Scientific Articles Exploration System Model based in Immersive Virtual Reality and Natural Language Processing Techniques

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***Abstract*—After having carried out a historical review and identifying the state of the art in relation to the interfaces for the exploration of scientific articles, the authors propose a model based in an immersive virtual environment, natural user interfaces and natural language processing, which provides an excellent experience for the user and allows for better use of some of its capabilities, for example, intuition and cognition in 3-dimensional environments. In this work, the Oculus Rift and Leap Motion Hardware devices are used. This work aims to contribute to the proposal of a tool which would facilitate and optimize the arduous task of reviewing literature in scientific databases. The case study is the exploration and information retrieval of scientific articles using ALICIA (Scientific database of Perú). Finally, conclusions and recommendations for future work are laid out and discussed.**

Keywords*—Immersive virtual environment; human computer interaction; natural user interfaces; natural language processing; Oculus Rift

I. INTRODUCTION

The production of scientific articles, which are the result of lines of research in various fields and which must be made available to research communities, are currently indexed in databases or scientific repositories, such as Scopus, Web of Science, Latindex, etc., which allow one to perform searches, explore the database, and obtain information. These computer systems generally use traditional interfaces composed of forms, windows, and menus which can even utilize hypertext or hypermedia resources. In addition to using keywords, the name of the author, or the year of publication, among other search parameters, the traditional interface presents the results generally as a textual list [1]. However, the information indexed in the databases is growing rapidly, thus creating difficulties for the exploration and adequate selection of scientific articles when using traditional interfaces and making the researchers searches tedious without any guarantee that they will actually find what they are looking for.

Furthermore, the traditional interaction conguration is limited. Common devices like the mouse and keyboard are used, whereas in the virtual environment, interaction possibilities are broader and more intuitive to the user due to elements existing in the users context in the immersive environment. Virtual Reality can provide solutions to the problems mentioned above [2], [3], as well as new opportunities to search for articles, for example, creating more intuitive and conversational interfaces for the user.

Therefore, it is important to develop new ways of representing and interacting with the information in order to facilitate the efficient selection of scientific articles stored in the extensive databases or repositories that index them with available techniques of knowledge extraction, such as Data Mining, Information Recovery, etc. Despite being important alternatives and becoming emergent and very robust computational techniques, in the end the user only has the graphical interfaces to narrow down information, and these traditional interfaces do not generally take advantage of human capacities (perception, cognition, intuition, etc.).

The aforementioned problems make it necessary to consider the opportunities that other approaches, methodologies, and technologies (e.g., Virtual Reality) can offer for the search for articles, as well as for the design of intuitive and even conversational interfaces for the user.

In this work, we propose a model for the exploration of scientific articles with Virtual Reality and Natural Language Processing [4], which aims to facilitate and simplify the work of researchers in the process of searching for and selecting scientific articles.

This project focuses on more efficient ways to navigate the database ALICIA, using immersive environment (i.e., virtual reality) technology for example, Oculus Rift, Leap Motion, headsets, computers, and speech recognition engines.

The sections regarding the theoretical framework (Section II), system model development (Section III), and conclusions (Section IV), will subsequently be developed.

II. THEORETICAL FRAMEWORK

In this section, the authors conduct a historical review, identify the state of the art, and explore the theoretical foundation of the research project.

A. Scientific Databases

Scientific databases contain information about books and other materials in a library or a bibliographic index, for example, the content of a set of journals and other scientific publications such as research articles, conference proceedings, book chapters, etc. These databases usually have an electronic format and are consulted via the Internet. They contain bibliographic citations, references, abstracts, and the full text of the indexed contents or links to the full text. Many scientific databases are bibliographic databases, but others are not. Even outside the scientific sphere, the same thing occurs. There are databases that contain citations for art-history, journal articles, or databases containing only artistic images [5].

For Concytec[1], there are 20 main scientific databases, thirteen of which are freely accessible and available to the scientific/academic community as well as the general population of the Republic of Perú.

On the other hand, the database ALICIA[2] (Fig. 1), provides open access to this intellectual heritage resulting from advances in science, technology, and innovation achieved by public sector entities or with state funding.

Fig. 1. ALICIA web interface.

B. Virtual Reality

The term virtual, its modern use was popularized by Jaron Lanier in the 1980s [6]. There are several denitions for Virtual Reality. According to one, Virtual Reality is a term used to describe a computer generated virtual Environment that may be moved through and manipulated by a user in real time [7]. Virtual Reality can also be defined as the way humans can visualize, manipulate, and interact with computers and extremely complex data [8]. Virtual Reality is only obtained when you are in a network, and several people share their realities amongst each other [9].

The main advantage of virtual environments is that they can be modeled and controlled exactly to an experiment's requirements, without having to build something similar in the real world [10]. Nowadays, virtual environments can be constructed with relative ease and it requires few resources to be able to run the necessary software [11]. Finally, These terms are the most popular and most often used [12], Virtual Environments (VE) and Virtual Reality (VR), are used in computer community interchangeably, but there are many others: Virtual Worlds, Artificial Worlds, Artificial Reality or Synthetic Experience.

For this research, the following themes are considered and developed:

[1]https://portal.concytec.gob.pe/index.php/informacion-cti/biblioteca-virtual
[2]http://alicia.concytec.gob.pe/vufind/

1) Virtual Reality technology: Virtual Reality and immersive environments, as part of the emerging technological evolution involving our senses and cultural, symbolic and representative factors, may present interdisciplinary approaches [12]. Virtual reality refers to immersive, interactive, multisensory, viewer-centered, three dimensional computer generated environments and the combination of technologies required to build these environments [7]. In immersive VR, simulated objects appear solid and have an egocentric location much like real objects in the real world [13].

In terms of psychology, immersion refers to being completely involved in something while in action. In immersive virtual reality, it is possible to give people the illusion that they have a different body. They wear a head-tracked head-mounted display, and when they look down towards themselves they see a virtual body that is spatially coincident with their real body [14]. Mental immersion has different levels in a Virtual Reality experience. Such an experience can consist of partial or complete mental immersion, although it is worthwhile to note that reaching complete mental immersion in a Virtual Reality experience is still an ongoing challenge for research [15].

The unique characteristics of immersive virtual reality can be summarized as follow [7]: head-referenced viewing, stereoscopic viewing, the virtual world is presented in full scale and relates properly to the human size, realistic interactions with virtual objects, the convincing illusion of being fully immersed in an artificial world.

Steuer [16], proposed three different factors involved with an individuals presence in Virtual Reality: vividness, interactivity, the inuence of a users personal characteristics. This derives from individual differences in the sense of presence when subjects are confronted with the same virtual environments. The individuals personal experiences and history contribute to this factor.

Virtual Reality possesses the characteristic of immersion, allowing users to immerse themselves in the simulation while stimulating intense emotions in the process. During the initial stages of development, Virtual Reality could only be used by scientific laboratories funded by the military at excessive costs. However, today virtual-reality glasses can be obtained at an affordable cost, for example, the Oculus Rift [17].

2) Display modes (2D vs 3D vs VR): There is currently an extensive discussion regarding the use of 2D, 3D, and VR modes in order to represent information [2]. The following briefly describes each.

- 2D is the rendering mode that uses only two dimensions. The graphics are at, providing simplicity, clarity, and precision in the display of information.
- The 3D vision can be simulated by stereoscopy, meaning de display of two or more images perceived by the brain through the eyes and recompounded by it in an spatial image similar to what we naturally perceive in the everyday reality. The normal human vision is stereoscopic [18].
- VR is a technique which enables immersion in a multimodal, visualization environment, also utilizing

stereoscopic images to improve depth perception. This type of VR system encases the audio and visual perception of the user in the virtual world and cuts out all outside information so that the experience is fully immersive [19].

- Sensory displays are used to display the simulated virtual worlds to the user. The most common sensory displays are the computer visual display unit, the head-mounted display (HMD) for 3D visual and headphones for 3D audio [20].

3) Virtual Reality Devices: The Oculus Rift uses stereoscopic vision technology, rendering a slightly different perspective of the 3D image for each eye. This enables the natural interaction of looking around while exploring a virtual three dimensional world [21].

It uses see-through lenses and 2 light engines to project the augmented content. It automatically calibrates pupillary distance, has a “holographic resolution” of 2.3M total light points and a “holographic density” of more than 2.5k light points per radian [22]. Samsung Gear VR is wireless, it only requires a smartphone. Finally, Oculus Go is an all-new standalone headset that doesn’t require you to snap in a phone, attach a cable or power up a PC. Oculus Go is hands-down the easiest way for people to get into VR. It’s perfect for those who haven’t experienced VR to play games, watch movies and connect with friends and family in new ways

4) Natural User Interfaces (NUI): NUI refers to both sensory inputs such as touch, speech and gesture [23]. NUI interfaces are those in which the interaction is natural, common, and familiar to the user [3]. This involves the use of new devices which enable new forms of interaction beyond the keyboard and mouse. This new generation of devices allow the use of gestures, tactile contact, body movement, and voice communication. An example of NUI devices is Kinect [24], a device which is able to record the movements of the body and transfer the data to a virtual avatar [17].

5) Evolution of Interfaces (CLI vs WIMP vs NUI): The user interface is the method or means by which the user communicates with the software. With the Natural User Interface, the interaction is natural; talking is prioritized over writing, listening over reading, and touch over clicking [25]. For this reason, the best choice to interact with the software is to use natural user interfaces [26].

C. Natural Language Processing

Natural Language Processing (NLP) is the function of software and/or hardware components in a computer system that analyzes or synthesizes spoken or written language [27].

The processing of Natural Language contributes to the retrieval of texts ranging from the length of a paragraph to that of a book. Technological advances have now made it possible to store, search for, and retrieve all or part of the full-text document online [28].

With a web search conducted with traditional approaches, several techniques are applied. These include building an index of the web content, building a database of the indices, and doing a search utilizing keywords which match the database contents. The problem with this approach is that it is not conducive to the acquisition of intelligence information [29].

On the other hand, the display of historical metadata in a virtual 3D environment implies several issues related to both user interface and data visualization and manipulation. A lot of work has been done in the field of user interfaces for Virtual Reality, even if the development of new devices is constantly challenging this research area [30].

Natural Language Processing possesses many applications, because on the Internet individuals communicate via natural language. The applications which are being developed range from the translation of texts to the implementation of talking robots. Some of them are mentioned below [31], [32]: automatic translation, text classification, sentiment analysis, information retrieval systems, search engine development, documentary databases, generation of automatic summaries, generation of natural language, etc. In this work, some approaches, methodologies, and techniques that use these applications will be used.

D. Related Work

As for the exploration of scientific articles, there are many applications which were developed for traditional environments, such as the case of scientific databases, which were designed for common interaction [33], where the majority of difficulties are due to the traditional configuration of the environment.

The literature mentions some frequent problems inherent in the traditional interfaces of scientific databases, such as Scopus, Web of Science, Scielo Google Scholar, etc. [34][35], which limit and complicate the search for scientific articles. These problems are detailed below:

Reduced Display Space: This is the weakness that most of the devices used in traditional visualization environments are prone to. LCD screens are the most commonly used display devices today, they come in different sizes, ranging from as small as cell phone screens, to medium, like those used in personal computers, to large screens such as those used in smart televisions. Obviously, the larger the visualization device, the more elements that can be visualized. Therefore, the size of the visualization device establishes a limit to the capacity of elements which can be displayed [36].

For example, in Google Scholar when one executes a search through its traditional interface, millions of results are obtained, but of the documents found, only about ten or even less are actually shown on the computer screen. There are alternative scanning and visualization interfaces, such as VR-Miner software which shows thousands of documents at the same time using graphical objects, but the disadvantage of this visualization technique is that occlusion or the overlapping of elements occurs, generating a disordered field of view for the user.

Faced with this problem, several researchers have proposed prototypes of visualization devices larger than the traditional ones. This problem of reduced space, limiting the visualization of search results is directly related to the device generating the image, which also has the characteristic of displaying the information in a flat way. Regardless of whether one is using two-dimensional or three-dimensional images, the final representation is without depth.

Interface overload: This generally occurs in the traditional interfaces of scientific databases of the WIMP-based interface type [37]. These interfaces are currently the most common, where the excessive use of menus, buttons, lists of options, icons, scroll bars, dialog boxes, text boxes, tabs, etc., cause the interface to be saturated with elements, reducing its versatility and ease of use [38].

While the tasks of retrieving user information are the same in each of the bibliographic query systems, this saturation of elements, commands, controls, parameters, etc., can confuse the user. What is more, most of these options are never used by the researcher upon using these tools to conduct a literature review due to the great complexity they usually represent.

Limited Interaction: Interaction is the set of actions through which the user communicates with the interface. These actions, in the context of exploration of scientific articles, include selecting elements, manipulating them, moving within the visualization environment, and reading the content of each document [39]. Generally, interaction with traditional scientific databases, whose interfaces are based on windows, icons, menus, and pointers, is deficient because only the mouse and keyboard are used as interaction elements, leaving the user's voice completely aside, not to mention the potential of the natural movement of his hands. In order to overcome these interactional limitations, several hardware prototypes have been developed and studied.

DocuWorld is an immersive virtual environment for document organization, where each file is displayed as a three-dimensional icon [40]. In Fig. 2, an example of visualization can be seen.

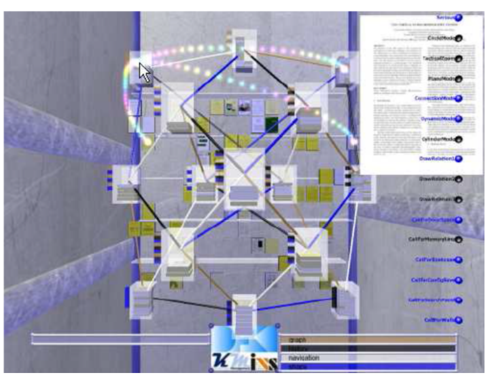


Fig. 2. DocuWorld - document visualizer.

@Visor is a software program designed for scanning and reading documents, using an electronic glove which is used instead of a mouse [17]. It is noteworthy due to its use of natural hand movements.

3D Spatial Data Mining is a visualization tool which differentiates itself by using a metaphor based on the real world for the exploration of automobile fault reports. It is a 3D model in the form of a car engine [41]. The great advantage of using this metaphor is that the user easily becomes familiar with it.

III. Model System Development

Next, we will describe the different elements that were developed as well as the procedural steps that were followed in order to build the model which the authors call AliciaVR.

A. *Physical Configuration Immersive Environment*

The first step consisted of configuring the equipment (Fig. 3). The Leap Motion device was attached to the front of Oculus Rift. Then both devices were connected to a laptop via two USB ports and an HDMI port. Regarding the configuration of the software, version 5.02 of the Unity3D graphics engine was installed.

Fig. 3. Configuration scheme of the immersive environment.

B. *Development of Virtual Environment*

For the development of a virtual, immersive 3D environment (Fig. 4), which is suitable for the exploration of scientific articles, the following considerations and recommendations are taken into account:

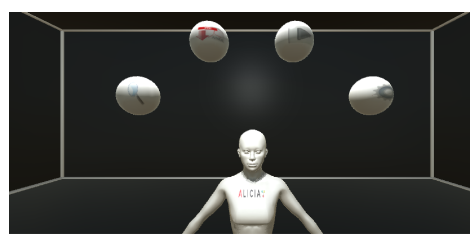


Fig. 4. Construction of virtual environment in unity3D.

- Simplicity: This is to avoid overloading the interface, using only the necessary elements. In this way, perception of the interface is smoother, thus maximizing the user's cognitive activities.
- Dark background: This is to mitigate dizziness and decrease the frequency of update snapshots required for the rotation of the observer's point of view.
- White lines: These delimit the virtual environment, allowing the user to perceive depth with greater precision.

- Color range close to the real: this is to avoid dizziness or discomfort if the images are not perceived as real.
- Rounded elements: These accommodate themselves to the shape of the hand better and allow degraded shadows to be generated, which facilitates their visualization.
- Visualization of an Avatar: This is in order to optimize the user's sense of presence in the environment [42].

Taking into consideration the last recommendation, an avatar was developed (Fig. 5). This avatar is defined as a digital character, which may resemble a real person, an animal, or any other form that could be given to it, according to system requirements and user preferences. The purpose is for the user to imagine having an assistant, which would allow them to intuit that it is possible to interact through voice commands. It is important to point out that its basic functions are defined within the context of the exploration of scientific articles.

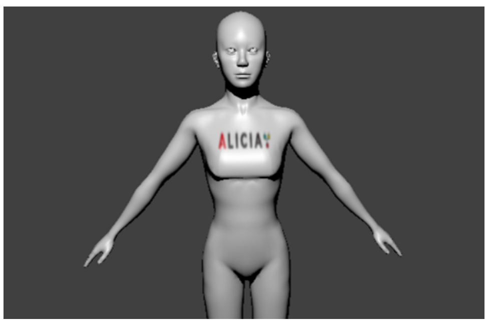


Fig. 5. AliciaVR model system avatar.

C. Natural Interaction Model System Implementation

After the immersive environment was configured, the interaction techniques for immersive, virtual environments were investigated and explored, according to the following parameters:

- Selection Technique by Direct Manipulation: this was done through the use of a virtual hand, which copies exactly the movements of the real hand. In Fig. 6, the selection of a node by direct manipulation is shown. As can be seen, the process is identical to grabbing an object in the physical world.
- Handling by Gestures: gesture manipulation consists of selecting elements in the immersive environment, utilizing gestures with the virtual hand. Specifically, in order to grasp an object, the 'pinch' gesture must be made, based on the metaphor of a pinch, and in order to release the element, the 'stop' gesture must be performed, which consists of extending the fingers so that the palm is exposed (i.e., the opposite of a 'grab' gesture). In Fig. 7a, the node is selected with the first gesture described, then in Fig. 7b, the node is released by the second gesture. This technique is not entirely intuitive because both gestures can have alternative meanings depending on the user or when performing them, they might expect a different action to be instantiated.
- Technique of Selection by Artificial Manipulation: This technique was proposed within a framework emphasizing the concepts of 'dimension', 'transduction', and 'reification' [43], which allow for prior-configuration experiences such as crossing objects. Therefore, in order to select an object, it is only necessary to cross it using the virtual hand. In order to release the element, it is only necessary to cross it again. In Fig. 8a the cube is selected by changing color to green and in Fig. 8b the cube returns to its previous state.

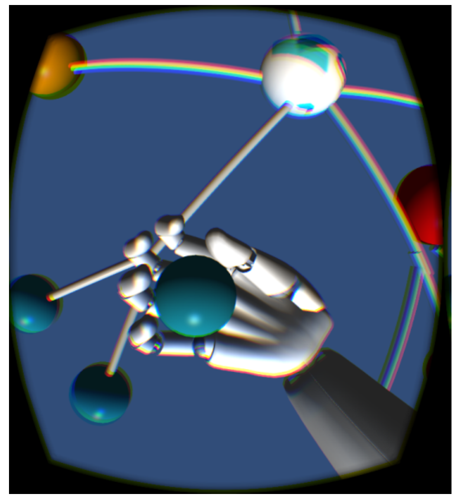
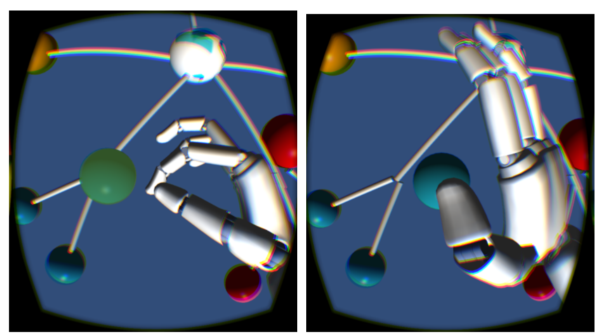


Fig. 6. Example of selection by direct manipulation of a node.

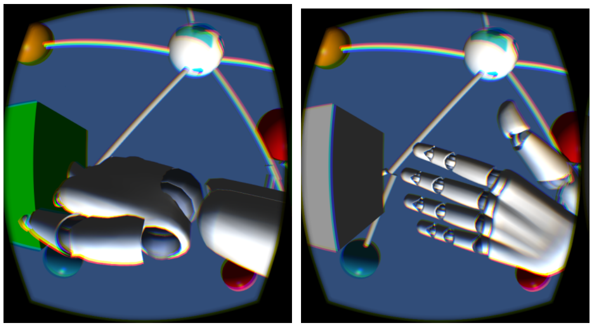


(a) Selecting the item (b) Releasing element

Fig. 7. Selection example gesture of a node.

D. Implementation of Web Crawler for Information Retrieval from the Model

The proposed interface model (AliciaVR), is connected to the ALICIA scientific database. In order to retrieve information from this system, a program of the crawler type was developed and implemented, which automatically communicates with ALICIA and extracts, through code analysis (source of the visual field), the information required for visualization within the interface based on Virtual Reality. This implementation involved studying the proper pattern in order to perform the tracking and recovery extraction in an automated way.



(a) Selecting the item (b) Releasing element

Fig. 8. Selection example by articial manipulation of a node.

E. Development of Speech Recognition Engine and Conversion to Text

For the recognition engine, the Intel Perceptual Computing Library was used, which incorporates audio-to-plain-text conversion functions. For more sensitive speech recognition, a wireless microphone certified by Dragon Natural Speaking has been added to the prototype design. A library has been developed in C# .Net, in order to capture the user's audio at all times, subsequently sending the data via sockets to Unity3D using network protocols, where a listening port was implemented through which all the user's voice commands are received.

Fig. 9 shows a representation of the process by which the sound waves produced by the user when speaking are captured by the microphone and through the Intel Perceptual Computing Library, they are interpreted and converted into plain text.

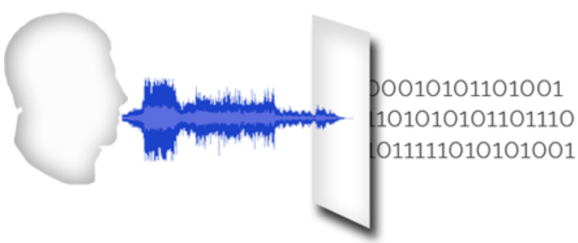


Fig. 9. Voice capture and conversion to text.

Using the previously-mentioned library, the desktop application was developed and configured using Visual Studio Community 2013. In order to start the speech recognition engine, it is necessary to start this application directly after initiating the Virtual Reality application developed with Unity3D. This is due to fact that within the Unity3D application, a listening server is implemented, and in the application for voice recognition the client is implemented for sending, in plain text, the voice of the user to the server. In Fig. 10, the speech-recognition engine interface is shown.

F. Implementation of the Syntatic Analyzer

In order to interpret the syntactic analysis of each of the voice commands, the Freeling library was used, because of the functions it possesses for the processing and conversion of the Spanish Language. This process of syntactic analysis

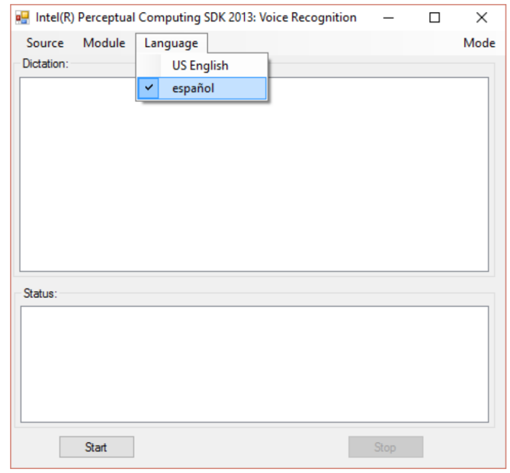


Fig. 10. Interface of the speech recognition engine.

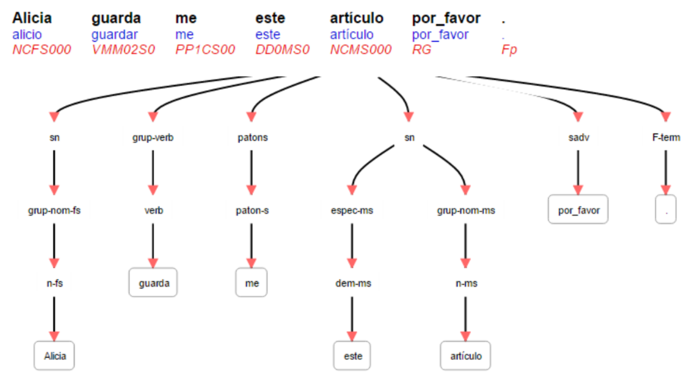


Fig. 11. Generation of the syntactic tree for a voice consultation.

first involves separating each of the words, parsing their content, and then adding part-of-speech labels, such as 'verb', 'adjective', 'noun', 'adverb', 'article', 'pronoun', etc. In Fig. 11, an example of the phrase analysis is shown, where the user says, "Alicia, save me this article please", generating its respective syntactic, phrase-structure tree.

The proposal, integrating all that is mentioned above, is described in the interface-model scheme for the exploration of scientific articles with Virtual Reality and Natural Language Processing, referred to in the research as AliciaVR and graphically described in Fig. 12.

Basically, the proposed model begins with the consultation of a user who wants to search for a scientific article in AliciaVR. The consultations are made by voice, which the speech recognition engine detects and converts into plain text. Then this information is processed by the semantic analyzer, where the respective syntactic tree is generated. This analyzer differentiates the interaction commands from the query, and then sends the latter to the tracker, which will be in charge of connecting with ALICIA and retrieving the information requested by the user. Finally, the results obtained are plotted in the immersive environment, where the user begins to interact with it. If the user is satisfied, then the process ends. Otherwise, a new search is initiated.

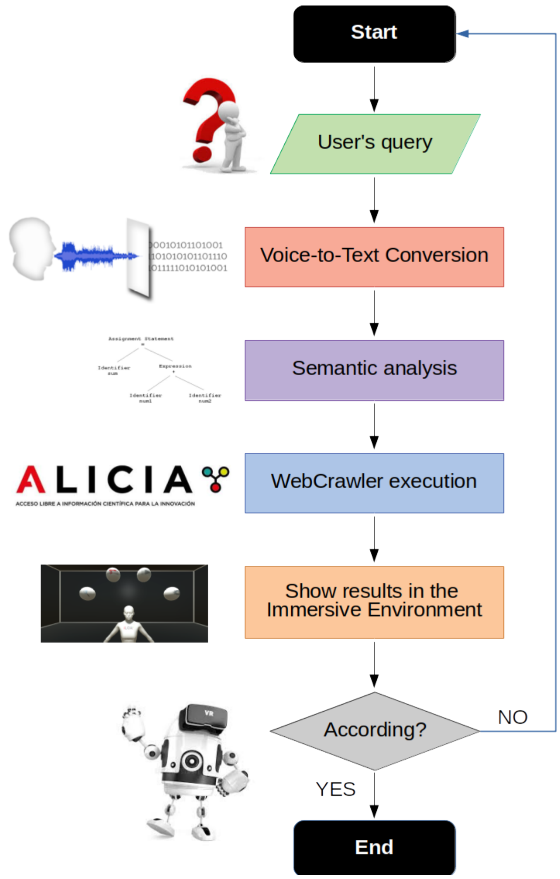


Fig. 12. Scheme of the proposed model AliciaVR.

G. Evaluation of proposed Model regarding Traditional

To evaluate the proposed interface model (AliciaVR) with respect to the traditional model (Alicia-Web), the ISO 9241 Interface Usability Standard will be used, which specifically evaluates three dimensions of user interaction with the interface: efficiency, efficacy, and satisfaction.

According to ISO 9241 Standard defines 'usability' as, "the degree to which a product can be used by specific users to achieve specific objectives with effectiveness, efficiency, and satisfaction in a specific context of use". The variables and their indicators are described below:

- 'Efficacy' is defined as the accuracy and integrity with which users reach their specified objectives, therefore implying ease of learning, absence of errors in the system, or ease of it to be remembered. The metrics used in the investigation are shown in Table I.
- 'Efficiency' is the relation of the resources used (effort, time, etc.) to the accuracy and integrity with which users reach their specified objectives. The metrics used in the investigation are shown in Table II.
- 'Satisfaction' is a subjective factor which implies a positive attitude in regards to the use of the product. The satisfaction parameters used in the research are shown in Table III.

H. Preparation of the Experiment with Users

After having set up the apparatus of interconnected devices (Oculus Rift, Leap Motion, a wireless headset and computer) and initiated all the software modules (i.e., immersion environment, speech recognition engine, web server for the tracker, etc.), the investigation then proceeds to the evaluation of the scientific-article exploration model with Virtual Reality and Natural Language Processing (AliciaVR) and also that of the traditional ALICIA model (Alicia-Web), with the assistance of five experimental users, this being the number of subjects that Nielsen recommends for the evaluation of interfaces [44]. A high speed internet connection of 8 Mbps is also be utilized.

Each of them is assigned the task of exploring scientific articles for thirty minutes using each interface within both interface models. During the experiment it is thought that the user will ask for help from an expert, who at the same time will be responsible for the observation and documentation of the experiment.

The first model to be evaluated is the exploration of scientific articles with Virtual Reality and Natural Language Processing. In this model the user is immersed in the software, being able to communicate by voice with the search engine and touch the elements selected. In Fig. 13 a user is shown using the proposed AliciaVR interface. What the user actually observes is shown in Fig. 14.

Fig. 13. Evaluation of the first interface model - AliciaVR.

Fig. 14. User's view - AliciaVR.

The second model to be evaluated is the exploration of scientific articles in the traditional way, which is the default interface of the ALICIA scientific database. In this interface model, the user has only the monitor with which to view the queries and only uses the mouse and keyboard to interact.

I. Evaluation of Results

This section presents the measurements made during the evaluation of and comparison between the traditional ALICIA (Alicia-Web) interface and the proposed interface model based on Virtual Reality (AliciaVR).

1) Tabulation of Collected Data: Table I, presents the data obtained by observing users using the two different interfaces, measuring the efficiency of each interface with the metrics defined by the ISO 9241 Standard. It should be recalled that 'efficiency' refers to the achievement of objectives or fulfillment of tasks. Therefore, it is represented by a number which indicates the number of objectives met. In the different metrics, the number of objectives fulfilled is counted, these being the tasks performed, functions used, etc.

TABLE I. COMPARISON OF INTERFACE EFFICACY

Metrics ISO 9241 Measurement of Efficacy	Alicia-Web (Half Quantity)	AliciaVR (Half Quantity)
Number of important tasks performed.	4.2	2.0
Number of relevant functions used.	7.8	3.8
Number of tasks completed successfully at the first attempt.	2.2	1.2
Number of calls for support.	0.6	3.4
Number of accesses to the aid.	0.2	0.4

Table II, presents the data obtained by observing users using the two different interfaces, measuring the efficiency of each interface with the metrics defined by the ISO 9241 Standard. Recall that 'efficiency' is the optimal use of resources required for the fulfillment of an objective, where time is the main resource used in the use of a software interface. The longer it takes for the user to perform the tasks, the less effective the interface will be considered. On the other hand, if this time is shorter, then the interface will be considered to be more efficient.

TABLE II. COMPARISON OF INTERFACE EFFICIENCY

Metrics ISO 9241 Measurement of Efficiency	Alicia-Web (Half time in seconds)	AliciaVR (Half time in seconds)
Time used in the first attempt.	47.3	35.6
Time used to relearn functions.	31.2.8	16.6
Productive time.	78.6	54.0
Time to learn characteristics.	48.6	34.2
Time to relearn characteristics.	29.4	10.2
Time used in the correction of errors.	54.6	55.8

TABLE III. COMPARISON OF INTERFACE SATISFACTION

Metrics ISO 9241 Measurement of Satisfaction	Alicia-Web (Half Percent)	AliciaVR (Half Percent)
Calibration of satisfaction with important characteristics.	0.32	0.72
Calibration of the learning facility.	0.44	0.64
Calculation of error handling.	0.28	0.24
Rate of voluntary use of the product.	0.64	0.92

2) Analysis by Inferential Statistics: To determine whether, judging by the data obtained, it can be concluded that efficiency is greater using one of the interfaces over the other, a statistical test to make the global inference is applied. The T-Student statistical test is used in order to differentiate between two paired means. In Table IV, the values obtained when applying the statistical test are shown.

The p value being 0.019, which is less than 0.05 ($p < \alpha$), is interpreted as sufficient, statistically-significant evidence, affirming that the groups are indeed different. Moreover, the difference being positive (0.81) indicates that the effectiveness of the first interface (Alicia-Web) is greater than the efficiency of the second interface (AliciaVR).

TABLE IV. T-STUDENT TEST FOR EFFICACY

	Difference by pairs				t	df	Sig.
	Dif.Average	Error D.E.	95% Confidence Int.				
			Low	High			
Efficacy	0.81	1.25	-1.989	3.589	0.639	10	0.019

To determine whether, with the data obtained, it can be concluded that efficiency is greater using one interface over other, the same "T-Student" statistical test used in order to differentiate between two paired means. In Table V, the values obtained upon applying the statistical test are shown.

The p value being 0.021, which is less than 0.05 ($p < \alpha$) is interpreted as sufficient evidence, confirming that the groups are significantly different, and, what is more, the difference being positive (13.87) indicates that the time spent on each task with the first interface (Alicia-Web) is greater than the time used using the second interface (AliciaVR). Therefore, since less time is spent on the second interface, it can be concluded that efficiency is greater using the AliciaVR interface than it is using the traditional ALICIA interface.

TABLE V. T-STUDENT TEST FOR EFFICIENCY

	Difference by pairs				t	df	Sig.
	Dif.Average	Error D.E.	95% Confidence Int.				
			Low	High			
Efficiency	13.87	10.57	-9.68	37.43	1.31	10	0.021

To determine whether, with the obtained data, it can be concluded that satisfaction is greater using one interface rather than the other, the "T-Student" statistical test is once again applied to make the global inference, measuring the difference between two paired means.

In Table VI, the values obtained upon applying the statistical test are shown. Here, it can be seen that the p-value is 0.024, which, being less than 0.05 ($p < \alpha$) is interpreted as sufficient evidence, confirming that the groups are significantly different. The difference being negative (-0.21) indicates that satisfaction with respect to the first interface (Alicia-Web) is less than that of the second interface (AliciaVR).

TABLE VI. T-STUDENT TEST FOR SATISFACTION

	Difference by pairs				t	df	Sig.
	Dif.Average	Error D.E.	95% Confidence Int.				
			Low	High			
Satisfaction	-0,21	0.16	-0.61	0.19	-1.28	6	0.024

J. Results Empirical Analysis

This section presents the results of empirical analyses based on the data obtained from the users' experiences [25][26]. The proposed model has attracted considerable interest from users, considering that it is a novel form of digital interaction which is full of possibilities. With every user a preliminary difficulty in both models was noticed.

Specifically, users who have never used ALICIA only use the basic functions, and not all possible tools which have been incorporated into the system. In contrast, the same users utilizing the proposed interface based on Virtual Reality were observed to have delayed initiation in order to accommodate themselves to the apparatus, at first failing to distinguish the three-dimensional character of the Oculus Rift device. However, after a few minutes of adapting to the equipment and watching their hands, they really wanted to explore all options available to perform.

For recovery-task items, users utilizing the AliciaVR interface managed to perform these tasks in less time than users of traditional, web-based interfaces were able to. Nevertheless, the big problem that arises is that the Virtual-Reality glasses are a bit uncomfortable and cumbersome for the user to say the least. This is to say that having to support a large, heavy apparatus on the head becomes annoying and tiresome after a while, especially during the last half hour, prompting the user to want to return to the real world.

IV. Conclusion

We have presented the whole process of creating a new interface for the exploration of scientific articles in scientific databases, based on Virtual Reality and Natural Language Processing techniques.

Users working with the traditional, web-based interface interact only with a mouse and keyboard. However, with the proposed new interface, the user interacts with the system in a much richer and more robust way, using Virtual Reality, full-immersion techniques. The proposed interface model and the traditional model of the ALICIA scientific database were evaluated using the ISO 9241 Standard, taking into consideration the three attributes of efficiency, efficacy, and satisfaction.

The statistical T-Student test was applied to evaluate the data obtained by means of inferential statistics. The results indicate that the proposed interface model, AliciaVR, is superior to the traditional interface of ALICIA (Alicia-Web) in the dimensions of efficiency and satisfaction, but it is inferior in the effectiveness dimension. Therefore, it is concluded that the model of exploration of scientific articles with Virtual Reality and Natural Language Processing is superior to the traditional exploration model.

An interesting future research project would be the inclusion in the model of the option to choose from among Oculus Go and Oculus Rift or to switch from one to the other.

Another future project would consist of extending the model that is currently focused on scientific databases, generalizing it to the exploration of business and management databases which are relative to the explicit knowledge defined in the discipline of Knowledge Management, for example, reports, contracts, operation manuals, schemes, and plans, among others. In this way, of particular importance would be the extension and development of the model for the exploration of tacit knowledge adequately linked to that of explicit knowledge utilizing, for example, a hybrid e-learning system that incorporates “case-based reasoning”.

This would make it possible to treat and examine processes and procedures, industrial manuals, and other types of tacit knowledge, whose explication and transference process is complex and could be facilitated enormously utilizing immersive, virtual reality and natural language processing techniques.

Virtual Reality is an emerging technology in the process of constant evolution and diffusion, at the level of both hardware and software, having already witnessed the advent of revolutionary advances, such as the Holographic Processor (HPU). The current tendency is in the direction of everyone possessing access to this technology at a low cost, and the first specialized operating system is already in development, executing applications developed in Virtual Reality.

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