Enhancement of Vehicle License Plate Images by Temporal Filtering

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ABSTRACT

Optical Character recognition is used widely as a tool in intelligent transportation systems for recognition of the car license plate from a still image or video. The accuracy of Optical Character Recognition partially depends on the quality of the input image. In this study, a set of simple and efficient methods are proposed to improve the quality of the car license plate image extracted from video clips to reduce the error rate for the license plate OCR even at low resolutions. Mean, median, and maximum filters are commonly used algorithms to filter noise and enhance an image. The proposed technique by Dr. Bodur extends them to time domain by including the pixels of the consequent images of the video clip in filtering algorithm. The OCR error rate is tested on fifty road and street video clips by decreasing the resolution of the images and filtering them with common and proposed filtering methods. The test results indicate that all proposed methods, improve the accuracy of OCR, and the highest reduction of error is obtained by the proposed temporal maximum filtering method.

Keywords: License Plate Recognition, temporal image enhancement, Vehicle Plate OCR.

ÖZ

Optik Karakter tanıma (OCR), akıllı ulaşım sistemlerinde hareketsiz bir görüntüdeki veya videodaki araç plakasını tanımak için yaygın olarak kullanılan bir araçtır. OCR'nın doğruluğu kısmen girilen görüntünün kalitesine bağlıdır. Bu çalışmada, düşük çözünürlüklerde bile plaka OCR'ındaki hata oranını düşürmek için video kliplerden araç plakası görüntüsü oluştururken görüntü kalitesini iyileştirmek için basit ve verimli bir dizi yöntem önerildi. Ortalama, medyan ve maksimum görüntü filtreleri, gürültüyü filtrelemek ve görüntüyü düzeltmek için yaygın olarak kullanılan algoritmalardır. Dr. Bodur tarafından önerilen teknikler video kliplerinin sonuç görüntülerinin piksellerini filtreleme algoritmasına dahil ederek uzaysal filtreleri zamana genişletmektedir. OCR hata oranı, çözünürlüğü dokuz seviyede azaltan elli yol ve sokak videosundan alınan görüntüler üzerinde yaygın kullanılan fıltreler ile önerilen filtrelerin OCR hatalarını karşılaştırarak suretiyle test edildi. Test sonuçları, önerilen tüm yöntemlerin OCR doğruluğunu iyileştirdiğini ve hata azalmasının en fazla önerilen zamansal maksimum filtreleme yöntemiyle elde edildiğini göstermektedir.

Anahtar Kelimeler: Taşıt Plakası Tanıma, Zamansal görüntü iyileştirme, Araç Plakası Tanıma.

DEDICATION

To my beloved family

&

My best friends

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Chapter 1

INTRODUCTION

1.1 Intelligent Transportation System

Intelligent Transportation System (ITS) is a common tool to control traffic. It is an automated scheme made of various applications related to vehicle transportation, and obtains on line inputs from many devices at the roadside or through a camera connected to the poles of traffic lights or the advanced sensors on smartphones. ITS is adopted and distributed in developed countries for purposes such as real time navigation, traffic review, lane regulation, calculating and forecasting travel point. Enhancing security, capacity and efficiency of the transport system are among the goals of ITS. It has been successfully installed in many developed countries such as, Australia, Singapore, Japan, UK, South Korea and USA. Installation of the ITS is not same in all countries, though the purposes are similar i.e. to advance the transport scheme operation as well as to reduce congestion, increase security and ease travelling. One of the major goals of ITS is to identify vehicles as specified in the regulations for open road utilization and crime prevention [1]. This is usually done via extraction and identification of license plates through digital image processing [2].

1.2 License Plate Recognition

A kind of Automatic Vehicle Identification (AVI) is the Vehicle license plate recognition (LPR). This does not just identify and count cars, but it defines them as unique. There are many uses of LPR in traffic monitoring fields. Time can be saved, overcrowding can also be reduced through permitting vehicle drivers go through the toll gates, weigh arena or station non-stopping. Financial benefits can be obtained through capturing and processing car data using LPR with no human input. Safety and security can also be enhanced through assisting in securing area for control access and also helping the law enforcement agency [3]. The automatic license plate recognition (ANPR) is a broad inspection technique which adopts optical character identification on images to examine the car’s license plates. A closed circuit television of security can be adopted or highway regulation enforcement cameras or the specific device built for the purpose [4].

1.3 Optical Character Recognition (OCR)

Optical Character Recognition (OCR) is a method through which printed files or scanned sheets are translated to ASCII character which can be processed by computerized information systems. The image of text might be printed by a machine or rather written by hand, or a mixture of both. An OCR system accelerates the input rate, and reduces any possibility of errors that might be caused by human due environmental effects such as shortage of time and insufficient lighting. A high-quality character identification method should have image processing operations on the raw image to smooth the image, to get proper identification, to extract features efficiently, to train the system and classify patterns [5]. In 1974 Ray Kurzweil created the Omni-font OCR, which found application by numerous organizations in the 70s. His invention made it possible to read out a text aloud by a computer system. The Matlab application provides OCR as an inbuilt operation. OCR function in Matlab uses Tesseract method, which is created by HP. It had been created and developed as an open-source OCR method from 1984 to 1994. It adopts shape classification for identification process [6]. Additionally, for examining outlines of pages it relies on the methodology described in [7] and for acclimatizing the Tesseract OCR Method for multiple languages, it adopts Kurzweil's [8] design. OCR can be useful in numerous areas such as car license plate identification, data recovery, file-automation, and in-text-to-speech program. This thesis relies on the Matlab Tesseract OCR tool in enhancing the recognition of the vehicle license plates embedded in road side video clips.

1.4 License Plate Recognition using OCR

License plate recognition has three main components: car license plate extraction, character segmentation and Optical Character Recognition (OCR). The license plate detection is termed vehicle license plate extraction. The detected license plate is initially processed to eliminate the trace, afterwards, the outcome is sent to the segmentation stage to separate the isolated characters from the extracted license plate. The isolated characters are then normalized and sent to the OCR algorithm. OCR translates the optical characters into text characters [9]. In the 90s, image processing and pattern recognition methods were combined with the Artificial Intelligence techniques, allowing to use neural networks, hidden Markov models, fuzzy set reasoning and natural language processing technologies in cameras and tablets [10].

1.5 Pre-processing Plate Image for OCR

The raw image which is obtained by cameras or scanners needs a preprocessing before the optical character recognition. Preprocessing targets to format and filter the raw image for an easy and reliable OCR [10]. Preprocessing operations consist of image processing, binarization, trace decline, twist identification & adjustment/amendment of a digital image so that succeeding algorithms during concluding classification be made straightforward and more precise[11].

1.6 Problem Statement

Optical character recognition is applied on car license plate to extract its plate number in text format. The accuracy of OCR is being affected by many factors, such as, the performance of devices used for collecting plate images and the distance between car and camera and also the movement of the car, which blurs the image. These factors affect reading the characters correctly. LPR system is also affected by the illumination level of the plates, the change of illumination level while the vehicle moves results in letters disappeared from frame to frame, especially when the lights are on at night time. OCR often fails to recognize low resolution license plate images, which has taken from far distances. High quality equipment's for capturing video or images are expensive and hard to use. They even may not be available for all conditions and all times. In this study a method of increasing the information contents in the image is used to increase the accuracy of the OCR program by using the successive image frames, the images before and after the selected image in a video.

This thesis targets to solve the problem high OCR error rate for the conditions of low quality video surveillance systems by developing temporal filters to support the information content of an image with the images on the previous and next frames.

1.7 Significance of Study

The proposed method is a frontier in increasing the quality of an image by temporal filtering. By this means, it decreases error of OCR for even mid or low quality images. The proposed process opens a door to develop similar image filters which can be used to design low cost surveillance devices for LPR systems. By this method, mobile cameras and low resolution security cameras may include in LPR systems. The proposed method is sufficiently simple to be integrated in a preprocessing unit of video cameras, phone cameras, and similar devices.

1.8 Thesis Organization

This thesis contains five sections. The First Chapter gives a basic introduction to Intelligent Transport Systems (ITS), License Plate recognition (LPR), Optical character Recognition (OCR). The second Chapter of this paper highlights the literature review for license plate image and text images enhancement techniques. Chapter three describes proposed methodology for the temporal mean of the video frames. The fourth section gives the test results for the proposed method**.** Finally, Chapter five states a conclusion and comments on future work.

Chapter 2

PRELIMINARIES FOR FILTERING AND OCR

A number of topics and methods are used in this study. In this chapter, each one of them is briefly introduced and defined. In this study, a method for improving car license plate images in a digital video is proposed, so that the OCR function in Matlab recognizes plate characters more accurately. Therefore, it is important to describe these topics:

2.1 Digital Video

Naturally, spatial and temporal domains of a video stream are continuous. As shown in Figure 2.1, for representing and processing a stream of digital video, it is important to sample temporally and spatially. The spatial domain is sampled by an image that is represented on a rectangular grid and the video stream is represented by a set of still images sampled at systematic intervals of time. These still images are named frames. A number of fields are interlaced to construct a frame for processing the signal of video on television. A positive digital number represents each sample pixel, which defines the colour components and illumination.

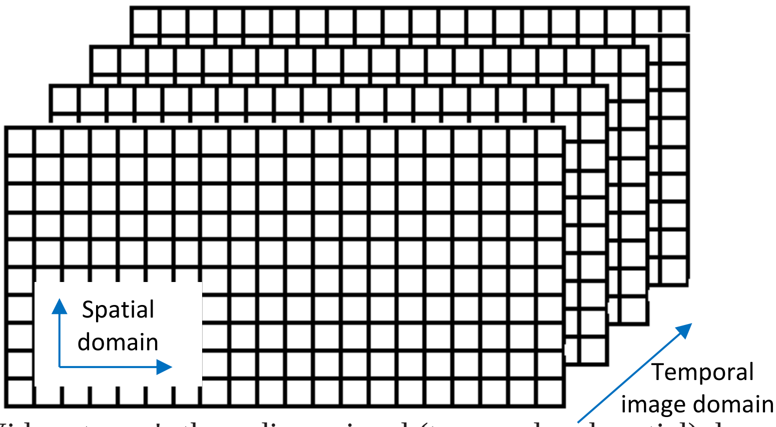

Figure 2.1: Video stream's three dimensional (temporal and spatial) domains

A camera can be used to capture a natural video scene, and then it is converted to a sampled digital representation. The digital color-difference format YC1C2 represents the digital video instead of the main natural color format (RGB). And the digital domain may use it in different fields such as processing, transmission, and storage. At the output of the system, it can be displayed to a viewer on a video monitor by reproducing it. The RGB (red, green, and blue) color space is the basic choice for image frame buffers and computer graphics because for creating the wanted color as three basic colors, color CRTs is using red, green, and blue phosphors [13].

2.2 Digital Image

The representation of visual data in a discrete form is called Digital image which is suitable for digital electronic transmission and storage. Techniques of Image sampling are used to obtain a digital image, by that a discrete array $P\ [a, b]$ is obtained from the continuous image domain at some time instant across some rectangular region A x B. Grey level is the name of the digitized brightness value. A pixel is the name of each image sample that is a picture element. The array of image pixels of a *2-D* digital image is represented in two-dimensional Cartesian coordinate system. The number of bits (x) needed to save an image of size $A \times B$ with 2^q gray levels is $x = A \times B \times q$. This means, 524,288 bits or 65,536 bytes are needed to save an image of size 256x256 with 256 gray levels [13].

2.3 Colour Spaces

A mixture of two or more colour channels is used to achieve the representation of colours in an image. The colour space is the representation that is being used to store the colours, identifying the nature and number of the color channels.

As a mathematical entity consideration, an image is organizing a set of numbers spatially with each pixel location addressed as *I*(*column, row*). One numerical value is allocated to each pixel of (grayscale and binary) *2-D* array images which represent the intensity at that pixel. These two types of image use only one channel color space that might limit into intensity (gray scale) or 2-bit (binary) color space. In contrast, true-color or RGB images are 3-*D* arrays that each pixel is allocated by three digital values when each value related to the red, green and blue element. In Figure 2.2 a Colour RGB image is distributed into the red, green and blue color tubes.

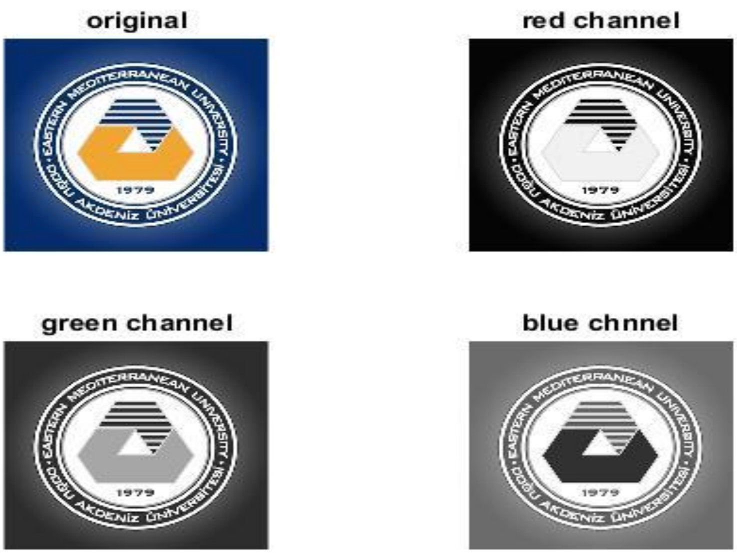

Figure 2.2: RGB three channels (Red-Green-Blue)

True colour or (RGB) images are *3-D* arrays that can be considered conceptually as three distinct *2-D* grids. Each grid of RGB image corresponds to one of the three colour channels (red, green, blue). RGB corresponds to the three primary colors which are combined to show on a display or related material, therefore it is the most popular colour space used for the representation of digital images.

As shown in (Figure 2.2), the three elements of the RGB image can easily be separated and viewed. It is crucial to know that the colours that are present in RGB images are permanently a mixture of colour elements from (red green and blue) channels. For example, items seen as green will surely appear brighter in the green channel they will hold more green data than the other colors) also they will have fewer elements of blue and red, in contrast to a common misconception that is, objects that are seen as green will only appear in the green layer.

If all the colours that can be represented within the RGB image are regarded, then it can be valued that the RGB colour space is fundamentally a *3-D* color space with three axes R, G and B. Each axis has the same range 0 →1 (this is scaled to 0-255 for the common 1 byte per color channel, 24-bit image representation). The color black conquers the source of the cube (position (0, 0, 0)), corresponding to the nonappearance of all three colours; white occupies the opposite corner (position (1, 1, 1)), the maximum amount of all three colors is indicated. Also, other colours in the scale lie within this cube [12].

2.4 Pixels

Digital images are composed of image elements (pixels). The color (or gray level) at a single point in the image is represented by a pixel, so a pixel is like a tiny dot of a specific colour. By measuring the colour of an image at a large number of points, we can create a digital approximation of the image from which a copy of the original can be reconstructed. Pixels are a little like grain particles in a conventional photographic image, but arranged in a regular pattern of rows and columns and store information somewhat differently. A digital image is a rectangular array of pixels, sometimes called a bitmap [14].

2.5 Image Filtering

The mean filter calculates the mean value of the intensities of the pixels in the neighbourhood of a pixel as the new intensity of that pixel. The *average mean filter* is the simplest of the mean filters. Let *N*(a,b) represent the set of coordinates in a rectangular sub image window of size x × y as the neighborhood which is centered at point (a, b). The arithmetic mean filter computes the average value of the corrupted image $g(a, b)$ in the area defined by $N(a,b)$. The intensity f at point (a, b) is simply the arithmetic mean computed using the pixels in the region defined by N. In other words

$$f(a,b) = \frac{1}{xy} \sum_{(s,t) \in Nab} g(s,t) \qquad (2.1)$$

where x, y denotes the size of spatial filter so that total $x\,y$ number of pixels are used in mean operation. A mean filter smooth's local variation in an image, and noise is reduced as a result of blurring [14].

Median Filter is based on finding median of the pixel intensities in the neighbourhood of a centre pixel and replace the value of the centre pixel by the median of intensity levels in that neighborhood:

$$\hat{f}(a,b) = \text{median}_{(s,t) \epsilon Nab} \{g(s,t)\}. \qquad (2.2)$$

The pixels inside a box of size (x, y) are included in the computation of the median. Median filters are preferred because, for certain types of random noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Median filters are particularly effective in the presence of both bipolar and unipolar impulse noise [14].

Max and Min Filters provide replacement of intensity values by the maximum or minimum value of the intensities in the neighbourhood of a centre pixel. It is an extension of median filter, which uses the 50th percentile of the sorted values. A max or min filter may use percentiles closer to 100% or 0% on the ranked list of the intensities. For example, using the 100th percentile results in the so-called max filter, given by:

$$\hat{f}(a,b) = \max_{(s,t)\in Nab}\{g(s,t)\}. \qquad (2.3)$$

This filter is useful for finding the brightest points in an image. Also, because pepper noise has very low values, it is reduced by this filter as a result of the max selection process in the subimage area S_{ab}. The 0th percentile filter is the Min filter [14]

$$\hat{f}(a,b) = \min_{(s,t)\in Nab}\{g(s,t)\}\,. \qquad (2.4)$$

2.6 OCR in MATLAB

Recently a new built-in function has added to Matlab program that called OCR. This function is an optical character recognition function which receives an image and read the text in this image and converts it to digital text. OCR function in the Matlab program depends on Tesseract method. As shown in Figure (2.3), the first step of Tesseract method outlines of the components is stored, which is connected components analysis. At this stage, Blobs are generated from matting together the outlines. Blobs are changed into lines of text, and then the regions and lines are examined for monospace or non-fixed-pitch text. Depending on the type of character spacing, the text lines are divided into words. Monospace texts are chopped easily by text cells because the space between characters is fixed. Non-fixed-pitch text is divided into separate words using fuzzy spaces and definite spaces. The next step is recognition procedure. The recognition process is passing through two levels. The first pass is making an attempt to identify every word in turn. Recognized words are used as training data to an adaptive classifier. This increases the accuracy of the adaptive classifier for recognition of text lower down the sheet. It again recognizes Words that were not recognized well enough by making an additional pass over the sheet, because in the first pass the adaptive classifier have learned some new patterns very late to contribute near the upper of the sheet.

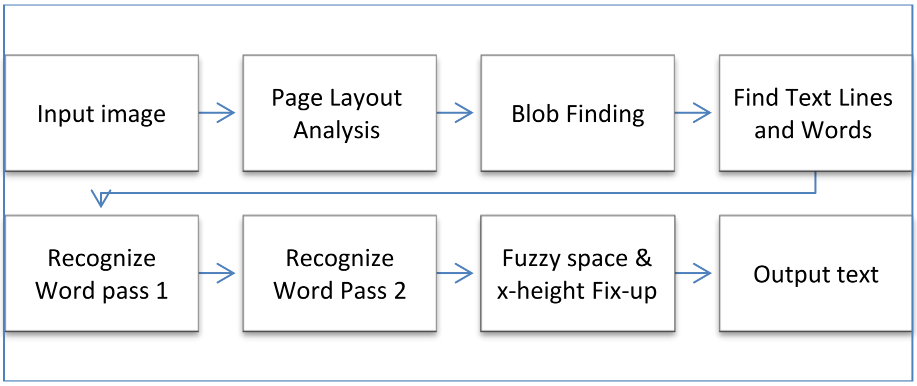

Figure 2.3: Task Flow of Tesseract method

2.7 Finding Text Line and Word Box

The de-skewing process is being applied on skewed pages for recognition, but this effect on the quality of the image, for this reason the Tesseract method provides the line finding mechanism to recognize skewed page without de-skewing them, for saving the loss of quality of image. The **text line finding** process is implemented in two parts line construction and blob filtering .

Assuming that roughly uniform text size, text regions are already provided by page layout analysis, vertically touching characters and drop-caps are being removed by using a height percentile simple filter. The size of the text in the region is approximated by the median height, for this reason, the blobs that are smaller than median height fractions are filtered safely, which probably are punctuation, noise, and diacritical marks.

A sample of parallel, non-overlapping, but curving lines are fitted from filtered blobs. A unique text line is assigned from blobs by processing and sorting the blobs by x-coordinate while following the curve across the page, then the danger of appointing to a wrong text line in the existence of skew is greatly reduced. After assigning lines from filtered blobs, for estimating the baselines, least median of squares fit is applied, and the appropriate lines are fitted back from the filtered-out blobs.

Merging the horizontally interfered blobs, reconnecting parts of some damaged characters correctly and placing diacritical symbols on the correct base is the final steps of the line creation process [6].

After finding the text lines, a quadratic spline is used for fitting the baselines more accurate. This enables Tesseract to deal with pages that contain sloped baselines that are prevalent object in scanning not only in book bindings.

Those blobs are divided into clusters by a reasonably continuous movement for the main straight baseline, to fit the **baseline**. The most overcrowded fraction is being fitted by the quadratic spline, which the least squares fit supposes it as the baseline. The disadvantage of the quadratic spline is that gaps can ascend if more than one spline segments are available. On the other hand, the advantage is that this calculation is stable reasonably.

Figure 2.4: Example of skewed line

Descender line, mean-line, ascender line and a fitted baseline are displayed in the example shown in Figure 2.4. The drawn lines are “parallel” and are sloped slightly. The black colored line is actually straight and the red line under it is ascender line. It can be seen that relative to the conventional black line the red line is sloped [6].

Detecting and Chopping Fixed Pitch in MATLAB is carried out by Tesseract. Text lines are being tested with Tesseract to define whether they are monospace. Where it detects monospace text, it cuts the words to characters by means of the space, and then stops the associator and chopper on these words for the word identification stage. A good instance of a monospace word is shown in Figure 2.5.

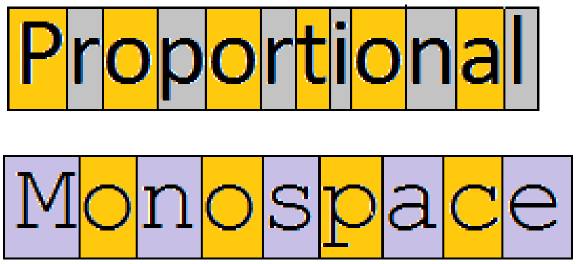

Figure 2.5: Proportional and Monospace Texts

Proportional text space is a non-trivial purpose. Some typical problems are illustrated in Figure 2.6. It can easily be notified that the size of general space is equal to the gap between the units and tens of '101.5', the gap between them is greater than the kerned gap between 'road' and 'joins'. Close inspection to the second sentence shows that between the frames of 'of' and 'fuzzy' the horizontal gap is not available. Most of these issues are solved in the Tesseract method by calculating the scale of gaps in a specific vertical domain between the mean-line and baseline. At this point, the gaps that are near the threshold are made fuzzy, so the last decision can be made after recognizing words [6].

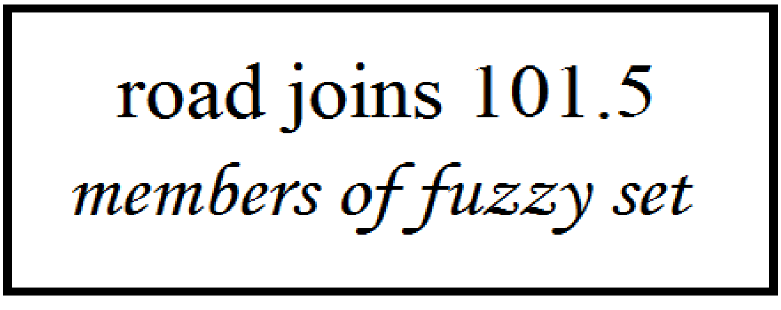

Figure 2.6: Some difficult cases for finding word spacing

2.8 Recognizing Words

Character segmentation is a part of the process of recognition in any character recognition method, and each system has different procedure for this process. Firstly, the output of finding lines is classified. Then only non-fixed-pitch text is passed through word recognition processes [6].

The Tesseract method tries to improve the outcome of unsatisfactory word recognition by cropping the blob that has worst trust from the character classifier. For finding candidate cut points, Tesseract method uses the polygonal approximation concave vertices of the framework, and also a line segment or another concave vertex may be available in opposite. For successfully separating joined characters, it may take more than 4 pairs of cutting points

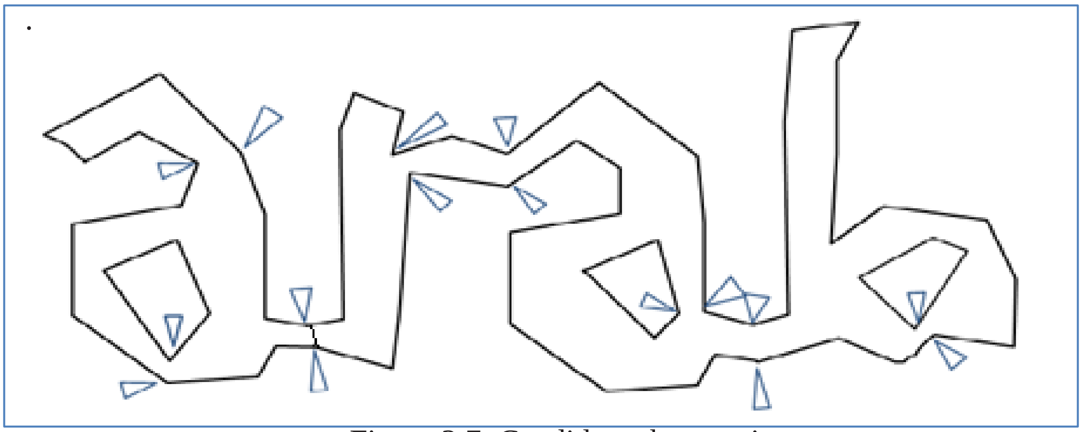

Figure 2.7: Candidate chops points

In Figure 2.7 a number of candidate cut points are shown using arrows, and the chosen cut is presented as a line through the framework where the ‘a’ bits the ‘r’.

The execution of chopping is done in priority order. The separation which is not increasing the confidence of the output is undone, but the cutting can be reused later via the associator if wanted therefor it is not completely discarded [6].

Reconstruction of the broken characters is accomplished by "Associator". The words that are not good enough even after chopping process are passed to the associator. An A* (best first) search of the separation graph of imaginable mixtures of the greatly cropped blobs is applied on candidate characters by the associator. Instead of constructing the division graph, it preserves a division table of applied states. The new state is a candidate from the priority queue and is being evaluated by classifying unclassified mixtures of fragments to proceed A* search. An example of damaged characters is shown in Figure 2.8.

Simplifying the structure of data which would be essential to uphold the entire segmentation diagram is one of the advantages of chop-then-associate scheme [6].

Figure 2.8: Examples of damaged characters

2.9 Static Character Classifier

The topographies in the training data dose need to be similar to the features in the unknown. The sections of a polygonal approximation are mined as features during training. On the other hand, in the recognition process, characteristics of a fixed and small dimension (in normalized elements) are mined from the shape, and then many-to-one matching is used beside the training data topographies that are clustered prototype. The thick, short lines In Figure 2.9 represent the features extracted from the test data, and the gathered parts of the polygonal approximation which are used as patterns are represented by long, thin lines. The bridge that connects between two pieces in sample data is not available in testing (unknown) features.

Four features are mismatched, but, except those, all prototypes and every feature are well matched. It can be seen from this instance, that this procedure of small characteristics matching large prototypes has the ability to deal with identification of broken character. The cost of calculating the distance between a prototype and the testing sample is very high, and that is the main problem with this process. The extracted features from the prototype are 4-D (length, angle, and *x, y* for position), by normally between (10 - 20) characteristic in a prototype outline, and the feature of test samples are *3-D*, (x, y positions and angles), through normally between (50- 100) features in a single character [6].

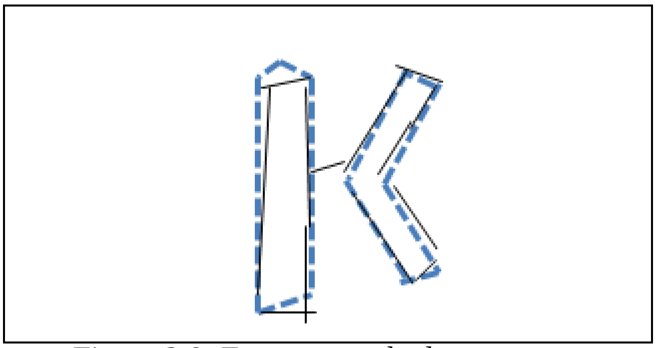

Figure 2.9: Feature matched to prototype

There are two steps in the classification process. The first one is creating a list of character groups that the test might pair. Each characteristic fetches a bit-vector of classes that it might match and also the bit-vectors that are summed over all the features, from a quantized 3-dimensional search table. For the next step of process a short list is made from the classes with the maximum amounts.

Every single feature of the test sample searches a bit vector of prototypes of the assumed class that it might match, after that the real match among them is calculated. A logical expression, sum-of-product, represents every class of character prototype with each term named configuration, therefore the process of calculation of distance holds a record of the complete matched data of specific characteristic in specified shape, similarly of every single prototype. And the greatest blended distance that is determined from the summed characteristic and prototype data, is the best over all the saved outlines of the class. The classifier dose doesn't train damaged characters because it is able to identify the broken characters easily [6].

Linguistic Analysis is contained in Tesseract of limited extent. When a new segmentation is being considered by the word recognition module, the best available word string is chosen by the linguistic module in each one of the given word categories: top dictionary, top numeric, top frequent, top classifier choice, top lower case and top UPPER case. The word that has lowest total distance score is the final decision for a given segment.

The different segmentation output of Words may contain different numbers of characters. The comparison between these words is very difficult. The solution for this issue in Tesseract method is by producing two values for classification of each single character. Confidence is the name of the first number. The normalized interval is being subtracted from the prototype to generate the confidence. This allows it to be "confidence" in the meaning that larger amounts are more efficient. The length of the total outline in the test character is multiplied by the normalized distance from the prototype to compute the second output. For all characters inside a word, the length of the total outline is often similar. Therefore, ratings for characters within the same word can be meaningfully summed [6].

Adaptive classifier is a useful tool in OCR methods. The ability of the static classifier is weakened to distinguish between various characters or non-characters and characters, because it has to be useful for any kind of font. An adaptive classifier that is more font-sensitive is used to find greater differentiation within each text. The output of the static classifier is used as the input for the adaptive classifier.

The Tesseract method uses the similar classifier and features as the static classifier in adaptive classifier. The main variance between these two classifiers is that the characters in static classifier are normalize using the centroid (first moments) for location and the second moments is used for anisotropic size normalization. While the baseline or x-height normalization is used in adaptive classifier.

The use of baseline/x-height normalization improves protection to noise dots as well as making it easier to differ between characters in lower and upper case. The removal of some degree of font stroke width and font aspect ratio is the main advantage of character moment normalization. It also simplifies the identification of superscripts and sub, however, needs an extra classifier's feature to differentiate some characters of lower and upper case [6].

Chapter 3

PERFORMANCE TEST OF TEMPORAL FILTERS

3.1 Introduction

In this study a simple method is proposed to test the improvement of the quality of license plate images by temporal filters. This chapter explains the method of testing the performance of proposed temporal filters for OCR of vehicle plates. The process diagram of testing method is shown in Figure 3.1. The videos of vehicles are recorded and the consecutive frames are captured from the video records. The next step is selecting a frame from the video and also select one frame before and one after the selected frame. The region of car plate is cropped in all three frames. Then, the cropped image of main selected frame is processed by OCR, and the text output is called *reference-text*. The resolutions of the plate images are reduced by 10% steps down to 10% of initial size. The low resolution raw images are fed to OCR process to get the same text, however with a considerable error due to the loss of information for reduced resolution. This OCR text output is called the *raw-text*. The error between reference text and raw text is a measure for the loss of information due to the limited resolution. This error is called the *raw-error*. The temporal filtering on low resolution images generates an image with higher information content with respect to the raw low resolution images. The OCR text obtained by the temporal filtered image is called *filtered-text*. The filtered-text is expected to have less error compared to raw-text if the filter has higher performance in improving the quality of the image.

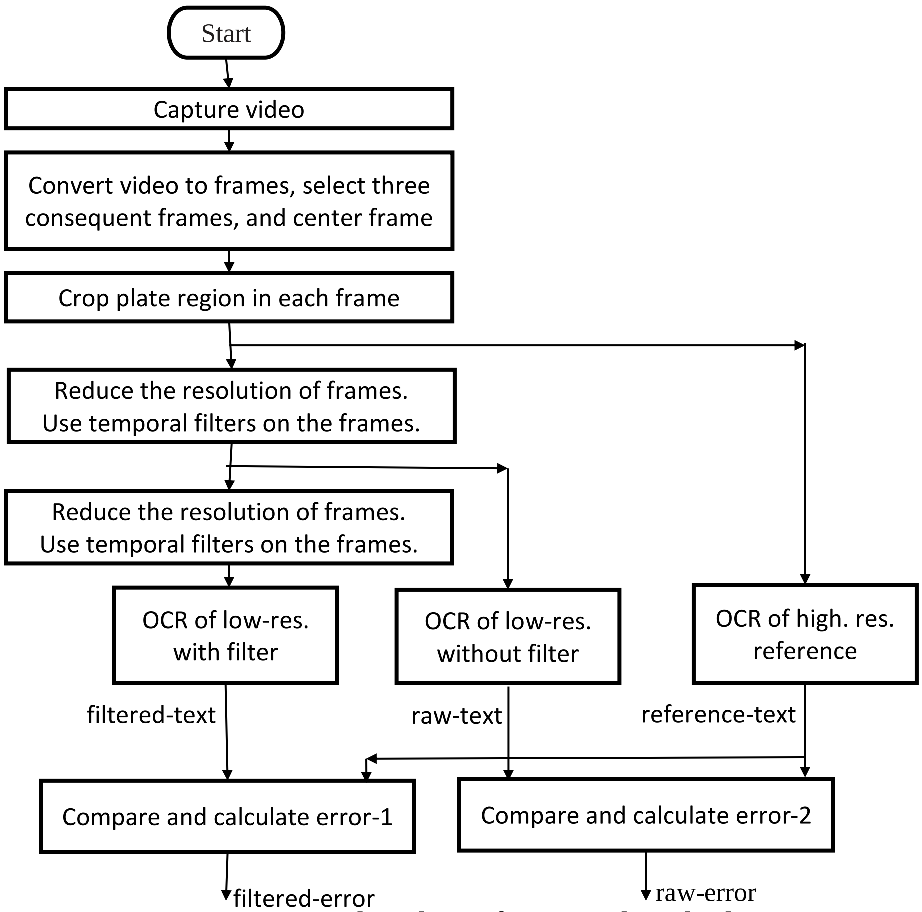

Figure 3.1: Flowchart of proposed method

3.2 Source of the Vehicle Plate Video Data Set

The videos that are used to implement the proposed method are captured using a mobile phone camera of "LG V10". The resolution of output video of this device is (1280×720). The format of video records is "MP4", with the frame rate 30 frames per second. Videos are recorded on a public road. During recording, the speed of cars changes mostly between 50-80km/h. In addition to the differences in illumination, the distances between the car and the camera were not constant, as well as the types and the colours of recorded cars. The distance between the camera and vehicle was changing in between 6 to 12 meters, and the captured car plates are of various size, colour and font type.

3.3 Extraction of Region of Interest

After video acquisition, video frames are extracted by using MATLAB built in function *read*, which reads the frames of a video with specific index and the output is frame of that index. The frames of mp4 videos are captured in coloured JPG image format. After reading the video to MATLAB memory buffer, a specific frame is selected manually, considering the full appearance of plate and the distance between car and camera, and called as *centre-frame*. The centre frame, its previous, and its next frame are selected for temporal filtering. Then the license plate regions of these three frames are cropped using MATLAB function *imcrop*. The imcrop function produces cropping rectangular box, which can be moved or resized to place it on any area of the image using the mouse to get the cropped image. The size of the cropped image differs from a plate to another because of the variety of distances and the original size of plate. But the size of all cropped images of the same plate in its three frames is similar.

After cropping the region of plate on the high quality images, a set of reduced quality image is generated from these raw high quality images to test the efficiency of the proposed filters on these low quality images. The resolution of each image is reduced in 10% steps by resizing them. The *bicubic interpolation* method is used as the method of resizing the images. Bicubic interpolation calculates the intensity of the pixels by weighted average of nearest pixels in 4×4 closest neighbourhood.

3.4 Proposed Filtering Method

The proposed temporal image filtering method is a novel idea introduced by the Supervisor of this study, Dr. Mehmet Bodur. It extends the spatial filtering techniques to the temporal domain by including the previous and next frames into the filtering operation. The temporal filter generates a less-noisy image from the three contiguous low quality car plate images using the intensity of pixels in the neighbourhood of a centre pixel. Three spatial filters are adapted to generate enhanced images using the proposed temporal filtering method.

Mean filter is used in two different ways. The first one is generating the value of pixel of the enhanced image by calculating the mean of the pixel values of the same position in low resolution images as shown in Figure (3.2 A). In other words, let f_p, f_c, and f_n denote the low resolution cropped plate images from the video record, and let f_o denote the filtered image. The temporal mean filter with depth 3 finds the intensity $f_o(x,y)$ at the pixel coordinate x, y by the expression

$$f_o(x,y) = \left[\begin{matrix} f_p(x-1,y-1) & +f_p(x,y-1) & +f_p(x+1,y-1) \\ +f_p(x-1,y) & +f_p(x,y) & +f_p(x+1,y) \\ +f_p(x-1,y) & +f_p(x,y+1) & +f_p(x,y+1) \end{matrix}\right.$$

$$\begin{matrix} +f_c(x-1,y-1) & +f_c(x,y-1) & +f_c(x+1,y-1) \\ +f_c(x-1,y) & +f_c(x,y) & +f_c(x+1,y) \\ +f_c(x-1,y) & +f_c(x,y+1) & +f_c(x,y+1) \end{matrix}$$

$$\left.\begin{matrix} f_n(x-1,y-1) & +f_n(x,y-1) & +f_n(x+1,y-1) \\ +f_n(x-1,y) & +f_n(x,y) & +f_n(x+1,y) \\ +f_n(x-1,y) & +f_n(x,y+1) & +f_n(x,y+1) \end{matrix}\right] /27 \qquad (3.1)$$

where all items in the large parenthesis are added on each other to calculate the sum for averaging all 27 pixel intensities. Omitting the spatial dimensions gives a purely temporal (1x1x3) mean filter that use the average of only three pixels.

$$f_o(x,y) = [f_p(x,y)+f_c(x,y)+f_n(x,y)]/3 \qquad (3.2)$$

Temporal median filters are similar to the mean filters, but instead of taking the mean of neighbour pixel intensities, they sort the use the median intensity as filter output $f_o(x,y)$. The median value is the value that is placed in the middle of ranked set of values. Same as mean technique, median technique is used in two ways. The first one is by calculating the median of the intensity value of specified pixel in selected frames to generate the new pixel values for higher quality image as shown below:

$$f_o(x,y) = \text{median}\begin{bmatrix} f_p(x-1,y-1), & f_p(x,y-1), & f_p(x+1,y-1), \\ f_p(x-1,y), & f_p(x,y), & f_p(x+1,y), \\ f_p(x-1,y) & f_p(x,y+1), & f_p(x,y+1), \\ f_c(x-1,y-1), & f_c(x,y-1), & f_c(x+1,y-1), \\ f_c(x-1,y), & f_c(x,y), & f_c(x+1,y), \\ f_c(x-1,y), & f_c(x,y+1), & f_c(x,y+1), \\ f_n(x-1,y-1), & f_n(x,y-1), & f_n(x+1,y-1), \\ f_n(x-1,y), & f_n(x,y), & f_n(x+1,y), \\ f_n(x-1,y), & f_n(x,y+1), & f_n(x,y+1) \end{bmatrix} \tag{3.3}$$

where, the listed 27 illumination values are sorted to determine the 50 percentile as the median value.

The second filter is pure temporal median, where only the temporal neighbour pixels are included to median operation

$$f_o(x,y) = \text{median}[f_p(x,y), f_c(x,y), f_n(x,y)] \tag{3.4}$$

Temporal max filter is extension of the median filter with only a simple difference. Instead of using the 50% percentile value as common for median, max filter uses higher percentile values. A 100% max is obtained just by replacing median to max in the expression of the median filter. Both spatial and temporal maximum over the range of 3 pixels per dimension gives (3x3x3) temporal max filter

$$f_o(x,y) = \max\begin{bmatrix} f_p(x-1,y-1), & f_p(x,y-1), & f_p(x+1,y-1), \\ f_p(x-1,y), & f_p(x,y), & f_p(x+1,y), \\ f_p(x-1,y) & f_p(x,y+1), & f_p(x,y+1), \\ \\ f_c(x-1,y-1), & f_c(x,y-1), & f_c(x+1,y-1), \\ f_c(x-1,y), & f_c(x,y), & f_c(x+1,y), \\ f_c(x-1,y), & f_c(x,y+1), & f_c(x,y+1), \\ \\ f_n(x-1,y-1), & f_n(x,y-1), & f_n(x+1,y-1), \\ f_n(x-1,y), & f_n(x,y), & f_n(x+1,y), \\ f_n(x-1,y), & f_n(x,y+1), & f_n(x,y+1) \end{bmatrix}. \qquad (3.5)$$

Similar to the mean filter case, an only temporal max filter that processes 3 frames can be called a temporal (1x1x3) max filter

$$f_o(x,y) = \max[f_p(x,y),\ f_c(x,y), f_n(x,y)] \qquad (3.6)$$

These techniques are applicable on the three layers of RGB coloured images by carrying the operation on each layer individually, and, combining them after the filtering.

3.5 Performance Evaluation

The three proposed filters are evaluated to compare their performance in reducing the OCR error rate of the vehicle plates as seen in Figure 3.1. The percent performance of the filters is measured using the raw-error and filtered error at the OCR output. The percent performance η of the filter is evaluated by the percent reduction of filtered error with respect to the raw error, i.e.,

$$\eta = (\text{raw-error} - \text{filtered-error}) / \text{raw-error} \qquad (3.7)$$

One of the major goals of this thesis is to determine the filter performances of the proposed temporal image filters.

Chapter 4

IMPLEMENTATION AND PERFORMANCE OF TEMPORAL FILTERS

In this chapter, implementation of the proposed filters, and their effects in reducing OCR error are described. The data set used for tests are collected personally by capturing video records with a mobile phone. The video records by mobile phone are low resolution compared to professional video recorder equipment which is necessary for an accurate OCR. After the recording the videos, and selecting the centre frames, the plate in each frame is extracted, and passed through the OCR, to obtain the *reference-text*. The centre and neighbour plate images are reduced in resolution at 9 steps, with 10 percent size reduction per step, to obtain the raw plate images. Then the raw centre plate image is fed to OCR to get the *raw-text*. Three temporal filters: mean, median and max filters are applied on raw plate image sets to obtain filtered plate images. Finally, the OCR outputs of the filtered plate images, which are called filtered-text, are compared to the reference-text to count the missed and false characters as error-count. The following sections compare the errors for raw-error against the filtered-error to determine the performance of the introduced filters.

4.1 Scoring the Performance of Filters

A fair scoring of filter performance is essential requirement to determine the best filter. For this purpose, the OCR output of high-resolution raw centre-images for total fifty video images is used as the reference-text. At each resolution of images, the OCR output of raw images, named as *raw-text*, were compared the reference-text to count the missing+extra+false characters for all fifty video records, as *raw-error*. Similarly, at each resolution of the images, the OCR output of the filtered images are called *filtered-text*, and they were compared to reference-text. The total count of missing+extra+false characters for all fifty video records are named *filtered-error*. These error values are measured for nine different image size, which is expressed in percentage with respect to the original high-definition size of the plate images. The error values are expected to increase while the size of image is reduced because of the decreasing resolution of the images. A filter performs better at the extent the filtered-error is smaller than raw-error. But, it is expected that for a very high resolution image filtered-error and raw-error is expected to be close to each other since both shall be nearly zero. On the opposite direction, for a very low resolution image the filtered and raw error will be equal since no characters can be recognized by OCR. Following subsections compare the raw and filtered errors of tested filters at nine different image resolution.

4.2 Performance Measurement for Temporal Mean Filters

Two different kind of mean filtering is applied on the images to reduce the OCR error of the low resolution images: the purely temporal (1x1x3) mean, and the temporal (3x3x3) mean filter with spatial components.

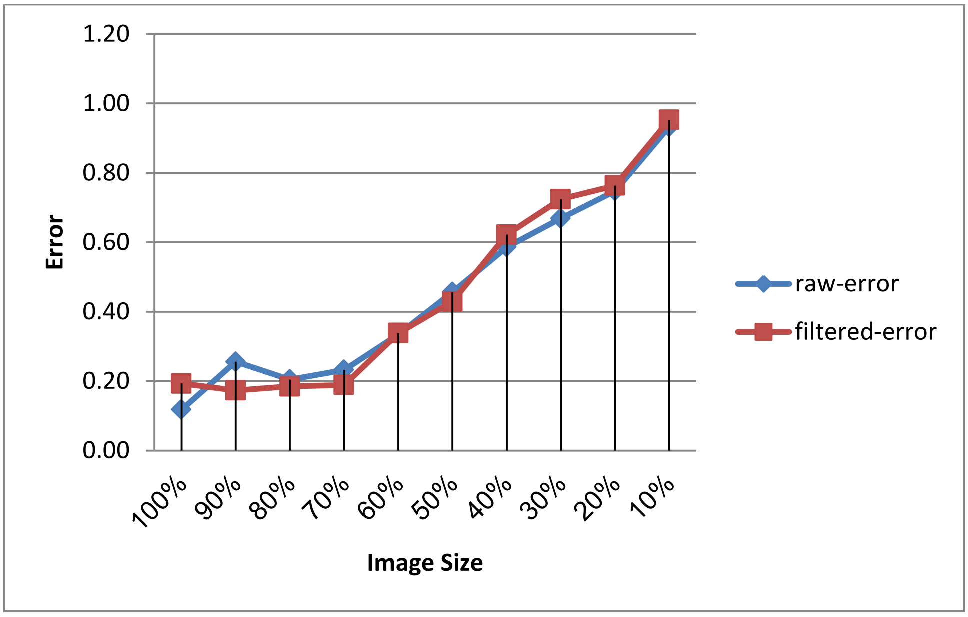

Figure 4.1: Errors for raw, and purely temporal (1x1x3) median filtered images

Table 4.1: Errors for raw, and purely temporal (1x1x3) median filtered images

Size compared to HD image	Percent raw-error	Percent filtered-error
100%	11.81%	19.29%
90%	25.59%	17.32%
80%	20.47%	18.50%
70%	23.22%	18.89%
60%	33.46%	33.85%
50%	45.66%	42.91%
40%	58.66%	62.20%
30%	66.92%	72.44%
20%	74.80%	76.37%
10%	93.30%	95.27%

In Figure 4.1 the blue line shows the raw-error count, and the red line shows the filtered-error count of OCR output compared to reference-text for purely temporal (1x1x3) mean filter. Figure 4.1 and Table 4.1 indicates that if quality of images are sufficiently high, the filter improves the images slightly. But for the lower resolution images it increases the OCR error. It may be explained as a result of loss of sharpness of the image because of the spatial averaging behaviour of the filter.

The raw-error, and filtered-error for the spatial+temporal filter is given in Figure 4.2 and Table 4.2.

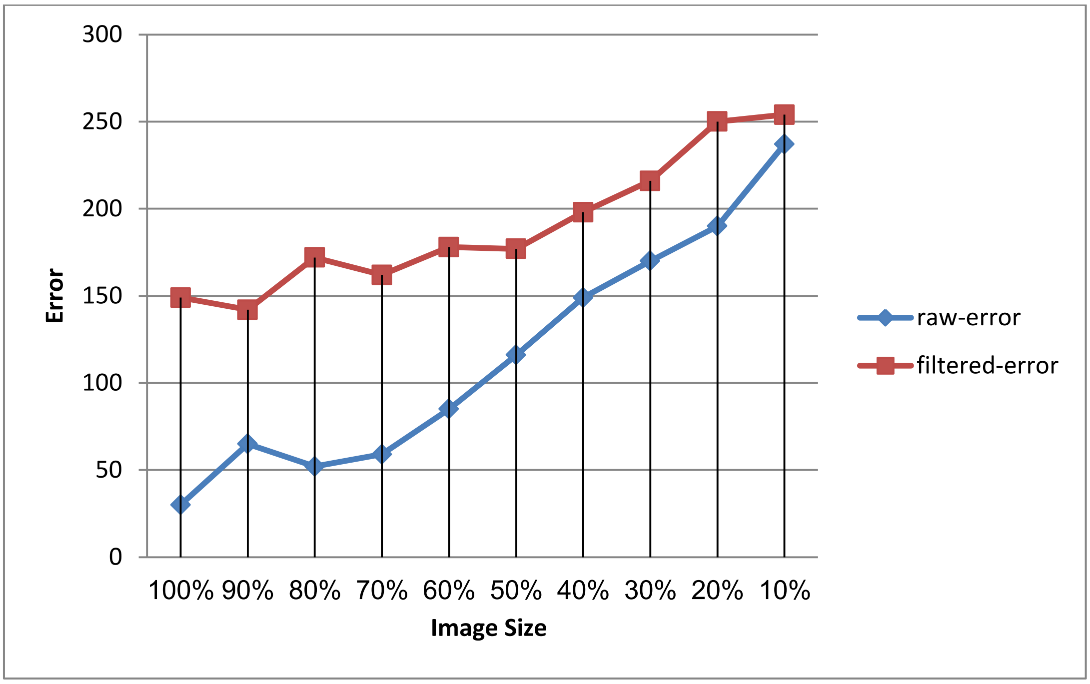

Figure 4.2: Errors for raw, and temporal-spatial (3x3x3) median filtered images

Table 4.2: Errors for raw, and temporal-spatial (3x3x3) mean filtered images

Size compared to HD image	Percent raw-error	Percent filtered-error
100%	11.81%	58.66%
90%	25.59%	55.90%
80%	20.47%	67.71%
70%	23.22%	63.77%
60%	33.46%	70.07%
50%	45.66%	69.68%
40%	58.66%	77.95%
30%	66.92%	85.03%
20%	74.80%	98.42%
10%	93.30%	100%

The results in Figure 4.2 and Table 4.2 shows that combining spatial components to pure temporal filter increases the OCR error. The errors of filtered text are higher after applying this filter compared to the errors of raw text. It may be because blurring of the critical parts in the image due to mean of large spatial region, resulting in to associate branches of characters as shown in Figure 4.3 (B), where the upper arms of H joined to each other and recognized as character “A”.

(A) (B)

Figure 4.3: (A) Original image (B) Mean of (3×3) neighborhood of pixels

4.3 Performance Measurement for Temporal Median Filters

The error of OCR output for the raw and temporal (1x1x3) median filtered images are shown below:

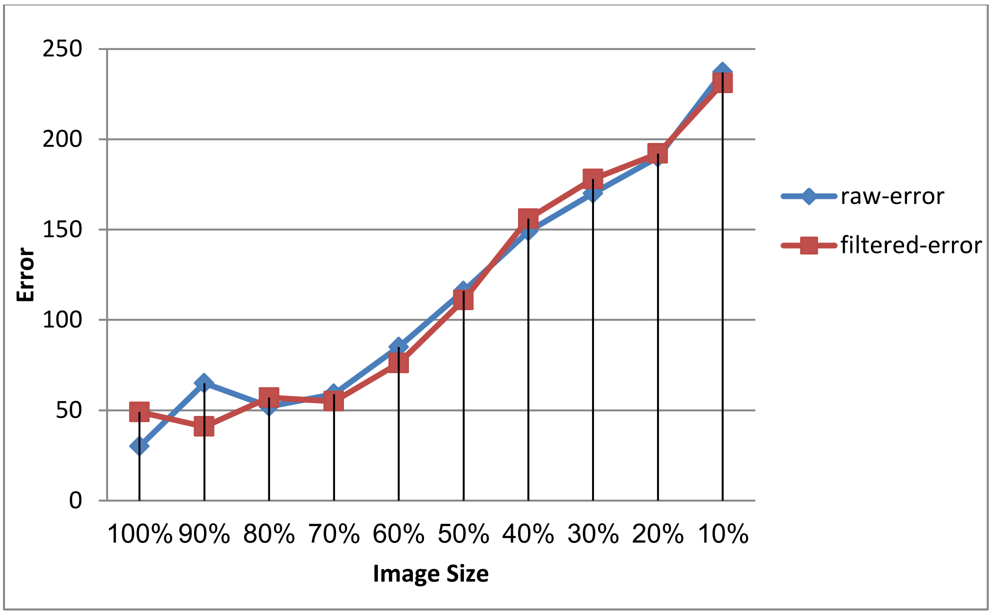

Figure 4.4: Errors for raw, and temporal-spatial (3x3x3) median filtered images

Table 4.3: Percent errors for raw, and temporal (3x3x3) median filtered images

Size compared to HD-image	percent raw-error	percent filtered-error
100%	11.81102	19.29134
90%	25.59055	16.14173
80%	20.47244	22.44094
70%	23.22835	21.65354
60%	33.46457	29.92126
50%	45.66929	43.70079
40%	58.66142	61.41732
30%	66.92913	70.07874
20%	74.80315	75.59055
10%	93.30709	90.94488

Figure 4.4 and Table 4.3 illustrate that using temporal+spatial median filter does not generate a better quality image for the OCR. The errors for median filter are approximately similar to errors for mean filter. A very little improvement can be seen in high-resolutions, but it is not sufficient to say that the results are significant.

The OCR error results for temporal median (3x3x3) filtering (for each RGB layer) are shown in Figure 4.5 and Table 4.4.

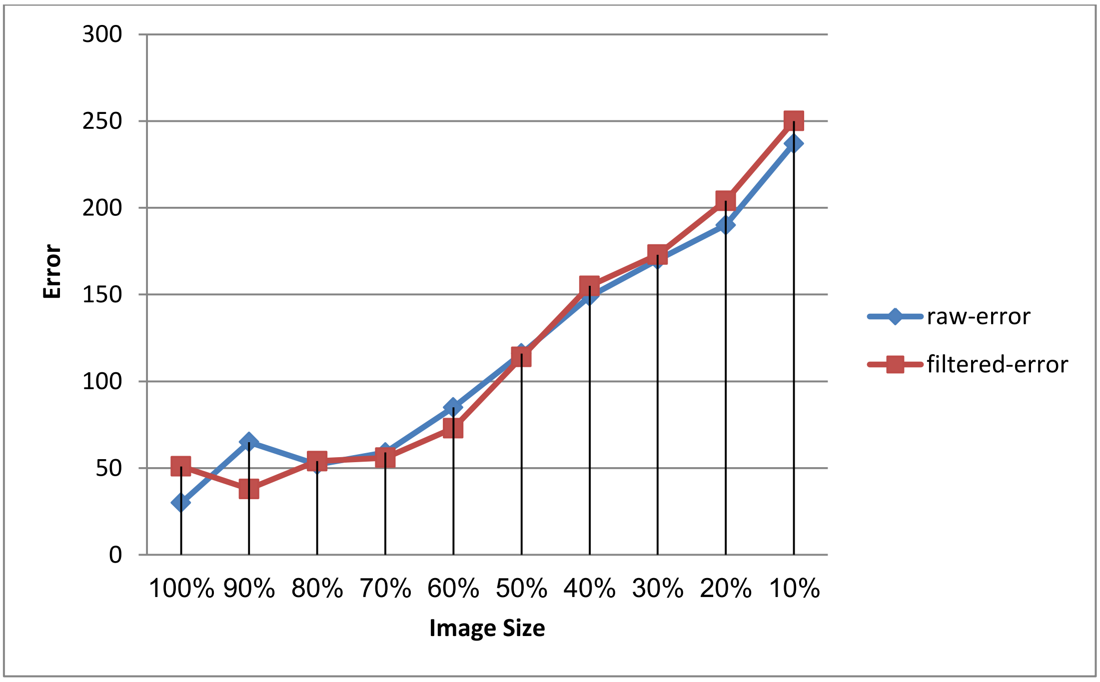

Figure 4.5: Errors for raw, and temporal-spatial (3x3x3) median filtered images

Table 4.4: Errors for raw, and temporal-spatial (3x3x3) median filtered images

Size compared to HD-image	percent raw-error	percent filtered-error
100%	11.81%	20.07%
90%	25.59%	14.96%
80%	20.47%	21.25%
70%	23.22%	22.04%
60%	33.46%	28.74%
50%	45.66%	44.88%
40%	58.66%	61.02%
30%	66.92%	68.11%
20%	74.80%	80.31%
10%	93.30%	98.42%

The improvement of the images by (3x3x3) mean filtere is not sufficient for a significant reduction of error.

4.4 Performance Measurement for Temporal Maximum Filters

The OCR text error of temporal (1x1x3) max filter to enhance the low-quality image are shown in Figure 4.6 and Table 4.5.

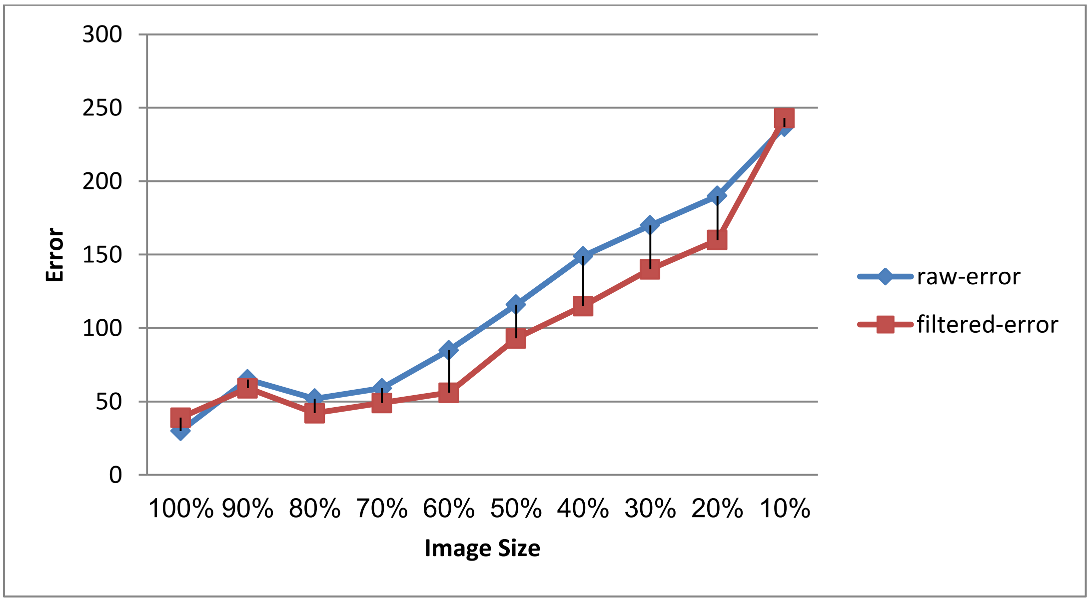

Figure 4.6: Errors for raw, and purely temporal (1x1x3) max filtered images

Table 4.5: Errors for raw, and purely temporal (1x1x3) max filtered images

Size compared to HD-image	percent raw-error	percent filtered-error
100%	11.81%	15.35%
90%	25.59%	23.22%
80%	20.47%	16.53%
70%	23.22%	19.29%
60%	33.46%	22.04%
50%	45.66%	36.61%
40%	58.66%	45.27%
30%	66.92%	55.11%
20%	74.80%	62.99%
10%	93.30%	95.66%

The results shown in Figure 4.6 and Table 4.5 indicate that max filter is highly efficient to improve the quality of the images considering the OCR text. The improvement of the quality of images dropped the OCR error from 60% to 20% at higher resolutions.

The results for the temporal+spatial (3x3x3) max filter are shown in Figure 4.7 and Table 4.6.

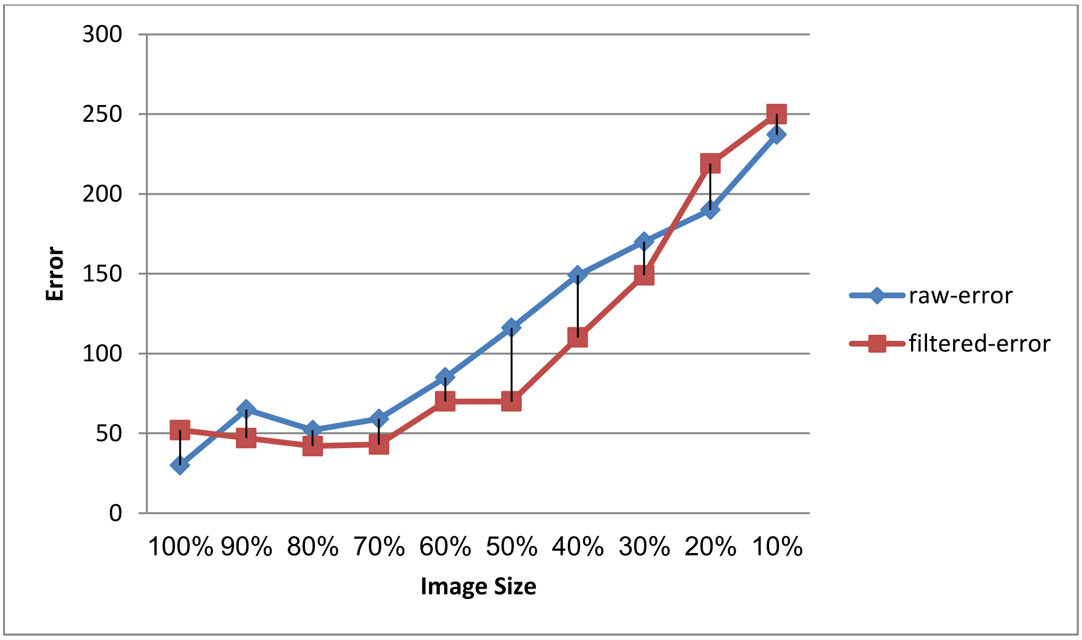

Figure 4.7: Errors for raw, and temporal-spatial (3x3x3) max filtered images

Table 4.6: Errors for raw, and temporal-spatial (3x3x3) max filtered images

Size compared to HD-image	percent raw-error	percent filtered-error
100%	11.81%	20.47%
90%	25.59%	18.50%
80%	20.47%	16.53%
70%	23.22%	16.92%
60%	33.46%	27.55%
50%	45.66%	27.55%
40%	58.66%	43.30%
30%	66.92%	58.66%
20%	74.80%	86.22%
10%	93.30%	98.42%

Figure 4.7 illustrates that this technique is efficient and has good results because the errors are reduced for most of resolution levels, especially between 60% and 20% of resolution of the original frame. On the other hand, in higher resolution levels the error of reading character is decreased by small amounts and also this technique doesn't work on very low resolutions that are less than 30% of the original resolution.

4.5 Comparisons between Proposed Techniques

In summary, the results demonstrated that max filter has the best results among all proposed temporal filters. Among the two kinds of max filters, the purely temporal filter reduces the OCR error more effectively compared to the temporal+spatial max filter. The mean and median filters do not improve the image quality for text recognition at the extent of max filter, and temporal+spatial mean filter increased the error unexpectedly.

Figure 4.8: Difference between outputs of each technique using 3 temporal pixels

A sample of the filtered images are shown in Figure (4.8). Inspecting the images, the main reason that might cause positive results of max technique may be explained by the high illumination level of the plate background. Max filter improves the contrast level of the text and provides more accurate binarization. It also makes the gap between the characters more contrast as well, which reduces the errors in chopping and associating characters by the OCR algorithm. Another reason might be the thickening effect of max filter that helps extraction step in the OCR.

Chapter 5

CONCLUSION

Development of intelligent transportation systems is an active area of research. These systems are being used to monitor crimes and offenses on public roads. License plate recognition is the key part of these systems. They mostly employ optical character recognition (OCR) to convert image of the car license plate to easily searchable text format. The accuracy of the OCR varies according to the quality of the input image. Therefore preprocessing is an important step to improve the quality of the plate image. This thesis tested Dr. Bodur's novel temporal filtering method which combines a set of consecutive video frames to a single improved quality image for the task of vehicle-plate character recognition purpose. Process started with vehicle-plate video records. Consecutive images of video records of car plates are filtered using the proposed temporal filters, after reduction of their size to convert them to low resolution images. The OCR output of raw image (raw-text) and temporal filtered images (filtered-texts) are compared agains the OCR-text of high resolution image to determine the raw-error and filtered-error for the specified resolution.

The temporal filtering method is expanded to temporal mean, temporal median and temporal max filters. They are applied to RGB color images to benefit from all details of the image. The results of tests show that the purely temporal max filter has better effect on the plate image for text recognition purpose. The median and mean filters do not effect the OCR error significiantly.

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APPENDICES

Appendex A: First part of only max pixel

Max pixel	100%				90%				80%				70%				60%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG 893	0	J5 893	1	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 833	1
GP 350	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 3530	1	SP 350	1	GP 350	0	GP 350	0
HT 722	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	HT 722	0
NB 389	NB38S	1	H8389	2	NB38S	1	NB38S	1	NB389	0	NB38S	1	NB389	0	NB389	0	NB389	0	NBBBS	3
FB 595	F3 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1
HR 607	HR 607	0	HR 807	1	HR 607	0	HR 807	1	HR 607	0	HR SCS7	3	HR 607	0	HR 807	1	HR 607	0	HR 607	0
GC 963	GC963	0	GC963	0		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0
KP 103	KP I03	0	KP IDS	2	KP I03	0	KP IDS	2	KP I03	0	KP I03	0	KP |D3	2	KP I03	0	KF1 IDI3	4	KP I03	0
FH 837	FH837	0	FH837	0		5	FHK37	1		5	FH837	0		5	FH837	0		5		5
FK 595	FK 595	0	FK 535	1	FK 595	0	FK 535	1	FK 595	0	FK 585	1	FK 595	0	FK 595	0		5	FK 595	0
JC 052	JG 052	1	JC052	0	JD 052	1	JC052	0	JO 052	1	JCO52	0	JC 052	0	JC 052	0	JC 052	0	JC052	0
JP 190	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0		5	JP I90	0
MN 222	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0	GL257	0	GL 2557	1	GL 2537	1	GL 257	0	GL257	0	GL 257	0	GL257	0	GL 257	0	GL 257	0
JG 335	JG 335	0	JG A335	1	JG 335	0	JG 335	0	JG 335	0	JG A335	1	JG 335	0	JG A335	1	JD 335 M	2	JG 335	0
JM 067	JM 067	0	JM067	0	JM 087	1	JM067	1	JM D87	2	JMD67	1	JMO67	0	JMO67	0		5	JM067	0
GB 693	GB693	0	GB693	0	GB693	1	GB693 V	1	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB593	1
LP 488	LP488	0	LP488	0	LP48B	1	LP488	0	LP48B	1	LP488	0	LP488	0	LP488	0	LP488	0	LP488	0
FK 740	FK740	0	FK740 L	1	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0
LS 082	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0		5	LS 082	0		5	LS 082	0
LP 339	LP339	0	V LP339	1		5	LP339	0	LP339	0	LP339	0	LP339	0	LP339	0		5	LP339	0
LS 188	LS I88	0		5		5	LS I88	0		5		5		5		5		5		5

TCD 570	TDD 570	1	TCD S70	1	TCD S70	1	TCD S70	1	TCD 570	0	N30 570	3	TOD S70	2	TCD 570	0	TCD 570	0	TCD 570	0
HR 912	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRS|2	2	HR9l2	0	HR9l2	0	HRSIZ	2	HRSIZ	2	HRSIZ	2	HR5l2	1
JE 748	JE 7482	1	VJE 748	1	JE 7482	1	JE 748	0	JE 748	0	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0
LB 493	LB493	0	LB493	0	LB493	0	LB433	1	L8493	1	LB493	0	LB493	0		5	LB433	1	LB493	0
MJ 784	MJ784	0	MJ784	0	784	2	MJ784	0	MAJ784	1	N!J784	2	784	2	MZJ784	1	784	2	MJ784	0
ND 992	[an 992	3	ND 992	0	an 992	2	ND 932	1	an 992	2	ND 992	0	an 992	2	ND 352	2	an 992	2	ND 393	3
TKT 656	TKT 656	0	TKT 856	1	TKT 856	1	TKT B56	1	TKT B58	2	TKT B58	2	TKT B56	1	TKT B56	1	TKT S58	2	TKT B55	2
JB 603	J8 603	1	JB 6fi3	2	J8 603	1	38 6133	5	18 603	2	J8 603	1	18 603	2	J8 6&3	2	38 603	2	J8 6&3	2
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0
DT 830	TTm830	3	DT 830	0	(F7830	3	DT 830	4		5	DT 830	0		5	DT 830	0		5	DT 830	0
FK 115	F KIIS	1	FKIIS	1	FKlIS	1	FKIIS	1	F KIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1
KB 474	KB 474	0	KB 472	1	KB474	0	I KB 4737	3	KB 474	0	KB 474	0	KB 474	0	L KB 4747	2	KB 474	0	L KB 4727	3
DK 187	nx I87	2	DK I87	0	BK |87	2	DK I87	1 2	DK |87	1	DK I87	0	DK |87	1	BK I87	1	DK |87	1	DK I87	0
JF 081	JF 08!	1	JF OBI	1	JF OBI	2	JF OBI	3	JF OBI	3	JF 08}	1	JP 08}	1	JF OBI	1	JF OBI	3	JP 08!	2
TNR 868	TNR868	0	TNR8 68	0	TNR868	0	TNR868	0	TNR868	0	NR 868	1	TNRT86 8	1	TNR868	0	TNR868	0	NR 868	1
DJ797	DJ797	0	UJ797	1	UJ797	1	UJ797	2	DJ797	0	UJ797	1	DJ797	0	UJ797	1	UJ737	2	UJ797	1
KR 361	KR 35!	2	KR 36!	1	KR 3$|	2	KR 3S|	3	KR 3S|	2	KR 3S|	2	KR 35!	2	KR 38!	2	KR 3S|	2	KR 38!	2
CP 341	CP34|	0	CP34l	0	CP 34|	2	CF34!	2	EP 34!	2	CF34!	1	EP 34!	2	CP34|	1	CP 34l	0	CP34|	1
NZ 732	N2 732	1	N2 732	1	N2 732	1	N2 732	0	N2 732	1	N2 732	1	N2 732	1		5		5		5
FB 595	F8 595	1	F8 595	1	F8 595	1	F8 595	1	WFB 595	1	F8 595	1	F8 595	1	F8 595	1	FB 595	0	F8 595	1
GB 081	G808!	2	GBU8l v	2	BBUBI	3	68081	2	G308!	2	6BU8|<	3	GB OBI	1	GBOBI	1	BB OBI	2	GBUSI	2
HE220	HE220	0	HE220	0	1-{E220	2	HE220	0	7 1- {E220	3	HE220	0	7 HE220	1	7 HE220	1	7 1- {E220	3	W HE220	1
HH 398	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 398	0
HT 114	HT IM	2	HT IM	2	HT [I4	1	HT II4	0	HT [I4	1	HT II4	0	H1 H4	3	HT II4	0	HT II4	0	H1 H4	3
KF 775	KF775	0	KFTIS	3	KFTIS	3	KF77S	1	KF775	0	KF77S	1	KF775	0	U775	2	KF775	0	KF77S	1

KLC 172	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLB 172	1
MR 887	NF! 887	3	N19 887	2	N19 887	3	N32 887	2	NR 887	1	N53 887	3	NE 837	3	NIR B87	3	NR 837	2	NH 887	2
EG 073	EC 073	1	E8 073	1	E5 073	1	E5 073	1		5		5		5		5		5		5
		30		39		65		59		52		42		59		49		85		56

Second part of only max pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG B33	2	J5 893	1	JG E53	2	JG BS3	2	JG BS3	2	JG 853	1		5		5
GP 350	GP 350	0	GP 2350	1	G53 350	2	GP 350	0	GP 35D	1	GP 35!!	2	GP 350	0	GP 350	0	EF lifl	5	5! iii	5
HT 722	HT 722	0	HT722	0	HT722	0	HT 722	0	JIT 722	2	HT 722	0	|IT72 2	2	HT 722	0		5	H11 1	4
NB 389	NB389	0	M8389	2	NBSB S	3	M5383	3	NBCJ BS	4	M3389	2	H835 5	4	H3389	2		5		5
FB 595		5	F8 595	1		5		5		5		5		5		5		5		5
HR 607	HR 607	0	HR 657	1	HR 507	1	HR 507	1	HR 507	1	HR 307	1	RI 507	3	NR 557	3	WM	5	K15 17	4
GC 963		5	GC96 3	0	GC96 3	0	GC963 #	1	GC96 3	0	GC96 3	0		5	GCBS L	3		5		5
KP 103	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KF IDS	3		5
FH 837		5		5		5		5		5		5	H183 7	2		5	W	5	W	5
FK 595		5		5		5		5		5		5		5		5		5		5
JC 052		5		5		5		5		5		5		5		5		5		5
JP 190		5	JP I90	0		5		5		5		5		5		5		5		5
MN 222	MN222	0	MN22 2	0	MN22 2	0	MN22 2	0		5	MN22 2	0		5	IN222	1	W2	4	M2 1	3
GL 257	GL 257	0	GL 257	0	GL 257	0	GL 257	0		5		5		5		5		5		5
JG 335	JD 335	1	JE333 S	3	JG 335	0	JG33S	1	JG 335	0	JG 335	0		5	JG 335	0		5		5

JM 067	JMD87	2	JMO6 7	0		5	JMDS 7	2		5	JMD6 7	1		5	MW	4		5		5
GB 693	GB693	0	A GB693	1		5	GB693	0		5	GB69 3	0		5	GBG9 3	1	C869 3	2		5
LP 488	LP4BB	2	LP488	0	LP£B B	3	LP488	0	LPCB B	3	LNB8	3	LPCE B	3	LPCB E	3	Lilli	4		5
FK 740	FK740	0	FK 740	0		5	FK 740	0		5		5		5		5		5		5
LS 082		5	LS 082	0		5	LS [182	2		5	LS UB2	2		5	LSUE2	2		5	LE W	4
LP 339		5		5	LP339	0	LP339	0	LP339	0	LP339	0	LP33 9	0	LPG39	1		5		5
LS 188		5		5		5		5		5		5		5		5		5		5
TCD 570	TCD 570	0	TCD 570	0	TED 570	1		6		6		6		6		6	M575	4	WE	6
HR 912	HR9I2	0	HRSIZ	2		5		5	HRSIZ	2		5	HRBI Z	2		5		5		5
JE 748	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE748	0	JE 748	0	JE 748	0	JE 748	0	ME	4	£74 5	5
LB 493		5		5		5		5		5		5		5		5		5		5
MJ 784		5	JJ784	1		5	MJ784	0		5	784	2		5	MJ784	0		5	117 34	5
ND 992	NO 592	2	ND 352	2	ND 552	2	ND 332	2	ND 552	2	ND E	3	"Di?	4		5		5		5
TKT 656	TKT S56	1	TKT 858	2	TKT B58	2	TKT 656	0	TKT 655	1	TKT 855	3		6	TKT SSE	3	TKTE SE	3	W5 56	4
JB 603	18 M33	4	18 W3	4	18 603	2	JB 6133	2		5		5		5		5		5		5
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0		5	FRIST	3		5	FR 197	0	FR H7	2	FIE!	3
DT 830	W 017830	4	DT 830	0	W|V83 O	3	DT 830	0	fT830	1	DT 330	1	FY83!	3	IJT E30	3		5	M5 31	4
FK 115		5	FKIIS	1		5		5		5		5		5		5		5		5
KB 474	KB 474	0	KB 4747	1	KB 474	0	KB 4747	1	KB 474	0	KB 474	0	KB 474	0	KB 414	1		5	W	5
DK 187	DK I87	0	DK I87	0		5	nx1a7	3		5		5		5		5		5		5
JF 081	JF 08}	1		5		5		5		5		5	JF B81	1	JF D81	1	M	5	lll	5
TNR 868	TNRT86 8	1	TNR8 58	1	TNR 868	0	TNR86 8	0	TNR 868	0	TNR 868	0	TNR8 68	0	INRBG B	4		6		6
DJ797	DJ797	0	UJ797	1	IJJ737	3	DJ797	0	M797	2	BJ797	0	M757	3	|JJ7§7	3		5		5
KR 361		5	KR 38	2		5		5		5		5		5		5		5		5

CP 341	EP 34|	1	CF34!	2		5	CF34!	2		5	tP34l	1		5	EF34|	3		5	M.	5
NZ 732		5		5		5		5		5		5		5		5		5		5
FB 595	F8 595	1	F8 595	1		5		5		5		5	H995	3		5		5		5
GB 081	GBDSI	2	GEUB I	3	GBOB I	1	GBUBI	2	G5 OBI	2	GRUB !	4	EIIJSI	4	93081	2		5		5
HE220	HE220	0	HE22 D	1	7 HE220	1	7 HEZZD	4	7 HE22D	2	7 HE22D	1		5		5		5		5
HH 398	HI-1398	3	HHES E	3	HH 358	1	HH 395	1	HH 39!	1	HH 398	0	NH ESE	4	NH 39E	2	Ml	5		5
HT 114	HT Ill	1	HT IM	2	HT IM	2	HT Ill	1		5	H II	2	HTIM	2	HIM	4		5		5
KF 775		5	F775	1		5	KF775	0		5	[F775	1		5	W75	3		5		5
KLC 172		6		6		6		6		5		6		6		6	W	5	W	5
MR 887	N33 387	4	NE 887	2	NH 337	4	Nil BB7	4	MI 357	3	W EH7	4		5	M1 IE7	3	Wm	5	M1	5
EG 073		5		5		5		5		5		5		5		5		5		5
		116		93		149		115		170		140		190		160		237		243

Appendex B: First part of max filter and pixels

	100%				90%				80%				70%				60%			
out1	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG 893	0	JB 893	1	JG 833	1	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 8533	2
GP 350	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 3530	1	GP 350	0	GP 350	0	GP 350	0
HT 722	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	HT722	0	HT722	0	HT 722	0	HT722	0	HT 722	0
NB 389	NB38S	1	HB389	1	NB38S	1	NB389	0	NB389	0	H8389	2	NB389	0	NB389	0	NB389	0	NB389	0
FB 595	F3 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1
HR 607	HR 607	0	HR 807	1	HR 607	0	HR 807	1	HR 607	0	HR 607	0	HR 607	0	HR 807	1	HR 607	0	HR 607	0
GC 963	GC963	0	GC963	0		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963?	1
KP 103	KP I03	0	KP I013	1	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP |D3	2	KP|O13	2	KF1 IDI3	4	KP I023	1
FH 837	FH837	0	FH837	0		5	H1&7	3		5	FH837	0		5	FHSW	3		5	FHBTI	3
FK 595	FK 595	0	FKSSS	3	FK 595	0	FKSSS	3	FK 595	0	FK 595	0	FK 595	0	FK 595	0		5	FKSSS	3
JC 052	JG 052	1	JCOSEV	4	JD 052	1	JCO52	0	JO 052	1	JC 052	0	JC 052	0	JC 052	0	JC 052	0	JCOS2	2
JP 190	JP I90	0	JP 190	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0		5	JP 190	0
MN 222	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0	GL257	0	GL 2557	1	GL257	0	GL 257	0	GL257	0	GL 257	0	GL257	0	GL 257	0	GL 257	0
JG 335	JG 335	0	JB335	1	JG 335	0	JG 335	0	JG 335	0	JD 335	1	JG 335	0	JD 335	1	JD 335 M	2	JD 335	1
JM 067	JM 067	0	H067	2	JM 087	1	M067	1	JM D87	2	H067	2	JMO67	0	JIICE7	4		5	3%?	5
GB 693	GB693	0	38693 T	3	GB693	1	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0
LP 488	LP488	0	LP488	0	LP48B	1	LP48B	1	LP48B	1	LP488	0	LP488	0	LP4B8	1	LP488	0	LP4BB	2
FK 740	FK740	0	FK74D	1	FK740	0	FK74OJ	1	FK740	0	PK 740	1	FK740	0	FK740	0	FK740	0	FK 740	0
LS 082	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LSUB2	2		5	LSDB2	2		5	LS 082	0
LP 339	LP339	0	LP339	0		5	LP339	0	LP339	0	LP339	0	LP339	0	LP339	0		5	LP339	0
LS 188	LS I88	0	LS I88	0		5	LS I88	0		5	LS I88	0		5	LS I88	0		5		5

TCD 570	TDD 570	1	TDD 570	1	TCD S70	1	TCD 570	0	TCD 570	0	TED 570	1	TOD S70	2	TCD 570	0	TCD 570	0	TCD 570	0
HR 912	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRSIZ	2	HR9l2	0	HRSIZ	2	HRSIZ	2	HRSI2	1	HRSIZ	2	HRSIZ	2
JE 748	JE 7482	1	JE 7482	1	JE 7482	1	JE 7482	1	JE 748	0	JE 7482	1	JE 7482	1	JE 748	0	JE 748	0	JE 7482	1
LB 493	LB493	0	LB493	0	LB493	0	LB493	0	L8493	1	LB493	0	LB493	0	LB493	0	LB433	1	LB493	0
MJ 784	MJ784	0	flJ784	2	784	2	MJ784	0	MAJ784	1	MJ784	0	784	2	MJ784	0	784	2	MJ784	0
ND 992	[an 992	3		5	an 992	2	no 392	3	an 992	2	ND332	2	an 992	2	H0953	3	an 992	2	Nnasg	4
TKT 656	TKT 656	0	TKT S58	2	TKT 856	1	TKT B58	2	TKT B58	2	TKT B56	1	TKT B56	1	TKT 656	0	TKT S58	2	TKT 555	2
JB 603	J8 603	1	38 603	2	J8 603	1	18 6B3	3	18 603	2	18 603	2	18 603	2	B 603	1	38 603	2	B 603	1
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0
DT 830	TTm830	3	DT 830	0	(F7830	3	DTV8313	3		5	DT 830	0		5	DT 830	0		5	DT 1830	1
FK 115	F KIIS	1	FKIIS	1	FKlIS	1	FKIIS	1	F KIIS	1	FKIIS	1	FKIIS	1	V FKHS	4	FKIIS	1	FKIIS	1
KB 474	KB 474	0	1 KB 473	2	KB474	0	KB 471	1	KB 474	0	I KB 47}?	3	KB 474	0	i KB 4747	2	KB 474	0	I KB 47?	2
DK 187	nx I87	2	BK I87	1	BK |87	2	BK I87	1	DK |87	1	BK I87	1	DK |87	1	DK I87	0	DK |87	1	DK I87	0
JF 081	JF 08!	1	JF OBI	2	JF OBI	2	JF 08}	1	JF OBI	3	JF U8}	2	JP 08}	1	JF 08}	1	JF OBI	3	JF OBI	2
TNR 868	TNR868	0	NR 868	1	TNR868	0	TNR868	0	TNR868	0	TNR868	0	TNRT868	1	NR 868	1	TNR868	0	TNR868	0
DJ797	DJ797	0	UJ737 j	2	UJ797	1	UJ737	2	DJ797	0	flJ797	2	DJ797	0	UJ797	1	UJ737	2	[U797	2
KR 361	KR 35!	2	KR 36| F	1	KR 3$|	2	KR 36| A	2	KR 3S|	2	KR 36! A	2	KR 35!	2	KR 36!	1	KR 3S|	2	KR 36|	1
CP 341	CP34|	0	CP34|	0	CP 34|	2	4934	3	EP 34!	2	EP34|	2	EP 34!	2	4934	3	CP 34l	0	CF34!	2
NZ 732	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1		5		5
FB 595	F8 595	1	F8 595	1	F8 595	1	F8 595	1	WFB 595	1	F8 595	1	F8 595	1	F8 595	1	FB 595	0	F8 595	1
GB 081	G808!	2	EBU8|	2	BBUBI	3	SE08!	3	G308!	2	EB 08!	2	GB OBI	1	E308!	2	BB OBI	2	E803!	4
HE220	HE220	0	HE22U	1	1-{E220	2	Z HE220	1	7 1-{E220	3	Z HE220	1	7 HE220	1	7 HE22D	2	7 1-{E220	3	K IE220	2
HH 398	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 398	0
HT 114	HT IM	2	HT II4	0	HT [I4	1	HT II4	0	HT [I4	1	HT II4	0	H1 H4	3	HT II4	0	HT II4	0	HT II4	0
KF 775	KF775	0	KF775	0	KFTIS	3	KF775	0	KF775	0	KF77S	1	KF775	0	KF775	0	KF775	0	[F775	1
KLC 172	KLC 172	0	KLE 172	1	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLE 172	1	KLC 172	0	KLC 172	0
MR 887	NF! 887	3	HQ 887	2	N19 887	3	N13 887	3	NR 887	1	H13 887	3	NE 837	3	HQ 887	2	NR 837	2	NFIBB7	5

EG 073	EC 073	1	EC 073	1	E5 073	1	ES 073	1		5	EC 073	1		5	EC 073	1		5		5
		30		52		65		47		52		42		59		43		85		70

Second part of max filter and pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	J5 893	1	JG B33	2	JG 893	0	JG E53	2	JG B93	1	JG BS3	2		5		5	IE	5
GP 350	GP 350	0	GP 350	0	G53 350	2	GP 350	0	GP 35D	1	GP 350	0	GP 350	0		5	EF lifl	5		5
HT 722	HT 722	0	HT 722	0	HT722	0	HT722	0	JIT 722	2	HT722	0	|IT722	2	HT712	1		5		5
NB 389	NB389	0	NB383	1	NBSBS	3	M8389	2	NBCJBS	4	H8199	4	H8355	4		5		5	[Pl	5
FB 595		5	F8 595	1		5	F8 595	1		5		5		5	H35	4		5		5
HR 607	HR 607	0	HR 807	1	HR 507	1	HR 507	1	HR 507	1		5	RI 507	3		5	WM	5		5
GC 963		5	GC963a	1	GC963	0	GC963	0	GC963	0	GC96	1		5		5		5		5
KP 103	KP I03	0	KP I03	0	KP I03	0	KP nos	3	KP I03	0	1P I03	1	KP I03	0	KP K08	2	KF IDS	3		5
FH 837		5	FHS37	1		5		5		5		5	H1837	2		5	W	5		5
FK 595		5	FK 595	0		5	FK39S	1		5	H4595	2		5		5		5		5
JC 052		5	JC 052	0		5		5		5		5		5		5		5		5
JP 190		5	JP 190	0		5	JP 1913	2		5	JH90	2		5	PBS	4		5	)5	5
MN 222	MN222	0	HN222	0	MN222	0	IN222	1		5	IH222	2		5	HN22	5	W2	4	H	5
GL 257	GL 257	0	GL257	0	GL 257	0	GL257	0		5	GL 257	0		5	GL257	0		5		5
JG 335	JD 335	1	16335	2	JG 335	0		5	JG 335	0		5		5		5		5		5
JM 067	JMD87	2	JIICB7	4		5		5		5		5		5		5		5	JP	4
GB 693	GB693	0	GB693	1		5		5		5		5		5	B693	1	C8693	2	3%	4

LP 488	LP4BB	2	LP4B8	1	LP£BB	3	LP4BB	2	LPCBB	3	LP4BB	2	LPCEB	3	U488	2	Lilli	4	Lna	4
FK 740	FK740	0	FK 740	0		5	FK740	0		5	FK 740	0		5	VH40	5		5		5
LS 082		5	LS 082	0		5	LS 082	0		5		5		5		5		5		5
LP 339		5	LP339	0	LP339	0		5	LP339	0		5	LP339	0	LFLfi	4		5		5
LS 188		5		5		5		5		5	LSIBB	2		5	L533	4		5		5
TCD 570	TCD 570	0		6	TED 570	1		6		6		6		6		6	M575	4		6
HR 912	HR9I2	0	HRSIZ	2		5	HR9l2	0	HRSIZ	2	HRSIQ	2	HRBIZ	2		5		5		5
JE 748	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE748	0	E 748	1	JE 748	0	I 748	2	ME	4	['13	5
LB 493		5	LB493	0		5		5		5		5		5		5		5	is	5
MJ 784		5	(MJ784	1		5	V MJ784	1		5	MJ78A	2		5		5		5		5
ND 992	NO 592	2	H0392	3	ND 552	2	{Q32	4	ND 552	2		5	"Di?	4		5		5		5
TKT 656	TKT S56	1	TKT B55	2	TKT B58	2	TKT 856	1	TKT 655	1	TKT BS6	1		6	HT 555	4	TKTESE	3		6
JB 603	18 M33	4	13 6B3	3	18 603	2	13 603	2		5	Z860Lu	4		5	£55?	5		5		5
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0		5	FR B7	2		5		5	FR H7	2		5
DT 830	W 017830	4	DT 830	0	W|V83O	3	DT83U	1	fT830	1	D1830	1	FY83!	3	mean	5		5		5
FK 115		5	FKIIS	1		5	FKH5	2		5	FKH5	2		5		5		5		5
KB 474	KB 474	0	! KB 4711	3	KB 474	0	I KB 4747	2	KB 474	0	KB 174	1	KB 474	0	E C4	4		5		5
DK 187	DK I87	0	DK I87	0		5	DK I87	0		5	BK 187	1		5		5		5		5
JF 081	JF 08}	1	JF OBI	1		5	JF UBI	2		5		5	JF B81	1		5	M	5	Jl	4
TNR 868	TNRT868	1	TNR868	0	TNR 868	0	TNR868	0	TNR 868	0	TNRB68	1	TNR868	0		6		6		6
DJ797	DJ797	0	UJ737	2	IJJ737	3	flj737	3	M797	2		5	M757	3		5		5		5
KR 361		5		5		5		5		5		5		5		5		5	H	5
CP 341	EP 34|	1	cP34I	0		5	EP34I	1		5	5934	3		5	53	5		5		5
NZ 732		5	H2732	2		5		5		5		5		5		5		5		5
FB 595	F8 595	1	F8 595	1		5	F8 595	1		5		5	H995	3	H35	4		5		5
GB 081	GBDSI	2	R! 081	2	GBOBI	1	NW1	4	G5 OBI	2	SIM	5	EIIJSI	4	ill	5		5	ll	5

HE220	HE220	0	HE220	0	7 HE220	1		5	7 HE22D	2		5		5		5		5		5
HH 398	HI-1398	3	HH 398	0	HH 358	1	DH395	2	HH 39!	1	HI396	1	NH ESE	4	WK	5	Ml	5	ii	5
HT 114	HT lll	1	HT H4	2	HT IM	2	HT II4	0		5	HT [I4	1	HTIM	2	N4	4		5		5
KF 775		5	D7775	2		5	[F775	1		5	[F775	1		5	5775	2		5		5
KLC 172		6	KLE 172	1		6	KLC 172	0		5	£172	3		6		5	W	5		6
MR 887	N33 387	4	PJIIBB7	6	NH 337	4	H13! 887	4	MI 357	3		5		5		5	Wm	5	l!‘	5
EG 073		5		5		5		5		5	3	4		5		5		5		5
		116		70		149		110		170		149		190		219		237		250

Appendex C: First part of only median pixel

	100%				90%				80%				70%				60%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG 893	0	JG 833	0	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 893	0
GP 350	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 3530	1	GP 350	0	GP 350	0	GP 350	0
HT 722	HT722	0	HT 722 A	1	HT722	0	HT 722	0	HT722	0	JIT 722	2	HT722	0	JIT 722	2	HT722	0	HT 722	0
NB 389	NB38 S	1	H8389	2	NB38 S	1	NB3BS	2	NB389	0	NB38S	1	NB389	0	NB389	0	NB389	0	NB38S	1
FB 595	F3 595	1	F8 595	1	F8 595	1	VVFB 595	2	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	FB 595	0
HR 607	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 507	1	HR 607	0	HR 607	0
GC 963	GC96 3	0	GC963	0		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0
KP 103	KP I03	0	KP |D3	2	KP I03	0	KP I03	0	KP I03	0	KP ID3	1	KP |D3	2	KP |D3	2	KF1 IDI3	4	KP |D3	2
FH 837	FH837	0	FH7	2		5	FH837	0		5	F!I837	2		5	FHfl7	2		5		5
FK 595	FK 595	0	V FK 595	1	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0		5	FK 595	0
JC 052	JG 052	1	JG 052	0	JD 052	1	JC 052	0	JO 052	1	JD 052	1	JC 052	0	JC O52	0	JC 052	0	JD 052	1
JP 190	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0		5		5
MN 222	MN22 2	0	MN222	0	MN22 2	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0	SL257	1	GL 2557	1	GL2257	1	GL 257	0	GL257	0	GL 257	0	GL257	0	GL 257	0	GL257	0
JG 335	JG 335	0	JG 335	0	JG 335	0	16335	2	JG 335	0	18335	2	JG 335	0	JG 335	0	JD 335 M	2	JG 335	0
JM 067	JM 067	0	JHO87	2	JM 087	1	JMO67	0	JM D87	2	JMD67	1	JMO67	0		5		5	JMO87	1
GB 693	GB69 3	0	GB693	0	GB693	1	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0
LP 488	LP488	0	LP4B8	1	LP48B	1	LP488	0	LP48B	1	LP4B8	1	LP488	0	LP4B8	1	LP488	0	LP468	1
FK 740	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0
LS 082	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0		5	LS 082	0		5	LS 082	0
LP 339	LP339	0	V LP339	1		5	LP339	0	LP339	0	LP339	0	LP339	0	LP339	0		5	LP339	0

LS 188	LS I88	0		5		5		5		5		5		5		5		5		5
TCD 570	TDD 570	1	TDD 570	1	TCD S70	1	TDD 570	1	TCD 570	0	TDD 570	1	TOD S70	2	TCD 570	0	TCD 570	0	TCO 570	1
HR 912	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRSIZ	2	HR9l2	0	HR9|2	1	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRSIZ	2
JE 748	JE 7482	1	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0
LB 493	LB493	0	LB493	0	LB493	0	LB493	0	L8493	1	LB433	1	LB493	0	LB493	0	LB433	1	LB453	1
MJ 784	MJ784	0	MJ784	0	784	2	MJ784	0	MAJ78 4	1	MJ784	0	784	2	MJ784	0	784	2		5
ND 992	[an 992	3	ND 992	0	an 992	2	ND 992	0	an 992	2	ND 392	1	an 992	2	ND 392	2	an 992	2	ND 953	2
TKT 656	TKT 656	0	TKT 656	0	TKT 856	1	TKT 856	1	TKT B58	2	TKT 656	0	TKT B56	1	TKT 656	0	TKT S58	2	TKT 856	1
JB 603	J8 603	1	13 603	2	J8 603	1	J3 6E3	2	18 603	2	33 603	2	18 603	2	33 603	2	38 603	2	18 603	2
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0
DT 830	TTm8 30	3	DT 830	0	(F783 0	3	DT 830	0		5	DT 830	0		5	DT 830	0		5	DT 830	0
FK 115	F KIIS	1	FKIIS	1	FKllS	1	FKIIS	1	F KIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1
KB 474	KB 474	0	KBTIY47	4	KB474	0	KB 3711	3	KB 474	0	KB 3711	3	KB 474	0	KB 31774	3	KB 474	0	KB 147147	4
DK 187	nx I87	2	nx |a7	4	BK |87	2	DK I87	0	DK |87	1	nx I87	2	DK |87	1	nx I87	2	DK |87	1	nx I87	2
JF 081	JF 08!	1	JF OBI	1	JF OBI	1	JF OBI	1	JF OBI	3	JF OBI	1	JP 08}	1	JF OBI	1	JF OBI	3		5
TNR 868	TNR8 68	0	TNR868	0	TNR8 68	0	WNR868	1	TNR86 8	0	TNR 868	0	TNRT8 68	1	WNR868	1	TNR86 8	0	NR 858	1
DJ797	DJ797	0	DJ797	0	UJ797	1	M797	2	DJ797	0	DJ797	0	DJ797	0	DJ737	1	UJ737	2	DJ797	0
KR 361	KR 35!	2	KR 381 A	2	KR 3$|	2	KR 36|	1	KR 3S|	2	KR 36|	1	KR 35!	2	KR 3S|	2	KR 3S|	2		5
CP 341	CP34|	0	EP34|	2	CP 34|	2	EP34|	1	EP 34!	2	CP34|	1	EP 34!	2	EP34|	2	CP 34I	0	CP34|	1
NZ 732	N2 732	1	NZ732	0	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1		5		5
FB 595	F8 595	1	F8 595	1	F8 595	1	VVFB 595	2	WFB 595	1	F8 595	1	F8 595	1	F8 595	1	FB 595	0	FB 595	0
GB 081	G808!	2	GB OBI A	2	BBUBI	3	GB OBI	1	G308!	2	C3 D8!	4	GB OBI	1	GB US!	3	BB OBI	2	GB OBI	1
HE22 0	HE22 0	0	T-{E220	2	1- {E220	2	TE220	1	7 1- {E220	3	TEZZU	4	7 HE220	1	TE220	1	7 1- {E220	3	TE220	1
HH 398	HH 398	0	HH 388	1	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 358	1	HH 398	0
HT	HT IM	2	H1H4	3	HT [I4	1	HT IM	2	HT [I4	1	HT [M	3	H1 H4	3	HT IM	2	HT II4	0		5

114																				
KF 775	KF775	0	KF775	0	KFTIS	3	KFTIS	3	KF775	0	KFTTS	3	KF775	0	KFTIS	3	KF775	0	KF775	0
KLC 172	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0
MR 887	NF! 887	3	NR 887	1	N19 887	3	NIR 887	2	NR 887	1	NIFI 887	4	NE 837	3	MR887	0	NR 837	2	NF! BB7	5
EG 073	EC 073	1	E5 073	1	E5 073	1	E6 073	1		5		5		5		5		5		5
		30		49		65		41		52		57		59		55		85		76

Second part of only median pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG B33	2	JG 833	1	JG E53	2	JG E53	2	JG BS3	2	JG 853	1		5	£553	4
GP 350	GP 350	0	GP 350	0	G53 350	2	GP 350	0	GP 35D	1	GP 35D	1	GP 350	0	G9 350	1	EF lifl	5	GF JEN	4
HT 722	HT 722	0	HT 722	0	HT722	0	HT 722	0	JIT 722	2		5	|IT722	2	JT722	1		5		5
NB 389	NB389	0	NB389	0	NBSBS	3	NBBBS	3	NBCJBS	4	NBCIES	4	H8355	4	H8339	3		5		5
FB 595		5	F8 595	1		5		5		5		5		5	F3995	2		5		5
HR 607	HR 607	0	HR 507	1	HR 507	1	Hfi S07	3	HR 507	1	HR 307	1	RI 507	3	HI SE7	3	WM	5	K1511	5
GC 963		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0		5		5		5		5
KP 103	KP I03	0	KP |D3	2	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KF IDS	3	KND3	3
FH 837		5		5		5		5		5		5	H1837	2	FN837	1	W	5	W	4
FK 595		5		5		5		5		5		5		5		5		5		5
JC 052		5		5		5		5		5		5		5		5		5		5
JP 190		5		5		5		5		5		5		5		5		5		5
MN 222	MN222	0	MN222	0	MN222	0	MN222	0		5	MN222	0		5		5	W2	4	M211	3
GL 257	GL 257	0	GL257	0	GL 257	0	GL257	0		5		5		5		5		5		5
JG 335	JD 335	1	JG 335	0	JG 335	0	JD 335	1	JG 335	0	JG 335	0		5		5		5	JG 115	2

JM 067	JMD87	2		5		5		5		5		5		5		5		5		5
GB 693	GB693	0	GB693	0		5	GB693	0		5		5		5		5	C8693	2	G369!	2
LP 488	LP4BB	2	LP4BB	2	LP£BB	3	LP48E	1	LPCBB	3	LPIBB	3	LPCEB	3	LNB8	3	Lilli	4	um	5
FK 740	FK740	0	FK740	0		5		5		5		5		5		5		5		4
LS 082		5	LS 082	0		5		5		5		5		5		5		5		5
LP 339		5		5	LP339	0		5	LP339	0	LP339	0	LP339	0	LP339	0		5		5
LS 188		5		5		5		5		5		5		5		5		5		5
TCD 570	TCD 570	0	TCD 570	0	TED 570	1		6		6		6		6		6	M575	4	WE	6
HR 912	HR9I2	0	HR5|2	2		5		5	HRSIZ	2		5	HRBIZ	2		5		5		5
JE 748	JE 748	0	JE 748	0	JE 748	0	JE 748	0	JE748	0	JE748	0	JE 748	0	JE74B	1	ME	4	£74!	3
LB 493		5		5		5		5		5		5		5		5		5		5
MJ 784		5	J] 84	2		5		5		5		5		5		5		5		5
ND 992	NO 592	2	ND 392	1	ND 552	2	ND 852	2	ND 552	2	ND 992	0	"Di?	4	wage	5		5		5
TKT 656	TKT S56	1	TKT 658	1	TKT B58	2	TKT SS8	3	TKT 655	1	TKT 656	0		6		5	TKTES E	3	M656	3
JB 603	18 M33	4	13 603	2	18 603	2	J8 603	1		5		5		5		5		5		5
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0		5	FR I97	0		5	FR N7	2	FR H7	2	H! !!)	4
DT 830	W 017830	4	DT 830	0	W|V83O	3	DT 830	0	fT830	1		5	FY83!	3	DY 830	1		5	W31!	4
FK 115		5	FKIIS	1		5		5		5		5		5		5		5		5
KB 474	KB 474	0	KB 317747	4	KB 474	0	KB 3174	2	KB 474	0	KB 4747	1	KB 474	0	KB 174	1		5	M	5
DK 187	DK I87	0	DK I87	0		5	ax |e7	4		5		5		5		5		5		5
JF 081	JF 08}	1		5		5		5		5		5	JF B81	1		5	M	5	III	4
TNR 868	TNRT86 8	1	TNR868	0	TNR 868	0	TNR868	0	TNR 868	0	TNR858	1	TNR868	0	TNRBBB	3		6		6
DJ797	DJ797	0	UJ797	1	IJJ737	3	DJ797	0	M797	2	M797	2	M757	3		5		5		5
KR 361		5	KR 38	2		5		5		5		5		5		5		5		5
CP 341	EP 34|	1		5		5	EP34|	2		5		5		5		5		5		5
NZ 732		5		5		5		5		5		5		5		5		5		5
FB 595	F8 595	1	F8 595	1		5		5		5		5	H995	3	F3995	2		5		5

GB 081	GBDSI	2	EB DBI	4	GBOBI	1	GB UBI	2	G5 OBI	2	0! Oil	5	EIIJSI	4		5		5		5
HE220	HE220	0	ii-|E22U	5	7 HE220	1		5	7 HE22D	2		5		5		5		5		5
HH 398	HI-1398	3	HH35E	2	HH 358	1	HI1355	4	HH 39!	1	HH SSE	3	NH ESE	4	HH 3!E	3	Ml	5	rm	5
HT 114	HT Ill	1		5	HT IM	2		5		5		5	HTIM	2	Ifllll	3		5		5
KF 775		5		5		5		5		5		5		5		5		5		5
KLC 172		6		6		6		6		5		6		6		6	W	5		5
MR 887	N33 387	4	NR 887	1	NH 337	4	NIIBB7	5	MI 357	3	NR 337	3		5	Ni SE7	4	Wm	5	W	5
EG 073		5		5		5		5		5		5		5		5		5		5
		116		1 11		1 49		1 56		170		178		1 90		1 92		2 37		2 31

Appendex D: First part median filter median pixel

	100%				90%				80%				70%				60%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 893	0
GP 350	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 3530	1	GP 350	0	GP 350	0	GP 350	0
HT 722	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	JIT 722	2	HT722	0	JIT 722	2	HT722	0	[T HT 722	2
NB 389	NB38S	1	H3389	2	NB38S	1	NB383	1	NB389	0	NB389	0	NB389	0	NB389	0	NB389	0	NB3B9	1
FB 595	F3 595	1	MFB 595	1	F8 595	1	VVFB 595	2	F8 595	1	WFB 595	1	F8 595	1	WFB 595	1	F8 595	1	TB 595	1
HR 607	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 807	1	HR 607	0	HR 507	1	HR 607	0	HR 607	0
GC 963	GC963	0	GC963	0		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0
KP 103	KP I03	0	KP |D3	2	KP I03	0	KP I03	0	KP I03	0	KP ID3	1	KP |D3	2	KP I03	0	KF1 IDI3	4	KP |D3	2
FH 837	FH837	0	FHE7	2		5	FII837	2		5	FH837	0		5	Hlfl7	3		5	FH837	0
FK 595	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0		5	FK 595	0
JC 052	JG 052	1	JC 052	0	JD 052	1	JC O52	0	JO 052	1	JO 052	1	JC 052	0	JC O52	0	JC 052	0	JC O52	0
JP 190	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0		5		5
MN 222	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0	SL257	0	GL 2557	1	GL257	0	GL 257	0	GL257	0	GL 257	0	GL257	0	GL 257	0	GL257	0
JG 335	JG 335	0	JG 335	0	JG 335	0	16335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JD 335 M	2	JG 3355	1
JM 067	JM 067	0	JMO87	1	JM 087	1	JMO67	0	JM D87	2	JMO67	0	JMO67	0		5		5	JMOS7	2
GB 693	GB693	0	GB693 M	1	GB693	1	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0
LP 488	LP488	0	LP488	0	LP48B	1	LP488	0	LP48B	1	LP4B8	1	LP488	0	LP4BB	2	LP488	0	LP488	0
FK 740	FK740	0	FK740	0	FK740	0	FK74D	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0
LS 082	LS 082	0	V LS 082	1	LS 082	0	LS 082	0	LS 082	0	LS 082	0		5	LS 082	0		5	LS 082	0
LP 339	LP339	0	VLP339	1		5	LP339	0	LP339	0	LP339	0	LP339	0	LP339	0		5		5
LS 188	LS I88	0		5		5		5		5		5		5		5		5		5
TCD 570	TDD 570	1	TCD 570	0	TCD S70	1	TDD 570	1	TCD 570	0	TDD 570	1	TOD S70	2	TDD 570	1	TCD 570	0	TCO 570	1

HR 912	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRSIZ	2	HR9l2	0	HRBIZ	0	HRSIZ	2	HRSIZ	2	HRSIZ	2	HR9l2	0
JE 748	JE 7482	1	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0
LB 493	LB493	0	LB493	0	LB493	0	LB433	1	L8493	1	LB493	0	LB493	0	LB493	0	LB433	1	LB433	1
MJ 784	MJ784	0	MJ784	0	784	2	MJ784	0	MAJ784	1	MJ784	0	784	2	MJ784	0	784	2		5
ND 992	[an 992	3	no sea	5	an 992	2	ND 992	0	an 992	2	ND 932	1	an 992	2	ND 332	2	an 992	2	ND 3sa	3
TKT 656	TKT 656	0	TKT 856	1	TKT 856	1	TKT 656	0	TKT B58	2	TKT 656	0	TKT B56	1	TKT E56	1	TKT S58	2	TKT 656	0
JB 603	J8 603	1	J8 603	0	J8 603	1	J3 6E3	2	18 603	2	38 603	2	18 603	2	J8 603	1	38 603	2	J3 603	1
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0
DT 830	TTm830	3	EJT830	2	(F7830	3	DT 830	0		5	DT 830	0		5	DT 830	0		5	DT 830	0
FK 115	F KIIS	1	FKIIS	1	FKlIS	1	FKIIS	1	F KIIS	1	F KIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	F KIIS	1
KB 474	KB 474	0	K317?	3	KB474	0	KB 3711?	4	KB 474	0	KB 3711	3	KB 474	0	KB 3174	2	KB 474	0	KB 3737	3
DK 187	nx I87	2	DK I87	0	BK |87	2	UK I87	1	DK |87	1	nx I87	2	DK |87	1	nx nev	5	DK |87	1	nx I87	2
JF 081	JF 08!	1	JF OBI	1	JF OBI	1	JF OBI	1	JF OBI	3	JF OBI	1	JP 08}	1	JF 08}	1	JF OBI	3	JF OBI	1
TNR 868	TNR868	0	TNR868	0	TNR868	0	TNR858	1	TNR868	0	TNR 868	0	TNRT86 8	1	TNR868	0	TNR868	0	NR 868	1
DJ797	DJ797	0	DJ797	0	UJ797	1	[JJ737	3	DJ797	0	DJ797	0	DJ797	0	DJ797	0	UJ737	2	DJ797	0
KR 361	KR 35!	2	KR38l%	2	KR 3$|	2	KR 3S|	2	KR 3S|	2	KR 36|	1	KR 35!	2	KR 3$|	2	KR 3S|	2		5
CP 341	CP34|	0	CF34!	1	CP 34|	2	EP34|	1	EP 34!	2	CP34|	1	EP 34!	2	EP34|	2	CP 34l	0	CP34|	1
NZ 732	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1		5		5
FB 595	F8 595	1	MFB 595	1	F8 595	1	VVFB 595	2	WFB 595	1	WFB 595	1	F8 595	1	WFB 595	1	FB 595	0	TB 595	1
GB 081	G808!	2	5308! V	4	BBUBI	3	GB OBI	1	G308!	2	C3 D8!	4	GB OBI	1	GB 08!	1	BB OBI	2	GB OBI	1
HE220	HE220	0	T-{E220	2	1-{E220	2	TE220	1	7 1- {E220	3	TEZZO	4	7 HE220	1	TE220	1	7 1- {E220	3	T8220	2
HH 398	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 398	0
HT 114	HT IM	2	HT IM	2	HT [I4	1	HT IM	2	HT [I4	1	HT [I4	1	H1 H4	3	HT IM	2	HT II4	0		5
KF 775	KF775	0	KF775	0	KFTIS	3	KFTIS	3	KF775	0	KFTTS	3	KF775	0	[F775	1	KF775	0	KF77S	1
KLC 172	KLC 172	0	100 172	3	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0
MR 887	NF! 887	3	NIP 887	3	N19 887	3	NH 887	2	NR 887	1	NR 887	1	NE 837	3	INEBS7	5	NR 837	2	N53! 887	4
EG 073	EC 073	1	EC 073	1	E5 073	1	E6 073	1		5		5		5		5		5		5

		30		51		65		38		52		45		59		56		85		73

Second part of median filter and median pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG B33	2	JG B33	2	JG E53	2	JG 853	1	JG BS3	2	£033	4		5		5
GP 350	GP 350	0	SP 350	1	G53 350	2	SP 350	1	GP 35D	1	GP 35!	1	GP 350	0	G935!	3	EF lifl	5	FE	5
HT 722	HT 722	0	RT 722	1	HT722	0	KT722	1	JIT 722	2		5	|IT722	2		5		5		5
NB 389	NB389	0	M8389	2	NBSBS	3	M3385	3	NBCJBS	4	NBJBS	3	H8355	4	IIIBS	4		5		5
FB 595		5	F8 595	1		5		5		5	PB 595	1		5	R55	4		5		5
HR 607	HR 607	0	HR 607	0	HR 507	1	H? 507	2	HR 507	1	HR 307	1	RI 507	3	W007	3	WM	5		5
GC 963		5	GC963	0	GC963	0	GC963i	1	GC963	0	GC963	0		5		5		5		5
KP 103	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KP I03	0	KF IDS	3		5
FH 837		5		5		5		5		5		5	H1837	2	film	4	W	5	HE	4
FK 595		5		5		5		5		5		5		5	H595	2		5	.11»Ill	5
JC 052		5		5		5		5		5		5		5		5		5		5
JP 190		5		5		5		5		5		5		5		5		5		5
MN 222	MN222	0	MN222	0	MN222	0	MN222	0		5	MN222	0		5	IN122	2	W2	4		5
GL 257	GL 257	0	GL 257	0	GL 257	0	GL257	0		5		5		5		5		5		5
JG 335	JD 335	1	JG 3353	1	JG 335	0	JD 335	1	JG 335	0	JG 335	0		5	JG 335	0		5	X335	5
JM 067	JMD87	2		5		5		5		5		5		5		5		5		5
GB 693	GB693	0	GB693	0		5	68693	2		5		5		5	B8693	2	C8693	2		5
LP 488	LP4BB	2	LP488	0	LP£BB	3	LPIBB	3	LPCBB	3	LNBR	4	LPCEB	3	LNII	4	Lilli	4		5
FK 740	FK740	0	FK740	0		5		5		5		5		5		5		5	KHZ	4
LS 082		5	LS 082	0		5		5		5		5		5	LSfli2	2		5		5
LP 339		5		5	LP339	0		5	LP339	0		5	LP339	0		5		5		5

LS 188		5		5		5		5		5		5		5		5		5		5
TCD 570	TCD 570	0	TDD 570	1	TED 570	1		6		6		6		6		6	M575	4		6
HR 912	HR9I2	0	HRSI2	1		5	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRBIZ	2		5		5		5
JE 748	JE 748	0	JE 748	0	JE 748	0	JE 748	0	JE748	0	JE748	0	JE 748	0	JE 743	1	ME	4		5
LB 493		5		5		5		5		5		5		5		5		5		5
MJ 784		5	MJ784	0		5	784	2		5	MJ784	0		5		5		5		5
ND 992	NO 592	2	ND 352	2	ND 552	2	ND 952	1	ND 552	2		5	"Di?	4		5		5		5
TKT 656	TKT S56	1	TKT 656	0	TKT B58	2	TKT 658	1	TKT 655	1	TKT 656	0		6		5	TKTESE	3	TE	5
JB 603	18 M33	4	18 603	2	18 603	2	J8 bfi3	4		5		5		5		5		5		5
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0		5	FR I91	1		5	HM!	5	FR H7	2		5
DT 830	W 017830	4	DT 830	0	W|V83O	3	DT 830	0	fT830	1		5	FY83!	3	DT830	0		5	ITE	5
FK 115		5	FKIIS	1		5		5		5		5		5		5		5		5
KB 474	KB 474	0	KB 217117	6	KB 474	0	KB 74774	2	KB 474	0	KB 371	2	KB 474	0	KNIT	4		5		5
DK 187	DK I87	0	nx I87	2		5	1K 97	3		5		5		5	M187	2		5		5
JF 081	JF 08}	1		5		5		5		5		5	JF B81	1	Hi	5	M	5		5
TNR 868	TNRT8 68	1	TNR868	0	TNR 868	0	TNR868	0	TNR 868	0	INR868	0	TNR868	0		6		6		6
DJ797	DJ797	0	[U797	2	IJJ737	3	[U797	2	M797	2		5	M757	3		5		5		5
KR 361		5	KR 36	1		5		5		5		5		5		5		5		5
CP 341	EP 34|	1		5		5	EP34I	1		5		5		5		5		5		5
NZ 732		5		5		5		5		5		5		5		5		5		5
FB 595	F8 595	1	F8 595	1		5		5		5	PB 595	1	H995	3	R55	3		5		5
GB 081	GBDSI	2	GE DBI	3	GBOBI	1	EI 081	2	G5 OBI	2		5	EIIJSI	4		5		5		5
HE220	HE220	0		5	7 HE220	1		5	7 HE22D	2		5		5		5		5	It-I	5
HH 398	HI-1398	3	HD4358	3	HH 358	1	HD1353	4	HH 39!	1	M395	3	NH ESE	4	M331	5	MI	5		5
HT 114	HT III	1		5	HT IM	2		5		5	HIIM	2	HTIM	2	Iflll	3		5		5
KF 775		5		5		5		5		5		5		5		5		5		5
KLC 172		6		6		6		6		5		6		6		6	W	5		5

MR 887	N33 387	4	NH 837	2	NH 337	4	NRBB7	3	MI 357	3	W BB7	4		5	WII7	4	Wm	5		5
EG 073		5		5		5		5		5		5		5		5		5		5
		11 6		11 4		14 9		15 5		17 0		17 3		19 0		20 4		23 7		25 0

Appendex E: First part of only mean pixel

	100%				90%				80%				70%				60%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG 893	0	J5 893	1	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 893	0
GP 350	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 350	0	GP 3530	1	GP 350	0	GP 350	0	GP 3530	1
HT 722	HT722	0	HT 722 A	1	HT722	0	HT 722	0	HT722	0	JIT 722	2	HT722	0	HT 722	0	HT722	0	HT 722	0
NB 389	NB38S	1	NB38S	1	NB38S	1	NB389	0	NB389	0	NB389	0	NB389	0	NB389	0	NB389	0	NB3B9	1
FB 595	F3 595	1	F8 595	1	F8 595	1	W F8 595	2	F8 595	1	F8 595	1	F8 595	1	F8 595	1	F8 595	1	7 F3 595	2
HR 607	HR 607	0	HR 607	0	HR 607	0	HR 807	1	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0	HR 607	0
GC 963	GC963	0	GC963	0		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0
KP 103	KP I03	0	KP |D3	2	KP I03	0	KP IO3	0	KP I03	0	KP ID3	1	KP |D3	2	KP |D3	2	KF1 IDI3	4	KP ID3	1
FH 837	FH837	0	FH837	0		5	FH837	0		5	FH837	0		5	FH837	0		5	FHE7	2
FK 595	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0	FK 595	0		5	FK 595	0
JC 052	JG 052	1	JC O52	0	JD 052	1	JG O52	1	JO 052	1	JD 052	1	JC 052	0	JC O52	0	JC 052	0	JC 052	0
JP 190	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0	JP I90	0		5		5
MN 222	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0	GL 257	0	GL 2557	1	GL257	0	GL 257	0	GL 2257	1	GL 257	0	GL 2557	1	GL 257	0	GL 257	0
JG 335	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JD 335 M	2	JG 335	0
JM 067	JM 067	0	JM 067	0	JM 087	1	JM 067	0	JM D87	2	JM 067	0	JMO67	0	JM 067	0		5	JMOS7	1
GB 693	GB693	0	GB693	0	GB693	1	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0	GB693	0
LP 488	LP488	0	LP488	0	LP48B	1	LP488	0	LP48B	1	LP4B8	1	LP488	0	LP4B8	1	LP488	0	LP48B	1
FK 740	FK740	0	FK740	0	FK740	0	FK74D	1	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0	FK740	0
LS 082	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0	LS 082	0		5	LS 082	0		5	LS 082	0
LP 339	LP339	0	V LP339	1		5	W LP389	2	LP339	0	W LP339	1	LP339	0	7 LP339	1		5	W LP339	1
LS 188	LS I88	0		5		5		5		5		5		5		5		5		5
TCD 570	TDD 570	1	TCD S70	2	TCD S70	1	TCD 570	0	TCD 570	0	TCD 570	0	TOD S70	2	TEL 570	2	TCD 570	0	TOD 570	1
HR 912	HRSIZ	2	HRSIZ	2	HRSIZ	2	IR912	1	HR9I2	0	HRSI2	1	HRSIZ	2	HRSIZ	2	HRSIZ	2	HRSIZ	2

JE 748	JE 7482	1	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0	JE 7482	1	JE 748	0	JE 748	0	JE 748	0
LB 493	LB493	0	LB493	0	LB493	0	LB433	1	L8493	1	LB493	0	LB493	0	L8493	0	LB433	1	LB4S3	1
MJ 784	MJ784	0	MJ784	0	784	2	MJ784	0	MAJ784	1	MJ784	0	784	2	MJ784	0	784	2		5
ND 992	[an 992	3	ND 992	0	an 992	2	ND 992	0	an 992	2	ND 992	0	an 992	2	ND 932	1	an 992	2	ND 352	2
TKT 656	TKT 656	0	TKT B56	1	TKT 856	1	TKT 856	1	TKT B58	2	TKT B56	1	TKT B56	1	TKT B55	2	TKT S58	2	TKT B56	1
JB 603	J8 603	1	13 603	2	J8 603	1	JB 6133	2	18 603	2	18 6B3	3	18 603	2	JB 6133	2	38 603	2	18 603	2
FR 197	FR I97	0	AFR I97	1	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0	FR I97	0
DT 830	TTm830	3	JT831	2	(F7830	3	DT 830	0		5	DT 830	0		5	DT 830	0		5	DT 830	0
FK 115	F KIIS	1	FKIIS	1	FKlIS	1	FKIIS	1	F KIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1	FKIIS	1
KB 474	KB 474	0	KTBTYT	4	KB474	0	L KB 474	1	KB 474	0	KB 474	0	KB 474	0	K8747	0	KB 474	0	K37471	3
DK 187	nx I87	2	M In	5	BK |87	2	M In	5	DK |87	1	nx |87	3	DK |87	1	nx I97	3	DK |87	1	nx I87	2
JF 081	JF 08!	1	JF OBI	1	JF OBI	1	JF OBI	1	JF OBI	3	JF OBI	1	JP 08}	1	JF OBI	1	JF OBI	3		5
TNR 868	TNR868	0	A TNR858	2	TNR868	0	A NR 868	1	TNR868	0	TNR 868	0	TNRT868	1	TNR858	1	TNR868	0	TNR 868	0
DJ797	DJ797	0	UJ797	1	UJ797	1	DJ797	0	DJ797	0	DJ797	0	DJ797	0	[JJ797	2	UJ737	2	UJ797	1
KR 361	KR 35!	2	KR 361	0	KR 3$|	2	KR 38|	2	KR 3S|	2	KR 38| A	3	KR 35!	2	KR 36|	1	KR 3S|	2		5
CP 341	CP34|	0	EP34|	2	CP 34|	2	EP34|	2	EP 34!	2	EP34|	2	EP 34!	2	EP34|	2	CP 34I	0	EP34|	2
NZ 732	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1	N2 732	1		5		5		5
FB 595	F8 595	1	F8 595	1	F8 595	1	W F8 595	2	WFB 595	1	F8 595	1	F8 595	1	F8 595	1	FB 595	0	7 F3 595	5
GB 081	G808!	2	S8 D8!	4	BBUBI	3	GB OBI	1	G308!	2	SB DBI T	4	GB OBI	1	GB OBI	1	BB OBI	2	E3 OBI	2
HE220	HE220	0	T2220	2	1-{E220	2	TE220	1	7 1-{E220	3	T2220	2	7 HE220	1	T2220	2	7 1-{E220	3	TE220	1
HH 398	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 398	0
HT 114	HT IM	2	HT IM	2	HT [I4	1	HT IM	2	HT [I4	1	HT IM	2	H1 H4	3	HT II4	0	HT II4	0		5
KF 775	KF775	0	KF775	0	KFTIS	3	KFTIS	3	KF775	0	KFTIS	3	KF775	0	KF77S	1	KF775	0	KF77S	1
KLC 172	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0	KLC 172	0		6
MR 887	NF! 887	3	NR 887	1	N19 887	3	HE 887	2	NR 887	1	NR 887	1	NE 837	3	K 887	2	NR 837	2	N33 887	3
EG 073	EC 073	1	ES 073	1	E5 073	1	ES 073	1		5		5		5		5		5		5
		30		49		65		44		52		47		59		48		85		86

Second part of only median pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG B33	2	JG 893	0	JG E53	2	JG B53	2	JG BS3	2	JG 8!!	2		5	H53	4
GP 350	GP 350	0	GP 350	0	G53 350	2	GP 350	0	GP 35D	1	GP 35!!	2	GP 350	0	GP 35D	1	EF lifl	5	ii iii	5
HT 722	HT 722	0	HT 722	0	HT722	0	HT 722	0	JIT 722	2		5	|IT722	2	HT 722	0		5		5
NB 389	NB389	0	NB38S	1	NBSB S	3	NBSBS	3	NBCJB S	4	NBZIES	4	H8355	4	H5333	4		5		5
FB 595		5	F8 595	1		5		5		5		5		5	F3595	1		5		5
HR 607	HR 607	0	HR 607	0	HR 507	1	HR 307	1	HR 507	1	HR 507	1	RI 507	3	NH EH7	3	WM	5	M17	4
GC 963		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0		5	GCQSL	3		5		5
KP 103	KP I03	0	KP |D3	2	KP I03	0	KP I03	0	KP I03	0	KP ID3	1	KP I03	0	KP I03	0	KF IDS	3		5
FH 837		5		5		5		5		5		5	H1837	2	HIBJ7	3	W	5	M7	4
FK 595		5		5		5		5		5		5		5		5		5		5
JC 052		5		5		5		5		5		5		5		5		5		5
JP 190		5		5		5		5		5		5		5		5		5		5
MN 222	MN222	0	MN222	0	MN222	0	MN222	0		5		5		5		5	W2	4	I111!	5
GL 257	GL 257	0	GL257	0	GL 257	0	GL257	0		5		5		5		5		5		5
JG 335	JD 335	1	JG 335	0	JG 335	0	JG 335	0	JG 335	0	JG 335	0		5		5		5		5
JM 067	JMD87	2	JMO67	0		5		5		5		5		5		5		5		5
GB 693	GB693	0	GB693	3		5		5		5		5		5		5	C8693	2	8693	2
LP 488	LP4BB	2	LP4BB	2	LP£BB	3	LP48B	1	LPCBB	3	LP4BB	2	LPCE B	3	LNB8	3	Lilli	4	Ulll	5
FK 740	FK740	0	vFK740	1		5		5		5		5		5		5		5		5
LS 082		5	LS 082	0		5		5		5		5		5		5		5		5
LP 339		5	W LP339	1	LP339	0		5	LP339	0		5	LP339	0		5		5		5

LS 188		5		5		5		5		5		5		5		5		5		5
TCD 570	TCD 570	0	TCD 570	0	TED 570	1		6		6		6		6		6	M575	4		6
HR 912	HR9I2	0	HRSIZ	2		5		5	HRSIZ	2		5	HRBIZ	2		5		5		5
JE 748	JE 748	0	JE 748	0	JE 748	0	JE748	0	JE748	0	JE748	0	JE 748	0		5	ME	4	£76!	4
LB 493		5		5		5		5		5		5		5		5		5		5
MJ 784		5		5		5		5		5	MJ784	0		5		5		5		5
ND 992	NO 592	2	ND 592	1	ND 552	2	up 352	4	ND 552	2	ND 532	2	"Di?	4	my	5		5		5
TKT 656	TKT S56	1	TKT 658	1	TKT B58	2	TKT S58	2	TKT 655	1	TKT S56	1		6	TKT SSE	3	TKTES E	3	TKTESE	3
JB 603	18 M33	4	JB 6133	2	18 603	2	18 33	4		5		5		5		5		5		5
FR 197	FR I97	0	FR I97	0	FR I97	0	FR I97	0		5	FR I97	0		5	FR V57	2	FR H7	2	W E!	5
DT 830	W 017830	4	DT 830	0	W|V83 O	3	DT 830	0	fT830	1		5	FY83!	3	DT 830	0		5	M333	4
FK 115		5	FKIIS	1		5	FKIIS	1		5		5		5		5		5		5
KB 474	KB 474	0	V K3747	3	KB 474	0	K3717117	4	KB 474	0	KB1737	3	KB 474	0	KB 471	1		5		5
DK 187	DK I87	0	nx I87	2		5	mc 97	4		5		5		5		5		5		5
JF 081	JF 08}	1		5		5		5		5		5	JF B81	1	JF U81	1	M	5	II	4
TNR 868	TNRT86 8	1	TNR868	0	TNR 868	0	TNR868	0	TNR 868	0	TNR868	0	TNR8 68	0	TNRBGB	3		6		6
DJ797	DJ797	0	DJ737	1	IJJ737	3	DJ797	0	M797	2	M797	2	M757	3		5		5		5
KR 361		5	KR 38	2		5		5		5		5		5		5		5		5
CP 341	EP 34|	1	4934	3		5	IZP34|	3		5		5		5		5		5		5
NZ 732		5		5		5		5		5		5		5		5		5		5
FB 595	F8 595	1	F8 595	1		5		5		5		5	H995	3	F3595	1		5		5
GB 081	GBDSI	2	EI OBI	3	GBOBI	1	CB OBI	2	G5 OBI	2	FI OBI	3	EIIJSI	4		5		5		5
HE220	HE220	0		5	7 HE220	1		5	7 HE22D	2		5		5		5		5		5
HH 398	HI-1398	3	HH 338	1	HH 358	1	HH SSE	3	HH 39!	1	HH 395	1	NH ESE	4	HH 3!E	2	Ml	5		5
HT 114	HT Ill	1		5	HT IM	2		5		5		5	HTIM	2	Iflll	5		5		5
KF 775		5		5		5		5		5		5		5		5		5		5

KLC 172		6		6		6		6		5		6		6		6	W	5		6
MR 887	N33 387	4	NH 337	4	NH 337	4	NIIBB7	4	MI 357	3	NR BB7	3		5	NH BB7	4	Wm	5	W	5
EG 073		5		5		5		5		5		5		5		5		5		5
		11 6		10 9		14 9		15 8		17 0		18 4		19 0		19 4		23 7		24 2

Appendex F: First part of mean filter and mean pixel

	100%				90%				80%				70%				60%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	I	5	JG 893	0	JG 893	0	JG 833	1	JG 893	0	JG 893	0	JG 893	0	JG 893	0	JG 893	0
GP 350	GP 350	0	GP 350	0	GP 350	0	IGP 350	1	GP 350	0	GP 350	0	GP 3530	1	GP 350	0	GP 350	0	GP 350	0
HT 722	HT722	0	HT 722	0	HT722	0	HT 722	0	HT722	0	JIT 722	2	HT722	0	HT 722	0	HT722	0	HT 722	0
NB 389	NB38S	1	fii	5	NB38S	1	H3389	2	NB389	0	M8389	2	NB389	0		5	NB389	0		5
FB 595	F3 595	1		5	F8 595	1	W595	2	F8 595	1		5	F8 595	1		5	F8 595	1		5
HR 607	HR 607	0	HR 607	0	HR 607	0		5	HR 607	0		5	HR 607	0		5	HR 607	0	T	5
GC 963	GC963	0	GC963 W	1		5	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0	GC963	0
KP 103	KP I03	0	FKP I031	2	KP I03	0	FIP I081	4	KP I03	0	FKD I031	3	KP |D3	2	FKP IDBW	5	KF1 IDI3	4	FKP I031	2
FH 837	FH837	0	FH837	2		5		5		5		5		5		5		5		5
FK 595	FK 595	0	FK 595	0	FK 595	0	FK 597	1	FK 595	0	FK 53	2	FK 595	0		5		5		5
JC 052	JG 052	1		5	JD 052	1		5	JO 052	1		5	JC 052	0		5	JC 052	0	XWTSF	5
JP 190	JP I90	0	JPIED	2	JP I90	0	JP I90	0	JP I90	0		5	JP I90	0		5		5		5
MN 222	MN222	0		5	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0	MN222	0
GL 257	GL 257	0		5	GL 2557	1		5	GL 257	0		5	GL 257	0		5	GL 257	0	[§L2§7	3
JG 335	JG 335	0	JG 335	0	JG 335	0	JD 335	1	JG 335	0	JG 335	2	JG 335	0	JG 335	0	JD 335 M	2	JG 335	0
JM 067	JM 067	0		5	JM 087	1		5	JM D87	2		5	JMO67	0		5		5		5
GB 693	GB693	0	GB693	0	GB693	1		5	GB693	0	L	5	GB693	0		5	GB693	0		5
LP 488	LP488	0	%	5	LP48B	1	i	5	LP48B	1	i	5	LP488	0	flea	5	LP488	0	P49	3
FK 740	FK740	0	FK740	0	FK740	0		5	FK740	0	FK4	2	FK740	0		5	FK740	0		5
LS 082	LS 082	0		5	LS 082	0	LS 082	0	LS 082	0	LS 082	0		5	LS 082	0		5	LS 082	0
LP 339	LP339	0	LP339	0		5		5	LP339	0		5	LP339	0		5		5		5
LS 188	LS I88	0		5		5	LSIB	2		5	LS|8	2		5		5		5		5
TCD 570	TDD 570	1		5	TCD S70	1	WD70	3	TCD 570	0	W$§7O7	6	TOD S70	2		6	TCD 570	0		6
HR 912	HRSIZ	2	IR912	2	HRSIZ	2	IR912	1	HR9l2	0		5	HRSIZ	2	HRSIZ	2	HRSIZ	2		5

JE 748	JE 7482	1	4274	3	JE 7482	1	JE748	0	JE 748	0	JENS	3	JE 7482	1	JE 748	0	JE 748	0	JE748	0
LB 493	LB493	0	LB493	0	LB493	0	L849	2	L8493	1	L349	4	LB493	0	fLB4F	3	LB433	1		5
MJ 784	MJ784	0	784	2	784	2	LT	5	MAJ784	1	ET	5	784	2	ET	5	784	2	1	5
ND 992	[an 992	3		5	an 992	2		5	an 992	2		5	an 992	2	$3.20	5	an 992	2	TE	5
TKT 656	TKT 656	0	f|KT 656	2	TKT 856	1	flKT65 5	3	TKT B58	2	flKT 556	3	TKT B56	1	FTKT 855	3	TKT S58	2	FFKT 556	3
JB 603	J8 603	1		5	J8 603	1	T3B8G3W	5	18 603	2		5	18 603	2		5	38 603	2		5
FR 197	FR I97	0		5	FR I97	0		5	FR I97	0		5	FR I97	0		5	FR I97	0	FRJ97	0
DT 830	TTm830	3	DT 830	0	(F7830	3	DT 830	0		5		5		5	DT 830	0		5		5
FK 115	F KIIS	1	Runs	5	FKllS	1	FKIIS 7	2	F KIIS	1		5	FKIIS	1	FKIIS	1	FKIIS	1		5
KB 474	KB 474	0	KB 474	0	KB474	0	KB 474	0	KB 474	0	KB 474	0	KB 474	0	KB 474	0	KB 474	0	KB 474	0
DK 187	nx I87	2	nx |a7	4	BK |87	2	finx I8	4	DK |87	1	mu	5	DK |87	1	mu	5	DK |87	1	mu	5
JF 081	JF 08!	1		5	JF OBI	1	UVITBW	5	JF OBI	3		5	JP 08}	1	JF OBI	1	JF OBI	3		5
TNR 868	TNR868	0	TNR868	0	TNR868	0	NR 868	1	TNR868	0	TNR 868	0	TNRT86 8	1	TNR868	0	TNR868	0	TNR 868	0
DJ797	DJ797	0	[U787	3	UJ797	1	[U797	2	DJ797	0	DJ797	0	DJ797	0	DJ797	0	UJ737	2	[U797	2
KR 361	KR 35!	2		5	KR 3$|	2		5	KR 3S|	2		5	KR 35!	2		5	KR 3S|	2		5
CP 341	CP34|	0	CP34|	1	CP 34|	2		5	EP 34!	2		5	EP 34!	2		5	CP 34l	0		5
NZ 732	N2 732	1	N2 732	1	N2 732	1	T777	4	N2 732	1		5	N2 732	1	TINT	5		5	T2737	3
FB 595	F8 595	1		5	F8 595	1	W595	2	WFB 595	1		5	F8 595	1		5	FB 595	0		5
GB 081	G808!	2	EB UQI	3	BBUBI	3	T	5	G308!	2		5	GB OBI	1	CB OBI	2	BB OBI	2		5
HE220	HE220	0		5	1-{E220	2	HE220	0	7 1-{E220	3	IE220 T	2	7 HE220	1	IE220 7	2	7 1-{E220	3	fiE22U	3
HH 398	HH 398	0	51 39a	3	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 398	0	HH 358	1	HH 356	2
HT 114	HT IM	2		5	HT [I4	1		5	HT [I4	1		5	H1 H4	3		5	HT II4	0		5
KF 775	KF775	0		5	KFTIS	3		5	KF775	0		5	KF775	0		5	KF775	0		5
KLC 172	KLC 172	0	1721	4	KLC 172	0	172	3	KLC 172	0	172	3	KLC 172	0	H1C 172	2	KLC 172	0		6
MR 887	NF! 887	3	JVB387	4	N19 887	3	RE 387	2	NR 887	1	NR 887	1	NE 837	3	T	5	NR 837	2		5
EG 073	EC 073	1		5	E5 073	1		5		5		5		5		5		5		5
		30		149		64	0	142		52		172		59		162		85		178

Second part of mean filter and mean pixel

	50%				40%				30%				20%				10%			
	before		after		before		after		before		after		before		after		before		after	
JG 893	JG 893	0	JG 893	0	JG B33	2	JI3 893	2	JG E53	2	JG B53	2	JG BS3	2		5		5		5
GP 350	GP 350	0	GP 350	0	G53 350	2	GP 350	0	GP 35D	1	SP 350	0	GP 350	0		5	EF lifl	5		5
HT 722	HT 722	0	HT 722	0	HT722	0	HT 722	0	JIT 722	2	VTIWZT	5	|IT722	2		5		5		5
NB 389	NB389	0	E	5	NBSB S	3	fl	5	NBCJB S	4	B38	2	H8355	4		5		5		5
FB 595		5	NEW	5		5		5		5		5		5		5		5		5
HR 607	HR 607	0		5	HR 507	1	HE 307	2	HR 507	1		5	RI 507	3		5	WM	5		5
GC 963		5	GC963	0	GC96 3	0	GCSSZL	4	GC963	0	GCSSS	3		5		5		5		5
KP 103	KP I03	0	FKP I031	2	KP I03	0	[KP I03	1	KP I03	0	[KP IDS	3	KP I03	0	KP I93	1	KF IDS	3		5
FH 837		5		5		5		5		5		5	H1837	2		5	W	5		5
FK 595		5		5		5		5		5		5		5		5		5		5
JC 052		5		5		5		5		5		5		5		5		5		5
JP 190		5	JIS	4		5		5		5		5		5		5		5		5
MN 222	MN222	0		5	MN22 2	0	MN222	0		5		5		5		5	W2	4		5
GL 257	GL 257	0		5	GL 257	0	TQES7	4		5		5		5		5		5		5
JG 335	JD 335	1	JG 335	0	JG 335	0	JG 335	1	JG 335	0	JG 335	0		5		5		5		5
JM 067	JMD87	2		5		5		5		5		5		5		5		5		5
GB 693	GB693	0	G36	3		5		5		5		5		5		5	C8693	2		5
LP 488	LP4BB	2		5	LP£B B	3	fies	5	LPCBB	3	P493	2	LPCEB	3		5	Lilli	4		5
FK 740	FK740	0	FK NU	3		5	FK NU	3		5		5		5		5		5		5
LS 082		5		5		5	DB2	5		5		5		5		5		5		5
LP 339		5		5	LP339	0		5	LP339	0		5	LP339	0		5		5		5
LS 188		5		5		5		5		5		5		5		5		5		5

TCD 570	TCD 570	0		6	TED 570	1		6		6		6		6	EI II]	6	M575	4		6
HR 912	HR9I2	0	HRSI2	1		5		5	HRSIZ	2		5	HRBIZ	2		5		5		5
JE 748	JE 748	0	JE748	0	JE 748	0	JE748	0	JE748	0	JENS	3	JE 748	0		5	ME	4		5
LB 493		5		5		5		5		5		5		5		5		5		5
MJ 784		5		5		5		5		5		5		5		5		5		5
ND 992	NO 592	2		5	ND 552	2	J	5	ND 552	2		5	"Di?	4		5		5		5
TKT 656	TKT S56	1	FTKT ass	4	TKT B58	2	nTKT8T58	4	TKT 655	1	|IT6§§	4		6		6	TKTES E	3		6
JB 603	18 M33	4		5	18 603	2		5		5		5		5		5		5		5
FR 197	FR I97	0		5	FR I97	0	FR I97	0		5	FR I97	0		5		5	FR H7	2		5
DT 830	W 017830	4	DT 830	0	W|V83 O	3		5	fT830	1		5	FY83!	3		5		5		5
FK 115		5	FKIIS	1		5		5		5		5		5		5		5		5
KB 474	KB 474	0	KB 474	0	KB 474	0	KB 474	0	KB 474	0		5	KB 474	0		5		5		5
DK 187	DK I87	0		5		5	mu	5		5		5		5		5		5		5
JF 081	JF 08}	1		5		5		5		5		5	JF B81	1		5	M	5		5
TNR 868	TNRT868	1	TNR868	0	TNR 868	0	TNR868	0	TNR 868	0	TNR 868	0	TNR86 8	0		6		6		6
DJ797	DJ797	0		5	IJJ737	3		5	M797	2		5	M757	3		5		5		5
KR 361		5	KF36|	2		5		5		5		5		5		5		5		5
CP 341	EP 34|	1	CP34|	1		5		5		5		5		5		5		5		5
NZ 732		5		5		5		5		5		5		5		5		5		5
FB 595	F8 595	1	NEW	5		5		5		5		5	H995	3		5		5		5
GB 081	GBDSI	2	CI 081	2	GBOB I	1		5	G5 OBI	2		5	EIIJSI	4		5		5		5
HE220	HE220	0		5	7 HE220	1		5	7 HE22D	2		5		5		5		5	M	5
HH 398	HI-1398	3	HR 358	2	HH 358	1		5	HH 39!	1		5	NH ESE	4		5	Ml	5		5
HT 114	HT lll	1		5	HT IM	2		5		5		5	HTIM	2		5		5		5
KF 775		5		5		5		5		5		5		5		5		5		5
KLC 172		6		6		6		6		5		6		6		6	W	5		6
MR 887	N33 387	4		5	NH 337	4		5	MI 357	3		5		5		5	Wm	5		5

EG 073		5		5		5		5		5		5		5		5		5		5
		116	0	177		149		198		170		216		190		250		237		254

Appendex G: Matlab code

%main function

```
clc
clear all
close all
h=waitbar(0,'  be patient...');
r=-4;
k=1;
for p=1:-0.1:0.1
    r=r+5;
for num=1:50
[MBRL MBRE referencepic lowres medans]=Untitled(num,p,r);
out{num,r}='';
out{num,r+1}=lowres;
out{num,r+2}='';
out{num,r+3}=medans;
out{num,r+4}='';
BRL(num)=MBRL;
BRE(num)=MBRE;
end
Lasbrl (k) =sum (BRL (:));
lasbre(k)=sum(BRE(:));

waitbar(1-p,h,'  be patient...');
k=k+1;
end
t=cell2table(out);
writetable(t,'51.xlsx');
x=1:10;
y=lasbrl(:);
y1=lasbre(:);
```

```
plot(x(1:10),y(:),'r')
hold on
title('medianpoint,medianfilter')
plot(x(1:10),y1(:),'b')
ax = gca;
ax.XTickLabel={'100%','90%','80%','70%','60%','50%','40%','30%','20%','10%'};
ylabel('number of recognized characters');
xlabel('presentage from original resolution');
close(waitbar);
```

%untitled

```
function [MBRL MBRE referencepic lowres medans]=Untitled(num,p,r)
m=1;
th=1;
row=0;
    col=0;
for i=1:3
    Im= imread([int2str(num) int2str(th), '.jpg']);
    if th==2
       ocr(Im);
    referencepic=ans.Text;
   end
   if th==1
       [row col]=size(Im);
       row1=row*p;
       col1=col*p/3;
   end
newim=imresize(Im,[row1 col1],'bilinear');
%using medean filter
if row1<=23||col1<=23
       if row1<=23
           row1=23;
       end
       if col1<=23
           col1=23;
       end
```

```
      kl(:,:,:,i)=imresize(newim,[row1 col1],'bilinear');
else
    kl(:,:,:,i)=newim;
end
if th==2
ocr(kl(:,:,:,i));
lowres=ans.Text;
%subplot(2,4,m)
%imshow(kl(:,:,:,i)),title(ans.Text)
% imwrite(kl(:,:,:,i),['original' int2str(p*100) '%', '.jpg']);
end
% median filter
% kl(:,:,1,i)= medfilt2(kl(:,:,1,i));
% kl(:,:,2,i)= medfilt2(kl(:,:,2,i));
% kl(:,:,3,i)= medfilt2(kl(:,:,3,i));
%max filter
% kl(:,:,1,i)= maxfilt(kl(:,:,1,i));
% kl(:,:,2,i)= maxfilt(kl(:,:,2,i));
% kl(:,:,3,i)= maxfilt(kl(:,:,3,i));



% %min filter
% kl(:,:,1,i)= minfilt(kl(:,:,1,i));
% kl(:,:,2,i)= minfilt(kl(:,:,2,i));
% kl(:,:,3,i)= minfilt(kl(:,:,3,i));
% %mean filter
% h = 1/3*ones(3,1);
%     H = h*h';
%
%      kl(:,:,1,i) = filter2(H, kl(:,:,1,i));
%      kl(:,:,2,i) = filter2(H, kl(:,:,2,i));
%      kl(:,:,3,i) = filter2(H, kl(:,:,3,i));
m=m+1;
th=th+1;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
%separating red, blue and green
for i=1:3
    reds(:,:,i)=kl(:,:,1,i);
    blues(:,:,i)=kl(:,:,2,i);
    greens(:,:,i)=kl(:,:,3,i);
end
% making new red, blue and green
for i=1:row1
    for j=1:col1
        newred(i,j)=uint8(max(reds(i,j,:)));
        newblue(i,j)=uint8(max(blues(i,j,:)));
        newgreen(i,j)=uint8(max(greens(i,j,:)));
    end
end
% joining all the 3 channels
newframe(:,:,1,num)=newred;
newframe(:,:,2,num)=newblue;
newframe(:,:,3,num)=newgreen;
%subplot(2,4,m+2)
ocr(newframe(:,:,:,num));
medans=ans.Text;
%imshow(newframe),title(ans.Text)
%imwrite(newframe(:,:,:,num),['max' int2str(p*100) '%', '.jpg']);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
MBRL=matchstr(referencepic,lowres);
MBRE=matchstr(referencepic,medans);
%maxfilt
function out = maxfilt(in,repeat)
%   out = maxfilt(in);
% returns maximum value in a 3 x 3 neighborhood
%   out = maxfilt(in,n) repeats the operation n times
% Author: John S. Loomis (17 March 2000)
if nargin<2
    repeat=1;
end
sp = size(in);
```

```
sm = sp-1;
out = in;
for k=1:repeat
   out(1:sm(1),:) = max(out(1:sm(1),:),out(2:sp(1),:));
   out(2:sp(1),:) = max(out(1:sm(1),:),out(2:sp(1),:));
   out(:,1:sm(2)) = max(out(:,1:sm(2)),out(:,2:sp(2)));
   out(:,2:sp(2)) = max(out(:,1:sm(2)),out(:,2:sp(2)));
end
```