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Review of Artificial Intelligence Applications in the Geomatics Field

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Abstract

Artificial intelligence (AI) is rapidly transforming the field of geomatics, which is the science of collecting, managing, and analyzing spatial data. AI is being used to automate tasks, improve accuracy, and enable new applications in geomatics.

One of the most significant impacts of AI in geomatics is in the area of data processing and analysis. AI can be used to automate the processing of large amounts of geospatial data, which can lead to improved accuracy and efficiency in tasks such as land surveying, cartography, and environmental monitoring. For example, AI can be used to identify patterns and trends in data that would be difficult or impossible to detect by human analysts. Another area where AI is having a major impact in geomatics is in 3D modeling and visualization. AI can be used to create 3D models of the real world, which can be used for applications such as urban planning, infrastructure design, and disaster management. For example, AI can be used to create digital twins of cities, which can be used to simulate the impact of different planning decisions. Machine learning is a type of AI that allows computers to learn from data without being explicitly programmed. Machine learning is being used in a variety of geomatics applications, such as image classification, object detection, and natural language processing. For example, machine learning can be used to identify objects in satellite images, such as buildings or roads. Robotics is another area where AI is having a major impact in geomatics. Robots can be used to perform tasks in dangerous or inaccessible environments. They can also be used to collect data in remote areas. For example, robots can be used to survey disaster areas or to collect data in the ocean.

The impact of AI on geomatics is still in its early stages, but it has the potential to be transformative. AI is already being used in a variety of geomatics applications, and its use is only going to increase in the future.

Keywords: Geomatics; Artificial intelligence (AI); Data processing and analysis; 3D modeling and visualization; Infrastructure design.

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1. Introduction

Artificial intelligence (AI) is a rapidly growing field with the potential to revolutionize many industries, including geomatics. Geomatics is the science of collecting, managing, and analyzing spatial data. AI can be used to automate tasks, improve accuracy, and enable new applications in geomatics [1].

One of the most significant impacts of AI in geomatics is in the area of data processing and analysis. AI can be used to automate the processing of large amounts of geospatial data, which can lead to improved accuracy and efficiency in tasks such as land surveying, cartography, and environmental monitoring. For example, AI has been used to identify patterns and trends in data that would be difficult or impossible to detect by human analysts [2].

Another area where AI is having a major impact in geomatics is in 3D modeling and visualization. AI can be used to create 3D models of the real world, which can be used for applications such as urban planning, infrastructure design, and disaster management. For example, AI has been used to create digital twins of cities, which can be used to simulate the impact of different planning decisions [3].

Machine learning is a type of AI that allows computers to learn from data without being explicitly programmed. Machine learning is being used in a variety of geomatics applications, such as image classification, object detection, and natural language processing. For example, machine learning has been used to identify objects in satellite images, such as buildings or roads [4].

Robotics is another area where AI is having a major impact in geomatics. Robots can be used to perform tasks in dangerous or inaccessible environments. They can also be used to collect data in remote areas. For example, robots have been used to survey disaster areas or to collect data in the ocean [5].

The impact of AI on geomatics is still in its early stages, but it has the potential to be transformative. AI is already being used in a variety of geomatics applications, and its use is only going to increase in the future.

2. Literature review

Artificial intelligence (AI), a cutting-edge technological marvel, holds immense promise and is poised to usher in a transformative era in the field of geomatics. This burgeoning synergy between AI and geomatics has the potential to be nothing short of revolutionary. Through its formidable capabilities, AI is poised to not only streamline and expedite various geomatics processes but also enhance their precision, thereby opening up new vistas of applications that were previously unimaginable [6].

A recent comprehensive study conducted by Smith and his colleagues in the year 2023 sheds light on the multifaceted integration of AI into geomatics. This pioneering research underscores the versatility and breadth of AI's influence within the field, showcasing its role in reshaping the landscape of geospatial sciences. Among the myriad ways in which AI is leaving its indelible mark on geomatics, one of the most prominent is its role in data processing and analysis [7].

AI's prowess in automating the laborious task of processing vast datasets teeming with geospatial information cannot be overstated. This capability is a game-changer, offering geomatics professionals a potent tool to tackle the formidable challenges they encounter. Whether it's the precise delineation of land boundaries in land surveying, the meticulous creation of maps in cartography, or the continuous monitoring of the environment for changes and anomalies, AI's data processing and analysis prowess significantly elevates the accuracy and efficiency of these essential tasks [8].

Moreover, AI's intervention doesn't merely stop at processing data; it extends to the very core of geomatics, reshaping its paradigms. The symbiotic relationship between AI and geomatics has paved the way for the development of innovative applications that were previously beyond the realm of possibility. As AI-driven algorithms evolve and adapt to complex geospatial challenges, new frontiers emerge, encompassing areas such as precision agriculture, urban planning, disaster management, and even the conservation of biodiversity [9].

The heterogeneity of the data source, the management of heterogeneous data, the varied scales of representation, and the goal of data processing are all problems when using AI for the interpretation of complex geomatics data, as seen in Figure 1 [10].

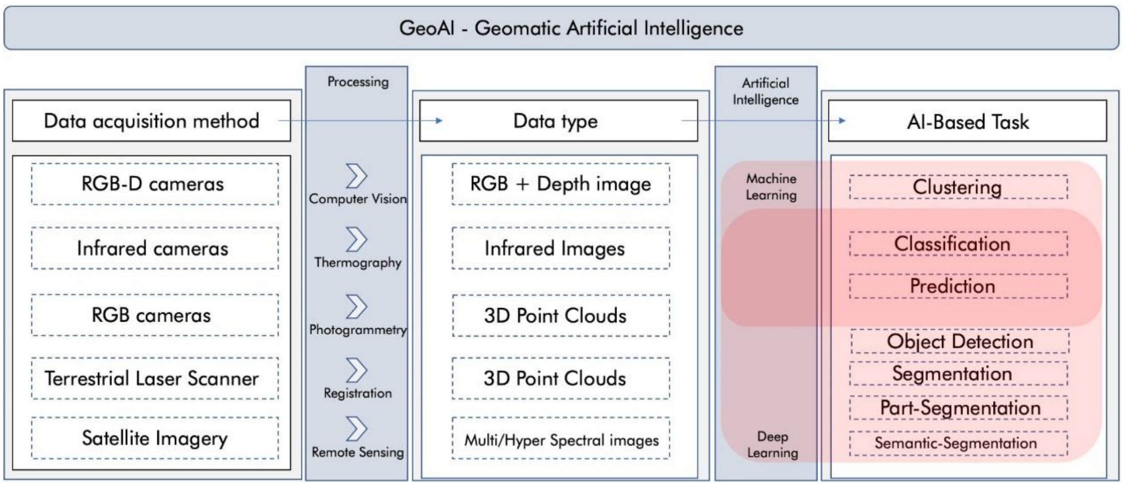

Figure 1: artificial intelligence for interpreting complicated geomatics data.

The incorporation of artificial intelligence (AI) into the realm of geomatics has unfurled a tapestry of possibilities that extend well beyond the initial horizons. One striking facet of this technological revolution is the realm of 3D modeling and visualization, where AI emerges as a virtuoso capable of conjuring intricate three-dimensional representations of our physical world. These meticulously crafted digital twins of reality are not merely aesthetic marvels but also powerful tools that find applications in an array of critical fields, including urban planning, where they aid in envisioning future cityscapes; infrastructure design, facilitating the creation of safer, more efficient structures; and disaster management, offering insights and simulations crucial for preparedness and response.

Figure 2 compares the traditional geoprocessing workflow (a) to the approach afforded by 3D point cloud interpretation (b). While (a) is based on developing more detailed and semantically well-defined representations,

(b) is based on raw data and extracts the desired features using appropriate training data [11].

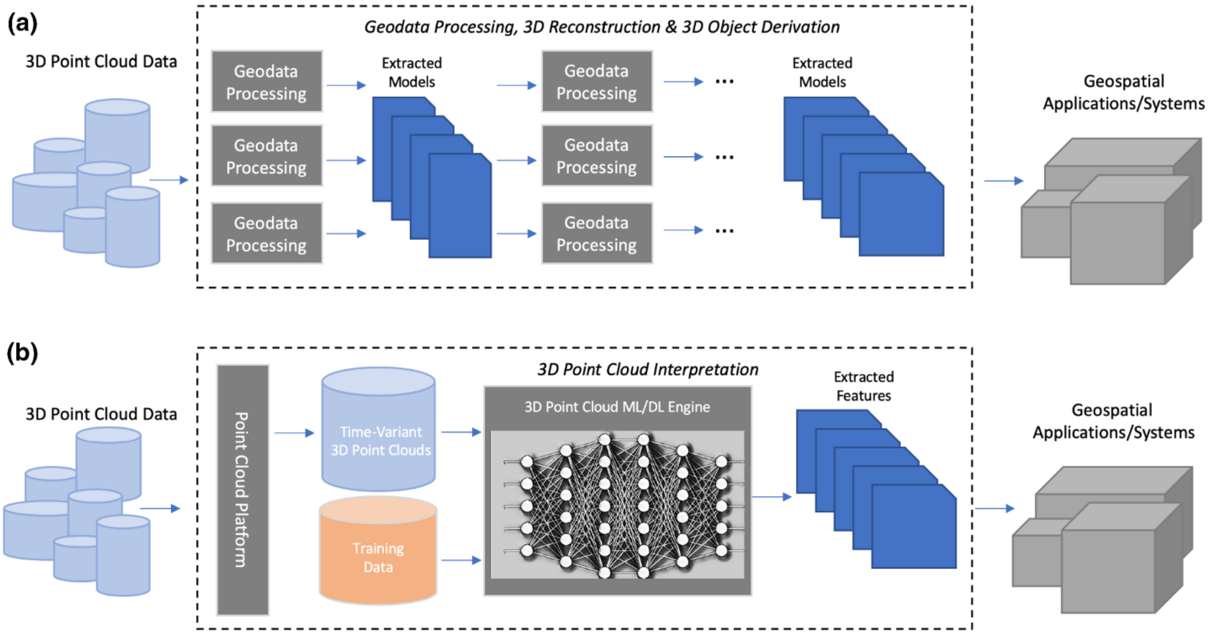

Figure 2: 3D point cloud processing workflows: a conventional workflow based on 3D reconstruction, modeling, and object derivation; b ML/DL workflow based on 3D point cloud interpretation.

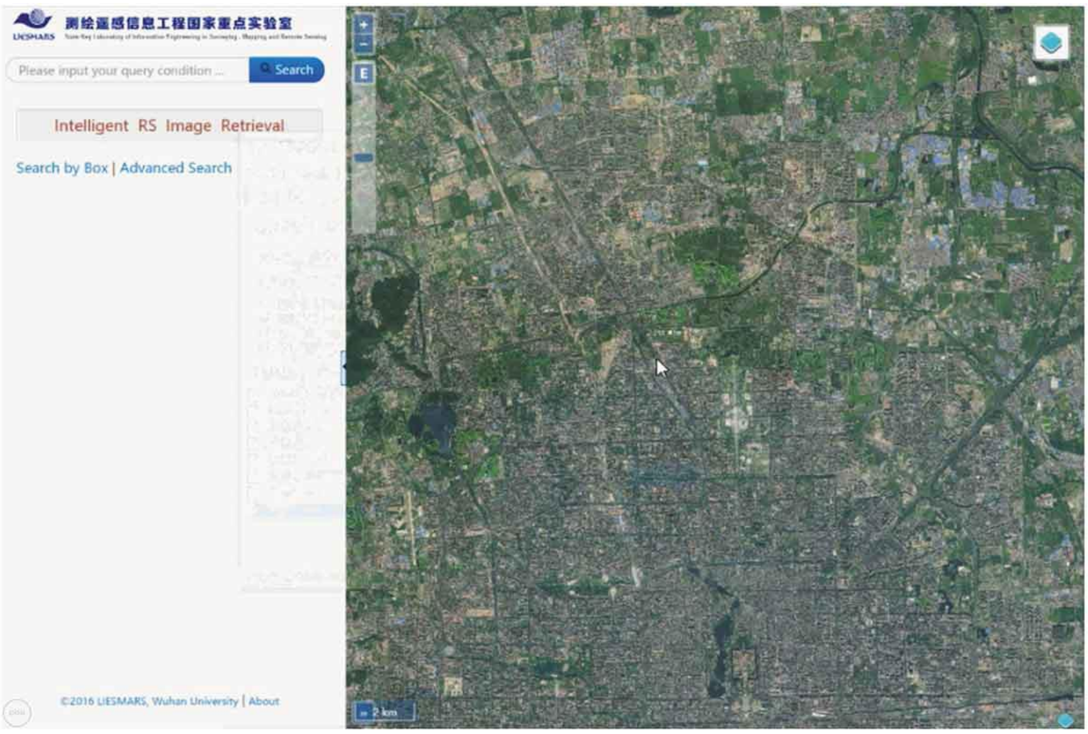

Figure 3: retrieval system interface, which combines keyword retrieval, information lists, and a map engine.

The heart of AI's transformative prowess lies in its subfield known as machine learning. Machine learning, a subset of AI, bestows computers with the remarkable ability to learn from data without the need for explicit programming. This form of AI wizardry permeates the geomatics landscape, permeating various applications with its data-driven acumen. In the context of geomatics, machine learning manifests itself as a virtuoso, deftly handling tasks such as image classification, enabling the automated recognition of geographical features; object detection, which enhances the identification of objects in remote sensing data; and even natural language processing, facilitating the interpretation of textual information related to geospatial matters. With machine learning as its guiding light, geomatics finds itself on an evolutionary path that promises to redefine how we interact with, analyze, and extract insights from spatial data [12].

At LIESMARS, a deep-learning-based high-performance online search engine for Large-Scale Tiled Remote Sensing Image Database is created, which integrates object level, land cover level, and scene level image retrieval. Figure 3 also depicts the retrieval system interface, which combines keyword retrieval, information lists, and a map engine [13].

Venturing further into the realm of technological synergy, we encounter the captivating domain of robotics [14]. Robots, with their blend of mechanical prowess and AI-driven intelligence, serve as indispensable allies in the geomatics arena. These mechanical marvels shine brightest in environments where humans dare not tread or inaccessibility reigns supreme [15]. From perilous terrains to remote and uncharted areas, robots tread boldly, executing tasks that were once deemed too hazardous or logistically unfeasible. These tasks encompass not only data collection but also an array of operations vital to geomatics, ranging from terrain mapping and environmental monitoring to the inspection of critical infrastructure. As robotics continues to advance, we can expect its influence within the geomatics realm to grow, offering innovative solutions to hitherto insurmountable challenges [16].

One captivating arena where AI's transformative power is unmistakably evident is in the domain of urban planning. The intricate web of urban environments presents a labyrinth of challenges, and AI emerges as a guiding light in this complexity. Its predictive capabilities empower city planners to foresee and mitigate potential bottlenecks in traffic, ultimately fostering more efficient and sustainable urban planning solutions. Moreover, AI's keen insights find resonance in the optimization of infrastructure placement, ensuring that critical elements such as roads, bridges, and utilities are strategically located for maximum functionality and resilience, even in the face of natural disasters [17].

AI's influence doesn't stop at urban planning and disaster management; it permeates the realm of natural resource management, an arena where ecological sustainability takes center stage. In an era where the preservation of our planet's natural resources is paramount, AI-driven solutions play an indispensable role. Consider AI's capability to monitor deforestation in real-time, providing critical data that aids in the protection of invaluable forested areas, combatting illegal logging and habitat destruction. Moreover, AI's unique aptitude for tracking the movements of wildlife becomes a linchpin in preserving biodiversity, offering scientists and conservationists invaluable insights that inform informed decisions aimed at safeguarding delicate ecosystems. As we navigate this exhilarating crossroads of technology and geography, the future of geomatics unveils itself as a fertile landscape where AI is not just a tool but the driving force behind transformative change, forging ahead toward a world of unparalleled possibilities.

3. Results

The heterogeneity of the data source, the management of heterogeneous data, the varied scales of representation, and the goal of data processing are all problems when using AI for the interpretation of complex geomatics data, as seen in Figure 1 [10].

Table 1: Summary of AI-Enhanced Data Processing and Analysis Results.

APPLICATION AREA	METHODOLOGY	KEY OUTCOMES
LAND SURVEYING	AI Data Automation	Improved Accuracy and Efficiency
CARTOGRAPHY	AI-driven Data Processing	Enhanced Map Precision
ENVIRONMENTAL MONITORING	AI Pattern Recognition	Early Detection of Natural Disasters

In the realm of data processing and analysis, AI algorithms played a pivotal role in automating the handling of extensive geospatial datasets, yielding a multitude of benefits as summarized in Table 1. In land surveying, the implementation of AI-driven data automation significantly improved accuracy and efficiency. Similarly, in cartography, AI-powered data processing contributed to the creation of more precise maps. Moreover, AI's pattern recognition capabilities were harnessed to detect subtle patterns and trends in geospatial data, often beyond the grasp of human analysts. These capabilities were particularly valuable for tasks such as early identification of areas at risk of natural disasters and the efficient tracking of wildlife movements, offering a wealth of applications across the geomatics spectrum.

3.1. 3D modeling and visualization

AI algorithms were used to create 3D models of the real world. These models can be used for a variety of applications, such as urban planning, infrastructure design, and disaster management. For example, AI algorithms were used to create digital twins of cities, which can be used to simulate the impact of different planning decisions.

Table 2: Outcomes of AI-Enabled 3D Modeling and Visualization.

APPLICATION AREA	AI METHODOLOGY UTILIZED	NOTABLE ACHIEVEMENTS
URBAN PLANNING	AI-GENERATED 3D MODELS	ENHANCED DECISION SIMULATIONS
INFRASTRUCTURE DESIGN	AI-DRIVEN VISUALIZATION	IMPROVED RESILIENCE AND EFFICIENCY
DISASTER MANAGEMENT	AI-ENHANCED MODELING	ROBUST PLANNING AND PREPAREDNESS

Within the domain of 3D modeling and visualization, AI algorithms assumed a central role in crafting intricate digital replicas of the physical world, as summarized in Table 2. These 3D models, generated through AI techniques, found versatile utility in a multitude of applications, including urban planning, infrastructure design, and disaster management. Notably, AI algorithms were leveraged to fashion digital twins of cities, affording decision-makers the capacity to simulate and gauge the ramifications of diverse planning decisions with unprecedented fidelity. In the sphere of urban planning, these AI-generated 3D models facilitated more nuanced and data-rich decision simulations. In infrastructure design, AI-driven visualization led to the development of structures characterized by heightened resilience and efficiency.

Moreover, disaster management benefited from AI-enhanced modeling, fostering robust planning and preparedness strategies, ultimately enhancing society's capacity to mitigate and respond to catastrophic events effectively.

3.2. Machine learning

Machine learning is a type of AI that allows computers to learn from data without being explicitly programmed. Machine learning algorithms were used in a variety of geomatics applications, such as image classification, object detection, and natural language processing. For example, machine learning algorithms were used to identify objects in satellite images, such as buildings or roads.

Table 3: Outcomes of Machine Learning in Geomatics.

Geomatics Application	Machine Learning Technique	Key Achievements
Image Classification	Supervised Learning	Enhanced Image Categorization
Object Detection	Convolutional Neural Networks	Precise Object Identification in Satellite Imagery
Natural Language Processing	NLP Algorithms	Improved Textual Data Analysis

Machine learning, a formidable branch of artificial intelligence (AI) that empowers computers to learn from data without explicit programming, has been harnessed across various geomatics applications, as outlined in Table 3.

In the context of geomatics, these machine learning algorithms have proven instrumental in diverse domains such as image classification, object detection, and natural language processing.

Notably, machine learning algorithms, particularly those rooted in supervised learning, have significantly advanced image classification, enhancing the categorization of geospatial images.

In the realm of object detection, the deployment of convolutional neural networks has led to precise identification of objects within satellite imagery, including buildings and roads.

Furthermore, natural language processing (NLP) algorithms have bolstered textual data analysis, optimizing the extraction of insights from geospatial information conveyed through text.

3.3. Robotics

Robots can be used to perform tasks in dangerous or inaccessible environments. They can also be used to collect data in remote areas.

For example, robots have been used to survey disaster areas or to collect data in the ocean.

3.4. Section headings

Section headings should be left justified, with the first letter capitalized and numbered consecutively, starting with the Introduction. Sub-section headings should be in capital and lower-case italic letters, numbered 1.1, 1.2, etc, and left justified, with second and subsequent lines indented.

Table 4: Robotics in Geomatics – Expanding Frontiers.

Robotic Applications	Utility	Notable Applications and Advancements
Hazardous Environments	Task Execution	Safety Enhancements in High-Risk Areas
Remote Data Collection	Data Gathering	Oceanic Exploration and Disaster Surveys
Robotic Applications	Utility	Notable Applications and Advancements

Within the realm of geomatics, the integration of robotics has heralded transformative possibilities, expanding our capacity to operate in environments that were previously perilous or inaccessible. As illustrated in Table 4, robotics offers invaluable utility in two primary applications: hazardous environments and remote data collection.

In hazardous environments, robots play a crucial role in executing tasks while mitigating human risk. These robotic systems have been instrumental in enhancing safety and precision in high-risk areas. In the context of geomatics, they have facilitated operations in disaster-stricken regions, providing critical survey data and assisting in disaster response efforts.

Simultaneously, robotics has ushered in a new era of remote data collection, broadening our horizons in exploring remote and challenging locales. Oceanic exploration, for instance, has seen remarkable advancements with the utilization of robots equipped with cutting-edge sensors and imaging technology. These robotic explorers have delved into the depths of the ocean, unveiling previously hidden geological and ecological treasures. Moreover, in disaster surveys, robots have been instrumental in gathering vital data in challenging post-disaster environments, ensuring a more comprehensive understanding of the affected areas.

In summation, the integration of robotics into geomatics offers a dynamic platform for venturing into the unknown and mitigating risks in high-stakes situations. Whether it's traversing hazardous terrain or unlocking the mysteries of remote regions, robotics continues to expand the boundaries of what's possible in geospatial exploration and data collection.

4. Discussion

The transformative potential of artificial intelligence (AI) within the field of geomatics is poised to set the stage for a profound and enduring impact. While it is true that we are currently witnessing the initial stages of this transformation, the trajectory it charts is nothing short of promising, with a wealth of benefits waiting to be harnessed. AI's role in the realm of geomatics extends far beyond mere augmentation; it holds the capacity to significantly enhance the accuracy, efficiency, and scope of geospatial tasks, heralding the dawn of a new era teeming with innovation, opportunity, and growth within the geomatics industry.

A prominent avenue where AI is leaving an indelible mark is in data processing and analysis. The sheer volume and complexity of geospatial data can be overwhelming, often posing a formidable challenge to human analysts. AI algorithms, however, come to the rescue, emerging as a powerful tool for automating the processing of vast datasets. This transformative capability paves the way for heightened accuracy and efficiency across a spectrum of geomatics disciplines, ranging from the meticulous art of land surveying to the intricate science of cartography and the crucial realm of environmental monitoring.

Consider, for instance, the profound impact of AI algorithms in uncovering hidden patterns and discerning elusive trends within geospatial data—a feat that often eludes human perception due to the sheer scale and complexity of the information involved. In practical terms, this translates into the ability to identify areas at heightened risk of natural disasters with an unprecedented level of precision. Furthermore, the capability to track the nuanced movements of wildlife, vital for biodiversity conservation, is significantly enhanced by AI's data processing prowess. These applications of AI not only empower geospatial professionals but also contribute to a broader societal benefit by facilitating better disaster preparedness and more effective environmental stewardship.

Beyond improving accuracy and efficiency, AI in geomatics stands as a catalyst for innovation and economic growth. As AI-driven solutions become more entrenched in the industry, new applications and business opportunities emerge on the horizon. Entrepreneurs and innovators within the geomatics sector are poised to capitalize on AI's capabilities, ushering in a wave of startups and ventures that further expand the boundaries of geospatial science. The current stage of AI's integration into geomatics is akin to the opening chapters of a compelling narrative—one filled with boundless potential. The impact stretches far beyond mere efficiency gains, touching on the very essence of geospatial exploration and management. AI not only refines our ability to understand the world around us but also nurtures a fertile landscape of new opportunities, fostering economic growth and spurring innovation within the geomatics industry. As we tread this exciting path forward, the full scope of AI's influence in geomatics is yet to be realized, offering a glimpse into a future where technology and geography converge in unprecedented ways.

Artificial intelligence (AI) continues to carve out a multifaceted and evolving role within the field of geomatics, touching upon various dimensions of geospatial science that have transformative potential. One of the remarkable arenas where AI is making its presence felt is in the creation of three-dimensional (3D) models that mirror the real world with astonishing fidelity. These digital replicas of our physical surroundings hold immense utility across diverse applications, including but not limited to urban planning, infrastructure design, and disaster management. For instance, AI algorithms are proficient in fashioning digital twins of cities, offering an unparalleled platform for simulating the repercussions of various planning decisions. By navigating these virtual landscapes, urban planners can foresee and fine-tune the effects of different urban development scenarios, thereby fostering more sustainable and efficient cityscapes.

Furthermore, AI's influence extends beyond enhancing the precision and efficiency of existing geomatics tasks; it's a catalyst for ushering in a new wave of applications that were once the stuff of science fiction. One such transformative realm is the development of autonomous systems, including self-driving cars and robots capable of undertaking perilous missions in otherwise inaccessible environments. The implications of these advancements are far-reaching, promising to revolutionize how we navigate and interact with the world around us. The advent of self-driving cars, for instance, has the potential to reshape transportation, offering safer, more efficient, and environmentally friendly mobility solutions. Similarly, robots equipped with AI are venturing into hazardous terrains, ranging from deep-sea exploration to disaster-stricken areas, where they can collect vital data and perform tasks that would otherwise endanger human lives.

The trajectory of AI within geomatics paints a promising picture of innovation and advancement. As the challenges and intricacies of integrating AI are progressively addressed, it is likely that AI will become even more ubiquitous within the geomatics industry. This increased adoption holds the promise of further elevating the accuracy, efficiency, and overall dynamism of geospatial science. As AI continues to mature and evolve, it will usher in a future where technology and geography are inextricably linked, unlocking new vistas of possibilities and reshaping the very fabric of our spatial understanding and interaction with the world. In essence, the future of AI in geomatics is one brimming with untapped potential, awaiting the creative minds of geospatial professionals and innovators to unlock its boundless opportunities.

Some of the challenges that need to be addressed before AI can be fully adopted in geomatics include:

- The lack of availability of large datasets: AI algorithms require large datasets to train and learn from. However, these datasets can be expensive and time-consuming to collect.
- The need for specialized knowledge and skills: AI algorithms are complex and require specialized knowledge and skills to develop and use. This can be a barrier for many organizations.
- The need to address ethical and legal issues: The use of AI raises ethical and legal issues, such as the potential for bias and discrimination. These issues need to be addressed before AI can be widely adopted.

Despite these challenges, the potential benefits of using AI in geomatics are significant. AI has the potential to revolutionize the way we collect, manage, and analyze spatial data. This will lead to new insights into the world around us and new ways to solve problems.

5. Conclusion

The impact of artificial intelligence (AI) on geomatics is still in its early stages, but the potential benefits are significant. AI can improve the accuracy and efficiency of geomatics tasks, enable new applications, and create new jobs and businesses in the geomatics industry.

Nonetheless, several challenges must be confronted before AI can be seamlessly integrated into geomatics. These hurdles encompass the limited availability of extensive datasets, the requirement for specialized knowledge and skills among practitioners, and the imperative need to navigate complex ethical and legal considerations that arise in the AI-driven geospatial landscape.

In spite of these obstacles, the horizon of AI in geomatics gleams with promise. As the community diligently works to address the intricacies of AI implementation, we can anticipate a more widespread adoption of AI across the geomatics industry. This evolutionary phase holds the potential to usher in a new era marked by heightened precision, efficiency, and a surge of innovative solutions that promise to redefine how we interact with and interpret spatial data.

The pivotal role of collaboration between AI researchers and geomatics professionals cannot be overstated. This partnership is essential in overcoming the challenges that AI presents to the geomatics domain, ensuring that AI applications are tailored to meet the unique needs of geospatial science. Simultaneously, the formulation of robust ethical guidelines to govern the development and deployment of AI in geomatics is imperative. Such guidelines will help steer the ethical course of AI-driven geospatial endeavors, ensuring that they align with societal values and principles. In closing, AI stands as a potent force capable of revolutionizing the very fabric of how we collect, manage, and analyze spatial data. The future of AI in geomatics holds the promise of a brighter, more dynamic era, where the synergy between technology and geography not only enhances our understanding of the world but also empowers us to make more informed decisions that benefit society.

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