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A CURRENT VISION

Bibliographic review and structuring of the state of the art on modeling immersive systems with usability features

Revisión y estructuración bibliográfica del estado del arte, sobre modelado de sistemas de inmersión con características de usabilidads

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ABSTRACT

In the development of any type of research, it is important to carry out a very good bibliographic review so that its results are important in the challenges of research.

This article makes a bibliographic review on the modeling of immersion systems with high usability features, for this we look for articles about this topic together and separately, thus obtaining a broad view of the current state of research.
To perform the analysis of the information obtained, an information analysis methodology is proposed and the SciMAT tool is used to obtain results that in the previous steps are not so clear.
Finally, conclusions are drawn that give strength to the bibliographic review and that allow it to be complemented.

RESUMEN

Cuando se desarrolla cualquier tipo de investigación es importante realizar una muy buena revisión bibliográfica para que sus resultados tengan el suficiente peso y realmente sean importantes en los desafíos de la investigación.

En este artículo se hace una revisión bibliográfica sobre el modelado de sistemas de inmersión con características altas de usabilidad, para ello se buscan artículos que se han trabajado sobre este tema en conjunto y por separado obteniendo así una visión amplia del estado actual de la investigación.

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Para realizar el análisis de la información obtenida se plantea una metodología de análisis de información y se utiliza la herramienta SciMAT para obtener resultados que en los pasos previos no son tan claros.
Finalmente se sacan conclusiones que dan fuerza a la revisión bibliográfica y que permiten complementarla.

1. Introduction

In this paper seeks to make a structured literature review on immersive systems modeling issues focused on usability features, and then make an analysis using the SciMAT tool in order to find important information that can contribute to research.

The bibliographic review is always the first step when doing any type of research since it allows knowing what has been worked on and what is the future of the field, in order to find the gaps in the research and have better results.

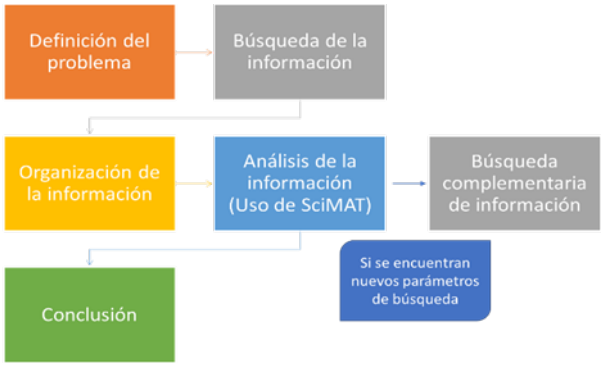
In the field of software development there are many branches of research and one of these is the modeling of systems; there is a research project on the modeling of immersive systems where usability features are included, so a literature review is required to make decisions during the research, this document will show the results of this research by adding a part of analysis on the documents consulted to find additional information that allows better results.

2. Methodology

The structured bibliographic review follows the methodology proposed in the article "Methodology for the bibliographic review and information management of scientific topics, through its structuring and systematization" [1], where five steps are proposed in the literature review, starting from the definition of the problem, then the information is searched and organized to then make an analysis of it and be able to conclude; in the analysis part, the SciMAT tool is used as proposed in the article "An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the Fuzzy Sets Theory field." [2].

If new information search parameters are found in the result analysis, a complementary review will be made with these parameters. In the Figure 1 shows the methodology in summary form:

Figure 1. Information review methodology.



Source: Own.

3. Problem definition

The main research consists of the design of a metamodel for immersive systems with high levels of usability, so it is required to make a literature review on modeling immersive systems and how usability is presented in these, likewise it is necessary to delve into the tests that are done on systems to see their degree of usability.

4. Review of information

The review was based on three particular topics: modeling of immersive systems, usability in these

systems and finally the tests that are done on the software to measure usability; to make the selection of articles, we searched in different scientific databases for these topics making a first filter by reading the abstract of the article, in this way we obtained a total of 37 articles that were reviewed to extract the relevant information from them.

4.1. Articles on modeling of immersive systems

The first article reviewed on immersive systems modeling is "Supporting constructability analysis meetings with Immersive Virtual Reality-based collaborative BIM 4D simulation." [3] this presents a framework developed for linking 3D models with the scheduling of construction activities, at the end a 4D simulation is used to show the results.

The following work was considered in the article "Agent Metamodel for Virtual Reality Applications" [4]. [4]where reference is made to multi-agent systems and how to relate these with immersive visualization techniques such as virtual and augmented reality, at the end a metamodel is generated which allows the integration of numerous agents in an immersive environment; another work reviewed is the one presented in the article "Automatic transformation tools of UML design models from virtual prototypes of multi-jointed robots" [5], in which a problem related to robotics is shown, seeking to manually adjust the motion functions for robots in general.

Following the review, the article entitled "Thinning trainer based on forest-growth model, virtual reality and computer-aided virtual environment" was analyzed [6]. In this article, the authors propose the "Thinning Trainer" solution, which is the union of a mathematical model of forest growth and a training and simulation software; in the field of medicine, interesting works are found such as the one presented in the research "Significant applications of virtual reality for COVID-19 pandemic" [7], which shows how the use of virtual and augmented reality tools helps a lot to meet patients without having to be face to face with them.

The next article in the review is "The Virtual Reality Lab: Realization and Application of Virtual Sound Environments" [8]. The authors show how virtual reality is used to design audiovisual communication environments and achieve more efficient testing of modern hearing devices; in the field of security there is the work presented in the article "Industrial Security Solution for Virtual Reality" [9]. In this research, the technology is used to create virtual reality simulations to obtain the response measures of an industrial security system.

In the article "Virtual Reality Therapy in Mental Health" [10] a different approach to the use of virtual reality is given showing the importance of using this technology in the treatment of different mental disorders such as the most common phobias, the next article reviewed is "3D data visualization system of immersive underground laboratory" [11]. In this article the authors build a 3D model of a subway laboratory with data from multiple sources, the most important part of the process was the division of the work, modeling and developing independently the laboratory and the terrain in which it was, thus speeding up the work.

The next article in the review is "Multi-model visualization based on integration of data models in semantic network environment" [12], which talks about the visualization of data coming from different models, the premise is to ensure a visual correspondence of what you want to show using metadata integration to obtain better results; then there is the research done in the article "Solid Modeling Interaction with Sensors in Virtual Environment for the Application of Virtual Reality Welding" [13], making reference to a process to achieve the interaction of a microcontroller with sensors and the visualization in virtual reality for the application of what is called virtual welding, always

emphasizing the high degree of usability that must be had.

In the article "Supporting System Modeling Learning Using Gestures for Visualization Control as Method of Immersion" [14] a teaching method is proposed using immersion techniques focused on software engineering topics, with the premise that teaching in this field can often be abstract.

Immersion systems have also been used in video games, as in the case of the article "An Automated Model Based Testing Approach for Platform Games" [15], in which a modeling methodology is proposed to perform automated tests of different games at a general level; in the following article entitled "An Integrated Cyber-Physical Immersive Virtual Reality Framework with Applications to Telerobotics" [16], an architecture is presented that integrates a series of platforms in immersive virtual environments of an interactive nature; the article "Approach to describing virtual reality competence components for services in production networks" [17] presents a way of describing Virtual Reality components from a competence-based approach.

The next research reviewed is "Augmented Reality maintenance demonstrator and associated modelling" [18], in which the authors work on the demonstration of object maintenance from a 3D model, obtaining as a final result a modeling that allows to describe a complete maintenance process with augmented reality; then the article entitled "Cadastral data as a source for 3D indoor modelling" was reviewed [19], in which a framework for indoor 3D modeling is developed, and in the course of its research a general development model is reached; in the article "Development of Augmented Reality Application on Android OS" [20], an analysis is made of sensors integrated in mobile devices using augmented reality and analyzing this type of systems.

The research "GML-based 3D Spatial Data Model for Geoscience Information in Coal Mines" [21], presents a spatial data model for integrating subsurface features through a 3D application; the article "Simulation System of a Reservation-Based 3D Intersection Crossing Scheme for UAVs" [22], presents a simulation system of a 3D intersection crossing model, analyzing several drones accessing an intersection without colliding; the next article reviewed is "Implementation of Mobile Augmented Reality Based on Vuforia and Rawajali" [23],which works with augmented reality applications using the Vuforia tool.

Following the review of articles on immersive systems modeling, the research done in "Software Architectures for Designing Virtual Reality Applications" is analyzed [24]. In this article, the authors present a software architecture for virtual reality systems; in the article "Visualization of Industrial Engineering Data in Augmented Reality" [25], the authors present the use of Augmented Reality in the field of industrial engineering is presented, analyzing data from different simulations.

4.2. Articles on usability in immersive systems

The next topic in the literature review is about usability in immersive systems, the first article worked on is "The Use of 3-Dimensional, Virtual Reality Models for Surgical Planning of Robotic Partial Nephrectomy" [26] in which reference is made to an experiment carried out on patients who were to undergo nephrectomy surgery, it is proposed to replace the CT scans currently used by 3D models that are interactive to facilitate surgery and obtain better results; another research reviewed is presented in the article "Implementation of accessibility standards in the process of course design in virtual learning environments" [27], which refers to the improvement of accessibility to people in virtual educational environments, identifying the current problems and giving recommendations on aspects of usability and accessibility.

The next article in the review is "Usability of the Combination of Brain-Computer Interface, Functional Electrical Stimulation and Virtual Reality for Improving Hand Function in Spinal Cord Injured Patients" [28]. This article presents an experiment in the area of neurology done with patients with spinal cord injury and reduced mobility in their limbs, three technologies were integrated among which virtual reality was used as feedback of the work done by patients, it is important to note that the immersive systems worked had to be accessible and with a high degree of usability.

The next article is "Reconstruction of Near Misses and Accidents for Analyses from Virtual Reality Usability Study" [29], which shows a concrete implementation of a virtual reality system used in a plant where operators simulated the work they were going to do in order to analyze the causes of accidents and try to reduce them; the research presented in "Acceptance and Usability of Immersive Virtual Reality in Older Adults with Objective and Subjective Cognitive Decline" [30] is also presented in "Virtual Reality Usability Study" [30]. [30]. The research presented in "Acceptance and Usability of Immersive Virtual Reality in Older Adults with Objective and Subjective Cognitive Decline" [30], seeks to evaluate an application of a simulation of a real walk in older adults with some cognitive deficits who are not very familiar with this technology.

Following the review is the article "Feasibility and usability study of a pilot immersive virtual reality-based empathy training for dental providers" [31], which presents a virtual reality simulation focused on an everyday life situation, so that users can better understand the concept of the social determinants of health; continuing, the article "Eye-Tracking for Clinical Ophthalmology with Virtual Reality (VR): A Case Study of the HTC Vive Pro Eye's Usability" is analyzed [32], in which an in-depth study is made of a virtual reality device focused on its use as an ophthalmology tool that allows studies such as perimetry; ending the topic of usability, the article "User's Perspective of Smartphone Platforms Usability: An Empirical Study" was reviewed, which refers to usability and accessibility as determining factors in the increase in popularity and consequent use of smartphones [33].

4.3. Articles on usability testing of software systems

The last topic evaluated in the review is the usability testing of different systems, starting with the article "Development and Usability Testing of Simulated Wind in a Racing Video Game" [34], in which the S.U.S. scale is used to evaluate a wind simulation system in video games, the participants of the experiment made use of the system and at the end of the test answered the ten-question questionnaire, thus establishing a baseline for the evaluation of the usability of the simulation devices.

Following the review, more research using the S.U.S. scale is found, such as "Usability Testing of Augmented Reality For Food Advertisement Based On Mobile Phone Using System Usability Scale" [35] where augmented reality is used for food advertising, usability being a very important issue; the test is performed on 20 people and a score of 5.1 was obtained, this could be due to the nature of augmented reality applications, it is observed that it is not easy for all people to focus the markers correctly; similarly in the article "Exploring the Usability of Nesplora Aquarium, a Virtual Reality System for Neuropsychological Assessment of Attention and Executive Functioning " [36], the S.U.S scale is used in conjunction with another mechanism to test usability in a virtual reality system that simulates an aquarium.

Although the S.U.S. scale is one of the best known and has given the best results, in many other works the authors show and make use of different tests, sometimes proposed by themselves, as in the case of "Good practices in usability testing on people with

disabilities" [37], among the tests evaluated are "Card sorting" to test content organization, "Eye-tracking", which corresponds to records of eye movements and visual stimuli, while the user examines a tool or system.

Following the use of proprietary methodologies to evaluate usability, the article "Usability Heuristics as an Assessment Parameter: for performing Usability Testing" [38], which proposes usability heuristics as an assessment parameter for this characteristic, items such as visibility of the state of the system or coincidence between the system were evaluated, and based on these, a usability survey was carried out, asking questions per heuristic that could be rated from 1 to 10, which was applied to 50 participants.

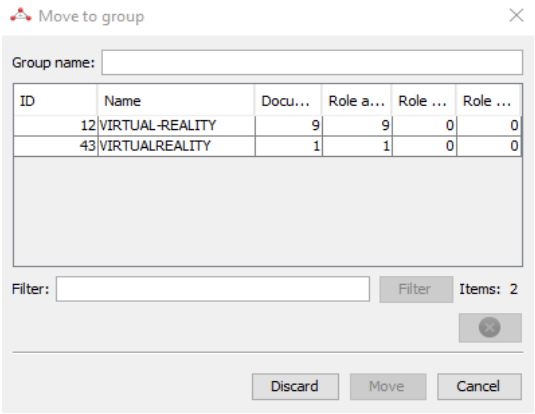
The latest article reviewed is "A Usability Scale for Handheld Augmented Reality" [39], which studies an important problem when evaluating the usability of augmented reality applications, it is mentioned that no standard questionnaire considers the problems of perception and ergonomics that are found in this type of applications, for it is presented an own test that is built from a 5-step methodology, a background study to identify previous problems in terms of usability of different applications, then the factors to be measured in the questionnaire are defined, with this already clear, the test format to be used is selected and the test is designed, the last step of the methodology is to establish a technique to measure the reliability of the test.

5. Information analysis

After reviewing the articles, analyzing them and obtaining a basis for the research, we proceed to the analysis on SciMAT, for this purpose we load the bibliographic information of each article on the tool, as shown in Figure 2.

Once the information has been loaded, it is necessary to perform a data cleaning on the keyword and author information, as shown in Figure 3:

Figure 3. Keyword unification process.



Source: Own.

Figure 2. List of documents loaded in the tool.

ID	Title	Authors	Year	...	wo...	A...	So...	Ad...
21	Visualization of industrial engineering data in Augmented Reality	Bruno, Fabio, C...	2006	0	3	3	0	0
20	Virtual Reality Therapy in Mental Health	Emmelkamp, Pau...	2021	0	7	7	0	0
35	Usability Testing of Augmented Reality For Food Advertisement Based On Mobile Phone ...	A. C. Wijaya, M....	2019	0	5	5	0	0
19	Usability of the Combination of Brain-Computer Interface, Functional Electrical Stimulatio...	Bayon- Calatayu...	2017	0	2	2	0	0
18	Usability Heuristics as an assessment parameter: For performing Usability Testing	Lodhi, Afifa	2010	0	5	5	0	0
40	Toward Standard Usability Questionnaires for Handheld Augmented Reality	Taketomi, Takaf...	2015	0	0	0	0	0
17	Thinning trainer based on forest-growth model, virtual reality and computer-aided virtual...	Fabrika, Marek, ...	2018	0	13	13	0	0
16	The Virtual Reality Lab: Realization and Application of Virtual Sound Environments	Hohmann, Volke...	2020	0	7	7	0	0
15	The Use of 3-Dimensional, Virtual Reality Models for Surgical Planning of Robotic Partial N...	Shirk, Joseph, K...	2018	0	3	3	0	0
39	Support of Temporal Change Observation Using Augmented Reality for Learning	Taketomi, Takaf...	2014	0	0	0	0	0
34	Supporting System Modeling Learning Using Gestures for Visualization Control as Method...	S. H. M. B. B. A...	2016	0	4	4	0	0
14	Supporting constructability analysis meetings with Immersive Virtual Reality-based collab...	Boton, Conrad	2018	0	3	3	0	0
33	Solid Modelling Interaction with Sensors in Virtual Environment for the Application of Virtu...	B. V G, R. Patil	2017	0	5	5	0	0
32	Software Architectures for Designing Virtual Reality Applications	Capilla, Rafael, ...	2004	0	2	2	0	0
31	Simulation System of a Reservation-Based 3D Intersection Crossing Scheme for UAVs	A. Rubenecia, M...	2019	0	4	4	0	0
13	Significant applications of virtual reality for COVID-19 pandemic	Singh, Ravi Prat...	2020	0	7	7	0	0
30	Reconstruction of Near Misses and Accidents for Analyses from Virtual Reality Usability S...	Nickel, Peter, Lu...	2017	0	6	6	0	0
29	Industrial Security Solution for Virtual Reality	Z. Lv, D. Chen, ...	2021	0	5	5	0	0
28	Implementation of mobile augmented reality based on Vuforia and Rawajali	C. Xiao, Z. Lifeng	2014	0	4	4	0	0
12	Implementation of Accessibility Standards in the Process of Course Design in Virtual Lear...	Amado-Salvatier...	2012	0	5	5	0	0
27	Good Practices in Usability Testing on People with Disabilities	G. Delgado-Que...	2019	0	5	5	0	0
26	GML-based 3D spatial data model for geoscience information in coal mines	Z. Wang, W. Ga...	2013	0	5	5	0	0

Source: Own.

Having the information in optimal conditions, the analysis begins.

The first thing that can be seen as shown in Figure 4 is that in terms of authors, there are not many articles written by the same people, there is a lot of variety; it can be seen that "Takafumi Taketomi" and "Goshiro Yamamoto" are present in three articles each, which shows that it is important to review more bibliography related to these authors.

Figure 4. List of authors and number of articles in which they appear.

Authors list

ID	Name	Ful...	Doc...	Affil...
10	Taketomi, Takafumi		3	0
11	Yamamoto, Goshiro		3	0
13	Kato, Hirokazu		2	0
1	Hou, Jiaxin		1	0
2	Wu, Ya-dong		1	0
3	Xu, Yang-jie		1	0
4	Li, Xue-jun		1	0
5	Wang, Song		1	0
6	Wang, Fu-pan		1	0
7	Zhang, Xiao-rong		1	0
8	Santos, Marc Ericson		1	0

Source: Own.

Then we proceeded to create periods to make the respective analysis, for this we took three periods of three years each up to the present and a fourth period to group the articles that are not so current; we also created a period that groups all the articles to make a unified analysis, as shown in Figure 5:

Figure 5. List of periods worked.

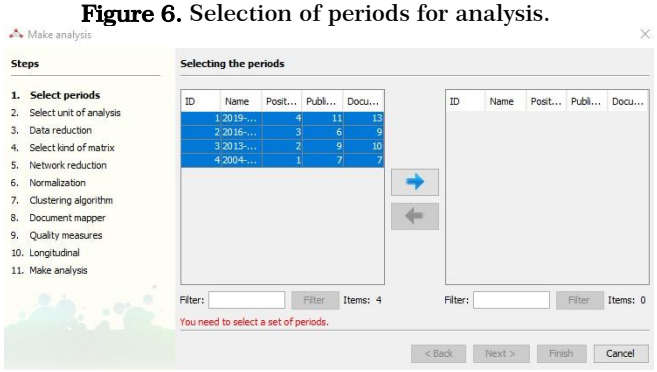
Periods list

ID	Name	Position	Publish d...	Documents
1	Todos	1	29	37
2	2019-2021	2	11	13
3	2016-2018	3	6	9
4	2013-2015	4	5	8
5	2004-2012	5	7	7

Source: Own.

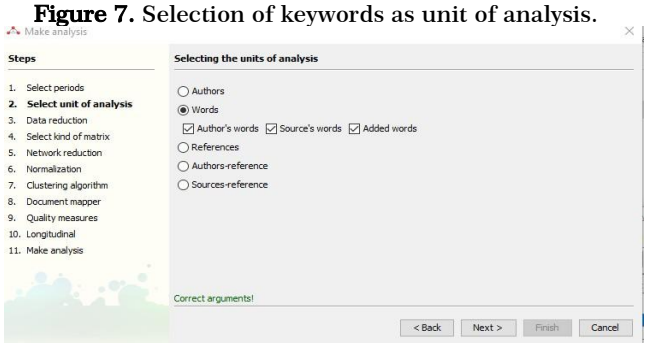
With the periods already created, we proceed to the analysis with the parameters recommended in the article "An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the Fuzzy Sets Theory field" [2]; in Figure 6 shows the selection of the period, then the keywords for the analysis should be chosen as shown in Figure 7. The next step is to choose the type of matrix as shown in Figure 8. Finally, the clustering algorithm must be selected as shown in Figure 9.

Figure 6. Selection of periods for analysis.



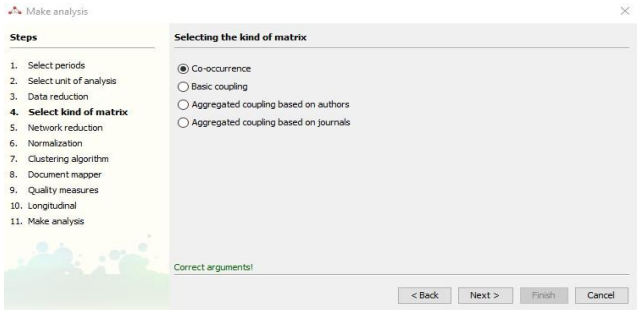
Source: Own.

Figure 7. Selection of keywords as unit of analysis.



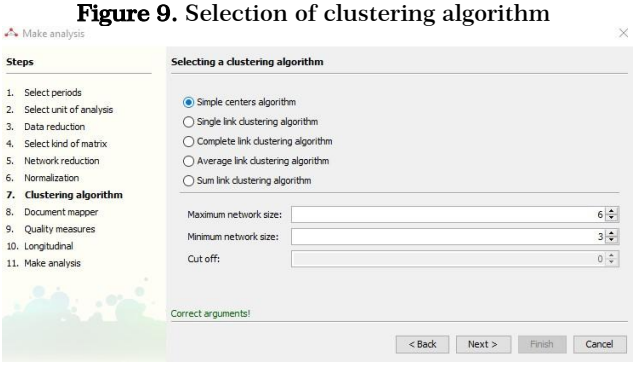
Source: Own.

Figure 8. Matrix type selection.



Source: Own.

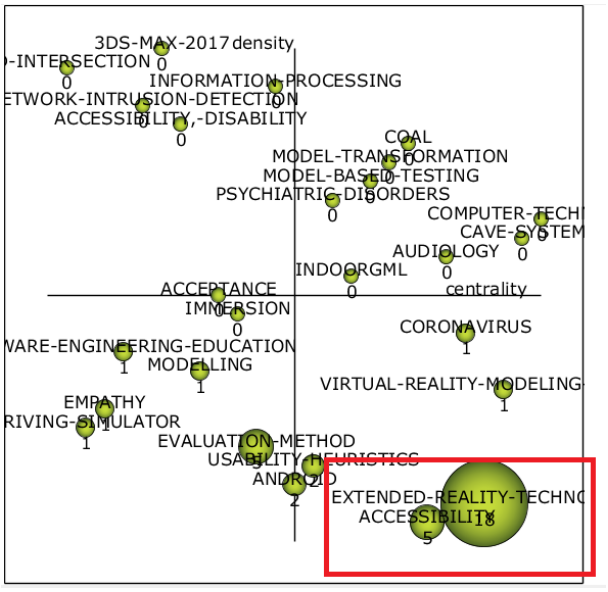
Figure 9. Selection of clustering algorithm



Source: Own.

For the period in which all items were grouped together, the centrality and density diagram shown in Figure 10 was generated:

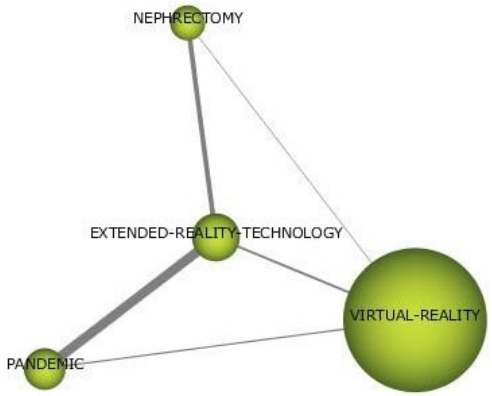
Figure 10. Centrality and density map for all periods.



Source: Own.

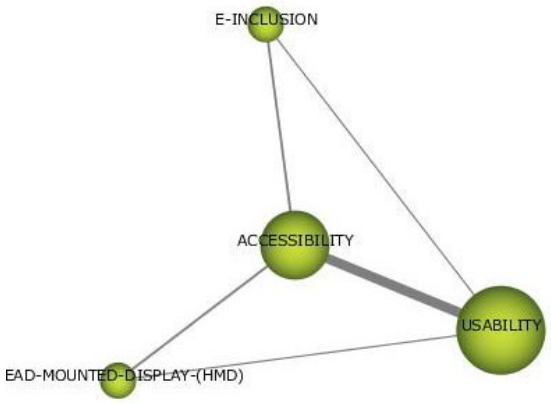
As can be seen, the "Extended-Reality-Technology" and "Accessibility" nodes are the ones that stand out the most, and being in the lower right box it can be inferred that they are transversal themes in the research. [2] that are very important to keep in mind, so a detailed view of these nodes is shown in Figure 11 shows the visualization of the virtual reality node, and in Figure 12 shows the Usability node.

Figure 11. Visualization of the virtual reality node.



Source: Own.

Figure 12. Visualization of usability node.

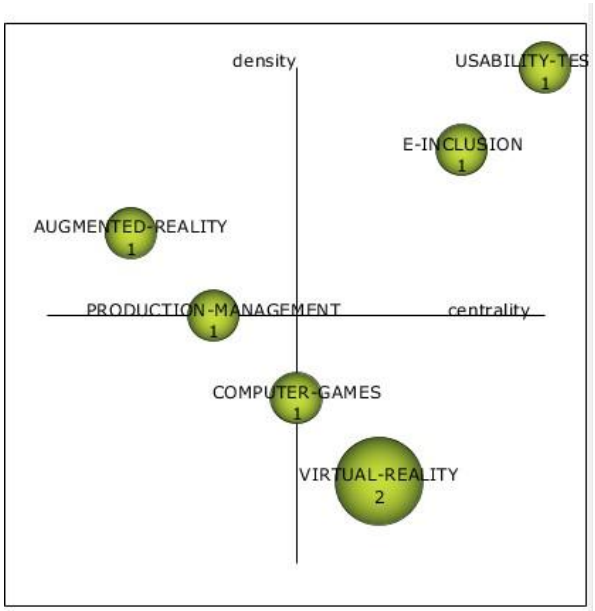


Source: Own.

It can be seen that they are nodes that group the central search axes of the literature review such as usability and virtual reality and it is possible to conclude something very important and that is that the topics of accessibility and extended reality technology should also be included in the literature review as they are closely linked to the research topics and can give a more complete perspective.

We now analyze the centrality and density diagram by grouping periods, starting with the period from 2004 to 2012 shown in Figure 13:

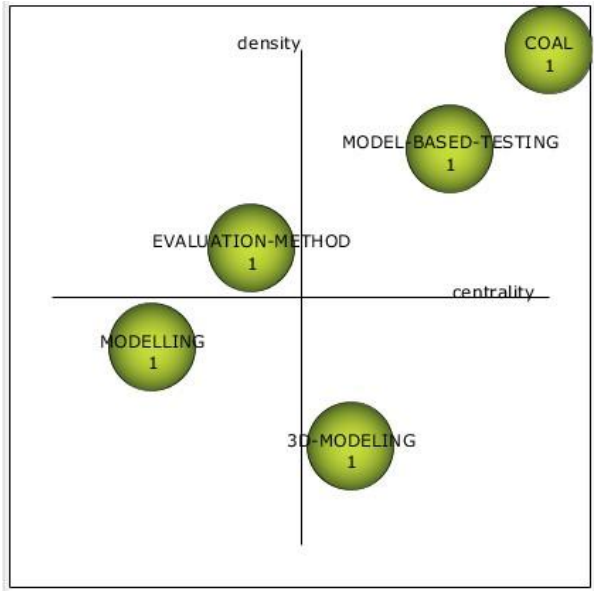
Figure 13. Centrality and density map for the period from 2004 to 2012.



Source: Own elaboration.

Then there is the diagram for the period from 2013 to 2015, as shown in Figure 14:

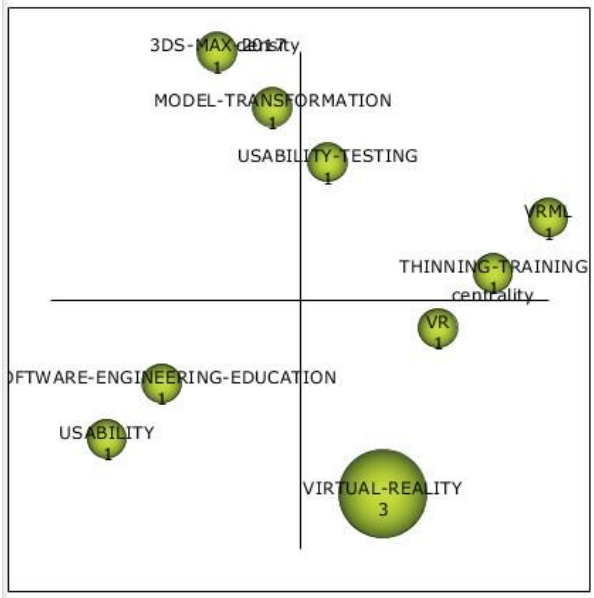
Figure 14. Centrality and density map for the period 2013 to 2015.



Source: Own elaboration.

The diagram for the period 2016 to 2018 is shown in Figure 15:

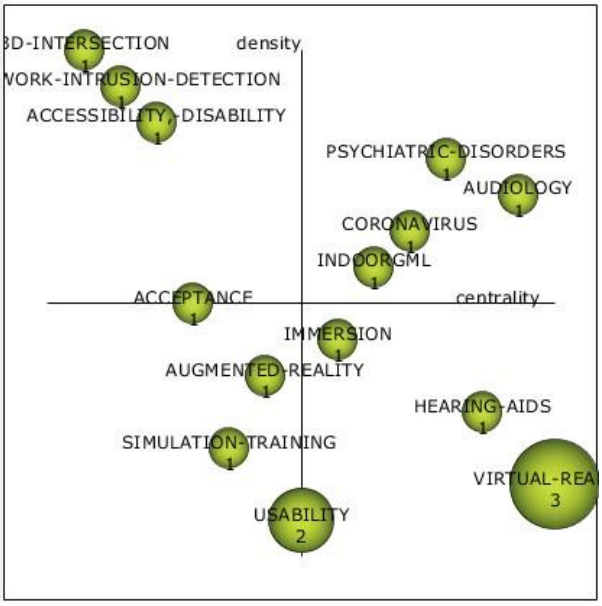
Figure 15. Centrality and density map for the period 2016 to 2018.



Source: Own.

Finally, there is the diagram for the period from 2019 to 2021 shown in Figure 16:

Figure 16. Centrality and density map for the period 2019 to 2021.



Source: Own.

As can be seen at first glance, the largest number of articles is focused on the period from 2019 to 2021, which is important, since it is certain that the information being inferred is current and still valid; in the same way it is evident that for the older periods there are not many topics located on the upper right side of the diagram, which is where the "engine" topics are concentrated, i.e. those that structure the research. [2] In contrast, in the last period studied there is more information in this quadrant; in the first periods the information is concentrated in the other quadrants, which group basic and general information or information that is little developed [2], this is logical, since the information that carries the most weight should be from more recent periods.

6. New review of information

In the analysis of the information, it was found that there are two authors who were more present in the articles studied, these are "Takafumi Taketomi" and "Goshiro Yamamoto", so a search for publications that they have made was made and 4 interesting articles were found for the review:

The first article reviewed is "EyeAR: Refocusable Augmented Reality Content through Eye Measurements." [40]. In this paper the authors show how their design of an augmented reality display improved the realism perceived by the user, and also established a display evaluation protocol that can be used by other researchers.

The next reviewed article is "SlidAR+: Gravity-aware 3D object manipulation for handheld augmented reality" [41], which presents a method to facilitate the positioning of objects in augmented reality spaces. In the paper "Towards large scale high fidelity collaborative augmented reality" [42], a technology called "HoloRoyale" is presented, which is a collaborative augmented reality experience, also implementing a multi-user oriented software architecture.

Finally, the article "Video-based Visualization of Knee Movement in Cycling for Quantitative and Qualitative Monitoring" was reviewed [43]. Although it is not based on immersive topics, it serves as a basis for analyzing the study of the visualization component, which is closely linked to virtual and augmented reality environments.

The analysis found two new topics closely related to the research that had not been taken into account, these are "Extended-Reality-Technology" and "Accessibility", so a new bibliographic review is made with these topics and 9 researches were found that complement the review already done:

The article "Extended Reality Framework for Remote Collaborative Interactions in Virtual Environments" [44] shows an extended reality framework that helps developers with object manipulation issues in virtual, mixed and augmented reality application implementations; following the line of extended reality is the article "Discerning User Activity in Extended Reality Through Side-Channel Accelerometer Observations" [45], which analyzes an interesting topic about security in extended reality sessions, how malicious people can try to know what is being done in the meeting by looking at the movements of the actors.

In the article "Extended Reality in Global Software Delivery - Towards a Common Fabric of Understanding and Insights" [46] covers a well-known problem in the software industry, which is the interaction between the different roles in the development of a system, since they have different perspectives and different needs; a work is done in extended reality that seeks to improve the way the different actors communicate through multidimensional views that are more telling than the traditional 2D views. Another article by the extended

reality branch is "Defining Extended Reality Training: A Long-Term Definition for All Industries" [47], which provides a conceptual framework for extended reality training for employees of any company, reviewing different approaches and providing a basis for future research in this field.

The next article reviewed is "User Interface Research in Web Extended Reality" [48] which is a literature review of web extended reality, specifically user interfaces, examining the existing literature and analyzing the future trends of this technology; finally the last article reviewed on this topic is "Exploring the possibilities of Extended Reality in the world of firefighting" [49], which presents a virtual reality simulator for training firefighters in firefighting, since the aim is to reduce the costs and danger currently involved in the preparation and instruction of firefighters.

Reviewing articles on the topic of accessibility in immersive environments, we found the article "Creating a Virtual Reality OER Application to Teach Web Accessibility" [50], which describes the implementation in virtual reality that seeks to raise awareness about the importance of accessibility in websites; the next article reviewed is "Accessible Augmented Reality to support chemistry teaching" [51]. In this article, the authors refer to the problems that visually impaired people have to work with augmented reality applications and review some guidelines to improve this problem through the development of an augmented reality system focused on chemistry teaching.

The latest article reviewed is "Accessibility of Immersive Serious Games for Persons with Cognitive Disabilities" [52], which works with accessibility issues on immersive games oriented to learning; it presents "Aiana" a system that works with massive open courses that has high accessibility features.

7. Conclusions

A literature review was made on the topics of modeling immersive systems with usability features and testing on these, obtaining a total of 37 important articles.

The articles were validated, showing that most of the information is current and that the information that is not current refers to basic and general topics.

Two authors were obtained: "Takafumi Taketomi" and "Goshiro Yamamoto", on whom a follow-up of publications was made and 4 more articles were found that complemented the bibliographic review.

Two new research topics were obtained: "Extended-Reality-Technology" and "Accessibility", which were not taken into account at the beginning but which are closely related to the ones we want to work on, and based on these topics, 9 more articles were reviewed and added to the bibliographic review.

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