Remote Sensing Identification Of Black And Odorous Water Based On ID3 Decision Tree: Taking Langfang As An Example

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ABSTRACT: The monitoring of black and odorous water bodies (BOW) is an important issue in of urban regional water environment management. Satellite remote sensing can provide rapid, synoptic, and repeated information, Therefore, remote sensing identification of urban water bodies is a hot issue in the field of environmental monitoring. Remote sensing technology have become a crucial important technical means for monitoring black and odorous water (BOW) due to its low cost, large range, long time, and high efficiency. At present, researchers mainly concentrate on the spectral characteristics of BOW, and have established several spectral indices to distinguish BOW from ordinary water using threshold segmentation methods. However, the current methods mostly use single-feature to detect BOW, meanwhile, the threshold is often determined by an empirical approach. All that would limit the precision of the result. In this paper, most scholars at home and abroad realize the remote sensing recognition of black and smelly water bodies through the statistics and observation of samples, determining the experience threshold and using shallow models such as gray-scale segmentation. This method is subjective. We propose a novel method to detect BOW based on the CARTID3 decision tree algorithm., A total of 93 samples were collected from pond waters in 2018, in Lang fang, China. Based on the laboratory analysis result and the criterion of BOW, the samples were divided into BOW and ordinary water. Combining with the spectral information from Sentinel-2A images, we use a multi-features approach to establish the ID3 decision tree, and fuzzy membership degree were calculated to determine the classification results. This paper proposes an improved remote sensing recognition method for black and odorous water bodies, and conducts experiments in Lang fang City, Hebei Province. Taking urban pit pond water as the research object, 93 water quality samples were collected systematically in the research area from 2018 to 2019. Combine the sentinel 2A image data to construct data samples, use multi-features to train ID3 decision tree and realize the classification of black and odorous water bodies. The results show that: (1) The spectral characteristics between BOW and ordinary water are significantly different in visible and near-infrared bands. The reflectance difference between green and blue bands, red and green bands, and the near-infrared reflectance can be used as spectral features to distinguish BOW form ordinary water. (2) The Lang fang dataset shows that it is difficult to identify BOW by means of single feature. For the spectral features widely proposed, such as BOI, WCI and NDBWI, there is a fuzzy interval where BOW and ordinary water have similar values, therefore the threshold is hard to determine and the classification accuracy is limited. (3) Compared with single-feature methods, ID3 decision tree can provide a solid methods to establish a multi-featured classifier and has a better classification accuracy, in this study, the result from ID3 performs better than other methods and the classification accuracy is 77.41%.

1 Introduction

Black and smelly water (Ministry of Housing and Urban-Rural Development of the People's Republic of China and Ministry of Environmental Protection of the People's Republic of China, 2015) is an extreme manifestation of serious organic pollution in a water body, that is, "presenting an unpleasant color or emitting an unpleasant smell". Because human production and living activities discharge a large amount of exogenous organic matter and animal and plant humus into natural water bodies, a large amount of dissolved oxygen in the water is consumed under the action of microorganisms, and the organic matter is decomposed to produce hydrogen sulfide, ammonia nitrogen and other volatile odors with obvious peculiar smell At the same time, metal elements such as iron and manganese are reduced to form black substances such as sulfides. In this process, as hydrogen sulfide, ammonia nitrogen and other gases volatilize and escape, they carry iron, manganese sulfide and underwater sludge into the water phase, which will eventually cause the water body to turn black and smelly. In recent years, with the rapid economic and social development, many cities in my country have experienced serious black and odorous water problems (Angel Hsu et al., 2020), leading to deterioration of water quality, and some urban rivers and lakes even losing water functions, which seriously threaten the urban ecology Environment and residents' health and safety. In 2015, the State Council issued the "Ten Water Regulations", which included the monitoring and management of black and odorous water bodies (Zhou Hongchun, 2017) as one of the important tasks of water pollution prevention and control. It clearly required that "the number of black and odorous water bodies in built-up areas in cities above the prefecture level should be equal to Control within 10%; by 2030, the black and odorous water bodies in urban built-up areas across the country will be eliminated. In the same year, in order to implement the "Ten Water Regulations", the Ministry of Housing and Urban-Rural Development jointly issued the "Urban Black Waters" (Urban Planning Communications, 2015). The "Guidelines for the Remediation of Smelly Water Bodies" (hereinafter referred to as the "Guidelines") clarify some technical issues in the monitoring and treatment of black and odorous water bodies. Black and odorous water bodies have gradually become a hot issue in the field of environmental monitoring and treatment in recent years.

Satellite remote sensing technology has the characteristics of macro, continuous and large-scale monitoring. Based on the spectral difference between black and smelly water bodies and general water bodies in remote sensing images, it can better realize the information extraction of black and smelly water bodies, which greatly improves the screening of black and smelly water bodies. Efficiency provides a new effective means for the identification and monitoring of urban black and odorous water bodies. In 2016, the Institute of Remote Sensing and Digital Earth of the Chinese Academy of Sciences cooperated with the Satellite Environment Application Center of the Ministry of Environmental Protection to implement remote sensing screening and verification of black and odorous water bodies in Beijing, Shenyang, Taiyuan and other cities, and related work was selected as one of the top ten events in the field of remote sensing in China.

At present, domestic scholars mostly use shallow models such as threshold segmentation for remote sensing recognition of black and smelly water bodies, which mainly include (1) single feature threshold segmentation and (2) construction of decision trees based on multiple features. Among them, the former is mainly based on the spectral difference between black and odorous water bodies and general water bodies. Through statistical analysis of actual samples, a certain spectral characteristic index is proposed and combined with empirical thresholds for classification. For example, Wen Shuang et al. compared methods such as single band and band difference, and constructed a band ratio method (Wen Shuang et al., 2018) to extract black and smelly water; Li Jiaqi et al. constructed WCI (Li Jiaqi et al., 2019) and combined several remote sensing methods. The image interpretation mark distinguishes two types of water bodies; Li uses the Nemerow comprehensive pollution index (Li et al., 2019) to characterize the pollution degree of urban water bodies, and compares the retrieval results of six regression models to find one suitable for retrieval in the current scene NCPI regression model is used to detect black and smelly water; Yao Yue and others carried out experimental verification in Shenyang, improved the band ratio method, and constructed the BOI algorithm (Yao Yue et al., 2019); Yao Huanmei and others based on PlanetScope images (Yao Huanmei Et al., 2019) proposed a HI index threshold segmentation method; Zhang Xue et al. proposed an improved index threshold method HCI based on HI (Zhang Xue et al., 2019); Qian Kaixuan et al. used the Gini index (Qian Kaixuan et al., 2019) to construct A fuzzy evaluation model of water quality is developed. Most of the above methods use spectral analysis or comprehensive comparison to use individual features to perform threshold segmentation. Unlike the above methods, Li Lingling et al. proposed a classification method based on multi-feature construction decision trees (Li Lingling et al., 2020). The water color and optical characteristics of the water body use the characteristics of DBWI, GR-NIR AWI, NDBWI and green band to set reasonable thresholds to realize the identification and grading evaluation of black and odorous water bodies.

The research on remote sensing recognition of black and odorous water bodies started late and is still in the stage of exploration and application. Although the above studies have achieved high recognition accuracy in some areas, most of them are shallow models based on empirical thresholds. , There is uncertainty in subjective factors when selecting features and determining thresholds, and the results are prone to controversy and poor universality. In addition, due to the complicated causes of black and odorous water bodies, especially some mild black and odorous water bodies are difficult to distinguish well from general water bodies, some of the above-mentioned single-feature threshold segmentation methods also have certain defects in dealing with this problem. In response to the above problems, this article carried out research and application in Langfang City, Hebei Province based on previous studies, and proposed a remote sensing recognition method for black and odorous water based on ID3 decision tree theory, which implements features based on the information entropy maximization criterion and bipartite recursive segmentation. The attributes and thresholds are determined, and differentiated processing is carried out to improve the accuracy and the application efficiency of the results, in order to optimize and improve the traditional technology system.

2 Study area and data selection

2.1 Research area and sampling point distribution

Langfang City, Hebei Province is located between 38°28′ to 40°15′ north latitude and 116°7′ to 117°14′ east longitude in the eastern part of the North China Plain. It is adjacent to Beijing and Tianjin and is known as the "Pearl on the Beijing-Tianjin Corridor". There are 11 counties (cities, districts) under the jurisdiction of Langfang City, which belong to the Haihe River Basin. According to the statistics of the Langfang City Ecological Environment Bureau, there are Xianghe River, North Canal, Chaobai River, Qinglongwan Jianhe River, Yongding River, Baigou River, and Datong River. In major rivers such as Qinghe and Ziyahe, there are nearly 6000 pits and ponds scattered in urban and rural areas. In recent years, due to the acceleration of urbanization and rapid economic development, the water pollution of pit ponds in Langfang City is relatively serious, and black and odorous water pollution incidents occur frequently in the region, such as the sewage seepage pit incident in Dacheng County, Langfang City in 2016, and Shengfang in 2016 The Zhongting River turned into the Red River incident, the red pit pond in Xiaojiabao Village, Bazhou in 2019, and so on. This article takes the pond water in Langfang City as the research object.

During 2018-2019, a comprehensive survey of rivers in Langfang City, Hebei Province was carried out. A total of 93 sampling points were set up in many rivers including Zhongting River, Yongjin Canal, Fenghe River, Yunchaojian River, etc. Among the 93 water quality sample points, 55 sample points belong to general water bodies, and 38 sample points are black and smelly water bodies. Measure the water surface spectrum and some water quality parameters at each sampling point, and collect water samples and send them back to the laboratory to analyze some water quality parameters.

2.2 Data preprocessing

2.2.1 Water chemical test data

The indicators analyzed for water quality samples include transparency (SD), dissolved oxygen (DO), oxidation-reduction potential (ORP) and ammonia nitrogen (NH3), among which transparency (SD), dissolved oxygen (DO), and oxidation-reduction potential (ORP) are measured on site Obtained, ammonia nitrogen (NH3) sent to the laboratory for testing and analysis, testing and analysis refer to the "Guide". According to the standards stipulated in the "Guide", all water samples are divided into black and odorous water bodies and general water bodies, which vary from transparency/cm, dissolved oxygen/(mg/L), redox potential/mV and ammonia nitrogen/(mg/L) Four aspects are used for judgment, and the specific judgment conditions are shown in Table 1. When one of the indicators in Table 1 is met, it is judged as black and odorous water. This guide divides the black and odorous water bodies into mild black and odorous water bodies and severe black and odorous water bodies. This article does not make detailed black and odor water bodies. This article only focuses on the distinction between black and odorous water bodies and general water bodies. Together with severe black and odorous water, it is defined as black and odorous water as the research object.

Table 1 Classification basis for urban black and odorous water bodies

Characteristic index	black and odorous water
SD cm	0~25
DO mg/L	0~2
ORP mV	0~50
NH_3 mg/L	≥8

2.2.2 Sentinel image data and preprocessing

The Sentinel-2 satellite is the second satellite in the "Copernicus Project", a global environmental and safety monitoring system jointly initiated by the European Commission and the European Space Agency. It includes two multispectral satellites 2A and 2B. The return visit period is 5 The Sentinel-2A and Sentinel-2B satellites were launched on June 23, 2015 and March 7, 2017 respectively. Sentinel-2 images are multi-spectral images with high time and high spatial resolution. They can be used for land monitoring. They can provide images of vegetation, soil and water coverage, inland waterways and coastal areas, and can also be used for emergency rescue services. Especially the application of water resources distribution mapping has received wide attention. The spatial resolution of the Sentinel-2 satellite is 10 m, 20 m and 60 m. Since most of the ponds in Langfang City have an area of more than 3000m2, the use of a resolution of 10m basically meets the data requirements for black and smelly water information extraction. The captured image is the Sentinel No. 2 image of Langfang City from 2018 to 2019. Sentinel-2A atmospheric correction was completed by Sentinel series data belt software Snap, Sen2cor and Anaconda integration software. Use Python language to realize Snap, Sen2cor, Anaconda software integration.

3 Spectral characteristic analysis

From 2018 to 2019, a comprehensive survey was carried out on the rivers in Langfang City, Hebei Province, and the spectral information of sample points was extracted, and the spectral characteristics of general water bodies and black and odorous water bodies were analyzed as shown in Figure 1. From the blue band (b1), Green band (b2), red band (b3) and near-infrared band (b4) can be seen that the general water body has large fluctuations in the remote sensing reflectance spectrum in the visible light range, while the remote sensing reflectance of black and odorous water tends to change in the visible light range. Gentle characteristics; while in the near-infrared band, the reflectivity of near-infrared remote sensing in general water has little change, mainly concentrated in a small part; but for black and odorous water, there will be obvious fluctuations in the remote sensing reflectivity in the near-infrared band , Near-infrared remote sensing reflectance difference will be very large, there are a large number of peaks and minimums.

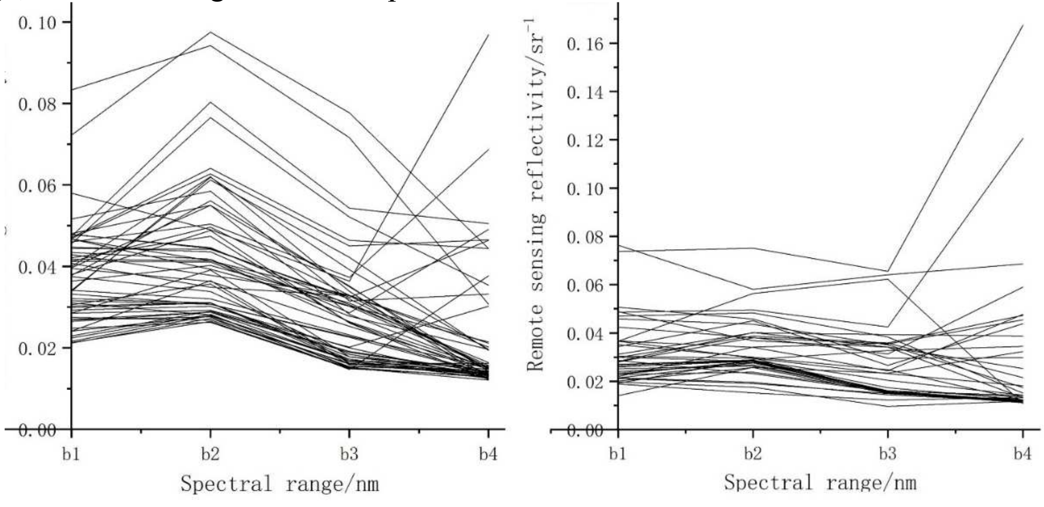

Figure 1 Comparison of spectral reflectance between black and smelly water bodies and general water bodies

In the visible light range, b2-b1 and b3-b2 are selected as the spectral features for classification. From Figures 3 and 4, it can be seen that the three spectral features selected in the visible light range can distinguish the two types of water bodies. For the near-infrared band, near-infrared spectroscopy can well characterize the chemical characteristics of organic pollutants such as total nitrogen and total phosphorus in water bodies (Zhang Chengbiao, 2009), and it is also fast and efficient (Liu Hongxin et al., 2008). Infrared spectroscopy is widely used by domestic and foreign scholars (He Jincheng et al. 2007) in the identification and detection of organic pollutants in water bodies (Xu Liheng et al., 2008). For general water bodies, the remote sensing reflectance in the near-infrared light band tends to Yu Ping, the reflectivity of near-infrared remote sensing has little change, mainly concentrated in a small part; but for black and odorous water bodies, there will be obvious fluctuations in the remote sensing reflectivity in the near-infrared light band. The rate difference will be very large, with a large number of peaks and minimums, which is consistent with the spectral characteristics of the remote sensing reflectance of the black and odorous water body measured by us, as shown in Figure 5. In general, the near-infrared remote sensing reflectivity of water bodies is mainly concentrated between D1 and D2. For black and odorous water bodies, the ammonia nitrogen content is unstable and there will be an obvious extreme phenomenon. It can be seen from Figure 5 that it is above D1 and D2. The bottom is all black and odorous water bodies with obvious extreme values. Therefore, the near-infrared spectral remote sensing reflectance is selected as the classification feature of the near-infrared part.

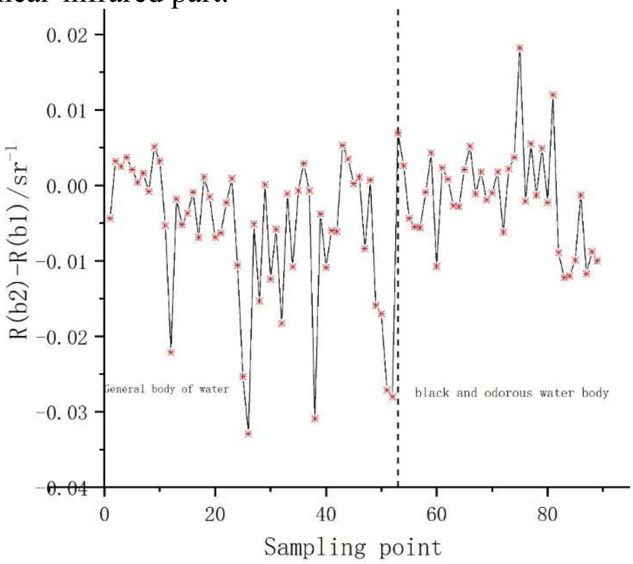

Figure 3 The difference in remote sensing reflectivity between the green band and the blue band

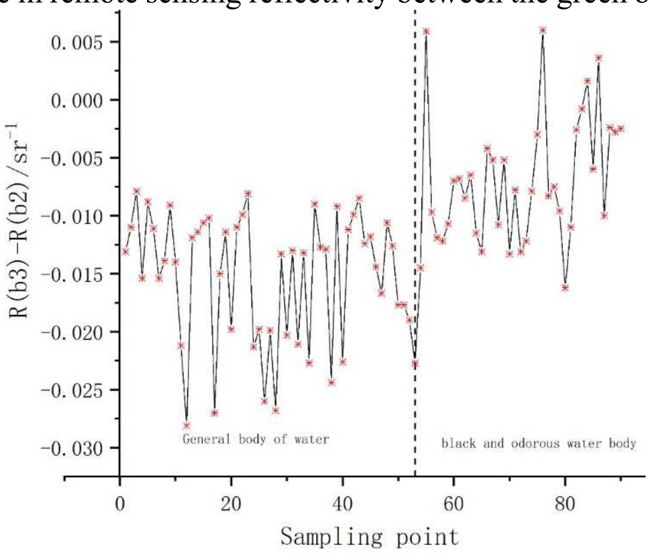

Figure 4 The remote sensing reflectance difference between the red band and the green Band

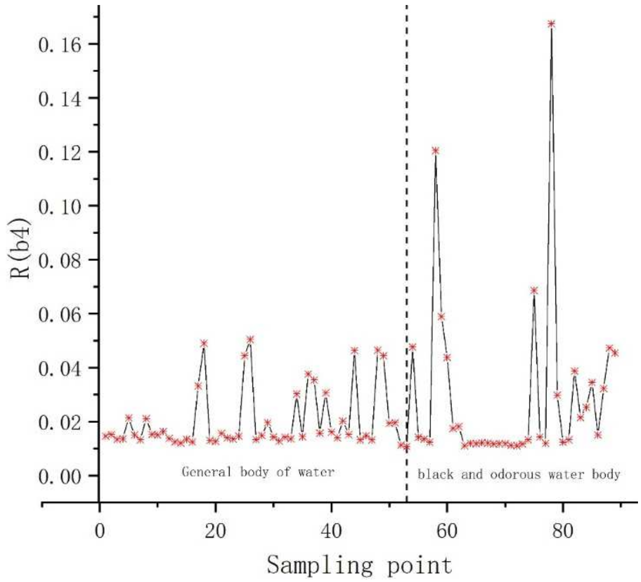

Figure 6 Remote sensing reflectivity in the near-infrared light band

After the above analysis, four spectral features of b2-b1, b3-b2 and b4 are selected as the classification features of the ID3 decision tree, which can achieve a good classification result.

4 ID3 algorithm black and smelly water body remote sensing recognition algorithm

4.1 ID3 decision tree and ID3 algorithm

Decision tree is a widely used classification method, it is a kind of supervised learning, is a graphical method that directly uses probability analysis. Since this kind of decision branch is drawn into a graph like the branches of a tree, it becomes a decision tree. In a decision tree, each internal node represents a test on an attribute, each branch represents a test output, and each leaf node represents a result or category.

The ID3 algorithm circumvents the empirical threshold and uses a more objective multi-feature comparison to select the optimal dividing point to generate new nodes, until the generated ID3 decision tree is all leaf nodes to form a completed ID3 decision tree as shown in Figure 6. . The optimal division point is mainly based on the maximum information gain of each feature as a judgment, which reduces the subjective judgment of people and makes the classification more accurate and objective.

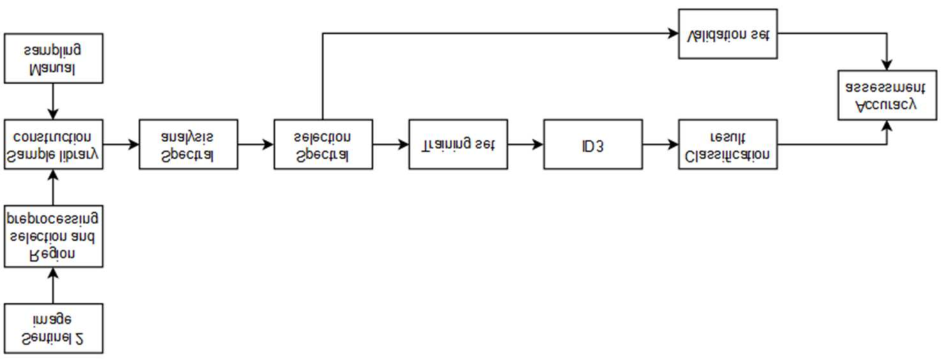

Figure 6 ID3 algorithm construction process

The ID3 algorithm adopted this time uses the principle of information entropy to select the attribute with the largest information gain as the classification attribute, recursively expand the branches of the decision tree, and complete the construction of the decision tree. The specific definition is as follows: Entropy represents a measure of the uncertainty of random variables, that is, the greater the entropy, the greater the uncertainty of the variable. Suppose is a discrete random variable of finite value, and its probability distribution is(1), Then the entropy of the random variable x is defined as(2)

$$P(X = xi) = pi, i = 1,2,\dots,n \ , \qquad (1)$$

$$H(X) = -\sum_{i=1}^{n} pi \log_2 pi(若pi = 0,定义0\log_2 0 = 0) \qquad (2)$$

Conditional entropy H(Y|X) represents the uncertainty of random variable Y under the condition of known random variable X. The conditional entropy of random variable Y given by random variable X is(3), Information gain, the information gain g(D,A) of feature A to training data set D, defined as the empirical entropy H(D) of set D and the empirical conditional entropy H(D|A) of D under the given conditions of feature A Bad(4).

$$H(Y|X) = \sum_{i=1}^{n} piH(Y|X = xi), \quad pi = P(X = xi) \qquad (3)$$

$$g(D,A) = H(D) - H(D|A) \qquad (4)$$

Since over-fitting may occur during the decision tree training process, it is necessary to suppress over-fitting by pruning. This article uses the pruning method. The pruning object is a group of leaf nodes with the same parent node, and whether to perform pruning is determined by the increase in entropy after merging (Thomas G Dietterich, 2020). Finally, use the pruned ID3 decision tree for classification.

4.2 ID3 decision tree establishment

Since the data this time is a discrete data set, there is no need to discretize the data. All feature calculation results are normalized, and each data is expanded by 10,000 times to facilitate observation and analysis. Through the random sampling method, 31 sampling points are selected as the training set, and the rest are the test set. According to the method described above, the ID3 decision tree is constructed as shown in Figure 7. In the result, 0 represents black and odorous water body, and 1 represents general water body.

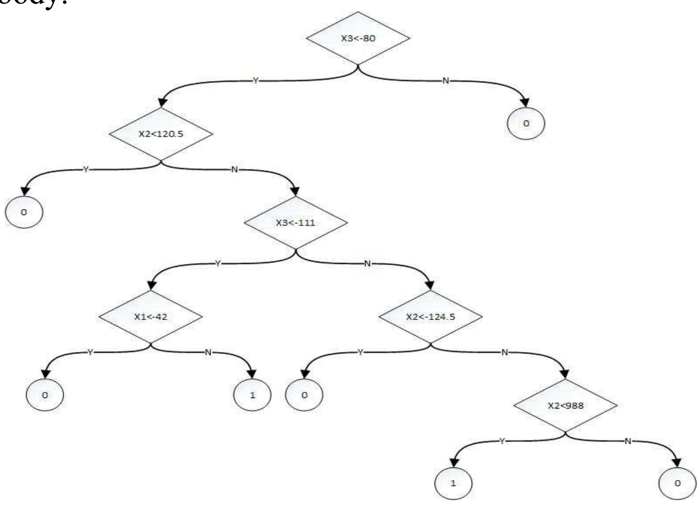

Figure 7 ID3 decision tree

5 accuracy verification

Use the test set to analyze the accuracy of the algorithm, and the calculation formula is as follows:

$$Accuracy = \frac{M}{N} \times 100\% \qquad (4)$$

In the formula, N represents the total number of samples, and M represents the number of samples that are judged correctly. Based on the categories determined by the ID3 algorithm used in the previous article, classify the water bodies in the satellite image, classify the water bodies of the pit ponds in Langfang City extracted in the previous article, and select the center pixel of each pit pond water body to represent the pit pond. 31 data points of the validation set were used to validate the classification results. In the case of a total of 31 verification points, 24 points were judged accurately and their accuracy was calculated. The accuracy of the calculation reached 77.41%, indicating that the method can more accurately extract the black and smelly water in the experimental area.

Table 2 Validation set results

number	actual	verification	result	number	actual	verification	result
Y1	Black	Black	Ture	Y17	general	general	Ture
Y2	Black	Black	Ture	Y18	Black	general	False
Y3	general	Black	False	Y19	Black	general	False
Y4	Black	Black	Ture	Y20	Black	general	False
Y5	Black	Black	Ture	Y21	general	general	Ture
Y6	Black	Black	Ture	Y22	general	general	Ture
Y7	Black	Black	Ture	Y23	general	general	Ture
Y8	Black	Black	Ture	Y24	general	general	Ture
Y9	general	Black	False	Y25	general	general	Ture
Y10	Black	Black	Ture	Y26	general	general	Ture
Y11	general	Black	False	Y27	general	general	Ture
Y12	Black	Black	Ture	Y28	Black	general	False
Y13	Black	Black	Ture	Y29	general	general	Ture
Y14	Black	Black	Ture	Y30	general	general	Ture
Y15	Black	Black	Ture	Y31	general	general	Ture
Y16	general	general	Ture				

Specifically, the accuracy is 77.41%. This is mainly because the spectral characteristics of some black and odorous water bodies are consistent with those of general water bodies, which is difficult to distinguish. Compared with the results of previous studies, the band ratio method, WCI, BOI, DT and other indicators were used to determine the threshold based on the statistical results of the training set, and the threshold segmentation method was used for classification. The results show (Table 5) that the ID3 decision tree used in this article has the highest accuracy, followed by the decision tree model proposed by Li Lingling and others, and finally the single feature threshold segmentation method.

Table3 Accuracy comparison table

method	accuracy	references
BR	63.44%	(Wen S , 2018)
BOI	73.12%	(Yao Y , 2019)
WCI	72.04%	(Li J Q , 2019)
ID3	77.41%	

6 Conclusion

According to the research on the remote sensing image ID3 model identification of the black and smelly water body and general water body in Langfang City, the following conclusions are obtained:

(1) From the comparison of spectra, it can be seen that black and odorous water bodies can be classified in the spectrum; however, there will be some data with similar spectral characteristics of general water bodies and black and odorous water bodies, which cannot be distinguished by using a single feature, and they are often used. Features can significantly improve the extraction accuracy.

(2) The remote sensing reflectivity of urban black and odorous water bodies in the multi-spectral range of green-blue and green-red light changes more smoothly than general water bodies, and the range of changes in the near-infrared light band is more obvious than general water bodies. For the above spectral feature attributes, b2-b1, b3-b2, and b4 are selected as the ID3 feature attributes.

(3) ID3 algorithm is a relatively good extraction algorithm with an overall accuracy of 77.41%. This algorithm uses multiple features to calculate information entropy and selects the best feature as the classification condition, avoiding the problem of insufficient applicability, and at the same time more objective classification criteria And judging criteria.

References

Angel Hsu, Zhi Yi Yeo, Amy Weinfurter.2020. Emerging digital environmental governance in China: the case of black and smelly waters in China. Journal of Environmental Planning and Management, Taylor & Francis Journals, 63(1):14-31.

Cristina Olaru，Louis Wehenkel.2003.A complete fuzzy decision tree technique.Fuzzy Sets and Systems,138(2):221-254.

Mohammed Al-Gunaid, Maxim Shcherbakov, Valeriy Kamaev.2016.Decision Trees based Fuzzy Rules.Advances in Computer Science Research,978-94-6252-196-4,2352-538.

Janikow C Z.1998. Fuzzy decision trees: issues and methods.. IEEE transactions on systems, man, and cybernetics. Part B, Cybernetics : a publication of the IEEE Systems, Man, and Cybernetics Society,28(1).

John Luebs, Tyson Tragon, Katie Traylor.2020. Decision-Tree Classification of Chordomas and Chondrosarcomas. J Neurol Surg B Skull Base, 81(S 01): S1-S272.

LV Utkin, Maxim S Kovalev, Frank P A Coolen.2020. Imprecise weighted extensions of random forests for classification and regression. Applied Soft Computing Journal, 92(3).

Li F W, Can H, Zheng X W. 2019. Monitoring of Urban Black-Odor Water Based on Nemerow Index and Gradient Boosting Decision Tree Regression Using UAV-Borne Hyperspectral Imagery. Remote Sensing, 11(20) 2402.

Li L L,Li Y M,Lü H,Xu J,Yang Z Q,Bi S,Xu J F.2020. Remote Sensing Classification of Urban Black-odor Water Based on Decision Tree. Environmental Science, 1-18.

Li J Q,Li J G,Zhu L.2019.Remote sensing identification and Ground verification of black and smelly water in Taiyuan city. Journal of remote sensing

Liu H X, Zhang J, Wang B G.2008. Nondestructive near-infrared spectroscopy of total Phosphorus in water quality monitoring. Journal of Analytical Sciences, 24(06):664-666.

Pranav ManjunathEmail, Kushal Naidu.2020. Apriori Algorithm and Decision Tree Classification Methods to Mine Educational Data for Evaluating Graduate Admissions to US Universities. Cybernetics, Cognition and Machine Learning Applications.4,103-115.

Qian K X, Luo J G, Lian Y N, Wang G, Yan X B.2020. Fuzzy comprehensive evaluation model of water quality based on gini coefficient and its application. Journal of hydropower energy science, 38(01):36-39.

Reza Ashraf Ganjoei, Hossein Akbarifard, Mashaallah Mashinchi.2020. Estimation of upper and lower bounds of Gini coefficient by fuzzy data.Data in Brief,29.

Thomas G Dietterich.2020.Ensemble Methods in Machine Learning.multiple classifier systems, 1-15.

Urban Planning Bulletin.2015.Guide to The Regulation of Urban Black and Smelly Water. Urban Planning Bulletin, (19):7.

Wen S, Wang Q, L Y M.2018. Remote Sensing Identification of Urban Black-Odor Water Bodies Based on High-Resolution Images:A Case Study in Nanjing. Huanjing kexue, 39(1).

Xu L H.2008. A method for the rapid determination of organic pollutants in water bodies by near infrared spectroscopy. Analytical Laboratory, (S1):448-450.

Yao Y, Shen Q, Zhu L, Gao H J, Cao H Y, Han H, Sun J G, LI J S.2019. Gaofen-2 remote sensing identification of black and smelly water body in Shenyang. Journal of Remote Sensing,23(2):230-242

Yao H M, Lu Y N, Gong Z Q.2019. Research on the Identification Method of Black and smelly water in Qinzhou City, Guangxi based on PlanetScope image. Environmental engineering, 37(10):35-43.

Zhou X L, Dasen Yan.2019. Model tree pruning. International Journal of Machine Learning and Cybernetics, 10(12).

Zhang X, Lai J B, Li J G, Wang L, Zhu L, Chen Y J.2019. Remote sensing identification of black and smelly water body in shenzhen based on gaofen-1 image. Science, technology and engineering,2019,19(04):268-274.