include a greater number of participants to increase validity. Also, data could be captured in other VW, from other areas, to compare the results among different environments. As a future research we intend to analyze the records from the database and establish an automatic way to give feedback to students and to allow teachers to see reports of users behavior, as well as compare the registers with pre and post tests of knowledge, to see if certain navigation patterns could be connected to good learning performances.

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