VESSELS CLASSIFICATION

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VESSELS CLASSIFICATION

NOR SURAYAHANI BINTI SURIANI

A project report submitted in partial fulfilment
of the requirements for the award of the degree
of Master of Engineering
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Faculty of Electrical Engineering
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APRIL 2006

"I declare that this thesis entitled " VESSELS CLASSIFICATION " is the results of my own research except as cited in references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree."

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ABSTRACT

Moment based invariants, in various forms, have been widely used over the years as features for recognition in many areas of image analysis. The proposed work will look at offline ship recognition using ships silhouette images which will include recognition of part of an object for situations in which only part of the object is visible. The model-based classification is design using Image Processing MATLAB Toolbox. The moment invariant techniques apply for features extraction to obtain moment signatures to do classification. The minimum mean distance classifier is used to classify the ships which works based on the minimum distance feature vector. This research study will address some other issue of classification and various conditions of images that might exist in real environment.

ABSTRAK

Momen yang tidak berbeza, dalam berbagai-bagai bentuk, telah banyak digunakan bertahun-tahun dahulu sebagai ciri-ciri untuk proces pengecaman dalam pelbagai bidang analisis imej. Cadangan projek ini akan melihat pada pengecaman kapal menggunakan imej bayang-bayang secara luar talian dan tumpuan diberikan kepada paparan sebahagian objek dalam situasi hanya sebahagian objek sahaja yang kelihatan. Klasifikasi berasaskan model ini direkabentuk dengan mengunakan perisian MATLAB. Teknik momen yang tidak berbeza digunakan untuk ciri-ciri pemisah bagi mendapatkan momen pengenalan bagi tujuan klasifikasi. Teknik klasifikasi yang digunakan untuk mengklasifikasi kapal ini menggunakan jarak purata minima bagi tiap-tiap vektor pencirian. Projek ini juga turut mengetengahkan isu-isu lain dalam proces klasifikasi dan pelbagai imej dalam situasi yang mungkin wujud dalam persekitaran sebenar.

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LIST OF SYMBOLS

μ	Mean
μ_x	Mean pixels values of x-coordinates
μ_y	Mean pixels values of y-coordinates
μ_n	n-th Central Moment
$\bar{x}, \bar{y}$	Centroid of image
σ^2	Variance
η_{pq}	Normalized Central Moment
γ	Normalisation factor
ϕ_n	n-th Moment Invariant
$d(X,i)$	Weighted distance
C	Covariance matrix

LIST OF ABBREVIATIONS

ROI	Region of Interest
FLIR	Forward Looking InfraRed

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Automatic object recognition has diverse applications in various fields of science and technology and is permeating many aspects of military and civilian industries. Autonomous recognition of ships can provide better tracking and automatic monitoring to control from potential enemy ships.

Recent advanced in imaging technology improves its ability to see ships at night and observed ships from any angle. Then, the classification is done to confirm its identity in the case of country of origin and vessels type. So, this project addresses model-based classification of warship of different categories with acceptable accuracy.

1.0 PROBLEM STATEMENT

Automatic ship recognition is an interesting research area in military industry. In current practice, a person is employed to watch the water area constantly to monitor and recognize the type of vessels. This process is very daunting for human to do. In present situation, a monitoring of the coastal area and recognizing the type of vessels that enter the coastline is very important in security. Thus, the use of image processing algorithms that could detect and identify incoming vessels is very useful for automatic system.

Figure 1.1: Left to right: clipped, overlapped with another silhouette

Figure 1.1 shows that classification of objects based on silhouettes is easily affected by scale changes, clipping and occlusions with another silhouettes. Moments based approached use to represent subregion of an object for situations in which only part of object is visible.

1.1 PROJECT GOALS

The main approach is model-based, where the types of warship to be recognized are known in advanced and can be categorized into different classes. Each class is defined by the structures it contains and their arrangement on the deck. The specific library divided into two categories which are Merchant (recorded image) and Combatant type. The specific model database contains 6 classes of ships: destroyer, frigate, aircraft carrier, patrol forces, mine warfare forces and merchant ship.

For each ship silhouette, feature vector will be extracted and calculate moment signatures. Then for testing purpose, compute the signatures for a ship image of unknown type. The unknown type could be change in positions, rotated in certain angle or scaled. Classification is done using the minimum mean distance classification by finding the minimum distance among all pattern vectors. This is done through the representation of means and variance of each class.

1.2 OBJECTIVES OF THE PROJECT

The objectives of this project are:

a. To design, develop and produce technique for the classification of vessels
b. To select features that adequately and uniquely describe the vessels to be identified

1.3 SCOPE OF PROJECT

Many researches have been done in this area using Forward Looking InfraRed (FLIR) images, radar images, simulated images and visual-light images. In this project, the sample data set are the offline ships images which is not applicable for real-time applications.

The design coding will be implemented based on MATLAB 7.0 software using the Image Processing Toolbox. Then, this project need some pre-processing before the objects can be detected to obtain the silhouette images sample data set.

There are some limitations in this project, where the data collections are horizontal view images and the distance of object is unknown. Thus, the proposed algorithm is not intended for satellite or aerial view images.

1.4 PROJECT OUTLINE

The Project is organized into five chapters. The outline is as follows:

- **Chapter 1 Introduction**
  This chapter discusses the objectives and scope of the project and introduces some background with respect to the problem to be solved.

- **Chapter 2 Literature Review**
  This chapter is about previous work regarding to the pattern recognition especially to the vessels classification for military purposes. Moment techniques approach will be explained in details and the chronology of moments invariants apply for pattern recognitions. This chapter also subsumes the classification techniques apply for vessels classifications.

- **Chapter 3 Design Methodology**
  Chapter 3 elaborates the techniques and steps taken to complete the task. The important part is the development phase that explained in detail how to classify imperfect Region of Interest (ROI).

- **Chapter 4 Results and Discussion**
  The results will evaluate all experiments that have been done and discuss the performance of the proposed techniques. Sensitivity analysis of the results is also included.

- **Chapter 5 Conclusion**
  This chapter consists of conclusion for this work. It also describe the problems arises and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.0 OVERVIEW

Pattern recognition involved the following distinction steps which call *image processing chain* [M.Egmont-Petersen, D. Ridder, H.Handels, 2002]: Pre-processing, Feature Extraction, Segmentation, Object detection and Recognition, Image understanding and Optimization. Object recognition consists of locating the positions and possibly orientations and scales of instances of objects in an image. The purpose may also be to assign a class label to a detected object. Object recognition can be performed based on pixel data or features, e.g., principal component, moments.

Classification of objects based on their silhouette is particularly useful in autonomous ship recognition. Most work has been done on radar images which acquired by imaging sensors operating at different spectral ranges (CCD, FLIR, image intensifier).

There are many methods for features extraction in automatic target recognition. The general methods used for two-dimensional shape recognition can be categorized as either global or local. Global methods use global features of an object boundary like Fourier Descriptors (FD), regular moments, autoregressive models and Curvature Scale

Space (CSS) applied for ship identification in decision support system is, it is curvature extrema, instead of zero crossings, that are tracked during silhouette evolution which is part of MPEG-7 standard [Á. Enríquez, C. Miravet, D Otaduy, C Dorronsoro, 2005]. This system makes use of the deployment of imaging sensors for surveillance and intelligence operations in naval scenarios.

Local methods use features such as critical points or high-resolution pursuit (HRP). It describes only part of the image in an object; hence only a few parts of the object are corrupted and only a small subset of the feature vectors to be affected. A possible disadvantage of local features is that relatively complex classifiers may be required in order to take advantage of the spatial relation between object parts. There is a wide variety of published literature for global-based approaches.

One early work is [Dudani, 1977], which used moment invariants for feature extraction of six different aircraft types and the images were based on physical models. His training set was based on over 3000 aircraft images taken in a 140^{o} by 90^{o} sector. The testing set contained 132 images (22 images of each of the six classes) obtained at random viewing aspects. Then, by assuming that the distance to the object was known the classification accuracy achieved was 95%.

Then [Reeves, 1988] suggested 'standard moment', which is a geometrical-moment approach using moments of the image that are normalized with respect to scale, translation and rotation. He used the same training and testing data as Dudani and obtained better classification results of standard moment compared to the conventional moments. Later, [Paschalakis S. and Lee P., 1999] produced better classification accuracy in four aircraft sample images using Complex Moment Magnitude and reduce computational load.

It is unclear how well the work on aircraft classification extends to ships, as ships are mainly distinguishable in small features when [Qian and Wang, 1992] proposed ships superstructure moment invariant. They achieved better performance in 1440 number of sample images (four types of ship model, sample to 10 ranges and 36 angles). But the algorithm applied to obtain the superstructure of the ships was not practical since the information of ships length and height were eliminated.

There seems to general agreement on the poor performance of the conventional moments in ships classification where in recent work, [Sanderson C. and Gibbins D.,2004] conclude that moment invariant approach give worse result in adverse conditions such as clipping, overlapping, scaled and corrupted by speckle noise. They also compare the performance of holistic and local feature approaches based on Principal Component Analysis (PCA) and 2D Hadamard Transform. This feature extraction technique basically produces dimensionality reduced versions of binary images and it would expect to be affected by scale changes, clipping and rotations. While Hadamard Transform method opposed to the holistic feature extraction. Where a given image is analyzed on a block-by-block basis; each block overlaps neighbouring blocks by a configurable amount of pixels.

There are several new techniques to increase accuracy and efficiency of moment descriptor [Teh C.H and Chin R.T, 1988]. Previous work, [Khotanzad ,1990] used Zernike Moment to recognize image patterns. He tested on 26 uppercase English characters (A to Z). These images were generated with arbitrarily varying scales, orientations, and translations. Then, the orthogonal property of Zernike moments makes the image reconstruction from its moments computationally simple. He obtained 99% classification accuracy for a 26 class character data set and conclude that Zernike moment perform well in the presence of a moderate level of noise.

In view of all the related literatures, Moment Invariant method has been proposed in this work to be an effective method for ship recognition extracted from a side view of the object. Operations such as rotation, translation and scale change achieved more easily in the moment domain than in the original pixel domain. Furthermore, the set of moments offer a more convenient and economical representation of the essential shape characteristics of an image segment than a pixel-based representation. This proposed processing scheme able to handle imperfectly Region of Interest (ROI). Further explanations of Moment Invariant technique will be presented in this chapter.

2.1 MORPHOLOGY

Morphology is the study of the shape and form of objects. Morphological image analysis can be used to perform object extraction, image filtering operations, such as removal of small objects or noise from an image, image segmentation operations, such as separating connected objects and measurement operations, such as texture analysis and shape description.

In this project the morphology techniques is used in pre-processing for background subtraction and apply to the recorded image, Merchant ship. This technique used to obtain the silhouette image that represents the shape of ships classes.

2.2 SHAPE DESCRIPTOR

In general, descriptors are some set of numbers that are produced to describe a given shape. The shape may not be entirely reconstructable from the descriptors, but the descriptors for different shapes should be different enough that the shapes can be discriminated. Recognition of objects is largely based on the matching of description of shapes with a database of standard shapes.

2.2.1 MOMENT

Another way to describe shape uses statistical properties called *moments*.

2.2.1.1 STATISTICAL MOMENT

For a discrete one-dimensional function *f*(*x*), we can compute the mean value of the function using the formula below:

$$\mu = \frac{\sum_{x=1}^{N} x f(x)}{\sum_{x=1}^{N} f(x)} \tag{2.1}$$

We can also describe the variance by

$$\sigma^2 = \frac{\sum_{x=1}^{N} (x-\mu)^2 f(x)}{\sum_{x=1}^{N} f(x)} \tag{2.2}$$

A third statistical property, describes how symmetric the function called *skew*, is as below:

$$skew = \frac{\sum_{x=1}^{N} (x-\mu)^3 f(x)}{\sum_{x=1}^{N} f(x)} \tag{2.3}$$

All of these are examples of moments of a function. One can define moments about some arbitrary point, usually either about zero or about the mean.

The n-th moment about zero, denoted as m_n, is

$$m_n = \frac{\sum_{x=1}^{N} x^n f(x)}{\sum_{x=1}^{N} f(x)} \tag{2.4}$$

The zero^th moment, m_0, is always equal to 1. The mean μ is the first moment about zero:

$$\mu = m_1 \tag{2.5}$$

The n-th moment about the mean, denoted as μn and called the n-th *central moment* is

$$\mu_n = \frac{\sum_{x=1}^{N} (x-\mu)^n f(x)}{\sum_{x=1}^{N} f(x)} \tag{2.6}$$

The zero^th central moment μ_0 is, again, equal to 1. The first central moment μ_1 is always 0. The second central moment μ_2 is the *variance*:

$$\sigma^2 = \mu_2 \tag{2.7}$$

The third central moment μ_3 is the *skew*:

$$skew = \mu_3 \tag{2.8}$$

The fourth central moment μ_4 is the *kirtosis*:

$$kirtosis = \mu_4 \tag{2.9}$$

If there are an infinite number of central moments, it can completely describe the shape of the function.

2.2.1.2 MOMENT OF TWO-DIMENSIONAL FUNCTIONS

The two-dimensional moment (p + q)th order of the moment of function *f(x,y)* are defined by:

$$M_{pq} = \int\int x^p y^q f(x,y)dxdy \qquad (2.10)$$

In digital form:

$$M_{pq} = \sum_X \sum_Y x^p y^q f(x,y) \qquad (2.11)$$

where p,q = 0,1,2..

Translation invariance is achieved by computing moments that are normalized with respect to the centre of gravity so that the centre of mass of the distribution is at the origin (central moments).

The central moments are given by:

$$\mu_{pq} = \sum_{x=0}^{Nx-1} \sum_{y=0}^{Ny-1} (x-\mu_x)^p (y-\mu_y)^q f(x,y) \qquad (2.12)$$

where the centroid of the image are :

$$\overline{x} = \frac{M_{10}}{M_{00}} \qquad \overline{y} = \frac{M_{01}}{M_{00}} \qquad (2.13)$$

The moments μ_{20} and μ_{02} are thus the variances of x and y respectively. The moment $\mu 11$ is the *covariance* between x and y. The covariance used to determine the orientation of the shape. The covariance matrix C is:

$$C = \begin{bmatrix} \mu_{20} & \mu_{11} \\ \mu_{11} & \mu_{02} \end{bmatrix} \tag{2.14}$$

The orientation can also be calculated using this formula:

$$\theta = \frac{1}{2} \tan^{-1} \frac{2\mu_{11}}{\mu_{20} - \mu_{02}} \tag{2.15}$$

2.2.1.3 RESPONDS TO TRANSFORMATION

Finally, moments respond to transformations of translations, rotation and scale as follows:

(a) **Translation** - If the object is translate, only the mean is changed, not the variance or higher-order moments. So, none of the central moments affected by translation.

(b) **Rotation** - If the shape is rotate, the relative variances and higher-order moments is change, but certain quantities such as the eigenvalues of the covariance matrix are invariant to rotation.

(c) **Scaling** - Resizing the object by a factor of S is the same as scaling the x and y coordinates by S give by matrix vector in (equation 2.16).

This merely scales $x - \mu x$ and $y - \mu y$ by S as well. Hence, the n-th moments scale by the corresponding power of Sn.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} Sx & 0 \\ 0 & Sy \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{2.16}$$

Ratios of same-order moments, such as the ratio of the eigenvalues of the covariance matrix, stay the same under scaling, as do area-normalized second-order moments.

By combining moments, it can thus produce *invariant moments*, ones that are invariant to rotation, translation, and scale.

2.2.1.4 MOMENT INVARIANT

Moment invariants have been frequently used as features for image processing, remote sensing, shape recognition and classification. Moments can provide characteristics of an object that uniquely represent its shape. Invariant shape recognition is performed by classification in the multidimensional moment invariant feature space.

In previous discovery [Ming Kuei Hu, 1962] set out the mathematical foundation for two-dimensional moment invariants using nonlinear combinations of regular moments and demonstrated applications to shape recognition. Moment-based invariants are the most common region-based image invariants which have been used as pattern features in many applications.

Size invariant moments are derived from algebraic invariants but these can be shown to be the result of a simple size normalisation. The normalised central moments are invariant to translation and scale. This is given by using this formula:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}} \tag{2.17}$$

where the normalisation factor is :

$$\gamma = \frac{p+q}{2} + 1 \tag{2.18}$$

From the second and third order values of the normalized central moments, [Ming Kuei Hu, 1962] derived seven set of moment invariant. These shape descriptor values have the desirable property of being invariant to translation, scale and rotation.

Seven set of moment invariant are as follows:

$$\phi_1 = \eta_{20} + \eta_{02} \tag{2.19}$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta^2_{11} \tag{2.20}$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (\eta_{03} - 3\eta_{21})^2 \tag{2.21}$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{03} + \eta_{21})^2 \tag{2.22}$$

$$\phi_5 = (3\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})\,[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \tag{2.23}$$

$$\phi_6 = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \tag{2.24}$$

$$\phi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})\,[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{30})^2] \tag{2.25}$$

These moments can be used to provide useful descriptors of shape. Suppose that for a binary shape we let the pixels outside the shape have value 0 and the pixels inside the shape value 1. Moments have been shown to be a very useful set of descriptors for matching.

For region-based invariants, all of the pixels of the image are taken into account to represent the shape. Because region-based invariants combine information of an entire image region rather than exploiting information just at the boundary points, they can capture more information regarding the image. As they take every image pixel into account, the computation cost will be much higher than local based approach.

2.3 FEATURE VECTOR

The above moments of an object can be computed for both the image boundary and the solid silhouette. Minute details such as the shape of the stacks of a ship are better characterized by the moments from the boundary. Gross structural features of the ship are better characterized by moments derived of silhouette. These moments are less susceptible to noise. In this model based system, all seven moment features values (ϕ_1, ϕ_2, ϕ_3, ϕ_4, ϕ_5, ϕ_6, ϕ_7) from the silhouette will be computed and used to identify the vessels classification.

2.4 CLASSIFICATION RULES

The weighted minimum-mean-distance classifier rules represent each class by the sample means and variances of its training features. The utilized classifier measures the sum of the squared distance between the feature vector of the test image X and the mean of the features vectors of each classes weighted by the inverse of the corresponding variances. The purpose of weighting is to balance the effect of each of the moment component of the feature vector.

Let $d(X,i)$ be the weighted distance between test image X and representation of class i. Then

$$d(X,i) = \sum \frac{(x-\mu)^2}{\sigma^2} \tag{2.26}$$

The minimum of d determines the class membership of pattern vector i. In other words, if the minimum of d is in its kth position, then scalar class will equal to k.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter discusses the research methodology which provides work plan and describes the activities necessary for the completion of project. For this project, the design methodology is divided into 3 phases:

i. ***Phase 1*** : *Design*
ii. ***Phase 2*** : *Library Creation*
iii. ***Phase 3*** : *Testing and Implementation*

3.1 DESIGN

The design phase involved on determining the chosen method for features extraction and classification techniques. The coding design is based on MATLAB Image Processing Toolbox which provides an extensive library of function that makes technical programming tasks easier and more efficient.

3.1.1 GENERAL MOMENT INVARIANT ALGORITHM

The moment features values are computed based on the general moment invariant algorithm below:

Step 1: Calculate the centroid position of the ship. The centroid position is $(\bar{x}, \bar{y})$, where $\bar{x} = m_{10} / m_{00}$ and $\bar{y} = m_{01} / m_{00}$.

Step 2: Normalized the second and third order central moment using equation (2.17).

Step 3: Then, compute the features values using seven set of moment invariant in equation (2.19 – 2.25)

Step 4: Finally, find the absolute value of logarithmic to reduce the dynamic range.

3.2 LIBRARY CREATION

Setting library database is needed before computing the moment feature vector. Figure 3.1 shows the vessels category that will be classified. In this work, vessels type can be divided into two categories which are recorded image for Merchant ship and scanned image for Combatant.

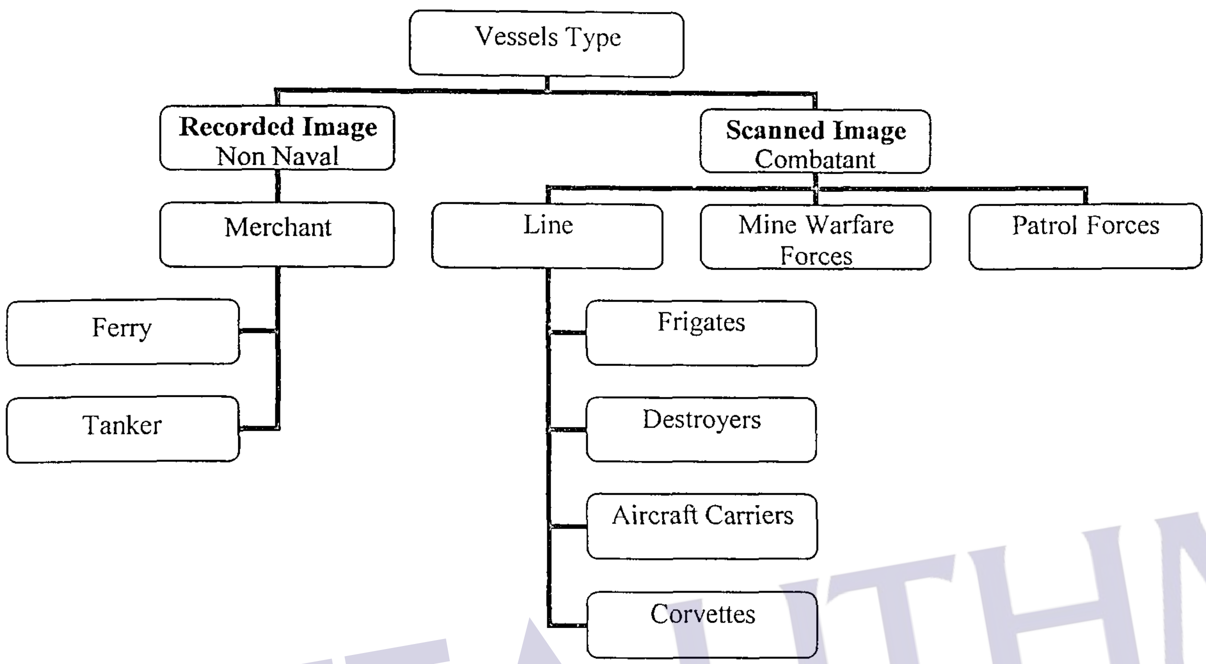


Figure 3.1: Vessels type category

Line ship type can be distinguished according to their ship length distribution. Figure 3.2 shows the probability density function of length distribution approximated by Gaussian.

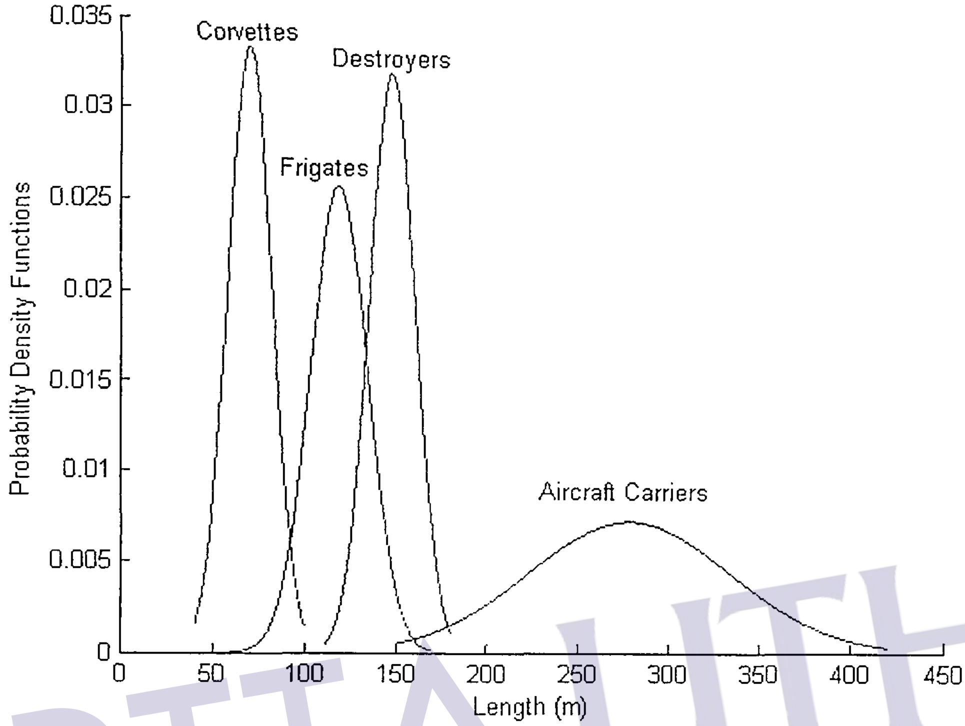
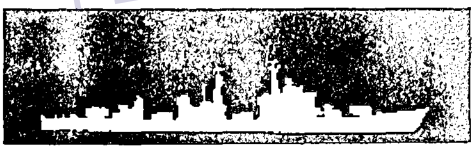
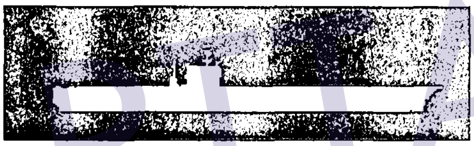
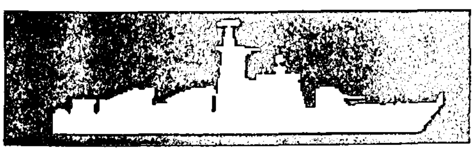


Figure 3.2: Probability density of length distributions

Instead of length distribution, there are many other considerations or features that can be used to for ships recognition. Table 3.1 below represents the different features to identify warship.

Table 3.1: Warship Recognition Features

Vessels Type	**Recognition Features**
Frigates 	- long slim hull with a high bow, - low in water - gun mounting in A, X and twin in Y position - tall flat bridge structure - large, low funnel aft of midships - forward superstructure with enclosed mainmast at after end - flight deck with quarterdeck below - midships superstructure with pyramid mainmast at after end
Destroyers 	- high bow with sweeping forecastle aft to bridge - gun mounting in A, B and Y position - twin, black-capped funnels angled astern - missile launchers, triple torpedo, mortar launcher - lamp fire control - air/surface search radar - tall superstructure - larger flight deck - helicopter hangar aft of midships

Corvettes 	- flat roofs - continous maindeck from stem to stem - high bow - low freeboard - short forecastle - no helicopter platform - gun mounting in A position - pyramid mainmast atop centre of main superstructure
Aircraft Carriers 	- 12° ski jump ramp - Squared 'chunky' island aft of midships - Air search radar - atop bridge - Starboard side, crane - Mid island - Twin funnel, one aft of bridge, - one aft of mainmast - CIWS mountings, - SAM launchers mounted port and starboard
Patrol Forces 	- small bridge forward of midships - high bow, low sloping forecastle - low freeboard - gun mounting in A, X and Y position - fire control radar - tall lattice at after end of bridge superstructure - high superstructure - steeped down at after end

Mine Warfare Forces 	- 20mm/70 gun mounting - high bow, stepped, smooth contoured superstructure - low freeboard with continous maindeck from stem to stem - small square structure on afterdeck - square sectioned funnel with sloping top sited midships - small crane on quarterdeck - low superstructure from forecastle aft to quarterdeck

Figure 3.3 shows the steps to setup the database involved background subtraction for recorded image. Then morphology process is used to obtain the silhouette image for each Merchant type. Each sample pattern need to be computed the features values based on moment techniques using MATLAB coding in previous design phase. Then all features values for each sample is stored in the database for testing purposes.

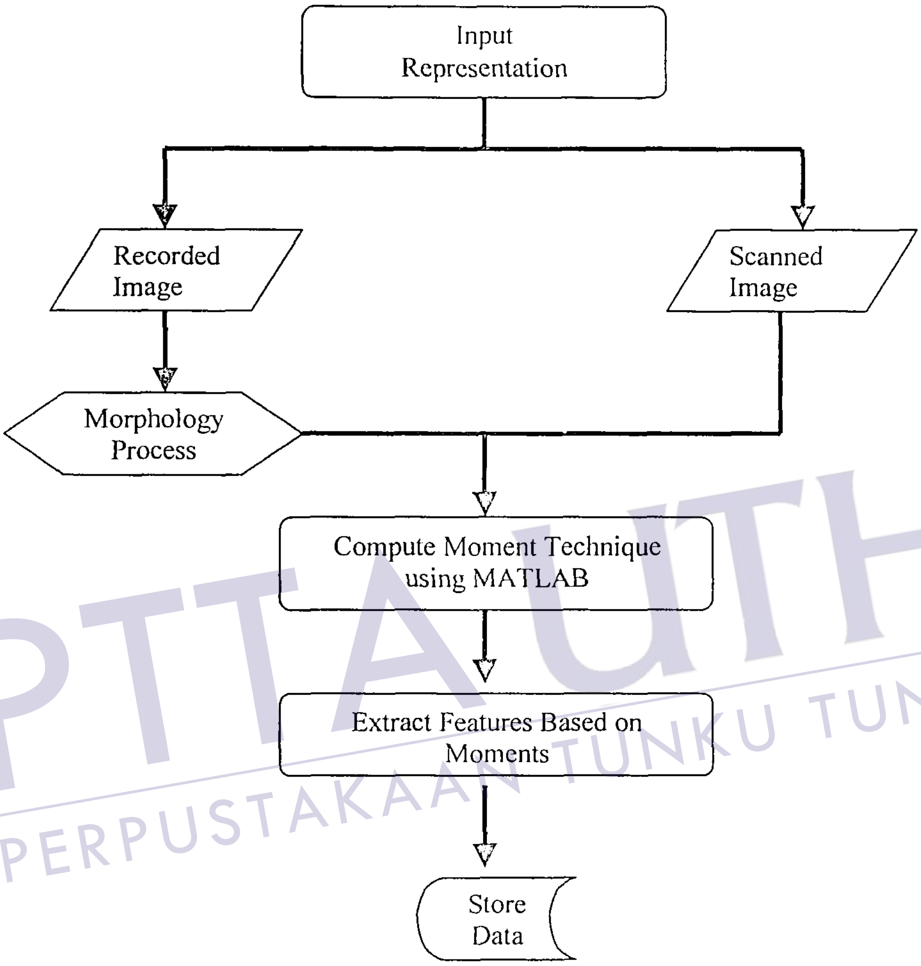


Figure 3.3: Library Creation Flow Chart

6.0 REFERENCES

6.1 BOOKS

This is the book that I have been using for collecting ships images and I found it very useful for ship identification research project.

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6.2 RESEARCH PAPERS/ THESIS/ CONFERENCES

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