Preprocessing and Layout Analysis for Offline Handwriting Recognition

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Overview

- Handwriting recognition
- Preprocessing
  - Stroke Width Analysis
- Layout Analysis
  - Bounding Box Expansion
  - RLSA
- Tests
- Test Results
- Conclusions
- Remaining Problems
- Future Work
- Questions and Answers

Handwriting recognition 1

- Offline handwriting recognition (HWR) is the process of extracting text in digital form from handwritten images.
- Offline recognition process can be divided into three main phases:
  - Preprocessing
  - Feature extraction
  - Classification
- Implementation done with MATLAB and its image processing toolbox

Handwriting recognition 2

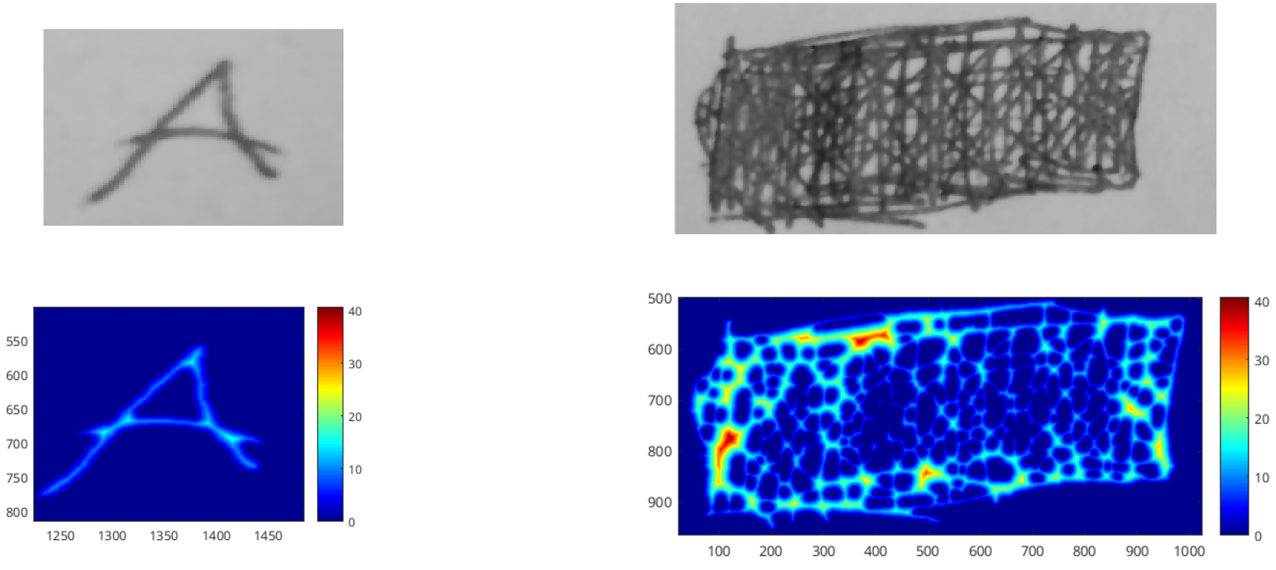
- Preprocessing
  - Image is enhanced for feature extraction phase and the detected characters are segmented from the original image.
  - Layout analysis can be considered to be a part of preprocessing.
- Feature Extraction
  - Shape describing features are extracted from previously acquired objects (words).
- Classification
  - Extracted features are used in machine learning algorithms to create the feature vector and to classify the inputs into word classes.

Preprocessing

- Most of the preprocessing is same than previously
  - Image aquisition
  - Noise removal
    - Adaptive Wiener filter
  - Binarization
    - Sauvola algorithm
  - Object property analysis
    - ~~Features such as holes in object, size, area or aspect ratio~~
    - Stroke width variation
- All methods need pre-defined parameters!
- Object property analysis now uses sroke width instead of other features.
- Majority of methods proved to be useful in preprocessing.

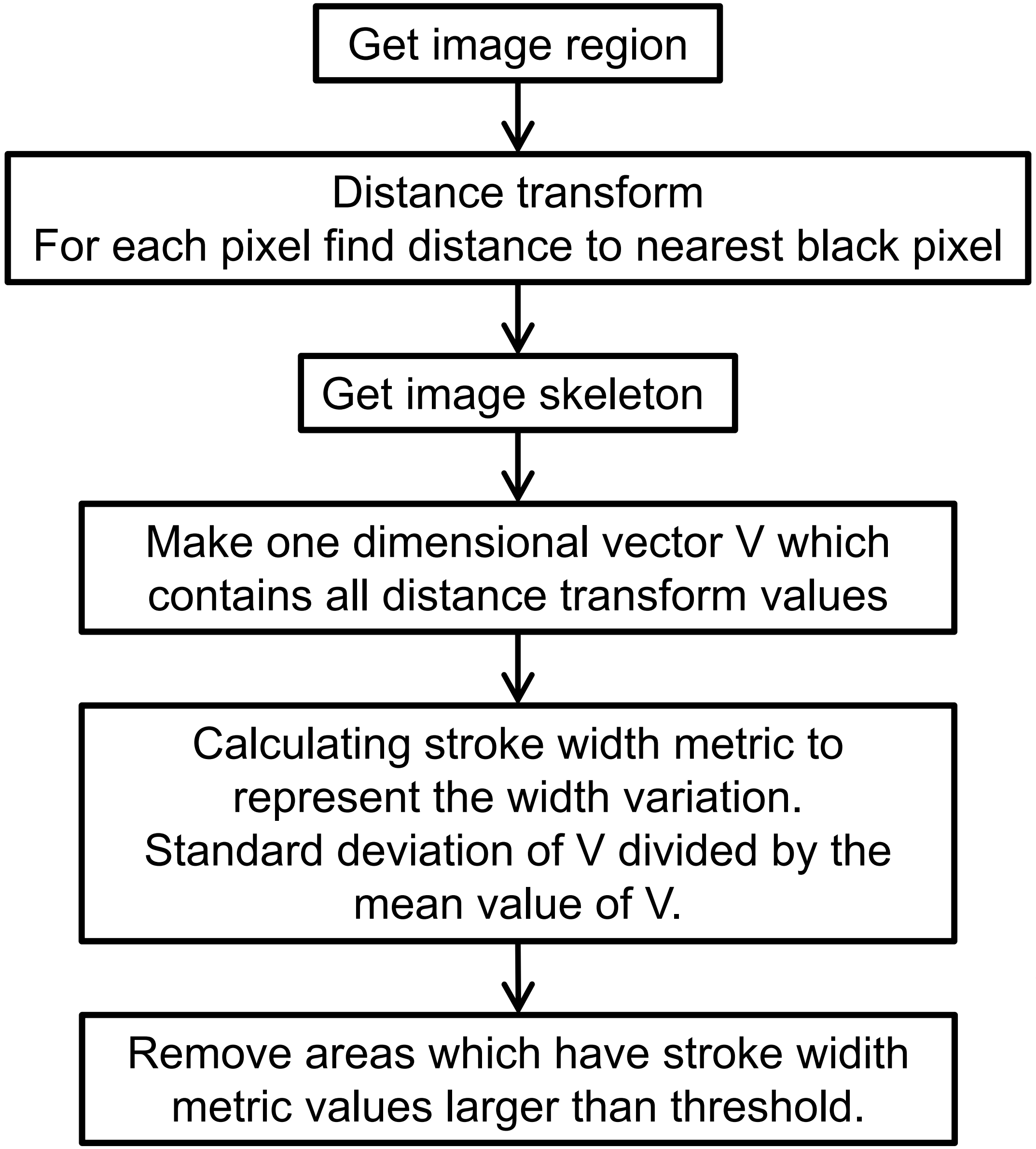
Stroke Width Analysis 1

- One distinctive feature of text is that it consists of ”strokes”.
- Strokes have only a little variation in thickness.
- Other objects such as images can have lot of variation in thickness.
- The amount of variation can be used to distinquish text from other objects.



Dark blue represents thin stroke width and dark red thick strokes.

Stroke Width Analysis 2



Get image region

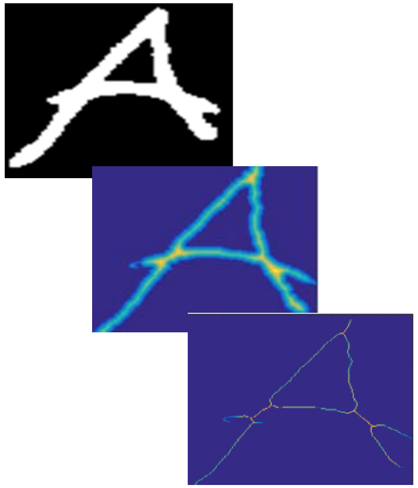
Distance transform
For each pixel find distance to nearest black pixel

Get image skeleton

Make one dimensional vector V which contains all distance transform values

Calculating stroke width metric to represent the width variation.
Standard deviation of V divided by the mean value of V.

Remove areas which have stroke widith metric values larger than threshold.

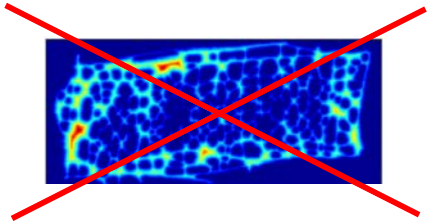


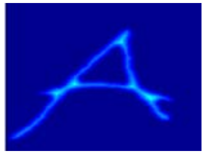
V = [6.403, 8.5440, 6.4031, 8.0623, 5.6569, 7.2801,...]

$$\frac{\sigma}{\bar{V}} = 0.2360$$

$\sigma = standard\ deviation\ of\ vector\ V$

$\bar{V} = mean\ of\ vector\ V$

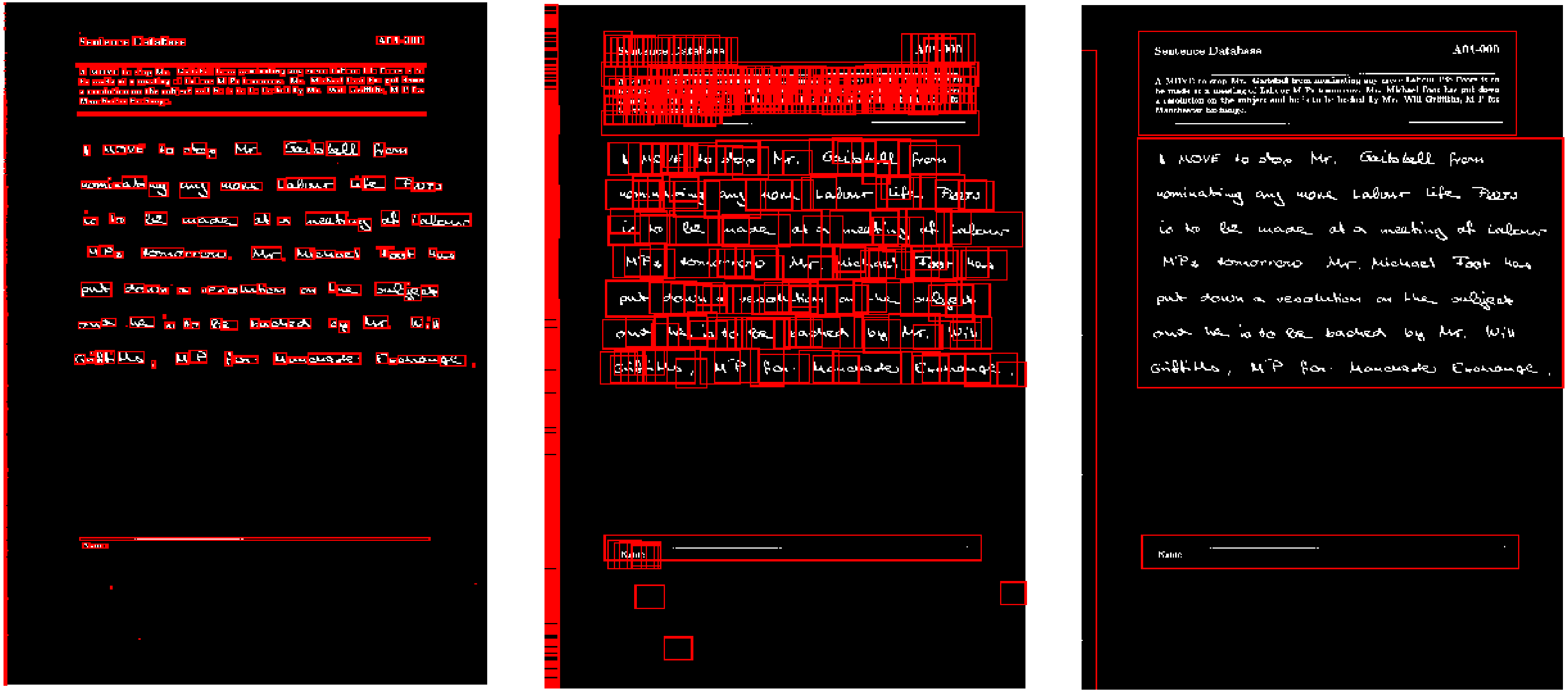




Layout Analysis

- Analysing the image regions to find where the text is located and what kind of bodies of text it contains.
- Columns, rows, words.
- Proposed method to find the areas of interest is to draw bounding boxes over the text objects, expand them in all directions and combine overlapping boxes.
- Layout is saved hierarchically into areas of interest, rows and words.

Bounding box expansion


Sentence Database
A01-000
I MOVE to stop Mr. Gaitskell from
nominating any more Labour life Peers
is to be made at a meeting of Labour
MPs tomorrow Mr. Michael Foot has
put down a resolution on the subject
and he is to be backed by Mr. Will
Griffiths, MP for Manchester Exchange.
Name:

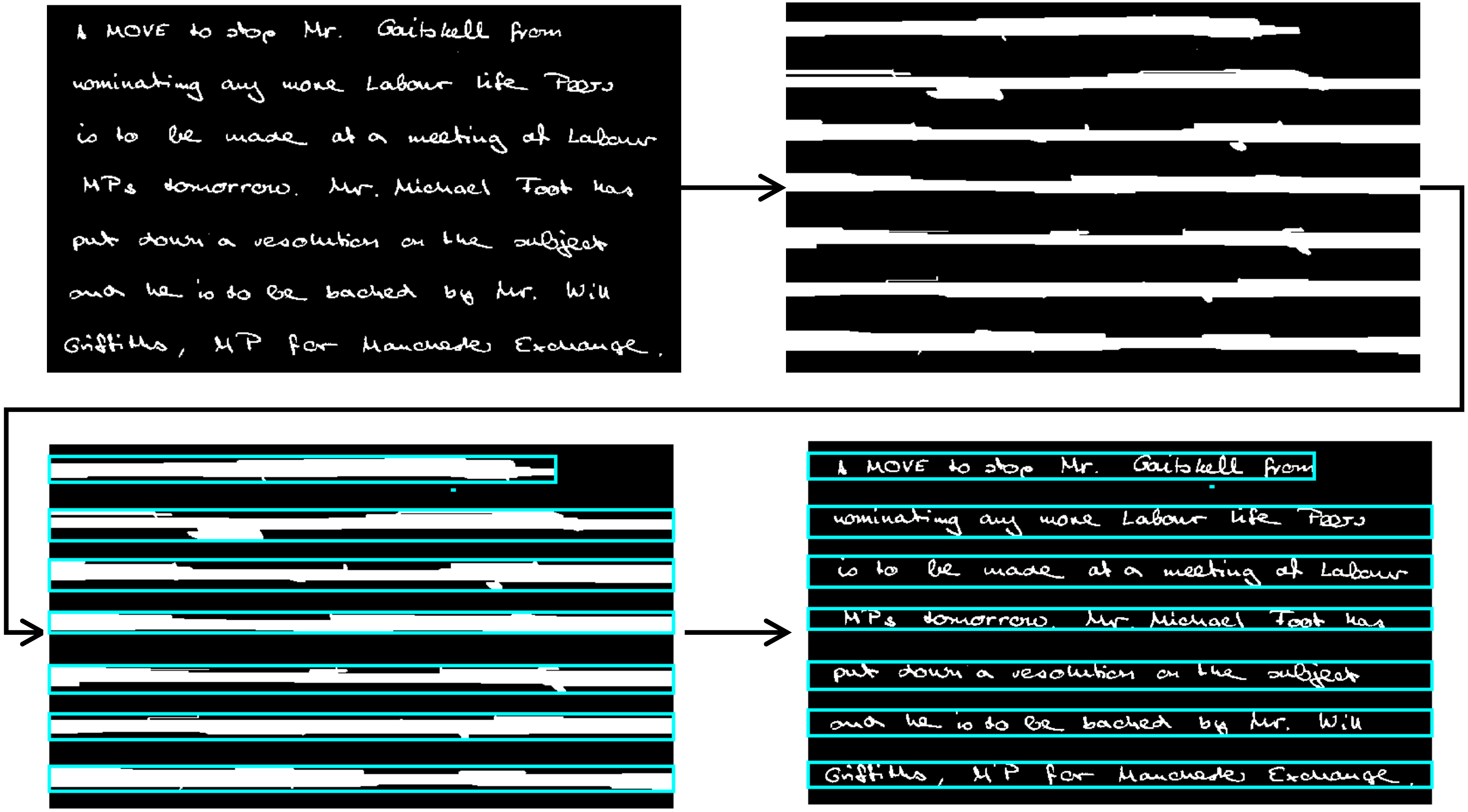
In the last phase boxes that take only a small fraction of the total area are removed.

□ = Area of interest box

Layout Analysis 2

- To find rows of text the run length smearing algorithm is used.
- The RLSA finds rows of black pixels and changes them to white if their lengths are under given threshold.
- The bounding box is aquired for each object generated by RLSA. These bounding boxes represent the rows.
- The same method is used to find individual words within rows. For words the RLSA is executed also vertically. Smaller threshold values are used.

RLSA for rows



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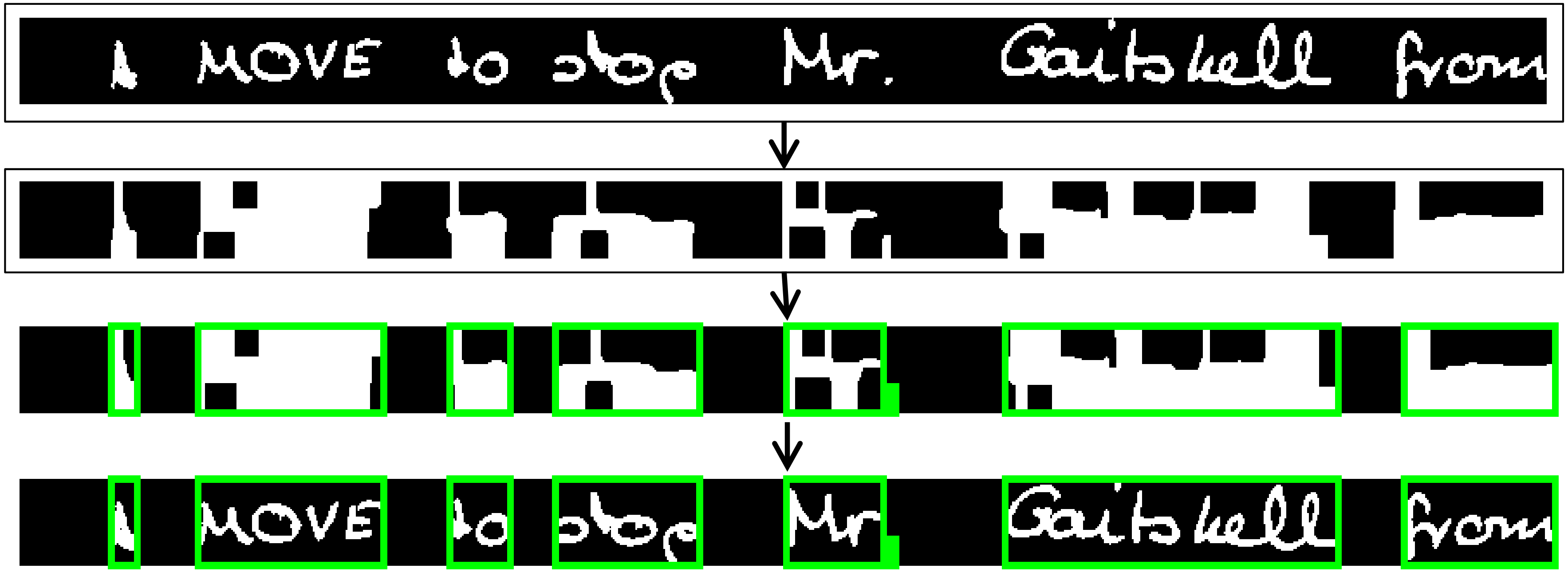
Griffiths, MP for Manchester Exchange.

□ = Row box

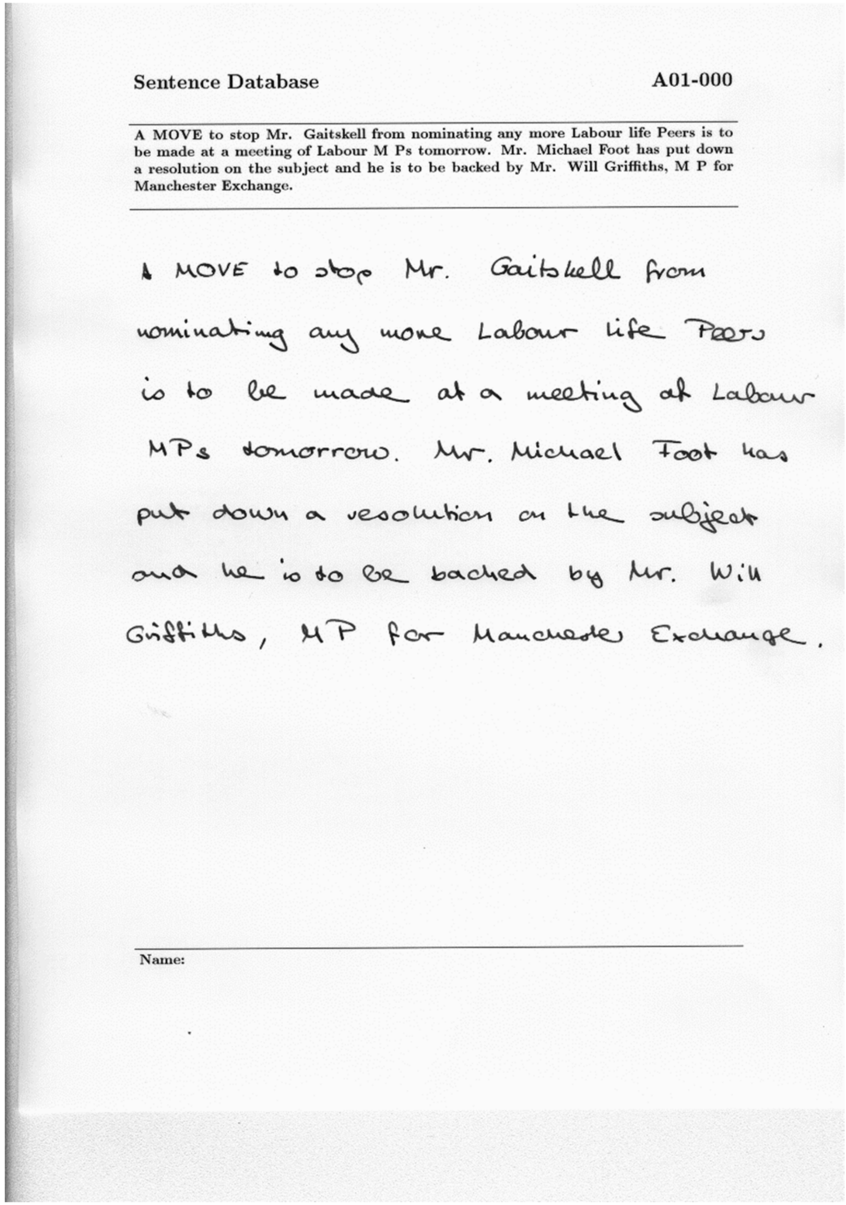
RLSA for words



□ = Word box

Same procedure but this time the algorithm is also run vertically to get dots or other broken characters into word.

Full layout visualized



Sentence Database A01-000

A MOVE to stop Mr. Gaitskell from nominating any more Labour life Peers is to be made at a meeting of Labour M Ps tomorrow. Mr. Michael Foot has put down a resolution on the subject and he is to be backed by Mr. Will Griffiths, M P for Manchester Exchange.

A MOVE to stop Mr. Gaitskell from
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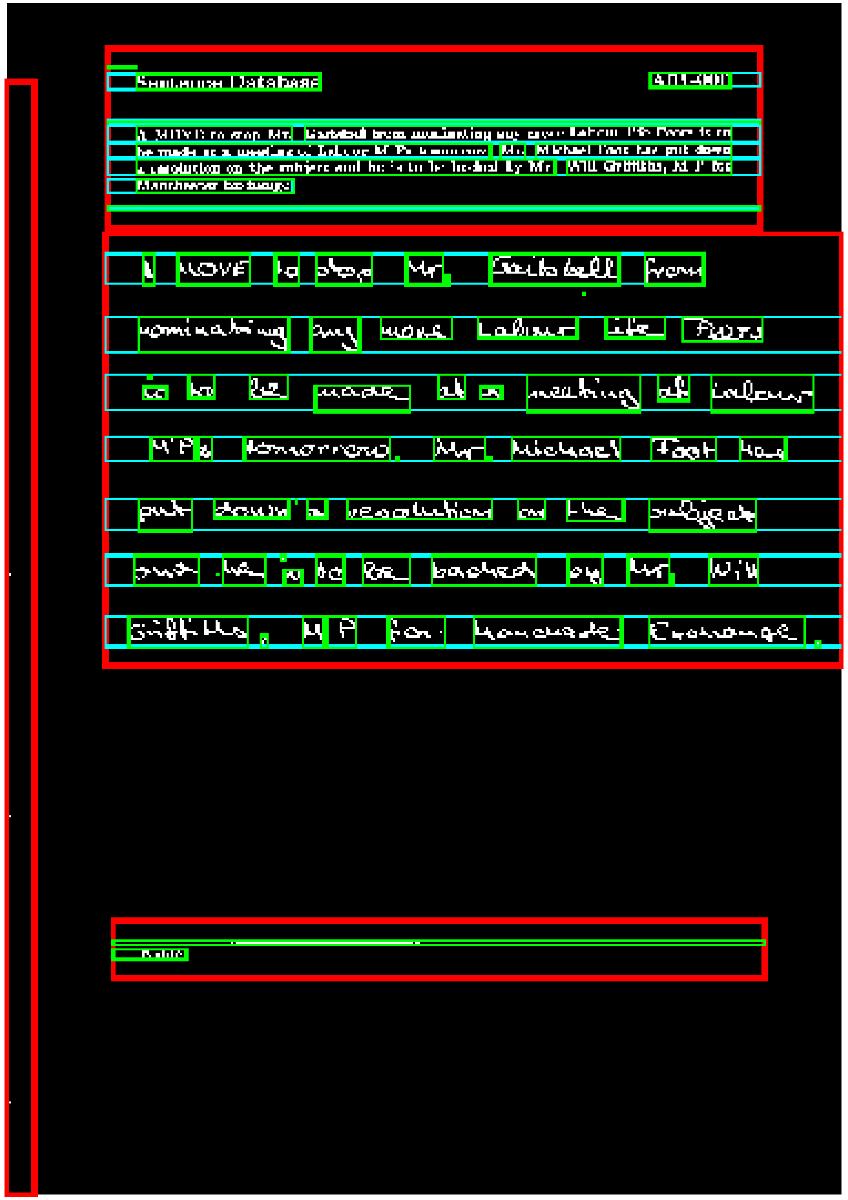
MPs tomorrow. Mr. Michael Foot has
put down a resolution on the subject
and he is to be backed by Mr. Will
Griffiths, MP for Manchester Exchange.

Name:



🟥 = Area of interest box

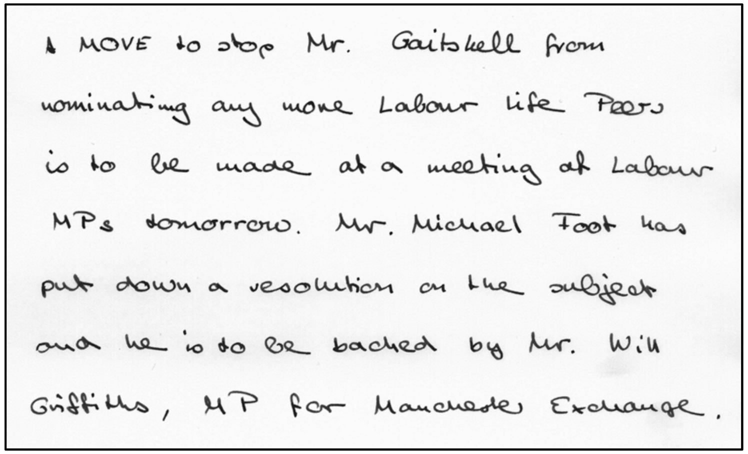
🟦 = Row box

🟩 = Word box

Tests

- The system is still dependant on the parameter values.
- The tests goal is to find the optimal threshold values for IAM database images.
- First the optimal parameter values are found and then the accuracy is tested with these parameters.
- How to evaluate the accuracy of the system mathematically?
  - IAM database contains metadata about the number of rows and words.
  - Compare the real values to those detected by the system.

Example entries in IAM handwriting database.


A MOVE to stop Mr. Gaitskell from
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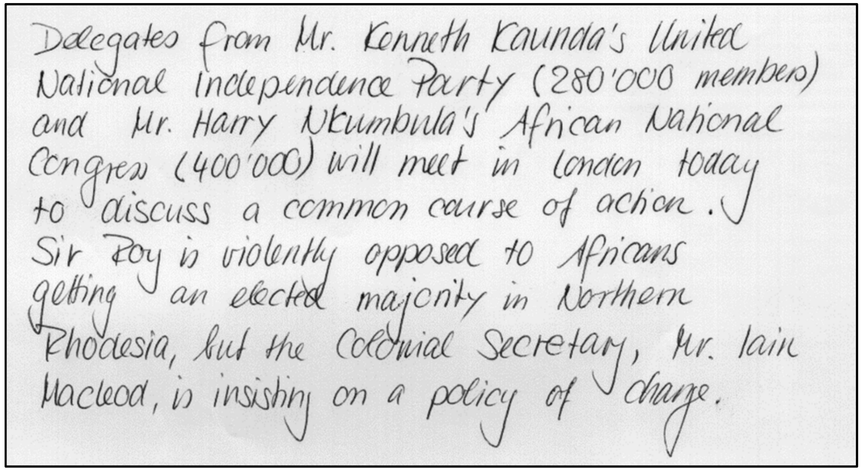
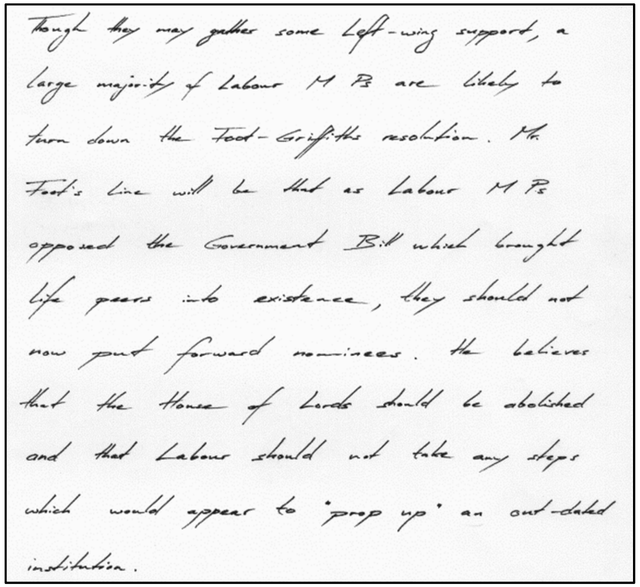
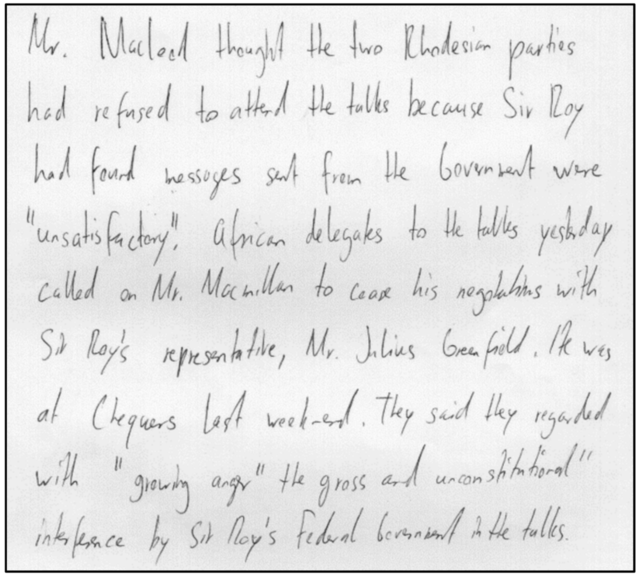
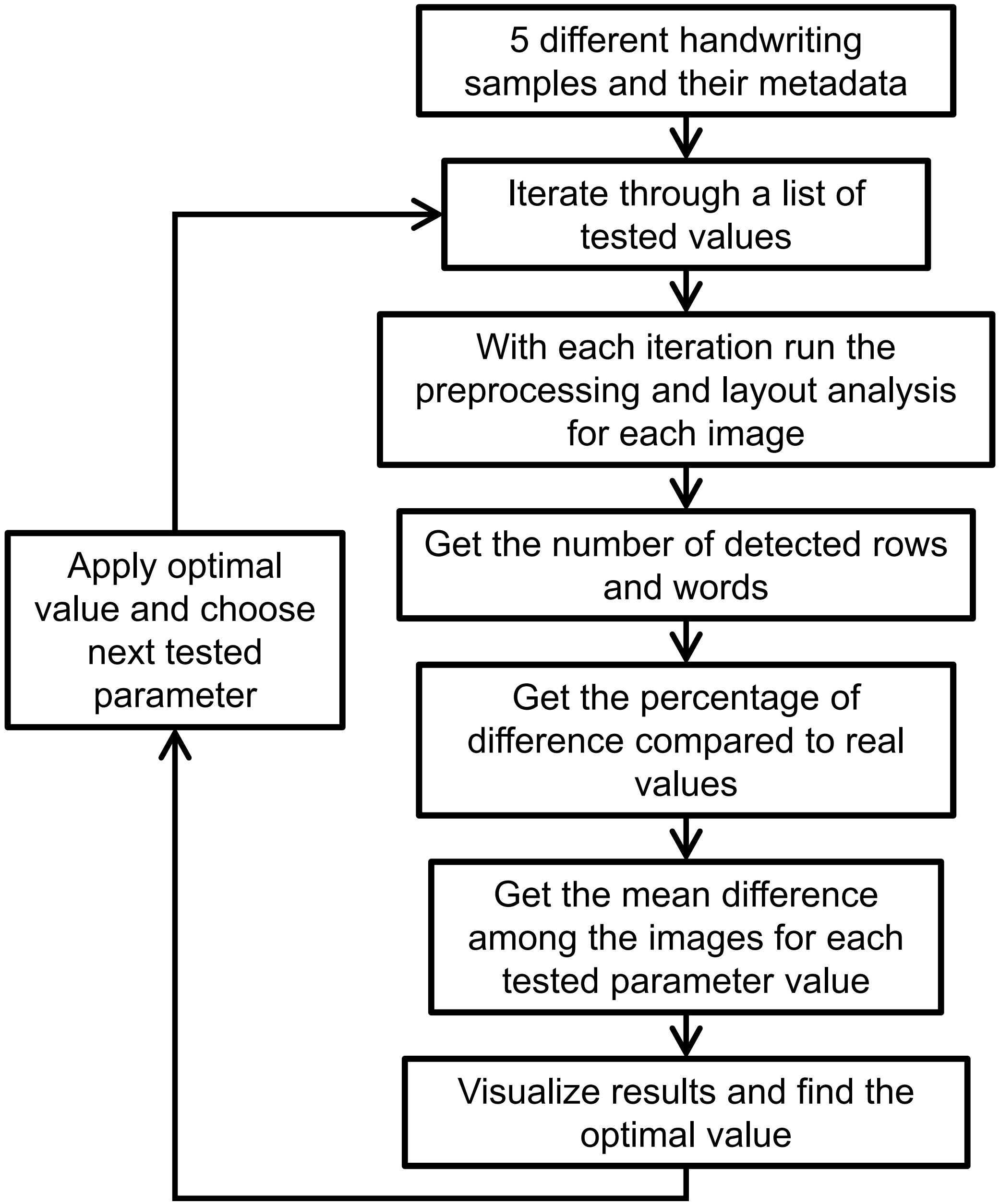

Delegates from Mr. Kenneth Kaunda's United
National Independence Party (280'000 members)
and Mr. Harry Nkumbula's African National
Congress (400'000) will meet in London today
to discuss a common course of action.
Sir Roy is violently opposed to Africans
getting an elected majority in Northern
Rhodesia, but the Colonial Secretary, Mr. Iain
Macleod, is insisting on a policy of change.


Though they may gather some Left-wing support, a
large majority of Labour M Ps are likely to
turn down the Foot-Griffiths resolution. Mr.
Foot's line will be that as Labour M Ps
opposed the Government Bill which brought
life peers into existence, they should not
now put forward nominees. He believes
that the House of Lords should be abolished
and that Labour should not take any steps
which would appear to 'prop up' an out-dated
institution.


Mr. Macleod thought the two Rhodesian parties
had refused to attend the talks because Sir Roy
had found messages sent from the Government were
"unsatisfactory". African delegates to the talks yesterday
called on Mr. Macmillan to cease his negotiations with
Sir Roy's representative, Mr. Julius Greenfield. He was
at Chequers last week-end. They said they regarded
with "growing anger" the gross and unconstitutional"
interference by Sir Roy's Federal Government in the talks.

Only the handwritten part was used during the tests.

Test procedure to find optimal parameters



5 different handwriting samples and their metadata

Iterate through a list of tested values

With each iteration run the preprocessing and layout analysis for each image

Get the number of detected rows and words

Get the percentage of difference compared to real values

Get the mean difference among the images for each tested parameter value

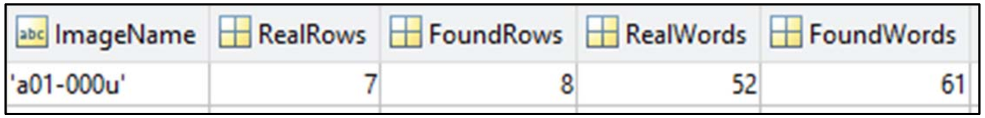
Visualize results and find the optimal value

Apply optimal value and choose next tested parameter

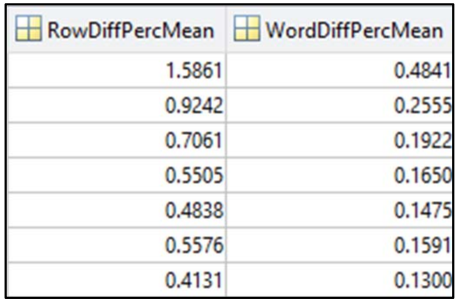
```
numberOfRows = 7
numberOfWords = 52
```

```
testValues = [0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1];
```

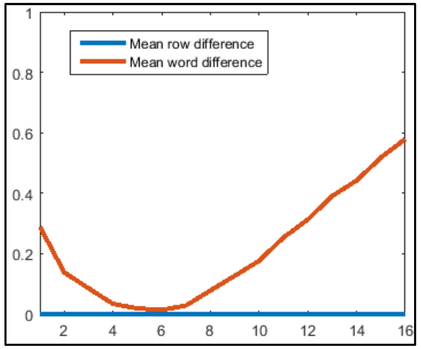
```
for testedValue in testValues:
    for image in images:
        result = preprocess(image,testedValue);
    end
end
```



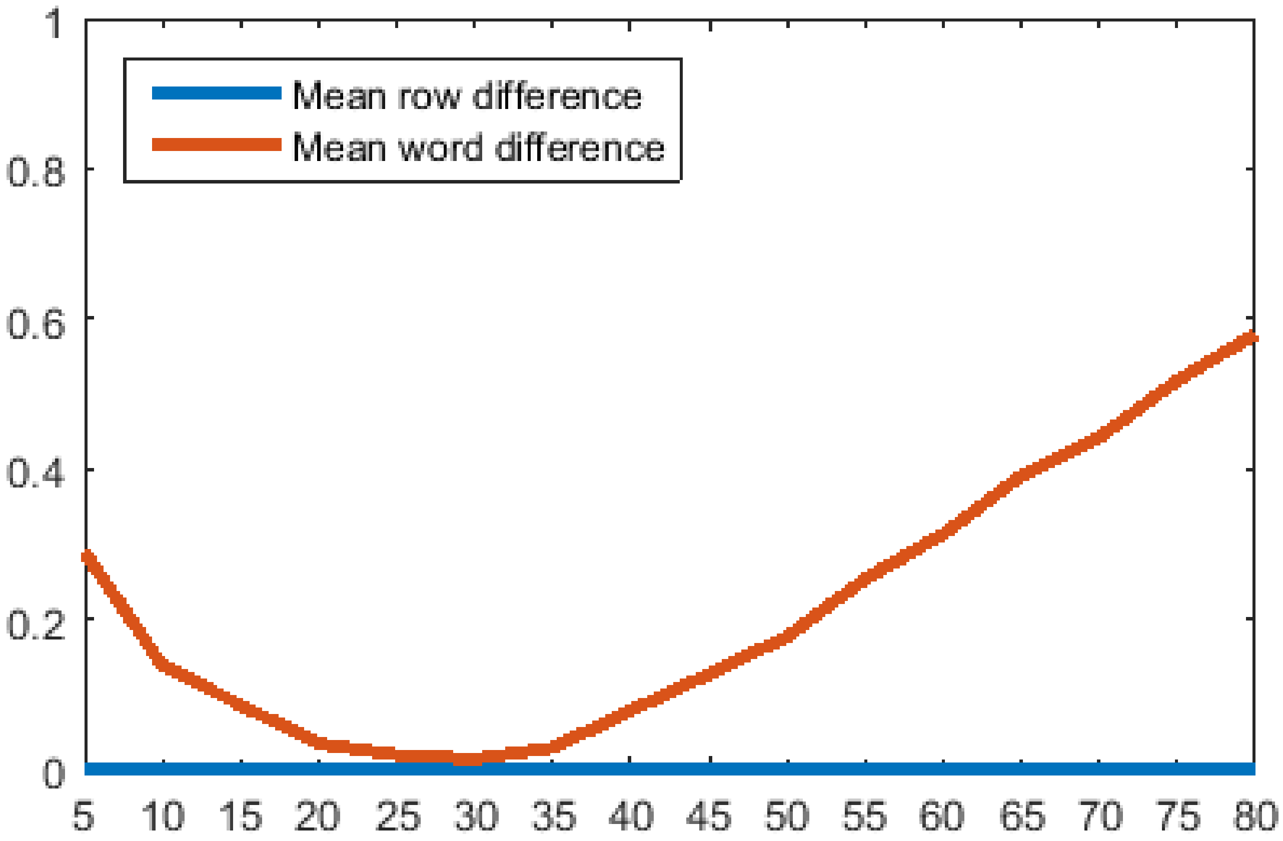
ImageName	RealRows	FoundRows	RealWords	FoundWords
'a01-000u'	7	8	52	61



RowDiffPercMean	WordDiffPercMean
1.5861	0.4841
0.9242	0.2555
0.7061	0.1922
0.5505	0.1650
0.4838	0.1475
0.5576	0.1591
0.4131	0.1300



Example of test data



Result data for RLSA horizontal threshold test.
Lowest difference is aquired with threshold 30.

Test results

Preprocessing parameters:

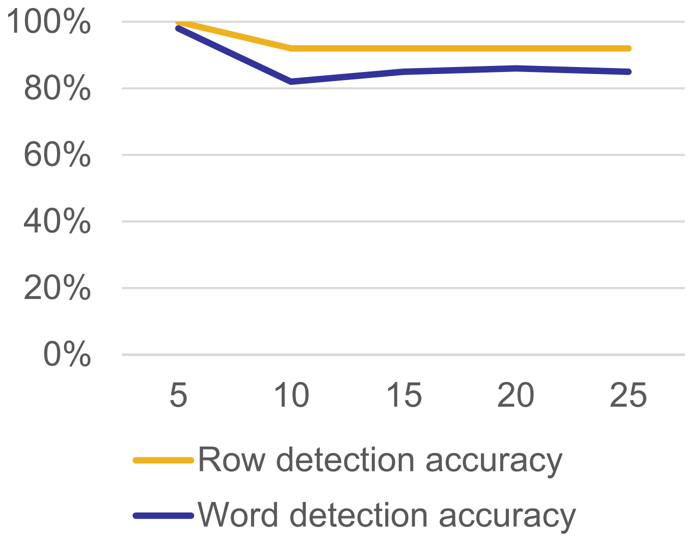
- wienerFilterSize = 15
- sauvolaNeighbourhoodSize = 180
- sauvolaThreshold = 0.3
- strokeWidthThreshold = 0.6

Layout analysis parameters:

- aoiXExpansionAmount = 40
- aoiYExpansionAmount = 60
- rlsaRowThreshold = 300
- rlsaWordHorizontalThreshold = 30
- rlsaWordVerticalThreshold = 30

With above parameters the system achieved following performance:

Number of images	Row detection accuracy	Word detection accuracy
5	100%	98%
10	92%	82%
15	92%	85%
20	92%	86%
25	92%	85%

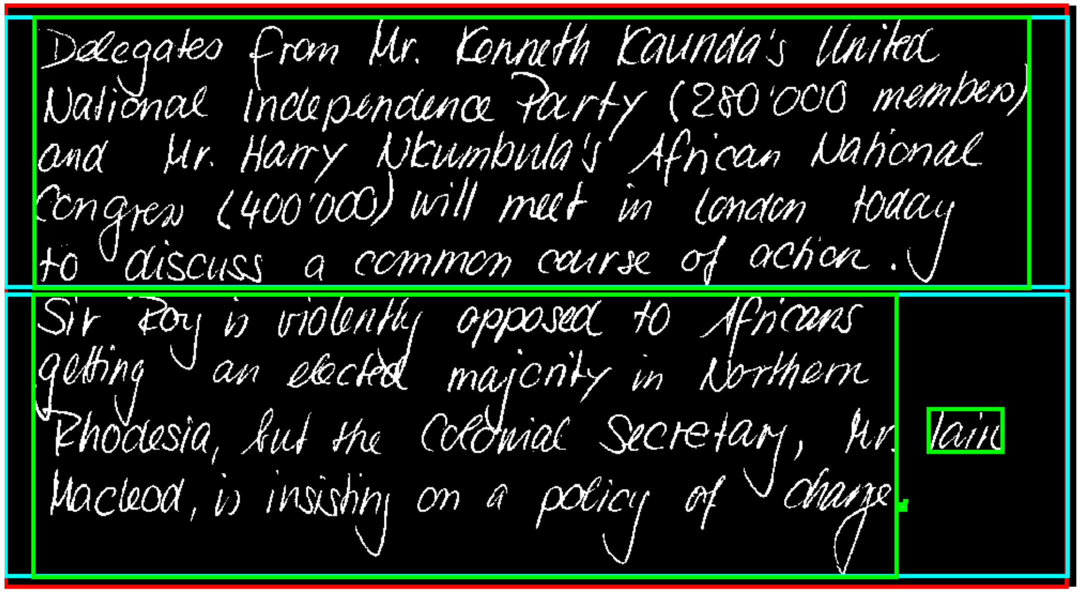


Conclusions

- The chosen methods proved to be useful in preprocessing and layout analysis.
- The tests proved that the chosen parameters work well for IAM database images.
- Word detection is slightly more sensitive about parameter changes than the row detection.

Remaining problems

- The row and word detection isn't perfect
  - If two rows contain overlapping characters those rows are combined as one.
  - For the same reason multiple words can also be combined as one.



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🟥 = Area of interest box

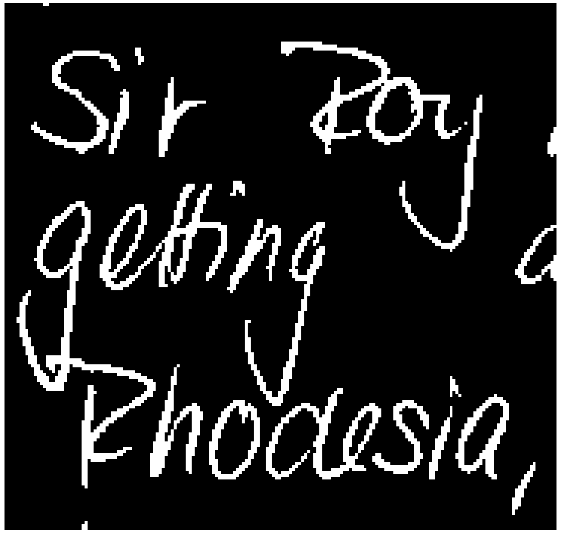
🟦 = Row box

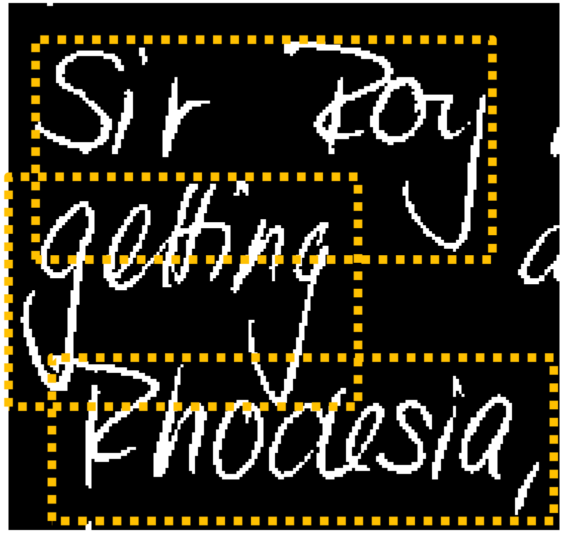
🟩 = Word box

Result: 2 rows and 5 words

Real values: 9 rows and 68 words

Remaining problems: Overlapping characters





⬚ = Real word box (unrealized)

Future work

- Solve the overlapping rows/words problem.
  - Some papers have been published regarding this problem. More research is needed.
- Automatic parameter choosing.
  - Use some mathematical properties such as object area or size to choose appropriate parameter value for some functions.
  - Average object area → RLSA threshold?
- Continue to feature extraction phase.

Questions and Answers 1

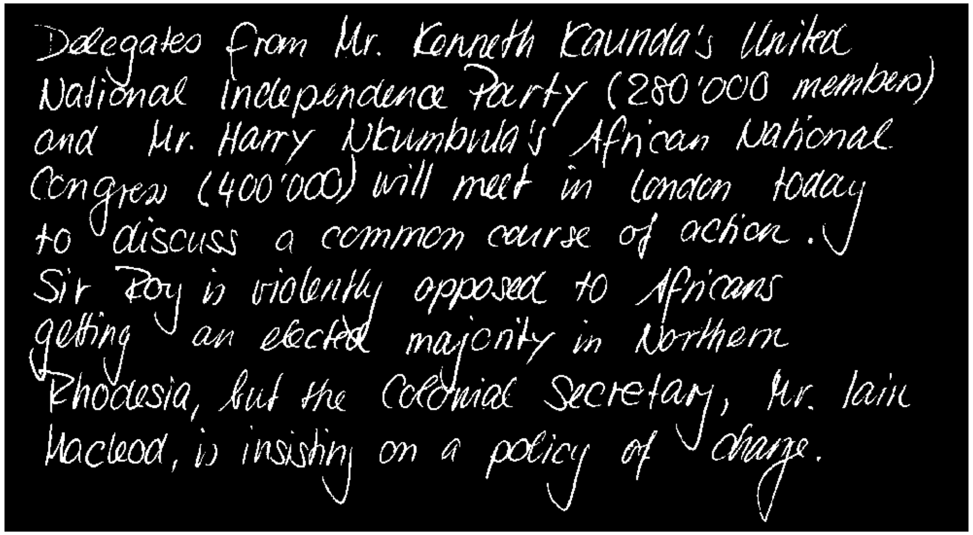
- Presentation time:
  - Presentation: 19:10
  - Questions: 19:40
- Okubo: (p.19) The accuracy of your proposed method is 92%. Is the error occurring only for the picture like in p.19?
  - The error can occur for multiple reasons. One reason is overlapping characters such as in p.19 and p.20 which are then combined into fewer large objects. Other reason can be broken characters/words which can make the word/row count higher than the real values.
- Okubo: (p.16) Please use vector image when you put a figure on the slide from MATLAB to avoid low resolution.
  - I will remember this for the next presentation.

Questions and Answers 2

- Kenya: You used the thickness information for text detection. Is the method better than your previous method? What is better than previous method? Accuracy or processing time? Comparing between the methods may show us interesting result.
  - I chose the thickness method because the previous methods based on area, aspect ratio, number of holes etc. were highly dependent on various parameters and were sensitive to change. The new method, on the other hand, only needs one threshold value and is more robust with varying text size. Mainly the motivation was to reduce the amount constant parameters in the system. I didn’t compare the processing time at this point nor did I made any other accuracy tests between these two approaches. I concede that it would have been appropriate to compare these two approaches before choosing one or another.

Questions and Answers 3

- Konta: (p.19) Can you show the result of RSLA?
  - I did not have the image at the time of presentation. Here it is now.



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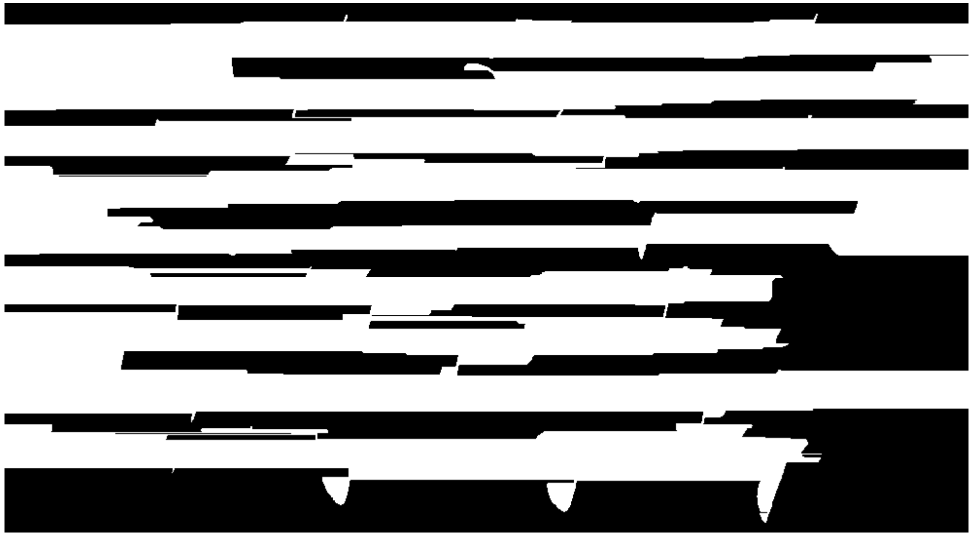

Questions and Answers 4

- Konta: How about detecting a long black line existing on the horizontal direction? This line could be the line that is dividing the row of the text and useful for avoiding the row box miss detection.
  - (Note: I must have misunderstood this question at the time of presentation) The suggestion would be one good method to detect rows. I need to put more research into the subject of overlapping characters and some papers have been published considering this subject.

Questions and Answers 5

- Sone: How is the accuracy defined? For example, how do you calculate the accuracy in following condition?

  1. RealRow = 7, FoundRow = 8
  2. RealRow = 7, FoundRow = 6

  - $d = \frac{|r-f|}{r}$ $\quad d = difference\ percentage,$

    $r = amount\ of\ real\ rows,$

    $f = amount\ of\ found\ rows$
  - $\frac{|7-8|}{7} = \frac{|7-6|}{7} \approx 0.1428$

- Sone: (p.17) What is the number of images? Are these images random and different?
  - Number of tested images is 25. The images have multiple different handwriting styles and texts. (All texts doesn't have different writers) There is quite lot of variation between the styles. The images were chosen randomly for the tests. The IAM handwriting database contains 1539 pages of text by 657 different writers. These images provide good amount of variation for future tests.

Questions and Answers 6

- Kawamata: The presentation was much better than previous time because you discussed a lot about the existing problem in your method.
- Kawamata: What is the meaning of RSLA?
  - Run Length Smearing Algorithm (see p.9)
- Kawamata: (p.6) What is the meaning of $\frac{\sigma}{\overline{V}}$?
  - This is the stroke width variation metric. Standard deviation of stroke width divided by the mean value of stroke width. The value is used to describe how much the width of the given object varies. Small number means low amount of variation, high number means high variation. The high variation objects are then removed if they exceed the pre defined threshold.
- Kawamata: Could you try to speak in Japanese? It is OK if it is only in few minutes.
  - Sure, next time I’ll try to speak a few minutes in Japanese.