Improvement and Application Analysis of Lake Water Body Tracking and Recognition Algorithm

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Abstract. Basing on 30 years’ historical image data sources of Sanshan Lake between 1986 and 2017, this paper proposes a water body tracking and recognition algorithm according to the complex water area features of the lake and its branches to conduct the extraction of the historical water surface area and analysis on influence factors of Sanshan Lake. Comparing to conventional image extraction methods such as the region growing algorithm and the two-pass scanning method, this method shows its advantage of being fast and accurate. By analysing the water surface variation law of Sanshan Lake in 30 years and the influence factors, the area of Sanshan Lake is found to show a significant attenuation trend with the annual average attenuation rate reaches 0.98%; the water surface area weakly correlated with the precipitation change; the lake shore waterline retreated 0.3-10 meters in the 30 years; the pond and farmland area increased by 133%, indicating that the regulation of the lake water body is more affected by the lake shoreline dike and the Regulating capacity of gate pump.

1. Introduction

Water resources are basic natural resources and one of the controlling factors of ecological environment. At the same time, they are strategic economic natural resources and an organic part of a country's comprehensive national strength [1-2]. Lake is an important part of water resources in China. It is very important to monitor the area change in time for the sustainable development of water ecology. Lakes are natural water resources, which are closely related to human production and life. They play an irreplaceable role in maintaining the ecological balance of the river basin, satisfying the production and living water and reducing flood and drought disasters. The visible impact of climate change and human activities on lakes is area change, which can be used as an important indicator for us to monitor lakes. Extracting lake surface area in real time and accurately plays an important role in comprehensively understanding lake change law and evolution trend [3-5].

Lakes play an important role in nature and human society, so more and more researchers pay attention to them. In recent years, with the emergence and development of remote sensing technology and geographic information technology, many scholars can acquire Lake area timely and effectively with the help of remote sensing image and land use information data, and analyse the natural and man-made driving factors that lead to the change of Lake area, and put forward forward effective and feasible measures for Lake protection. There are many methods to extract water body from remote sensing image at home and abroad, such as Ding Yongjian et al.50 climate factor analysis of cold region and dry region lake change in China[6], analysis of the impact of different factors on the dry region and cold region; Hang Fei et al Spatial and temporal dynamics and driving mechanism of Lake Aibi Lake in Xinjiang from 1998 to 2013[7]; Wang Haibo's research on remote sensing based dynamic change of lake water area Research
progress in chemical monitoring, remote sensing monitoring of main water area dynamic changes in Western Jilin Province, Ma Yanmin and other studies, Zhao Guoshuai and other studies on the dynamic evolution and driving factors of sandy land along Fujian coast from 1949 to 2014, Chen Wenqian and other studies on water extraction methods based on domestic GF-1 remote sensing images, etc.[8-13], a series of studies were carried out, and different image sources and extraction methods were analyzed; Extraction methods adapted to different regions. In this paper, a water body tracking and recognition algorithm is proposed, which is improved on the basis of two-pass scanning method and regional growth method. It can extract water area more effectively and accurately.

2. Overview, Data Sources and Research Methods of the Research Area

2.1. Research Area Overview and Extraction Difficulties
Sanshan lake is located in the middle of Ezhou City, Hubei Province, about 15km away from the south of Ezhou City. It is to the east of Liangzi Lake water system, adjacent to huama Lake in the East, connected with Baoan Hu in the south, crossing Ezhou City and Daye City. At the end of 1955, it was transferred to Ezhou City by Daye county. Sanshan Lake belongs to a submerged depression lagoon lake. The lake water relies on surface runoff and lake precipitation recharge. In flood season, Liangzi Lake and Baoan Lake are injected into the lake, and the outflow is discharged into the Yangtze River through Changgang at Fankou Gate or Xuejiagou Gate.Since the 1950s and 1960s, Sanshan Lake began to develop a large number of reclamation and fencing culture. In recent years, with the rise of Sanshan Lake Resort and the increasing scale of fence culture, the water ecology of Sanshan lake has been greatly damaged, so it is urgent to strengthen the environmental protection and ecological construction of the lake.

Sanshan lake is a drowning depression stagnant lake with shallow water depth and numerous bay branches. Moreover, the waters of Sanshan lake are not connected and composed of three parts. There are paddy fields and aquaculture areas around the lake. There are many noise interferences in the water extraction of remote sensing image. How to eliminate the noise interferences and accurately extract the area is of great significance to analyze the area changes reasonably and correctly.

2.2. Data Sources
In this study, Google Earth historical image of 1986-2017 is used to extract the area of Sanshan Lakes in each year, and the historical interannual area of Sanshan lake is obtained. The historical image of Google Earth used in this paper is a satellite image downloaded by U shield in the WGS-84 geographic coordinate system of BIGMAP downloader, which is converted into UTM-WGS84 projection coordinate system with a resolution of 17.61 meters.

Google Earth's satellite image is not a single data source, but the integration of satellite image and aerial data. Its satellite images are mainly from QuickBird (Fast Bird) commercial satellite of Digital Globe and EarthSat (mostly from Landsat-7 satellite), BlueSky (mainly from aerial photography and GIS/GPS related business), Sanborn (mainly from GIS geographic data and aerial survey) and IKONOS (USA). And French SPOT5, etc.

2.3. Research Methods
For the special landform of Sanshan lake, the conventional ENVI and ERDAS commercial remote sensing inversion software can not meet the requirements of high-precision water extraction, and it is also inconvenient to carry out the comprehensive analysis and data mining of historical multi-stage remote sensing image results. Therefore, in view of the above difficulties, this paper uses a remote sensing image water tracking recognition algorithm, which can accurately track various shapes of lakes. Compared with the two-step scanning method and the regional growth method, this method takes less time and has low scanning repetition rate.

2.3.1. Water Body Tracking and Recognition Algorithm. Region growing method is an algorithm that connects pixels with similar properties to get a simply connected region. For lakes with partition, it can't extract all of them. Another commonly used method of region extraction is two pass. This method is to
scan the image twice, find all the connected regions in the image and give a unique identification to each connected region found, so as to distinguish other regions. This method is to extract all regions in the image without difference, unable to classify, and to extract large-scale image. For example, scanning the image twice will take a long time [14-15].

In the tracking recognition algorithm based on region growth and twice scanning, this paper uses the algorithm to start scanning from the upper left corner of the image. If a point (Xi, Yi) is scanned, the spectral information (R0, G0, B0) of a point is used to determine whether the point belongs to water body. Scan to meet the requirements of pixel points as seed points, adopt 4-neighborhood method to track the pixels around the seed points, and mark the area, label from 2. The algorithm selects the spectral information of the image as the feature to classify the water body and non water body:

\[
F(X_i, Y_i) = \begin{cases} 
T_{R1} < R_0 < T_{R1} \\
T_{G1} < R_0 < T_{G1} \\
T_{B1} < R_0 < T_{B1} 
\end{cases}
\] (1)

The algorithm adopts the double threshold method, \(T_{R1}, T_{R2}\) is represents the two thresholds of r-channel binarization, \(T_{G1}, T_{G2}\) is g-channel binarization and \(T_{B1}, T_{B2}\) is B-channel binarization. When f is true, it represents the seed point. Then judge four points \(F(X_{i-1}, Y_i), F(X, Y_{i-1}), F(X_{i+1}, Y_i), F(X_{i-1}, Y_{i-1})\), in turn. After judging the neighborhood of the seed point, the connectivity of the point and its four neighborhoods is determined. Connectivity means that the pixel value of the seed point is equal to that of the surrounding point, which means that the seed point is connected with the point. If:

\[
F(X_i, Y_i) \cap F(X_{i-1}, Y_i) = \{1\}
\] (2)

The seed point is connected with the pixel point of the previous row.

\[
F(X_i, Y_i) \cap F(X, Y_{i-1}) = \emptyset
\] (3)

The seed point is not connected with the pixel points in the previous column. Put all the pixel points connected with the seed point into the stack, and then take out the pixel points in the stack as the seed points to track the whole area. Until all the points in the stack are taken out, the area is considered to be tracked, then track down. When another pixel meets the requirements of seed point, mark it as "lable + 1", which will distinguish it from other areas until the whole image is tracked.

This method avoids the loss of unconnected water area and the interference of surrounding noise, with short duration and high accuracy.

![Regional growth algorithm](image1.png)
![Two pass scanning](image2.png)
![Water Tracking Recognition Algorithms](image3.png)

**Figure 1.** Experimental results.
Table 1. Image area of Sanshan Lake in 2010.

| Algorithm                              | Extracted area (km²) | Error rate (%) |
|----------------------------------------|----------------------|----------------|
| Measured area                          | 18.47                |                |
| Regional growth algorithm              | 15.62                | 15.43          |
| Two pass scanning Water tracking       | 37.95                | 105.43         |
| recognition algorithms                 | 18.33                | 0.75           |

3. Analysis on the Trend of Lake Area Change and Its Influencing Factors

3.1. Change of Lake Area
Using the area extracted by the water body tracking and recognition algorithm, the dynamic map of the water surface in each period is obtained. It can be seen that the average water surface area of Sanshan lake is 19.96km² for many years. The minimum appeared in 2013, reaching 15.3km²; the maximum appeared in 1987, the area reached 24.2 km², and the maximum to minimum range was 1.58.

![Figure 2. The change trend of lake area in Sanshan Lake during the year.](image)

3.2. Impact Factor Analysis
Ezhou City belongs to subtropical monsoon climate, showing the characteristics of rainy in early summer and dry in autumn. Combining the natural and human aspects of Ezhou City, the analysis of the change of the area of Sanshan Lake

3.2.1. Natural Factors
(1) Rainfall
Rainfall is one of the important water supplement sources of the lake, which has a certain impact on the lake area [16]. Combined with Ezhou City rainfall station, the annual rainfall data of Sanshan Lake area is obtained. The study shows the relationship between the area of Sanshan Lake and rainfall, as shown in Figures 3 and Figures 4. It can be seen from Fig. 3 that the area of Sanshan Lake shows a significant attenuation trend, and the rainfall changes in a wavy manner; table 2 shows that the relationship between the lake area of the high flow year and the low flow year is weak, indicating that the relationship between rainfall and lake area is minimal.
Table 2. Rainfall and area in high flow and low flow year years.

|                | high flow | low flow |
|----------------|-----------|----------|
|                | Rainfall  | Area     | Rainfall  | Area     |
|                | (mm)      | (km²)    | (mm)      | (km²)    |
| 2010 year      | 1692.5    | 18.33    | 2008 year | 844.1    | 19.98    |
| 2002 year      | 1673.4    | 19.67    | 1992 year | 1006.3   | 22.58    |
| 1996 year      | 1601.2    | 20       | 2005 year | 1009     | 19.69    |

According to the correlation coefficient \( r = |0.2229| < 0.5 \) in Figure 4, it can be seen that rainfall is not the main influencing factor for the change of Sanshan Lake area. Rainfall is an important source of water supply for lakes. Although it is not the main influencing factor, its role cannot be ignored. According to the remote sensing image, the farmland around Sanshan Lake increased by 5.72 km² in 2017 compared with that in 1986. Again, it shows that the impact of rainfall on the lake area is far less than the interference of non-natural factors such as human reclaiming the lake for farmland.

3.2.2. Anthropogenic Factors

(1) Fence farming

Ezhou City, the hometown of bronze mirrors, is a famous historical and cultural city in Hubei Province, which is called the hometown of bronze mirrors and the origin of the famous “Wuchang Fish” in China and abroad. It is known as the “city of Baihu” and “hometown of fish and rice”. With the popularity of Wuchang fish, fish farming around the lake has developed rapidly results in more and more stocking pond was established around the lake. Fence breeding in Sanshan Lake, a large number of lakes have become fenced farming areas. The large increase in artificial ponds not only makes the ecological pollution of Sanshan Lake [17] serious, but also worsens the water quality, which is an important human factor for the reduction of the lake area of Sanshan Lake.

(2) Landfill tidal flat

Since the beginning of the 21st century, the Sanshan Lake has set off a tourist resort in order that broaden the villagers' wealth. With its beautiful natural scenery, Sanshan Lake has attracted many tourists, which of tourist resort has ushered in a development boom; The real estate industry has also emerged; Such as the housing construction and Scenic building around lake from landfill tidal flat is one of the factors of lake area reduction, which purpose is to increase the usable land area and obtain more benefits.

(3) Reclaim land from a lake

Beginning in the 1950s and 1960s, experienced the beginning of China's reform and opening up, it required the rapid development of the economy. Wrap the lake to create a field caused the Sanshan Lake area shrinks sharply, but this was also the fate of most lakes at that time. Wrap the lake to create a pond, which is the main contradictions. There are artificial ponds on both sides of the lake bank and continue to develop into the lake center. Fill in some sub-lakes and lakes to develop tourism and real estate. Among them, Yishan Lake sub-lake with a surface area of several thousand acres in Sanshan Lake, which has been reclaimed for half and even the Sanshan Village Committee once proposed to reclaim all the Yishan Lake and build a pool in order to solve the problem that villagers' production and employment.
Table 3. The area comparison of farmland, pool, water and beach.

|                  | average from 1986 to 1890 (km²) | Average from 2013 to 2017 (km²) | Rate of change |
|------------------|----------------------------------|---------------------------------|----------------|
| farmland         | 24.45                            | 30.17                           | 23.39%         |
| pond             | 0.2                              | 2.5                             | 1150%          |
| territorial waters | 23.05                           | 17.85                           | -22.56%        |
| Tidal flat       | 5.93                             | 3.46                            | -41.65         |

According to Table 3, the area of farmland and ponds increased by 8.02 km² in the 30 years from 1986 to 2017, and the water area and tidal flats decreased by 7.67 km². The area of water reduction mainly turned to the area of farmland and ponds. The area increase of farmland and ponds was slightly larger than the area reduction of water area and the tidal flats, because some of the woodland and grassland became farmland.

It can be concluded that the main causes for the decrease of the historical area of the water body of Sanshan Lake are the lake-reclaim for land, fence breeding and tidal flats landfill. However, the phenomenon of lake-reclaim for land was meant to promote the economic development in the early stage of the reform and opening-up. In modern times, the principal contradiction on Sanshan Lake was fence breeding, and the solution of this problem will greatly improve the lake area of Sanshan Lake.

4. Conclusion
The study applies Google-earth historical imagery to extract the area of Sanshan Lake from 1986 to 2017 according to the difficulty in extracting the Sanshan Lake water body by means of the water body tracking and recognition algorithm, which is more time-saving and accurate than the region growing algorithm and the two-pass scanning method. The lake area of Sanshan Lake is found in the analysis to be in a state of fluctuation, but the overall trend tends to decrease.

In this paper, the main influence factors of nature and human activities are discussed and analyzed. By comparing the rainfall data with the interannual area of the lake, the fluctuation of rainfall is found to have little effect on the lake area. The conclusion from the analysis of the change curve of the lake area is that: before 2000, the large scale of lake-reclaim for land and landfill tidal flats during the development and rising period of the reform and opening up caused a sharp reduction of the lake area; in around 2000, the lake area rebounded mainly due to returning-land-to-lake policy; after 2000, the aquaculture industry developed rapidly and the construction of dense artificial ponds around the lakes drastically reduced the lake area; in recent years, the development of tourist resorts and real estate industries has a soaring demand for land, causing some water bodies and tidal flats to be landfilled. The above is mainly the interference of human factors on the lake area, which is mainly analyzed from fence breeding and lake-reclaim for land.

The research indicates that the human factors mainly affect the area change of Sanshan Lake. During the period between 1986 and 2017, the area of Sanshan Lake reduced by 5.2 km², and the lake waterline retreated by 0.3-10m. Lake is an important storage node of water resources system and an important part of ecological civilization construction. The method of high-precision extraction of lake water by historical remote sensing image is of great significance for quantifying lake evolution and ecological restoration.

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