The Who in VR/AR for Education: A Scoping Review from IEEE Publications

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Abstract

HEIs have continuously been the vanguard of novel technologies, pushing progress and establishing the afterward generation of scientists, businesspersons, and engineers. Virtual and augmented reality technologies are on the borderline of enlargement nowadays. To better understand who are essential actors in this new research area, we have extracted metadata of all published papers by IEEE, dating from 1990 to 2021, using keywords VR, AR, and Education. For each publication, we have extracted the list of all the authors, creating a co-authorship dataset. This dataset is then further processed using social network analysis metrics. The results are discussed to understand research publications' main actors driving VR/AR/Education trends.

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Introduction

The future of VR and AR use in education will be determined by better awareness of this technology and improved user experience. There is a false impression that VR and AR only have applications for entertainment and video games and cannot be used as a business tools. VR/AR technologies have excellent prospects in explaining complex concepts in fields such as medicine, healthcare, military, aviation, engineering, space, etc., offering a unique advantage for virtual learning in higher education.

There is a need to introduce the concept of virtual technologies as a tool for accelerating university modernization while contributing to developing a knowledge-driven society. This will increase the quality and level of efficiency in teaching and knowledge retention through virtual technologies, thus contributing to skills enhancement and other building digital society.

Related Work

When starting to explore the trends in a new field that is popping up, the first thing that comes to mind is which publications are announcing these trends. This goes hand in hand with the question of the authors who model innovative knowledge communities (Paavola et al., 2004). For this research, we are interested in the innovative knowledge needed to utilise VR/AR technologies to improve teaching and learning. Improving and expanding the learning practice is at the core of what Virtual Reality can offer to learners and is one of the most effective ways that could transform the learning process (Kazanidis et al., 2021). It defines a new classroom ecosystem transforming the teaching process from a teacher-based to a student-centered education (Papanastasiou et al., 2019; Martín-Gutiérrez et al., 2017; Dede et al., 2017). Furthermore, it increases engagement via interactivity (Moro et al., 2017; Bozzelli, 2019; Dow et al., 2007), boosts learning potential (Mallam et al., 2019; Gonzales, 2019; Chen, 2013), and offers personalised learning experiences (Kurilovas, 2016; Marienko et al., 2020; Bucea-Manea-Ţoniş et al., 2021).

Methodology

For this research, we have extracted metadata of all published papers by IEEE, dating from 1990 to 2021. The retrieved metadata are based on our search regarding abstracts that contain these keywords:

- Virtual Technologies, VR, Education
- Virtual Reality, VR, Education,
- Augmented Reality, AR, Education.

From these three searches, we retrieved three datasets. Firstly, we merged all three datasets, removing duplicate publications since some can occur in more than one dataset. The results dataset has 340 records for different publications in the field, with the following metadata: title, authors, author affiliations, publication title, publication year, keywords, abstract, citation count, DOI, and many other categories.

For each publication, we have extracted the list of all the authors. For each such list then, we created a list of pairs (combinations of two) of authors, which resulted in a list of 1924 coauthors (teams of authors) who have collaborated regarding some research on VR/AR in Education. Some of these collaborations occur more than once. We removed all the duplicates but preserved the association count since this number suggests a more robust connection/collaboration in more than one research in the field.

We further analyzed the data in these datasets to investigate the main actors driving VR/AR trends in research publications. This analysis was conducted using algorithms and metrics from the social network analysis area.

SNA Metrics

We have used the following SNA metrics: degree centrality, PageRank, and betweenness centrality:

- *Degree centrality* is defined as the number of links occurring upon a node. There are considered the number of unique edges that are connected to the node (Kadriu et al., 2013). The degree can be interpreted as the immediate risk of a node catching whatever flows through the network.
- PageRank is a metric that indicates or outputs the probability distribution that a random walk across hyperlinks will send us to a particular node. So, the higher the value of PageRank is, the higher the probability of quickly finding that node, regardless of the way of the walk (Sahatqija et al., 2019).
- Between centrality quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. It was introduced as a measure for quantifying the control of a human on communication with other humans in a social network by Linton et al. (1977).

Results and Discussion

After the duplicate removal, the final dataset of coauthors resulted in a list of 1855 pairs of coauthors, which participated in 1035 unique author names. The highest number of repeated co-authorships was 3, where these repetitions can be seen only in two cases. There are 64 examples of being coauthors twice, and all other co-authorship cases occur only once. These numbers indicate that we must deal with new research areas in academia.

Firstly, we wanted to understand which authors have the highest collaborations. For this purpose, we used the degree centrality metric. Table 1 gives the top authors regarding how many different research collaborations they have (10 or more). An author with the highest number of collaborations in the field is Dr. Nassir Navab, from the Technical University of Munich, whose main research is in the field of augmented medical reality, computer-aided surgery, and medical robotics, has patents related to VR/AR and serves on the Steering Committee of the IEEE Symposium on Mixed and Augmented Reality (ISMAR). With the same university in his CV is the second researcher on the list, Dr. Pascal Fallavollita, whose research is again related to research activities in medical augmented reality and health technologies. This can conclude that the Technical University of Munich is one of the most relevant institutions in this area, having two researchers with the highest number of collaborations and two other researchers that show up in the top ten (Dr. Felix Bork and Dr. Ulrich Eck). Universitas Negeri Malang from Indonesia is the second relevant institution when considering active researchers from Table 1 (Dr. Ahmad Mursyidun Nidhom and Dr. Azhar Ahmad Smaragdina).

Table 1
Top authors in terms of collaborators

Author	Degree centrality
N. Navab	14
P. Fallavollita	12
M. Billinghurst	11
A. M. Nidhom	11
A. A. Smaragdina	11
X. Wang	11
S. Ahn	11
J. Kim	11
J. Zhang	10
F. Bork	10
U. Eck	10

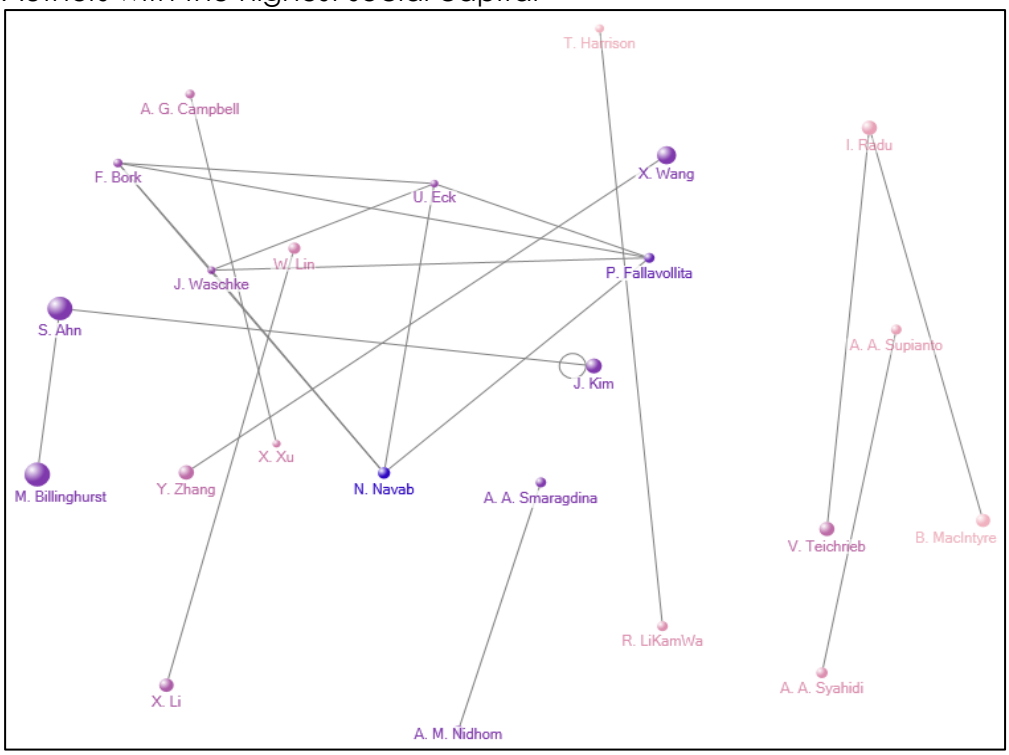
Source: Authors' work

The important element to explore was the main actors staying between different groups. These are researchers with the highest social capital in the VR/AR in the Education field. Figure 1 illustrates the authors with the highest social impact, which can serve as a bridge between different groups researching VR/AR in Education. Some of the authors with the highest social capital are those previously listed in Table 1 (Navab, Nidhom, Bork, Eck, Smaragdina, etc.), having Dr. Mark Billinghurst (University of South Australia) and Dr. Sangchul Ahn (Korea Institute of Science and Technology) at the top when asking for social capital in VR/AR in Education.

Similarly, Figure 2 gives a visualisation that can help identify the most visible authors when trying to understand the role of different actors in the field, using PageRank as a measure for visibility. It can be easily seen that the top two when visibility comes into question are Dr. Xiaoyin Wang (the University of Texas at San Antonio) and Dr. Joaquín Cubillo (National University for Distance Education of Spain (UNED)). It is interesting that Dr. Wang's primary interest is in software engineering and programs analysis and not the application of VR/AR itself. But still, he shows himself to be a significant researcher in this area, concluding that software and program analysis are relevant for VR/AR. Dr. Cubillo's background is in Electrical Engineering, but he has a lot of work regarding applications of VR/AR in Education, particularly for distance learning. This implies that VR/AR can be considered seriously when establishing study programs that are mined to be accomplished at a distance.

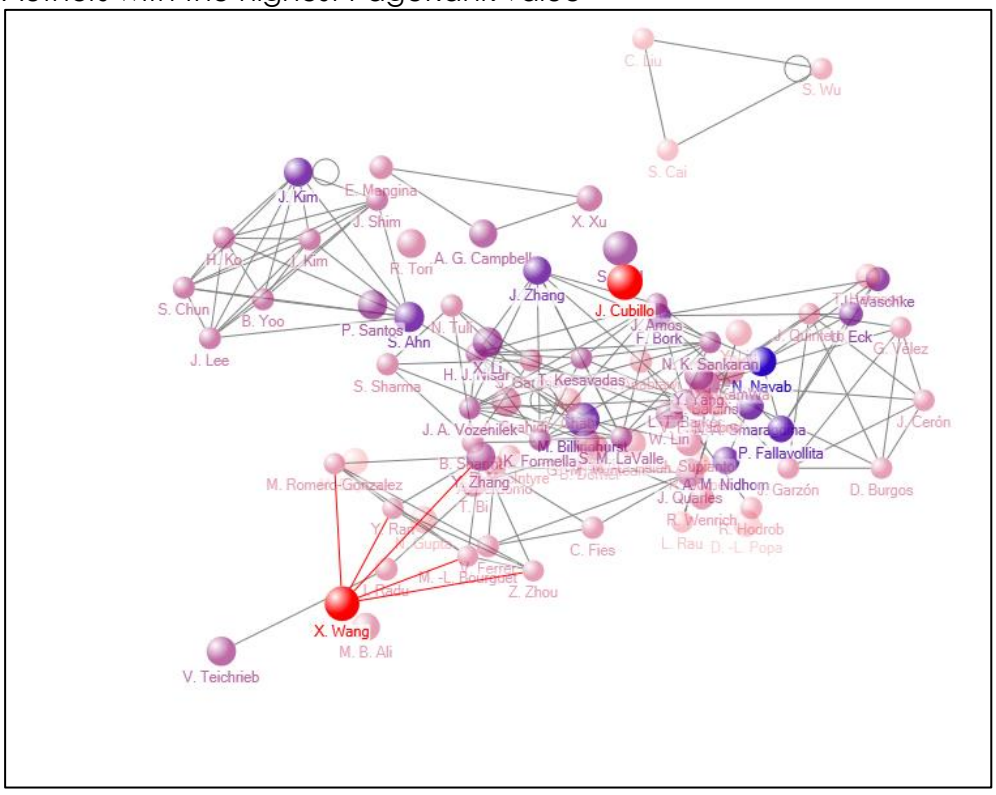
And lastly, we have tried to identify the research groups/teams that cooperate for better utilisation of virtual reality technologies in education, using automatic clustering with the Girvan-Newman algorithm (Girvan et al., 2002). Figure 3 illustrates this. It is gained that these groups are groups of authors who have only one common paper, and most of them do not have any other coauthor in any other article related to VR/AR (Sankaran et al.; Nidhom et al. 2021; Meng et al. 2013; Sahin et al. 2016; Ahn et al. 2014; Bheda et al. 2021). Usually, these are researchers whose primary research interests are in sectors such as Computer Vision, Pattern Recognition, HCI, Medical Computing, Bioengineering, Electrical Engineering, etc., which means that more than understanding who is who, with automatic clustering, we can better understand which research areas are more expected to be linked to VR/AR.

Figure 1
Authors with the highest social capital



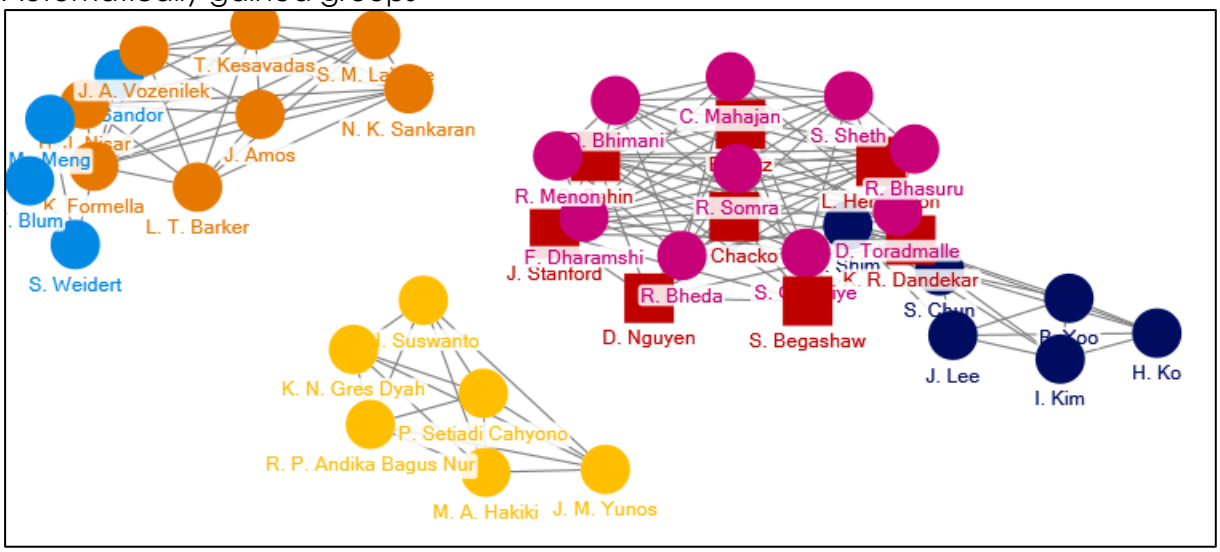
Source: Author's illustration

Figure 2
Authors with the highest PageRank value



Source: Author's illustration

Figure 3
Automatically gained groups



Source: Author's illustration

Conclusion

Although VR/AR technologies are not brand-new, their role in education still appears only in the last few years. With this research, we have tried to foster the perception that virtual technologies can be used beyond games and entertainment by analysing IEEE papers and determining important researchers, trends, and other factors influencing virtual and augmented reality applications in education. Firstly, we have identified individuals who can be considered gurus in this sector using SNA metrics. This can serve other researchers as a starting point when attempting to undertake research that involves the application of VR/AR. And besides the individuals, again, by using SNA metrics, we have discovered that this research field has a multidisciplinary nature that implies research from different knowledge domains such as healthcare, engineering, bioengineering, and education.

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