ADVANCEMENTS IN AUTONOMOUS NAVIGATION IN SPACE EXPLORATIONS THROUGH ARTIFICIAL INTELLIGENCE: A SYSTEMATIC REVIEW

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ABSTRACT

New generation technology has the potential to increase the space exploration industry's efforts. The adoption and implementation of autonomous navigation is becoming increasingly effective with the integration of artificial intelligence. The application of artificial intelligence in space exploration is vast, ranging from automating rocket launches, rocket landings, research, communication, mobility among other activities. By influencing machine techniques and learning, the algorithm systems can process and sensor an immense amount of databases and information. The most important aspect of artificial intelligence is the ability to autonomously navigate in space exploration. Because of the cost of assembling the facilities and operating space missions, artificial intelligence has to be created in such a way that its decision making capability superceeds that of humans and human error during real space exploration. For this to be successful, different researches have been conducted on both simulations and real life space exploration missions to determine if artificial intelligence is equipped and effective in conducting a successful space exploration. This study investigated the effectiveness of advancement in autonomous navigation in space through artificial intelligence. The objectives of the study were: to; identify the type of autonomous navigation technologies in space through artificial intelligence; evaluate the use of autonomous navigation in space through artificial intelligence; performance of autonomous navigation in space through artificial intelligence. The study used systematic review, which is a type of qualitative research design that involves identifying scholarly journals aligned with the topic of this study. In terms of the inclusion criteria, the researcher selected journals published between 2023 and 2024. The study also included sources that were conducted using primary data collection methods such as observations, simulations, and real life experiments or practices in relation to the topic of the study. In terms of the exclusion criteria, the study disregarded databases containing raw and inconclusive data, in addition to studies that also conducted systematic review of the issue being studied. A total of 14 sources were searched and therefore provided the target population. Out of the targeted sources, the study selected 9 sources that were reviewed and findings established. This raised a 64.29% response rate which was considered adequate to proceed with data analysis, presentation, and intepretations. The risk of bias was determined using the Robvis methods. Robvis visualizes is an inclusion and exclusion tool during a systematic review. Data analysis was conducted using comparative data analysis. The study presented the findings using narratives, numerically created tables, and figures. The study's findings were as follows:
Keywords: Advancement, autonomous, navigation, space, exploration, and artificial intelligence.

INTRODUCTION

In the innovative system of space exploration, the integration of Artificial Intelligence-driven autonomous navigation is going to be the next frontier for the space industry [1]. Artificial Intelligence algorithms are being deployed to navigate through expanses of space across intimate environments, adapting to different conditions and capabilities without human interaction [2].

Nowadays, people strive to advance the scientific understanding of the universe for the benefit of everyone [3]. In the modern world, almost every little thing depends on technology [4], therefore, for the enhancement of it, it is significant to look into the fields the knowledge comes from which is for the most part space [5]. If individuals want to advance their understanding, autonomous navigation through space is essential in this case. We can take as an example the automated machines that were under the watch of the users on Earth [6], the late communication delays between the users and automated robots were demonstrated as a challenge [7, 8]. The vast distances between the individuals and machines were between celestial bodies like planets, comets, meteorites, and asteroids, requiring an immense amount of calculations for the estimated time of arrival to the destinations [9]. Mentioning the distances, the large number of intervals caused problems with keeping in touch, precisely the delays of communication which ranged from minutes to hours and were impossible to deal with in critical situations [10]. Another issue was the precision landing of the robotic machines such as rovers was extremely difficult due to distinct atmospheres [11].

Later on, it was decided to decrease the cognitive thinking loaded on the individuals, forthat to focus on more high-level tasks. This way the researchers on Earth may focus on tasks they might enhance rather than waste time on trying to find a connection with the spacecraft far away. Nevertheless, one question remains: Are AI algorithms able to be made more effective to reduce the amount of difficulties faced with autonomous navigation in space explorations?

LITERATURE REVIEW

In the early days of space exploration, the missions were often courageous and strived to explore something new far from Earth's gravity [12]. The initial start of the missions expanded from the Moon to Mars and other planets [13]. Because of the explorations, the limitations of resources became apparent, and the realization gave an opportunity to

independently process systems [14]. Instances for used automatic machines were ones such as rovers used on Mars missions [15]. Exactly these rovers demonstrated the ability to avoid obstacles and collisions [16], being able to navigate through the terrains safely and independently [17]. Autonomous navigation notable studies from missions that were successful in the systems are the Mars Rovers, which are the main examples of machines powered by Artificial Intelligence in navigation throughout space [18]; The Voyager probes 1 and 2 were launched in 1970 and have reached beyond the limits of the solar system. Currently, the voyagers are still able to transfer valuable information to Earth and back [19]; New Horizons the Pluto Flyby has demonstrated autonomous navigation through space and the spaceship has been able to apprehend the pictures of Pluto and Charon [20].

There are challenges and risks faced by the users of the spaceships [21]. They include most importantly algorithmic errors [22]. Artificial Intelligence robots are not flawless and are vulnerable to errors mostly when faced with unforeseen circumstances [23]. It is fundamental to think through the process of the AI machine's algorithms since the damages can be severe if faced with one of the errors [24].

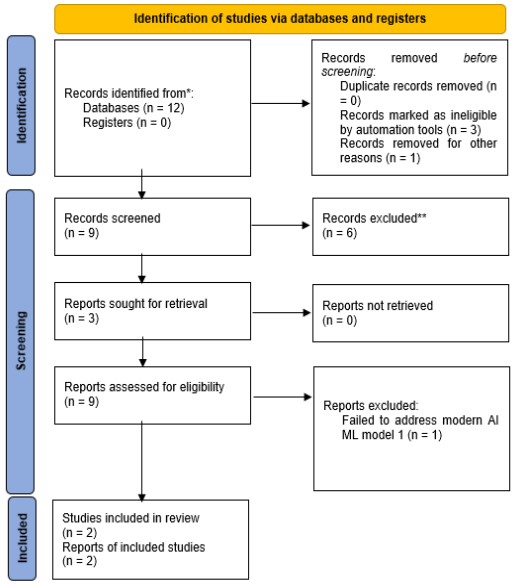
This involves data protection too, as both space and Earth itself boast data protection laws which are significant [25]. The AI algorithms that are made to process protected information are obliged to stick to the protection laws and regulations [26]. Therefore, as Artificial intelligence systems are becoming more connected to updates of databases they are weak enough to receive cyberattacks [27]. There was a separate study applied to Spacecraft's Autonomous decision planning for collision avoidance.

This study is strongly tied to the past of autonomous navigation since collision avoidance is one of the main factors applied in the machine's algorithm. The solutions to the issues given and suggested currently are things such as adaptive planning and resource management. In other words Enhanced Mission planning. Resource management focuses on the management of the resources based on real-time information known and the priorities for the missions. Adaptive planning is for the reason of unexpected situations that include spacecraft malfunctions or unforeseen celestial bodies in the way. Adaptive planning can be implemented in AI machines for fast response in unexpected circumstances that might be faced during mission performance.

METHODOLOGY

The PRISMA guidelines guided this section of the study (Flow Chart 1) below.

Flow Chat 1: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.
Source: Page MJ, et al. BMJ 2021;372:n71. Doi: 10.1136/bmj.n71.

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3.1 Eligibility criteria

The inclusion criteria were that the study used journals published between 2023 and 2024. The study also included journals that tested Artificial Intelligence systems' accuracy in fault detection in three-phase transmission lines and distribution transformers. The study excluded sources that were older than 2023.

3.2 Information sources

The study used an extraction form to identify the sources that are suitable for the study. The extraction form was as presented below as [17] recommended. The extraction form presented as Table 1 is as an illustration of the data collection form. After the data collection, the empty extraction form (Table 1) was filled latter on and presented as shown in Table 2.

Table 1 Extraction form

Study ID	Protocol	Was the author contacted for additional outcome data	Contact record	Date last searched/consulted.
	[ ] Published 2023-2024 [ ] Journal (type) [ ] Used simulated data [ ] Addressed types of faults [ ] Addressed fault detection ML models [ ] Addressed levels of accuracy of fault detection techniques	[ ] Yes, positive response [ ] Yes, but no response [ ] No [ ] It was N/A		

Source: Author (2024)

Outcome Key: [✓] Full report of results, [o] Partial reporting of results, [×] No reporting of results

The sources of information were journals written by professionals and scholars in the field of Artificial intelligence and engineering. The sourced journals came from Google search engine that helped the researcher establish a total of 12 credible journals for the systematic review.

3.3 Search strategy

The study used a qualitative research design. Systematic literature review involved identifying scholarly articles from respectable international journal websites. In this case, this study conducted a systematic literature review to determine types of faults in power transmission systems, examine fault detection machine-learning models in power transmission systems, and assess levels of accuracy of fault detection techniques in power transmission systems. The study applied a direct search strategy since the articles reviewed were readily provided in the internet (i.e., Google and Google scholar). There filtering of the sources was limited to the extraction form (Table 1).

1.4 Selection process

The selection process involved assessing the sources based on the extraction form. The researcher identified the sources according to the presence of the protocols section presented in the extraction form. All the two sources met the inclusion criteria of the review. Four reviewers reviewed the sources, each screening and retrieving the records. The supervisor provided the sources: a professor at Cambridge University. Each reviewer worked independently in the absence of the author. No automation tools were used in this process.

1.5 Data collection process

The research used an extraction form to collect qualitative and quantitative data from the two journals. The study also used comparative analysis to present the findings from the two sources. Further, two reviewers were responsible for independently collecting data from each report. The other three reviewers confirmed the authenticity and accuracy of the data from the study's investigators. The process was manual, and thus, no automation tools were used.

1.6 Data items

List and define all outcomes for which data were sought. Specify whether all results compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.

List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.

1.7 Study risk of bias assessment

The study had a limitation in that it reported results based on only two sources, which introduced potential bias in the exclusion criteria. To assess the risk of bias in the included studies, the researcher used the Robvis methods that visualized risk-of-bias during the inclusion criteria for sources used in the systematic review. Robvis refers to an open-source Shiny web app and R package that is used to assess the risk-of-bias figures, thus providing an evidence synthesis workflow inside R. To back up the process, the researcher further used a manual approach whereby it employed a peer review approach to check and classify the sources. The study employed two reviewers to certify and select the two sources independently.

1.8 Effect measures

To determine the effect measures, the study used the Odds Ratio (OR) to synthesize or present results. Odds Ratio (OR) is a type of risk estimate whereby the Odds of Event 1 are divided by the Odds of Event 2. In this case, ORs close to 1 mean the estimated effects are likely the same for groups 1 and 2. In reverse, ORs far from 1 mean a lower likelihood that the two events will be identical. In the case of this study, the OR equaled 1.00. This implied that the sources adequately complemented each other and were reliable for systematic review.

1.9 Synthesis methods

The study used the extraction form provided in Table 1. According to Table 1, the two sources reviewed were eligible. Data was collected from secondary sources, namely scholarly articles dated between 2023 and 2024. The collected data was analyzed using qualitative analysis techniques. Qualitative analysis dealt with the thematic coding of data to determine the common themes and trends provided by the sources selected to inform the study. Comparative analysis was conducted to elaborate on the differences in the findings and come to a proper conclusion about the issue under study. Case studies demonstrated the practical implementation of the phenomena the study proposed to analyze.

Performance metrics that determine the accuracy of fault detection and classification models apply the receiver operating characteristic curve (ROC). The ROC curve was also chosen to demonstrate the binary classifier's capability.

In addition, machine learning, being a binary classification, led to this study using true positive (TP), false positive (FP), true negative (TN), and false negative (FN) to determine the accuracy of models in fault detection.

Accuracy is defined as a ratio that sums up correct predictions from a total of several dataset samples. It is calculated as:

$$Acc = [(TP+TN)/(TP+TN+FP+FN)] \times 100\% \quad \ldots\ldots\ldots (2)$$

Precision is the ratio of correct predictions of all positive classes from all optimistic predictions. It is calculated as:

$$P=TP/(TP+FP) \quad \ldots\ldots (3)$$

Recall is a sensitivity ratio summarizing all correct predictions from a positive class and all incorrect predictions from a negative class.

$$R=TP/(TP+FN) \quad \ldots\ldots (4)$$

The F1 score is defined as a weighted average of recall and precision. The F1 score is valuable if the dataset has an uneven class distribution. It is calculated as:

$$F1-score=2 \times (Precision \times Recall)/(Precision+Recall) \quad \ldots\ldots (5)$$

The study, therefore, provided results from other existing studies that presented a confusion matrix to summarize the accuracy of their machine-learning classification models.

1.10 Reporting bias assessment

To assess the risk of bias in the included studies, the researcher used the Robvis methods that visualized risk-of-bias during the inclusion criteria for sources used in the systematic review.

3.11 Certainty assessment

To assess the level of confidence of the sources used in the research, the study used the Cronbach alpha calculation, referred to as the reliability test. Before using the findings, the study generated a reliability of 0.76, sufficient to proceed with data analysis.

RESULTS

In the end, AI was applied in the field of space with different examples of it. The Artificial Intelligence integration into space exploration and mission planning illustrates a life-changing jump forward in humanity's understanding of the galaxy. As given, there are a bunch of historical examples of autonomous machine systems and some algorithms are still relevant and send useful information back to Earth. It is fundamental to appreciate the ability and relevance of space missions. The rovers presented on Mars are a great instance of such great

functioning and relevance to this day. Nevertheless, many different types of algorithmic errors, cybersecurity issues, and vulnerabilities remain. These are the qualities that are still being considered and mitigated daily.

On the other hand, allowing Artificial Intelligence to complete its work independently, with little to no human interaction would be a benefit to most of the individuals in the field of space. However, letting robotic intelligence take over and perform tasks independently in complex situations for a long amount of time may pose severe consequences later on. By providing the robotic body with a plethora of information about independent work in navigation through the vastness of space, not only are they gaining the information, they would be able to learn from the data they have received and use it for future purposes while getting used to its full range. Not only do they possess one individual as the data flow, but since it's a lot of community members involved in this process the robotic body can process every information they get from each person. Additionally, the perceptions of the AI algorithms in autonomous navigation should receive routines to adapt and recognize future missions involving autonomous navigation. This leads to the information gained by the robot, and the data being offered to them whereas the data might get exploited, posing severe threats to the futures of the individuals and the environment. Hence, gaining access to information is not the only risk the robot may develop, another important aspect is that the AI-powered machine can adapt learn, and manage to improve the system's performance by exploiting interaction and databases from individuals.

DISCUSSION

When talking about the risks and difficulties faced by the ones in the space facility considering AI in autonomous navigation, a very important and useful step to take is to make AI more useful in reducing the risks faced during the navigation process.

According to that, the question is: Can AI algorithms be made more effective to diminish the challenges faced with autonomous navigation in space explorations, such as great distances, lack of resources, and communication delays?

Artificial intelligence can be made more efficient to reduce the number of problems faced with autonomous navigation [28], for the reason that AI is capable of average problem solving, and if it can process and manage the data given on its own it is obvious that it would be able to be made more effective [29]. It is significant to note that Artificial Intelligence may be made more advanced to not only help with the main process which is autonomous navigation, but also throughout the process. AI has limitless boundaries and nonstop development that is happening. Due to the issues the community members are facing lately such as long distances, communication problems, and scarce resources, instead of trying to decrease the amount of unsatisfactory impacts these issues cause it is better to think in another way. The study also suggests trying to try and diminish these issues from another opportunity that individuals might get. The study believes this question is essential to research to first get a bigger perspective and understanding of the situation itself. Today, if artificial intelligence is used almost for everything, why not try and use it in another way even through the main process as long as it does not bring any harm to the main task that is being performed? One of the challenges listed before was Algorithmic errors meaning that Artificial intelligence could make mistakes that may cause severe problems, especially in unexpected situations. That would be another reason why it would be pivotal to find out how algorithmic bodies can be made more trustable and stable when faced with sudden situations.

The significance of the results gained is how this information will affect future space explorations and missions. However, as much as Artificial Intelligence does help a lot in space explorations, it still possesses challenges and risks tied to its understanding of the whole process [30]. Leading the robot algorithm to process given information and therefore exploit it.

CONCLUSION

In conclusion, that article investigated the advancement in autonomous navigation in space through artificial intelligence. The article established that AI in space exploration and mission planning illustrates a life-changing jump forward in humanity's understanding of the galaxy. The rovers presented on Mars are a great instance of such great functioning and relevance to this day. Artificial Intelligence completes its work independently; with little to no human interaction. Robotic intelligence independence in complex situations poses severe consequences later on. The perceptions of AI algorithms in autonomous navigation receive routines to adapt and recognize the future missions involving autonomous navigation; leading to the information gained by the robot being exploited, posing severe threats to the futures of the individuals and the environment. AI-powered machines can adapt, learn, and manage to improve the system's performance by exploiting interaction and databases from individuals.

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