Journal of Universal Computer Science, vol. 31, no. 8 (2025), 831-850
submitted: 26/6/2024, accepted: 4/2/2025, appeared: 28/7/2025 CC BY 4.0

A Bibliometric Analysis of Virtual Reality Applications in Anthropology

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Abstract: As a relatively new technology that has gone through several iterations in the last decade, virtual reality (VR) applications have been used in a plethora of activities pertaining to various sciences, including anthropology. In this paper, we expound a bibliometric analysis of the reviews and research articles regarding the use of VR applications in anthropology between 2010 and 2023. The analysed publications were obtained from the Scopus database, and Microsoft Excel and VOSViewer were used to analyse the data. Utilizing bibliometric methods, the analysis encompasses a thorough examination of scholarly publications, identifying and scrutinizing prominent journals, prolific authors, affiliated institutions, and key research themes within the realm of VR applications in anthropology. The objective is to provide a systematic and insightful overview of the evolution, current state, and emerging trends in the integration of VR within the anthropo-logical discourse, shedding light on the interdisciplinary nature and impact of this innovative technology on anthropological research and practice.

Keywords: Virtual Reality, Anthropology, Bibliometric analysis, VOSviewer
Categories: H.3.1, H.3.2, H.3.3, H.3.7, H.5.1
DOI: 10.3897/jucs.130590

1 Introduction

Anthropology studies humanity from a holistic perspective, focusing both on its bio-logical and cultural/ social dimensions of life. As people's everyday experiences have been increasingly digitalized in the past two decades, an increasing number of authentic practices have been replaced with a plethora of digital artefacts: online social

movements, cyberdating and cybersex, virtual tours and tourism, cyber entertainment, virtual shopping, etc. With the emergence of the COVID-19 pandemic, online and/or virtual interactions at work became prevalent, particularly in the first half of 2020. Accordingly, a large number of people dramatically increased their activities in virtual environments, which determined attaining a more detailed "virtualized identity in solidarity and competitive interaction with Others" [Abad Espinoza, 2022]. A result of this sharp increase in virtual interactions was a more flexible identity for all those involved.

This article presents a bibliometric analysis of virtual reality (VR) applications in anthropology (ANTHVR) between 2010 and 2023, focusing on research trends, applications, and technological advancements. The study examines Scopus databases to identify VR's role in anthropology, including its use in research, education, and professional training. By analyzing the volume, distribution, and themes of published studies, we offer insights into how VR has been integrated into anthropology over time. Additionally, we assess scientific contributions by identifying leading researchers, institutions, and countries driving innovation in this field. Given VR's interdisciplinary nature - spanning digital humanities, archaeology, forensic science, and education - our analysis also explores co-authorship networks and citation patterns to understand knowledge exchange.

VR applications entail the use of various computer and communication technologies to create immersive digital experiences that simulates real or imaginary environments, creating a sense of presence and enabling user interaction [Bareišytė, 2024]. They involve an assortment of sensory functions associated with sight, hearing, touch and seldomly smell. Users of such apps can research, for example, various artefacts in the fields of cultural and archaeological anthropology, 3D models of human anatomy in biological anthropology, associations between various concepts in linguistic anthropology, spatial practices in proxemics, and the juxtaposition of space and place in urban anthropology etc. VR can also serve as a gateway to imaginative, fantastic worlds, providing unlimited possibilities of exploration[Pouke, 2018]. Immersion in the VR environments is performed by interacting with entities and artefacts through several types of devices: perception helmets and gloves, tracking balls, controllers, haptic suits (e.g., Teslasuit), etc.

The use of VR technologies has multiple advantages. The environment created through VR apps is automated, digitalized, standardized and virtualized. It has the potential to increase the realism of interactions. Furthermore, the environment designed in virtual space offers researchers the possibility of attaining a clearer perspective about the artefacts and phenomena they study. VR applications can be used to approach a cultural system or a biological feature from multiple viewpoints, which increases the level of detail and can prove instrumental in the analysis and interpretation phase of the research. VR constructs can increase the level of researchers' engagement in an immersive environment, which may lead to an increase in anthropologists' concentration and improve their research efficiency.

In our analysis, we identified that VR applications were used to (a) study three-dimensional models of anatomical structures and features in biological anthropology, (b) research artefacts, practices, rituals, cultural systems, patterns, proxemics, and behaviours in social and cultural anthropology, and (c) teach anthropology by stimulating students' responses to sensorial and motor immersion in virtual settings. The study examined both immersive VR systems (head-mounted displays, tracking

devices, data gloves) and 3D environments accessed via traditional computing devices (PCs, smartphones).One of the pioneering uses of VR in anthropology is the virtual reconstruction of ancient archaeological sites. As an example, the "Zamani Project" at the University of Cape Town allows researchers to explore Petra form Jordan in an immersive VR environment [Wessels, 2014]. Another study proposed an integrated approach of reconstruction to create accurate 3D virtual models of archaeological sites, such as Huaca Arco Iris in Peru, facilitating both archaeological research and public engagement [Pierdicca, 2016]. VR has also been employed to simulate and study cultural practices. For instance, Wayne State University's Virtual Ethnographic Field School in Ecuador provides students with a unique opportunity to engage with Ecuadorian culture virtually [Lyons, 2024]. By participating in online interactions with villagers, students can develop language skills, cultural understanding, and research abilities. In forensic anthropology, a VR application was used to assess the participants' ability to determine age and sex from virtual skeletal models [Jepps, 2023].

Museums and cultural institutions have increasingly adopted VR to create virtual exhibitions. “Agnano RiVive”, an immersive VR application designed for the Museum of Preclassical Civilizations of Southern Murgia, enable users to explore the Upper Paleolithic settlement [De Paolis, 2022]. Also, VR is being integrated into anthropological education to offer immersive learning experiences. In a pilot study, VR was used in an introductory anthropology course at Utah Valley University . It highlights the emerging trend of using VR technology to enhance anthropological learning experiences [Dulin, 2022]. Another research explored the use of VR for forensic anthropology education by creating 3D skeletal models, particularly focusing on the femur bone [Harahap, 2023]. The goal was to address the decreasing availability of physical skeletal remains for learning and training.

One serendipitous aspect identified in the articles reviewed is the enjoyment often associated by the researchers with the use of VR applications [Almas, 2022]. This feature increases their application potential. Anthropologists can repeatedly interact with or practice observation of cultural practices and investigate anatomical features in a controlled environment.

Despite the growing adoption of VR in anthropology, its prospects have only been broadly outlined over the past decade. A systematic bibliometric analysis is essential to assess the current body of research and provide a comprehensive overview of how VR is shaping anthropological studies. To our knowledge, no such analysis has been conducted, leaving a critical gap in understanding the evolution, impact, and interdisciplinary connections of VR applications in anthropology. Bibliometric analysis, leveraging large-scale scientific literature databases, allows for an objective evaluation of contributions based on key categories such as journals, keywords, authors, co-citations, publication trends, institutions, and geographic distribution. Over the past three years, this method has gained prominence across various disciplines, offering valuable insights into research trajectories. By constructing a knowledge map of VR applications in anthropology, our study not only documents current developments but also provides a strategic foundation for future research, ensuring that VR continues to drive innovation and methodological advancements in the field.

2 Methods

2.1 Data Source and Search Strategy

To collect data relevant for our analysis, we used the Scopus database. Scopus was launched by Elsevier in 2004 and it became a powerful competitor of WoS [Ghaemi, 2022]. Scopus is regarded as the most extensive database in terms of abstracts and citations of peer-reviewed articles across many scientific domains [Hall, 1966], ensuring that only the highest quality data are indexed through rigorous content selection and evaluation [Han, 2021]. Moreover, it is a multidisciplinary database, covering different areas, such as the social sciences, health sciences, physical sciences, and life sciences [Hawlitschek, 2017] and it has been widely used in bibliometric studies [Iachini, 2016].

The data were obtained in two steps, on February 20, 2023, and then on June 19, 2023. The retrieval strategy included some specific steps. The first step was to select the relevant keywords for the bibliometric analysis. For this purpose, we performed a preliminary search in the ScienceDirect database to analyse the author keywords used in some of the most recent articles published in well-ranked journals considered relevant for the pro-posed topic. After trying various combinations of terms, we settled on the following query string:

"Virtual Reality" AND "Anthropology" OR "Biological Anthropology" OR "Physical Anthropology" OR "Cultural Anthropology" OR "Social Anthropology" OR "Ethnology" OR "Ethnography" OR "Archaeological Anthropology" OR "Proxemics".

2.2 Eligibility criteria

In the next step, we defined some eligibility criteria. We used the following inclusion criteria:

(1) The publication year of the literature was from January 1, 2010, to June 2023;
(2) The language of the literature was English;
(3) The type of literature was article or conference paper;
(4) The research topic of the literature was the application of VR in anthropology.

Conversely, we have considered the following exclusion criteria:

(1) The types of documents were book chapters, reviews, reports and letters;
(2) The documents did not use virtual reality as the research topic;
(3) The documents did not use anthropology as the research topic;
(4) Non-English documents.

2.3 Query and data analysis

Title-abs-key based search for rapid visibility and retrieval was used. The final query string used in Scopus was as follows:

TITLE-ABS-KEY ("Virtual Reality" AND "Anthropology" OR "Biological Anthropology" OR "Physical Anthropology" OR "Cultural Anthropology" OR "Social Anthropology" OR "Ethnology" OR "Ethnography" OR "Archaeological Anthropology" OR "Proxemics") AND PUBYEAR > 2009 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "p")) AND (LIMIT-TO (LANGUAGE , "English"))

The initial search generated 390 documents, and after applying the limitations related to source type, language and publication period, 287 works remained, as shown in Fig. 1. We followed the main steps defined described in the PRISMA methodology [Jurda, 2019], but they were used from the point of view of a bibliometric study. In the screening phase, 8 articles were excluded based on the absence of authors or source title. In the eligibility phase, 279 articles were screened by two authors using EndNote 20 software. The irrelevant articles were excluded, resulting in a total of 220 items included in the analysis.

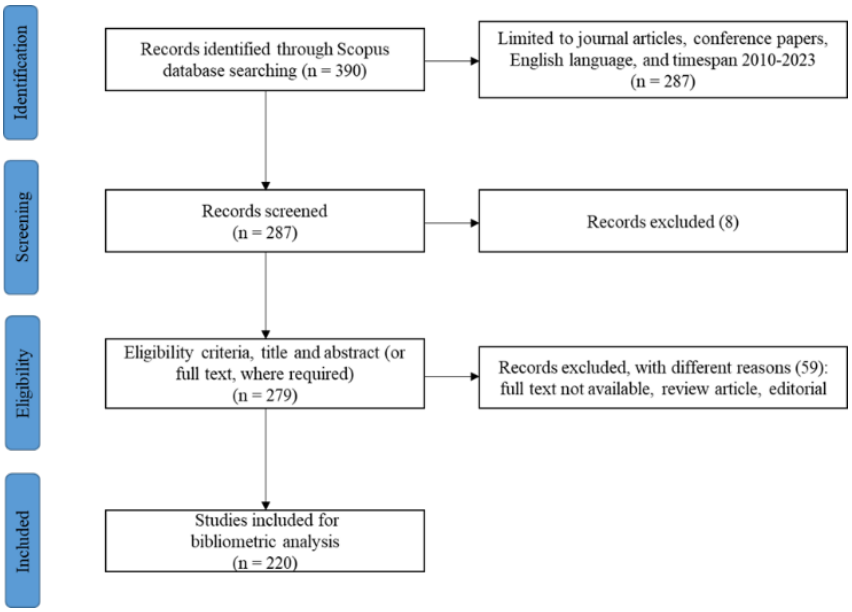

Figure 1: Flow diagram of the methodology search for bibliometric analysis

The next step was to analyse the data from a quantitative and descriptive point of view, using a combination of Microsoft Excel, EndNote and VOSViewer. We mapped a comprehensive description of various publishing characteristics, including keywords, co-citations, publication numbers, institutions, countries, authors, and journals.

3 Results

During the selected time span, 220 papers were published on VR-based applications in anthropology. Their characteristics are shown in Table 1.

Parameter	Value
No. of selected articles	220
Time span	2010-2023

Sources	138 79 journals, 59 conference proceedings)
Authors	776
Papers written by a single author	38
Authors per article	3.84
Average citations per article	11.86
No. of selected articles	220

Table 1: Scopus information about the data

The results revealed 776 authors, with a collaboration index of 3.84. Except for 38 papers that were written by a single author, all the others were part of multi-author publications.

Fig. 2 displays published papers on VR-based applications in anthropology from 2010 to 2023 in conjunction with the average citations of documents by year. It can be seen that the research increased over time, with certain variations. The peak was reached in 2019, with 26 papers (11.82% of the total number of papers). Regarding the average number of citations, most were obtained for articles published in 2014, even though only 6 papers were published in the respective year.

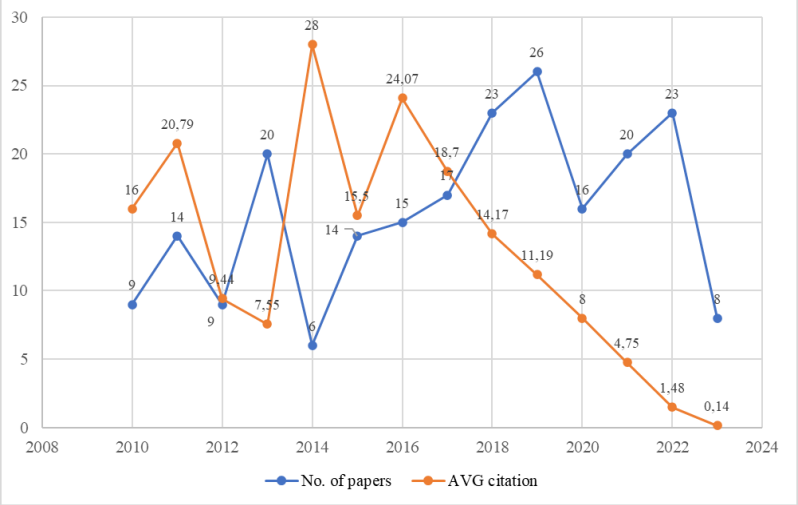

Figure 2: Annual scientific productivity for publications indexed in Scopus (number of papers published per year and average total citations per year)

The results showed that 50.45% (n=111) of the total number of papers were published in journals, while 49.55% (n=109) were published in conference proceedings. Table 2 pre-sents a list of the most prolific journals regarding the topic under discussion. The top journal is Forensic Science International, with 9 publications and 228 citations. The sec-ond prolific journal is the American Journal of Physical

Anthropology, with 6 publications and 118 citations, followed by IEEE Transactions on Visualization and Computer Graphics, with 5 scientific papers and 65 citations. Table 2 illustrates that the journal with the highest impact factor is Computer in Human Behavior, and is also the journal with the highest citation score, 17.8, meaning that it received high citations from the articles published in the Scopus database.

No.	Source	Papers	Citations	IF[a]	Cite Score	Publisher
1	Forensic Science International	9	228	2.676	4.8	Elsevier
2	American Journal Of Physical Anthropology	6	118	2.868	-	Wiley
3	IEEE Transactions On Visualization And Computer Graphics	5	65	5.226	10.5	IEEE
4	Computers In Human Behavior	4	49	8.957	17.8	Elsevier
5	Journal Of Forensic Radiology And Imaging	4	3	-	-	Elsevier
6	International Journal Of Gaming And Computer Mediated Simulations	3	21	0.583	2.5	IGI Global Publishing
7	Journal Of Forensic And Legal Medicine	3	39	1.691	3.1	Elsevier
8	Plos One	3	63	3.752	6.0	Public Library of Science
9	Virtual Reality	3	136	4.697	10.0	Springer
10	ACM Transactions On Applied Perception	2	130	1.676	3.8	ACM

[a] Impact Factor – based on 2021 Journal Citation Reports

Table 2: Top 10-most prolific journals regarding ANTHVR research

Furthermore, the results of this analysis identified the top 7 most prolific authors from 2010 to 2023. They are affiliated with different institutions from 4 countries: the United States (4), Italy (1), the Czech Republic (1), and the Netherlands (1). Table 3 lists only the first 7 authors with more than 3 publications in the field of anthropology combined with VR. Gerd Bruder and Thomas J. Palazzolo are the most productive authors, with 4 publications each within the study period. The rest of the authors published 3 re-search articles each within the same period. We mention that the h-index

presented in the table is calculated only for the articles selected in this analysis and is not the total h-index of the authors.

No.	Author	Scopus Author ID	Affiliation	Number of publications	h-index
1	Bruder, Gerd	23391698600	University of Central Florida, Orlando, United States	4	4
2	Palazzolo, Thomas J.	56404631900	Drexel University, Philadelphia, United States	4	1
3	Benazzi, Stefano	24068504800	Alma Mater Studiorum Università di Bologna, Bologna, Italy	3	3
4	Jurda, Mikoláš	46961314600	Masaryk University, Brno, Czech Republic	3	2
5	Novick, David G.	7007104505	The University of Texas at El Paso, El Paso, United States	3	2
6	Reynolds, Robert G.	74018300677	Wayne State University, Detroit, United States	3	1
7	Shah, Mamta	56052481900	Elsevier B.V., Amsterdam, Netherlands	3	2

Table 3: The most prolific authors in ANTHVR research

Table 4 presents the top 10 papers in terms of citations in the field throughout the time. Iachini, T. et al., 2016 placed first, with 156 citations, followed by Llobera, J. et al., 2010, with 101 citations, and Sagayam, K. M. & Hemanth, D. J., 2017, with 97 citations. It can be seen that all of the papers are published in different sources. Eight of them are published in journals, while two of them are published in conference proceedings. We used in our query the umbrella term “proxemics”, which designates “the interrelated observations and theories of humans use of space as a specialized elaboration of culture” [Kamaruzzaman, 2022]. As a discipline, it was developed by the cultural anthropologist Edward T. Hall in the middle of the twentieth century. Proxemics has become a staple term in a series of disciplines, such as social psychology, architecture, sociology, and cybernetics. The terminology from some of

the publications referenced in our review pertains to social psychology (Iachini et al., 2016). However, the basis of this discipline is predicated on anthropological insights. Therefore, we decided to include in our review articles that retain the initial sense attributed to this discipline by Hall [22]. In the last decade, research into proxemics, with a particular emphasis on proxemic behaviours, was implemented in studies that focused on digital and virtual environments [23,24].

No.	Paper	Publication	TC[a]
1	[25]	Journal of Environmental Psychology	156
2	[26]	ACM Transactions on Applied Perception	101
3	[27]	IEEE Computer Graphics and Applications	76
4	[28]	Proceedings of 2015 IEEE Virtual Reality Conference	72
5	[29]	IEEE Transactions on Professional Communication	57
6	[30]	Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility - ASSETS 2016	47
7	[31]	Journal of Biomedical Informatics	44
8	[32]	Forensic Science International	42
9	[33]	Virtual Reality	38
10	[34]	American Journal of Physical Anthropology	38

[a] TC - Total number of citations

Table 4: Top 10 highly cited articles

A list with the top 10 most productive countries in terms of published scientific works is presented in Table 5. The United States, with 75 papers (34.09%), is at the top of the list, also leading with the highest number of citations (1056). The list is followed by the United Kingdom, with 46 documents (20.91%), 628 citations and an average publication citation of 13.65. The list is followed by Germany (25 documents, 11,36%), Italy (13 documents, 5.91%), and France (12 papers, 5.45%). The table shows that the research in VR ap-plications related to anthropology comes from developed countries, all of them being in the top 20 world economies.

Table 5 also shows the h-index obtained by each country for the published articles and the number of articles published by each country alone, meaning that the authors of the respective articles did not collaborate with authors from other countries.

No.	Country	No. of papers	SCP[a]	TC[b]	ACP[c]	h-index
1	United States	75	48	1056	14,08	18
2	United Kingdom	46	11	628	13,65	15
3	Germany	25	12	278	11,12	10
4	Italy	13	6	315	24,23	7
5	France	12	3	472	39,33	7

6	Spain	11	4	157	14,27	4
7	Japan	8	3	30	3,75	3
8	Australia	7	3	74	10,57	6
9	Netherlands	7	2	87	12,43	6
10	Canada	6	1	78	13	4

[a] SCP – Single country publication; [b] TC – Total number of citations;
[c] AAC – average number of citations per publication

Table 5: Top 10 most productive countries

The collaboration between countries was investigated using co-authorship analysis from VOS Viewer. Every frame in the network represents a distinct country that is linked to others. The thickness of the connection lines indicates the strength of the link between the two countries. From the total number of 49 countries, 18 have fulfilled the condition of at least 5 documents and they formed 5 clusters. The results show that the United Kingdom has the highest linkage, with 15 links and total link strength of 37. It is followed by the United States (10 links, total link strength of 25), Germany (9 links, total link strength of 20), France (10 links, total link strength of 15), and Italy (5 links, total link strength of 10).

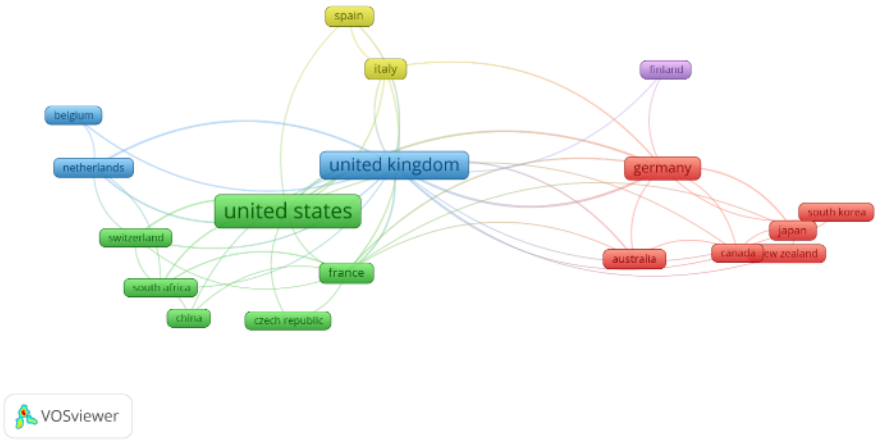

Figure 3: Collaboration network between countries

Table 6 presents the metric of the top 10 academic institutions in terms of the number of published papers. The leader in the list are University College London, United Kingdom, and Sapienza Università di Roma, Italy, with 5 documents each. They are followed by other institutions from different countries, with 5 published articles each. It can be observed that there are 9 universities and a research institute in the list. The authors found that 6 of the listed universities are in the world's top 100 universities and the other 3 are in the top 600 in the world [Roberts, 2014].

No.	Affiliation	Country	No of papers
1	University College London	UK	5
2	Sapienza Università di Roma	Italy	5
3	University of Glasgow	Scotland	4
4	CNRS Centre National de la Recherche Scientifique	France	4
5	Wayne State University	USA	4
6	Universität Zürich	Switzerland	4
7	Stanford University	USA	4
8	Oulun Yliopisto	Finland	4
9	Ludwig-Maximilians-Universität München	Germany	4
10	University of Wisconsin-Madison	USA	4

Table 6: List of most prolific institutions

Regarding the main topics that the authors of ANTHVR research write about, a co-occurrence analysis was performed in VOSViewer using both the author keywords and the index keywords. Out of the total of 2357 keywords, 107 had a minimum of 5 occurrences, 13 of which were excluded on the grounds that they are not relevant or are similar terms, such as 'article', 'priority journal', 'aged', 'procedures', 'male', 'female', 'aged', and 'very elderly'. The most recurrent keywords are grouped into 4 clusters, represented with different colours in Fig. 4. The result depicts that 'virtual reality' is the most prominent keyword, with 199 occurrences, 92 links, and a total link strength of 814. It is followed by 'three-dimensional imaging', with 21 occurrences, 40 links, and a total link strength of 172, 'human computer interaction' (39 occurrences, 50 links, 165 total link strength), 'proxemics' (36 occurrences, 39 links, 148 total link strength), and 'forensic anthropology' (13 occurrences, 28 links, 110 total link strength).

These terms are organised into four clusters, as follows: the first larger cluster includes 28 items, such as 'image processing', 'computer simulation', and 'diagnostic im-aging', the second contains 25 items, such as 'cultural anthropology', 'social behaviour', and 'perception', the third consists of 19 items related to 'virtual worlds', 'virtual community', and 'second life', and the last cluster contains 19 items, such as 'virtual reality', 'human computer interaction', 'augmented reality', or 'virtual character'.

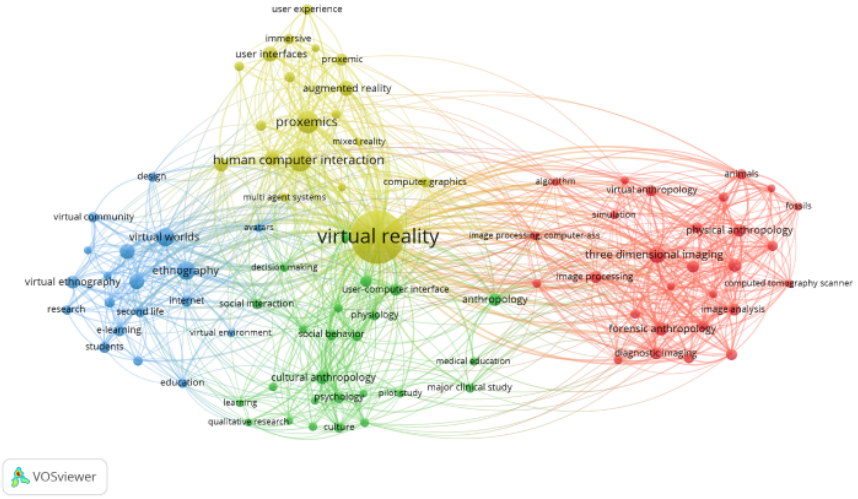

Figure 4: Clusters of co-occurring keywords

4 Discussion

In our study, we were able to review the following anthropological activities in which virtual reality applications were used:

1) Research is considered by some authors to be both (a) an activity per se and (b) an umbrella term used to designate a cluster of activities in which VR applications are relevant. The two meanings associated with the term were found in 290 publications. Furthermore, VR applications were used to develop new types of research methods and techniques that borrow from anthropological methods and techniques. New qualitative re-search methods such as go-along interviewing have appeared in the last decade. Such methods include aspects from both participant observation and ethnographic interview-ing. For example, in [Anastasovitis, 2017] is illustrated the way in which VR go-along interviews were used to obtain "contextualised perspectives in which informants and observers conduct mobile interviews while navigating in real or imagined sites". Go-along interviewing was applied to six participants to explore the spatial representation of urban decontextualization with the help of Google Street View. While the sample size is extremely limited in this study, the authors illustrated two interesting directions of development, as a proof of concept: (a) the immersion determined by VR induced emotions and allowed the researchers to obtain a plethora of information from the respondents; (b) the engagement predicated on cultural influences, acquaintance with various places and temporal changes determine the "contextual perspective of participants when visiting" specific places, such as heterotopias [Anastasovitis, 2017]. Furthermore, researchers can conduct various types of research through direct observation without revealing themselves [Baas, 2020]. VR applications allow researchers to attain better insights into the routines, habits, gestures and statements about behaviours, beliefs, and values of respondents [Baas, 2020]. Nonverbal communication, including gestures, posture and social distancing can be studied with

VR applications. In video games, the possibility of using social cues as elements of gameplay enriches social experiences [Baier, 2017], and allows anthropologists to relativize fieldwork, because "virtual communication dematerializes the ethnographic encounter, making possible the intangible interconnectedness between observers and observed subjects who do not participate in the same spatiotemporal setting" [Beltramini, 2022]. Space and time become relative in virtual settings such as, for example, the open worlds of Massive Multiplayer Online Role Playing Games (i.e. MMORPGs). Furthermore, VR applications allow diverse anthropological studies, ranging from (a) anthropometric measurements of maintaining balance with open and closed eyes [Benazzi, 2014] to identity and sacredness [Bogachenko, 2020].

2) Education is an activity commonly expected to be developed with VR applications [Burlacu, 2023]. Our review revealed that the effectiveness of VR in educational contexts was approached in 15 studies published as articles, conference papers and book chapters. Several of these studies included topics dedicated to reconstructive archaeology, physical anthropology, cultural anthropology and philosophical anthropology [Coover, 2018], [Dickinson, 2019], [Dobre, 2022], [Dooley, 2020]. Furthermore, some articles specifically approached "the use of scientific metaphor as an image or symbol with epistemic and educational value" to create a space that could be considered a "world of science" [Economou, 2008]. When it was loaded with significance, such a space became a place of learning, a development tool similar to the one called "Personality Garden" [Erickson, 2018]. Accordingly, VR applications can be used to develop constructs that inform and encapsulate the ways in which experiences are shaped and contribute to the teaching tools and the overall educational practices of both the educator and student.

3) Professional training is associated in the reviewed publications with the exploration of specific places and virtual artefacts. Training has similarities with education from the standpoint of the methods employed. However, while training developed with VR ap-plications in anthropology prepares users for a specific task, such as developing research based on go-along interviews, education entails a broader purpose. It prepares users for an occupation in which VR applications are used as a set of tools. The use of VR applications entails a series of advantages: (a) users can develop scientifically informed models that consume less time and resources than the "classic" tools used in the past; (b) there are no physical limitations; (c) users' immersion can be enhanced through gamification; (d) the virtual background entailed by VR applications enables training in an accelerated timeframe; and (e) the complexity of the sociocultural phenomena that can be modelled for training with VR applications may exceed the intricacies of their counterparts from "real" emplacements

We used VOSviewer to analyse keywords in 290 articles, which were filtered out of a total 4900 publications. We have identified the following keywords that have higher frequencies: technology, application, group and participant. Accordingly, we wanted to identify the most mentioned VR technologies and applications in anthropology:

1) The HTC Vive headset combined with customized applications, such as A.R.T. (i.e. Augmented Reconstruction Toolset), which was compatible. UNITY cross-platform game engine. The HTC Vive virtual reality platform was developed by HTC and Valve in 2016. The headset combines sensors, cameras and laser tracking to provide the user with an immersive VR experience. Additionally, it has two high-resolution OLED displays, one for each eye. The resolution of 1080 x 1200 pixels per

eye and the refresh rate of 90 Hz offer the users a smooth and enjoyable experience. Furthermore, the users can interact with the virtual environment with two handheld controllers, a base station that tracks the users' movements in the room, a built-in microphone and headphones for audio input and out-put. This technology and its associated applications are specifically mentioned as being used in the fields of forensic medicine and anthropology in one article [Sánchez, 2017].

2) Oculus Rift allows for immersion in an environment where various artefacts and the "reality" itself can be redesigned. In anthropology, this technology was used in the past five years to reconstruct and study anatomical details that were difficult to research, in biological anthropology. They were also used to visualize virtual representations of either real places, or illustrations of circumstances that were previously described by anthropologists and cultural heritage sites [Sanz, 2015].

3) Mozilla Hubs is an open-source virtual environment platform that runs in most standard browsers. It allows users to develop a plethora of activities, such as: (a) host virtual events; (b) create digital galleries; (c) build an environment for hobbies; and (d) open classrooms and coordinate interactive lectures. It entails multiple options for developing virtual environments tailored for various types of interactions dedicated to research, education and applied endeavours. The use of this technology was illustrated in one of the re-viewed publications [Simeone, 2011].

4) CAVE (i.e., Cave Automatic Virtual Environment) is a technology that uses a cu-be-shaped room to immerse the user. All of its surfaces (i.e. floor, walls ceiling) is regularly used as a projection screen. The result is a virtual environment that is highly immersive and allows for more complex activities than other technologies and/or applications, such as Oculus Rift. Stereoscopic glasses allow the user to study 3D modelled artefacts that seem to be "suspended" in the air. Researchers have the possibility to walk around the 3D models to gain a level of understanding that would not be possible using older optic technology. The illusion of reality is based upon high-resolution projection systems. Furthermore, in the CAVE room there are sensors that track the user's movements to adjust the video projections [Spasić, 2022], [ST Engineering, 2022]. This technology was specifically mentioned in one of the reviewed articles.

5) Serious games were used for educational purposes, research analysis and cultural heritage conservation [Burlacu, 2023]. In the last decade, numerous articles dedicated to this ample topic have been published [Tham, 2018]. While the extent of this topic far exceeds the scope of our article, the applications of serious games for VR have been studied by researchers belonging to numerous scientific fields [Vankipuram, 2011]. The articles that presented the applications of serious games in VR used this term with one of the following two senses:

(a) In a "weak" sense from a logical standpoint, it was used to designate any immersive environment that is developed using digital technologies, without specialized hard-ware and software dedicated to simulating experiences using pose tracking and high-fidelity 3D near-eye displays fashioned into goggles.

(b) In a "strong" sense from a logical standpoint, the term "virtual reality" labels specialized hardware that includes but is not limited to pose tracking stations, controllers, high-fidelity goggles, haptic suites. etc. According to this sense, VR applications and de-vices entail more complex input mechanisms than traditional user interfaces. In non-VR digital applications, users are limited to 2D interfaces (i.e. keyboard, mouse, game controller, etc.). In VR applications, any user can deploy a

plethora of 3D motions and reactions: "they can use their limbs, head, or their whole body as a form of input to drive the interaction, as they would do in their day-to-day life" [Baier, 2017]. Accordingly, both sociocultural anthropologists who attempt to develop online ethnographies, and biological anthropologists who try to reconstruct the crania of Homo habilis, Homo heidelbergensis or Homo neanderthalensis have multiple options that allow in-depth studies [Ringland, 2016], [World, 2023].

The biggest commonality between these technologies is the fact that they allow researchers, trainers, students, and other categories of users to develop their own virtual platforms that entail features specific to laboratories, theme parks, natural emplacement simulations and other controlled environments. However, the reviewed literature mentioned in our article revealed that approaches to VR applications are often developed without epistemological grounding. Consequently, the terms used in various publications have nuanced meanings that often are distinct. For example, the term "proxemics" is used in some articles in a sense that is different from the original meaning attributed in anthropological literature [Kostakos, 2019], [Zhu, 2020].

Furthermore, the approaches pertaining to anthropology are based on theoretical models without direct mentions of their epistemological foundations, which raises questions about the scientific character of the insights allegedly gained and about their relevance. This problem is further compounded by the fact that in the past two decades the theoretical perspectives developed in biological anthropology are largely not compatible with the new directions from sociocultural anthropology. While this aspect exceeds the subject of our publication, it represents an interesting potential direction of future research.

While this study provides valuable insights into the application of VR in anthropology, it is important to acknowledge certain limitations. The focus on English-language publications may have inadvertently excluded relevant research conducted in other languages. Additionally, the specific selection of databases and keywords could have influenced the scope of the analysis. Future research may benefit from expanding the language search and considering a broader range of databases to capture a more comprehensive overview of VR applications in anthropology.

5 Conclusions

The current study provides valuable insights into the use of virtual reality applications in the field of anthropology, between 2010 and 2023. We have focused on publications extracted from the Scopus database that approach both biological/ physical and sociocultural anthropology studies.

The analysis revealed a significant growth in the number of publications related to VR applications in anthropology, indicating a growing interest and recognition of their potential as tools, which offer clear advantages in comparison to "classic" tools. This in-crease can be ascribed to technological developments, increasing accessibility of VR equipment, and a rising awareness of the unique capabilities VR applications provide for immersive anthropological studies.

Our findings demonstrate that VR has been extensively explored across various sub-fields of anthropology, including archaeology, cultural anthropology, and biological anthropology. Researchers have utilized VR applications to enhance traditional methods to develop site reconstructions and virtual museums, as well as to

explore novel research avenues, such as embodied virtual experiences, identities and participatory ethnographic simulations. In-depth analyses of virtual interactions and new customs represent topics that were addressed with VR applications in the past decade. Space and time received more flexible definitions in virtual emplacements in which interconnectedness became "intangible" in its classic sense [Beltramini, 2022].

Moreover, the analysis highlights the diverse benefits of VR in anthropology. VR provides researchers with the ability to recreate and study remote or inaccessible sites, allowing for a deeper understanding of cultural contexts and past civilizations. It also facilitates immersive and embodied experiences, enabling participants to engage with cultures and environments in ways previously unimaginable. VR has emerged as a powerful tool for education, public outreach, and fostering cross-cultural empathy.

However, despite the promising opportunities, challenges remain. Technical limitations, such as the need for high-quality hardware and software, continue to hinder wide-spread adoption. Ethical considerations, including informed consent and the potential for the simulation of culturally sensitive experiences, also need to be carefully addressed. Any form of simulation entails questions regarding the "authenticity" of these experiences and their impact on the users' perceptions.

The epistemological assumptions regarding endeavours in biological anthropology and ethnographies in sociocultural anthropology should be reconsidered. Philosophical reflections concerning anthropological investigations, both biological and sociocultural, should be reconsidered, especially because of the growing divide between the former and the latter. While biological anthropologists navigate between the phenotypical features that can be better understood using virtual applications, sociocultural anthropologists approach the challenges associated with the "physical absence of the ethnographic encounter" [Beltramini, 2022]. An equilibrium between (a) physical and digital ethnography in sociocultural anthropology, and between (b) virtual and physical anthropometric and morphological studies in biological anthropology has the potential to provide captivating future advances in general anthropology. Instead of allowing anthropologists to focus on disjointing general anthropology into various fields, disciplines and subdisciplines, VR applications that are epistemologically and ethically predicated could connect the various sociocultural and biological realities of humankind. Ultimately, VR applications may represent ways to connect various sociocultural and biological human realities from a holistic perspective. This perspective, which was considered in the past to be one of the hallmarks of anthropology per se, was neglected in the publications reviewed by us.

6 Future Work

Looking ahead, the bibliometric analysis indicates several promising directions for future research. There is a need for interdisciplinary collaborations, bringing together anthropologists, technologists, and VR developers to further explore the potential of VR in anthropology. Additionally, longitudinal studies examining the long-term impact of VR experiences on individuals and communities are necessary. Furthermore, the ethical im-plications of using VR in anthropological research should be a focal point for future discussions and guidelines.

The meanings associated with the term "proxemics" have diversified in the past two decades to the point that only a fraction of the publications mentioned the term in

the original sense, as it was envisaged by Hall [Kamaruzzaman, 2022]. Proxemics was increasingly used as an umbrella term correlated with social psychology, computer science, and behavioural sciences, with no mention of its origins as an anthropological discipline. This entails the danger of essentializing and therefore reducing a body of knowledge to only a few notions, as some articles have illustrated [Kostakos, 2019], [Zhu, 2020].

In conclusion, this bibliometric analysis underscores the transformative potential of VR applications in anthropology. As technology continues to advance and accessibility improves, VR will undoubtedly play an increasingly prominent role in anthropological research, education, and public engagement. By embracing this immersive and interdisciplinary approach, we can forge new paths of knowledge and understanding, pushing the boundaries of anthropological inquiry in the digital age.

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