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The role of maritime geospatial in navigating uncharted waters mapped

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ABSTRACT
Background: Modern maritime navigation, especially in uncharted waters, faces major challenges that require innovative solutions. Geospatial technologies play a key role in providing effective solutions for mapping and navigation. This study aims to explore the role of geospatial technologies in improving the safety and efficiency of maritime navigation, as well as supporting sustainable management of marine resources. **Methods**: This study used both qualitative and quantitative approaches. Data was obtained through secondary collection from journals, books and other documents. **Results**: Data analysis revealed that geospatial technology plays an important role in identifying safe navigation routes, monitoring sea conditions, and sustainably managing marine resources. The integration of geospatial data from various sources enables more effective decision-making in maritime spatial planning and safe navigation. **Conclusion**: This research concludes that geospatial technology is a critical aspect of modern maritime navigation. With an integrated and collaborative approach, these technologies can improve navigation efficiency and safety, and support sustainable management of marine resources. Awareness and education on geospatial technology in the maritime industry is considered essential to maximize its potential in maintaining the balance of marine ecosystems and the sustainability of the maritime industry.

KEYWORDS: geospatial; maritime geospatial; remote sensing.

1. Introduction

In the modern era of maritime navigation, the biggest challenges are often found in uncharted waters. The role of maritime geospatial technology is key, providing innovative solutions for mapping and navigation. Battamo et al. (2021) argue that maritime geospatial is changing the landscape of marine navigation by utilizing data and analysis. From bathymetric mapping to environmental surveillance, it will be understood how these technologies not only strengthen safety and efficiency in marine navigation but also assist in the sustainable management of marine resources and protection of marine ecosystems.

The maritime domain in a vast ocean plays a critical role in the context of global security and trade. This vast region has a lot of dynamics that are always monitored and analyzed using geospatial technologies developed specifically to analyze maritime issues. According to Depellegrin et al. (2021), maritime geospatial refers to the use of geospatial tools and data in marine spatial planning. It involves the analysis and representation of data in geospatial processes, both in the marine environment and in the relationships between terrestrial and marine ecosystems.

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Zhang et al. (2021), stated that maritime geospatial technology plays an important role in analyzing and mapping marine accidents. It helps in understanding the risk factors associated with maritime navigation channels and supports the development of effective maritime safety and management strategies. These technologies are globally connected and rely on satellite imagery and oceanographic data to display actual conditions in a map-organized format. These tools are essential not only for navigation but also for monitoring maritime boundaries and sustainably managing marine resources. With this technology, maritime environmental data and conditions can be well visualized.

2. Methods

This research aims to explore the role of geospatial technologies in modern maritime navigation, particularly in uncharted waters. The main focus is on how these technologies can improve navigation safety and efficiency, as well as support sustainable management of marine resources and protection of marine ecosystems. This research is expected to provide a comprehensive understanding of the role of geospatial technology in maritime navigation, particularly in uncharted waters. The results are expected to form the basis for the development of safer and more efficient navigation strategies and support the sustainable management of marine resources. Based on this, the following research brainstroming can be seen in figure 1.

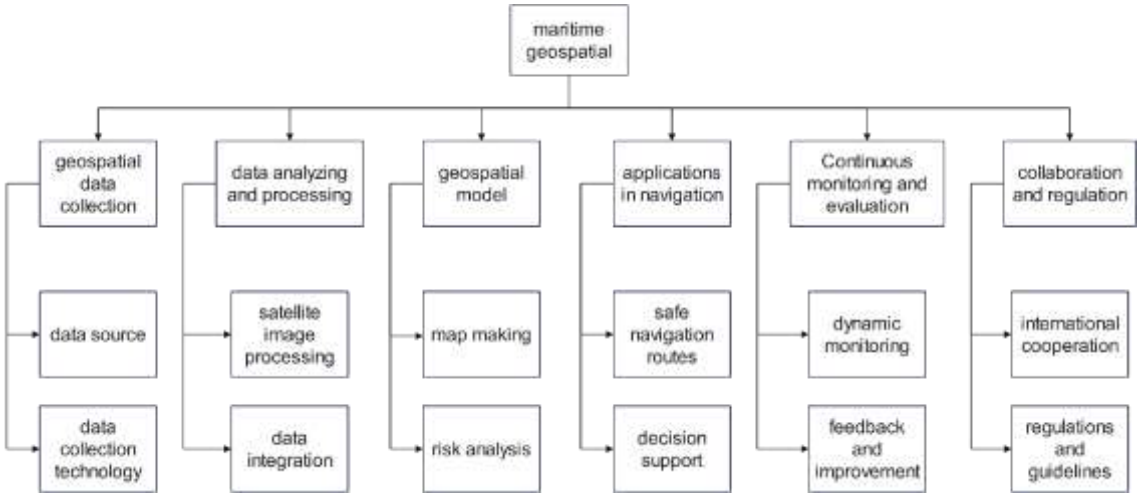

Fig. 1 Brainstroming

3. Results and Discussion

3.1 Geospatial data collection

Maritime navigation has undergone a significant transformation with the advancement of geospatial technology. According to Zhang et al. (2021), In the context of uncharted waters geospatial technology and navigation systems in identifying safe routes and avoiding obstacles are very important to implement. Technologies such as radar, lidar, and automatic identification system (AIS) are used to detect and avoid water obstacles. The use of geospatial data can help address threats to navigation, such as unseen obstacles and unpredictable sea conditions, through more accurate data collection and processing of relevant information.

According to Xiao et al. (2022), geospatial data collection is done through various sources and technologies. Data sources include satellite imagery, Automatic Identification

System (AIS) data, oceanography, and field observations. The use of advanced technologies such as satellite remote sensing, UAVs (Unmanned Aerial Vehicles), and deep-sea sensors, enables accurate and comprehensive data acquisition. This data is then processed using geospatial technologies such as ArcGIS for risk analysis and visualization, providing deep insights into maritime conditions and sea lane security.

Depellegrin et al. (2021), conducted research on the use of geospatial technology in maritime spatial planning (MSP) which resulted in an understanding of the importance of geospatial data for shipping navigation, especially in uncharted areas. Geospatial technologies enable more accurate and detailed data acquisition, essential for identifying safe navigation routes and avoiding obstacles at sea. The data acquisition process involves collecting data from various sources, including satellite imagery and sensors, and analyzing it to identify risk areas and assist in marine spatial planning. This analysis is very useful for minimizing navigation risks and improving shipping safety in uncharted areas. However, there are several obstacles in maritime geospatial data acquisition, such as limitations in data precision and resolution, and challenges in collecting data from large and diverse areas. Overcoming these problems requires synergy and integration of data from various sources to produce more accurate and comprehensive information. This data integration is important to support effective decision-making in maritime spatial planning, ensuring navigation safety, and managing maritime resources sustainably.

3.2 Data analyzing and processing

The geospatial approach is the most effective approach used to solve maritime problems.Davies et al. (2021), discusses geospatial data processing to detect underwater features and their utilization in the maritime field. In their research, they use tracking data to identify important areas on the high seas and provide information on conservation measures. Geospatial data is important for shipping navigation, especially in uncharted areas, by providing information about habitats, migration patterns, and ecological zones including this data helps overcome challenges in managing marine areas and supports the protection of migratory species. Geospatial technologies are used to collect data on ocean topography, ocean currents and weather conditions. This data is then analyzed to identify safe and efficient navigation routes, and to detect potential obstacles or hazards including in conservation areas. This analysis is critical to reducing risk and improving safety in shipping navigation, especially in uncharted or under-mapped areas.

According to Mohn et al. (2011), ocean currents can be precisely mapped and understood which has important implications for shipping navigation and maritime environmental research. Geospatial data integration in the maritime context plays an important role in providing a holistic view of uncharted water conditions. By combining various geospatial data, we can develop effective geographic information systems (GIS), creating detailed and informative thematic maps. The implementation of geospatial in the maritime field not only improves our understanding of the maritime environment but also helps in more informed and efficient decision-making.

The application of geospatial technologies in the maritime field offers a wide range of benefits, including enhanced maritime security, more effective management of marine resources and more accurate environmental monitoring. By continuing to develop and integrate geospatial technologies, we can gain a deeper understanding of the maritime ecosystem and face existing challenges with more innovative and sustainable solutions. According to Papageorgiou et al. (2020), this research shows how geospatial data integration can improve the effectiveness of marine spatial planning and help address the challenges faced in maritime resource management. A place-based approach in MSP (Maritime Spatial Planning) enables more informed and sustainable decision-making for coastal and marine area management.

3.3 Geospatial model

According to Zhu & Yang (2019), the geospatial model is an important tool in managing, analyzing, and visualizing data related to geographic information. This model uses data processing techniques to match open source data available on the web with the geospatial model being worked on. This process enables wider and more efficient use of data in a variety of geospatial applications, including maritime navigation and resource management. The model utilizes advances in information and communication technology to improve the efficiency and effectiveness of geospatial data processing. One form of geospatial model is thematic maps of shipping navigation channels.

The creation of detailed maps of uncharted waters, including bathymetry, seabed structure and potential routes, is an important aspect of maritime navigation. Recent technologies allow for more accurate and efficient bathymetry mapping. David et al. (2021), explored the use of drones to reconstruct topography and bathymetry on coral reefs and coasts showing the potential and limitations of regular drones in producing accurate topographic and bathymetric data. He explained the process of creating maps using technologies such as photogrammetry through UAVs (Unmanned Aerial Vehicles) and Structure-from- Motion techniques. These techniques make it possible to obtain accurate topographic and bathymetric details, although there are some challenges such as distortion due to water refraction. Meanwhile, Mazza et al. (2023), showed that UAV (Unmanned Aerial Vehicles) based photogrammetric techniques can collect bathymetry and seabed structure data with high accuracy. This method enables the identification of safe and efficient shipping navigation routes, and provides important insights into maritime conditions in uncharted areas. It also emphasizes the advantages in terms of time and cost compared to traditional survey approaches.

According to Zhang et al. (2021), to plan potential routes in uncharted waters, an in-depth analysis of bathymetry and seabed structure is required. This process involves using geospatial data to identify risky areas and seabed conditions that may affect navigation. Potential routes are planned with these factors in mind to ensure navigation safety and efficiency. This approach enables the identification of safer and more efficient paths in uncharted waters. Thus, geospatial models play a crucial role in the determination of uncharted shipping routes.

3.4 Applications in navigation

Planning safe navigation routes in uncharted waters is a challenge in maritime navigation. The use of data and maps generated through geospatial technology is crucial in overcoming this challenge. According to Lee & Yu (2023), to plan safe navigation routes in uncharted waters, the data and maps generated are used strategically. This process involves analyzing the distribution of maritime traffic and analyzing lane density using data from Automatic Identification Systems (AIS). This approach helps in identifying main and alternative routes, taking into account vessel distribution and traffic patterns. The results of this analysis are important for determining safe and efficient navigation routes, especially in uncharted or hard-to-reach areas. Key considerations in determining shipping routes include maritime traffic distribution analysis, lane density assessment, and geographic characteristics. Criteria for route width, as suggested by the IMO (International Maritime Organization) and other organizations are taken into account to ensure safe navigation.

In maritime navigation, particularly in uncharted waters, it is important for navigators and ship captains to have access to up-to-date geospatial data, including accurate nautical charts, information on weather conditions, ocean currents and waves. Captains should consider water depth, underwater obstacles and maritime traffic in planning routes, based on a comprehensive risk analysis. In difficult conditions, safe decisions may depend on the experience and advice of the navigation team, as well as

effective communication with maritime authorities and other vessels for up-to-date information. Perttola (2022), outlines a decision support method to provide navigators and ship captains with critical information to make informed navigation decisions. The method integrates geospatial data, technology, and weather condition analysis to optimize shipping routes. This includes voyage modeling based on wind and current conditions, as well as risk and cost analysis to select the safest and most efficient route. This approach is essential in maritime navigation, especially in uncharted waters, to ensure travel safety and efficiency.

3.5 Continuous monitoring and evaluation

Continuous dynamic monitoring of water conditions is an important aspect of maritime navigation, especially in uncharted waters. This monitoring involves constant observation of various factors such as currents, depth, weather conditions, and the presence of obstacles or other hazards that may affect navigation routes. According to Berenter et al. (2021), explain geospatial monitoring through the use of satellite data to identify and track anomalies that occur in an area, in this case a water area. This involves analyzing satellite imagery to produce monitoring results to determine uncharted shipping lanes. The results of the satellite image analysis are used to produce thematic maps. These maps are then disseminated to relevant stakeholders, assisting in the response to emerging issues as well as being an important part of the establishment of shipping lanes in the region.

In the world of maritime navigation, especially in uncharted waters the application of feedback from navigation experience to update charts and risk models is an important and ongoing process. This geospatial analysis to evaluate the impact of Global Environment Facility (GEF) projects on water quality in Marine Ecosystem Areas using multiple satellite images and sensors was chosen for its extensive period of activity, global coverage, and pre-processing features for rapid analysis. This approach is particularly useful for handling long time series data, spanning several decades. To address this, pixel values from daily images were averaged over four quarters of each year. This approach aims to provide a more accurate representation of each quarter, avoiding biased results due to missing parts. The data was then spatially averaged across the region to obtain the average chlorophyll value per quarter, which was further used to observe trends over time. Geospatial analysis provides a dense time series of quantitative data, showing trends over time and allowing spatial comparisons across different parts of the water area. However, this method alone cannot provide insight into the factors driving these trends. To overcome these limitations, qualitative methods such as interviews and literature review were used. The combination of quantitative geospatial analysis with qualitative approaches was found to be effective in evaluating the impacts of environmental development projects. While this approach has its advantages in providing extensive and unbiased quantitative data, it is complemented by qualitative methods to fully understand the impacts of GEF projects and other interventions on seawater quality (Sidman et al., 2020).

3.5 Collaboration and regulation

International cooperation within the framework of maritime policy, aiming to achieve sustainable development in maritime countries. The framework integrates maritime policy at all levels of policymaking, including long-term national strategies, local and regional policies, and sectoral policies. The implementation of this policy is supported by a multi-level local maritime governance structure, where tasks and responsibilities are shared between different structures at different levels, such as ministries, local governments, and sub-institutions. This approach is based on a business management style and allows for continuous adaptation to change. The maritime sector is divided into five components: maritime industry, ports, maritime transportation, fisheries, and

maritime fundamentals that include cultural traditions, cultural heritage, coastal living, and marine environmental protection. This division allows the creation of separate policies or development plans for each sector that focus on its specificities. Maritime fundamentals, as a horizontal dimension of the entire maritime sector, should be integrated into national strategies and other sectoral policies. The framework advocates policy-making that goes beyond sectoral policies and views the maritime sector not only as a separate economic sector that has a significant impact on a country's economic performance, but also as a well-integrated component of the functioning and achievements of each maritime nation. This supports improving the sustainable development performance of maritime nations, by focusing on the specificity of this subsector in relation to sustainable development when setting goals and implementing policies (Nõmmela & Kaare, 2022).

On aspects of safety culture within the maritime sector, particularly among seafarers. Regulations and guidelines developed to support safe navigation in uncharted waters while protecting marine ecosystems. The International Maritime Organization (IMO) has been implementing activities to ensure the safety of maritime autonomous surface ships (MASS) through international regulations. This includes the adoption of interim guidelines for trials in 2019 and regulatory scope exercises (RSEs) of international conventions related to maritime safety. The development of regulations and guidelines for safe navigation in uncharted waters, while protecting marine ecosystems, involves a comprehensive approach, considering technological advances, crew management, and the need for efficient data and information transfer. This includes not only technical aspects but also the welfare and mental workload of operators (Yoshida et al., 2021).

4. Conclusions

The importance of geospatial technologies in modern maritime navigation, especially in uncharted waters. Geospatial technologies, such as bathymetry data, environmental monitoring and satellite imagery, improve the safety and efficiency of marine navigation. These technologies are also important in the sustainable management of marine resources and the protection of marine ecosystems. Emphasis is placed on collecting accurate and comprehensive geospatial data, using technologies such as radar, lidar and Automatic Identification Systems (AIS), to address navigation challenges. Geospatial data integration and analysis support effective decision-making in maritime spatial planning and safe navigation.

The evolution of intelligence in maritime geospatial will continue to be an integral part of navigating the complex and changing maritime landscape. Awareness of the importance of maritime geospatial technology must continue to be spread. Education and training to maritime industry players, including mariners and port management, are key in optimizing the utilization of this technology. With improved skills and understanding in geospatial technology, it can be expected that the maritime industry will be more efficient, safe and environmentally friendly. These measures will also help in maintaining the sustainability of the marine maritime ecosystem, which is not only important for life underwater but also for human survival. In addition, maritime geospatial technology development must always adapt to climate change and environmental challenges. Research initiatives and collaboration between countries in the development of these technologies are important to support global policies on climate change and marine conservation. Through international cooperation and knowledge exchange, we can create a safer and more sustainable maritime future that fully utilizes the potential of geospatial technology to maintain the balance between industrial progress and the preservation of marine ecosystems.

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