Machine Perception DS/NC/ESD 863
Denoising Dirty Documents
Project Review

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List of Figures

List of Tables

1 Goal Statement Description

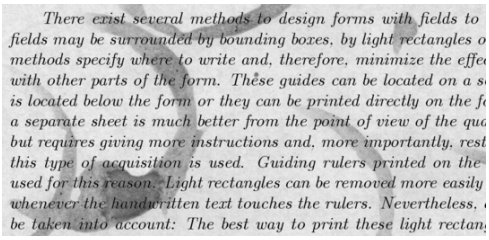
Optical Character Recognition (OCR) is the process of getting typed or handwritten documents into a digitized format. The motivation of converting to a digitized format is to ensure security, accessibility, edit-ability and ease of searching and sharing. Also, digital documents don't get dirty and cannot be ruined by coffee stains. [2]

Unfortunately, a lot of documents eager for digitization are being held back. Coffee stains, faded sun spots, dog-eared pages, and lot of wrinkles are keeping some printed documents offline and in the past.

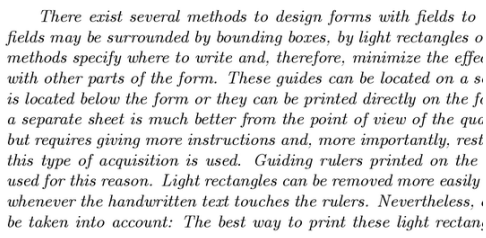
Given a dataset of images of scanned text (synthetic images) that are "noisy" with stains and wrinkles, we propose to clean up the noise and help with the digitization process.

2 Dataset

Kaggle provided a dataset which consists of two sets of images - train and test. These images contain various styles of text, to which synthetic noise has been added to simulate real-world, messy documents. The dirty images contain stains as well as creased paper. The training set also includes the cleaned up images of those found in the test file (train_cleaned) [2]. By clean, we mean black letters on a white background. Below are two sample images:



(a) Original Image



(b) Cleaned Image

Figure 1: Sample Images

Kaggle calculates the score based on the root-mean-squared-error (RMSE) value between each pixels of the generated output and the actual cleaned image.

3 Literature Review

The project is one of *Kaggle's* old competition. *Kaggle* has a section called Kernels & Discussions for each dataset which contains snippets of codes, discussions between participants, ideas for future expansion.

We came across a blog [1], which contained the methods used by the author to solve this. He has used a variety of techniques to solve this. We proposed our methods based on our understanding of the problem and the approach taken by him and the other users.

4 Methods

Taking the proposed plan of action forward, we have implemented 4 methods mentioned in our previous project report. We have identified the methods that have worked well and for which images and the challenges we have faced.

4.1 Histogram Suppression

To understand the data-set, we plotted the images alongside their histograms. It gives us a clearer understanding of the noise in the images.

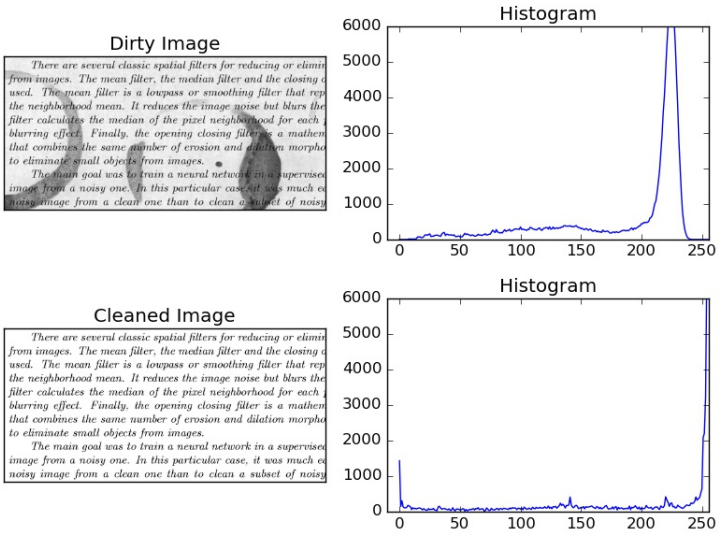


Figure 2: Image 3 and its Histogram

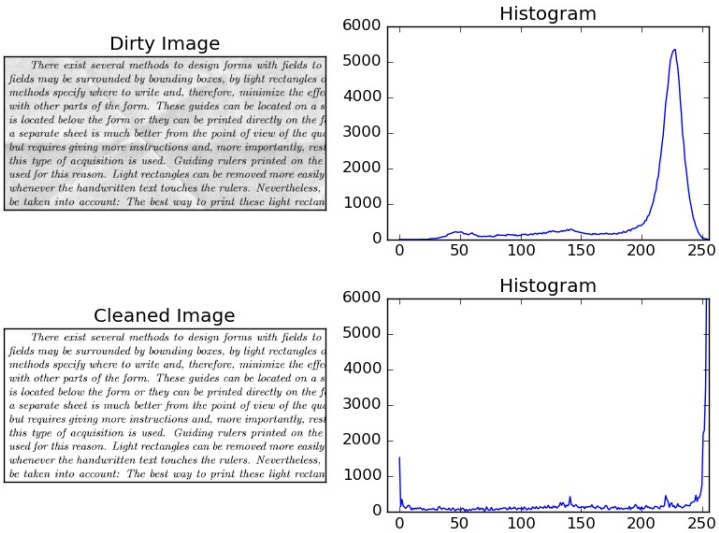
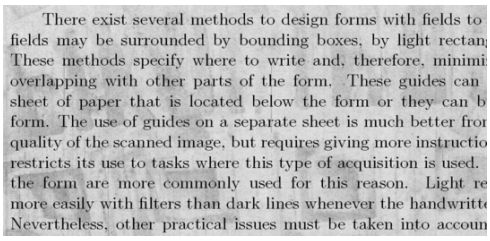


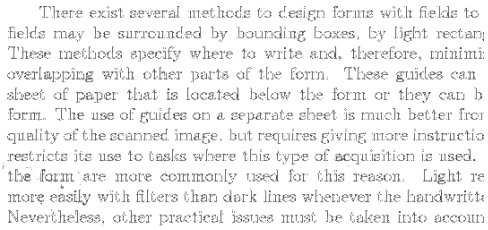
Figure 3: Image 5 and its Histogram

As you can see from the plots, most of the pixels are concentrated near the 200's there are some scattered around the range (50 to 150). This pattern arises in all of the images, some more denser than others. This leads us to conclude that the intensity of the characters are in this range (Note, noise could also be found in this region).

We propose an algorithm that changes all pixel values to 255 (white) leaving only the ones in the range 50 to 150 unchanged. The results are displayed below.

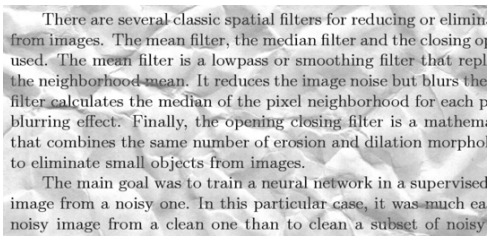


(a) Original Image 1

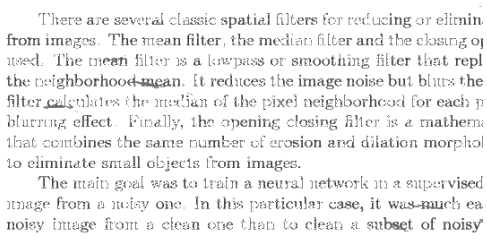


(b) Cleaned Image 1

Figure 4: Histogram Suppression a)

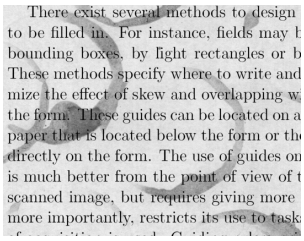


(a) Original Image 2

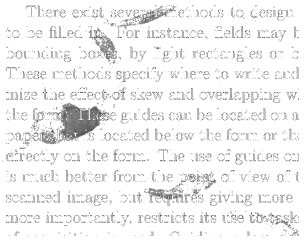


(b) Cleaned Image 2

Figure 5: Histogram Suppression b)



(a) Original Image 3



(b) Cleaned Image 3

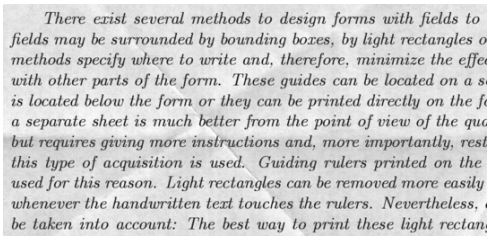
Figure 6: Histogram Suppression c)

The RMSE value turned out to be 239.53297.

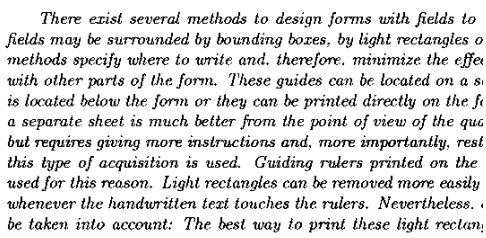
4.2 Fixed Thresholding

In order to separate the writing from the background noise, we first tried out the fixed thresholding method. We recognised that the writing was significantly darker than

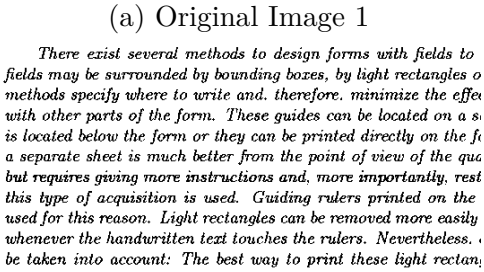
the background which contained noise in the form of creases or dog eared pages. The biggest challenge here was the trial and error involved in deciding on a good value to threshold the image on. Below are the different potential values that gave us a reasonable output.



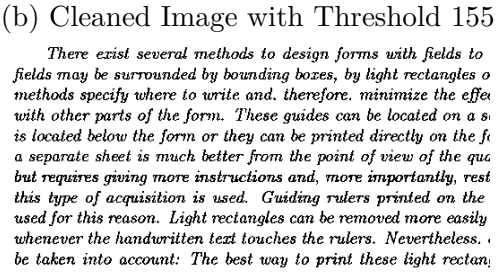
(a) Original Image 1



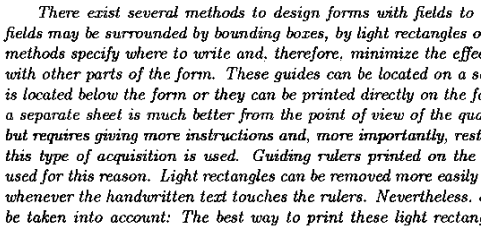
(b) Cleaned Image with Threshold 155



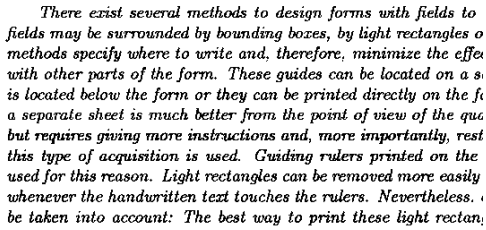
(c) Cleaned Image with Threshold 160



(d) Cleaned Image with Threshold 165



(e) Cleaned Image with Threshold 170

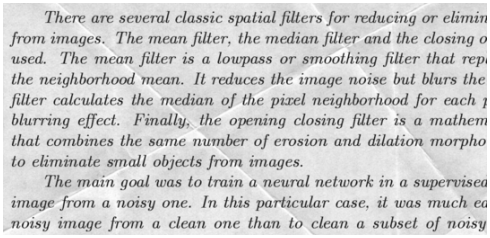


(f) Cleaned Image with Threshold 175

Figure 7: Fixed Thresholding with Multiple Threshold Values

We decided that out of these values, a threshold value of 165 gave us the best result for the most images. Below are the dirty and cleaned image pairs after fixed thresholding with a threshold value of 165.

```
ret,thresh1 = cv2.threshold(img,165,255,cv2.THRESH_BINARY)
```



There are several classic spatial filters for reducing or elimin
from images. The mean filter, the median filter and the closing o
used. The mean filter is a lowpass or smoothing filter that rep
the neighborhood mean. It reduces the image noise but blurs the
filter calculates the median of the pixel neighborhood for each
blurring effect. Finally, the opening closing filter is a mathem
that combines the same number of erosion and dilation morpho
to eliminate small objects from images.

The main goal was to train a neural network in a supervisea
image from a noisy one. In this particular case, it was much ea
noisy image from a clean one than to clean a subset of noisy

(a) Original Image 2

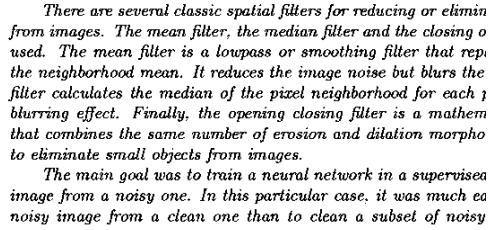


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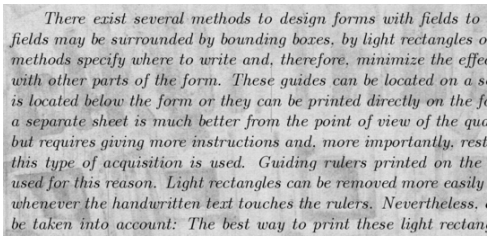
image from a noisy one. In this particular case, it was much ea
noisy image from a clean one than to clean a subset of noisy

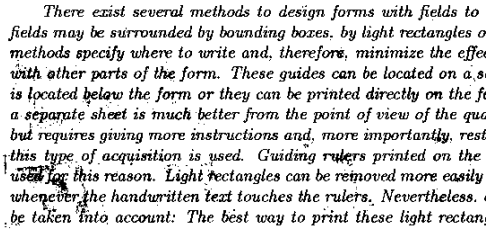
(b) Cleaned Image with Threshold 165

Figure 8: Fixed Thresholding a)



There exist several methods to design forms with fields to
fields may be surrounded by bounding boxes, by light rectangles o
methods specify where to write and, therefore, minimize the effe
with other parts of the form. These guides can be located on a s
is located below the form or they can be printed directly on the f
a separate sheet is much better from the point of view of the qu
but requires giving more instructions and, more importantly, rest
this type of acquisition is used. Guiding rulers printed on the
used for this reason. Light rectangles can be removed more easily
whenever the handwritten text touches the rulers. Nevertheless,
be taken into account: The best way to print these light rectan

(a) Original Image 3



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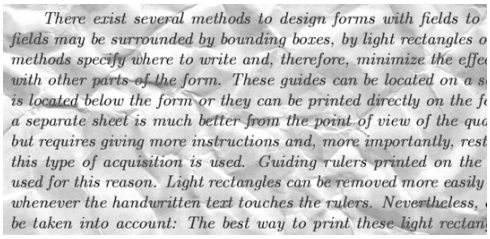
(b) Cleaned Image with Threshold 165

Figure 9: Fixed Thresholding b)



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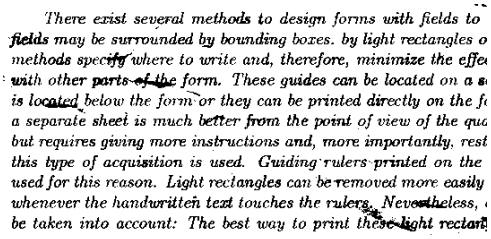
(a) Original Image 4



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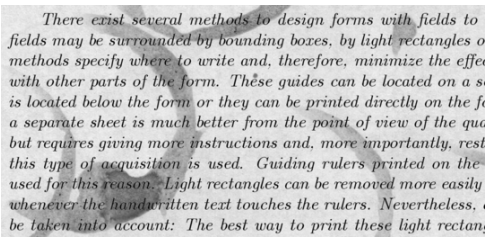
whenever the handwritten text touches the rulers. Nevertheless,
be taken into account: The best way to print these light rectan

(b) Cleaned Image with Threshold 165

Figure 10: Fixed Thresholding c)

The problem with this method that it worked only when the noise was in the form of creases or dog eared pages i.e., when the background was much lighter that the writing. However, when the noise is in the form of coffee stains, fixed thresholding didn't work as seen in the image below. This is because the noise was not much lighter than the writing itself. If we increase the threshold value to one that is high enough to remove the coffee stains, then it may remove the dark writing along with the stains.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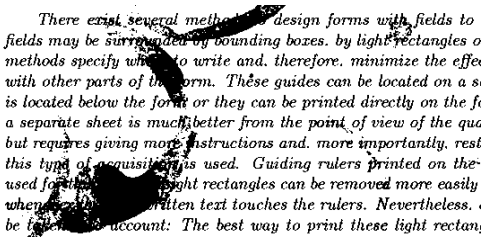
whenever the handwritten text touches the rulers. Nevertheless,
be taken into account: The best way to print these light rectan

(a) Original Image 5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whenever the handwritten text touches the rulers. Nevertheless,
be taken into account: The best way to print these light rectan

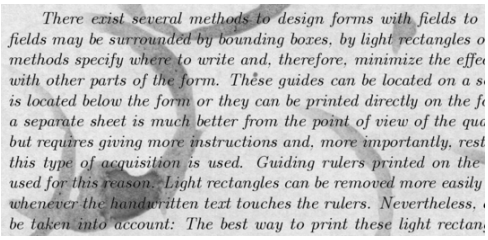
(b) Cleaned Image with Threshold 165

Figure 11: Fixed Thresholding on Coffee Stained Image

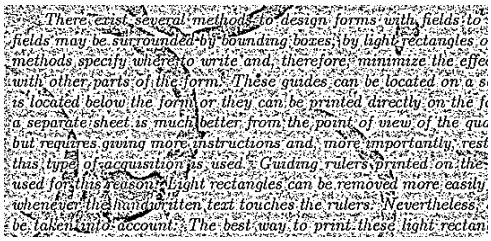
The RMSE value is 220.00782.

4.3 Adaptive Thresholding

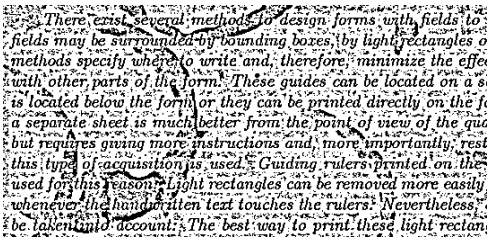
For images which contain coffee stains, we proposed to use adaptive thresholding. This is because although the coffee stains are darker than creases, they are definitely not as dark as the writing. Since adaptive thresholding looks at the neighbourhood of a pixel to do the thresholding, the neighbourhood of the coffee stains is definitely lighter than if we look at the neighbourhood of the writing. Below are the different values for 'box size' and 'constant c' that we tried with both Gaussian and Mean thresholding.



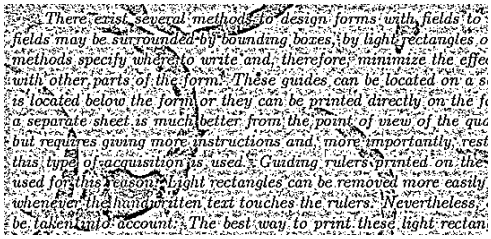
(a) Original Image 1



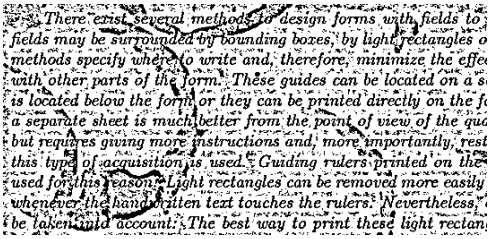
(b) Gaussian Box Size 9 and Constant 2



(c) Mean Box Size 9 and Constant 2



(d) Gaussian Box Size 11 and Constant 2

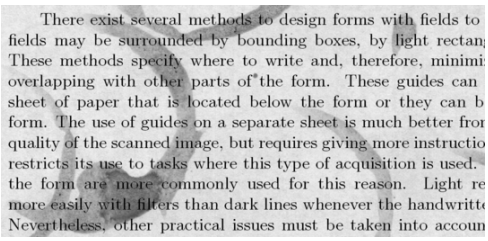


(e) Mean Box Size 11 and Constant 2

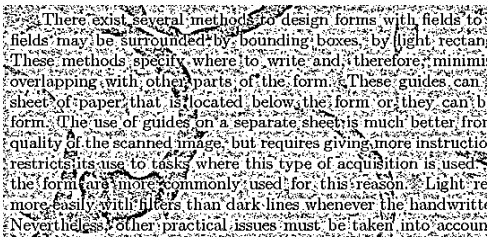
Figure 12: Adaptive Thresholding with Multiple Cleaned Images

We decided that out of these values, a combination of Box Value of 11 and Constant value of 2 with Gaussian Filtering gave the best output for most images. Below are the dirty and cleaned image pairs after adaptive thresholding.

```
thresh2 = cv2.adaptiveThreshold(img,255,1, cv2.THRESH_BINARY,11,2)
```

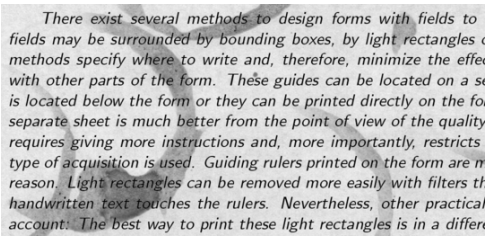


(a) Original Image 2

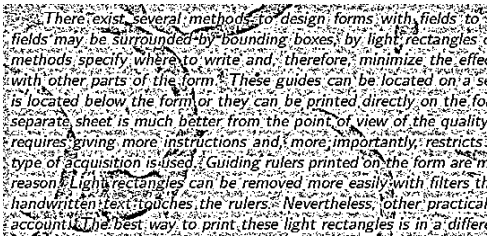


(b) Cleaned Image

Figure 13: Adaptive Thresholding a)



(a) Original Image 3



(b) Cleaned Image

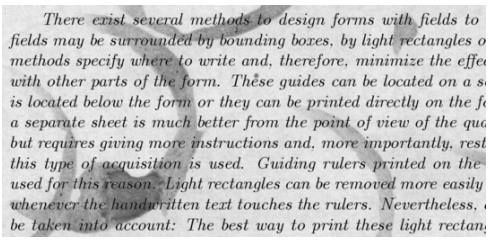
Figure 14: Adaptive Thresholding b)

However, from the above images we see that adaptive thresholding has left a pattern of specks in the place of the coffee stains which further need to be cleaned.

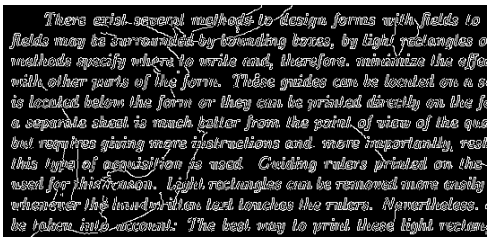
Calculated RMSE value turned out to be 212.28749.

4.4 Canny Edge Detection and Morphology

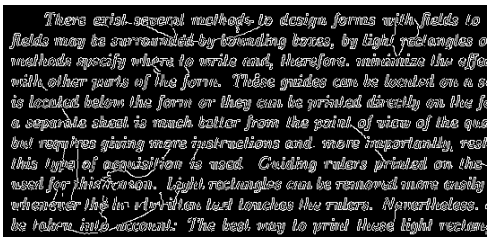
Although the stains are cleaned up to a large extent we still see a bunch of specks which need to be addressed. As proposed, we decide to tackle this problem by first applying Canny Edge Detection on the images. We did trial and error on the min and max value for the Canny Edge Detector. Below are the different potential value pairs that we thought gave us the best result.



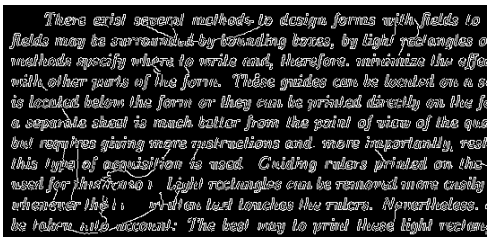
(a) Original Image 1



(b) Minimum 100 Maximum 300



(c) Minimum 100 Maximum 400

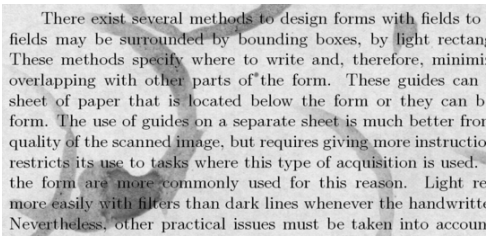


(d) Minimum 100 Maximum 500

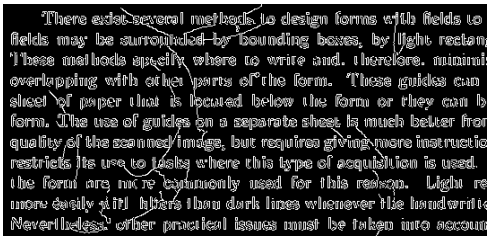
Figure 15: Canny Edge Detection a)

We decided that for a minVal of 100 and maxVal of 500, the speckled part was getting cleaned up for most of the images.

```
edges = cv2.Canny(img,100,200)
```



(a) Original Image 2

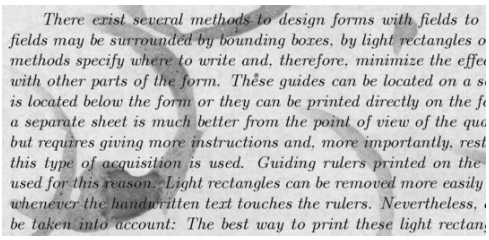


(b) Cleaned Image

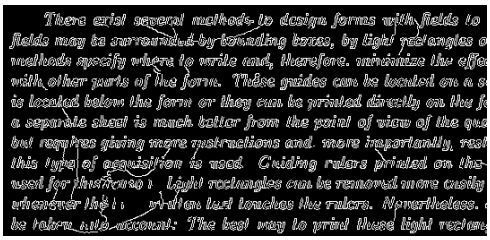
Figure 16: Canny Edge Detection b)

What we notice is that two edges are formed around the writing, like a stencil. While the coffee stains have only a single edge. We attempted we use morphological techniques of erosion and dilation in order to get rid of the stain edges completely. We tried dilating the image once, in order to make the writing much thicker than the edges (as the writing had two edges that would expand) and then eroding the image in order to get stains while keeping the writing intact due to the thickness difference. Below is an example of the step by step process followed.

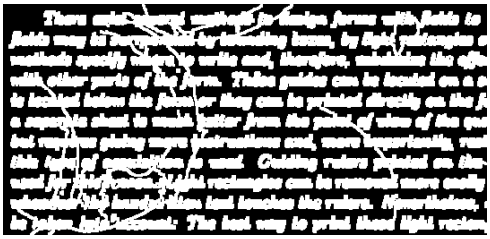
```
kernel = np.ones((3,3),np.uint8)
dilation = cv2.dilate(edges,kernel,iterations = 1)
erosion = cv2.erode(dilation,kernel,iterations = 1)
```



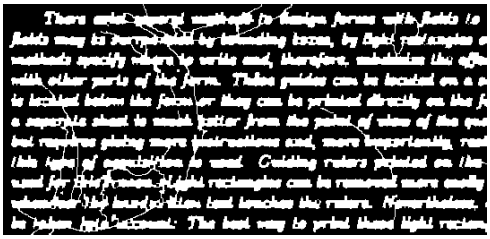
(a) Original Image 1



(b) Canny Edge Detection



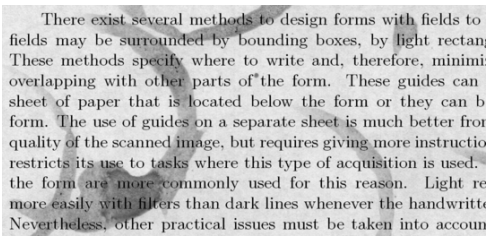
(c) Dilation



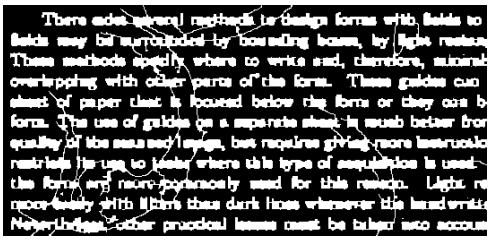
(d) Morphological Operation

Figure 17: Step by Step Transformations

Below are the dirty and cleaned image pairs after dilation and erosion are done.

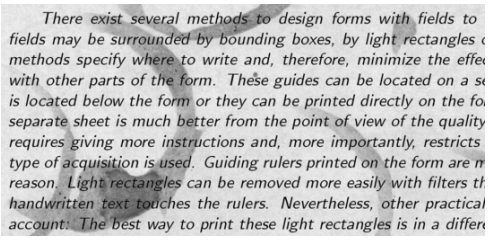


(a) Original Image 2

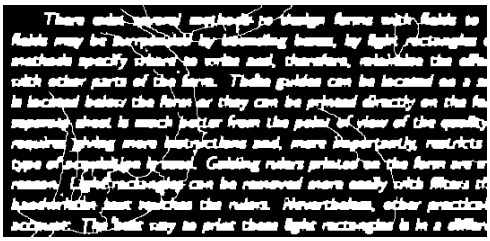


(b) Cleaned Image

Figure 18: Morphological Operation a)



(a) Original Image 3



(b) Cleaned Image

Figure 19: Morphological Operation b)

However we see that the writing isn't clear in the cleaned up image after the final erosion is done. Hence, we decided to avoid doing the morphological operations.

RMSE value for dilation is 196.74589.

RMSE value for erotion is 218.05208.

Methods/Score	RMSE
Histogram Suppression	239.53297
Fixed Thresholding	220.00782
Adaptive Thresholding	212.28749
Canny Edge (Dilation)	196.74589
Canny Edge (Erotion)	218.05208

Table 1: Table with methods and their RMSE scores

5 Future Work

Until now, we focused on using image processing techniques to "denoise" the dirty documents. We propose to take a few machine learning focused approaches to see if it gives us an improved denoising ability. One approach we thought of is the prediction of the brightness of a pixel (black for writing and white for background) based on the 9 surrounding pixels. We can use this information on different supervised learning models and see if this gives us good results. We also believe that we can integrate this local pixel information with known properties about the structure of the document like line or word spacing to improve our models.

References

[1] Colin blog. http://tinyurl.com/gnptby6. Accessed: 2017-04-18.

[2] Kaggle - denoising dirty documents. http://tinyurl.com/z4ukatx. Accessed: 2017-04-18.