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Artificial Intelligence applied to Autonomous Vehicles: A Bibliometric Analysis

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Edwin Fontalvo Montoya
medwin@uninorte.edu.co
ORCID: https://orcid.org/0000-0003-3367-8339

Universidad del Norte, Barranquilla, Colombia

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— Abstract—

This article aims to analyze the Artificial Intelligence (AI) field of study regarding autonomous vehicles (AV). Through a bibliometric study, an overview of this research area was constructed. From the scientific production available on the Web of Science (WoS) database, we sought to recognize the critical issues that are being addressed about autonomous vehicles and the use of AI in them. Assuming which direction Artificial Intelligence in autonomous vehicles is taking is relevant to point out paths for recent research, infrastructure, laws, and official policies, mainly in Latin America, where the subject is barely explored.

Keywords:

Artificial Intelligence; AI; Autonomous Vehicles; Bibliometric.

The beginnings of Artificial Intelligence go back centuries. Since the Renaissance, automata with limited functions were created. In the mid-twentieth century, with the construction of the first electronic computers, the possibility of building thinking machines began to be discussed. In 1950, Alan Turin, created his test to know if a machine is intelligent or not, but only focused on a human-machine dialogue.

John McCarthy coined the term Artificial Intelligence (AI) in 1956, to refer to the part of engineering and science responsible for building intelligent machines, specifically in the software area. Later, in 1980, John Searle refuted the Turin test, which he called "the Chinese room". In it, Searle claims that deceiving a human does not prove that software or machine thinks for themselves, and showed that they can do activities without understanding exactly what they do.

The meaning of AI has had different concepts and perceptions, which has led to different investigations into what an intelligent machine really is. Gartner (Gartner, 2020), an information technology consulting firm, defines AI as applying logic-based analysis and techniques, including autonomous learning when interpreting events, decision making, and performing tasks. In this way, AI can be understood as the science that seeks to design and program machines to perform tasks that mimic human intelligence.

Among some of its modern applications are games, especially chess, checkers, and go (Chinese strategy game). Outstanding cases were the Deep Blue computer won in 1997 by the chess champion Gari Kasparov and the Watson supercomputer, which won three games of Jeopardy, beating human champions. It has also been applied to the creation of robots such as those used by NASA for space exploration (Spirit and Opportunity).

One of the practical cases of the use of AI is the driving of vehicles by themselves, that is, autonomous vehicles (AV). According to Gartner (Gartner, 2020), AVs are those that can drive from a point of origin to a destination, in "autopilot" mode, using various technologies and sensors. In 1980, the U.S. Defense and Research Projects Agency (DARPA) launched its first autonomous vehicle for military purposes. Currently, important companies such as Apple, Google, Amazon, and Uber, among others, develop different technologies for their AV worldwide. These are equipped with all kinds of sensors, GPS, LIDAR, computer vision, and, of course, orchestrated by AI (Meseguer Gonzalez & Badia, 2017).

This AI technology coupled with the AV has been around for around 40 years, but it has not become robust and secure. In 2018, the first pedestrian on a AV subscribed to Uber died in Tempe, Arizona (United States). As a result of this accident, society and industry have questioned the safety and risks that this type of vehicle still has. Reliability and protection against cyberattacks must be guaranteed, without neglecting ethical, moral, and legal issues in the event of accidents.

Bellow, the methodology used in this article to review the research published in Claritave Analitycs' Web of Science (WoS) on the use of AI in AV is explained, and the state of the art with future research trends is described.

METHODOLOGICAL STRATEGIES

In this bibliometric review, we reviewed the publications made in the Web of Science Database (WoS), using its Core Collection and excluding emerging sources (Emerging Sources Citation Index – ESCI) for lacking impact indexes. The number of articles found is then detailed and the abstract reading review is initiated to identify articles relevant to this analysis.

Planning: The objective of this analysis is to identify how research has evolved in scientific journals on AI and AV indexed in WoS.

Revision: Keywords, search equation using Boolean operators, with the search period from 2000 to 2020, the language and types of documents were identified. Below, are the inclusion and exclusion criteria.

1) *Keywords*: artificial intelligence; inteligencia artificial; autonomous vehicles; self-driving cars; autonomous mobility; vehículos autónomos; driverless mobility.
2) Articles indexed exclusively in academic journals were reviewed. Books, theses, essays, forums, and other types of works were excluded from the analysis.
3) To make this revision replicable, the following search equation was developed:

   TOPIC: (("artificial intelligence" OR ai OR "inteligencia artificial") AND ("autonomous vehicles" OR "self-driv* cars" OR "autonomous mobility" OR "vehiculos autonomos" OR "driverless mobility")) Refined by: LANGUAGES: (ENGLISH OR SPANISH) AND DOCUMENT TYPES: (ARTICLE) AND RESEARCH AREAS: (ENGINEERING OR COMPUTER SCIENCE) Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, BKCI-S, BKCI-SSH.

Inclusion criteria:

- All countries: To examine how different regions contribute to the scientific production of the subject matter.
- Language: Academic articles written in English and Spanish.
- Type of documents: Articles were included.

Exclusion criteria:

- Language: Articles written in languages other than English and Spanish.
- Non-academic articles or articles not included in the main WoS collection, reviews, books, book chapters, patents, and conference papers (Proceedings) were excluded.
- The search in the areas of engineering and computer science was framed.

RESULTS AND DISCUSSION

A systematic and thorough bibliometric analysis was performed, using the result analysis system provided by Web of Science (WoS) and the free scientific mapping tool vosViewer.

The results of this study, carried out in June 2020, were 61 articles, 21 open access, from 2005 to 2020, with the last two years accounting for 67.2% of the total. As Fig. 1 shows, this topic is emerging in the literature and currently increasing.

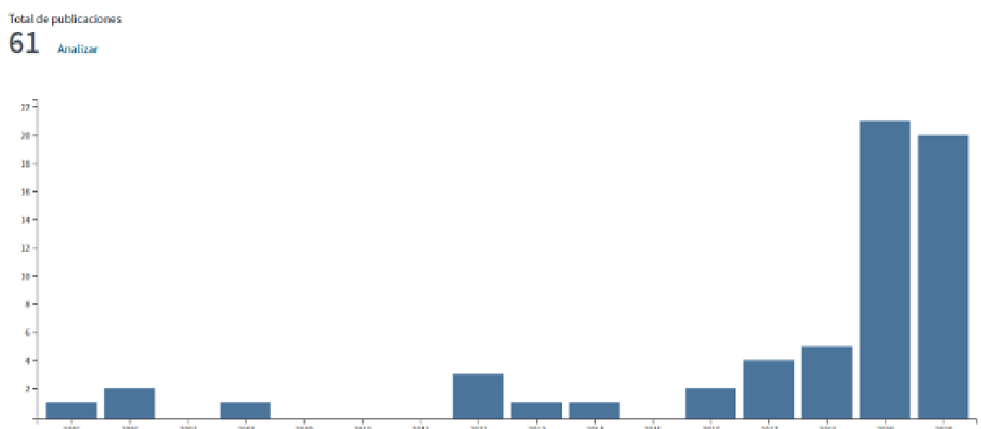

Fig. 1. Publications per year. Source: WoS results analysis

Sorting these results by the most cited, in the first place is the article by Dresner and Stone (Dresner & Stone, 2008), on autonomous management at intersections, from 2008 with 379 citations, followed very far with 90 citations by the article by Akhtar and Mian (Akhtar & Mian, 2018), on adverse attacks on deep learning in artificial vision. Being the first from the United States and the second from Australia.

The review of articles production by countries/regions shows significant activity in the United States (42.6%), followed in Asia by China (14.75%). Only Brazil makes a presence among Latin American countries, with one article. Europe, which has a total of 15 countries, has 50.8% of articles published. An analysis of the most productive countries and their relationship is shown in Fig. 2. The results show that the United States ranks first with 605 citations and 13 co-authorships. It is followed by China, with 12 citations and 9 co-authors.

Studying the scientific contribution between organizations, it is seen that universities lead the research. This study shows MIT in the first place, with 3 papers and 79 were identified, followed by Stanford University with 3 papers and 8 citations. Research centers and private companies are relegated due to their low academic production.

After an analysis of the co-occurrence of keywords in the documents, the relationships and interrelationships between AI applied in AV and emerging research trends can be noted (Fig. 3). The most found terms were: autonomous vehicle (17), artificial intelligence (13), machine learning, big data (6), computer vision, automation, and neural networks.

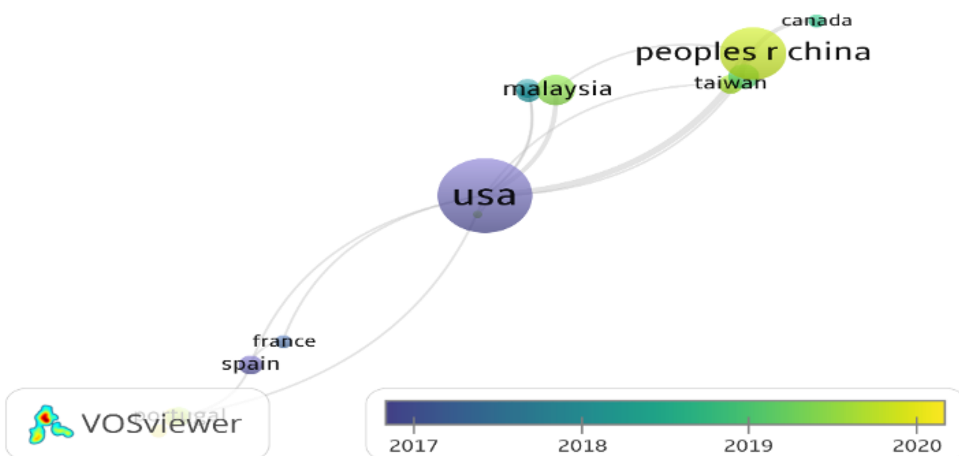

Fig. 2. Collaboration between countries. Source: own creation with VOSviewer. Source: Own elaboration

Bibliometrically analyzing the frequency of appearance of keywords (indexed by authors and editors), allows us to evaluate the weight of research on these topics. The visualization of the network in Fig. 3 corresponds to the 51 most common terms, out of a total of 361 words, in the 61 results works. Using vosViewer, the keywords were divided into 4 clusters (Fig. 3). A cluster is a set of related nodes, depending on the weights assigned to each (Van Eck & Waltman, 2013). This classification was taken to analyze the literature found.

The first set is made up of the important keywords for the search for autonomous vehicles and artificial intelligence. In addition, they are related to very important issues in terms of security, decision making, ethics, computer vision, and user experience, among others. According to the literature found, J. Millar (2016) studied how we should automate ethical decision-making in robots and autonomous vehicles. It proposes five specifications for a tool that assists designers in the ethical evaluation of decision-making. Human-robotic interaction ethics (HRI) principles should be considered for acceptable designs, as it helps to highlight design problems while suggesting how to solve them. On the other hand, J. Hass, recently in April 2020, proposed a novel approach to reinforcement learning, by "worlds of the moral grid", in which AI learns from the environment, instead of programming them with content learned by humans. Contrary to them, H. Etienne in February of 2021, exposes the shortcomings and dangers existing in the "Moral Machine" (MM), where AI is fed with people's votes and leaves aside normative ethics. Among some dangers he mentions are the use of these AVs for terrorist purposes and legislation for the protection of data taken by these vehicles.

For proper decision making the AV must be equipped with the best technology in radars, sensors, cameras, LIDAR, convolutional neural networks (CNN) to perform reconnaissance and WiMAX techniques. The above was studied by Zhou (2019), with a vehicle used in the DARPA Urban Challenge 2007. The improvement in driving and fewer collisions were evidenced, by having information exchange between the vehicles that allows planning and avoiding obstacles with precision.

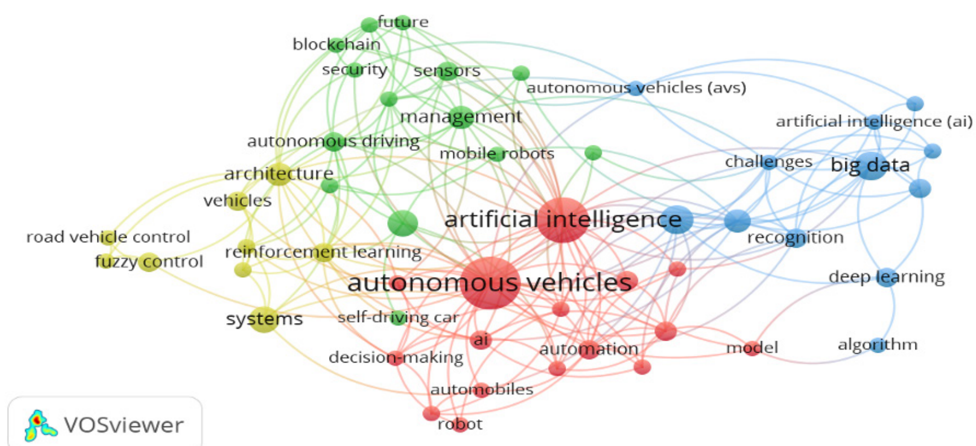

Fig 3. Map of co-occurrences of keywords. Source: own creation with VOSviewer. Source: Own elaboration

In cluster number two, autonomous driving appears surrounded by such important terms as the Internet of Vehicles (IoV), connected vehicles, blockchain, sensors, and the future. It is in the scenario that P. Bagga (2020), analyzed the emerging trends of the Internet of Vehicles (IoV) and its vulnerability to attacks such as false information, message injection, cookie theft, Sybill attack, denial of service (DoS), hardware, and malware intrusion, among others. They propose a security taxonomy for IoV, focusing on authentication by Blockchain, to improve transparency and reliability. Likewise, in 2020, F. Yuchuan presented a collective learning framework (BCL) for CAV, distributed to train machine learning (ML) attached to a Blockchain network to use distributed intelligence. They showed the limitations of single-vehicle intelligence, as opposed to the centralized approach where CAVs are connected to the cloud to share information. They also performed a simulation with a AV (Toyota Rav4) measuring learning efficiency and accuracy.

The third cluster shows the most recent challenges of autonomous vehicles: big data, machine learning, deep learning, and smart cities. A 2017 literature review with a focus on mathematical modeling by F. Alam on data fusion for IoT discusses future developments in these emerging areas and the benefits for smart cities and AVs. They concluded that probability-based approaches to Data Fusion are simple and highly accepted as classical data fusion approaches. They show that the use of data fusion in AV, while not new, has not had much application until 2010. They also show the use of Data Fusion for smart cities by controlling traffic, energy supply, and controlling pollution.

In the last cluster, terms such as coordination, reinforced learning, diffuse control, vehicle control on the road, and intelligent control appear. In this line of ideas, C. Yu (2020) proposed to use a dynamic coordination graph to model changing topologies, following two learning approaches to coordinate driving maneuvers with a group of vehicles. One approach is multi-agent reinforcement learning (MARL). This model was only used for driving, without taking into account road intersections. This problem was attacked precisely by K. Dresner and P. Stone (Dresner & Stone, 2008; Vasirani & Ossowski, 2012) with a multi-agent approach based on reservations with defined communication protocols. They also propose to solve the dilemmas of intersections with a combinatorial auction-based approach to the allocation of reserves. On the other hand, logic and diffuse control are used to simulate human control in AV and improve decision-making performance (Naranjo, Gonzalez, Garcia, de Pedro, & Haber, 2005; Naranjo, Jimenez, Gomez, & Zato, 2012).

The companies that are testing AVs promise to improve air quality, decrease accidents, be inclusive, and be safe. But in the wake of some accidents, these promises are in question.

Although the use of artificial AI in cell phones, video games, space exploration, and so on is increasingly common, it still takes a few years for its use in autonomous vehicles to be reliable and massive. There are already the first approaches with companies such as Tesla, Uber, and Google that carry out tests in developed countries, especially in the United States.

AVs have five levels of automation, according to the Society of Automotive Engineers (SAE) (NHTSA, 2020), but scarcely those currently rolling are at level three. To reach level five, it is necessary to cover many doubts about security and ethical decision-making, and cyber risks, without counting the countries' legislations and infrastructures.

The United States and China are ahead of the studies found. Only Brazil is present, for Latin America, with an article from the Federal Universities of Piaui in conjunction with Universities of India and Portugal. This, coupled with little designed infrastructure and legislation, leaves Latin American countries with little chance of seeing AV rolling on their roads, according to the KPMG ranking (KPMG, 2020).

CONCLUSION

This article showed a brief literature review on the application of AI in AV, from the bibliometric and academic point of view, using publications in WoS and the VOSviewer tool.

A systematic increase among academics was tested for analyzing the application and use of AI in AV from 2005 to 2020. The analysis indicates that intelligent transport systems and artificial intelligence are growing fields of study in the last two years, characterized by raising important questions for future smart cities on infrastructure and legislation.

The results of this review can be taken as a reference by academics, private companies, and governments for the improvement of the quality of life of citizens and expand the scope of research to include other sources of reliable information such as Scopus, ACM, and IEEE, and new bibliometric tools and techniques.

REFERENCES

Akhtar, N., & Mian, A. (2018). Threat of Adversarial Attacks on Deep Learning in Computer Vision: A Survey. *Ieee Access, 6*, 14410–14430. https://doi.org/10.1109/ACCESS.2018.2807385

Alam, F., Mehmood, R., Katib, I., Albogami, N. N., & Albeshri, A. (2017). Data Fusion and IoT for Smart Ubiquitous Environments: A Survey. *Ieee Access, 5*, 9533–9554. https://doi.org/10.1109/ACCESS.2017.2697839

Bagga, P., Das, A. K., Wazid, M., Rodrigues, J. J. P. C., & Park, Y. (2020). Authentication Protocols in Internet of Vehicles: Taxonomy, Analysis, and Challenges. *Ieee Access, 8*, 54314–54344. https://doi.org/10.1109/ACCESS.2020.2981397

Dresner, K., & Stone, P. (2008). A multiagent approach to autonomous intersection management. *Journal of artificial intelligence research, 31*, 591–656. https://doi.org/10.1613/jair.2502

Etienne, H. (2021). When AI Ethics Goes Astray: A Case Study of Autonomous Vehicles. *Social science computer review*. https://doi.org/10.1177/0894439320906508

Fu, Y., Yu, F. R., Li, C., Luan, T. H., & Zhang, Y. (2020). Vehicular Blockchain-Based Collective Learning for Connected and Autonomous Vehicles. *Ieee wireless communications, 27*(2), 197–203. https://doi.org/10.1109/MNET.001.1900310

Gartner. (2020). Artificial Intelligence (AI). Recuperado el 6 de julio de 2020, de https://www.gartner.com/en/information-technology/glossary/artificial-intelligence

KPMG. (2020). *Assessing the preparedness of 30 countries and jurisdictions in the race for autonomous vehicles 2020 Autonomous Vehi cl es Readi ness Index*. Recuperado de https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf

Meseguer Gonzalez, P., & Badia, R. L. de M. (2017). *Inteligencia artificial.* Recuperado de https://elibro.net/es/lc/unorte/titulos/42319

Millar, J. (2016). An Ethics Evaluation Tool for Automating Ethical Decision-Making in Robots and Self-Driving Cars. *Applied artificial intelligence, 30*(8), 787–809. https://doi.org/10.1080/08839514.2016.1229919

Naranjo, J. E., Gonzalez, C., Garcia, R., de Pedro, T., & Haber, R. E. (2005). Power-steering control architecture for automatic driving. *Ieee transactions on intelligent transportation systems, 6*(4), 406–415. https://doi.org/10.1109/TITS.2005.858622

Naranjo, J. E., Jimenez, F., Gomez, O., & Zato, J. G. (2012). Low level control layer definition for autonomous vehicles based on fuzzy logic. *Intelligent automation and soft computing, 18*(4), 333–348. https://doi.org/10.1080/10798587.2012.10643247

NHTSA. (2020). Vehículos Automatizados para la Seguridad - NHTSA. Recuperado el 10 de julio de 2020, de https://www.nhtsa.gov/es/tecnologia-e-innovacion/vehiculos-automatizados-para-la-seguridad

Van Eck, N. J., & Waltman, L. (2013). vosviewer manual. Recuperado de Leiden: Univeristeit Leiden website: http://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf

Vasirani, M., & Ossowski, S. (2012). A Market-Inspired Approach for Intersection Management in Urban Road Traffic Networks. *Journal of artificial intelligence research, 43*, 621–659. https://doi.org/10.1613/jair.3560

Yu, C., Wang, X., Xu, X., Zhang, M., Ge, H., Ren, J., … Tan, G. (2020). Distributed Multiagent Coordinated Learning for Autonomous Driving in Highways Based on Dynamic Coordination Graphs. *Ieee transactions on intelligent transportation systems, 21*(2), 735–748. https://doi.org/10.1109/TITS.2019.2893683

Zhou, Z., Akhtar, Z., Man, K. L., & Siddique, K. (2019). A deep learning platooning-based video information-sharing Internet of Things framework for autonomous driving systems. *International journal of distributed sensor networks, 15*(11). https://doi.org/10.1177/1550147719883133