Journal of Electronic Research and Application, 2024, Volume 8, Issue 2
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Analysis of the Design and Implementation of a GIS System Incorporating Intelligent Recognition Models

Baoshan Zeng*

School of Geomatics and Urban Spatial Informatics, Beijing University of Civil Engineering and Architecture, Beijing 102616, China

***Corresponding author**: Baoshan Zeng, zbs1048596@163.com

Abstract: The rapid economic growth, urbanization, and industrialization have led to a scarcity of land resources in coastal areas, exacerbating the conflict between humans and the environment. In order to promote economic development, attention has turned to the sea, and various coastal engineering projects have been undertaken, sparking a wave of land reclamation. However, while these efforts bring economic and social benefits, they also have implications for ecological relationships. To respond to and plan for changes in the coastline and land cover in a timely manner, this paper proposes and constructs a GIS system that integrates remote sensing image recognition models. The system combines geographic information system development technology with image recognition technology, streamlining the processing and identification of image data. This approach is particularly advantageous for marine management departments in their long-term monitoring and dynamic management of coastal lines, ensuring a more effective and efficient response.

Keywords: GIS; Image recognition; Image data; System construction

Online publication: March 29, 2024

1. Introduction

With its unique geographical advantage, the eastern coastal region has become a vital pillar supporting the rapid growth of China's national economy. However, the flourishing economy, along with rapid urbanization and industrialization, has led to a gradual depletion of land resources in coastal areas, intensifying the conflict between humans and the environment. In order to continuously promote economic development, attention has turned to the sea, and various coastal engineering projects have been undertaken, sparking a wave of land reclamation. While these endeavors have generated significant economic and social benefits, they have also altered the natural coastal landscape, resulting in profound changes in the coastal zone and causing imbalances in marine ecosystems, leading to a series of severe environmental disasters [1]. Therefore, it is of great practical significance to accurately extract and timely grasp information on the dynamic changes in China's coastline and land reclamation.

High-resolution remote sensing data offers significant information, ease of acquisition, real-time capability, and high accuracy, making it widely applicable in various fields. The phenomenon of coastal erosion [2], resulting from human-induced land reclamation [3,4] and other integrated factors, often occurs. Currently, extensive monitoring of such events through manual field surveys is time-consuming and labor-intensive. To address this challenge, the combination of high-resolution satellite imagery with broad spatiotemporal coverage along the coastline and the effectiveness of artificial intelligence object recognition can play a crucial role in the intelligent identification of land reclamation and erosion targets. This integration of technologies serves as a key approach for coastal line monitoring.

The development of GIS-based application systems is an important solution for addressing various issues related to geographic data, including map information, image data, and other data with spatial attributes [5]. This study focuses on the development of a GIS software tool that integrates intelligent recognition models, with land reclamation and coastal erosion models as the foundation. The aim is to optimize and enhance this specific aspect of the existing coastal line monitoring workflow, thereby improving the level of intelligent information in coastal protection operations. By utilizing deep learning algorithms to recognize high-resolution remote sensing images, the study identifies, extracts, and processes three target areas: land reclamation, coastal erosion, and marine reclamation. Vector maps of these three areas are generated, and an intelligent recognition model is trained and obtained. By combining the intelligent recognition model with various functions within the GIS software tool, the system enables preprocessing, recognition, and reprocessing of image data. This provides firsthand data and evidence for assessing operations and implementing corrective measures.

The remaining structure of this article is as follows: **Section 2** introduces the overall framework of the system. **Section 3** describes the key technologies and various functional modules of the system during the implementation process. **Section 4** presents the results of this study.

2. System architecture

After conducting a survey and analysis of the identification needs in coastal areas, Windows application development technology is employed to combine with GIS development components to achieve visualization and data processing of image data. Additionally, by training deep learning algorithms using processed image data, an identification model is created and integrated into the system, facilitating the fusion of GIS technology with remote sensing image recognition technology.

The overall design concept of the system is based on a multi-layer application architecture using distributed component technology. It incorporates modular design for various functionalities and follows a C/S architecture for system design and development. The system architecture comprises the infrastructure layer, data service layer, software service layer, and user layer. The complete system architecture diagram is illustrated in **Figure 1**.

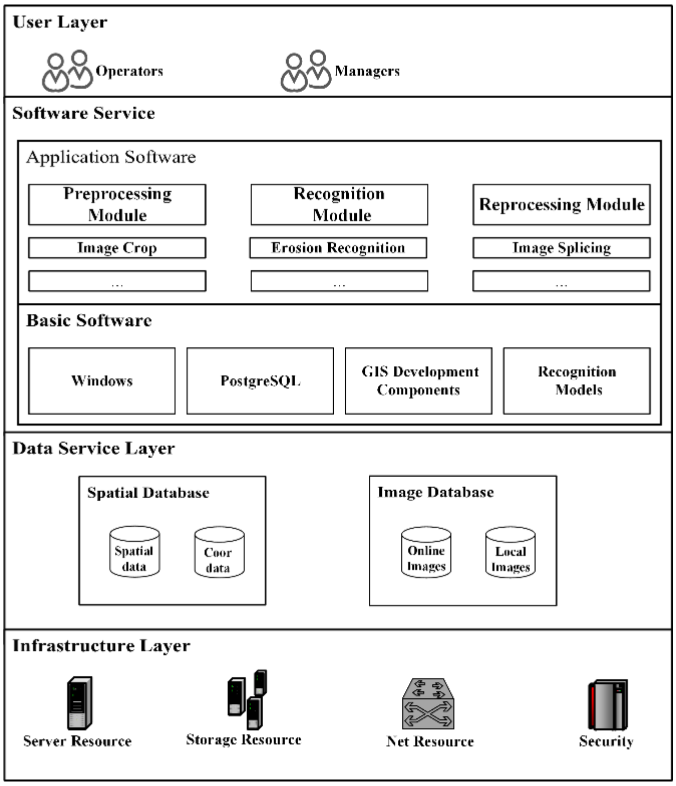

Figure 1. System architecture

3. System implementation

The functional structure framework of the system is shown in **Figure 2**, which is mainly divided into three main modules, namely preprocessing module, recognition module, and reprocessing module.

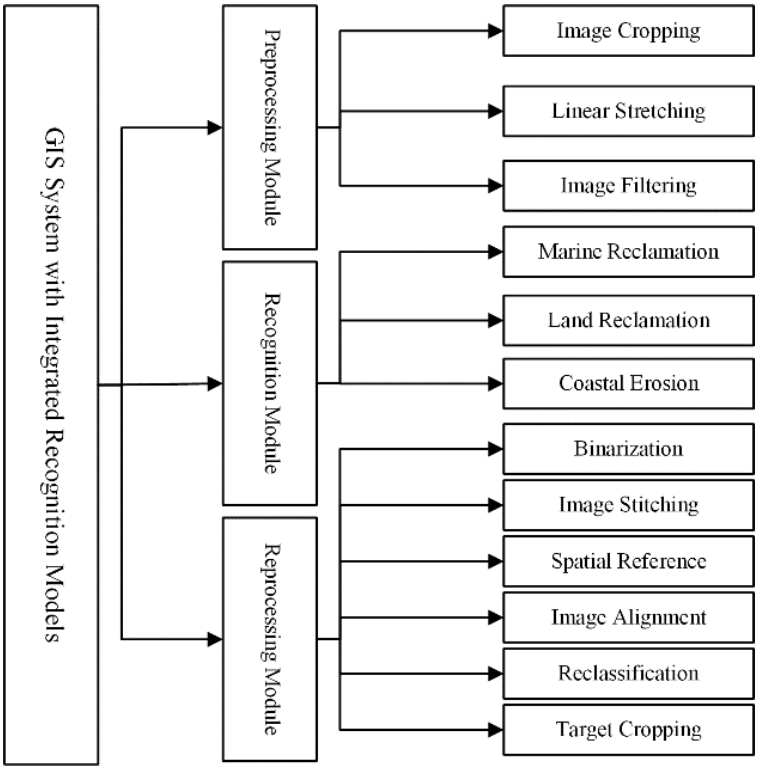

Figure 2. System functional modules

3.1. Preprocessing modules

The preprocessing module consists of three main functions: image cropping, linear stretching, and image filtering, as shown in **Figure 3**. The image cropping function, depicted in **Figure 4**, allows users to import the image to be processed into the system and select or input the required parameters. By utilizing the functionalities of GIS components, the image is segmented for subsequent data processing operations.

The linear stretching and image filtering functions involve further image processing on the cropped image from the previous step. The system integrates corresponding Python scripts, enabling users to easily perform sequential image processing steps, which prepares the image data to meet the requirements for recognition.

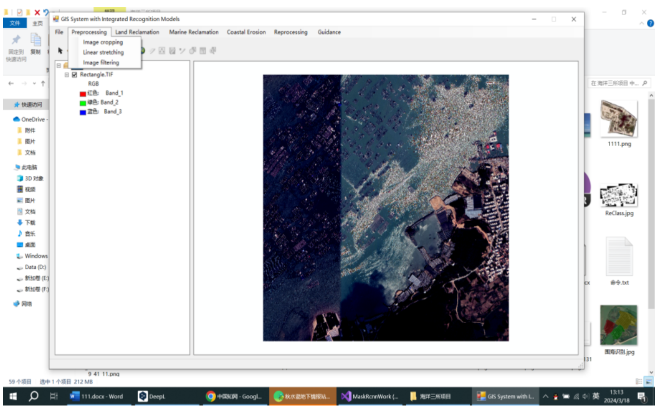

Figure 3. Main interface

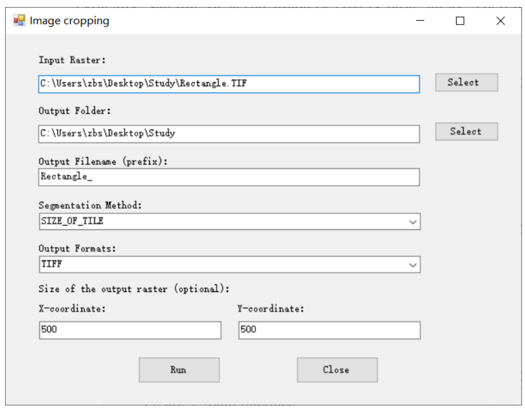

Figure 4. Image cropping

3.2. Recognition modules

The recognition module of this system, based on the aforementioned requirements, involves three parts of remote sensing recognition models: land reclamation recognition, marine reclamation recognition, and coastal erosion recognition. When selecting the corresponding recognition function, a prompt window will appear, allowing the user to choose the appropriate data folder. After the system completes the recognition process, the user can view the resulting image data from the current model, as shown in **Figure 5**. **Figures 6–8** demonstrate the comparative results of the recognition models, facilitating decision-making and analysis for management personnel.

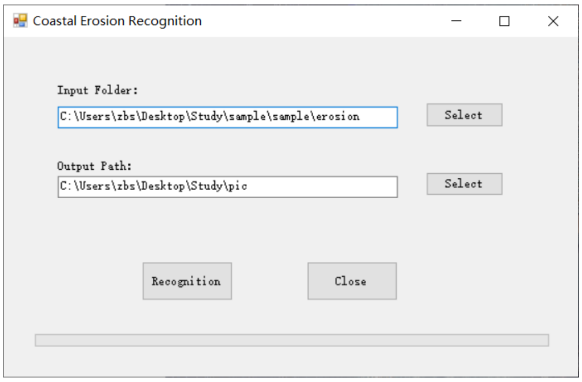

Figure 5. Recognition interface

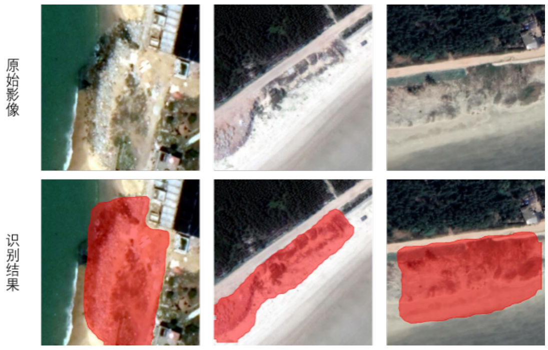

Figure 6. Coastal erosion recognition results

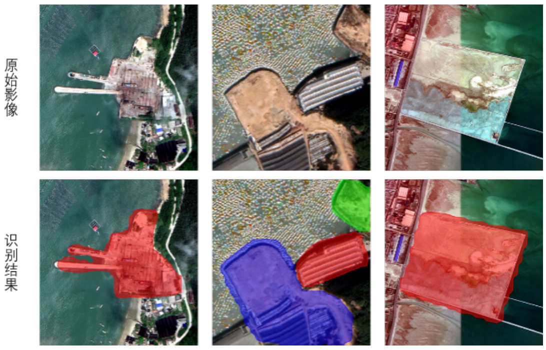

Figure 7. Marine reclamation recognition results

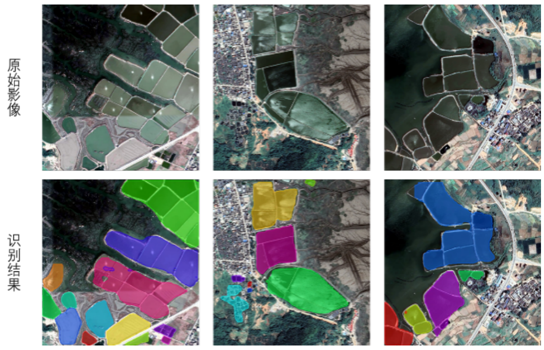

Figure 8. Land reclamation recognition results

3.3. Reprocessing modules

The reprocessing module consists of six functions: binarization, image stitching, spatial referencing, image registration, reclassification, and target cropping.

Here are the specific operations for each function module:

(1) Binarization: This function extracts binarized data from the identified targets. The operation is similar to linear stretching and image filtering in the preprocessing step. Users need to select the corresponding input and output locations and wait for the prompt in the text box to confirm completion.

(2) Image stitching: Image stitching can be performed horizontally or vertically. Depending on the actual situation, you may need to modify the backend Python script file. In general, select the desired stitching option and click "OK" to proceed.

(3) Spatial referencing: This function assigns a reference system to the stitched image. Users are required to select the stitched image data and then choose the required projection file or a shapefile with the desired spatial reference.

(4) Image registration: Image registration adjusts the position of the processed image to the correct location. This operation requires the presence of a spatial reference, depicted in **Figure 9**.

(5) Reclassification: Reclassification assigns different values to the target and background. Typically, only two classes need to be defined, as shown in **Figure 10**.

(6) Target cropping: Users are required to select the image to be cropped, import the mask data for cropping, and save it to the desired location.

The reprocessing workflow of the recognized images allows for the targeted extraction of feature images, enabling managers to selectively analyze and utilize them for subsequent management and decision-making purposes.

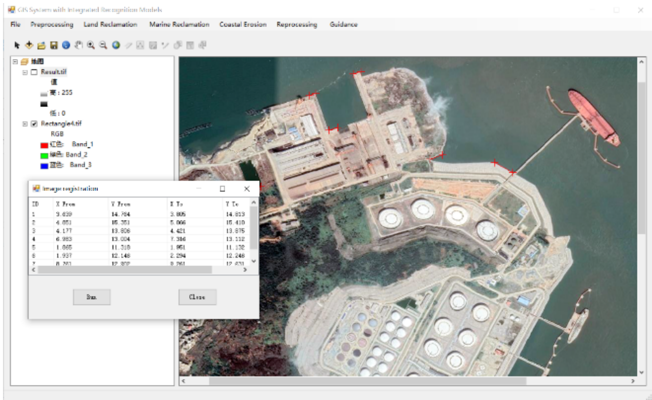

Figure 9. Image registration

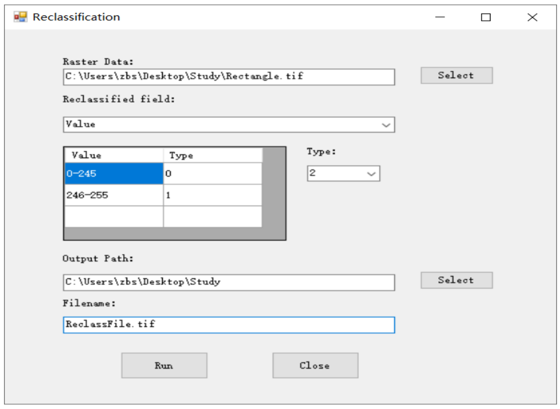

Figure 10. Reclassification

4. Conclusion

Given the numerous ecological issues in coastal areas, the extraction of coastlines and classification of coastal features have become increasingly important. The completion of this research project will greatly assist land planning departments and ecological management agencies in coordinating and planning their work in coastal regions. It will enable them to respond and plan more effectively to changes in coastlines and land cover categories.

This system is developed based on a C/S architecture using the C# development framework. It incorporates GIS tool interfaces, allowing the system to display and process map and image data. By integrating Python scripts and target recognition models, the system combines image data visualization, processing, and recognition into a single desktop application. This simplifies the operational complexity of certain technical processes and reduces the burden on operators. Ultimately, it facilitates long-term monitoring and dynamic management of coastlines by marine management authorities.

Disclosure statement

The author declares no conflict of interest.

References

[1] Yu S, Li B, 2011, A Brief Discussion on Strengthening the Scientific Management of Land Reclamation in China. Chinese Public Administration, 2011(09): 49–52.

[2] Moon J, 2024, The Impact of Coastal Erosion and Shoreline Changes on Beach Leisure Activities: Evaluating the Importance of Maritime Police in Maintaining Public Safety. Journal of Coastal Research, 116: 663–667.

[3] AlQahtany AM, Dano UL, Elhadi Abdalla EM, et al., 2022, Land Reclamation in a Coastal Metropolis of Saudi Arabia: Environmental Sustainability Implications. Water, 14(16): 2546.

[4] Song N, Wang N, Li W, 2022, Assessment of the Impact of Artificial Island Airport Reclamation on Marine Ecosystem Health: A Case Study of the Dalian Offshore Airport, China. Ocean and Coastal Management, 226: 106281.

[5] Liu Y, Liu J, Feng G, 2021, Design and Implementation of GIS Data Production System for Expressway Video and Road Infostructure. International Journal of Geosciences, 12(01): 23–38.