EN.600.461 Computer Vision
Final Project
Recognizing and Translating Text from Document Images

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Abstract

This work explores optical character recognition (OCR) in photos of typed and handwritten documents. It first explores basic preprocessing of photos of documents using `OpenCV` [1] for blurring, thresholding, and denoising. It next discusses the use of `tesseract-ocr` [2] to perform OCR. It then discusses the incorporation of the Google Cloud Translation API [3] to translate the OCR results into different languages. It finally discusses template matching using signatures of three U.S. presidents and the Johns Hopkins University (JHU) logo and on document images.

1 Introduction

This work achieved the following main goals stated in the original proposal: 1) Given a photo of a document, convert it into a clean scanned version; 2) Take the scanned version and perform OCR. Optionally, this work took the OCR output and translated the text into different languages using the Google Cloud Translation API. This work also experimented with template matching using signatures of three U.S presidents and the JHU logo in input documents. Lastly, this work performed CNN training on the MNIST handwritten digit dataset as an experiment. In this document, we discsuss 2. Dataset, 3. Methods, 4. Results, 5. Discussion, and 6. Conclusion.

2 Dataset

2.1 Typed Documents

We took photos of the final project guidelines for this course, the author's final project proposal, JHU's Lav Note, and four aesop's fables, which the author typed and printed in different font types and sizes. A sample input image is shown in Figure 2.

2.2 Handwritten Documents

We collected photos of letters written by three U.S. presidents: Barack Obama, George W. Bush, and Bill Clinton. We also wrote portions of the aesop's fables mentioned above by hand with different handwriting and photographed them under different settings. Figure 3 shows one of our reasonably neat images `hand_cat.png`, and Figure 4 shows a sample letter written by Preisdent Obama, `obama2.png`.

2.3 Templates

For the template mathcing experiments, we collected images of the JHU logo in several sizes and signatures of the three U.S. presidents listed above. We used images from **2.1** and **2.2** as input images.

3 Methods

In this section, we discuss the methods we took and external libraries used for each stage of our work.

3.1 Image Preprocessing

We implemented our program in Python using `OpenCV`. In order to feed the OCR algorithm clean input to achieve best performance, we used `cv2.medianBlur` to smoothen the input image

[1] http://opencv.org/

[2] https://github.com/tesseract-ocr

[3] https://cloud.google.com/translate/

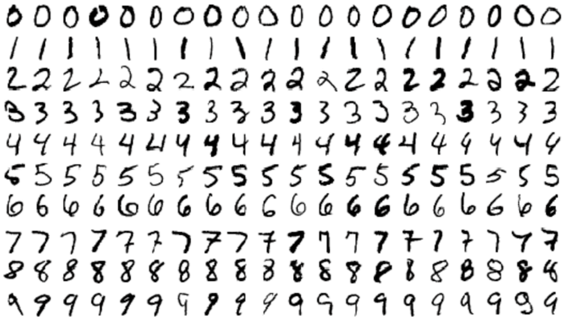


Figure 1: Sample images from MNIST

with an aperture size of 5. Then, we performed binary thresholding on the smoothened image using `cv2.adaptiveThreshold` with *adaptiveMethod= ADAPTIVE_THRESH_GAUSSIAN_C*, *threshold = binary*, *blockSize=5x5*, and *C=2*. The adaptive method we selected uses the weighted sum of (*(blockSize* x *blockSize) neighborhood of pixel (x, y)* − *C*) as its threshold value.

Finally, we performed denoising on the thresholded image to remove noise and make the output clean. We used `cv2.fastNlMeansDenoising` with *templateWindowSize=7*, *searchWindowSize = 21*, and *h=7*. Parameters were chosen empirically.

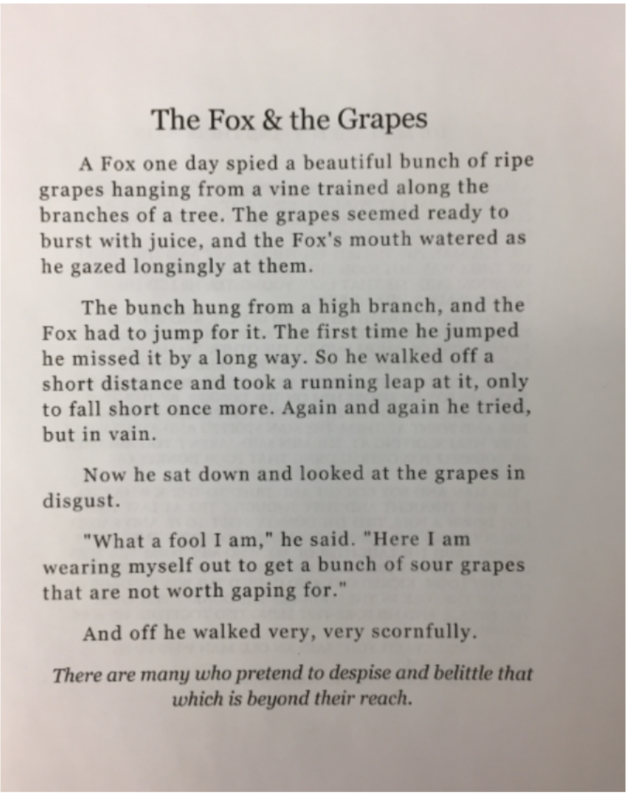
3.2 OCR

In order to perform OCR on the preprocessed inputs, we used the `tesseract-ocr` library via its Python wrapper `pytesseract`. Raw output from `pytesseract`'s `image_to_string` method was used to pass into Python's file writer and Google Cloud Translation API.

As a side experiment, we used the `Keras` [4] library to train the MNIST [5] dataset of 70,000 handwritten digits on three different convolutional neural networks (CNN). We referred to code available online [6] to build the three CNNs. Refer to Figure 1 for some sample images in the MNIST dataset.

3.3 Text Translation

We made use of Google Cloud's Translation API in order to translate the OCR processed document into several different languages based on user command line input. We referred to external code [7] to make API calls and modified the details to fit our purpose. Moreover, we needed to carefully deal with the translated output characters in `utf-8` when writing them in .txt since they were not simple ASCII.



The Fox & the Grapes

A Fox one day spied a beautiful bunch of ripe grapes hanging from a vine trained along the branches of a tree. The grapes seemed ready to burst with juice, and the Fox's mouth watered as he gazed longingly at them.

The bunch hung from a high branch, and the Fox had to jump for it. The first time he jumped he missed it by a long way. So he walked off a short distance and took a running leap at it, only to fall short once more. Again and again he tried, but in vain.

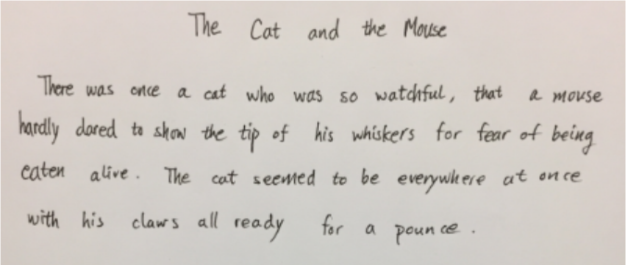
Now he sat down and looked at the grapes in disgust.

"What a fool I am," he said. "Here I am wearing myself out to get a bunch of sour grapes that are not worth gaping for."

And off he walked very, very scornfully.

There are many who pretend to despise and belittle that which is beyond their reach.

Figure 2: Sample typed document `aesop_fox.png`



The Cat and the Mouse

There was once a cat who was so watchful, that a mouse hardly dared to show the tip of his whiskers for fear of being eaten alive. The cat seemed to be everywhere at once with his claws all ready for a pounce.

Figure 3: Reasonably handwritten doc `hand_cat.png`

3.4 Template Matching

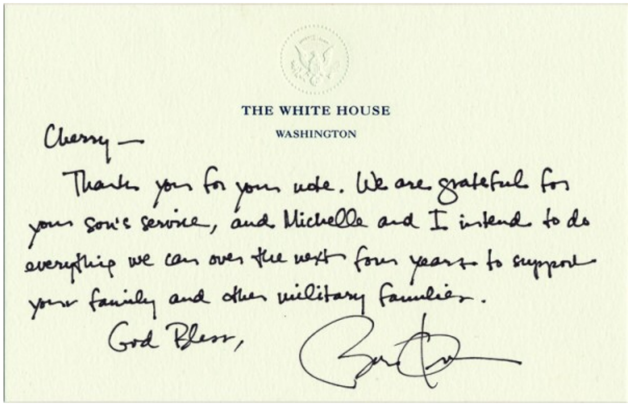
Aside from OCR, which was the main focus of this project, we also experimented with template matching in images. We tested with various targets. First,

[4] https://keras.io/

[5] http://yann.lecun.com/exdb/mnist/

[6] http://machinelearningmastery.com/handwritten-digit-recognition-using-convolutional-neural-networks-python-keras/

[7] http://github.com/mouuff/mtranslate


THE WHITE HOUSE
WASHINGTON

Cherry —

Thank you for your note. We are grateful for your son's service, and Michelle and I intend to do everything we can over the next four years to support your family and other military families.

God Bless,

Figure 4: Less neatly handwritten doc obama2.png

we targeted to identify signatures of U.S. Presidents Barack Obama, George W. Bush, and Bill Clinton in documents. Our dataset consisted of handwritten letters written by the presidents as input images and their respective signature images as templates.

Next, we experimented with the JHU logo to determine whether an input document was an official JHU document. We simply assumed that official JHU documents contained a JHU logo for experimental purposes. We used cv2.matchTemplate with our input documents as the source image, multiple JHU logo images (each with different sizes since cv2.matchTemplate is scale sensitive) as templates, and matching method cv2.TM_CCOEFF_NORMED. If the normazlied TM_CCOEFF value came out to be greater than 0.51 for any of the input JHU logo templates, we determined that the input document contained a JHU logo in it. The matching method and determinant value of 0.51 were chosen empirically.

4 Results

Please see **Appendix A** for experiment run outputs on the three sample images aesop_fox.png, hand_cat.png, and obama2.png.

4.1 OCR on Typed Documents

We ran our code on seven document images with different font types and font sizes. The images were cv_proj_description.png, cv_jchoi_proposal.png, aesop_fox.png, lav_notes1.png, aesop_miller.png, aesop_goose.png, and aesop_cat.png. With the exception of aesop_goose.png, performance on all documents were nearly perfect. Potential reasons of failure with this particular image are discussed in **5.2**.

4.2 OCR on Handwritten Documents

We applied our code on photos of handwritten documents. Performance on very neatly written documents (hand_fox.png and hand_goose.png) was nowhere close to what we saw for the printed dataset. Any reasonably neatly handwritten documents (hand_miller.png and hand_cat.png) showed even poorer performance. Moreover, our code was not able to detect a single word from document images with much less neat handwriting. Such images were obama1.png, obama2.png, obama3.png, bush1.png, bush2.png, clinton1.png, and clinton2.png.

4.3 Template Matching

The results for the U.S. presidents' signatures was poor. We then used the JHU logo to determine whether the input document was an official JHU document. This experiment showed more promising results. We discuss potential reasons in **5.3**.

5 Discussion

5.1 Image Processing

In running our experiments, we tested with various configurations for denoising and smoothening. Certain parameter configurations worked almost perfectly for some images while they produced disappointing outcome for others. We chose parameter values that performed acceptably well on all images in our dataset. The motivation behind denoising in our work was that document scans usually have many random specs spread throughout the entire image. Such noise can greatly reduce OCR accuracy because an OCR algorithm may confuse a random spec with punctuation marks or associate a spec with an actual character nearby. (e.g. confuse an l and ' with an i)

5.2 OCR

The reason that aesop_goose.png did not produce satisfactory results was that the font in the document was relatively thick and bold. Therefore, after the preprocessing stage, the alphabet characters in the thresholded document were hollow with just the edges remaining. Therefore, the OCR algorithm could not recognize any of the characters in this text.

The two images `cv_jchoi_proposal.png` and `lav_notes1.png` were taken under suboptimal conditions: irregular lighting, partial skew, and/or glossy surfaces. Moreover, these documents had mixed font types and sizes, and the structures of the documents were more complicated than the previous inputs. We ran our code on these two document images. Despite the less optimal settings, we correctly denoised and thresholded the images and obtained similar OCR results as before.

5.3 Template Matching

Performance for experiments with U.S. presidents' signatures was poor, and we decided to experiment with an easier, rigid template. Performance on the JHU logo template experiments was better compared to that of the U.S. president signature experiments. The reason that the signature experiment is harder is that the JHU logo is fixed in terms of how it is comprised (e.g. lines, curves, color density) whereas signatures vary each time it is signed (e.g. penstroke width, curvature, ratio of one part of the signature with respect to other parts). Therefore, we conjecture that the "signature matching task" bears more resemblance to an object recognition task than an OCR task.

Another reason that the U.S. president experiment did not work well could be that the input documents (*i.e.* letters written by the presidents) were handwritten. The template matching algorithm had more variability to deal with since the entire document contained many likely matching candidates for the given template. This was apparent when we saw the algorithm output locations of random words within the letters as matches to the signature templates.

6 Conclusion

We explored optical character recognition on photographed documents in various settings and formats. We tested with optimal and suboptimal photography settings, experimented with documents with various fonts, and compared performance on typed and handwritten documents. For typed documents, we saw accurate results under both optimal and suboptimal settings even if they contained various font sizes and font types. However, we were not able to achieve accurate results with handwritten document photos, disregarding the neatness of the handwriting. For sufficiently small portions of handwritten documents (e.g. a single word or a short sentence), the OCR algorithm was able to produce correct output occasionally. However, even this was not often enough to be considered reliable.

Nonetheless, on typed documents, we were able to effectively preprocess the document image and perform OCR on the cleaned data. Moreover, we leveraged the Google Cloud Translation API to translate documents into several different languages. Our final experiments on template matching also deserve future development into a project of its own.

How to Run the Code

Please refer to our GitHub repository [8]. Assuming that the user has installed all required packages and dependencies, run the following command:

$> python driver.py {path-to-image-file} {list of target languages separated by a space}

Sample usage: *python driver.py doc7.png es fr ko*

The sample command above performs OCR on `doc7.png`, outputs the thresholded image, the text in the original input language, and the text translated in Spanish, French, and Korean.

Saved Output from Experiments

Please refer to our GitHub repository.

Acknowledgments

We thank `OpenCV` and `tesseract`, the code we referred to for constructing CNNs using `Keras`, MNIST for the handwritten digit dataset, and Google for the translation API.

We also thank Ji Won Shin (*JHU Class of 2019*) for generously providing the author with a Macbook Pro that could run `tesseract`.

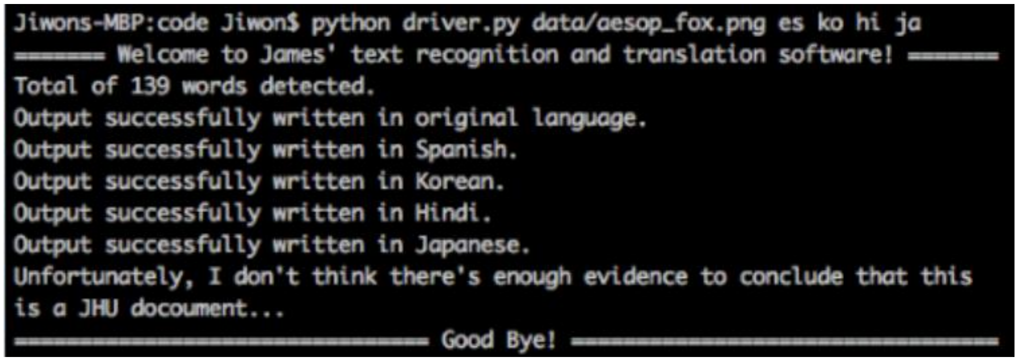
And many thanks to Professor Reiter and the TAs for a great semester! Have a great winter break.

[8] https://github.com/jchoi100/computer_vision_project

Appendix A.

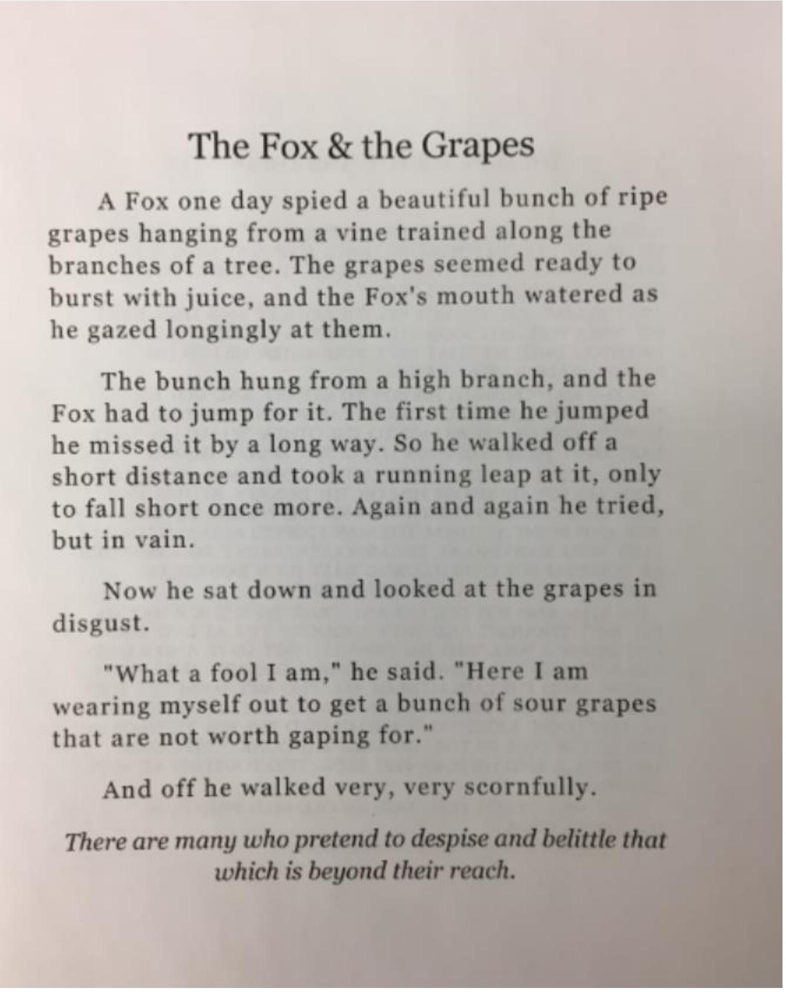
The following are sample runs for the three images referred to in our report.

1. Image 1: `aesop_fox.png`



```
Jiwons-MBP:code Jiwon$ python driver.py data/aesop_fox.png es ko hi ja
======= Welcome to James' text recognition and translation software! =======
Total of 139 words detected.
Output successfully written in original language.
Output successfully written in Spanish.
Output successfully written in Korean.
Output successfully written in Hindi.
Output successfully written in Japanese.
Unfortunately, I don't think there's enough evidence to conclude that this
is a JHU docoument...
================================ Good Bye! ================================
```

Command line argument and standard out.



The Fox & the Grapes

A Fox one day spied a beautiful bunch of ripe grapes hanging from a vine trained along the branches of a tree. The grapes seemed ready to burst with juice, and the Fox's mouth watered as he gazed longingly at them.

The bunch hung from a high branch, and the Fox had to jump for it. The first time he jumped he missed it by a long way. So he walked off a short distance and took a running leap at it, only to fall short once more. Again and again he tried, but in vain.

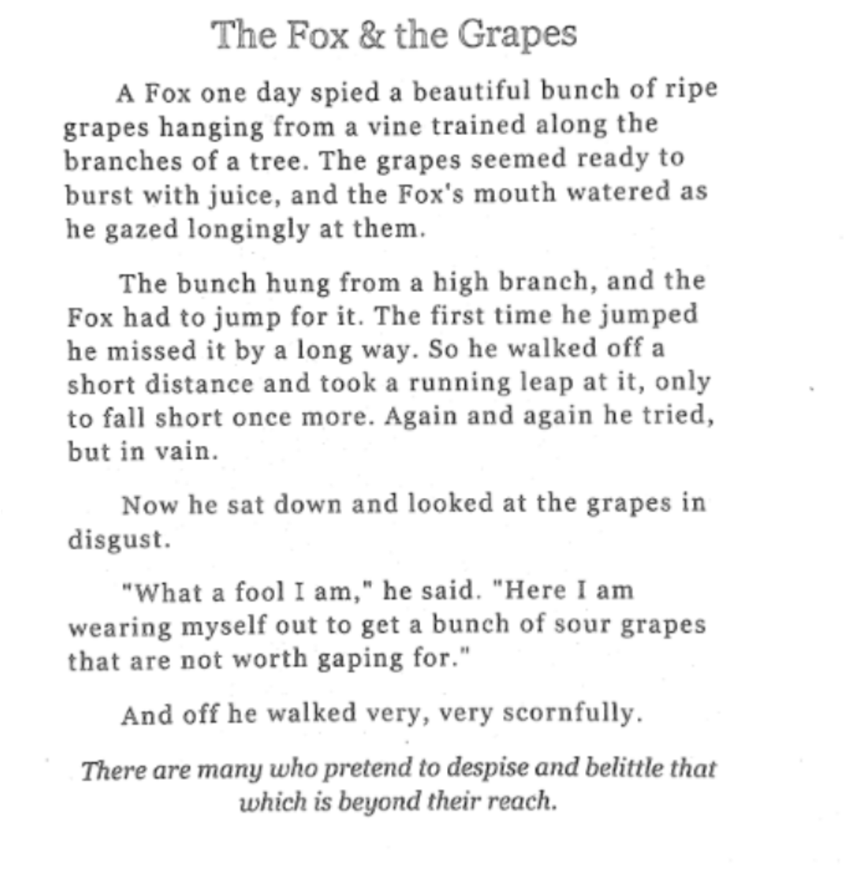
Now he sat down and looked at the grapes in disgust.

"What a fool I am," he said. "Here I am wearing myself out to get a bunch of sour grapes that are not worth gaping for."

And off he walked very, very scornfully.

There are many who pretend to despise and belittle that which is beyond their reach.

Original input image `aesop_fox.png`, unprocessed.



The Fox & the Grapes

A Fox one day spied a beautiful bunch of ripe grapes hanging from a vine trained along the branches of a tree. The grapes seemed ready to burst with juice, and the Fox's mouth watered as he gazed longingly at them.

The bunch hung from a high branch, and the Fox had to jump for it. The first time he jumped he missed it by a long way. So he walked off a short distance and took a running leap at it, only to fall short once more. Again and again he tried, but in vain.

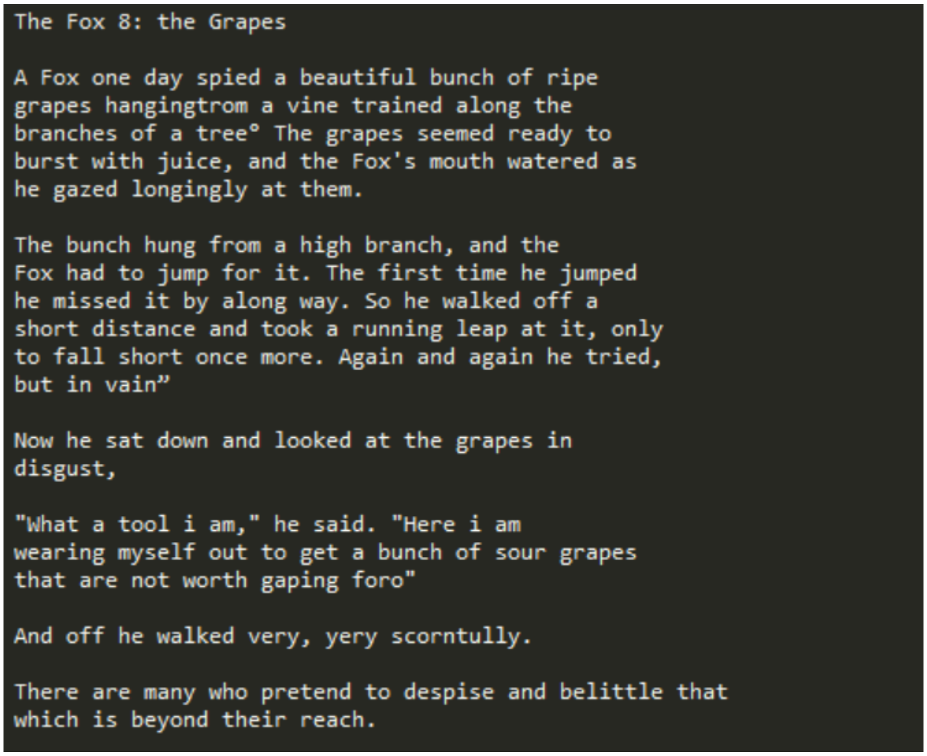
Now he sat down and looked at the grapes in disgust.

"What a fool I am," he said. "Here I am wearing myself out to get a bunch of sour grapes that are not worth gaping for."

And off he walked very, very scornfully.

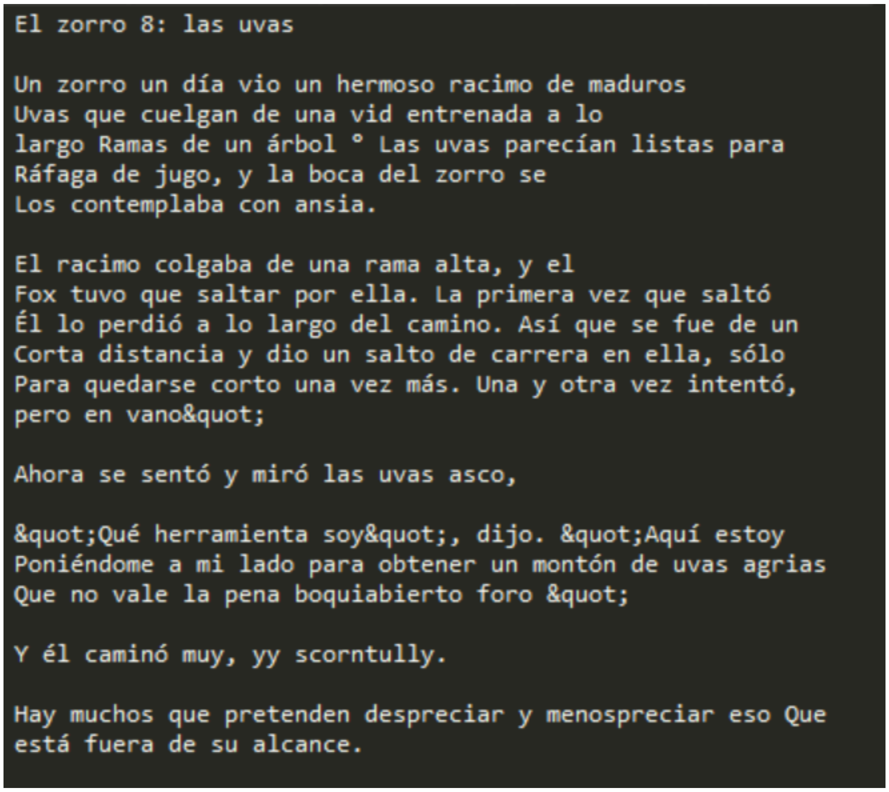
There are many who pretend to despise and belittle that which is beyond their reach.

Thresholded input image `aesop_fox_thresh.png`**.**



```
The Fox 8: the Grapes

A Fox one day spied a beautiful bunch of ripe
grapes hangingtrom a vine trained along the
branches of a tree° The grapes seemed ready to
burst with juice, and the Fox's mouth watered as
he gazed longingly at them.

The bunch hung from a high branch, and the
Fox had to jump for it. The first time he jumped
he missed it by along way. So he walked off a
short distance and took a running leap at it, only
to fall short once more. Again and again he tried,
but in vain”

Now he sat down and looked at the grapes in
disgust,

"What a tool i am," he said. "Here i am
wearing myself out to get a bunch of sour grapes
that are not worth gaping foro"

And off he walked very, yery scorntully.

There are many who pretend to despise and belittle that
which is beyond their reach.
```

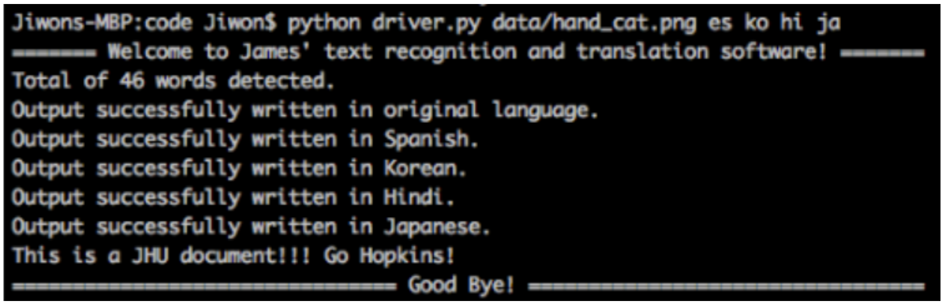
Text output in English. (`aesop_fox_output.txt`)



```
El zorro 8: las uvas

Un zorro un día vio un hermoso racimo de maduros
Uvas que cuelgan de una vid entrenada a lo
largo Ramas de un árbol ° Las uvas parecían listas para
Ráfaga de jugo, y la boca del zorro se
Los contemplaba con ansia.

El racimo colgaba de una rama alta, y el
Fox tuvo que saltar por ella. La primera vez que saltó
Él lo perdió a lo largo del camino. Así que se fue de un
Corta distancia y dio un salto de carrera en ella, sólo
Para quedarse corto una vez más. Una y otra vez intentó,
pero en vano&quot;

Ahora se sentó y miró las uvas asco,

&quot;Qué herramienta soy&quot;, dijo. &quot;Aquí estoy
Poniéndome a mi lado para obtener un montón de uvas agrias
Que no vale la pena boquiabierto foro &quot;

Y él caminó muy, yy scorntully.

Hay muchos que pretenden despreciar y menospreciar eso Que
está fuera de su alcance.
```

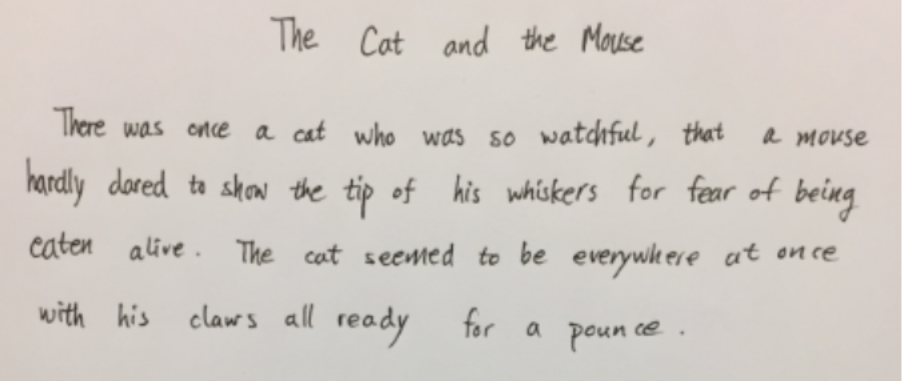
Text output in Spanish. (`aesop_fox_output_es.txt`)

2. Image 2: `hand_cat.png`



```
Jiwons-MBP:code Jiwon$ python driver.py data/hand_cat.png es ko hi ja
======= Welcome to James' text recognition and translation software! =======
Total of 46 words detected.
Output successfully written in original language.
Output successfully written in Spanish.
Output successfully written in Korean.
Output successfully written in Hindi.
Output successfully written in Japanese.
This is a JHU document!!! Go Hopkins!
================================= Good Bye! =================================
```

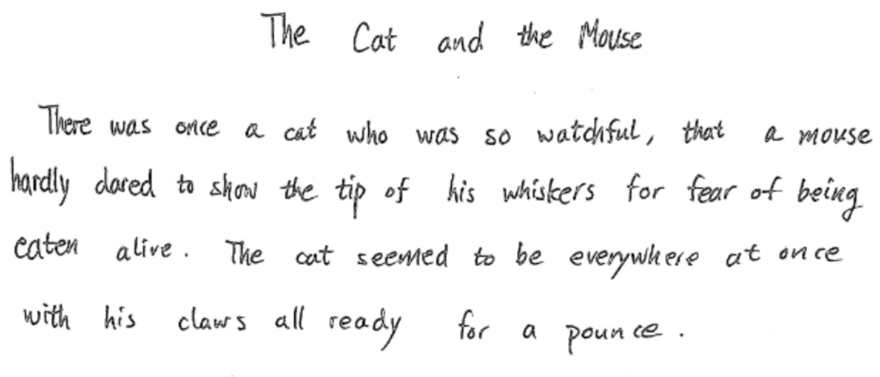
Command line argument and standard out.



The Cat and the Mouse

There was once a cat who was so watchful, that a mouse
hardly dored to show the tip of his whiskers for fear of being
eaten alive. The cat seemed to be everywhere at once
with his claws all ready for a pounce.

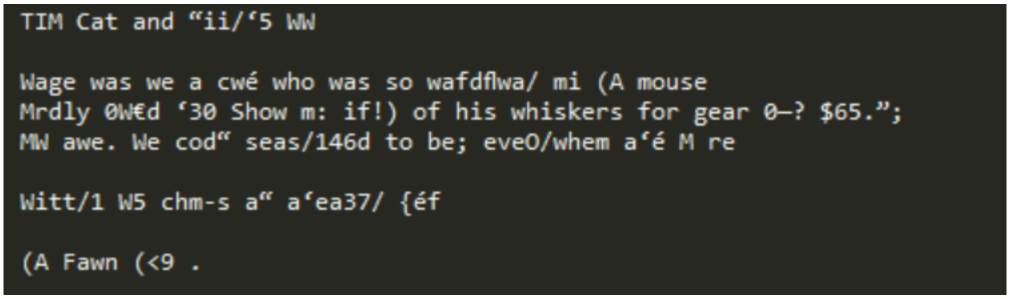
Original input image `hand_cat.png`, unprocessed.



The Cat and the Mouse

There was once a cat who was so watchful, that a mouse
hardly dored to show the tip of his whiskers for fear of being
eaten alive. The cat seemed to be everywhere at once
with his claws all ready for a pounce.

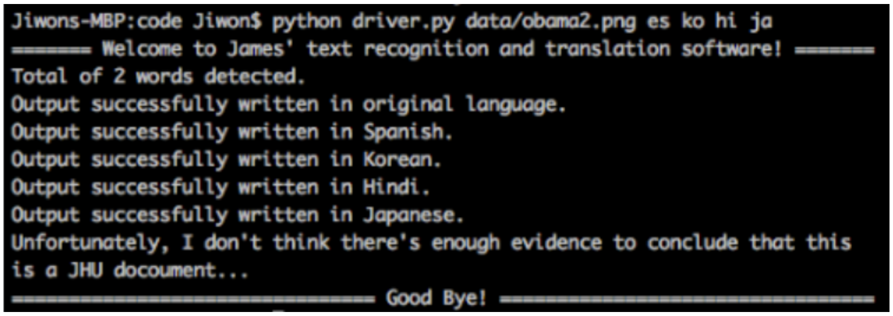
Thresholded input image `hand_cat_thresh.png`.



```
TIM Cat and “ii/‘5 WW

Wage was we a cwé who was so wafdflwa/ mi (A mouse
Mrdly 0W€d ‘30 Show m: if!) of his whiskers for gear 0—? $65.”;
MW awe. We cod“ seas/146d to be; eveO/whem a‘é M re

Witt/1 W5 chm-s a“ a‘ea37/ {éf

(A Fawn (<9 .
```

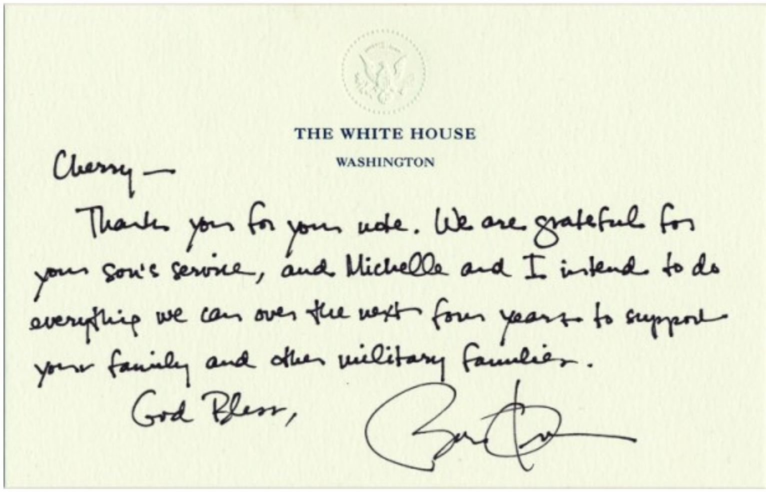
Text output in English. (`hand_cat_output.txt`)

3. Image 3: `obama2.png`



```
Jiwons-MBP:code Jiwon$ python driver.py data/obama2.png es ko hi ja
======= Welcome to James' text recognition and translation software! =======
Total of 2 words detected.
Output successfully written in original language.
Output successfully written in Spanish.
Output successfully written in Korean.
Output successfully written in Hindi.
Output successfully written in Japanese.
Unfortunately, I don't think there's enough evidence to conclude that this
is a JHU docoument...
================================= Good Bye! =================================
```

Command line argument and standard out.



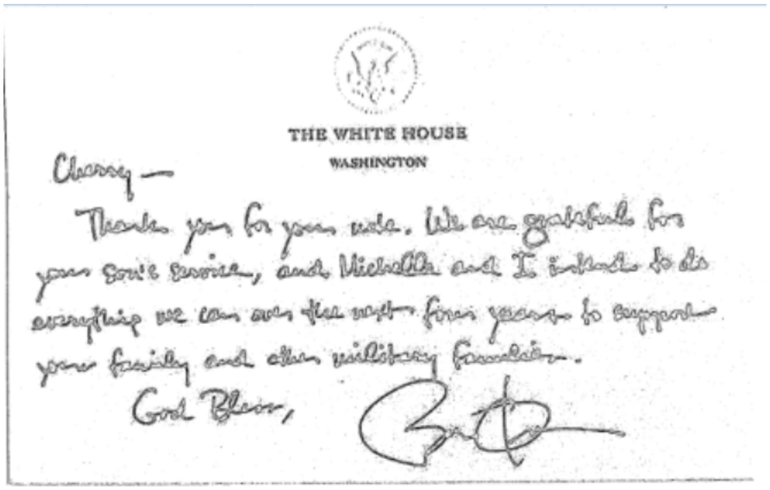
THE WHITE HOUSE
WASHINGTON

Cherry —

Thank you for your note. We are grateful for your son's service, and Michelle and I intend to do everything we can over the next four years to support your family and other military families.

God Bless,

Original input image `obama2.png`, unprocessed.



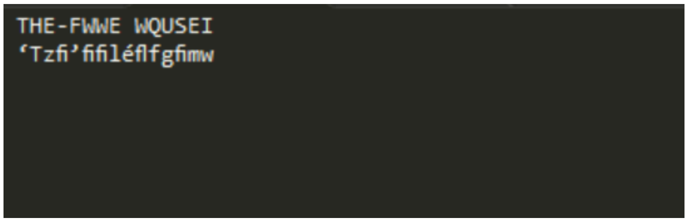
THE WHITE HOUSE
WASHINGTON

Cherry —

Thank you for your note. We are grateful for your son's service, and Michelle and I intend to do everything we can over the next four years to support your family and other military families.

God Bless,

Thresholded input image `obama2_thresh.png`.



```
THE-FWWE WQUSEI
‘Tzﬁ’ﬁﬁléﬂfgﬁmw
```

Text output in English. (`obama2_output.txt`)