

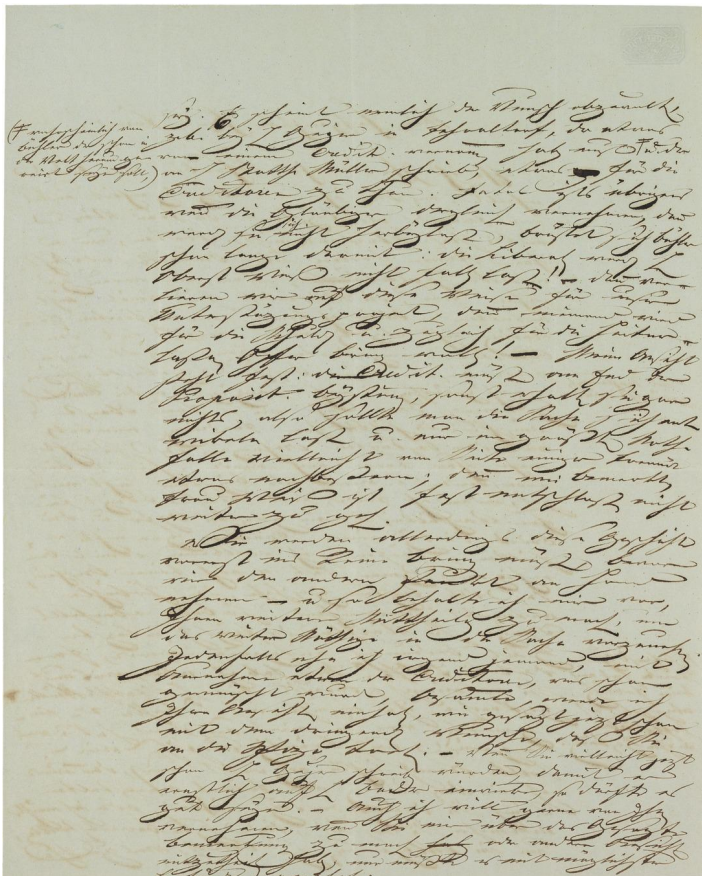
End-to-end, Full Page, Handwriting Recognition

Curtis Wigington, Brian Davis, Chris Tensmeyer, Bill
Barrett

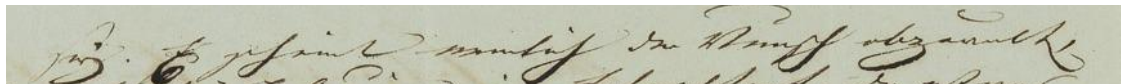
End-to-end, Full Page, Handwriting Recognition

1. Prior work and why assumptions they make are invalid.
2. Handwriting Recognition Method
3. Training Process
4. Results

Full Page Handwriting Recognition



1. Line Segmentation



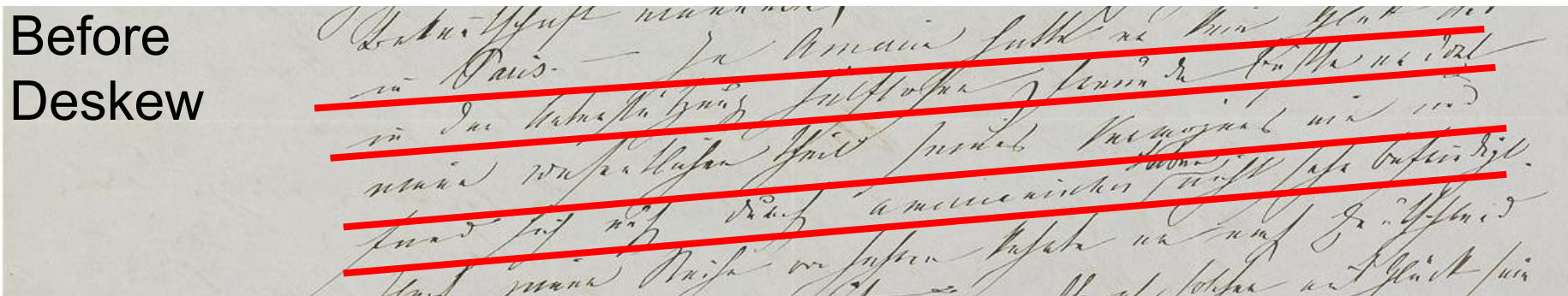
2. Recognition



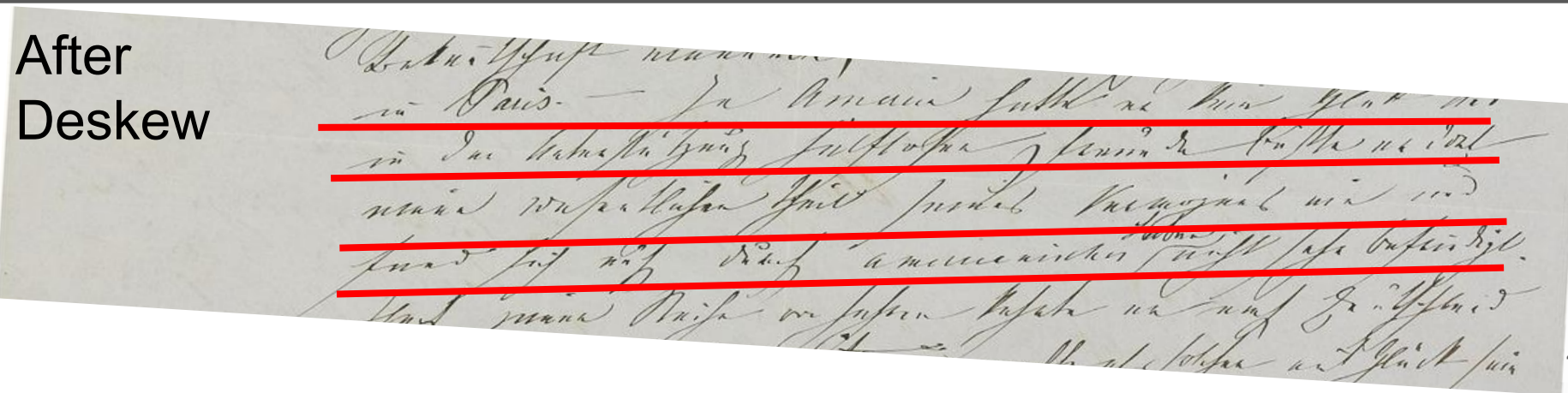
sey. Es scheint nemlich der Wunsch obzuwalten,

Line Segmentation - Deskewing

Before
Deskew

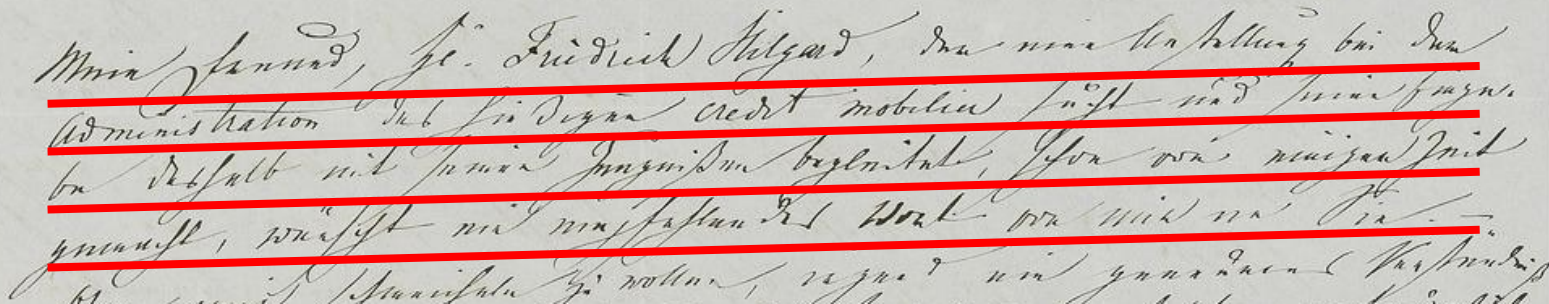


After
Deskew



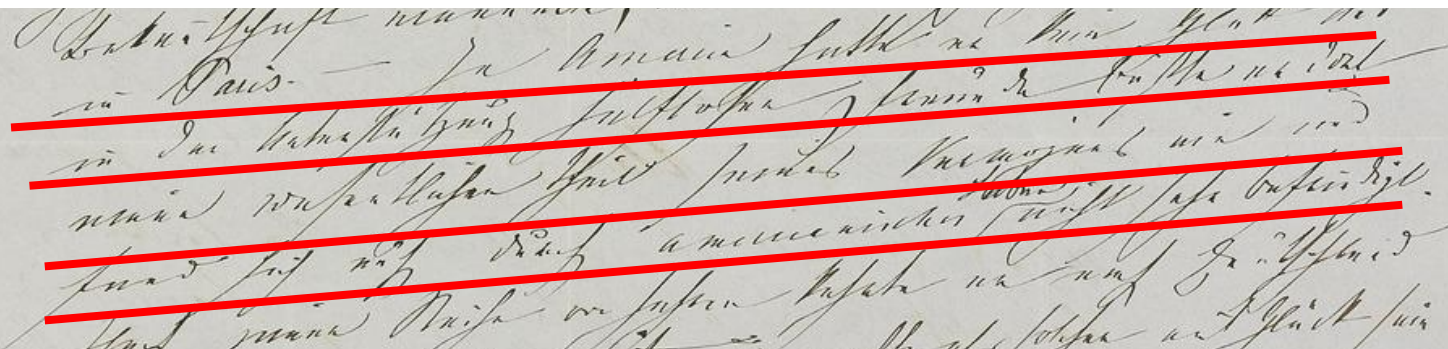
Line Segmentation - Deskewing

Top of
Page



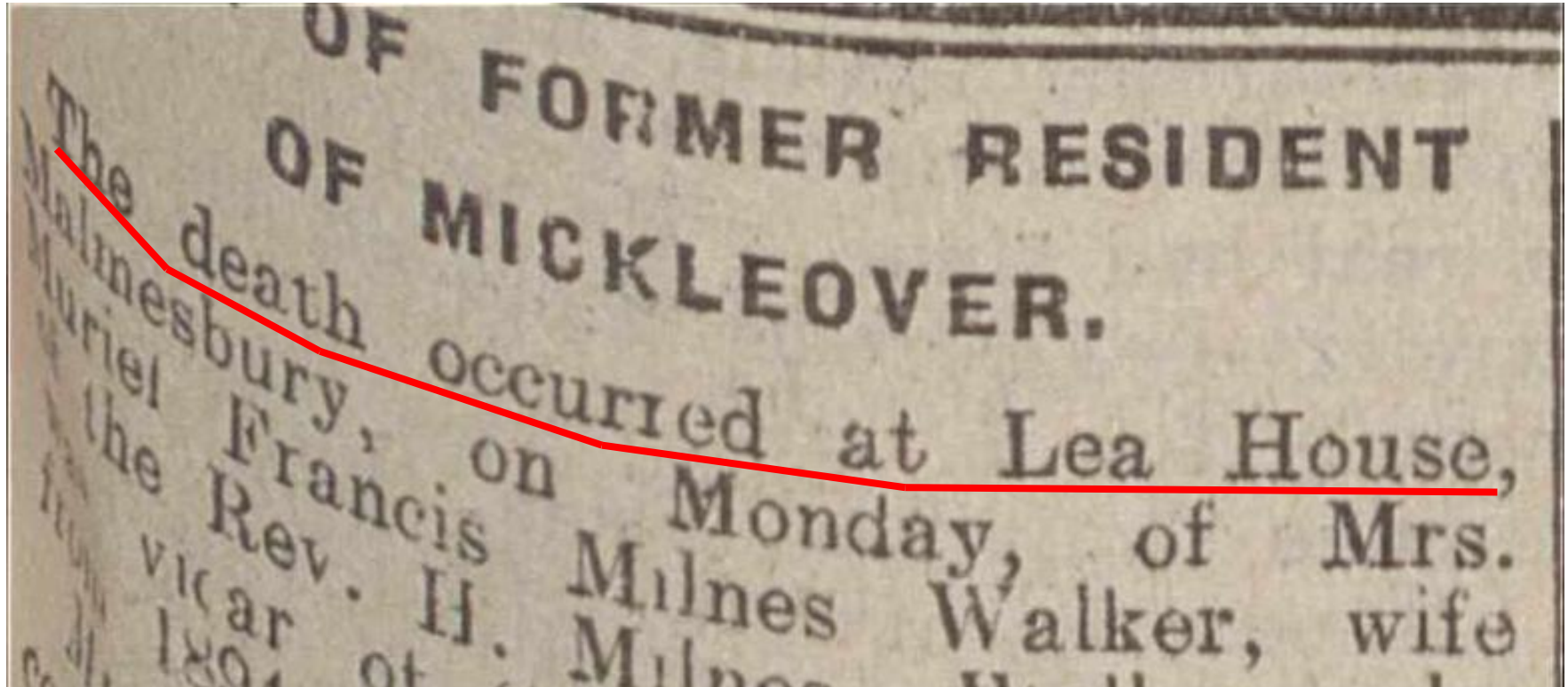
Maria Johann, Ge. Friedrich Hilgard, da meine Anstellung bei der
Administration des für die Credit mobilien fürst sind meine Aufgaben
bezüglich mit meine Jugendzeit begeben, von der meine Jugendzeit
genügend, weißt mir meine Aufgaben der Welt von mir in der
da meine Aufgaben zu wollen, regnet mir meine Aufgaben der Welt

Bottom of
Page



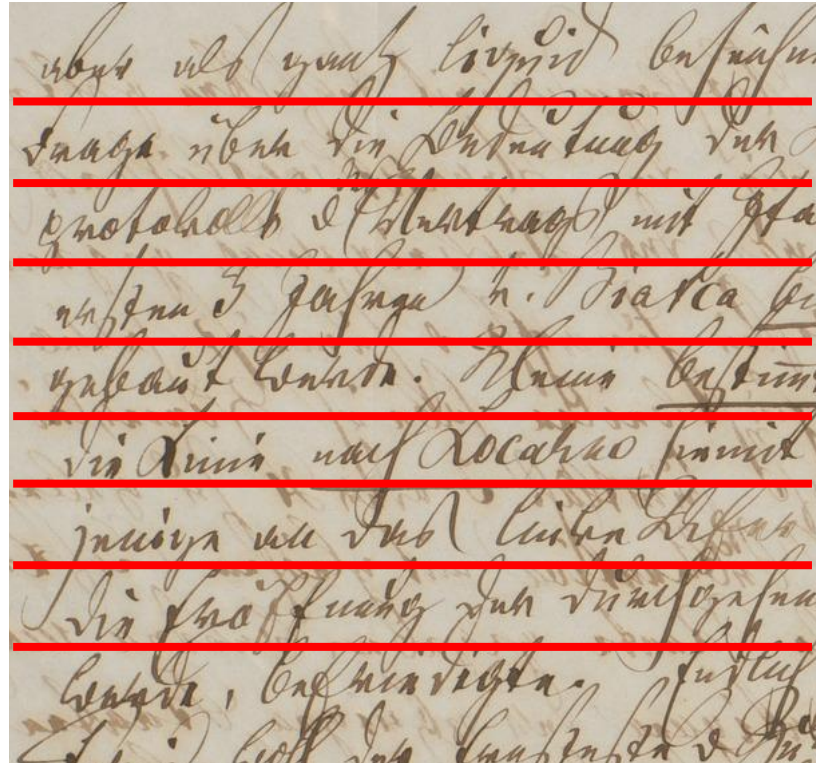
Wiederholung meiner
in Paris. Ja meine Aufgabe bei der Welt
in der Welt meine Aufgaben der Welt
meine Aufgaben der Welt meine Aufgaben der Welt
meine Aufgaben der Welt meine Aufgaben der Welt
meine Aufgaben der Welt meine Aufgaben der Welt

Line Segmentation - Deskewing



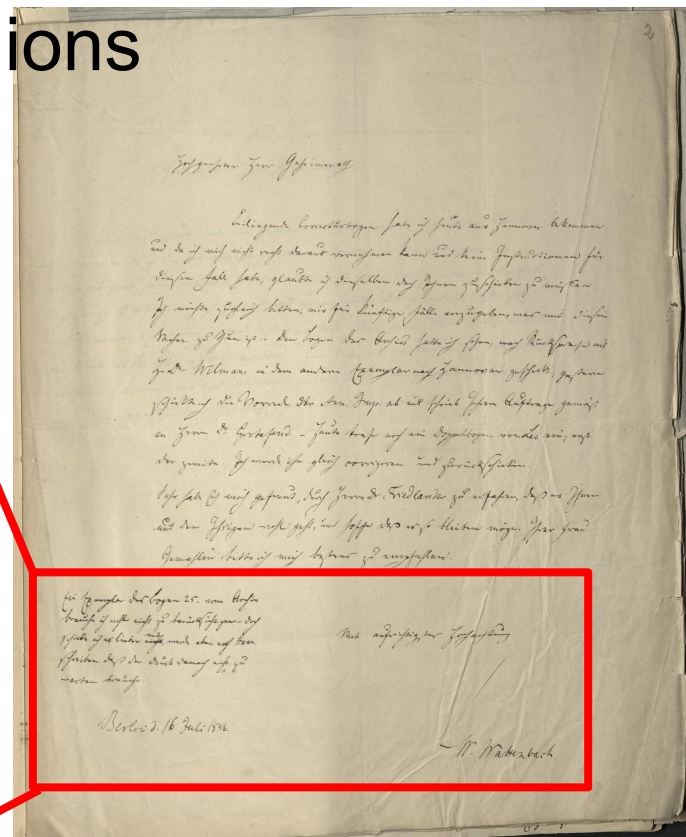
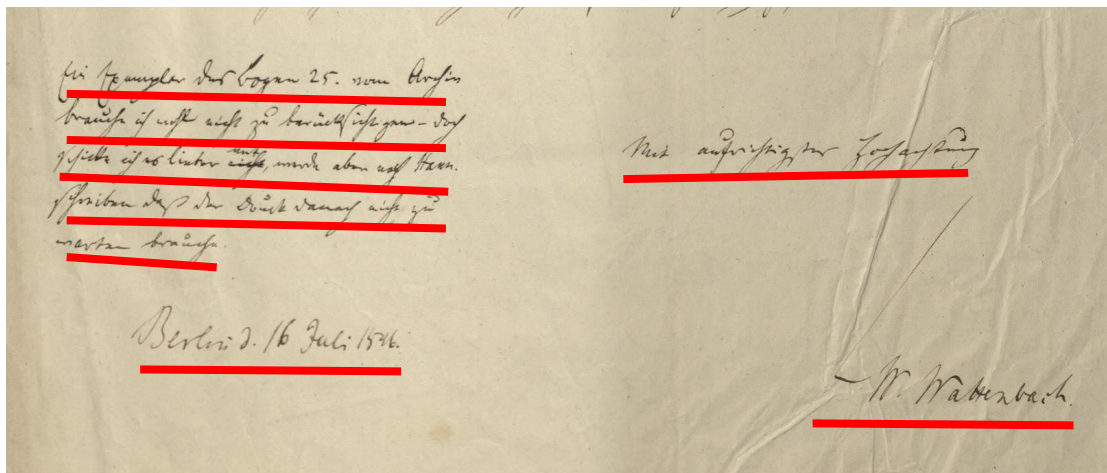
Line Segmentation - Multiple Regions

Northern Rhodesia is a member of the Federation. Mr. Macleod was not at the week-end meeting. But he told OM B yesterday: "I have no knowledge of secret negotiations." He said Britain had an obligation to consult the Federal Government. Mr. James Callaghan, Labour's Colonial spokesman, said Sir Roy had no right to delay progress in the talks by refusing to sit round the conference table.



The image shows a sample of handwritten text in a cursive script, overlaid with horizontal red lines for segmentation. The text is written in a dark ink on a light-colored background. The lines are evenly spaced and extend across the width of the text, illustrating how a single line of text can be segmented into multiple regions.

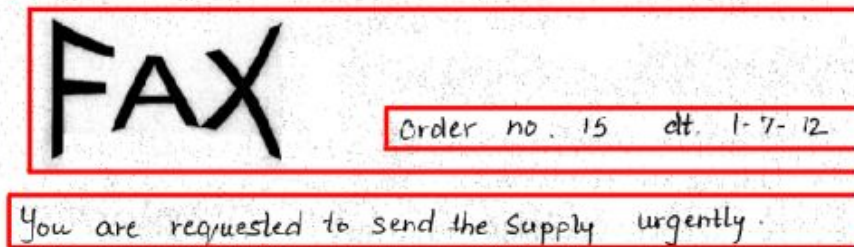
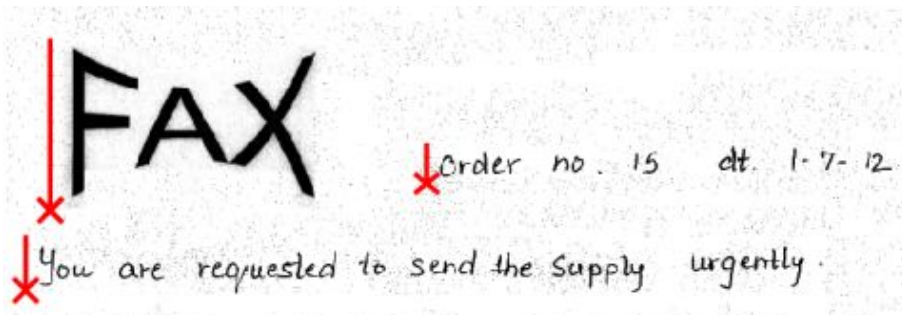
Line Segmentation - Multiple Regions



Full Page Recognition

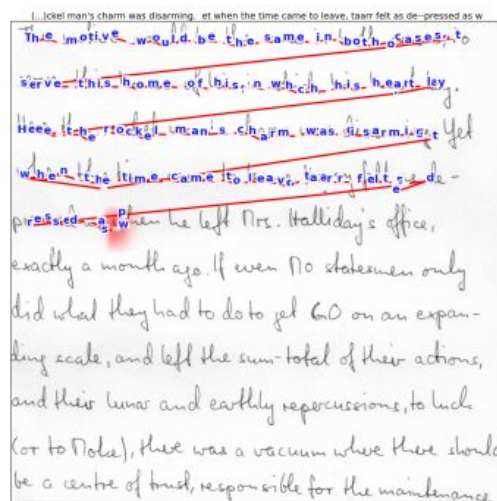
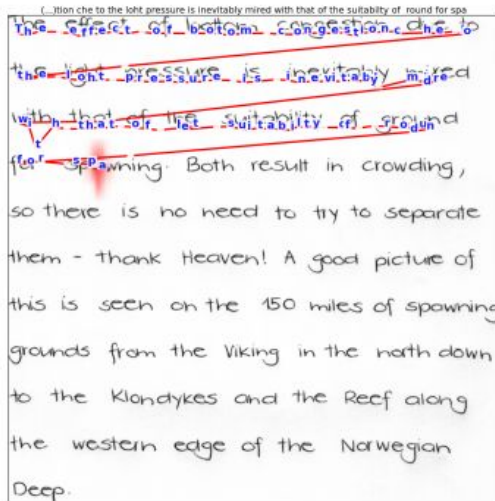
- Two part system: Start of line finder and handwriting recognizer.
- Does not consider rotation or skew.
- Requires start of line training data

Moysset et al., Full-Page Text Recognition: Learning Where to Start and When to Stop.



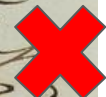
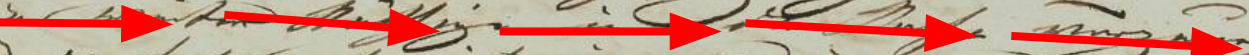
Full Page Recognition - MDLSTM Attention

- Attention by character or line
- Character level: “the presented system is very slow due to the computation of attention for each character in turn.”
- Line level: Recognition is fast, but assumes lines span entire width.



Proposed Solution

1. Start of line finder



2. Line follower

3. Handwriting Recognition:
sey. Es scheint nemlich der Wunsch obzuwalten,

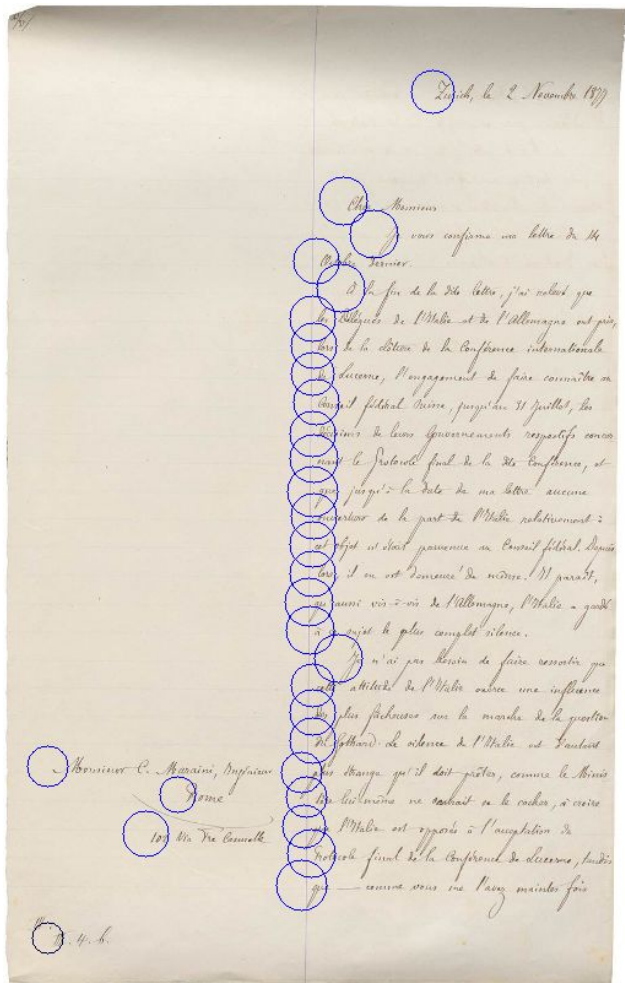
Handwritten text in German script, likely a letter or document. The text is partially obscured by red annotations. A red circle highlights a word, and several red arrows point from it to other words. A large red 'X' is visible in the upper right corner.

OF FORMER RESIDENT
OF MICKLEOVER.
The death occurred at La House
Malmesbury, on Monday, of Mrs.
buried Francis Milnes Walker, wife
the Rev. H. Milnes Walker, vicar of
1804 of

Handwritten text in German script, likely a letter or document. The text is partially obscured by red annotations. A red circle highlights a word, and several red arrows point from it to other words. A large red 'X' is visible in the upper right corner.

Start of Line Finder

- Fully Convolutional Neural Network
- One prediction for every 16x16 window
- Predicts: X, Y, Rotation, Scale and Confidence



Start of Line Finder - Pretraining

Ich bin es wieder, der ich mich nunmehr begeben, so bald als ich die Möglichkeit finde, Ihre Briefe
 zu lesen, und die Sie von mir zu erwarten. Ich habe es mir zum Zweck gemacht, Sie durch meine Briefe
 über alle meine Angelegenheiten im Klaren zu setzen, und Ihnen den Zustand meiner Gesundheit
 mitzuteilen. Ich habe es mir zum Zweck gemacht, Sie durch meine Briefe über alle meine Angelegenheiten
 im Klaren zu setzen, und Ihnen den Zustand meiner Gesundheit mitzuteilen. Ich habe es mir zum Zweck
 gemacht, Sie durch meine Briefe über alle meine Angelegenheiten im Klaren zu setzen, und Ihnen den
 Zustand meiner Gesundheit mitzuteilen. Ich habe es mir zum Zweck gemacht, Sie durch meine Briefe
 über alle meine Angelegenheiten im Klaren zu setzen, und Ihnen den Zustand meiner Gesundheit mitzuteilen.

1362

Rome le 26. Nov. 1879

Honorable le Commandeur

J'ai l'honneur de vous adresser le
 double que j'ai vu si d'avance bien sûr, comme si
 vous en auriez besoin.
 Je vous prie de bien vouloir agréer, avec mes
 sentiments de haute estime et de haute sympathie,
 l'assurance de mon respectueux dévouement,
 et de vous adresser, en même temps,
 l'assurance de ma haute sympathie et de ma haute
 estime.

Honorable le Commandeur
 Général de la Cavalerie
 à Rome

Rome le 5 Mars 1879
 3 APR. 1877.
 11110

Honorable Monsieur

Je ne tarderai pas de m'excuser auprès de vous,
 pour l'honneur Monsieur, de mon long silence. Je serais
 ravi de vous exposer l'histoire de ces derniers mois de la
 République Italienne à laquelle, par mon journal et par mes
 rapports personnels, je me trouve lié d'une manière toujours
 très considérable. Plus considérable même que je ne le
 croyais, parce que pas la semaine dernière de toute liberté
 je ne me suis jamais senti si libre, et que je n'ai
 jamais parlé autant de questions politiques que d'habitude.
 La situation est très délicate et en même temps assez
 complexe. Les partis sont nombreux et les nouvelles
 idées apparaissent dans les provinces. Je m'occupe
 de faire les propositions de collection de Chemins de fer
 qui regardent les nouvelles constructions de Chemins de fer
 et les nouvelles constructions de Chemins de fer. Je suis
 président et le chef résistant à ces propositions pour ne pas
 compromettre l'équilibre du Budget de l'Etat et parce que je
 suis sûr que les lignes qui en demandent sont trop coûteuses, et
 que l'avantage qui en résulte est trop petit.
 Fait qu'on cherche de cacher pour dissimuler

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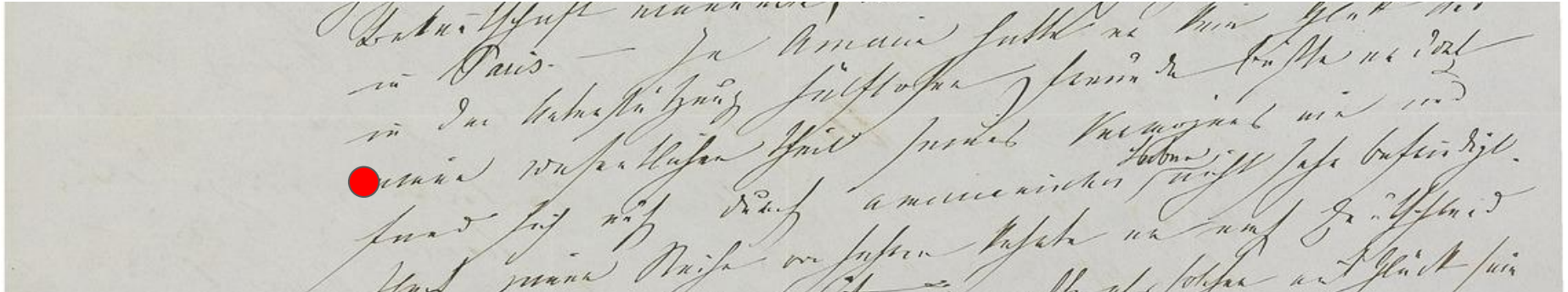
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Line Follower

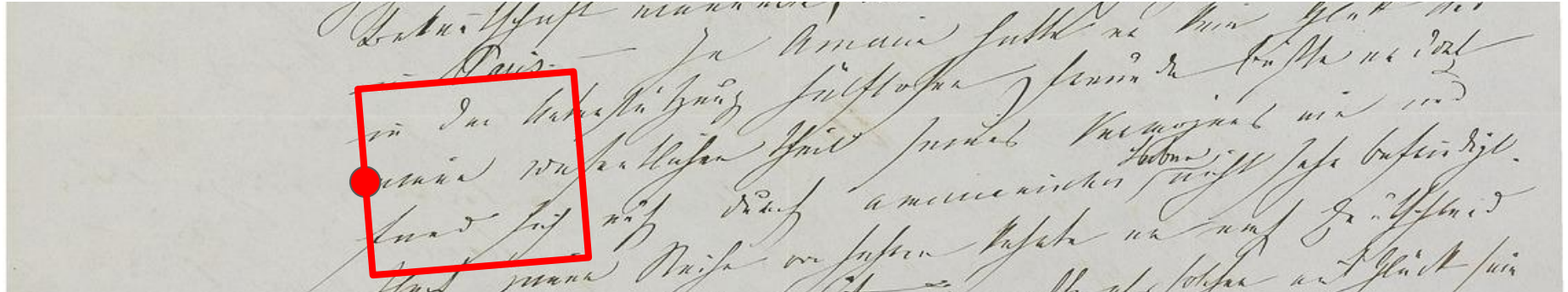
- Recurrent Spatial Transformer CNN
- CNN Regresses the next position (X, Y, Rotation, Scale and Confidence)
- Stops based on confidence or reaching the edge of the page.



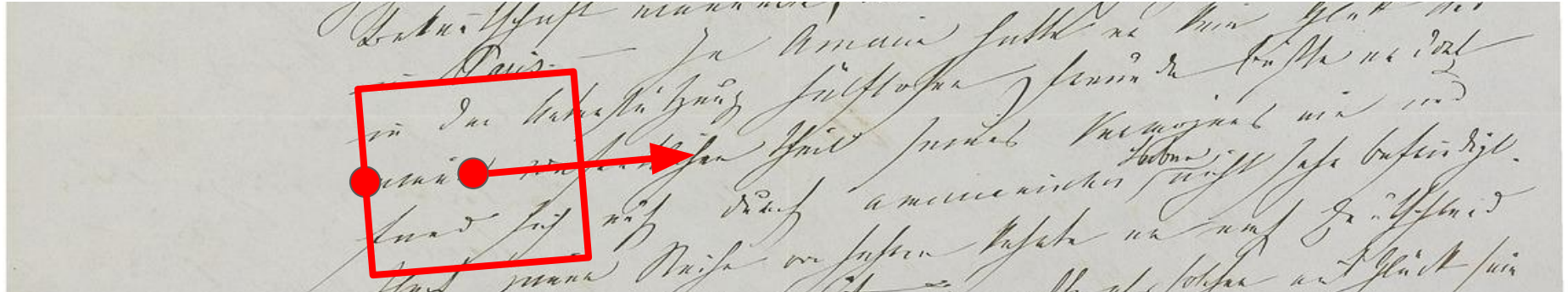
Line Follower



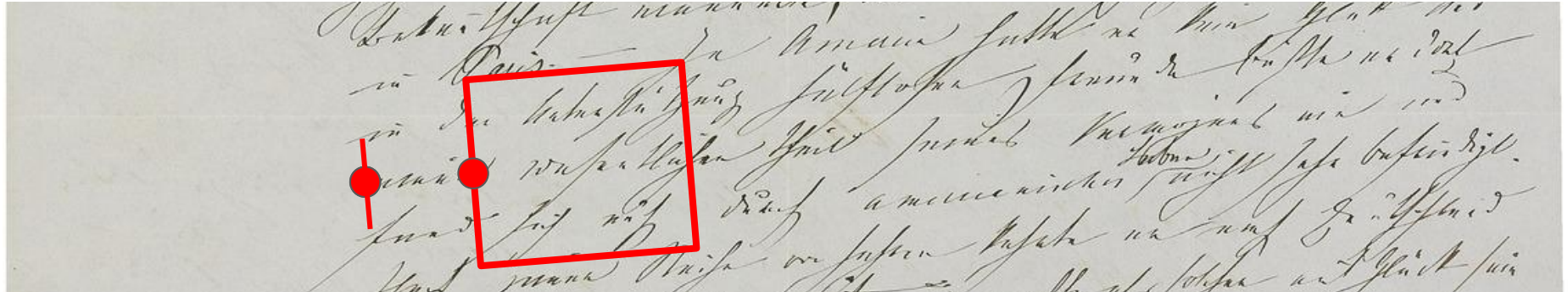
Line Follower



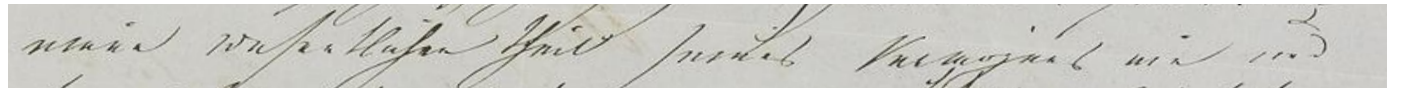
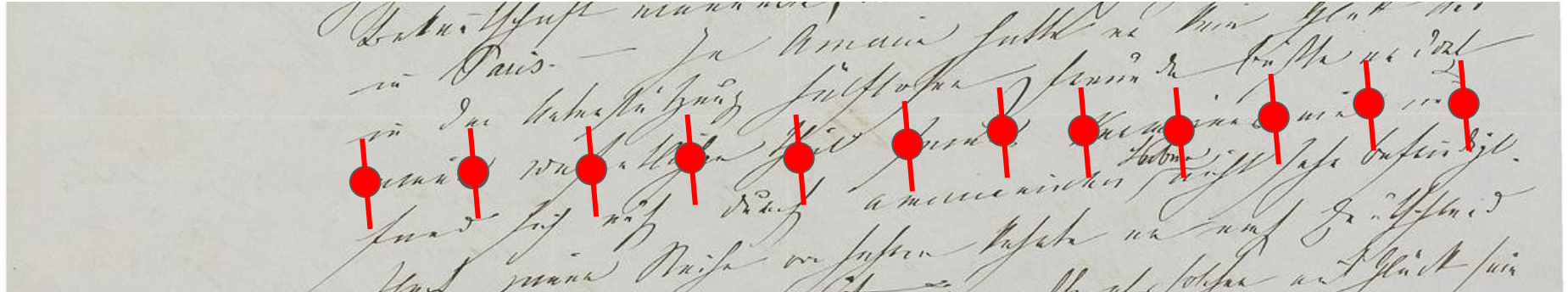
Line Follower



Line Follower

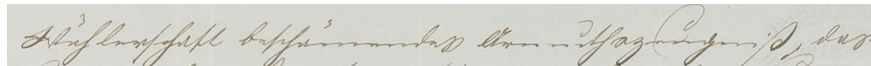


Line Follower

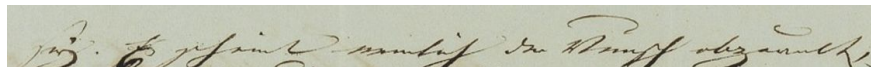


Handwriting Recognition

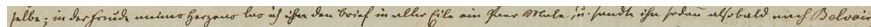
- CNN-LSTM
- CNN Extracts features over a local window
- LSTM processes features over entire length of the handwriting line



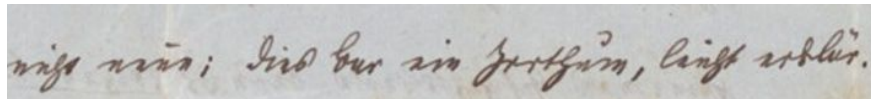
Aufnahmefähigkeit beifürnehmend den ... fagungen, das



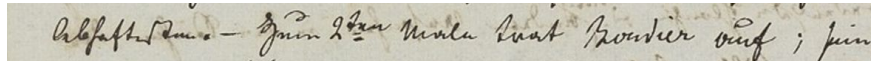
... zu ... an ... der ... ab ...



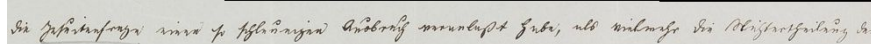
... in der ... meines ... des ... in ... alle ... ein ...



... nicht ...; ... nur ... in ... Zeit ... , ...

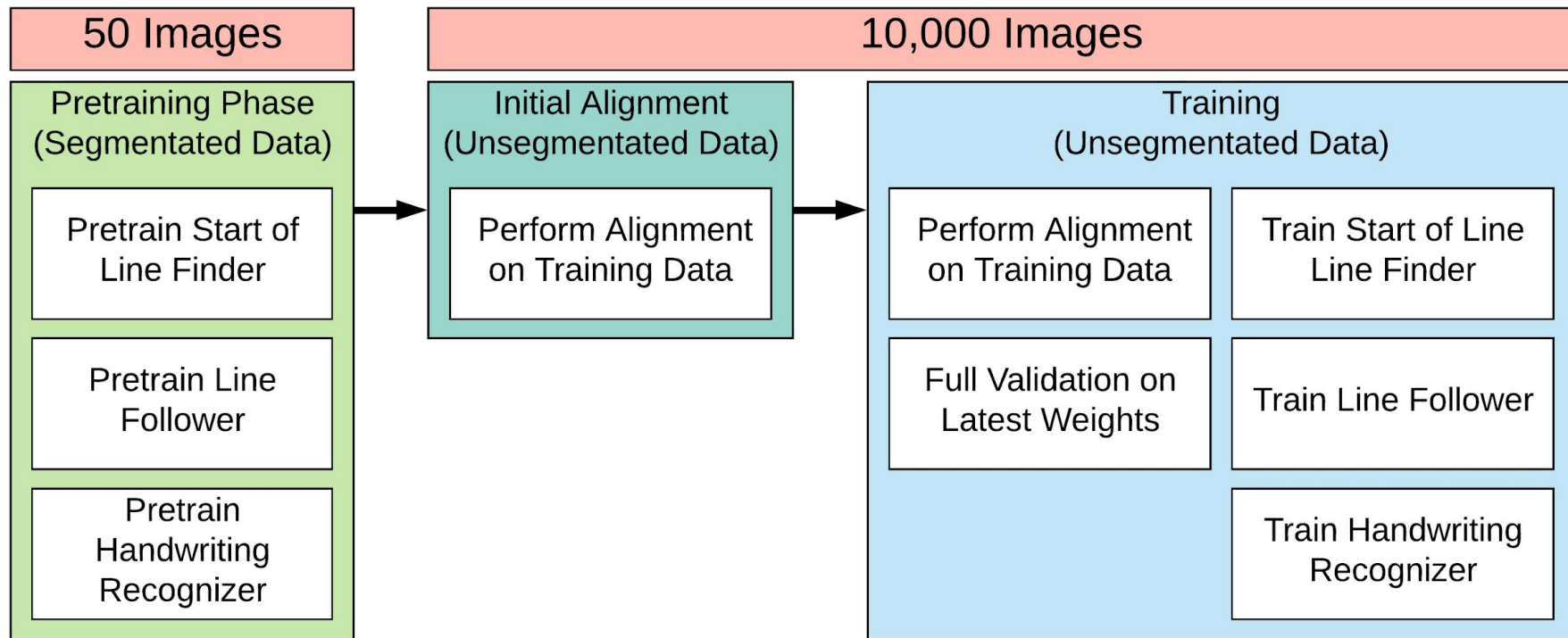


... ab ... - ... 2 ...



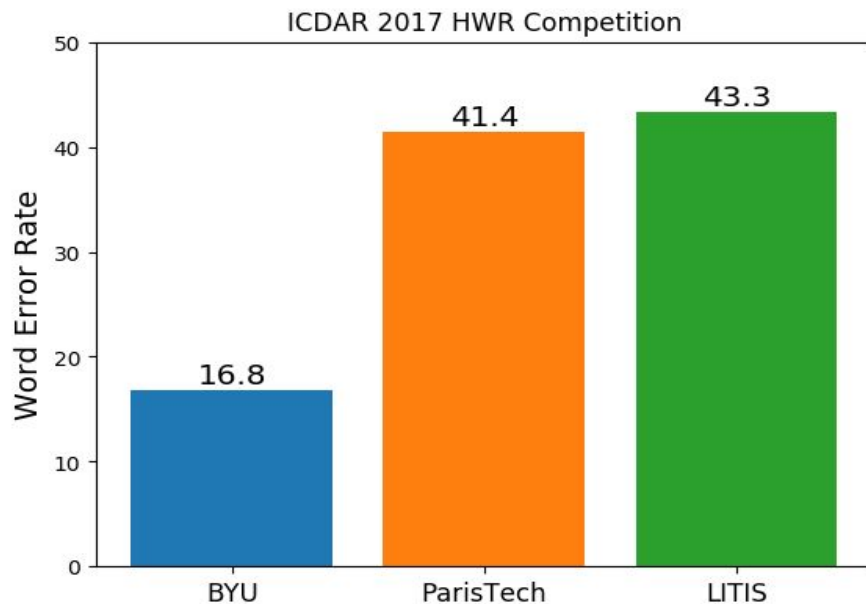
... die ...

Training



Results: ICDAR 2017 Handwriting Recognition Competition

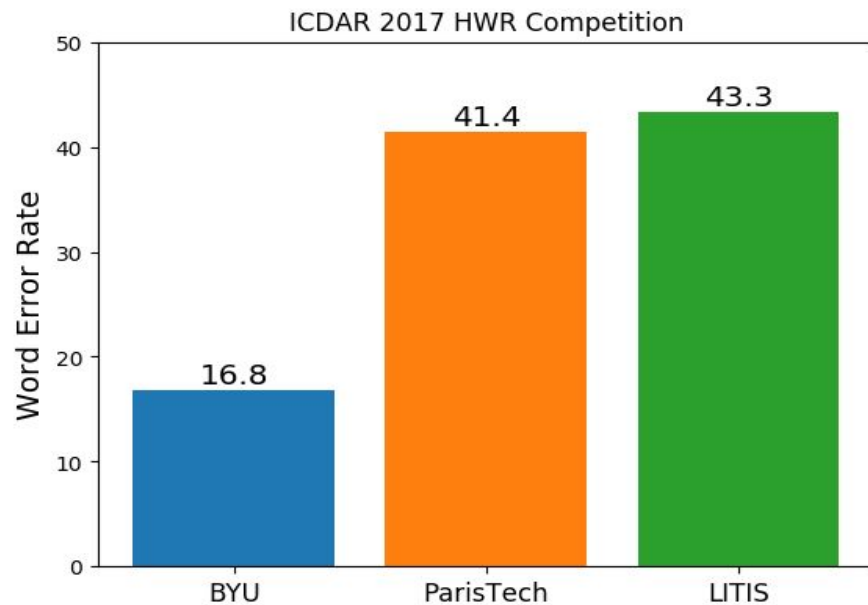
- 50 Images with line-level segmentations and transcriptions
- 10,000 images with only transcriptions
- We won! (Big thanks to FamilySearch and their line segmentation)



Results: ICDAR 2017 Handwriting Recognition Competition

We Cheated!

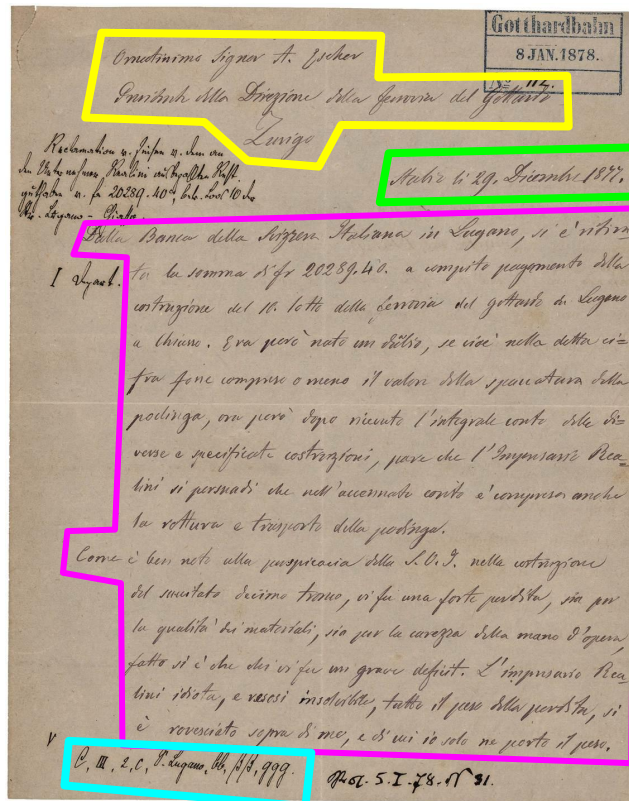
(and so did everyone else)



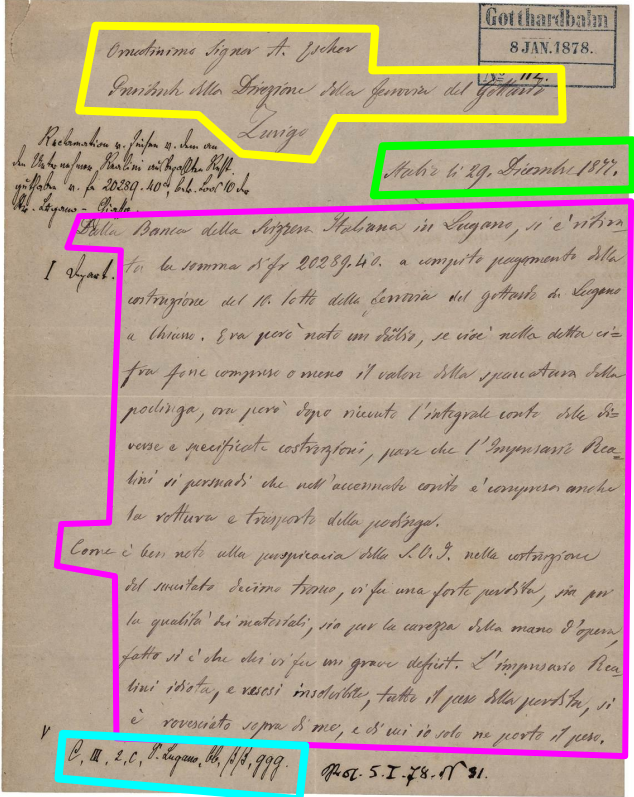
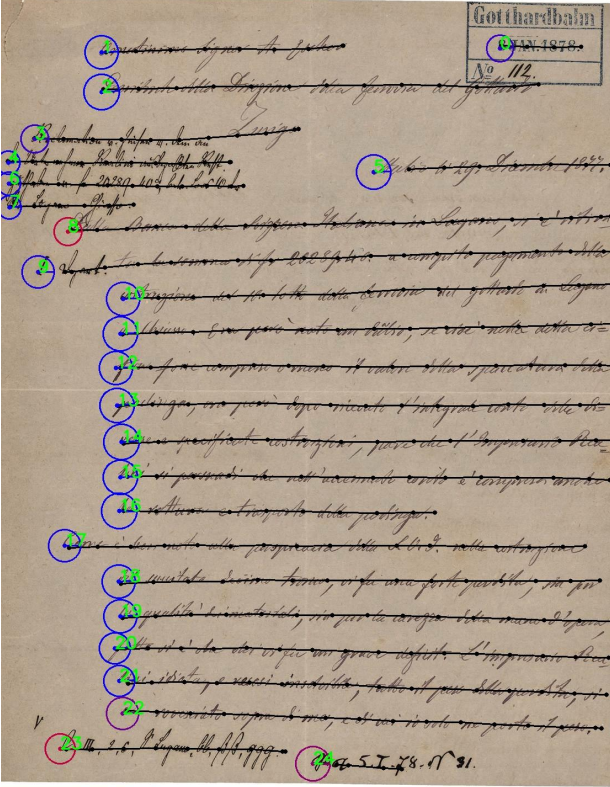
Results: ICDAR 2017 Handwriting Recognition Competition

We Cheated!

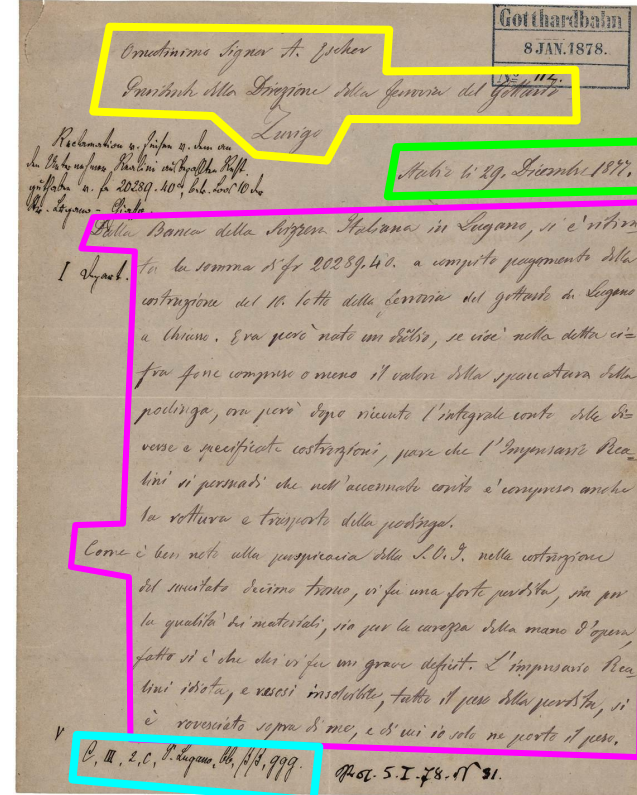
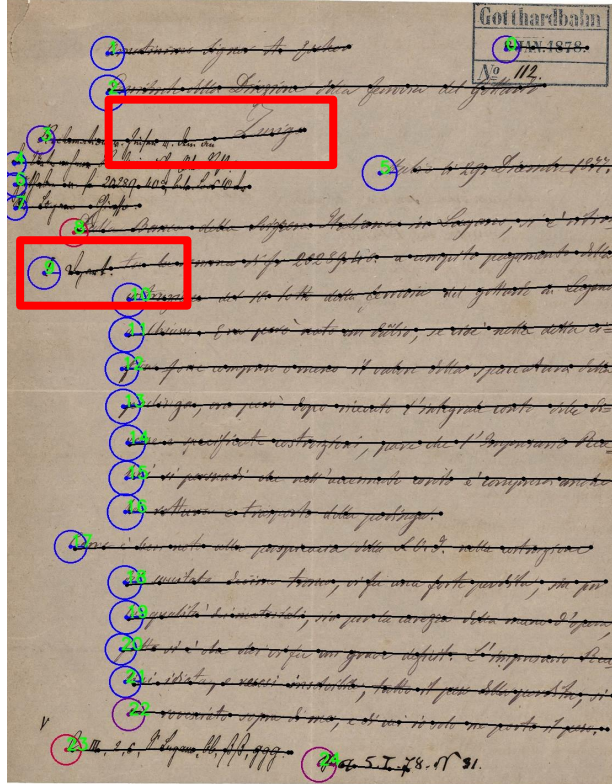
(and so did everyone else)



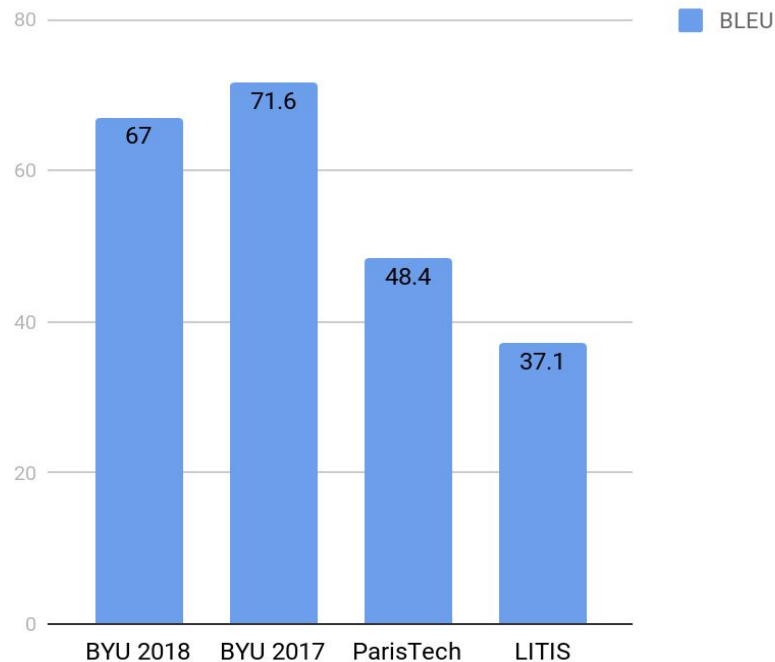
Results: ICDAR 2017 Handwriting Recognition Competition



Results: ICDAR 2017 Handwriting Recognition Competition



Results without “Cheating”: BLEU Score



BONUS:

10,000 images with good line level segmentation data - use to train other algorithms

1. ...
2. ...
3. ...

4. ...

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16. ...

17. ...

18. ...

19. ...

20. ...

21. ...

22. ...

23. ...

24. ...

25. ...

Handwritten text on a page with 25 numbered lines. The text is written in a cursive script and is mostly illegible due to fading and bleed-through from the reverse side. The lines are numbered 1 through 25 on the left margin.

25

~~1. Einmal zum Hofe~~

- 1. Einmal zum Hofe
- 2. Einmal zum Hofe
- 3. Einmal zum Hofe
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1. Einmal zum Hofe

1. Einmal zum Hofe

1. Einmal zum Hofe

1. Einmal zum Hofe

2. Einmal zum Hofe

- 1. Einmal zum Hofe
- 2. Einmal zum Hofe
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- 18. Einmal zum Hofe
- 19. Einmal zum Hofe
- 20. Einmal zum Hofe

Does it Generalize?

Thursday, May 9, 1889

Went to Salt Lake to attend a party given a Eldridges. There was present Kate and Celia Sharp Katie B. Young Mel Sharp Lottie and Georgie Welber, Mon Thatcher and girl Walt Jennings, Mr. Teasdale. and others It fell to my lot to take the Webber's home. Stayed at Eldridges that eve.

- 0: Thursday, May 9, 1889
- 1: Went to Salt Lake to attend a
- 2: party given a Eldridge's. There was
- 3: present Kate and Celia Sharp Katie
- 4: B. Young Mel Sharp, Lottie and
- 5: Georgie Webber, Mose Thatcher and girl
- 6: Walt. Jennings, Mr. Teasdale. and others
- 7: It fell to my lot to take the
- 8: Webber's home.
- 9: Stayed at Eldridges that eve.

Thursday, May 9, 1889

~~Went to Salt Lake to attend a party given a Eldridges. There was present Kate and Celia Sharp Katie B. Young Mel Sharp Lottie and Georgie Welber, Mon Thatcher and girl Walt Jennings, Mr. Teasdale. and others It fell to my lot to take the Webber's home. Stayed at Eldridges that eve.~~

- 0: S2S. N27 d. 2853
- 1: Went e Galt Sahe to attend a
- 2: party gine a Cloridgés. There uas
- 3: purent Hatid belia Sharf Halie
- 4: B. Zang Mel Sharf, Lothen
- 5: Peorgie Welher, Mon Thatcherd'giel
- 6: Walt, Grnnengs, Mr. Peanalle. And others
- 7: Z7 Foll tomy lot to take the
- 8: Webbars homl.
- 9: Stanged ab Clanedges that eor.

Thank You