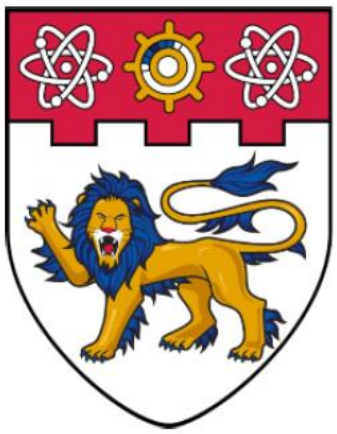

NANYANG TECHNOLOGICAL UNIVERSITY
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CZ4003 Project Report

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Contents

Introduction

This project aims to utilize the concepts learn throughout the course of Computer Vision in the application of Optical Character Recognition domain. As briefed in the project task, OCR involves a series of image processing and recognition tasks:

1. Text image binarization – converts a colour/grayscale image into a binary image with multiple foreground regions (usually characters)
2. Connected component labelling that detects each binarized character region
3. Character recognition by using some classifiers such as a pre-trained neural network

Objective

Explore and develop various image binarization algorithms targeting optimal character recognition accuracy.

Note

The codes are found in ‘ocr.py’ and have been commented respective to the sections in this report. All output of this script can be found in the ‘output.zip’ folder.

Experiment

1. Implement the Ostu global thresholding algorithm. Evaluate the OCR accuracy. Discuss any problems with the Otsu global thresholding algorithm.

Original image:

The **original** images are as shown below:

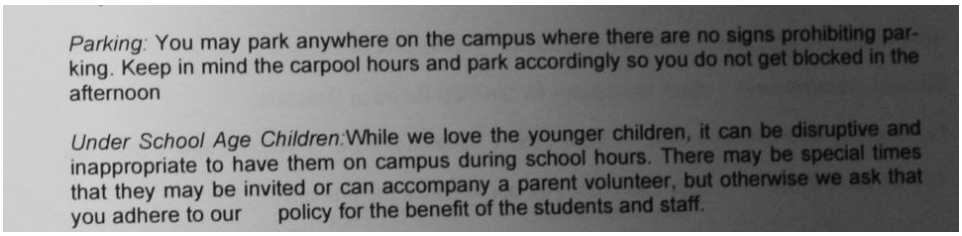


Figure 1: sample01.png

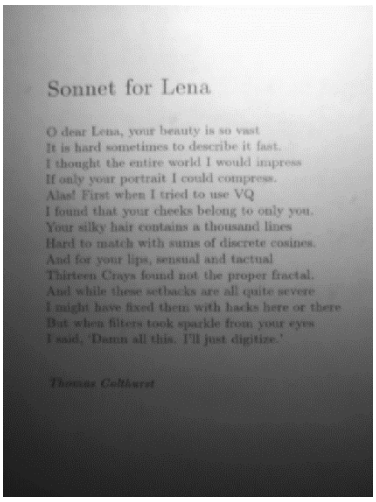


Figure 2: sample02.png

Otsu global threshold:

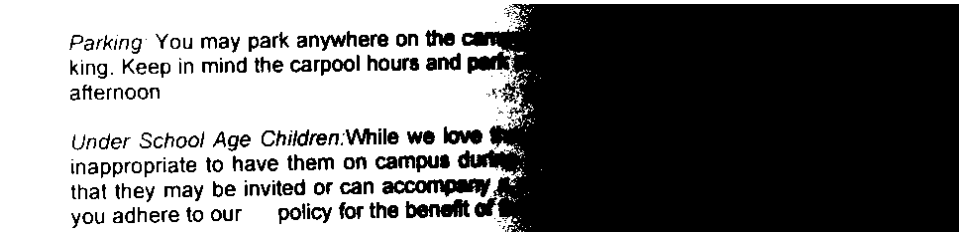


Figure 3: sample01 after applying Otsu

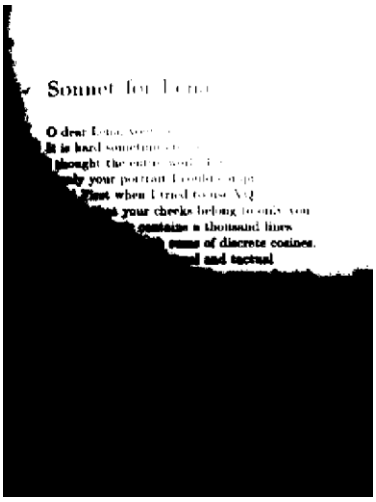


Figure 4: sample02 after applying Otsu

Evaluate the OCR accuracy:

To evaluate the accuracy of the OCR process, we will be transcribing the text from the image recognized into an output file and compare this to the original image on a word level basis. An excerpt of the transcribed text will be shown in the report for discussion.

Transcription with Otsu implementation shown below:

Image 1:

```
Parking You may park anywhere on the cf
king. Keep in mind the carpool hours and pari 3m
afternoon ae
7
Under Schoo! Age Children.While we love $i
inappropriate to have them on campus d ee
that they may be invited or can accompany 4
you adhere to our _policy for the benefit off ¥
```

Image 2:

```
Sonnet for ler
Odear Fotucvees |
fe beard Soret
Peowght the ent wen i
by your pourrait Pedr. aye
Fleet when [trialt ue Veg
your cheeks belong becins sen
 tbutisaud lines
ih eumme of discrete cosines.
and toctual ;
```

Observations:

As we can see from the images above, the OCR transcription seems to be incoherent and the sentences are incomplete. Furthermore, there are some special characters that are being transcribed even when they are not present in the original image. This could be the result of noise in the threshold images.

Discussion:

Thresholding divides the pixels into two classes: pixels higher than or lower than the threshold. The most optimal outcome would be a threshold that would minimize the intra-class variance while maximizing the inter-class variance.

The intra-class variance would mean that the pixels are less dispersed from one another in its respective class while inter-class variance would create a more distinctive difference between the two classes.

From the original images, we can see that the images are exposed to different levels of light, or a difference in illumination levels. This would suggest the image having more than one 'regions' to segment when it comes to applying filters. The limitations of simple thresholding come into play when there are more than two image regions to segment, which we are facing in this situation. As expected, we did not obtain a good result from Otsu global thresholding.

2. Design your own algorithm to address the problem of Otsu global thresholding algorithm.

Method:

1. Applying gaussian filter to the image to remove noise
2. Apply adaptive threshold

Output:

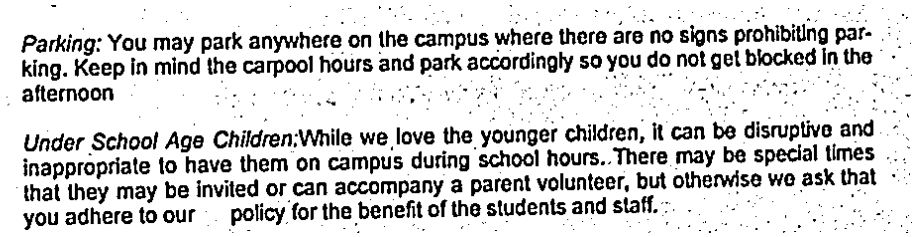


Figure 5: Adaptive threshold for image 1

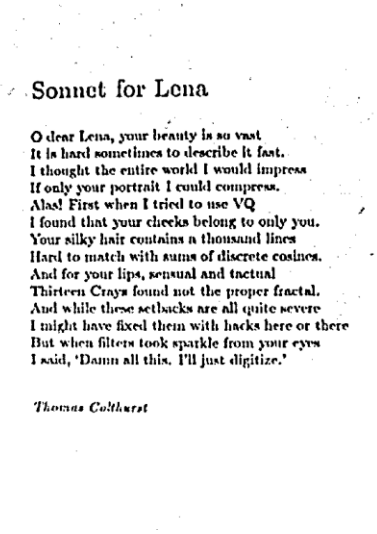


Figure 6: Adaptive threshold for image 2

General Observation

From the images above, we are able to obtain decent results where the output is not affected by the 'two' regions where one is completely obscured as we see in the Otsu's thresholding. Most of the characters are discernible and readable.

The adaptive thresholding method works better than Otsu's because the threshold value is localized to the specific region of the image within the window size. By using `ADAPTIVE_THRESH_GAUSSIAN_C`, the threshold value is a gaussian-weighted sum of the neighbourhood values (minus the constant c). As a result, the threshold would elicit better OCR accuracy as compared to a global thresholding like Otsu's.

Evaluate OCR Accuracy

Image 1 OCR:

```
Parking: You may park anywhere on the campus where there are no signs prohibiting par-
king. Keep in mind the carpool hours and park accordingly so you do not get blocked In the ©
. afternoon St yt al Totton cena tn
Under School Age Children:While we love the younger children, it can be disruptive and.
inappropriate to have them on campus during school hours.. There may be special times.
that they may be invited or can accompany a parent volunteer, but otherwise we ask that -
you adhere to our. policy for the benefit of the students and staffin. 0 oe
```

Image 2 OCR:

```
- Sonnet for Lena /
O dear Lena, your beauty basa vast |
Tels hard sometiines to describe [t fant.
I thought the entire world [ would impress
If only your portrait [ could compress.
Alas! First when I tried to tise VQ ,
1 found that your checks belong te only you.
Your silky hair contains n thousand lines
Hard to match with sums of discrete cosines, .
And for your lips, sensual and tactual
Thirteen Cray found not the proper fractal, .
And while these setbacks are all quite severe |
Limight have fixed thein with hacks here or there
Bat whe filters took sparkle from your eyes
Taaid, 'Damn all this, PM just digitize."
Thomas Colthurst
```

Observation:

From the above images, we can see that the sentences are more fully formed and there are more characters appearing in the transcription than before (otsu implementation). However, there are instances where the transcription is being misinterpreted. For example, in image one, the sentence transcribed to be "…so you do not get blocked In the ©. Afternoon St yt al Totton cena tn" as oppose to the ground truth: "so you do not get blocked in the afternoon". Although most of the contents of the sentences are there, the presence of noise (as seen from the image in Figure 5) distorts the transcription process and consequently disrupts the meaning of the sentence altogether.

Specific Image Analysis (Enhancement): Image 1

Method 1: Increase Gaussian Blur kernel size

Image 1 (sample01.png):

For image 1, the output obtained comes with some noise towards the right side of the image. In order to reduce this noise, we can increase the kernel size of the gaussian filter. When increased the size of the kernel to 7, the following output is obtained.

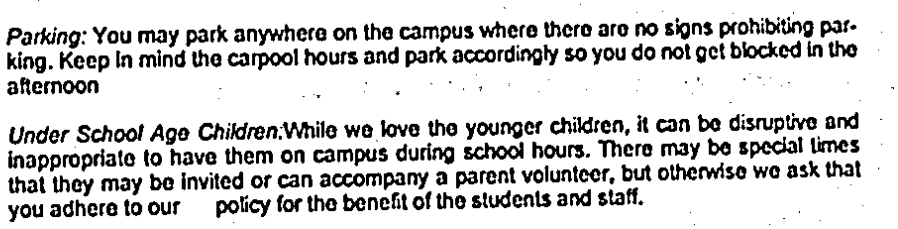


Figure 7: kernel size=7

Evaluate OCR Accuracy

```
Parking: You may park anywhere on the campus where there are no signs prohibiting par-
king. Keep In mind the carpool hours and park accordingly so you do not get blocked in the
afternoon Ct eee

Under School Age Children While we love the younger children, it can be disruptive and
inappropriate to have them on campus during school hours. There may be special times.
that they may be invited of can accompany a parent volunteer, but otherwise we ask that
you adhere toour policy for the benefit of the students and staff.
```

From the image above, we can see that we have successfully remove the bulk of the noise that was present in figure 5. This translates to better OCR transcription. However, the increase in size for the gaussian kernel comes at a cost. The semicolon in between “Under School Age Children” and “While” is removed and the space between “adhere to our policy” is not accurately being transcribed. Although, the core semantics of the texts is not lost. Some of the noise that remain present cannot be removed without compromising the quality of the texts.

Method 2: Morphological Transformation

OpenCV also provides another method to remove noise – via morphological transformations. The ‘opening’ method implements the erosion method followed by dilation. This method would be effective in reducing noise as the erosion method will decrease the size of the foreground (white region). Subsequently, the dilation method will join broken parts of an object. The result is as follows:

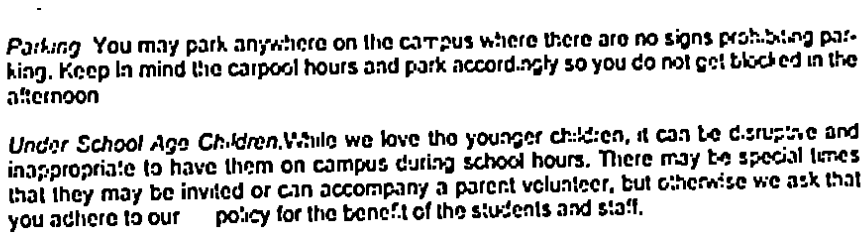


Figure 8: morphology transformed

We can see that most of the speckled noise are removed from the image. We shall inspect if the OCR accuracy improves.

Evaluate OCR Accuracy

```
Partsag You may park anyenere on the caT pus vere there aro no signs proh.taung pale
hing, Keep la mind tie carpool hours and park accord.ngly so you do not get blicked in the
akemoon

Under School Ago Children.Veule we love tho younger ch:ktren, it can be Gsrupie and
inag:propriate to have them on campus during school hours. There may te specal lines
thal they may be invited or can accompany a parert velunteer, but ovheraise we ask that
you adhere toour – poucy for the teneftof the students and sia‘.
```

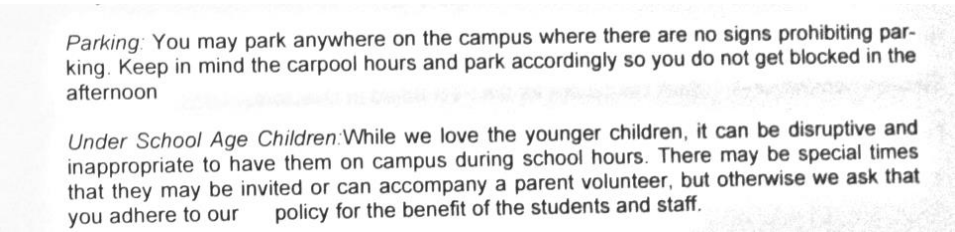
The OCR transcription is much more incoherent than before. Some of the words are misspelled while others are beyond comprehension. Even though the random noise were successfully removed, some of the character pixels are removed in the process. This creates a lot of broken lines just like in Canny edge detector. This could possibly be fixed with a process similar to Hough transform but for texts.

The distortion present within the character pixels decreases the accuracy of the OCR process.

It can be noted that this method of morphological transformation would be more effective with handwritten texts as individual’s handwriting are not uniform and some pen inks have different bold weight.

Method 3: Division

Another method, other than adaptive thresholding, that we can implement is an elementwise division of the original image and a gaussian filter to obtain a better result. The process is explained in the next section “specific image analysis (enhancement): image 2”.



Parking: You may park anywhere on the campus where there are no signs prohibiting parking. Keep in mind the carpool hours and park accordingly so you do not get blocked in the afternoon

Under School Age Children: While we love the younger children, it can be disruptive and inappropriate to have them on campus during school hours. There may be special times that they may be invited or can accompany a parent volunteer, but otherwise we ask that you adhere to our policy for the benefit of the students and staff.

Just from the image above alone, we can see that our image is not distorted by noise and the texts are clear and illumination is rather uniform compared to the original image.

Evaluate OCR Accuracy

```
Parking: You may park anywhere on the campus where there are no signs prohibiting par-
king. Keep in mind the carpool hours and park accordingly so you do not get blocked in the
afternoon

Under School Age Children:While we love the younger children, it can be disruptive and
inappropriate to have them on campus during school hours. There may be special times
that they may be invited or can accompany a parent volunteer, but otherwise we ask that
you adhere to our _ policy for the benefit of the students and staff.
```

We achieve an almost perfect OCR accuracy with this method, other than the underscore character.

Specific Image Analysis (Enhancement): Image 2

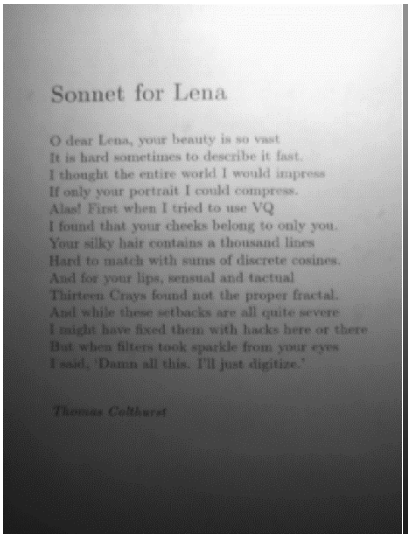
Image 2 (sample02.png):

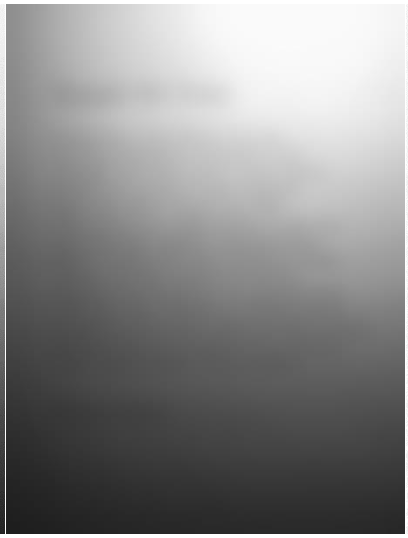
The original image was not sharp to begin with. After applying the adaptive threshold method, we are able to fix the issues that came with Otsu's global thresholding. However, the blurry texts still affect the accuracy of the OCR.

We can employ a different method other than adaptive thresholding to obtain better OCR accuracy.

Method: Division

1. Apply Gaussian filter with a very large kernel size (kernel = 95)
2. Element-wise divide the blurred image and the original image to obtain a resultant image of more 'uniform' illumination.
3. Apply OCR





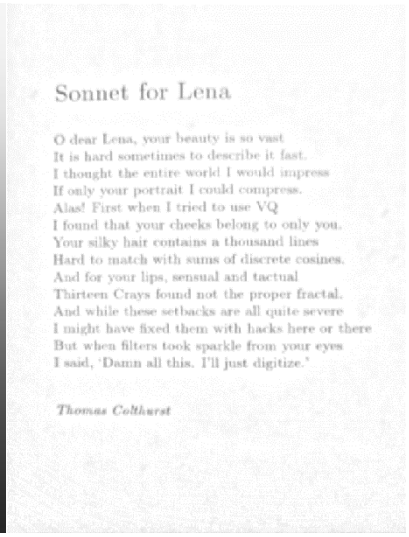
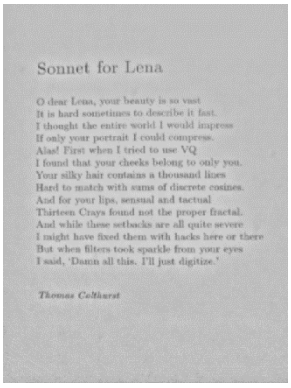


Figure 9: original sample02.png *Figure 10: high kernel gaussian blur* *Figure 11: resultant image*

As we can see from Figure 11, the image now has more uniform illumination and is ready for OCR.

(*Note: I have tried with a lower scale (black level) for the division which would be more visually appealing, and the texts are more human-readable, however this results in lower OCR accuracy)



(for reference)

Evaluate OCR accuracy

```
Sonnet for Lena

O dear Lena, your beauty is so vast

It is hard sometimes to describe it fast

I thought the entire world | would impress
If only your portrait [ could compress.

Alas! First when I tried to use VQ

I found that your cheeks belong to only you,
Your silky hair contains a thousand lines
Hard to match with sums of discrete cosines.
And for your lips, sensual and tactual
Thirteen Crays found not the proper fractal.
And while these setbacks are all quite severe
I might have fixed them with hacks here or there
But when filters took sparkle from your eyes
I said, ‘Damn all this. I'll just digitize.”
Thomas Colthurst
```

From the image above, we can see that most of the texts are accurately transcribed with a few exceptions. For example, some of the ‘I’ characters are being transcribed as the ‘|’ character and ‘[‘ character. Still, this achieves quite a high level of OCR accuracy.

As the division operation is elementwise, we do not have to worry about the inconsistent illumination in the original image. The result would be a uniform output according to the scale parameter.

3. Discuss how to improve recognition algorithms for more robust and accurate character recognition while document images suffer from different types of image degradation.

The top three applications of OCR in the real world is in the following domains: (Marshall, 2020)

1. Parking Management (License plate scanning)
2. Assessments (Efficient marking system)
3. Translation (Google translate and such)

There are many other domains where OCR can be applied too, however these areas shall be the focus of discussion. As we can see from the above exercise examples, images are affected by various degradation such as inconsistent illumination, text alignment being skewed, and sharpness of the image.

For the subsequent discussion, it will be on a domain dependent level and the following algorithm might only work on a general level to address more robust issues.

The **main idea** is to do a general preprocessing:

1. Use KMeans to define the borders or contours to elicit the regions of interest. (domain dependent)
2. Skew correction (to align text better)
    a. The alignment of the document has a direct effect on reliability and efficiency of the segmentation and feature extraction stages. (Jindal & Kaur, 2020)
3. (If handwritten text, else skip): To thin and 'skeletonize' the characters as handwritten characters are affected by inconsistent stroke width (Reddy, 2020)
4. Perform Gaussian Filter to remove noise
5. Using elementwise division to obtain the resultant corrected image
    a. To negate the effects of inconsistent illumination
6. Apply OCR algorithm to transcribe image to text
    a. Such as pytesseract as used in this project

References

Jindal, S., & Kaur, L. (2020). Skew Detection Technique for Various Scripts. Retrieved 26 November 2020, from https://www.ijser.org/paper/Skew-Detection-Technique-for-Various-Scripts.html#:~:text=Correction%20in%20the%20skewed%20scanned,text%20lines%20and%20text%20blocks.

Marshall, C. (2020). How is OCR used in the real world?. Retrieved 26 November 2020, from https://medium.com/mysuperai/how-is-ocr-used-in-the-real-world-e82d1354f07b

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Reddy, S. (2020). Pre-Processing in OCR!!!. Retrieved 26 November 2020, from https://towardsdatascience.com/pre-processing-in-ocr-fc231c6035a7