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A Bibliometric and Visual Analysis of Autonomous Vehicles-Pedestrians Interaction

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ABSTRACT

This article aims to clarify the concepts and research developments in the interaction between pedestrians and autonomous vehicles. The literature on "Interaction between Pedestrians and Autonomous Vehicles" in the Web of Science database was used to construct knowledge graphs based on keywords, countries, and journals as nodes, as well as a research knowledge graph on the interaction between pedestrians and autonomous vehicles. The article discusses the research progress, hotspots, and development trends of the interaction between pedestrians and autonomous vehicles in the field of human-computer interaction. It also reveals key research directions of the external human-machine interface (eHMI). This article provides more detailed information on the research progress in the field of human-vehicle interaction for researchers and practitioners, through the combination of traditional literature reviews and bibliometric analysis methods.

Keywords: Autonomous vehicles, Information communication, eHMI, Bibliometrics

INTRODUCTION

As society becomes more intelligent, our relationship with artificial intelligence (AI) in the digital world is growing closer. This relationship has the potential to greatly benefit our lives, with technological advancements expanding the ways we interact with AI, such as intelligent vehicles (Hao Tan et al. 2019). The design of future intelligent vehicles is evolving towards a seamless cross-vehicle travel system that includes humans, vehicles, infrastructure, and urban environments.

The human-machine interface (HMI) of intelligent vehicles is a research topic in the field of transportation that involves psychology, human factors engineering, social science, and more. The HMI of intelligent vehicles refers to the interactive interfaces both inside and outside the vehicle, including the information transmission and operation methods between the driver and passengers and the vehicle. The HMI of intelligent vehicles is a complex system that needs to consider many factors such as human cognitive characteristics, ergonomics, interaction modes, and safety. While drivers need to pay more attention to driving information and status while driving, passengers are more concerned with entertainment, comfort, and other aspects.

For pedestrians, the external HMI of intelligent vehicles can help them better understand the driving status of the vehicle to avoid traffic accidents.

Previous researchers have extensively explored the literature on human-vehicle interaction in automobiles, most of which were followed up after the early 21st century (Kun, 2018). Kun reviewed and predicted the main findings in this research field and recommended areas for future work. With the introduction of more automated functions and the transfer of control from the driver to the vehicle, pedestrians no longer rely on nonverbal cues. In order to study what the interaction between pedestrians and autonomous vehicles (AVs) might look like in the future and how AVs convey intent to pedestrians (Habibovic et al. 2018), they designed an external vehicle interface called the Autonomous Vehicle Interaction Principles (AVIP). (Li et al. 2020) provided a new perspective for conceptualizing trust in automation, which can be used to help guide future research and design processes to enhance the collaboration between drivers and autonomous vehicles. (Pappas et al. 2021) explored the interaction between pedestrians and autonomous vehicles in a safe virtual environment.

METHODS

The Web of Science Core Collection is a valuable database that provides access to academic information from around the globe. It contains over 12,400 high-impact academic journals covering a variety of fields, including natural sciences, engineering, biomedical research, social sciences, arts, and humanities. To achieve our research objectives, we used the following search query in the Web of Science Core database: TS=("pedestrian") AND ("automated" OR "autonomous" OR "self-driving" OR "driverless" OR "auto-pilot") AND ("vehicle" OR "car" OR "automobile") AND ("interaction" OR "communication"). We selected the five major citation indexes commonly used in the WOS database, which are SSCI, SCI-Expanded, A&HCI, CPCI-S, and CPCI-SSH, as our search sources. To collect all relevant articles, we set the search time span from January 2002 to September 2022. We exported the resulting literature in the format of "full records and cited references" as a TXT file, and eliminated irrelevant articles that deviated from the research topic or lacked critical information such as time, keywords, author information, or duplicate data. In the end, we obtained 679 relevant articles, which will be used for further knowledge graph analysis and research review (see Table 1).

Table 1. Leliterature data source search information.

Database	Citation indexes	Years	Search words	N
Web of science core collection(1985-present)	SCI/SSCI;AHCI/CPCI-S/CPCI-SSH/ESCI/CCR-EXPANDED/IC	2002.01-2022.09	TS=(“pedestrian”) AND(“automated”OR“autonomous” OR“self-driving”OR“driverless”OR “auto-pilot”)AND(“vehicle”OR “car”OR“automobile”) AND(“interaction ”OR“communication”)	679

RESULTS

Study on the Annual Variation of Literature Quantity and Research Hotspots

The amount of published research is an indicator of the sustainability and level of attention a particular research area has received. The higher the number of publications and the longer the duration, the more attention and faster development that field has experienced. This study analyzed data from the Web of Science core collection database using "pedestrian and autonomous vehicle" and "interaction communication" as research topics. The figure shows the analysis of the number of publications over time, indicating an increasing trend in the literature on pedestrian interaction design with autonomous vehicles since 2014 (see Figure 1). Notably, the field has experienced rapid growth from 2017 to 2019 and reached its peak in 2020 and 2021 with a total of 142 publications per year. These findings suggest sustained attention to research on pedestrian interaction with autonomous vehicles over the past nine years.

Keyword Co-Occurrence Clustering Network Map

The keywords in the literature are highly refined in our research, and high-frequency co-occurring keywords reflect the long-term research hotspots in pedestrian interaction with autonomous vehicles. In this study, 2,120 keywords were identified from the 697 articles in the search scope. To conduct the keyword co-occurrence analysis, VOSviewer was used on the 697 Web of Science core collection database articles. A total of 62 keywords were selected based on a minimum of 10 occurrences for each keyword. A keyword co-occurrence clustering view of pedestrian interaction with autonomous vehicles was created, as shown in Figure 2. The clusters in the figure are based on analysis results, with keywords of the same color being part of the same cluster. The research hotspots in pedestrian interaction with autonomous vehicles can be divided into four main clusters.

Cluster #1 (yellow) focuses on the external human-machine interface, communication, and design aspects of the interaction. Research in this cluster now emphasizes safety and trust aspects, shifting from internal human-machine interaction to the external interface with pedestrians (see Figure 3).

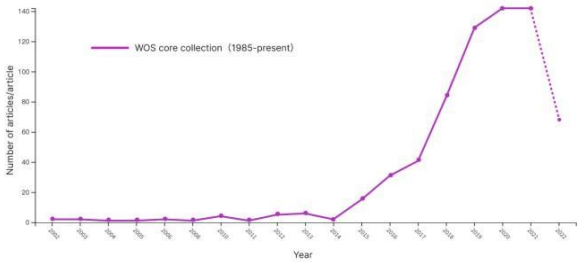

Figure 1: Annual trends in the number of articles related to pedestrian interaction with autonomous vehicles.

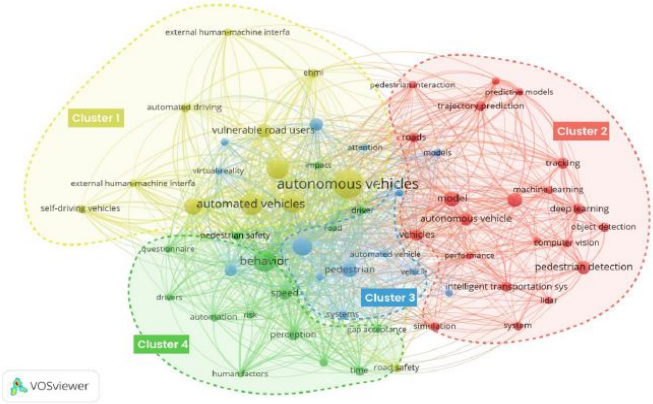

Figure 2: WOS keyword co-occurrence clustering network.

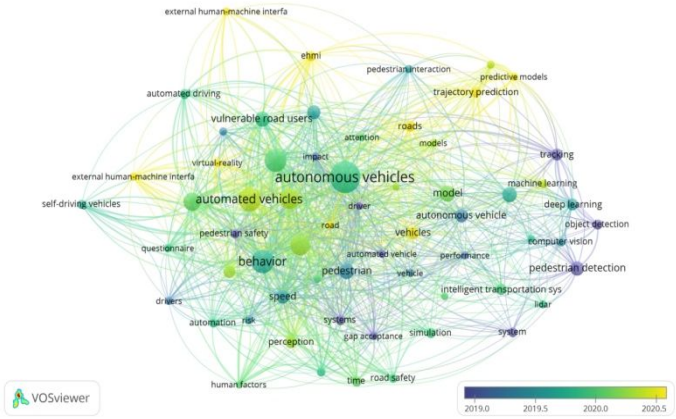

Figure 3: Keyword co-occurrence tag view.

Cluster #2 (red) concentrates on the technical aspects of the interaction, including pedestrian detection, machine learning, and computer vision. This cluster highlights the importance of developing models and predictive systems for pedestrian safety.

Cluster #3 (blue) focuses on the general attitudes and perceptions of pedestrians towards autonomous vehicles, including acceptance, trust, and safety. It also examines the impact of the interaction on pedestrian perception of safety and willingness to cross the street.

Cluster #4 (green) investigates the decision-making process of pedestrians when interacting with autonomous vehicles, including factors such as behavior, perception, speed, time, and human factors. Research in this cluster aims to identify effective communication strategies and understand the various factors that influence pedestrian decision-making.

Overall, these clusters represent different aspects of research related to the complex interaction between pedestrians and autonomous vehicles, with a focus on safety, trust, and effective communication.

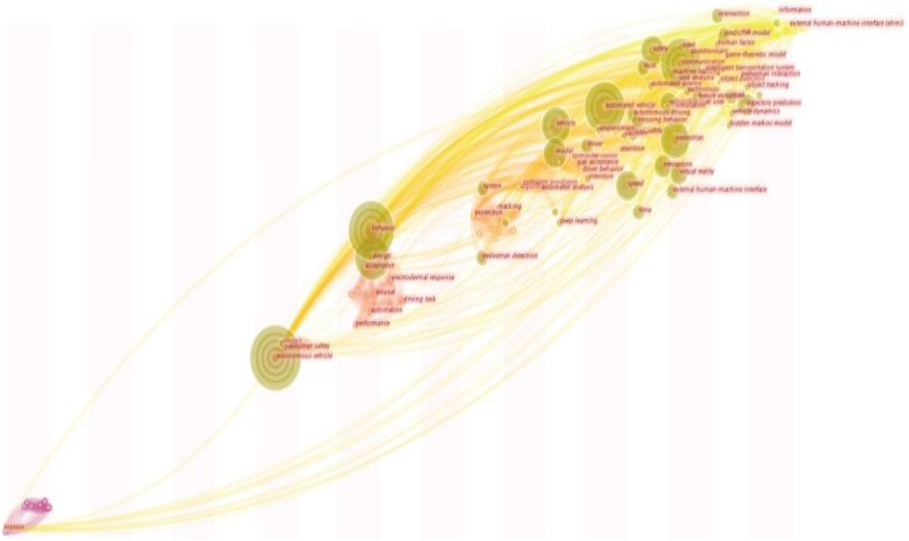

Figure 4: Keyword co-occurrence tag view.

Analysis of Periodic Research Hotspots and Frontiers Trends

The timeline chart featuring the keyword, drawn using CiteSpace (see Figure 4), includes a clearer time axis as the horizontal axis. This allows for a more intuitive understanding of research hotspots and trends during a certain time period. It also highlights the importance of understanding the communication of pedestrians' intentions with autonomous vehicles as the control of autonomous driving technology gradually shifts to the vehicles. Li et al. (2020) offer a new perspective on trust in automated driving technology, providing a guide for future research and design programs aimed at enhancing cooperation between drivers and autonomous vehicles.

CONCLUSION

This article provides an overview of research on the relationship between pedestrians and autonomous vehicles over the past two decades, using bibliometric analysis and knowledge mapping to identify trends and hotspots. Future research will focus on the design of human-machine interactions with autonomous vehicles and the factors influencing pedestrians' attitudes and decisions towards them. The article highlights the importance of developing a human-machine interaction design that can enhance driving efficiency and safety, which will have significant implications for the future of the automotive industry.

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