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An algorithm to Recognize Number in Image: Based on Statistical Image Analysis

A thesis submitted in partial fulfillment of the requirements for The degree of Master in the faculty of science, dept. of statistics

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بسم الله الرحمن الرحيم

فلله الحمد رب السموات ورب

الأرض رب العالمين (36) وله

الكبرياء في السموات والأرض

وهو العزيز الحكيم (37)

صدق الله العظيم

الآيتان 37,36 من سورة الجاثية

Abstract

In many applications, images consist of different types of objects, recognition problems are considered to be the largest challenge in image processing and computer vision. This work aims to recognize the numbers as objects in image. This thesis introduce an algorithm for number recognition. The algorithm based on three major approaches, that are: thresholding for converting gray level image into binary image, by using global threshold value which obtained by iterative algorithm. The second approach is median filter method for noise reduction, that is considered to be good approach in case of salt and pepper noise. The third method is projection approach for dimensional reduction (image strip), this is done by calculate the sum of rows and columns of filtered image, then determine the properties of each number. The algorithm has been applied to simulated data and gave good results, after then algorithm is applied to real data, and success results have been achieved in this case.

Acknowledgments

In the first and the end I thank god.

I would like to express my sincere thanks to my father, for his unconditional support, vanishing any troubles comes in my way.

I am also grateful to my advisor Dr, Fathi M Elramly for his guidance and patience to complete this thesis

Dedication

To my Parents, Brothers,

Sisters, and Grandmother

With appreciation

Amna

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Chapter 1

Introduction

1.1 Background

Newspaper industry was the first to use digital image applications. The picture sent from London to New York by submarine cable early 1920. This leads to reduce process time to less than three hours rather than one weak, when it sent through Atlantic. Printing approach is used to create pictures in 1921. Bartlane systems could be used to convert picture into 5-gray levels, in 1929 these systems convert picture into 15-gray levels. The use of digital picture became too limited, since there are no computers during that time. Computers became stronger and stronger to use of digital image processing early 1960, space program appeared during the stages of computer developments, where the first picture of moon is obtained in 1964 by space probe. Last 1960 and early 1970 image processing is used in medical imaging, astronomy, remote Earth-resources observation. The most important applications of image processing are computerized axial tomography (CAT), which is used in medical diagnosis, and X-ray which is discovered in 1985, see Gonzalez and Woods (2001).

Image analysis has become more and more important field, and has a wider use in many areas, such as statistics science. Image analysis satisfied many successful applications by using statistical concepts such as, Markov random models, statistical moments, conditional probability, and Bayesian approaches, see Mardia (1989).

Image analysis is a process of image description with quantities measurement, where the input in this process is an image, while the output is quantities information. As simple examples of image analysis are calculation the mean of image, reading price of product sells, measurement the size of cell in medical image. The quantities information that are obtained from image analysis can be used to build complex decisions, such as using the robot to carry things after recognition them.

The definition of image processing is different from image analysis, where the techniques those are used to enhance pictures or any other images, such as space probes pictures, aircraft pictures, are called image processing. Some of these techniques are image representation, image preprocessing, image reconstruction. Generally there are two approaches of image processing, these are: analog image processing, and digital image processing. The main steps of image processing concept are: image scanning, storing, enhancing, and interpretation. Image processing is applied in many fields, for example, graphic arts, film industry, documents processing, medical imaging, etc. For more details see Rao (2004).

Pattern recognition is a process to detect one object or more from noisy image, after enhancing it. This process depends on determination number of objects in scene, location of each object, objects size, shapes, and spatial relation. The different techniques of pattern recognition have been developed in recent years. So these techniques become more commonly day after day. The pattern recognition is considered to be classification process, and sometimes learning process. There are two approaches of pattern recognition, decision-theoretic and structural, recognition the object by quantitative descriptors ,such as length, area…etc leads to first approach, while the second approach depends on recognition object by qualitative descriptors, see Gonzalez and Woods (2001). The application of pattern recognition appears in many areas, such as computer vision, character recognition, speech recognition, safety, astronomy, automated cytology, and industrial robot vision.

This work seeks to introduce an algorithm to recognize the object in the image. The study depends upon considering these objects as numbers then the objective will be to identify the number in the image automatically. To attain successive results of recognition process, the object shape should be determined. This means the recognition process will be applied after image processing. The algorithm is a combination of methods and approaches which set as stages in the algorithm. The algorithm is based on explore some characters for each number. These characters are used to recognize the numbers.

The first step in the suggested algorithm is to segment the image into foreground (object) and background, the thresholding method will be applied in this step, herein the iterative method is used.

The segmented image may contains on salt and pepper noise, then the median filter method is proposed to remove this noise.

The projection method is the third stage in the algorithm, this method produces the horizontal and vertical profiles of image. These profiles will be used to extract some characteristics for each number to identify it.

The proposal algorithm will be applied on simulated data. If achieves good results, the algorithm will be applied to real data.

1.2 Literature Review

“object recognition can be formulated as a parameter estimation problem by direct analogy with the formulation of segmentation and classification.” Geman and Geman (1984) and Besag (1986).

Many authors and researchers introduce algorithms and apply them to detect numbers in image.

Ozbay and Ercelebi (2005) designed a simple algorithm for Automatic Vehicle Identification by Plate Recognition. The algorithm depends on three major steps: extraction of plate region, segmentation of characters, and characters recognition.

They convert RGB (Red Green Blue) image into BW (Black White) image by using threshold, and used smearing algorithm to determine text area. After then, dilation is used for specifying the plate location. Segmentation is applied to separate plate character, but before this step they applied the filtering on the image for image enhancement, noise reduction, and remove unwanted spots, then dilation is used for separate the character of the plate. They also applied the horizontal and vertical smearing to fined character regions. After this step they cut the plate character by determination the points of the starting and end of each character in horizontal direction, they also applied the normalization to reduce the space of each character in each block, next step is recognition the characters in each block by using template matching algorithm, this algorithm measures the correlation coefficient between known image with sub image, the highest correlation give the best match.

Maarif and Sardy (2006) introduced a system for plate number recognition. The basic steps in their study are plate localization, and plate character recognition. In first they used mathematical morphology for plate localization, artificial neural network for plate character recognition, network learning process is achieved by back propagation algorithm, the development methods for recognition system consist of threshold to convert multi-colour image into binary image, opening and closing morphological operation for noise reduction, correlation template was used for plate localization, thin window scanning was conducted to extract the characters from the plate, finally neural network is designed to recognize 26 letters and 10 numbers.

Osorio *et al*. (2008) designed an artificial vision system used to recognize the Spanish cars license plate number. The system is independent of the distance from the car to the camera, the size of the plate number, the inclination, and the light condition. The basis in recognition process are: plate localization, character segmentation, and character recognition. Firstly they used soble to determine the boundaries of the plate. After this step they used threshold to convert multi colour image into binary image to reduce the time of processing. Also they applied soften filter to count the number of white pixels in the image which are expected to give an idea about plate location. But this procedure may give more than one white area of plate location, while in fact there is just one area for plate location, so some heuristics may take in account such as:

- The ratio of width to heights greater than two.
- The distance to the center of the image will be the nearest to plate location.

After this step, they applied a coarse method to remove the blobs of black pixels, which are noise not to be character, also they used normalization to make learning process more speed, finally character recognition has been done by techniques of data mining.

1.3 Motivation

Numbers can be formatted by different forms, some applications depend on numbers in using, such as traffic systems, that is concerned with car recognition by recognition character of plate, numbers is considered as part of that character.

Detect numbers could be useful in case of numbers in digital clocks or watches, that helps blind people.

So the motivation behind this work is to build an algorithm to recognize numbers, such of these numbers are shown in Figure1.1.

Figure 1.1: Image of numbers.

1.4 Thesis Overview

This study aims to apply an algorithm to recognize numbers where each number is considered to be an object in the image. This study briefed in chapters as following:

Chapter 2 starts with some principle concepts of image analysis, image processing and methods that maybe needed to build the algorithm. Chapter 3 introduce the algorithm that is suggested to detect numbers in the image. The algorithm is combination of methods and approaches. In additional to properties for each number. chapter 4 explains how proposal algorithm work on simulated data, thought feature extraction of numbers, where good results are obtained of applying the proposal algorithm. The simulated data is used to evaluate the algorithm and judge its performance.

Since the algorithm has been tested successfully by using simulated data, chapter 5 shows applying the algorithm to real data. This chapter presents suggestion to deal with the case of image contains multiple numbers.
The ending of this study briefed as summary and conclusions in chapter 6 with some suggestions to further work.

Chapter 2

Theoretical Background

2.1 Introduction

This chapter presents some important concepts those are related to image analysis and image processing, such as image component, types of images, neighborhood, etc. In addition to some methods related to detect and reconstruct numbers in noisy image.

2.2 Important Definitions

Image

Image can be defined as a function in two dimensions i and j. This function is denoted as $X(i, j)$, where i and j are coordinates, while X is an intensity value or gray colour level at that coordinates.

Pixel

Pixels or discrete picture elements are the smallest points in the image, match each pixel in an image digital number has only one value of the range that starts from 0 to 255.

Image details appear more clearer as the number of pixels increases.

Foreground and Background

Any image consists of two groups of pixel, the group that represents object is considered to be foreground, while the rest group is defined as background.

Digital Image

Digital image is shown as a matrix of numbers which represents a certain type of image (binary, gray level, or multi-colour image), to analysis the image it should be converted into digital matrix.

The horizontal path of intensity values in digital image represents the rows, while the vertical path represents the columns, picture elements values in i row and j column defined as intensity value and denoted by $X(i, j)$. Generally, any image consists of foreground and background, pixels.

Types of Digital Images

Digital images are classified, according to intensity values. Accordingly, there are three types of digital images:

Binary Image

When the image consists of just two levels of colours black and white, black for group of pixels represents foreground and white for the rest pixels that represent background (or vice versa) this type of image is called binary image, that is, each pixel in binary image can take one numeric value either 0 or 1.

In most scientific studies image convert into binary image for two reasons: the first for analysis simplest, and the other for reduce processing time, so this type of image is commonly used. Figure 2.1 shows this type of image.

Figure 2.1 Binary image.

Gray-Level Image

A grayscale image consists of 8-bits colour depth, $2^8 = 256$ level of colours between black and white, this means that there are many shades of gray. Figure 2.2 shows gray-level image.

Figure 2.2 Gray-level image.

Multi-Colour Image

True images or RGB (red, green, and blue) are mixture of three intensity maps. This kind of image has 24 bits equal to $256\times256\times256$. Approximately 16 million of colours, in monochrome images there is one value per pixel, while in colour image there are three values per pixel. Figure 2.3 views colour image.

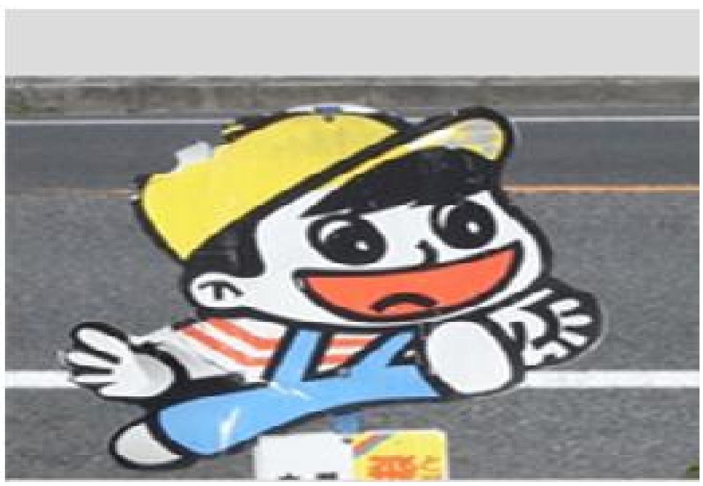

Figure 2.3 Colour image.

There is another type of true colours which is cyan, magenta, and yellow. This type is resulted by mixture two primary colours only, as example cyan is resulted by combination of green and blue, magenta is resulted by combination of blue and red and yellow from red and green. True colour image models commonly used in television, computers, and web graphic. Figure 2.4 shows the three intensities maps of colour image.

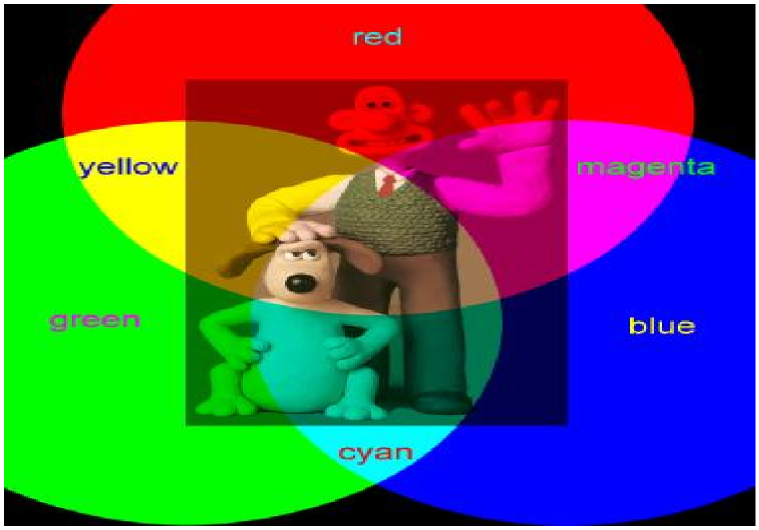

Figure 2.4: Three intensity maps of colour image.

Neighborhood

A pixel x at coordinates (i,j) with two horizontal, and vertical pixels, neighborhood is defined as first order neighborhood, $X_{(i-1,j)}, X_{(i,j-1)}, X_{(i+1,j)}$, $X_{(i,j+1)}$. As displayed in Figure 2.5(a). First order neighbourhood with diagonal pixels are defined as second order neighbourhood. Figure 2.5(b) shows eight connected horizontal and vertical points around studied pixel $X_{(i,j)}$.

(a)

	$X_{(i-1,j)}$	
$X_{(i,j-1)}$	$X_{(i,j)}$	$X_{(i,j+1)}$
	$X_{(i+1,j)}$	

(b)

$X_{(i-1,j-1)}$	$X_{(i-1,j)}$	$X_{(i-1,j+1)}$
$X_{(i,j-1)}$	$X_{(i,j)}$	$X_{(i,j+1)}$
$X_{(i+1,j-1)}$	$X_{(i+1,j)}$	$X_{(i+1,j+1)}$

Figure 2.5: (a) First order neighbourhood ; (b) Second order neighbourhood

2.3 Noise in the image

Noise are undesirable values effect on the true part that represents the body image, noise are random quantity takes many shapes sometimes follows certain distribution such as Gaussian, Poisson, exponential, gamma,…etc, or not such as blur and salt and pepper noise. all type of noise effect on image quality, so it necessary to use some methods to reduce it with protection on object feature. For more details see Bovik (2009).

2.3.1 Salt and pepper noise

One of the common types of noise is the salt and pepper noise (isolated points). In a binary image isolated pixels, appear as black pixels in white background (or vice versa), are called salt and pepper noise. Restoration of image that are corrupted by salt and pepper noise can be done by median filter, Chan *et al.* (2005).

2.4 Pattern Recognition

Pattern recognition has been received a lot of advertence since 1960, as process of description and classification input data. Pattern recognition is a collection of mathematical and statistical techniques, which are applied to achieve tasks like human being by computers.

To now, this system is applied in widely areas and defined by many definitions.

Pattern recognition defined as system concerned with classification of input data, this step is coming after features extraction from noisy data, see

Gonzalez and Thomas (1978). Also pattern recognition is defined as machine learning process how to recognize object in noisy data or complex environment, see Srihari and Govindaraju (1993).

Pattern recognition algorithm based on some properties in image such as: object size, object location, number of objects in image, and spatial relationship.

2.5 The Classification of Pattern Recognition System

The major classification of pattern recognition system (PRS) is:

Rule Based System, Classical Fuzzy System, Neural Networks System, Fuzzy Neural Networks System, and Bayesian System. See Liu *et al.* (2006).

Pattern Recognition Procedure

Pattern recognition system has a long history and its applications are used in many fields such as ratification intelligence, computer engineering, medicine image analysis, archaeology, agriculture, geography, and other fields.

Generally, the mainly structure of PR procedure is shown as:

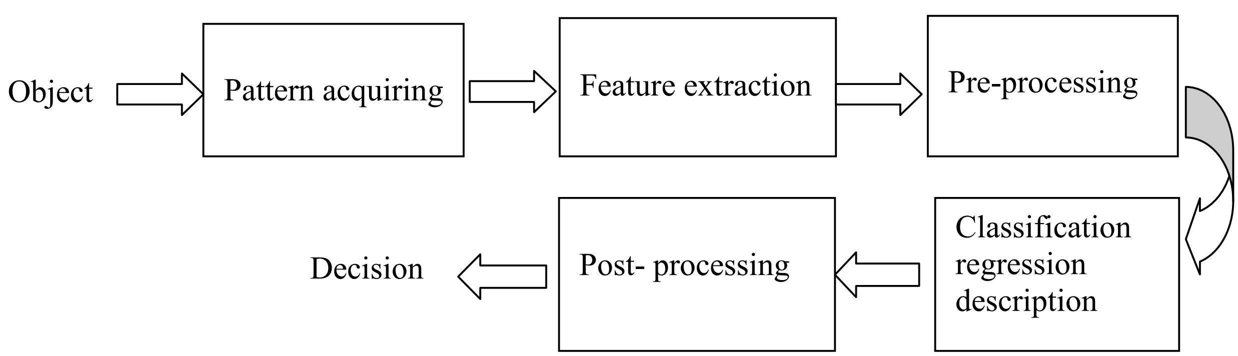

Figure 2.6: Diagram of pattern recognition structure.

Some scientific area, which is used image in its applications, needs to produce interpretation of that image, through portion image into regions. Image segmentation is the basic step to satisfy this task.

2.6 Method of analysis

In this thesis our interest is to recognize the number in image. To satisfy this goal it is necessary to use some approaches such as segmentation to separate object from background. In the segmented image, some mask noise or stains of noise may be appeared in the image, then median filter might be help for noise reduction. Then, the projection approach may be needed to reduce dimension of image, that help to see and detect some properties in the image.

2.6.1 Segmentation

In image analysis our intent is to estimate the unknown part in the image. This part represents the reality, image segmentation is important procedure works by the same manner.

Segmentation means dividing the image into disjoint regions by using different methods such as:

1. Edges segmentation methods.
2. Regions segmentation methods.

These methods are related by two characteristics, discontinuity and similarity. Different properties determine which of segmentation methods are more suitable in implementation. For example if there exists rapidly change in intensity values, then edges segmentation methods are better than regions segmentation methods. The basic in regions segmentation methods is to portion the image into similar regions where pixel values that represent foreground have the same value and the others which represent the background have the same value too, some of these methods are thresholding, region growing, splitting and merging, while the basic in edge detection is to segment the object from background according to huge different in pixel intensity, such edges segmentation operator are soble, canny, laplasing and prewitt, see Gonzalez and Woods (2001).

Segmentation procedure should stop when the object is detected, and the final result of segmentation gives an idea about accuracy of segmentation methods, one of the most important approaches of segmentation is the thresholding.

2.6.1.1 Thresholding

In the field of digital image processing, some methods require dividing an image to regions represent the objects and the other represent the background. According to intensity properties the different in intensity values can be determined by edges detection operations, also similarity in separated regions values can be obtained by many methods one of the most common methods is thresholding, see Gonzalez and Woods (2001).

The basic concept of thresholding method is to classify a group of pixels that have values higher than threshold values as foreground with unique values equal to 1, and the other group of pixels that have values equal or lower than threshold values as background with unique values equal to 0 (or vice versa). So the output thresholding is a binary image, but the input may be colour or gray level image. For more details see Medasani and Krishnapuram (1994). Threshold is classified into two categories, local threshold, and global threshold.

Global Threshold

In some cases one threshold value is enough to separate the foreground and the background in image. This threshold is applied over entire region of image. This case is called global threshold and defined as:

$$g(i,j)=\begin{cases}0 & x(i,j)\le T\\ 1 & x(i,j)>T\end{cases}$$

where

T is threshold value.

$x(i,j)$ is the intensity function.

$g(i,j)$ is the threshold output.

Image with light background and a dark object (or vice versa) results, single threshold or global threshold, as plotted in Figure 2.7(a).

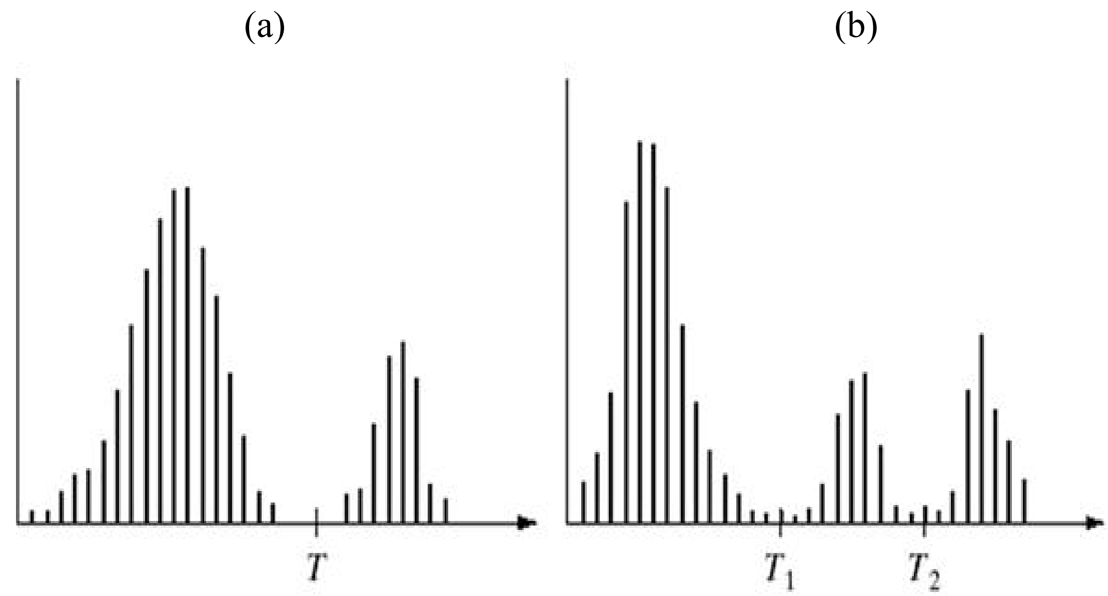

Figure 2.7(a) Single thresholding; (b) Multiple thresholding.

Local Threshold

Many applications require obtaining binary image from gray-level, or colour image, in some cases unique thresholding is sufficient to achieve this mission, but sometimes image histogram with three peaks yields two threshold values (multi-thresholding). Local threshold can be formed as follows:

$$g(i,j) = \begin{cases} a & x(i,j) > T_2 \\ b & T_1 < x(i,j) \le T_2 \\ c & x(i,j) \le T_1 \end{cases}$$

where,

T_1 and T_2 are two different level of threshold,

a, b, c, any three constants.

Image with dark background and two light objects (or vice versa) results multiple threshold, as plotted in Figure 2.7(b).

Pixels are classified to background if $x(i, j) \le T_1$, and classified to object if $T_1 < x(i, j) \le T_2$, the rest pixels are classified to other object if $x(i, j) > T_2$.

Available information about the object may help to select threshold value, such of these information are:

- Size of the object.
- Number of different objects in the image.
- Area of object in the image.

There are many approaches to select thresholding, such as histogram method, percentile method, and iterative method.

In this thesis threshold value will be selected by an iterative algorithm.

Iterative algorithm

Threshold system which select suitable threshold without human intervention by some knowledge of object such as size, location is called automatic thresholding. Iterative thresholding is one of algorithms that is used to choose global threshold automatically.

The basic steps in iterative algorithm are classified as follows:

1. Select initial value of thresholding (often the best value is the mean).
2. Portion the image into two regions R_1 and R_2 according to initial value.
3. Calculate the mean for each region.
4. Calculate new value of T by

$$T = \frac{m_1 + m_2}{2}$$

where:

m_1 and m_2 are the means of R_1 and R_2 respectively.

5. The steps from 2 to 4 will be repeated until the mean for each region in sequential iterations remain fixed, this lead to threshold value.

Example 2.1

Consider an image represents watch, that contains multi-number, these numbers are objects in the image. Figure 2.8 shows real image.

Figure 2.8: Image of watch

In this image some details are not necessary so to reduce processing time, some details will be removed, and the processing will confine on the part that consists of the numbers as shows in Figure 2.9.

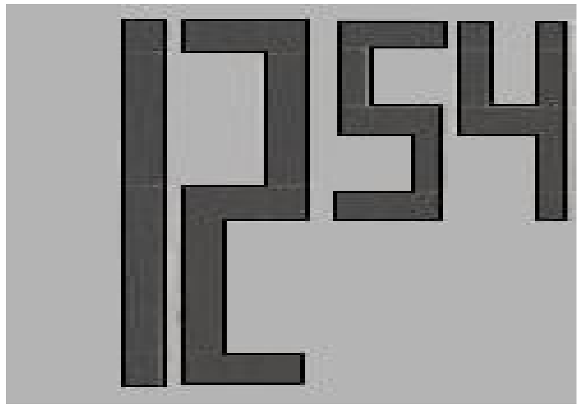

Figure 2.9: Sub-image contains numbers only from example 2.1

To detect the numbers, it will be suitable to separate these numbers from background (make an image binary) using thresholding based on intensity of pixels.

Since there are many approaches to select threshold, herein threshold value is chosen by using iterative algorithm, this value is found to be 90.8. which is applied to image and, it gave good results as shows in Figure 2.10.

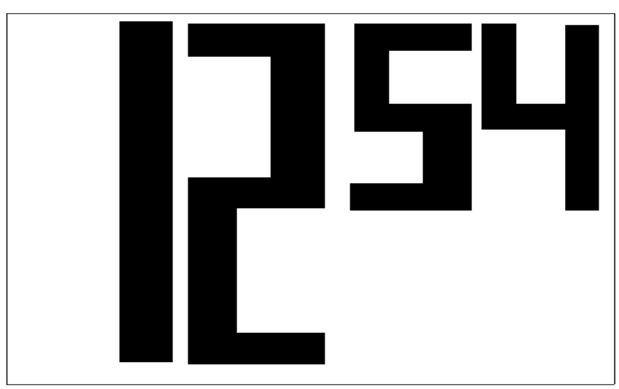

Figure 2.10: Thresholded image

Enhancing techniques of image processing, such as smoothing filters, are concerned with removing the noise from the image. The simplest smoothing algorithms are mean filter and median filter.

In this thesis the median filter is used rather than the mean filter since the median is more effective than the mean in the case of salt and pepper noise and edges protection.

2.6.2 Median Filter

Median filter, which suggested by Tukey in 1974, is used to reduce the effect of noise. The median filter is defined as internal pre-processing for each pixel corrupted by noise, this is non linear process, is more appropriate than the mean filter when the value of the pixel diverges from its neighbors by large magnitude.

Also, median filter is used when the pattern of the noise trends to appear as white points in black foreground and black points in white background, this kind of noise is called salt and pepper noise.

The basic idea of the median filter is sorting the intensity values of specified neighborhood (first order or high order) and replacing each pixel in this neighborhood by median of its neighbors, this process will be achieved for all pixels in the image, Hwang and Haddad (1995).

Mean filter can be used, if the distribution of neighborhood is Gaussian distribution, Hayat *et al.* (1995) . As known, and in many cases median filter is robust than mean filter in case of object edges protecting, since median value is the pixel value in the neighborhood.

The median method depends on replacing gray-level value of pixel by median of its neighbors, it is convenient to select this window to be odd order, but if even , the median in this case will be the mean of two middle values.
Sorting intensities values in increasing or decreasing order makes median approach too expensive to time as the resolution increases. After sufficient iterations of median process, the final result will produce more accurate version of input image See Church *et al.* (2008).

As the area of neighborhood increases as the median filter can be applied, but some details may lost. First order median filter means that selecting median value from four sorted pixels with studied pixel, while second order is selected median from eight sorted pixels in neighborhood with studied pixel. Figure 2.11. shows the calculation of first and second order median filter.

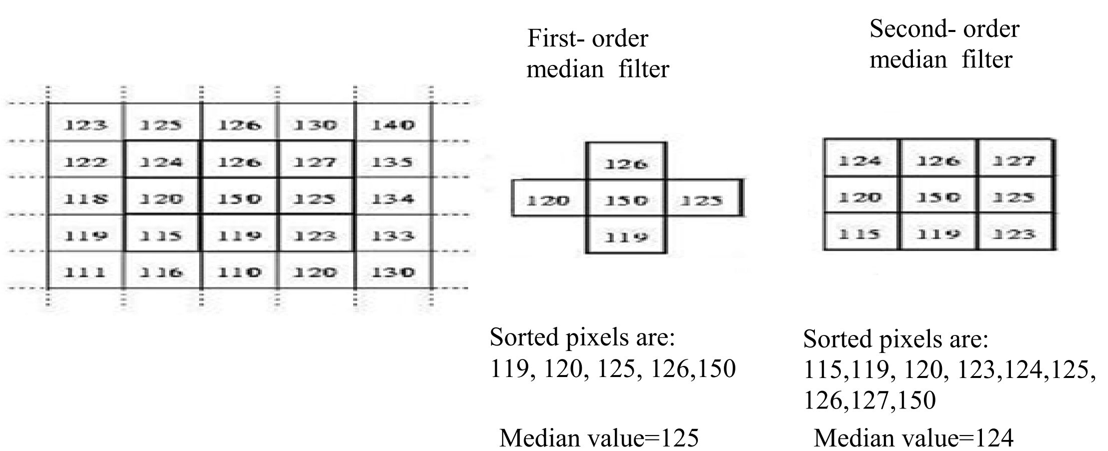

Figure 2.11: Calculation of the median value from first and second neighborhood.

Example 2.2

This example explains how median filter is worked well to remove isolated points (salt and pepper noise). Salt and pepper noise have been added to an image with level 2%, median filter process is implemented to select median value of sorted pixels of first order neighborhood. Figure 2.12(a) shows an image from example 2.1 with isolated pixels, while Figure 2.12(b) presents the result of applying median filter.

(a) (b)

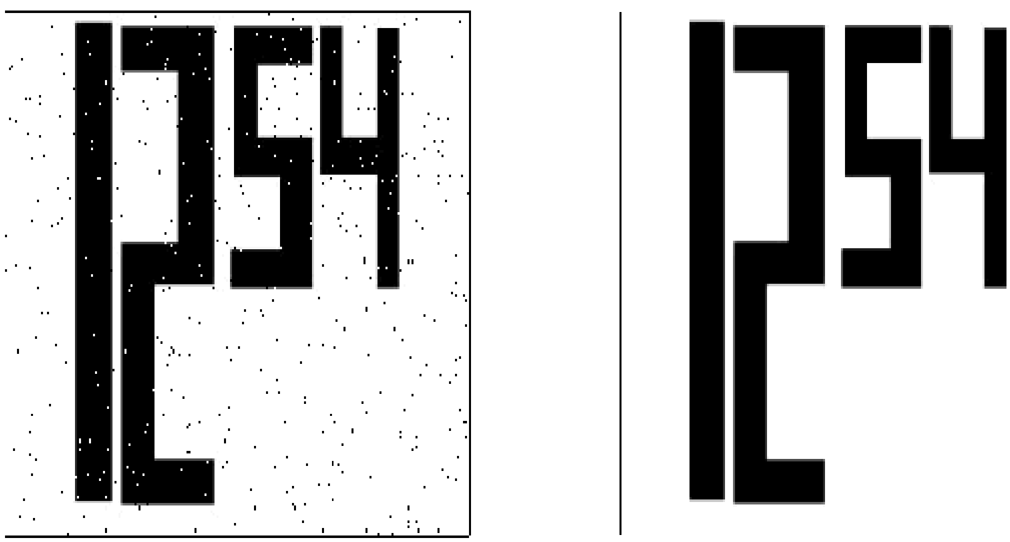

Figure 2.12: (a) Image with isolated pixels; (b) Filtered image.

2.6.3 Projection Approach

Projection method is used for dimension reduction, it is a mathematical transformation which is used to map three dimensional plane (3D) into two dimensional plane (2D). The projection method is widely used in many scientific areas such as chemistry, physics, and medicine.

Image reconstruction from Projection which is considered to be special class of image restoration, this is done by obtained two or higher dimension of object from one dimension project, as example, x-ray pictures which is used in medical imaging, Rao (1995).

Projection approach techniques are useful in many fields such as, medical imaging (C.T.scanners), radar pictures, geological exploration, and astronomy.

In this work, projection method is suggested to obtain image stripe (one dimensional data) by calculation the sum of rows and columns of binary image. Suppose numerical matrix of image data is denoted by A, horizontal vector is denoted by H which consists of elements, say, $H = (h_1, h_2, h_3, ..., h_N)$. The vertical vector is denoted by V which consists of elements, say, $V = (v_1, v_2, v_3, ..., v_M)$, then the projection can be computed by the form:

$$h_i = \sum_{j=1}^{M} a_{ij}\ , \quad v_j = \sum_{i=1}^{N} a_{ij}\ , \quad \begin{matrix} i = 1,2,\ldots,N \\ j = 1,2,\ldots,M \end{matrix}$$

H= Horizontal projection, *V* = Vertical projection, *a* = Elements in matrix *A*. As simple concept of projection approach. That is displayed in Figure 2.13. Letter A is represented as an object in this image. The horizontal projection is calculated and plotted in Figure 2.13(b), which consists of three groups of numbers, while vertical projection has four groups of numbers.

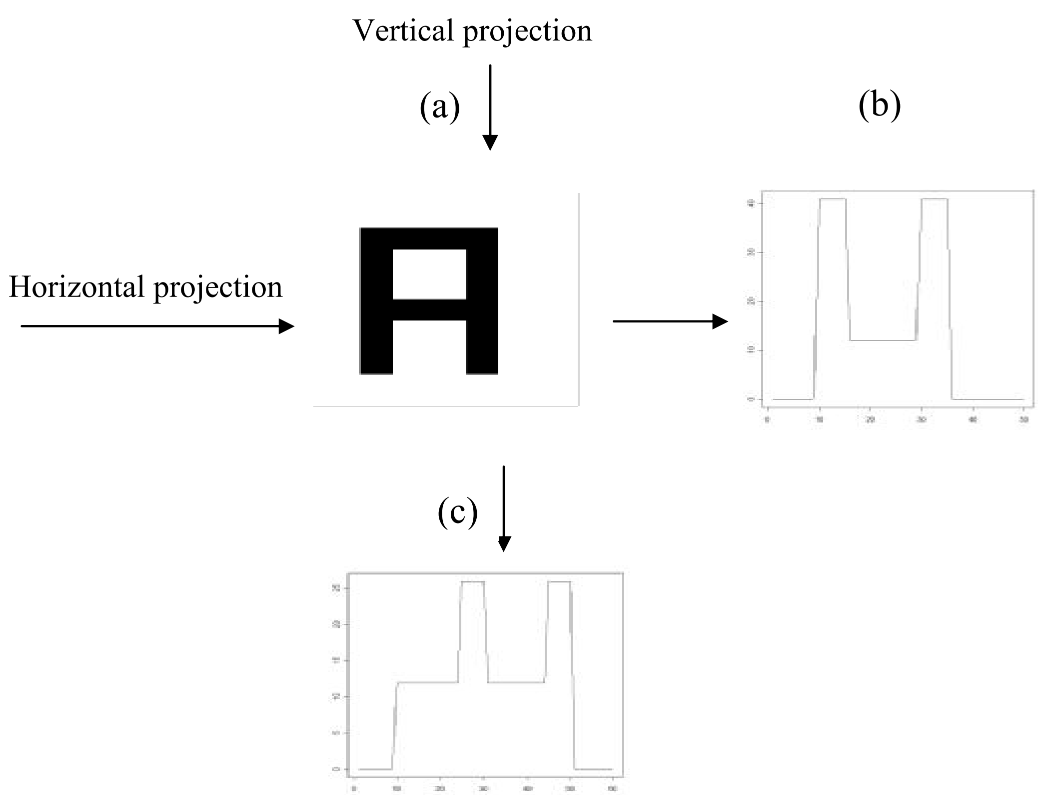

Figure 2.13: (a) letter A; (b) Horizontal projection; (c) Vertical projection.

Example 2.3

In this example the concept of projection approach will be explained and applied to the image which is introduced in Example 2.2. Figure 2.14 shows the profile, which is obtained from image 2.12(b). This profile is resulted by calculating the sum of each row in the data in Figure 2.12(b).

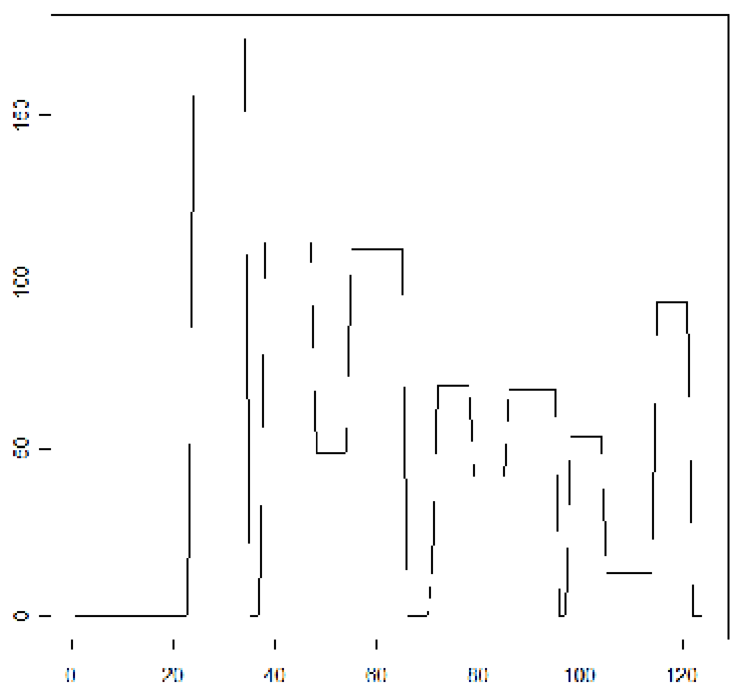

Figure 2.14: profile of rows.

The profile of rows is plotted in Figure 2.14. this profile is done by summation of each rows in Figure 2.12(b).

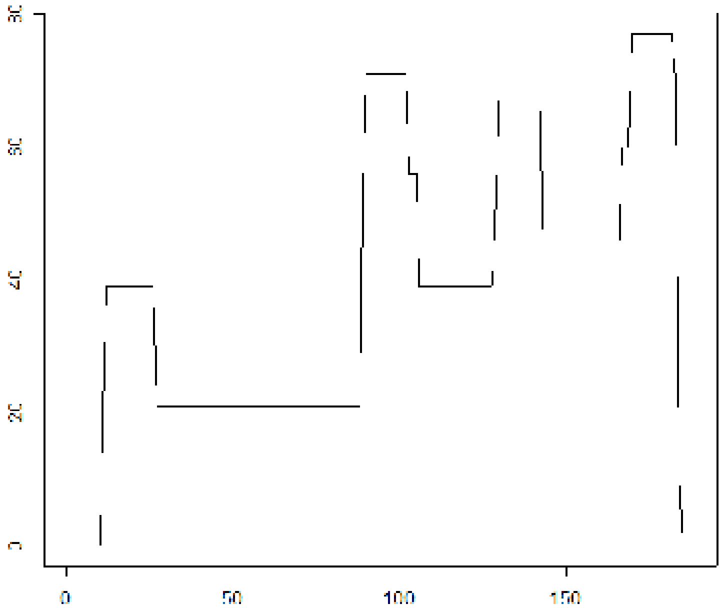

Figure 2.15: profile of columns.

The profile of columns, in Figure 2.15, has been shown four main blocks with three gaps among the blocks, each block represents object (number) in Figure(2.12)b.

Chapter 3

Number Recognition Algorithm

3.1 Introduction

To recognize the objects in the image, the shape of the object should be determined. Here the objects will be considered as numbers. Since the numbers can be formulated by many forms, the motivation behind this work is to design recognition algorithm of specific type of numbers. Those are consisted of lines and corners.

This chapter presents proposed algorithm, which is supposed to deal with noisy image with digital number as object. So, the algorithm suggests methods to remove the noise and keep the image as binary image. Then the algorithm proposes an approach to recognize the number in the image automatically.

3.2 Proposed Algorithm

Usually, image data is noisy and sometimes blurred. So recognition algorithm starts with pre-processing steps (noise reduction) such as threshold method.

In many cases, kind of noise will appear, such as salt and pepper noise, the median filter method is suggested to remove this noise. The next step in the recognition algorithm is feature extraction of each number from the profile image, by calculating the sum of both rows and columns of the filtered image. Then, criterion of each number will be proposed to recognition each number.

After then the algorithm will be evaluated on simulated image, if good results are obtained, the algorithm will be applied to real data. Finally the result of recognition algorithm appear as theoretical decision explain the number. As example, if the input image contains number five, and the general algorithm(Thresholding , median filter, projection method) is applied to the input image, the final result will appears as a massage explains the number, such as: " the number is five ".

The General Algorithm

The general algorithm, of number recognition, consists of some methods and steps which can be summarized as follows:

Firstly, the image is converted to binary and free-noise image, as much as possible, by the following steps.

1. Select global threshold by the iterative algorithm.
2. Apply the obtained threshold to segment the image into foreground (object) and background.
3. Use the median filter method to remove the noise in the thresholded image.

After the techniques of low-level image processing have been done, next step is number recognition or high- level image processing which is constructed as follow:

4. Find the vector H that consists of horizontal profile, and another vector V for vertical profile. This step is projection approach.
5. Remove the zeros values, and repeated values from the vectors H and V in step 4.

Now, the properties to recognize each number are in the following steps

6. If there are three elements in both vectors H^* and V^*, the first value is equal to the third value in both vectors H^* and V^*, also the first value and the third value are greater than the second value in both vectors H^* and V^* then the number is zero.
7. If there exist one element only of vectors H^* and V^*, then the number is one.
8. If there are three elements in vector H^* and five elements in vector V^*. The first value and the third value are greater than the second value in vector H^*, also the first, the third, and the fifth value are greater than the second and the fourth value in vector V^*, this property is important to recognize the number two but it is not sufficient since the profiles of numbers two, five, and eight are similar, the algorithm will give misleading results. So, the algorithm suggests extra properties to distinguish the numbers two, five, and eight, these properties are:

Store the first group of the vertical non-zeros values in matrix, that represents the binary image, in vector A this process will continuous until get on first zero in the image and store the last group of the vertical non-zeros values in matrix, that represents the binary image, in vector B if the length of vector A is greater than the length of vector B, then the number is two.

9. If the length of vector H^* is equal to two, and the length of vector V^* is equal to five, the second value is greater than the first value in the vector H^*, then the number is three.
10. If three elements are in both vectors H^* and V^*. The third value has the largest value in vector H^* and the middle value has the largest value in vector V^* then the number is four.
11. If there are three values in vector H^* and five values in vector V^*. The first value and the third value are greater than the second value in vector H^*, also the first, the third, and the fifth value are greater than the second and the fourth value in vector V^*, extra properties are:

Store the first group of the vertical non-zeros values in matrix, that represents the binary image, in vector A this process will continuous until get on first zero in the image and store the last group of the vertical non-zeros values in matrix, that represents the binary image, in vector B if the length of vector A is less than the length of vector B, then the number is five.

12. If there are three values in vector H^* and five values in vector V^*. The first value has the largest value in vector H^* and the second value is greater than the fourth value in vector V^* of the same vector, then the number is six.

13. If the length of vectors H^* and V^* are equal to two, the second value is greater than the first value in both vectors H^* and V^* then the number is seven.

14. If there are three values in vector H^* and five values in vector V^*. The first value and the third value are greater than the second value in vector H^*, also the first, the third, and the fifth value are greater than the second and the fourth value in vector V^*, extra properties is:

Store the first group of the vertical non-zeros values in matrix, that represents the binary image, in vector A this process will continuous until get on first zero in the image and store the last group of the vertical non-zeros values in matrix, that represents the binary image, in vector B if the length of vector A is equal to the length of vector B, then the number is eight.

15. If there are three values in vector H^* and five values in vector V^*. The third value has the largest value in the vector H^* the fourth value is greater than the second value in vector V^*, then the number is nine.

The above properties to recognize each number are summarized in Table 3.1, but before this it is necessary to explain some symbols.

N = number of rows.

M =number of columns.

H^* : Vector contains values those resulted from horizontal profile, after excluding the zeros and repeated values.

V^* : Vector contains values those resulted from vertical profile, after excluding the zeros and repeated values.

$$h_i^* = i^{th} \text{ element of vector } H^*, \text{ and } v_j^* = j^{th} \text{ element of vector } V^*.$$

The vectors A and B contain additional steps to recognize the numbers two, five, and eight.

Table 3.1: Summary of general algorithm steps

	Properties of rows	Properties of columns	The classification
1	$h_1^* = h_3^*, \quad h_1^*, h_3^* > h_2^*$	$v_1^* = v_3^*, \quad v_1^*, v_3^* > v_2^*$	The number is zero
2	One element in vector H^* h_1^*	one element in vector v^* v_1^*	The number is one
3	$h_1^* = h_3^*, \quad h_1^*, h_3^* > h_2^*$	$v_1^*, v_3^*, v_5^* > v_2^*, v_4^*$ Length(A) > Length(B)	The number is two
4	$h_2^* > h_1^*$	$v_1^* = v_3^* = v_5^*, \quad v_2^* = v_4^*$	The number is three
5	$h_3^* > h_1^*, h_2^*$	$v_2^* > v_1^*, v_3^*$	The number is four
6	$h_1^* = h_3^*, \quad h_1^*, h_3^* > h_2^*$	$v_1^*, v_3^*, v_5^* > v_2^*, v_4^*$ Length(A) < Length(B)	The number is five
7	$h_1^* > h_2^*, h_3^*$	$v_1^* = v_3^* = v_5^*, \quad v_2^* > v_4^*$	The number is six
8	$h_2^* > h_1^*$	$v_2^* > v_1^*$	The number is seven
9	$h_1^* = h_3^*, \quad h_1^*, h_3^* > h_2^*$	$v_1^*, v_3^*, v_5^* > v_2^*, v_4^*$ Length(A) = Length(B)	The number is eight
10	$h_3^* > h_1^*, h_2^*$	$v_1^* = v_3^* = v_5^*, \quad v_2 < v_4$	The number is nine

Chapter 4

Application to Simulated Data

4.1 Introduction

In this chapter the stages of the recognition algorithm will be applied to simulated data through some examples. These examples are used to evaluate the algorithm. An example to recognize number four will be demonstrated. The cause to select number four as first example, return to special characteristic shape of this number, and its profile (horizontal and vertical profile). The other numbers will be presented briefly in next examples. After that the algorithm will be applied to real data.

Before the recognition algorithm has been used, it is important that the noise in the image should be removed. Since the noise may appear in any image, the ability of using median filter algorithm will be available in this case.

In this chapter recognition algorithm will be applied to simulated data, if successful results are obtained, the algorithm will be applied to real data.

Example 4.1

Number four has been generated to demonstrate the suggested algorithm. An image, with number four as object, is generated and displayed in Figure 4.1(a). The resolution of this image is 200×200 pixels. The values of pixels those represent the object are equal to one.

The Gaussian noise, with mean 0 and standard deviation 0.2, has been added to the image and the resulted image is shown in Figure 4.1(b).

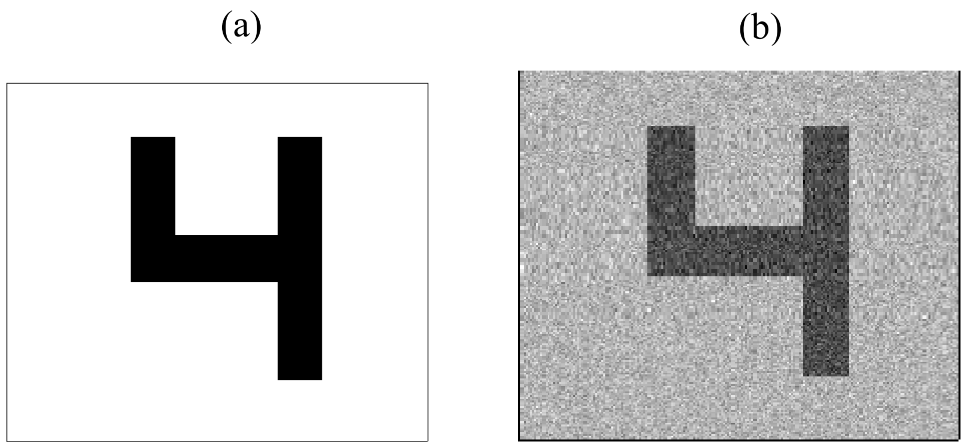

Figure 4.1 (a) Binary image; (b) Noisy image.

According to the algorithm, the first step is to segment the noisy image into binary image, the value of threshold is obtained by using iterative method and it is equals to 0.492. Figure 4.2 shows the thresholded image. Salt and pepper noise still appears in the image.

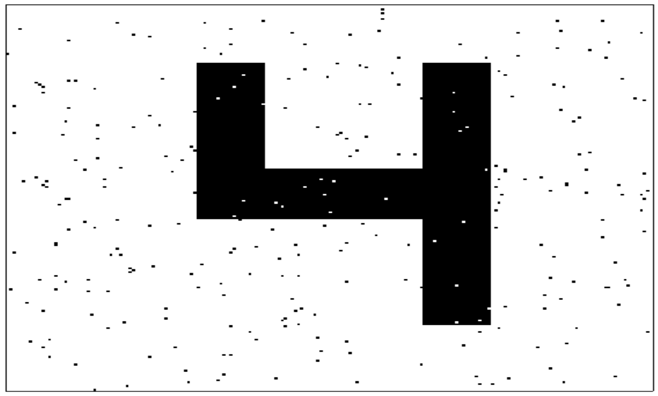

Figure 4.2 Thresholded image.

The median filter method is suggested in the algorithm to remove salt and pepper noise. First order median filter has been applied to the thresholded image. The result is shown in Figure 4.3.

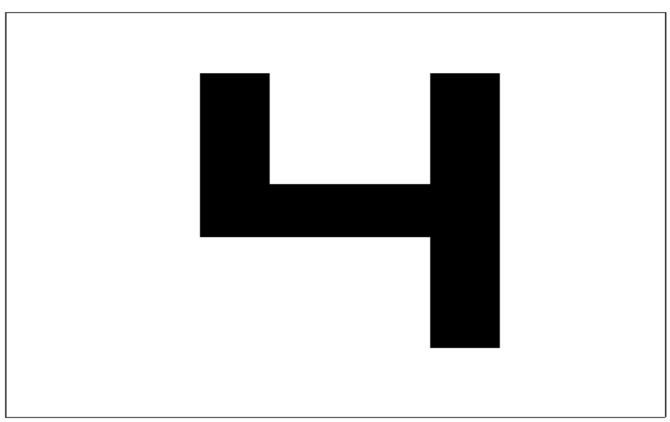

Figure 4.3 Filtered image from example 4.1.

According to step 4 in the general algorithm, the profile image (projection) is obtained by store the summation of each row in the binary image, in vector H. And calculate the summation of each column, then store the results in vector V. The vector H and the vector V are plotted in Figure 4.4(a) and (b) respectively.

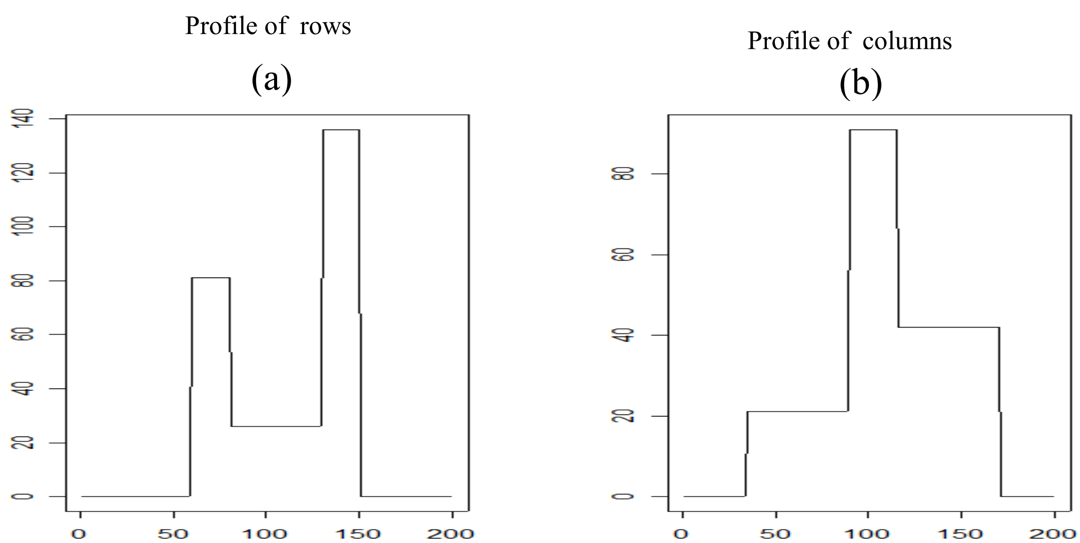

Figure 4.4 Projection: (a) Horizontal profile, (b) Vertical profile.

Since the goal is to recognize the number (foreground) in the image, and the zeros, in the vectors H and V are represented the background, then the zeros will be ignored in both vectors. The values in vectors (H and V) will be summarized in new vectors (H^* and V^*), where the summarizing is made by take one value from every group of values, which have similar values (step 5 in the algorithm). In this example the new vectors are:

H^* = (81, 26 , 136) , V^* = (21, 91, 42). This result explained in Figure 4.4.

Since the vectors H^* and V^* contain three values, where the third value is the largest value in the vector H^*, and the middle value is the largest value in the vector V^*. This result is satisfying the condition of step 10 in the general algorithm and the property 5 in Table 3.1, $h_3^* > (h_1^* \& h_2^*)$, $v_2^* > (v_1^* \& v_3^*)$. Then the number in the image is four.

Since the data in this example is simulated and the algorithm recognizes the number in the image correctly. This gives an indication that, the algorithm is doing well.

The next examples will testify the algorithm to other numbers, the examples present the steps of the algorithm and the results briefly.

Example 4.2

Number zero:

The object of the image in this example is number zero, that simulated and it displays in Figure 4.5(a), the threshold value is found to be 0.494, and the thresholded image is in Figure 4.5(b). Median filter is applied to the thresholded image and the result is given by Figure 4.5(c).

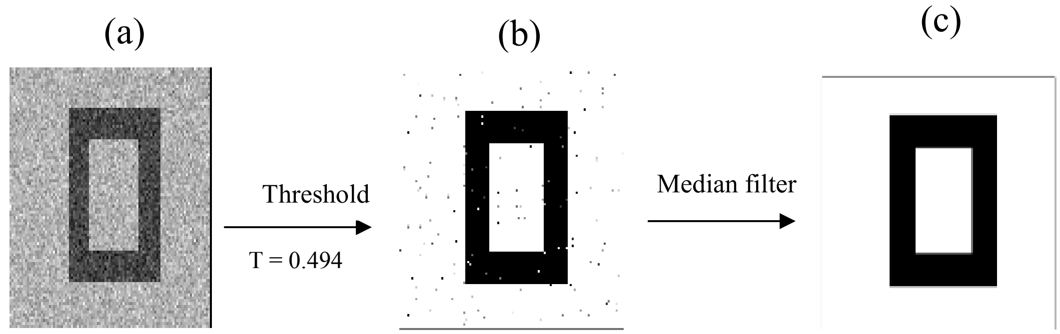

Figure 4.5 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

The projection approach has been applied to the filtred image and plotted in Figure 4.6(a) and (b).

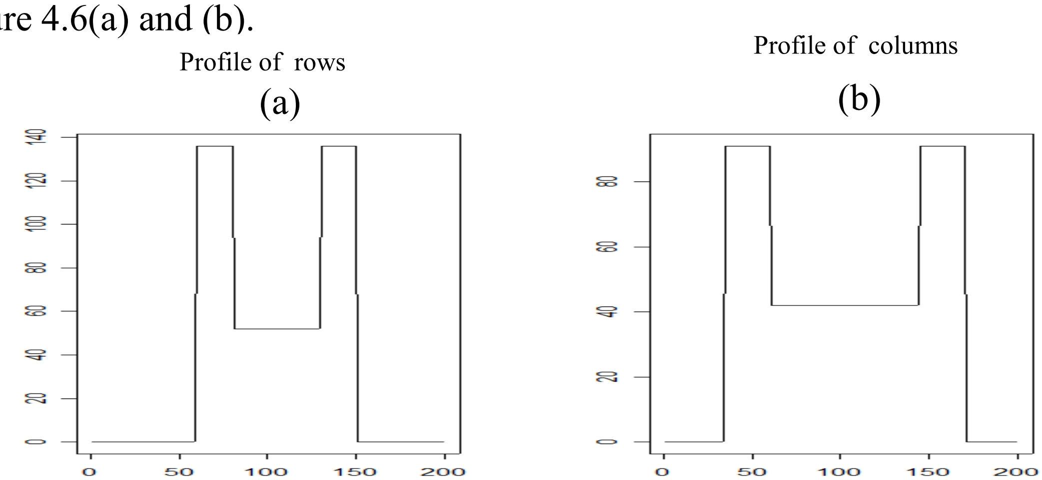

Figure (4.6) Projection: (a) Horizontal profile, (b) Vertical profile.

Both profile of rows and columns consist of three groups, and they yield H^* = (136, 52 , 136) , and V^* = (91, 42, 91). As mentioned in the general algorithm, the number recognizes as zero if the first value equal to the third value in the vector H^* and the vector V^* , also the first value and the third value are largest than the second value in the vector H^* and the vector V^* , where $h_1^* = h_3^*$ and $(h_1^* \,\&\, h_3^*) > h_2^*$, $v_1^* = v_3^*$ and $(v_1^* \,\&\, v_3^*) > v_2^*$.

This result is corresponded to property 1 in Table 3.1.(step 6 in the general algorithm). So, the algorithm detects number in this example as zero.

Example 4.3

Number one:

Noisy image, thresholded image, filtered image, and profile for number one are plotted in Figure 4.7 and Figure 4.8, where threshold value is equal to 0.475

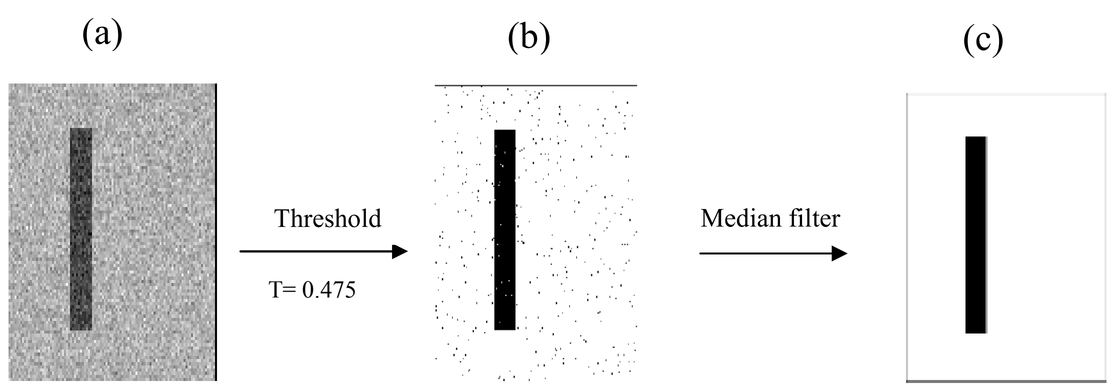

Figure 4.7 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

The projection approach has been applied, and explained in Figure 4.8.

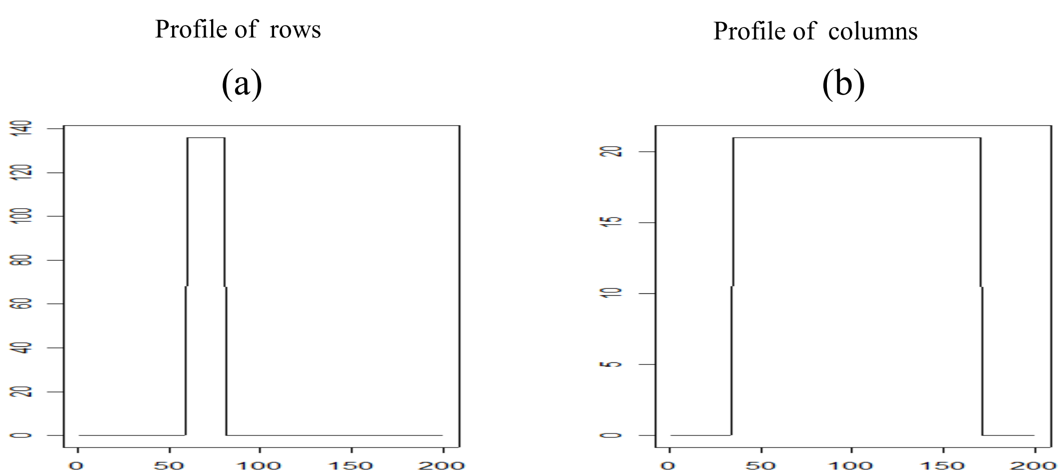

Figure (4.8) Projection: (a) Horizontal profile, (b) Vertical profile.

There are one group in the profile of rows and profile of columns in this example, then H^*= (136) , V^*= (21), both vectors contain one value. h_1^* and v_1^*. The property 2 in Table 3.1 is uniquely appeared for number one only. So, the number in this example is detected by the algorithm as number one, (step 7 in general algorithm).

Example 4.4

Number two:

The threshold value in this example is obtained 0.493, this value yields the thresholded image, as shown in Figure 4.9(b), and then median filter is used.

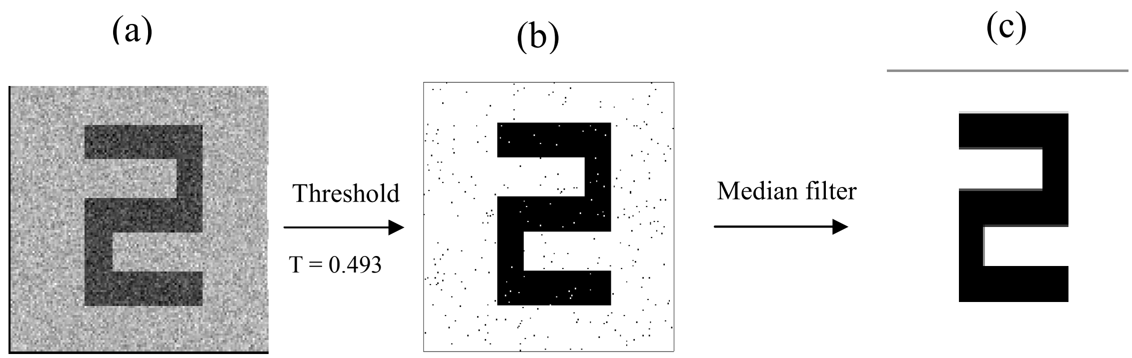

Figure 4.9 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

Results of applied projection approach are plotted in Figure 4.10(a), and (b).

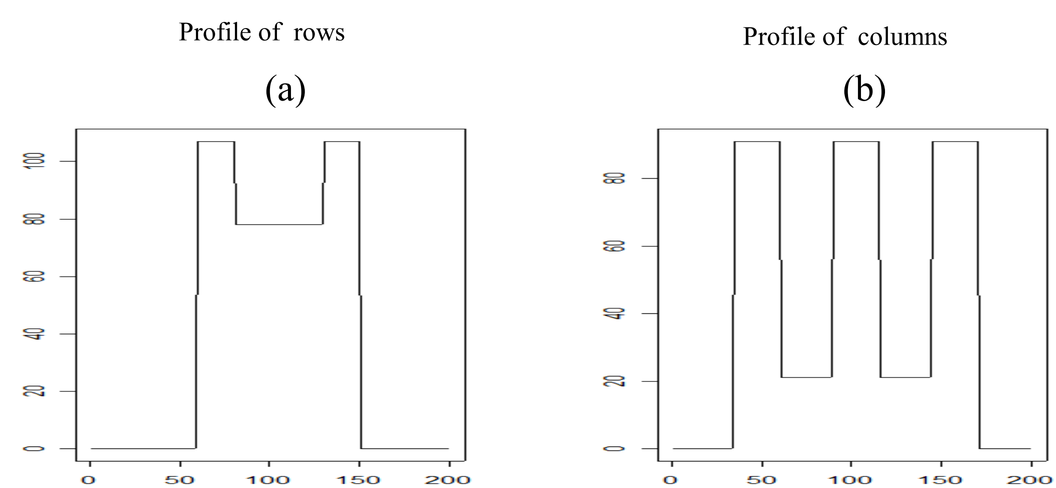

Figure (4.10) Projection: (a) Horizontal profile, (b) Vertical profile.

Profiles in this example show three groups of numbers in row profile, and five groups of numbers in columns profile. The profile can be summarized in these two vectors $H^* = (107,78,107)$, $V^* = (91,21,91,21,91)$. The first and the third values in the vector H^* have largest value than the second value $(h_1^* \& h_3^*) > h_2^*$, also the first value , the third value, and the fifth value are the largest values than the second and fourth values in the vector V^* , $(v_1^* \& v_3^* \& v_5^*) > (v_2^* \& v_4^*)$. The property 3 in the Table 3.1.

According to extra steps in the general algorithm, length of vector *A* in this example is 110, and the length of vector *B* is 55. So, the length of vector *A* is greater than the length of the vector *B* (step 8 from general algorithm). The algorithm is recognized the number as two.

Example 4.5

Number three:

The threshold value that obtained from iterative algorithm is 0.493. Then filtered image is obtained by median filter approach.

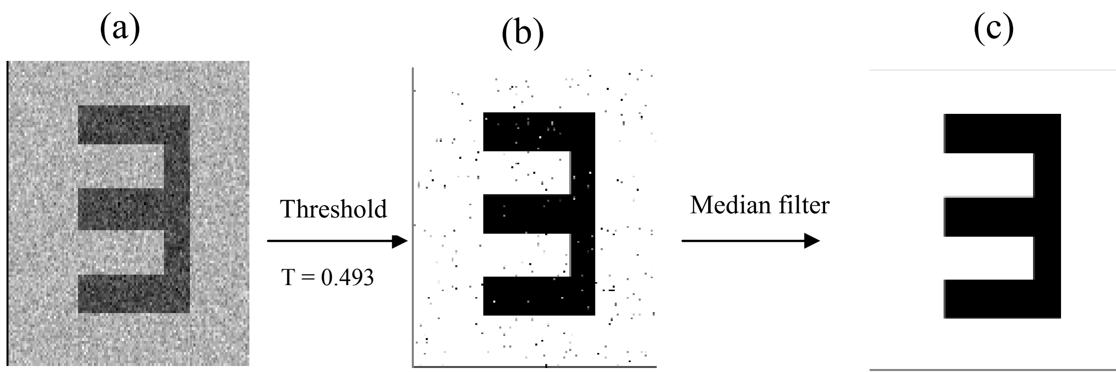

Figure 4.11(a) Noisy image, (b) Thresholded image, (c) Filtered image.

Projection method is plotted in Figure 4.12.

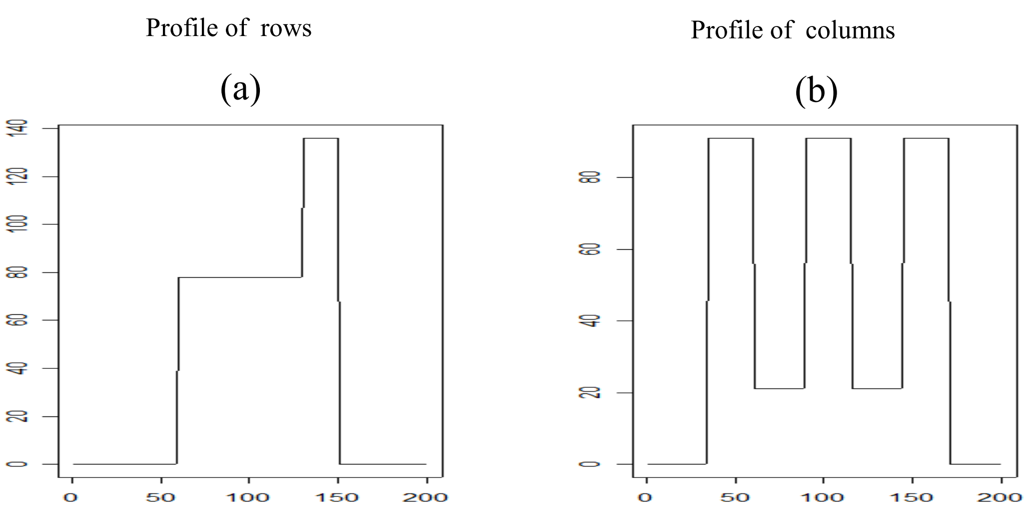

Figure (4.12) Projection: (a) Horizontal profile, (b) Vertical profile.

The profile of rows is shown two groups of non-zero data, while the profile of columns, has five groups of non-zero data. The two profiles are summarized to: $H^{*}=(78,136)$, and $V^{*}=(91,21,91,21,91)$.

Since the length of vector H^{*} is equal to two, and the length of vector V^{*} is five, also the second value in the vector H^{*} has the largest value $h_{2}^{*} > h_{1}^{*}$. The property 4 in the Table 3.1, then the number in the image is detected as number three, (step 9 in the general algorithm).

Example 4.6

Number five:

The object in the image in this example, is simulated to be number five. The threshold value has been obtained as 0.495.

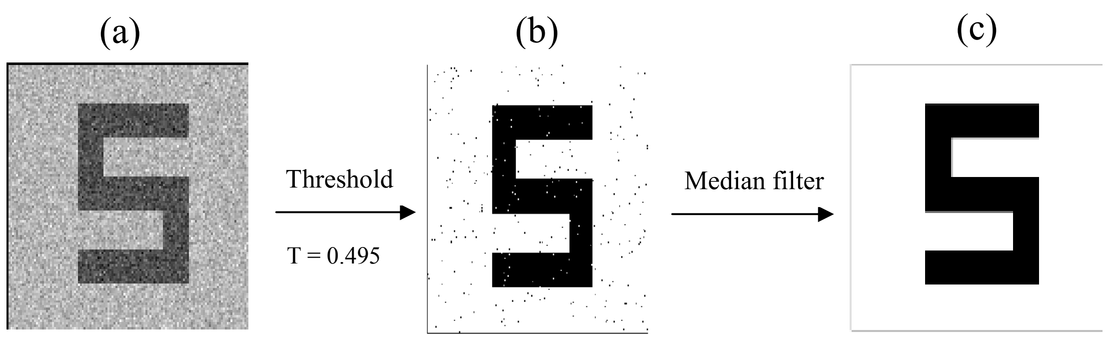

Figure 4.13 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

Horizontal and vertical profile of the filtered image are plotted in Figure 4.14.

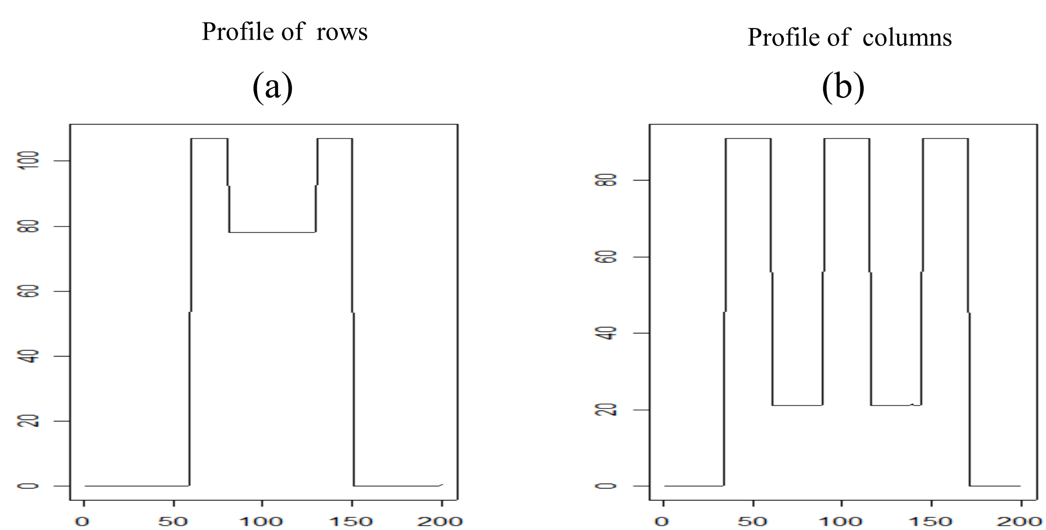

Figure (4.14) Projection: (a) Horizontal profile, (b) Vertical profile.

Horizontal profile contains three groups, and vertical profile has five groups. Then H^* =(107, 78, 107), and V^* =(91, 21, 91, 21, 91). The first and the third values in the vector H^* are greater than the second value $(h_1^* \& h_3^*) > h_2^*$, also the first value , the third value, and the fifth value are the largest values than the second and fourth values in the vector V^* , $(v_1^* \& v_3^* \& v_5^*) > (v_2^* \& v_4^*)$. The property 6 in the Table 3.1.

According to the additional steps in the general algorithm of number five:

Length of vector A is 55, and it is less than the length of vector B which is equal to 110. So, the algorithm is successfully detected the number in this example as number five, (step 11 of the general algorithm).

Example 4.7

Number six:

Figure 4.15 explains the algorithm steps to convert the noisy image into binary one.

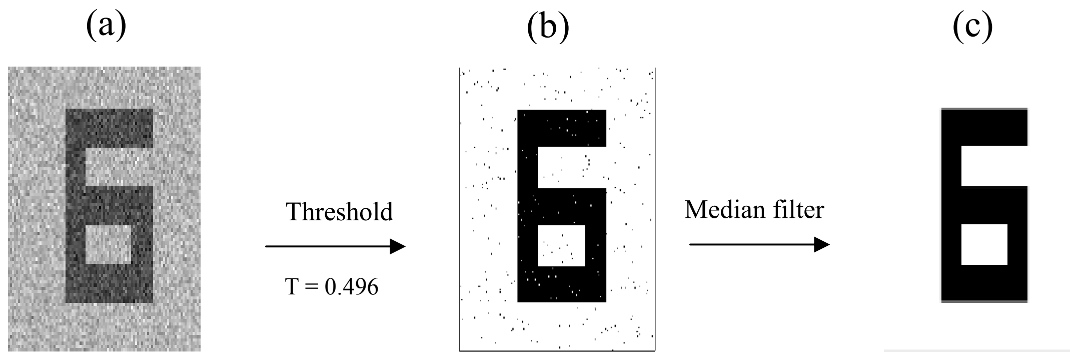

Figure 4.15 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

The hoizontal and vertical projections of the binary image are displayed in Figure 4.16.

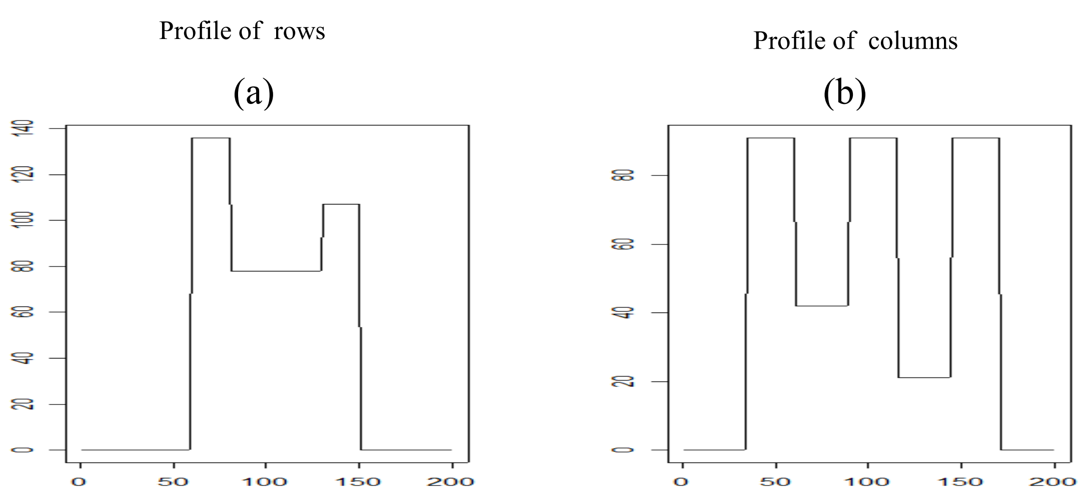

Figure (4.16) Projection: (a) Horizontal profile, (b) Vertical profile.

The rows profile consists of three groups of numbers, and the columns profile has five groups of numbers, these groups are represented in the vectors,

H^*= (136, 78,107) , V^*= (91,42,91,21,91). The first value in the vector H^* is the largest value, $h_1^* > (h_2^* \& h_3^*)$ while the second value in the vector V^* is greater than the fourth value, $v_2^* > v_4^*$ and the first, the third, and the fifth values are equal, $v_1^* = v_3^* = v_5^*$. The property 7 in the Table 3.1, then the algorithm will detect the number as six, (step 12 from the general algorithm).

Example 4.8

Number seven:

This example shows the summary of the algorithm steps when applied to simulated data with nummber seven as object. The threshold value is obtained, and equal to 0.486

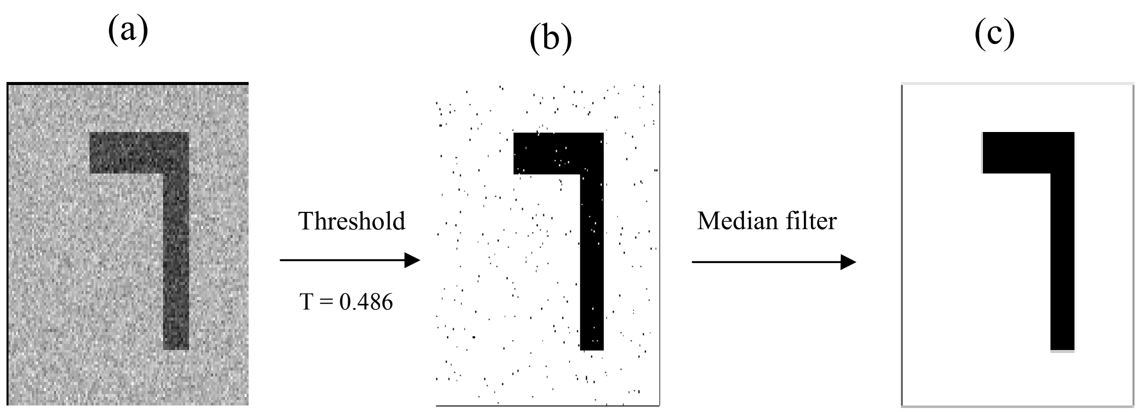

Figure 4.17 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

The projection method is demonestrated in Figure(4.18).

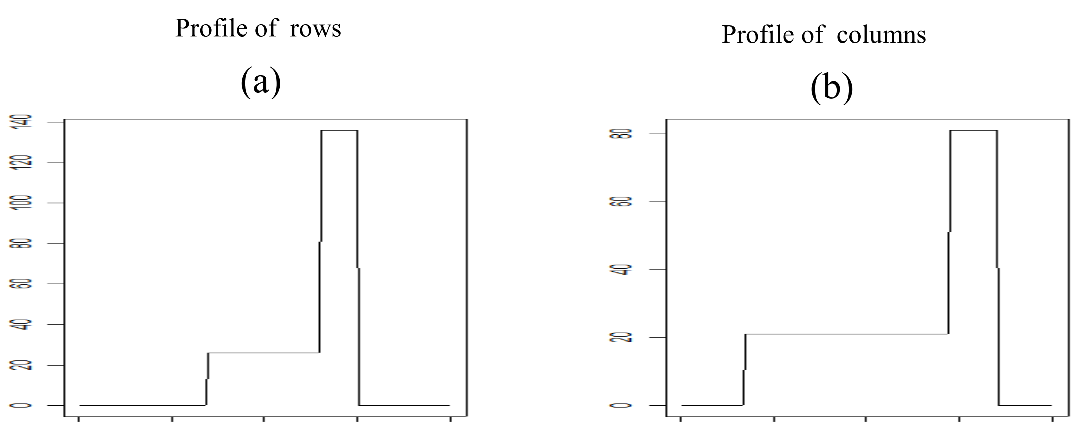

Figure (4.18) Projection: (a) Horizontal profile, (b) Vertical profile.

Horizontal profile, and vertical profile consists of two groups, these groups are summarized in the vectors H^* = (26,136) and V^* = (21,81).

The length of vector H^* is equal to the length of vector V^*, the second value in the vectors H^* and V^* are greater than the first value $h_2^* > h_1^*$, $v_2^* > v_1^*$. The property 8 in the Table 3.1.

According to step 13 in the general algorithm, the number in this example is correctly detected as number seven.

Example 4.9

Number eight:

The main algorithm steps, in this example are shown in Figure 4.19 with threshold value equal to 0.496

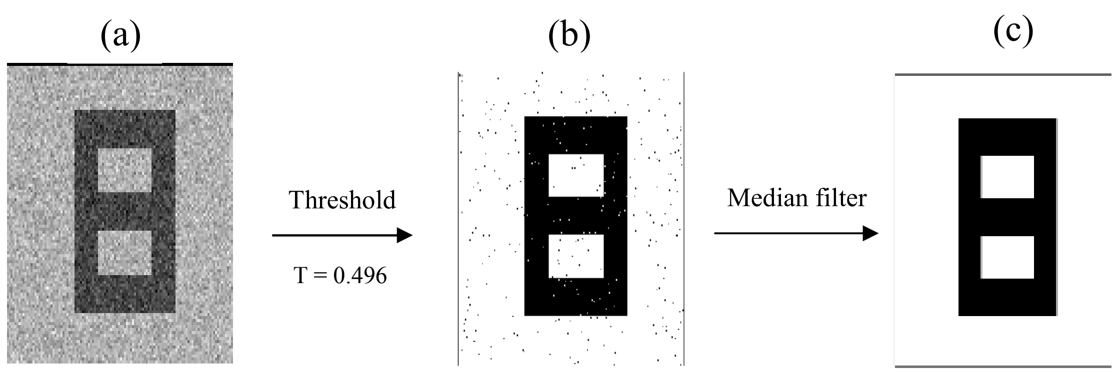

Figure 4.19 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

The projection approach of binary representation is obtained, and displayed in Figure 4.20.

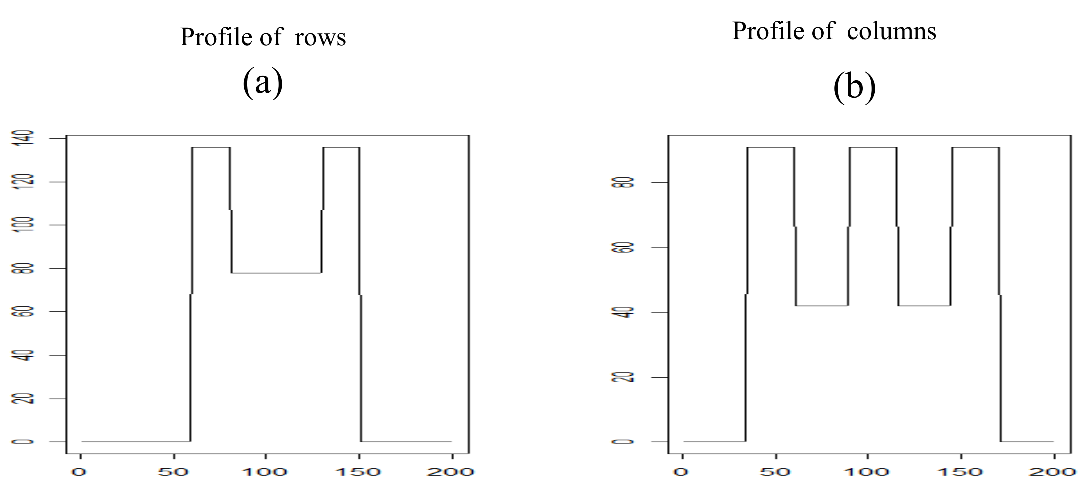

Figure (4.20) Projection: (a) Horizontal profile, (b) Vertical profile.

There are three groups in the horizontal projection, and five groups of vertical projection, these results are summarized in vector H^*, and the vector V^*

H^* = (136, 78, 136), and V^* = (91,42,91,42,91). The first and the third values in the vector H^* are greater than the second value $(h_1^* \& h_3^*) > h_2^*$, also the first value , the third value, and the fifth value have largest value than the second and the fourth values in the vector V^* , $(v_1^* \& v_3^* \& v_5^*) > (v_2^* \& v_4^*)$. The property 9 in the Table 3.1

According to extra steps in the general algorithm, to detect the number in this image as number eight, the vector *A* and the vector *B* should have the same length. So, in this example, the length of vector *A*, and the length of vector *B* are equal to 194. This means, the algorithm has correctly recognized the number as eight.

Example 4.10

Number nine:

Simulated image with number nine as an object has been processed by the general algorithm steps.The threshold value is obtained and found to be 0.496.

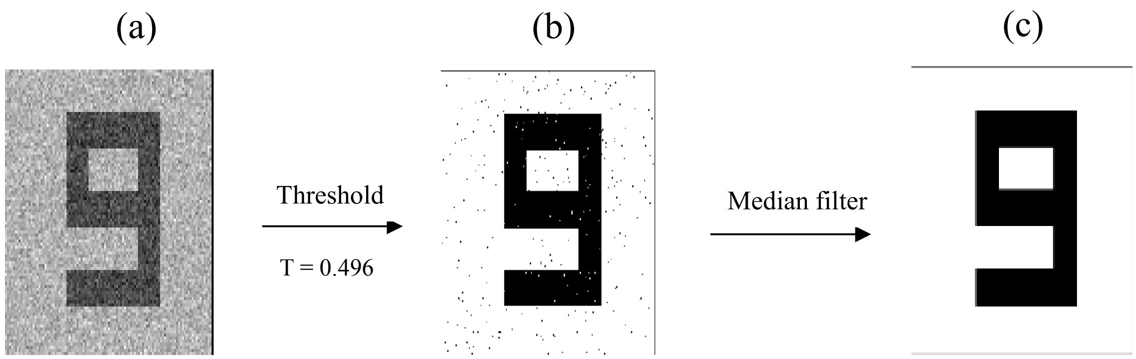

Figure 4.21 (a) Noisy image, (b) Thresholded image, (c) Filtered image.

Horizontal and vertical projections of number nine are obtained from filtered image, see Figure 4.22.

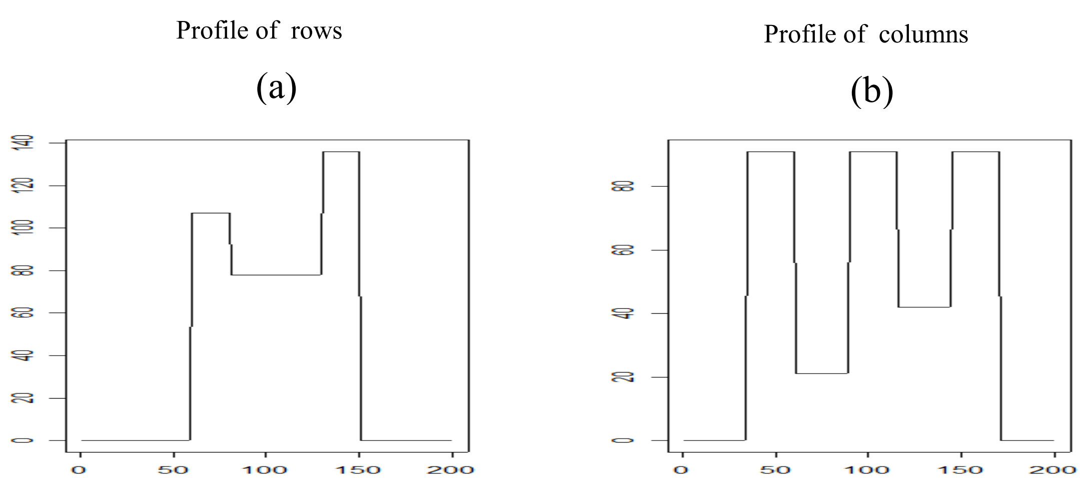

Figure (4.22) Projection: (a) Horizontal profile, (b) Vertical profile.

The rows profile has three groups of numbers, while the vertical profile contains five groups of number, these results are shown in the vectors H^* and V^*, where,

$H^* = (107,78,136)$, $V^* = (91,21,91,42,91)$.

The third value in the vector H^* is the largest value $h_3^* > (h_1^* \& h_2^*)$, and the forth value in the vector V^* is greater than the second value $v_4^* > v_2^*$ while the first, third, and fifth value are equal $v_1^* = v_3^* = v_5^*$. The property 10 in the Table 3.1, the number in this example is recognized as number nine (step 15 from the general algorithm).

Chapter 5

Application to Real Data

5.1 Introduction

The good achievement in the applications to simulated data has been obtained, gives to the algorithm validation to apply to real data. This chapter presents example for applying the algorithm to real data.

Example 5.1

Real image data, in this example, has been taken from the website:

http:// www.pongsaversshot.html.

last update: 24/8/2009, and it is shown in Figure 5.1, represents the numbers which are one,seven, two, and eight. The image resolution is 193×368. Matlab softwere version 7 is used to read the data as a matrix.

Figure 5.1: Real data image.

The next step is to segment the image into object (foreground) and background. To do so, iterative threshold is used for image. The threshold value for this image is 64.615 this value is used to segment image into binary image, as shown in Figure 5.2.

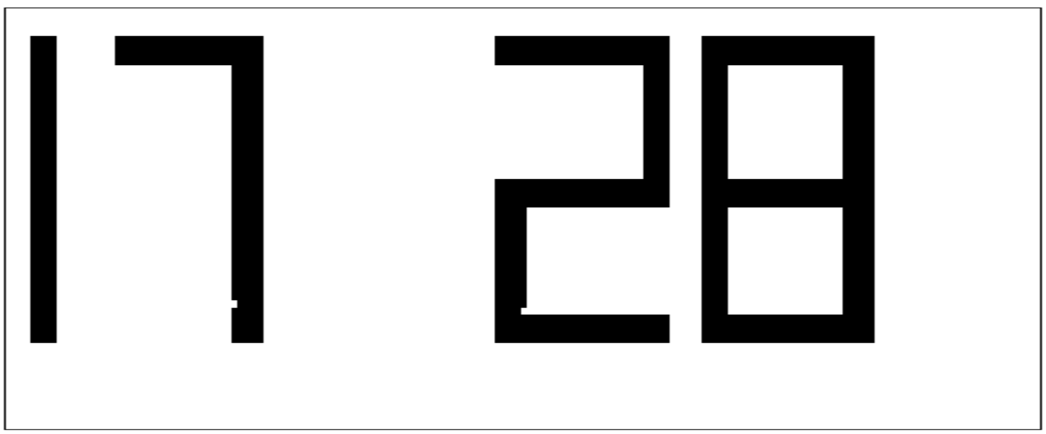

Figure 5.2: Segment image for real data image.

Visually the image is seemed to be free of noise, but some edges of numbers two and seven are lost this will cause a problem in recognition them, since those edges represent important information for recognition algorithm. So median filter will be used to solve this problem, because it is considered to be good method to protect the edges, since the median value is one of the value of pixels in neighborhood. The data will be passed through the median filter as next step in the algorithm, the filtered image is illustrated in Figure 5.3.

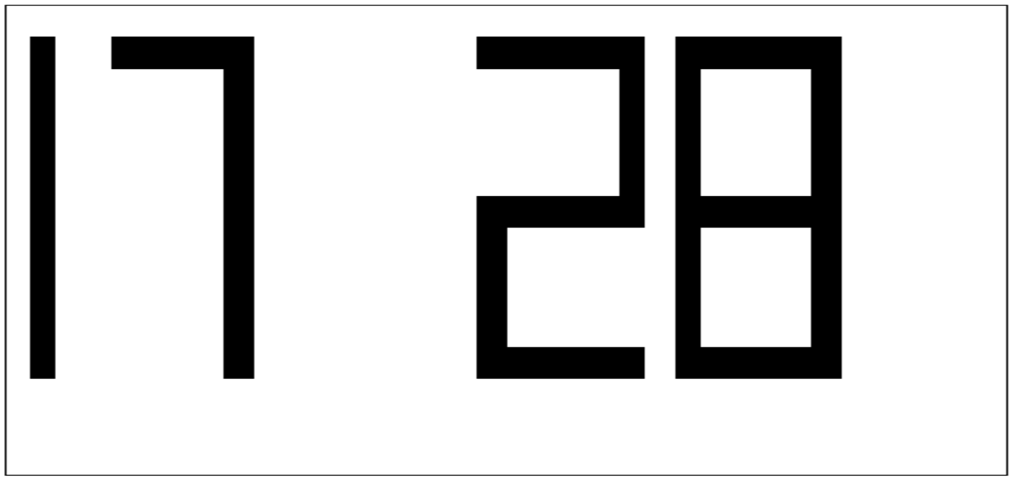

Figure 5.3: Filtered image using median filter.

Since the algorithm is designed to detect one number in image, so it is necessary to divide the image into four sub-images. Figure 5.4 shows this step which is needed to apply the algorithm.

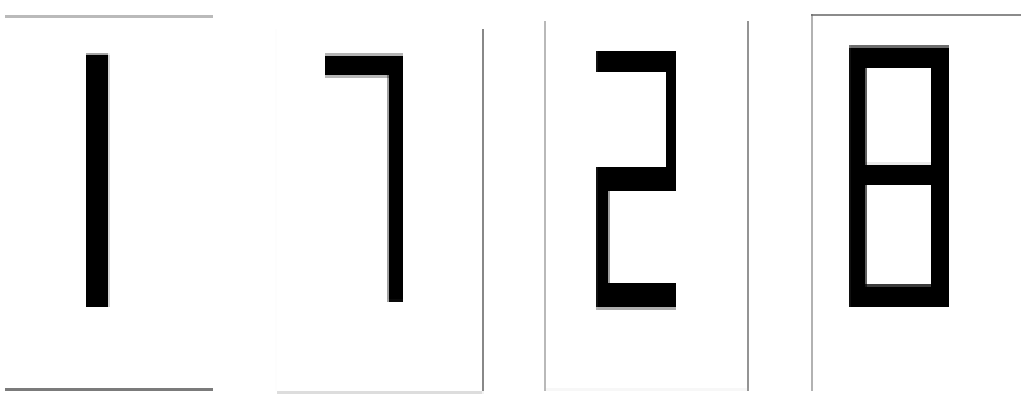

Figure 5.4: Sub-images of the filtered image.

Projection method is implemented to the binary data. This method will yield horizontal and vertical profiles, which are plotted in Figure 5.5.

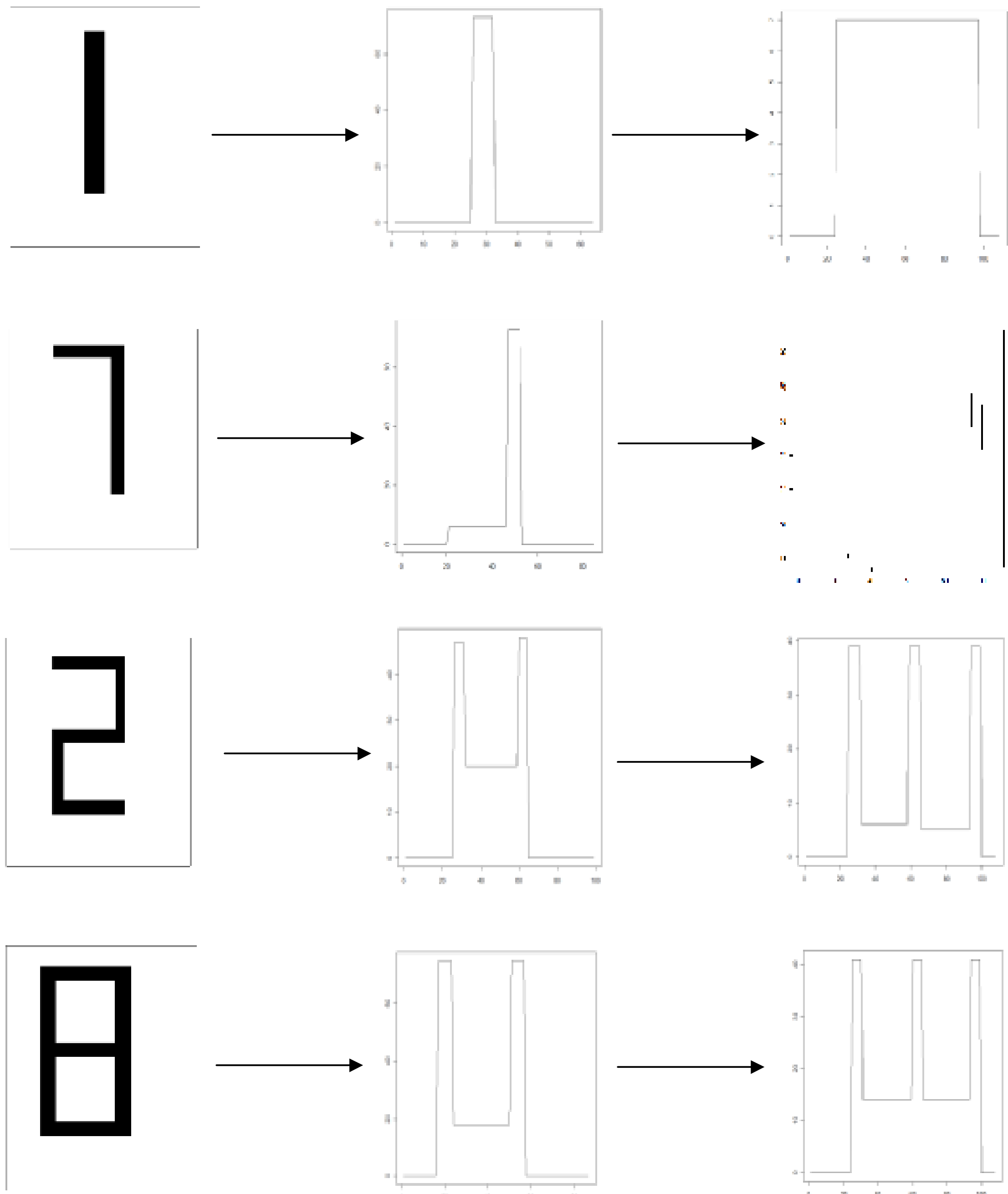

Figure 5.5: sub-image; Middle panel: horizontal profile for each sub-image; Right panel: vertical profile of each sub-image.

The horizontal and vertical profiles, for each number, have been summarized into the following vectors:

Object	Horizontal profile (H^*)	Vertical profile (V^*)
Number 1	(73)	(7)
Number 7	(6,32)	(6,73)
Number 2	(47, 20, 48)	(39, 6, 39, 5, 39)
Number 8	(75, 18, 75)	(41, 14, 41, 14, 41)

For one element only in both vectors H^* and V^*, the algorithm is recognized the first object in this image as number one, as said property 2 in the Table 3.1.

Since the length of vectors H^* and V^* are equal and the second value is greater than the first value of vectors H^* and V^* , $h_2^* > h_1^*$ and $v_2^* > v_1^*$ This results satisfy the property 8 in the Table 3.1 and the step 13 in the general algorithm, then the second object is recognized also which is seven.

There are three values in vector H^* and five values in vector V^*. The first value and the third value are greater than the second value in vector $H^*, (h_1^* \,\&\, h_3^*) > h_2^*$ also the first, the third, and the fifth value are greater than the second and the fourth values in the vector V^*, $(v_1^* \,\&\, v_3^* \,\&\, v_5^*) > (v_2^* \,\&\, v_4^*)$. According to extra steps in the general algorithm, the length of vector *A* is 69, and the length of vector *B* is 34, since length (*A*) > length (*B*), the algorithm will detect the number in this image as number two (see, the property 3 in the Table 3.1).

Both vectors *A* and *B* have the same length of 132, then the number is detected as number eight. This is according to the property 9 of Table 3.1.

Chapter 6

Conclusions and Future Works

6.1 Conclusions

The aim behind this work was to detect object in image, herein the object has been considered to be number. This thesis proposed an algorithm to detect the numbers in an image The proposed algorithm is based on a combination of some methods, such as threshold approach, median filter method, and projection method.

The iterative threshold method was adopted to segment image into object and background. The median filter method is applied to remove isolated pixels. The projection method has been used for dimensions reduction. The properties, which characterize each number, have been created to recognize the number.

Due to similarity in properties of some numbers such as two, five, and eight, the algorithm suggested to add extra properties be more able to distinguish these numbers.

The design of algorithm was independent of size and position of the object.

The suggested algorithm which is applied to simulated images (numbers from zero to nine) has achieved its goal in detecting numbers. The algorithm is then applied to real data.

6.2 Future works

This thesis can be considered as a key of many future studies, that useful to use in scientific applications, if these points are taken in account

- In some cases there are unwanted pixels those effect on the shape of the number, so we suggest in future using morphological operation to remove unwanted pixels.
- The algorithm is designed to recognize single number, in future the algorithm can be extended to use in case of multi numbers in image, by adding some steps.
- Since the numbers can be formulated by many shapes, then the algorithm maybe adjusted to recognize any type of numbers.
- Letters recognition can be done by using number recognition algorithm, which presented in this thesis if properties of each letter can be created.

References

1. Besage, J. (1986) *Statistical analysis of dirty pictures,* Journal of the Royal Statistical Society, Series B, 48, University of Durham, PP 259-302.
2. Bovik, A. C. (2009) *The essential Guide to Image processing,* Academic Press, ISBN 0123744571, The University of Texas at Austin.
3. Chan, R. H., Chung, W. H. and Nikolova, M. (2005) *Salt-and-Pepper Noise Removal by Median-Type Noise Detectors and Detail-Preserving Regularization*. IEEE Transactions on Image Processing.
4. Church, J., Chen, Y. and Rice, S. (2008) *A Spatial Median Filter for Noise Removal in Digital Image,* IEEE, University of Mississippi, Oxford, PP. 618-623.
5. Geman, S. and Geman, D. (1984) *stochastic relaxation, Gibbs distributions and the Bayesian restoration of image,* IEEE Transactions on Pattern Analysis and Machine Intelligence, 6, PP. 721-741.
6. Gonzalez, R. C. and Woods, R. E. (2001). *Digital image processing*. 2 edition, Prentice Hall, New Jersey 07458.
7. Gonzalez, R. C. and Thomas, M. G . (1978) *Syntactic Pattern Recognition: an Introduction*, Addison Wesley, Reading. UK.
8. Hayat, L., Fleury, M. and Clark, A. F. (1995). *Two-dimensional median filter algorithm for parallel reconfigurable computer*, IEEE proc-vis Image Signal Process.

9. Hwang, H. and Haddad, R. A. (1995). *Adaptive Median Filters: New Algorithms and Results*, IEEE Transactions on Image Processing.
10. Liu, J. and Sun, J. and Wang, S. (2006) *Pattern Recognition: An overview*. IJCSNS International Journal of Computer Science and Network Security, vol. 6 No. 6, pp. 57-61.
11. Mardia, K. V. (1989) *Markov models and Bayesian methods in image analysis*, Journal of Applied Statistics, PP. 125-130.
12. Maarif, H. and Sardy, S. (2006). *Plate Number Recognition by Using Artificial Neural Network*. University of Al-Azhar Indonesia. pp. 176-182.
13. Medasani, S. and Krishnapuram, R. (1994). *Image Thresholding via Possibilistic Clustering*, ISE 0-7803-2125, IEEE, Univesity of Missouri Columbia. pp. 423-426.
14. Osorio, C., Diez_Paster, J. F. Rodrigues, J. J. and Maudes, J. (2008) *License Plate Number Recognition New heuristics and a comparative study of classifiers*, Universidad da Madeira, PP. 268-273.
15. Ozbay, S. and Ercelebi, E. (2005). *Automatic Vehicle Identification by Plate Recognition*. University of Gaziantep, Turkey. pp. 222-225.
16. Rao, K. M. M. (2004) *Overview Of Image Processing*. Deputy Director, National Remote Sensing Agency, IETE, Hyderabad, India, 500-037.
17. Rao, K. M. M. (1995). *Medical Image Processing, Proc. Of workshop on Medical Image Processing and applications*. NRSA, Hyderabed-37.

18. Srihari, S.N., Covindaraju. (1993) *Pattern recognition*, Chapman & Hall, London, 1034-1041.
19. Tukey, J. W. (1974). *Nonlinear (Nonsuperposable) Methods for Smoothing Data*, in Proc. Congr Rec. EASCOM, P. 673.