A survey of ship target feature extraction based on video surveillance

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Abstract. Ship target feature extraction plays an important role in ship recognition and tracking based on video surveillance. However, the current feature extraction of ship targets based on video surveillance does not have a complete summary, so this article reviews these methods. This article summarizes the main ship target feature extraction methods used in ship target recognition and tracking in different application environments, including traditional artificial ship feature extraction and automated learning ship feature extraction. It focuses on the core ideas, advantages and disadvantages of the representative methods in each type of problem, and discusses the current problems in the feature extraction of ship targets and the future development of feature extraction technology.

1. Introduction
Ship target feature extraction plays an important role in ship detection, recognition and tracking based on video surveillance. However, due to the complexity of the marine environment, such as turbulent waves, land and water background, sea fog, cloudy and rainy weather, sea breeze blowing and illumination changes, it is often difficult to extract ship image features in intelligent ship video surveillance. With the extensive application of computer vision and artificial intelligence technology in coastal defense security, many researchers have proposed a variety of ship target feature extraction methods for specific marine environment intelligent ship video. However, there is no comprehensive overview of the current feature extraction methods of ship targets. In order to understand the current situation of ship target feature extraction, this paper takes the ship target recognition and tracking in the current video surveillance as the target, summarizes the typical ship target feature extraction methods in different application environments, compares their advantages and disadvantages, and discusses the existing problems of ship target feature extraction methods. Some problems and future development, so as to better understand and research the ship target recognition and tracking system.

2. Feature extraction method of ship image
In reality, people usually recognize the objective things according to the characteristics of things and the differences between different things. In computer vision, distinguishing different objects also depends on the specific properties of things -- eigenvalues. Therefore, feature selection and extraction is an important functional module of ship image recognition and tracking based on video surveillance.
Ship image recognition and tracking is based on this module. It can be said that the quality of feature extraction is directly related to the effect of subsequent processing and analysis. Ship image features are some attributes representing the nature of ship image. The purpose of feature extraction is to give the mathematical descriptive features of specific ship image which are different from other images. At present, ship feature extraction methods mainly include two categories: manual feature extraction and automatic learning feature extraction. The former is the main extraction method that people rely on artificially designed features for a long time in the past; the latter is the way people use convolutional neural networks for feature extraction in recent years[1]. The difference between them is obvious, but the goal is to accurately and quickly identify or track ship objects based on appropriate characteristics.

2.1. Artificial ship feature extraction

Manual feature extraction has always been dominant in the field of ship image recognition or tracking. The mainstream idea is to first use region selection methods to locate and extract regions of interest, and then manually design and extract target features.

2.1.1. The complexity of ship image feature extraction and selection principles.

Under the background of a complex ocean environment, ships in images acquired at different times are likely to be presented with different brightness, contrast, size, position, and posture, and the same ship will be very different in different images. In addition, the types of ships are diverse, and different types of ships have differences in size, shape details, and colors, making it extremely difficult to construct an apparent model with generalization capabilities. For a long time, researchers have been committed to extracting high-dimensional target features which can distinguish ship from non ship and have invariance of rotation, scale and translation. At present, there is no general method for ship target characteristics, but according to specific applications and problems, a few target features with high distinguishability, strong independence and high reliability should be selected. For example, for ship detection, if the camera is installed on a moving underwater unmanned aerial vehicle or a maritime buoy, it will take images of water targets from different angles, and there will be angle distortion, such as size scaling and translation. Therefore, in the selection of feature extraction methods, we should try to select those stable features. It can be said that the distinguishing and stable characteristics are good features. In addition, the uniqueness is also an important aspect to be considered in the target visual feature selection, mainly to distinguish the target from the target feature space. For the targets to be detected, tracked and recognized, the selection of appropriate target features has an extremely important impact on their performance. Generally speaking, the selection of good target features should follow the four principles of distinguishability, reliability, independence and less quantity[2][3].

2.1.2. Extraction method of ship features.

According to literature research, the extraction of ship features involves salient features such as ship color, texture, geometric shape and spatial relationship[4]. In marine security applications based on intelligent video surveillance, the selection of ship target features is closely related to the target representation method, so different target features should be selected according to different target representation methods[5]. The commonly used target features mainly include: color features, transformation features, edge features and shape features.

1. Method based on color features.

The main objects in the sea visual video images are islands, coast, sky, sea surface, platform and ship. According to the field observation, there are vegetation and buildings on islands and coasts. The vegetation is green, and the buildings are white, red and other colors. When the weather is fine, the sky is blue, and in rainy and foggy weather, the image is generally gray. The color of visible light images on the sea surface is relatively simple, mostly gray yellow area (near the coast of some sea areas) and blue; ships are silver gray, white, and white Red and grey black. So many people consider using color features to distinguish ship and non ship targets.

Color histogram is a color feature widely used in many intelligent video surveillance systems. It describes the proportion of different colors or gray levels in the whole image, which can reflect the
statistical distribution and basic tone of image colors. In the early stage, color histogram is often used as the feature of object in video image. A.W.Smith et al. [6] used the gray histogram feature of wave in each area of statistical image to distinguish the sea and objects in the anti-collision system of ships on the sea surface. However, the accuracy of the feature statistics is difficult to guarantee under the conditions of vast sea surface and complex scene changes. Chen Huimin [2] designed a particle filter algorithm with adaptive fusion of color and edge features, and applied it to the tracking of moving sea targets. However, in the complex ocean environment, the color features of ships are unstable, which may lead to the failure of tracking. Based on the fusion of HSV color histogram and shape features, Wang Kun [7] studied the particle filter algorithm for tracking moving targets at sea. When color histogram is used to describe color features, it has less calculation and is easy to be counted. It has strong adaptability for image transformation and image rotation, but it can not describe the spatial distribution of color in the image[8]. When the camera is installed on a moving monitoring ship or maritime buoy, it will take images of water targets from different angles, and there will be abnormal changes in the angle of view, such as size scaling, translation, etc. Zhou Liping [9] thinks that color features are not sensitive to these angle distortion, so it is not suitable to select color features for feature extraction.

2 Methods based on transformation features
Transformation feature is a feature that obtains the value of the transformation space by transforming the image, and then makes statistics. The usual ones are Fourier, Gabor, Hough transformation, etc. J. G. Sanderson et al. [10] describe the state of the sea surface by collecting the wave frequency domain characteristics as a matching template to distinguish the sea and the object, and then track the target by using the motion constraint equation.

3 Methods based on edge features
An edge is a collection of pixel points that have a step change in color or gray scale or a roof-like change in the surrounding pixels. In general, edges exist between target and target, between target and background, and between region and region [11]. The simplest method for extracting target edge information is to construct an edge detection operator based on a certain neighborhood of the original image. Common edge detection operators include Canny operator, Laplacian operator, Sobel operator, Roberts operator and Prewitt edge operator, etc. For the recognition and tracking of ship targets at sea, Wang Mingfen [12] designed an adaptive threshold Susan edge detection algorithm by extending SUSAN algorithm. Based on the edge detection, the shape context features of the target are described. The matching cost between the shape histogram of one target and the shape histogram of another target is calculated by using the concept of $\chi^2$ distance. Finally, a two-level recursive coarse and fine matching method based on shape context feature is used to realize the correct classification and recognition of sea moving targets.

4 Method based on shape features
The target is segmented from the image. The target is composed of the boundary and the pixels in the area enclosed by the boundary, which completely constitute the shape information. Shape is a very important feature, and it plays a very important role in understanding the target. At present, there are two methods to obtain shape features: one is based on the entire segmented area including boundary pixels, that is, pixels in all areas are considered to obtain valuable shape information, such as convex hull, area, eccentricity rate, Hu invariant moments, affine invariant moments, etc.; the other is to only consider the pixels on the boundary, that is, the contour line to generate shape descriptors, such as Fourier shape descriptors, chain codes and other description methods. Generate shape information based on the target contour. The other is to generate shape descriptors by considering only the pixels on the boundary or contour lines, such as Fourier shape descriptors, chain codes and other description methods. According to the target contour, shape information is generated.

1) Invariants of ship characteristics
There are many types of ships, but they are generally composed of decks, hull frames, cabins and superstructures, with similar shapes and features. One of the key characteristics of shape feature display is that it can keep stable when the object changes in displacement, rotation and scaling. Liu
long [13] discussed the invariance characteristics of the ship target profile, including the invariants of rotation, proportion, translation and invariant moment. The ship is a rigid object, and its contour features are invariable. Other features, such as color characteristics, do not show, especially in the weather conditions of poor visibility, the color characteristics of ships are basically the same. At the same time, the texture features are not significant under this condition, and the performance is consistent in the long-term view.

(2) Main extraction methods

1) Extraction based on classical geometric characteristics

In the classic geometric theory, features such as area, perimeter, long and short axis, main axis direction, tightness, solidity and eccentricity have a wide range of applications. For the calculation of ship deadweight tonnage, Hill [14] uses segmentation of ship feature images, based on SVM training, and obtains the target edge contour and captain based on morphological processing to achieve the calculation target. In view of the large deviation of the gross tonnage measured by manual measurement and reference to the navigation book when the passing ships charge according to the gross tonnage, Lin kunjie [15] introduces machine vision into the gross tonnage detection by referring to the factors of ship tonnage and water area, and designs an active contour model (snakes) algorithm based on improved difference combined with GVF force field threshold judgment to obtain the initial contour line, Then the automatic calculation of the water area occupied by ships is realized. Zhang Yihui [4] thought that the area and perimeter of the target image changed irregularly in the relative motion of the target on the water surface, and could not be used as the recognition feature. Therefore, it performed target recognition based on the geometric characteristics of the ship's elongation feature C, rectangularity feature J, and roundness feature R extracted from features such as area, major and minor axis, and compactness. Shen Rui [16] uses the ship feature extraction algorithm to obtain the motion feature parameters of the target ship (center of mass position, ship area, sailing speed, etc.), and then uses the Kalman prediction algorithm to predict the center of mass location of the target ship in subsequent images, thereby establishing a tracking gate and reducing the matching range of the target ship. Finally, an improved cost function based on feature matching is used in the tracking gate of the subsequent image to match the target ship, and find the corresponding target ship to realize the tracking of the target ship. Aiming at the development of Suzhou Creek digital ship monitoring system, Zhou Hao [17] extracted eight features of the target, such as length, area, maximum height, average height of the first section, average height of the second section, average height of the third section, average height of the fourth section and fifth section. SVM classifier is used to classify ships.

2) Extraction of features based on geometric invariance

Considering that the ship target may be deformed in motion, it is often necessary to describe the characteristics of rotation, scaling and translation without change (that is, RST invariance), such as maximum curvature and minimum curvature point, area density, body ratio, rectangularity, invariants based on distance from center to boundary, normalization of projection vector in long axis direction, rectangular block area ratio vector and invariant based on curvature measure [18]. Among them, the invariants based on the distance from the center to the boundary include the ratio of the average distance between the target center to the nearest boundary point and the center to the boundary, the vector angle between the target center to the nearest point and the farthest point, and the probability that the distance from the center to the boundary point is greater than the average distance; The invariants based on the curvature measure include the curvature of the farthest and closest point from the center to the boundary, the largest and the smallest curvature of the target boundary.

In order to meet the requirements of target recognition in the application of remote sensing or aerial images in military investigation, Dong Jianguo[19] measures the ratio of the area and perimeter of the target image, the ratio between the center to the longest distance and the average distance, etc., so as to identify the ship from the target image. Aiming at shape-based target recognition, Zhou Zhengjie [20] proposed a contour-based shape feature extraction and recognition method. Li Yicheng [18] took the center of the ship as the center of the circle, and calculated the ratio of the area of the ship in each circle to the area of the corresponding circle, so that the feature has translation and rotation invariance,
and normalizes the distance from the center to the farthest boundary point to realize the scaling invariance. This feature value extraction method makes the extracted features have RST stability in the same ship target, and thus has strong anti-interference ability.

3) Extraction based on moment features and geometric invariance features

In the commonly used target contour feature invariant analysis, there are mainly invariants such as basic geometric features, moment features, and Fourier descriptors. The simplest solution is the basic geometric features of the target, but the geometric features of rigid objects of the same kind are almost the same. Therefore, when extracting the target feature, not only its geometric features should be described, but also its moment invariant features should be extracted at the same time. Moment (central moment) actually reflects the statistical distribution of the object's gray scale relative to the center of mass. In terms of characterizing invariants, the moment invariant theory is a relatively mature method from one-dimensional to multi-dimensional. In the feature extraction process of ship target image recognition, the moment technology has been widely adopted. Its greatest advantage is that it can keep good stability to the changes of rotation, scale and translation (RST). Even if the target is in the occluded state, it also has the ability to recognize the target. Moment invariants include Hu moment, affine moment, Zernike moment and wavelet moment.

In 1962, Hu used the linear combination of geometric moments to construct seven classical moment invariants, which are the most widely used moment invariants in ship feature extraction. The characteristics of Hu moment feature description not only show its invariance to target rotation, proportion, and translation changes, but also show that it can effectively describe target features regardless of whether the target is fully connected. Therefore, in view of the relatively simple contour features of ship targets, Liu long [13] determined that in the case of general target detection and tracking, the geometric features of ship targets are selected as matching recognition conditions; in more special cases, as similar ship targets appear in the same scene, Hu invariant moments are used for ship target matching recognition. Yang Gaoxing [21] used the extracted characteristic values of the ship’s length to height ratio, three Hu invariant moments and the ship angle ratio as the input of the support vector machine classifier to identify the ship types in the inland waterway area. Aiming at the problems in template matching, Zhu Chenghe [22] uses Hu invariant moments to extract the shape feature information of the target, forms a template information database through normalization and trains the target template features, and finally inputs the features of the ship to be identified into the SVM to make the ship target Recognition. Yan Zhongzhen [23] uses the improved Hu invariant moment method to extract the characteristics of the target ship image. The sample invariant moment value obtained by the improved Canny operator is used as the feature input of neural network classification algorithm. The recognition and classification of ship target image is realized based on the additional momentum factor BP neural network algorithm with optimized weights.

Affine moments play a key role in identifying distorted targets [24]. In the real environment, the target will undergo affine deformation because it is often affected by distance, visual angle, etc. The superiority of the affine moment is more obvious in this situation [25]. Zhang Yihui [4] extracts features of the segmented target image, and uses 5 texture features to distinguish between ships and non-ships. The combination of six Hu invariant moments, three affine invariant moments and three geometric features was applied to the classification process of surface ship types. In terms of ship target recognition, according to the ship's geometric characteristics and shape invariance characteristics, the ship type recognition based on LVQ (Learning Vector Quantization) neural network is studied.

5 Methods based on texture features

The image texture can specifically represent the color distribution and light intensity distribution of an image or a certain area. Generally speaking, the texture of an object has certain statistical characteristics and can be identified based on the calculated texture features. Histogram of Oriented Gradient (HOG) is a feature commonly used in computer vision and pattern recognition to describe the local texture of an image, and it is a feature descriptor used for object detection. The HOG feature constitutes the feature by calculating and counting the gradient direction histogram of the local area of
the image. It can maintain good invariance to the geometric and optical deformation of the image. Therefore, Wang Kun [7] in ship target detection based on the bidirectional fusion of visual attention mechanism and hog features, through the visual attention model and region extraction, the salient ship region is quickly obtained, which effectively eliminates the background interference and reduces the target search area. Then, the candidate regions of ships are quickly obtained by combining edge detection and region tracking, and their hog features are extracted. The ship classifier based on SVM is used to identify ship targets.

2.2. Automatic learning to extract ship image features

Automatically learning and extracting features from a large number of training sample images will be a major technological breakthrough in the field of target recognition or tracking. The traditional neural network was once believed to be able to achieve this function, and then due to the shortcomings of its training process such as overfitting, complex algorithm design, and long training period, people were forced to give up this fantasy. In just a few years, with the increasing popularity of cloud computing and the rapid development of GPU and deep learning technology, automatic learning and extracting features has gradually become a reality. Deep learning technology can make up for the shortcomings of traditional neural networks. Using deep neural networks, through the multi-layer nonlinear transformation of the network, it can automatically learn features from massive image data sets. The deep structure makes it have strong expression and learning ability, especially good at extracting complex global features and contextual information [26]. Among them, the landmarks are the convolutional neural network and the region proposal (RP) algorithm. The target detection method represented by R-CNN opened the first in the application of deep learning to target detection. The target detection framework of RP combined with CNN classification is mainly based on 3 steps: one is to generate a large number of candidate windows through sliding window or object proposals method; the other is to use the trained classifier to classify and score the candidate windows; finally, Non-maximum suppression (NMS) is used to eliminate overlap detection. At present, the target detection methods of deep learning mainly include two types[27][28]: one is the target detection method based on region proposal, which is a combination of region proposal and CNN network [29], and the classification-based R-CNN series target detection framework (two stage) mainly include CNN, SPP-NET, Fast R-CNN and Faster R-CNN, etc.; the other is the detection method that converts target detection into regression problem, such as YOLO and SSD. Both of them have made breakthroughs in the field of target detection, and gradually set off the upsurge of deep learning technology in the field of ship target detection.

Because convolutional neural network is more effective in general target classification and recognition, and has made great breakthroughs in other fields, if it is applied to ship target recognition based on video surveillance, especially in complex marine environment, it will be more flexible and universal than ship target recognition based on artificial feature extraction. At present, some researchers have carried out some research on ship target recognition based on deep learning. Li Hui [28] uses faster R-CNN algorithm to solve the problem of ship target detection in marine environment, which has higher accuracy than traditional target detection algorithm. Xia Ye et al. [1] adopted the framework of a bridge active collision avoidance video monitoring system based on SSD (Single Shot Multi Box Detector) target detection, and used a pre-trained convolutional neural network model to analyze ship targets in inland river video images through self-built ship data sets. Compared with the Vi Be algorithm, it has obvious advantages in stability and accuracy.

3. Existing problems in feature extraction of ship targets

In summary, the feature extraction methods used in the detection, recognition and tracking of marine targets based on intelligent video surveillance are diverse. Although respective reasonable solutions have been proposed for different ship target application requirements, there are still some problems as follows:

The first category: belongs to the aspect of artificial feature extraction
The first is the detection, recognition and tracking of ship targets in the marine environment. So far, there is no unified method for feature extraction of ship targets. The existing feature extraction methods are only suitable for specific environments.

The second is that most of the current ship target feature extraction methods have high requirements for the applicable conditions of the environment. When the environment changes slightly, they are easy to fail.

The third is that the current methods of feature extraction are relatively simple, and they are less combined with other methods of ship detection, such as radar and AIS. The extracted features have little application value in ship target recognition and tracking.

The second category: belongs to the aspect of automatic learning feature extraction

At present, target detection based on deep learning technology is mainly for public data sets, and the features extracted by self-learning are not yet fully adapted to the needs of marine security for ship target recognition. The rate of missed detection and false detection is high. It is necessary to extract ship features based on the common data set in the field of marine security.

4. The development of ship feature extraction technology

In view of the many unpredictable factors in the detection, recognition and tracking of ship targets based on video surveillance, according to the previous article, we believe that the future development of ship feature extraction technology is as follows:

1) Ship detection and other application systems are not allowed to contain too many features due to real-time requirements. For specific needs, the basic principle of feature selection is sufficient and feature extraction is not complicated, otherwise too many features will seriously affect the subsequent various Real-time application.

2) Each system has a specific environment, so it is necessary to select suitable and stable features according to the actual situation, and focus on selecting those features that will not change due to navigation (translation, position from far to near and from near to far) and steering during ship navigation.

3) In video surveillance, the accuracy of single ship feature extraction for ship detection, recognition and tracking is limited. If it can be combined with the ship target based on radar or other methods, it will greatly improve the effectiveness of ship target detection, recognition and tracking. Therefore, the combination of ship target feature extraction based on video surveillance and other methods of ship target feature extraction will be an important development direction in the future.

4) The traditional ship target feature extraction is a manual method, which requires manual design and is of low efficiency. In recent years, with the development of deep learning technology, target detection and target recognition based on convolutional neural networks have made important progress in many fields[30][31]. Convolutional neural networks can extract higher-level and better expressive features in target detection, and can complete feature extraction, selection and classification in the same model, and target detection and recognition have achieved higher accuracy[32]. It has attracted the attention of ship target detection researchers. Therefore, automatic feature extraction based on deep learning technology is an important future development direction in this field.

Acknowledgment

This research was financially supported by Zhejiang cultural relics protection science and technology project (2017016), Project of Department of Education of Zhejiang Province (Y201840248), Research plan of public welfare Technology in Zhejiang Province (LGG19F02006) and Dinghai District University and Local Cooperation Projectt (2019C3104).

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