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An Assessment of the Applications of Artificial Intelligence (AI) in Remote Sensing and Geographical Information System (GIS)

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ABSTRACT

The aim of this study was to examine the application of artificial intelligence (AI) in remote sensing and geographical information systems (GIS). The study adopted the use of a review method in which some previous works in the research area were reviewed and important points brought out for the benefit of Remote sensing and GIS experts as well as for the benefit of the public. It was observed from the review that AI could be applicable in Remote Sensing and GIS in areas like change detection analysis by using AI algorithm to investigate land use/cover, image classification, predictive analysis such as forecasting of future occurrences from the present analysis, spatial distribution analysis, mapping such as creation of topographic and land use/cover maps, etc. It was concluded from the review that AI has numerous applications or uses in remote sensing and GIS. It is therefore recommended that application of AI in some common environmental problems like erosion, flooding, and others be studied in future works to bring a lasting solution to the problems, or to mitigate its impacts on the people and the country at large.

KEYWORDS: *Algorithm, Artificial intelligence, Mapping, Spatial distribution, Remote sensing*

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1. INTRODUCTION

Artificial intelligence is defined as the science of making machines do things that would require intelligence if done by men (Minsky, 1968). According to Rapaport (2019), AI is a branch of computer science (CS), which is the scientific study of what problems can be solved, what tasks can be accomplished, and what features of the world can be understood computationally (i.e., using the language of Turing Machines), and then to provide algorithms to show how this can be done efficiently, practically, physically, and ethically. Steven *et al.* (2015) define Remote sensing as the science and art of obtaining

information about the earth from a vehicle, which is at a distance from the surface, most often satellites orbiting the earth and even airplanes, they also defined GIS as computer-based systems that are used to capture, store, analyze, and display spatial information. In a simple term, remote sensing is defined as the art, science and technology of observing an object, scene or phenomenon by instrument-based techniques without physical contact.

Natural disasters are not so rare events and happen all around the world causing a lot of destruction and loss of human lives. To respond quickly to a disaster, make adequate evacuation, and put in place recovery plans, accurate and up-to-date spatial data are required. It is also important to know the location, as well as be able to track and analyze passive and active threats in order detect and identify possible dangers and hazards in time (Ivić, 2019). Also, the task of forecasting crop yields accurately is fundamental to enhancing agricultural productivity and managing food supply chains efficiently to ensure food security. Traditional methods of yield prediction which are heavily reliant on historical data and empirical observations are increasingly proving inadequate due to their inability to accommodate the complexities of climate change and varied agricultural practices. In this context, AI has emerged as a revolutionary tool, offering new dimensions of accuracy and efficiency in predicting crop yields.

Recent advances in AI, particularly through machine learning and deep learning, have facilitated the analysis of vast and complex datasets, encompassing climatic variables, soil properties, and Satellite imagery (Ratul, 2024). Based on the literatures, present trend in AI technology as well as the role of remote sensing and GIS in various aspects of the economy and in our daily lives, there was a need to study the applications of artificial intelligence (AI) in remote sensing and geographical information system (GIS), hence, the need for this work.

Figure 1.0 shows the structure of Artificial intelligence and its subfields.

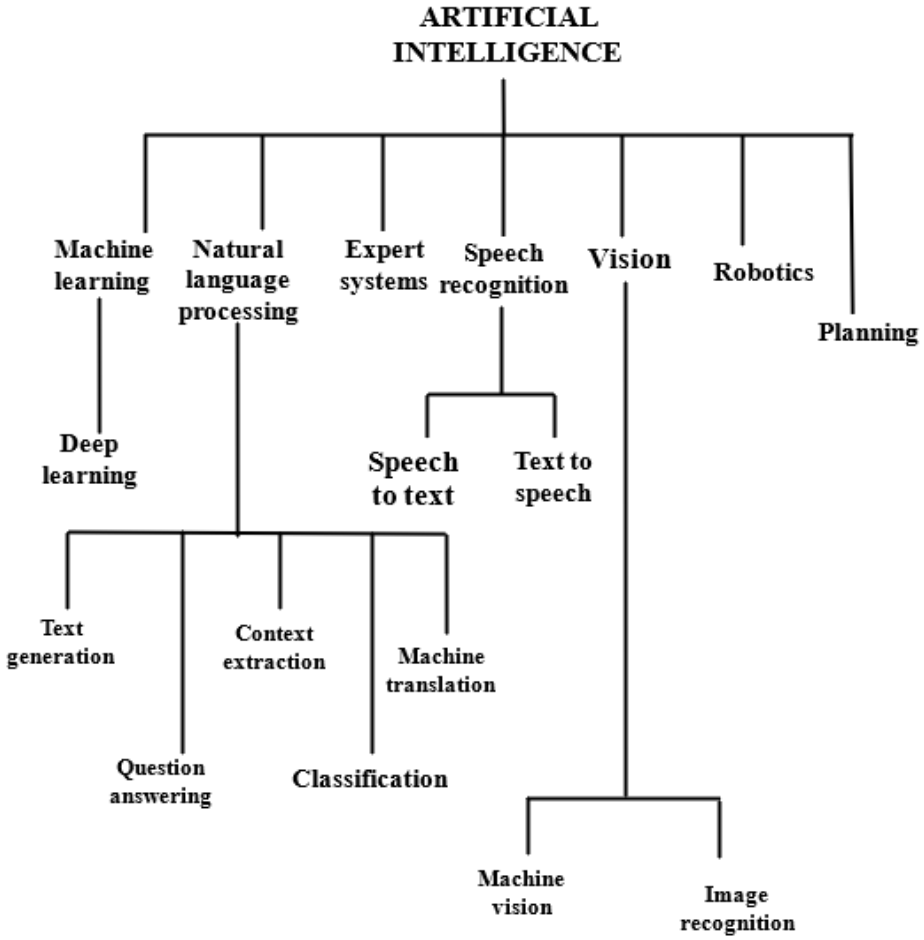

Fig. 1.0: Artificial intelligence and its subfields (Source: Ivić, 2019)

2. Methodology

The study adopted the use of review method in which some previous works in the research area were reviewed and important points brought out for the benefit of AI in remote sensing and GIS as well as for the benefit of the public. The review research method was used in order to have a comprehensive understanding and to identify the research gap, thereby revealing the need for further studies.

3. Results and Discussion

This section answers the research question.

Research question: What are the applications of Artificial Intelligence (AI) in Remote Sensing and Geographical Information System (GIS)?

Some applications of Artificial Intelligence (AI) in Remote Sensing and Geographical Information System are as follows:

1. Change Detection: Change Detection can be defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1998 and Theau, 2008). Remote sensing image change detection is the detection process in determining the surface change area and change feature type for the same image area from multiple time series remote sensing data (Wen and Pan, 1961). Artificial intelligence has the capability to carry out change detection or displaying the differences in an object, area or phenomenon through the analysis of remote sensing images of various periods or times. In the work by Wenzhong *et al.* (2020) on change detection based on AI technology, the results showed that integrated artificial intelligence technology has become a research focus in developing new change detection methods. They added that change detection based on remote sensing (RS) data is an important method of detecting changes on the earth's surface and has a wide range of applications in urban planning, environmental monitoring, agriculture investigation, disaster assessment, and map revision. Though the work was a review, it stated the various remote sensing data that can be used for change detection using AI technology such as optical RS data, synthetic aperture radar (SAR) data, street view images, and combined heterogeneous data. The capability of AI technology in performing change detection analysis of remote sensing and GIS data was confirmed in the work by Long and Siamak (1999)**.** It was observed from their result that the use of AI neural networks algorithm can effectively perform change detection on remote sensing images. According to them, the algorithm for an automated land-cover change detection system was developed and implemented based on the current neural network techniques for multispectral image classification. The trained four-layered neural network which was able to provide complete categorical information about the nature of changes and detect land-cover changes with an overall higher percentage accuracy. Training of model or algorithm is the process of teaching the model to take an action based on data presented. It involves data preparation, model initialization, forward pass, error correction, backward pass, optimization, evaluation and iteration. In another work which also collaborates with the other authors, Zhujun and Maimai (2023), in their work titled "The Use of Artificial Intelligence and Satellite Remote Sensing in Land Cover Change Detection: Review and Perspectives", it was found out that the integration of Artificial Intelligence (AI) and Satellite Remote Sensing in Land Cover Change Detection has gained increasing significance in scientific discovery and research. Artificial Intelligence can play an important role in change detection analysis of remote sensing and GIS images, this can be used is determining the change in the size, expansion and compression of water bodies, land degradation monitoring, detection of land use (such as farming, settlements), change in forest structure (afforestation/deforestation), vegetation, land degradation, quarrying activities, and even urbanization. The above can be achieved through the analysis of multiple remote sensing images over time.

2. Image Classification: Image classification is defined as the process of categorizing all pixels in an image or raw remotely sensed satellite data to obtain a given set of labels or land cover themes (Lillesand, Keifer 1994, Jwan, *et al.,* 2013). Image classification can also be defined as the process of assigning pixels or objects in a remote sensing image to specific categories or classes in accordance with their features and characteristics. Image classification is done on satellite imagery or remote sensing and GIS images to detect and classify specific objects like buildings, roads, and vehicles or to identify and label different land cover types. These land cover types could be water bodies, forests, urban areas, crop types, and soil types. The operation of image classification is based on the fact that different feature types on the earth's surface have different spectral reflectance and remittance properties. In other words, it deals with the classification of an image based on its visual content. In the views of Jwan, et al, (2013), due to many limitations of both major classification methods (supervised and unsupervised) coupled with the difficulty in getting satisfactory results by using supervised and unsupervised methods alone when using new generation images, characterized by a higher spatial and spectral resolution, scientists have made great effort to develop advanced classification procedures Automated Classification Approach such as Neural Networks(NN) which is an aspect of Artificial intelligence. Neural Networks are statistical learning algorithms and are used for a variety of tasks, from relatively simple classification tasks to computer vision and speech recognition. This is done by feeding a huge amount of data into software or

tools like classifiers, which will analyse them and extract the important or useful features.

Image classification in remote sensing involves: Data Collection which deals with Gathering remote sensing data through sensors or satellites, Preprocessing which deals with Correcting and enhancing the data to improve quality, Feature Extraction which deals with Selecting relevant features from the data, such as spectral values, texture, and shape, Classification which deals with Applying algorithms to assign pixels or objects to classes based on the extracted features, and validation which deals with Verifying the accuracy of the classification results (Gong and Howarth 1990). With AI algorithms, classification of crop types, forest, grassland, urban, water, wetlands, etc. can be done.

3. Predictive Analytics: Predictive analytics is defined as the use of advanced statistical and machine learning techniques to forecast or predict future events, trends, or patterns based on historical and current remote sensing data. It is also defined as a branch of advanced analytics that makes prediction about the future outcomes using historical data with machine learning and data mining techniques ("What is predictive Analytic": www.ibm.com). Predictive Analytics can be used to determine the size of gully erosion or land degradation caused by quarrying activities in the next ten or fifteen years based on the results of the analysis of the previous remote sensing and GIS data like the satellite imagery on the location or study site. The stages followed to perform predictive analytics in remote sensing and GIS using AI are: Data Integration which deals with combining remote sensing data with other relevant data sources, such as weather data, soil moisture data, or socioeconomic data, Pattern Recognition which deals with Identifying relationships and patterns in the data using machine learning algorithms, Model Development which deals with creating predictive models that can forecast future events or trends, Validation which deals with Testing and validating the accuracy of the predictive models, Deployment which deals with Implementing the predictive models in real-time or near-real-time to support decision-making. In a simple term, predictive analysis using AI is a form of forecasting the future scenarios based on historical or previous and current data.

AI models can predict or forecast future scenarios based on historical data and trends, such as Crop yields, rainfall, earthquake, market structure, flood, Weather pattern, disease spread, etc.

4. Spatial Analysis: Spatial analysis in remote sensing is defined as the process of examining and interpreting the spatial relationships, patterns, and trends in data collected from remote sensing technologies, such as satellite or aerial imagery. It is also defined as the method of studying the location, distribution, and relationship of spatial distribution, and relationship of spatial phenomenon (Encyclopedia of Quality of Life and Well-Being Research. link.springer.com). It involves processes like Spatial Autocorrelation which deals with Analyzing the similarity of values in nearby locations, Spatial Interpolation which deals with Estimating values at unsampled locations based on nearby sampled values, Spatial Regression which deals with Modeling the relationship between a dependent variable and one or more independent variables across space, spatial Clustering which deals with Identifying groups of similar values or features in close proximity, and Spatial Pattern Analysis which deals with Identifying and describing patterns, such as texture, shape, and orientation. Taitawip and Sean (2019) did a work titled "Spatial Distribution of Building use Recognition and Prediction of use with machine learning". Their work looked at the degree to which the likelihood of use types of individual buildings can be determined based on spatial measures of the street segment graph alone, using supervised machine learning on a detailed dataset of buildings in London. Also, Ylenia *et al.,* (2022) carried out a research work on machine learning for spatial analyses in urban areas. The result showed that with the availability of large datasets, Machine Learning (ML) and Artificial Intelligence are promising to revolutionize the way people analyze and plan urban areas, and that it will open new opportunities for the sustainable city agenda.

5. Automated Mapping: Automated mapping in remote sensing with AI deals with the use of algorithms and computer programs to automatically generate maps from remote sensing data, such as aerial imagery and satellite. Automated mapping using AI algorithms involves using machine learning and computer vision techniques to create maps from remote sensing data (Markova, 2021). The procedure for automated mapping using AI are: Data Preprocessing which deals with Cleaning and preprocess the remote sensing data to remove noise and correct errors, Feature Extraction which deals with Extracting relevant features from the data, such as edges, lines, and shapes, Classification which deals with Using AI algorithms to classify the features into different categories, such as land cover types or objects, Segmentation which deals with Segmenting the data into individual objects or features, Mapping which deals with Creating a map from the classified and segmented data, and Post-processing which deals with refining and correcting the map using additional

data or manual editing. This can be done using some AI algorithm like Convolutional Neural Networks, Deep Learning, Transfer Learning, Random Forest, Support Vector Machines, Unsupervised Learning, Semi-Supervised Learning: For combining labeled and unlabeled data to improve performance. With these AI algorithms, one can create topographic maps, erosion maps, land use/cover maps, forest maps, water bodies map, crop type maps, etc. using Remote sensing and GIS data or images.

6. Disaster Response: Disaster response is defined as the actions taken directly before, during or immediately after a disaster or a sudden or gradual change in the environment that causes widespread damage, destruction, or disruption to human societies, ecosystems, or infrastructure in order to save lives, reduce the health impacts, ensure public safety and meet the basic needs of the affected people (Ivić; 2019, and Response: undr.org). Examples of disasters are earthquakes, floods, hurricanes, wars, conflicts, landslides, wildfires, volcanic eruptions, chemical accidents, nuclear meltdowns, etc.

As reported by Wable, *et al.,* (2023), AI can be used in disaster situations in four ways such as disaster mitigation, disaster preparedness, disaster response, and recovery. AI may be implemented to predict any disaster with a view to mitigating it. AI may also help to prepare for it by proper allocation of resources, can help the concerned authority during disaster situations to evaluate the situation and respond accordingly, as well as paving the ways toward recovery through proper planning.

AI-powered systems can process data from various sources, including weather sensors, satellites, and social media, to detect early signs of impending disasters. AI can be used to carry out accurate prediction of floods when it is used alongside global luminescence. In the case of hurricanes, AI algorithms can analyze atmospheric data or parameters to predict their path, time and intensity of the hurricanes accurately. (Ceola et al., 2014). In confirmation of the above sources or research results, Lin *et al.,* (2021), stated that Researchers have been able to predict tsunami amplitudes by combining data from the Global Navigation Satellite System with artificial intelligence. They went further to say that early warnings of earthquakes may also be possible through using AI technology. Similarly, in the work of Arora *et al.,* (2020), it was said that AI had been used in the COVID-19 pandemic to disseminate resources properly, carrying out early diagnosis, contact tracing, as well as development of vaccines.

7. Crop Monitoring: Crop monitoring is defined as the use of remote sensing technologies, such as satellite or aerial imagery, to observe, track, and analyze crop growth, development, and health throughout the growing season (Karthik, 2014). With AI, remotely sensed data enables real-time tracking of changes in vegetation cover, climate data, and other parameters related to cropping activities. In addition, recent developments in machine learning and computer modeling make it possible to track and predict crop production using remotely sensed data (Akademiya2063). According to Karthik, *et al.,* (2023), Modern agriculture integrates modern-day technologies for automatic and green practices. This solution combines actual-time crop tracking with an RGB camera sensor, thermal camera sensors, and horn sensors. RGB data is utilized to automatically detect pests and diseases by utilizing real-time RGB and thermal data. Activating the scarecrow dynamically improves the accuracy of the repellent. RGB and thermal sensor facts underpin precision farming, automating useful resource utilization for better overall performance. Automatic irrigation management also makes use of this RGB data. Furthermore, the Integration of AI mechanism into a farmer gadget allows real-time data transfer, crop and pest control management, and customized alerts through push notifications. This helps the farmers to receive timely updates on essential situations, enabling remote farm management through mobile accessibility.

Also, Rachhpal*et al.,* (2023) did a work with the title "Rice Crop Yield Prediction Study by Artificial Intelligence Techniques", which reported a study done after analyzing some artificial intelligence techniques as Deep Learning (DL) with its hybrid approaches using Recurrent Neural Network (RNN), Deep Neural Network (DNN) and Artificial Neural Network (ANN). It was said that these techniques become helpful for identification and improvement in the rice crop yield prediction. This means that AI has a lot of roles to play in crop yields, and agriculture in general.

8. Object tracking: AI object tracking using AI and remote sensing and GIS imagery deals with the use of artificial intelligence algorithms to track and monitor objects or features within remote sensing imagery, like aerial images or satellite, and GIS data. AI tracking method can be used for vehicle tracking, airplane tracking, satellite tracking, vehicle tracking, wildlife tracking, crop monitoring, and all these are done using remote sensing and GIS images. Some techniques used by AI for object tracking in remote sensing and GIS are; Object detection which deals with detecting objects within remote sensing imagery. According to Prabakar et al., (2024), The usage of

machine learning and deep learning algorithms have necessitated artificial intelligence. They also inferred that the use of AI for various functions can be achieved through several deep learning algorithms that reflect the human brain's intelligence, and that the AI algorithms can be manipulated according to changing needs and improved efficiency. According to Deepan and Sudha (2018), nowadays, object detection in remote sensing aerial images is a fundamental and challenging task. The object detection is mainly used for detecting roads, buildings, vehicles, ships, trees, forests and used various applications such as geographic information system (GIS) update, environmental monitoring, geological hazard detection, urban planning, precision agriculture. Others are Object recognition which deals with recognizing and classifying objects within remote sensing imagery, Tracking algorithms which deals with using algorithms, Machine learning which deals with using machine learning algorithms, such as deep learning, to improve object tracking accuracy, Data fusion which deals with fusing remote sensing imagery with other data sources, Change detection which deals with detecting changes in remote sensing imagery to track objects or features, Feature extraction which deals with extracting features from remote sensing imagery to track objects or features..

4. Conclusion

The investigation of application of artificial intelligence (AI) in remote sensing and GIS has been carried out with the aim of finding out some useful ways AI can be integrated with remote sensing and GIS data analysis and results presentations. The study adopted the use of review method in which some previous works in the research area were reviewed and important points brought out for the benefits of AI, Remote sensing and GIS experts as well as for the benefit of the public. From the review and the analysis, it was observed that AI is applicable in Remote Sensing and GIS in areas like change detection analysis using AI algorithm to investigate land use/cover, image classification, predictive analysis such as forecasting of future occurrences from the present analysis, spatial distribution analysis, mapping such as creation of topographic and land use/cover maps, etc. It can, therefore, be concluded from the review of these several research works that AI has numerous applications or uses in remote sensing and GIS.

5. Recommendation

The application of AI in some common environmental problems of the country like erosion, flooding, and others be studied in future works in order to bring a lasting solution to the problems, or to mitigate its impacts on the people in particular and the country at large.

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