

# Towards automatic parsing of arbitrary form images

The Label-Value pairing problem

Brian Davis

Work done in collaboration with

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BYU

Adobe Research

# Outline

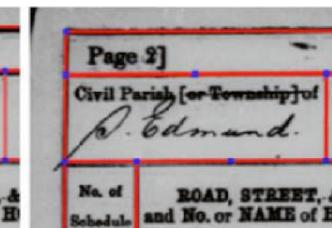
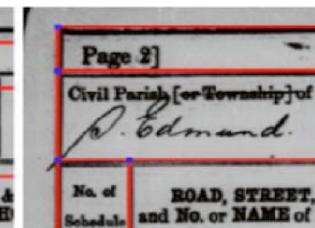
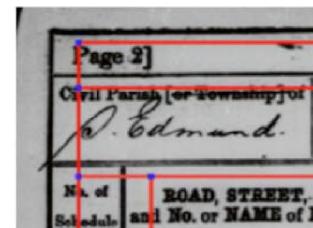
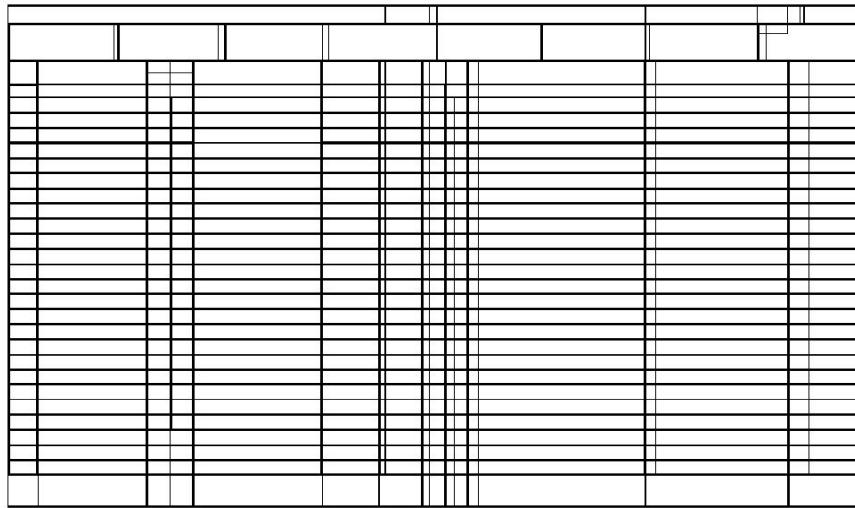
- Problem definition
- Previous work
- Dataset
- Elements of a solution
- Subproblem: Label-Value pairing
- Method
  - Detection
  - Pairing
  - Optimization
- Results
- Conclusion

# The problem

- Genealogical data is often recorded on forms
  - Birth, death, marriage records, etc.
- We'd like to automatically extract this information

# The problem

Template based solutions



Date of birth	PARENTAGE		If born within the year, state month (Jan., Feb., etc.)	If married (from, to, date)	Attended school within the year	EDUCATION.	W. M. F.
	Father of foreign birth	Mother of foreign birth					
11	12	13	14	15	16	17	

# The problem

- Some collections are not of uniform form types
  - Most have variations of the same form
  - Some are fairly random assortments for forms
- We want to be able to automatically extract information from a form image that we have never seen before
  - **Template-free**
  - **Noisy, historical forms**

# Elements of a solution

1. Detect (locate) pre-printed text and input writing on the page
2. Transcribe (read) the pre-printed text and input writing
3. Identify the meaning of the input writing (using the pre-printed text and layout)
4. Format the transcription of the handwriting to match a data schema

## Previous work

<p style="text-align: center;"><b>The University of Kashmir</b>            Hazratbal, Srinagar Kashmir, 190 006  <b>Registration Form</b></p>		
Name ..... Parentage ..... Registration No. .... Date of Birth ..... Sex ..... Permanent Address ..... Address for correspondence ..... Class ..... Branch ..... Courses offered ..... College Name .....		
S.No	Name	Parentage
This is test for the table of the document	This is the second column of the document and is wider	This again is the third column and is the largest of all the columns This line is

納付済通知書				
路便振替口座 00190-9-960000				
加入者 日立 区役戸役				
113123705112121200660323100000000217070				
23	記号番号	CD	取扱事務所	納付義務者
	66-6032	3	1	3
①この納付書では記載されている納付金額しか納めることができます。				
②お求められた保険料は 区に収入されるまでに 10日間かかります。				
【お問い合わせ】 この用紙は直轄機械に読みますので、汚した り、びしで止めたり、折ったりしないで下さい。				
平成12年度 12月 2170円				
納期限 3月2日				
平成12年度 合計 四民税 養育費 個人徴収 後計 款 国民健康保険料 項 国民健康保険料 取り扱い局 〒111-8999 東京貯金事業センター 〒332-0000 日立区生活販売部保険料会議 主管課 110000 電話番号(2222)1111 印				

Top-left: J. Zhou, H. Yu, C. Xie, H. Cai, and L. Jiang, "IRMP: From printed forms to relational data model," in High Performance Computing and Communications; IEEE 14th International Conference on Smart City; IEEE 2nd International Conference on Data Science and Systems (HPCC/SmartCity/DSS), 2016 IEEE 18th International

Conference on . IEEE, 2016, pp. 1394–1401.  
Bottom-left: J. Hirayama, H. Shirijo, T. Takahashi, and T. Nagasaki, "Development of template-free form recognition system," in Document Analysis and Recognition (ICDAR), 2011 International Conference on . IEEE, 2011, pp. 37–241.  
Right: M. Hammami, P. Heroux, S. Adam, and V. P. d'Andeyc, "One-shot field spotting on colored forms using

(Remplir une demande par police)	
<b>1 - IDENTIFICATION</b>	
N° DE POLICE	<b>1252890 2X 1401.</b>
NOM	<b>CHARPY</b>
PRÉNOM : <b>Ferréol</b>	
Code délégué : <b>A82E</b>	
<b>2 - RISQUE A RÉSILIER</b>	
✓ RÉSIDENCE	
• Adresse	
Code Postal	
Commune	
VEHICULE OU NAVIGATION DE PLAISANCE	
• Marque	
Immatriculation (ou nom pour les bateaux)	
AUTRE POLICE : préciser la nature de la police à résilier	
DATE DE RÉSILIATION DEMANDÉE : <b>05/11/2009</b>	
<b>MOTIF DE LA RÉSILIATION :</b>	
A L'ÉCHÉANCE ANNUELLE (telle de prévoir d'un mois)	
POUR VENTE	
Pour les véhicules, donne le certificat de vente ou la photocopie de la carte grise banlieu au nom de l'acheteur.	
Pour les résidences et la navigation de plaisance, préciser :	
- Date de vente	
- Nom et adresse de l'acheteur	
POUR DESTRUCTION DU VÉHICULE (indiquer le certificat de dépôt de carte grise à la Préfecture).	
DISPARITION DU RISQUE : préciser	
✓ AUTRE MOTIF : préciser <b>renouvellement de contrat</b>	
<b>NOMMRE DE PIÈCES JOINTES :</b> <b>1</b>	
ATTENTION : Toute demande de résiliation hors échéance annuelle devra être justifiée par document joint.	
<b>3 - SIGNATURES</b>	
A <b>Gérard</b>	le <b>30/11/2009</b>
Déclaration remise le <b>30/11/2009</b>	
Signature de l'adhérent	
 	
Signature et cachet	
DU <b>30/11/2009</b>	

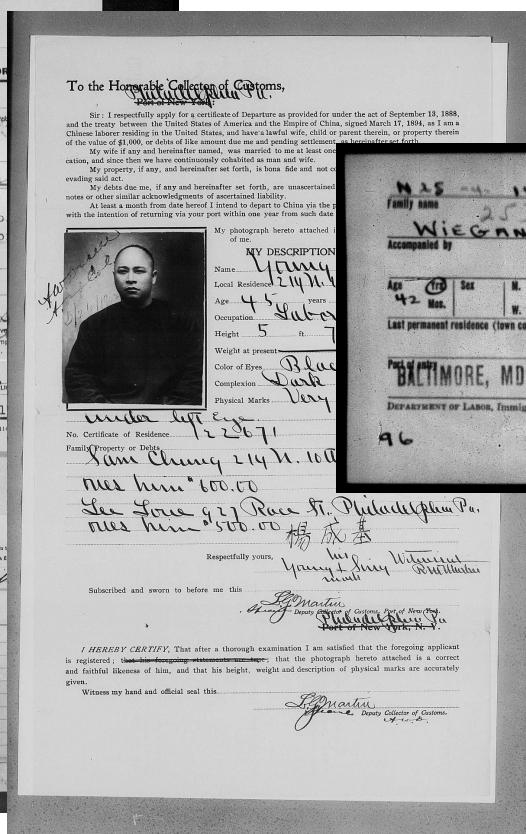
<b>1 - IDENTIFICATION</b>			
N° d'adhésion	1 monsieur	2 madame ou mademoiselle	N° prospect
1 monsieur	2 madame ou mademoiselle	3 collectivité / personne morale	14ème adhésion , je suis
Nom de la famille		Prénom : <b>LIONE</b>	
Nom de la famille		Nationalité : <b>France</b>	
Né(e) le <b>26 06 1973</b> à		Code postal : <b>75000</b>	
à			
3 - SITUATION DE LA FAMILLE			
1 époux/épouse	2 marié(e)	3 veuf/veuve	4 concubinat
Concubin/époux AGPM Families	1 OUI	11e adhésion du conjoint	5 divorcé(e)
Présumé(e) concubin/épouse	6 séparé(e)	12 OUI	6 séparé(e)
Composition de la famille : nom prénom	relatif le	situation familiale	profession / CSP
Conjoint			
Enfant 1			
Enfant 2			
Enfant 3			
<b>3 - ADRESSE</b>			
Valeable pour le conjoint adhérent	1 OUI	2 NON	date d'effet
Présumé(e) concubin/épouse	1 monsieur	2 madame	14ème adhésion
Légitime partenaire	Légitime professionnel		
Appartement, bâtiment, résidence			
N° et adresse de votre lieu de résidence	3 Rue LAFAYETTE PARIS Dugny		
Code postal	93100	Commune	C Gagny - Paris
Parcours	Prix moyen		
Télé domicile	Télé professionnelle		
Télé portable	Télé professionnelle		
Méthode de paiement			
4 - PARRAIN			
10 parrainage	2 amis	3 enfants	4 parents
7/10 proche	8 relation travail	9 délégué	10 personnes porté account
Non	Prénom : <b>P</b>		
N° adhésion AGPM ou AGPM Families ou date de naissance : <b>1973-06-26</b> Code porteur de résidence :			
<b>5 - PRÉLEVEMENT AUTOMATIQUE valable aussi pour le conjoint oui non</b>			
Paiement de la cotisation statutaire : <b>1 annuel</b> 2 bimestriel <b>3 trimestriel</b>			
<b>6 - ORIGINE DE L'ADHESION A L'AGPM FAMILLES</b>			
Canal d'adhésion	CC Vente	CC Cession	CC Finances
Media d'adhésion	Telephone	Fax	E-mail
Entretien	en domicile	en unité	en point d'accueil
<b>7 - RENSEIGNEMENTS COMPLEMENTAIRES CONCERNANT L'ADHÉRENT AGPM FAMILLES</b>			

# The data we care about

**APPLICATION FOR HEADSTONE OR MARKER**  
 (Please note and return in duplicate)

Check TYPE REQUIRED <input type="checkbox"/> UPRIGHT MARBLE HEADSTONE <input type="checkbox"/> UPRIGHT GRANITE HEADSTONE <input type="checkbox"/> FLAT MARBLE MARKER <input checked="" type="checkbox"/> FLAT GRANITE MARKER <input type="checkbox"/> BRONZE MARKER (WITH RESTRICTIONS)	ENTRANCE DATE April 26, 1917	EMBLEM (Check <input type="checkbox"/> CHRISTIAN <input type="checkbox"/> HERETIC <input type="checkbox"/> NONE)
NAME Enslin, Irving David	DISCHARGE DATE Feb. 8, 1919	PENSION NO. 285, 607
STATE Illinois	RANK Sargeant	COMPANY C-128th
U. S. REGIMENT, STATE ORGANIZATION, AND DIVISION	32nd Div.	
NAME OF CEMETERY Mount Hope	Sgt. Irvin L. Dunn Post No V. F. W.; Waterloo, Illinois	
LOCATION (City and State)		
NEAREST FREIGHT STATION (City and State) Belleville, Illinois		
POST OFFICE ADDRESS OF CONSIGNEE 3008 - Washington St.		
SHIP TO CERTIFY THE APPLICANT FOR THIS STONE HAS MADE ARRANGEMENTS WITH ME TO TRANSPORT THE STONE FROM THE FREIGHT STATION TO THE CEMETERY		
D. Enslin (SIGNATURE OF CONSIGNEE)		
DO NOT WRITE HERE		
FOR VERIFICATION APR 28 1947		
ORIGINATED WOOLSFORD, MASS. APR 9 1947		
R.R. SHIPPED 6698417		
ADDRESS (Street, City, State) 1915 Pennsylvania Ave; E. St. Louis, IL		
IMPORTANT--Complete Reverse Side		

DDMG FORM 623 REV 6 NOV 62



Page No. 3

**SCHEDULE 1—Free Inhabitants in** *Montgomery* **in the County of** *Montgomery* **enumerated by me, on the** *3rd* **day of June 1860.** *W. W. Bishop* **Am't Marshal**

Post Office *Montgomery*

**Description**

Family Number	Family Name	Given Name	Accompanied by	Value of Estate Owned	Place of Birth
1	May	12		1	Native or Born, Territory, or Country
2	Eliza	14		1	Abroad
3				1	Value of Real Estate
4				1	Value of Personal Estate
5				1	Amount of Money and Goods in Bank
6				1	Amount of Money and Goods in Cash
7				1	Amount of Money and Goods in Stocks
8				1	Amount of Money and Goods in Bonds
9				1	Amount of Money and Goods in Notes
10				1	Amount of Money and Goods in Checks
11				1	Amount of Money and Goods in Drafts
12				1	Amount of Money and Goods in Bills of Exchange
13				1	Amount of Money and Goods in Promissory Notes
14				1	Amount of Money and Goods in Stocks and Bonds
15				1	Amount of Money and Goods in Securities
16				1	Amount of Money and Goods in Gold and Silver
17				1	Amount of Money and Goods in Diamonds and Precious Stones
18				1	Amount of Money and Goods in Other Goods
19				1	Whether and how, and in what manner, the above amounts are held

**Remarks**

Number of persons whose usual place of abode is the first key of June, 1860, was in my family.

1. *Adam Wiegrand* 250 *Ja*  
 2. *Eliza Wiegrand* 100 *Ja*  
 3. *Samuel Wiegrand* 100 *Ja*  
 4. *James Wiegrand* 100 *Ja*  
 5. *John Wiegrand* 100 *Ja*  
 6. *Anna Wiegrand* 100 *Ja*  
 7. *George Wiegrand* 100 *Ja*  
 8. *Charles Wiegrand* 100 *Ja*  
 9. *John Wiegrand* 100 *Ja*  
 10. *John Wiegrand* 100 *Ja*  
 11. *John Wiegrand* 100 *Ja*  
 12. *John Wiegrand* 100 *Ja*  
 13. *John Wiegrand* 100 *Ja*  
 14. *John Wiegrand* 100 *Ja*  
 15. *John Wiegrand* 100 *Ja*  
 16. *John Wiegrand* 100 *Ja*  
 17. *John Wiegrand* 100 *Ja*  
 18. *John Wiegrand* 100 *Ja*  
 19. *John Wiegrand* 100 *Ja*  
 20. *John Wiegrand* 100 *Ja*  
 21. *John Wiegrand* 100 *Ja*  
 22. *John Wiegrand* 100 *Ja*  
 23. *John Wiegrand* 100 *Ja*  
 24. *John Wiegrand* 100 *Ja*  
 25. *John Wiegrand* 100 *Ja*  
 26. *John Wiegrand* 100 *Ja*  
 27. *John Wiegrand* 100 *Ja*  
 28. *John Wiegrand* 100 *Ja*  
 29. *John Wiegrand* 100 *Ja*  
 30. *John Wiegrand* 100 *Ja*  
 31. *John Wiegrand* 100 *Ja*  
 32. *John Wiegrand* 100 *Ja*  
 33. *John Wiegrand* 100 *Ja*  
 34. *John Wiegrand* 100 *Ja*  
 35. *John Wiegrand* 100 *Ja*  
 36. *John Wiegrand* 100 *Ja*  
 37. *John Wiegrand* 100 *Ja*  
 38. *John Wiegrand* 100 *Ja*  
 39. *John Wiegrand* 100 *Ja*  
 40. *John Wiegrand* 100 *Ja*

No. white males, \_\_\_\_\_ No. colored males, \_\_\_\_\_ No. foreign born, \_\_\_\_\_ No. blind, \_\_\_\_\_  
 No. white females, \_\_\_\_\_ No. colored females, \_\_\_\_\_ No. deaf and dumb, \_\_\_\_\_ No. lame, \_\_\_\_\_  
 No. idiots, \_\_\_\_\_ No. paupers, \_\_\_\_\_ No. convalescent, \_\_\_\_\_

*John Martin, Deputy Collector of Customs, Port of New York, N.Y.*

# Dataset

- From the National Archive, imaged by FamilySearch
- We restrict our problem to forms without tables or fill-in-the-blank paragraphs
  - Though we use the whole set to pre-train our detector
- Size
  - Train: 143 images (full 682)
  - Validation: 13 images (full 59)
  - Test: 13 images (full 62)

This is a handwritten application form for a headstone or marker, specifically for a sailor named Robert F. Young. The form is dated 26 May 1944 and signed on 1 SEP 1940. It includes fields for the deceased's name, rank, service number, and place of death. The form also specifies the cemetery and the location where the stone will be transported. There are several red ink signatures and initials over the handwritten text.

**APPLICATION FOR HEADSTONE OR MARKER**  
(Please make out and return in duplicate.)

**CHECK TYPE REQUIRED**  
(See instructions above)  
 CUMMINS MARBLE HEADSTONE  
 BRIGHT GRANITE HEADSTONE  
 FLUOR-MARBLE MARKER  
 FLAT GRANITE MARKER  
 BRONZE MARKER (NOTE RESTRICTIONS)  
NAME (Last, First, Middle initial)  
Enslay, Robert F.

ENLISTMENT DATE: 26 May 1944  
DISCHARGE DATE: 8 Feb. 1946

SERVICE NO.: 971 95 45  
RANK: PO2  
STATE: Tennessee  
U.S. REGIMENT, STATE ORGANIZATION, AND DIVISION:  
U.S. Navy 53rd Naval Construction Battalion  
COLUMBIA, Tennessee  
U.S. FREIGHT STATION (City and State):  
Columbia, Tennessee  
POST OFFICE ADDRESS OF CONSIGNEE:  
811 So. Garden St., Columbia, Tennessee

DATE OF BIRTH (Month, Day, Year): July 24, 1925  
DATE OF DEATH (Month, Day, Year): June 28, 1949  
PLACE OF DEATH: Rose Hill Cemetery, Columbus, Ga.  
SHIP TO: (Center) THE APPLICANT FOR THIS STONE HAS MADE ARRANGEMENTS WITH ME TO TRANSPORT THE STONE FROM HIS VARIOUS STATIONS IN THE SERVICE  
ROBERT F. YOUNG  
Robert F. Young (Signature of Consignee)  
I CERTIFY THIS APPLICATION IS SUBMITTED FOR A STONE FOR THE ABOVE INDIVIDUAL  
I HEREBY AGREE TO ASSUME ALL RESPONSIBILITY FOR THE REMOVAL AND ARRIVAL AT DESTINATION, AND PROPERLY PLACE IT AT THE DECEDENT'S GRAVE  
ADDRESS (Street, City, State): Carters Creek, Rd. 1, Tennessee  
DOING FORM 623 REV 1940-6  
IMPORTANT—Complete Reverse Side

Talk to me if you're interested in using it.

# Subproblem: Label-Value pairing

Often determining the meaning of input writing is as simple as knowing it's label

<input type="checkbox"/> BRONZE MARKER (NOTE RESTRICTIONS)	
NAME ( <i>Last, First, Middle Initial</i> )	
Ensley, Buford L.	
DATE OF BIRTH ( <i>Month, Day, Year</i> )	DATE OF DEATH ( <i>Month, Day, Year</i> )
July 24, 1925	June 28, 1949
NAME OF CEMETERY	
Rose Hill Cemetery	
SHIP TO (I CERTIFY THE APPLICANT FOR THIS STONE HAS MADE ARRANGEMENTS WITH ME TO TRANSPORT	

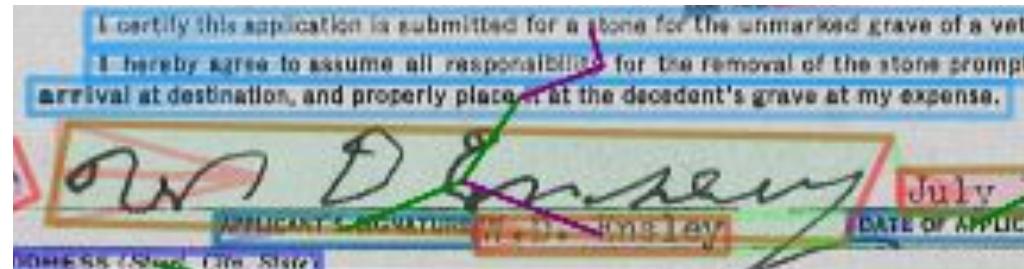
# Subproblem: Label-Value pairing

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<input type="checkbox"/> BRONZE MARKER (NOTE RESTRICTIONS)	
NAME (Last, First, Middle Initial)	
Ensley, Buford L.	
DATE OF BIRTH (Month, Day, Year)	DATE OF DEATH (Month, Day, Year)
July 24, 1925	June 28, 1949
NAME OF CEMETERY	
Rose Hill Cemetery	
SHIP TO (I CERTIFY THE APPLICANT FOR THIS STONE HAS MADE ARRANGEMENTS WITH ME TO TRANSPORT	

# Subproblem: Label-Value pairing

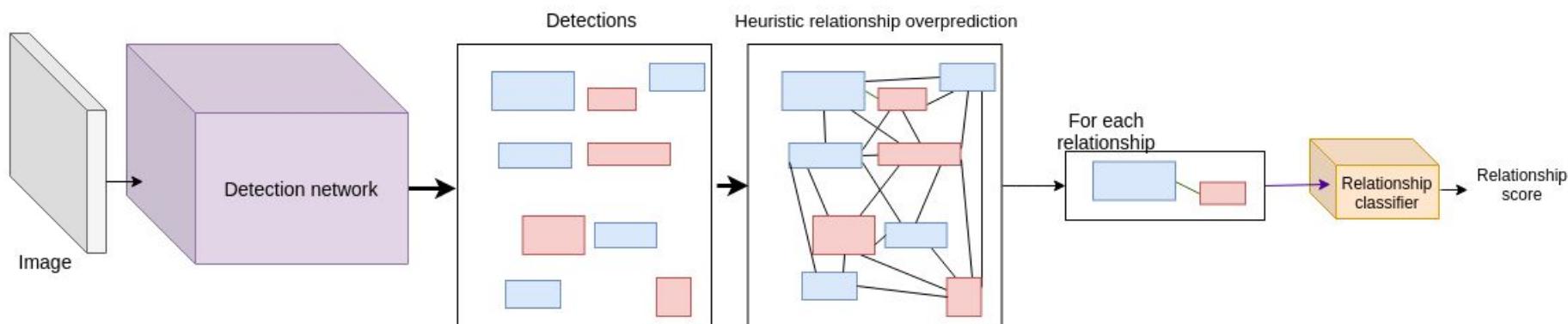
- First pre-printed text and input writing must be detected/located
- Then we need to decide which pre-printed text is related to which input writing
  - Not always one-to-one relationships!



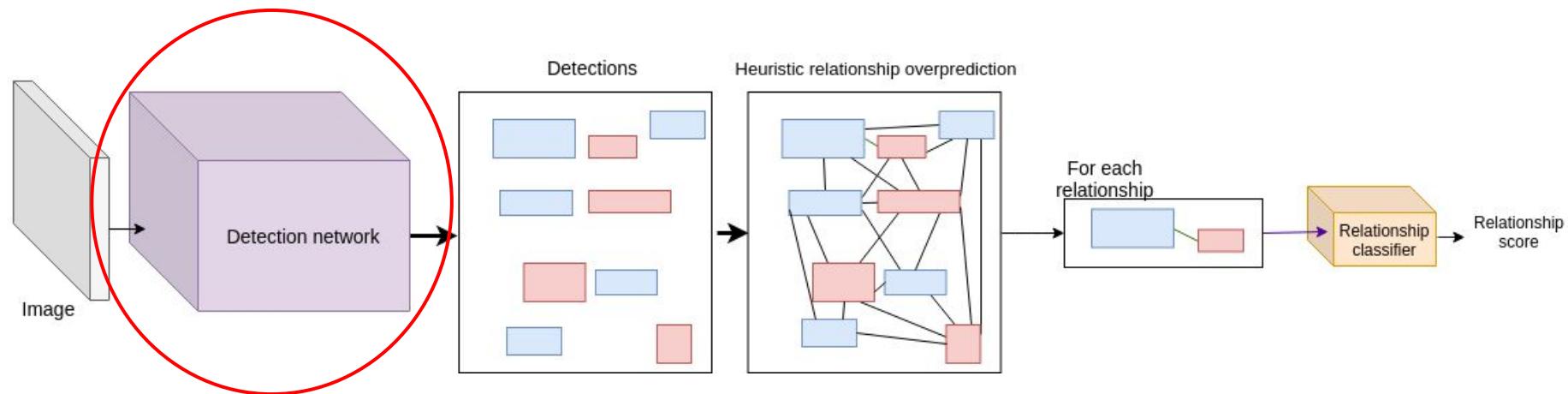
We do this without transcribing/reading the text and handwriting.

- Language agnostic

# Method

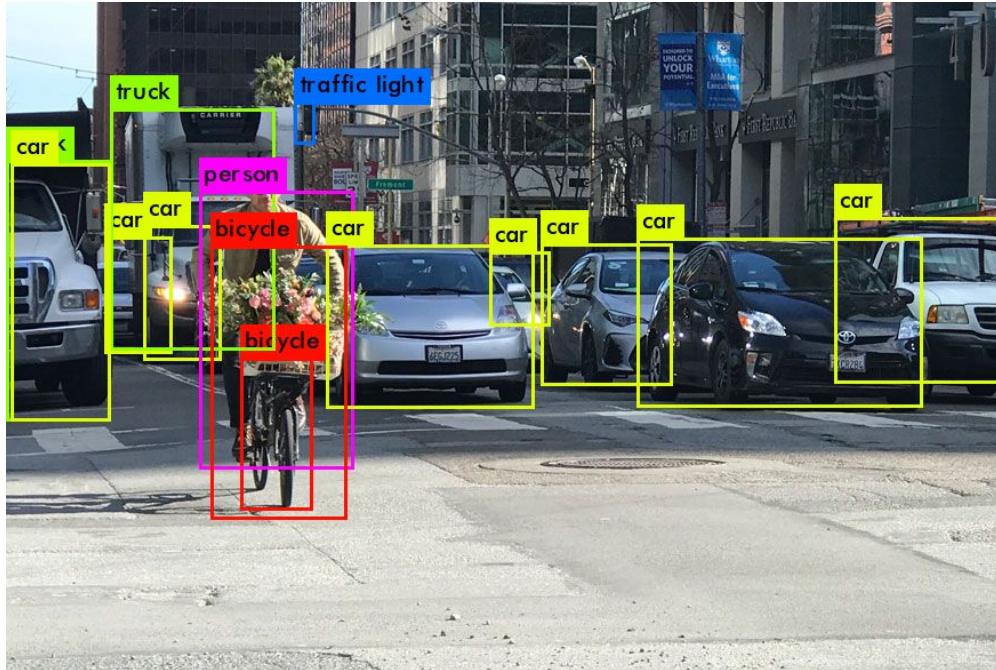


# Method



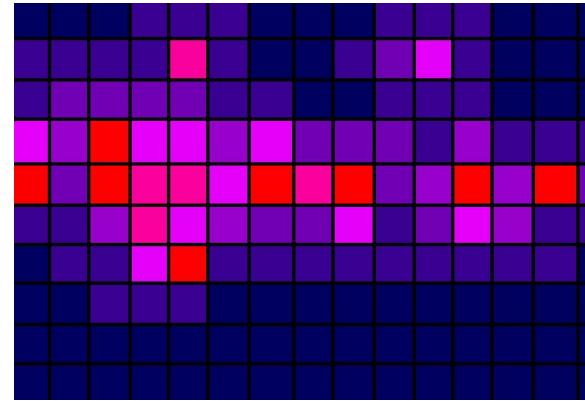
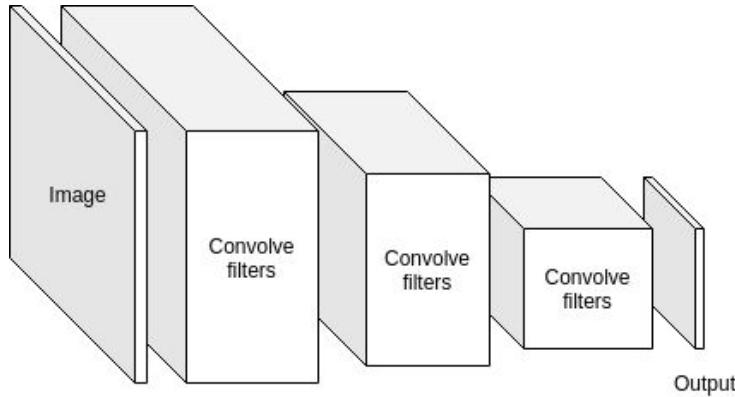
# Detection

- We detect lines of text/writing using an object detection method.
- Specifically we model our detector after YOLOv2/v3.
  - Single fully convolutional network



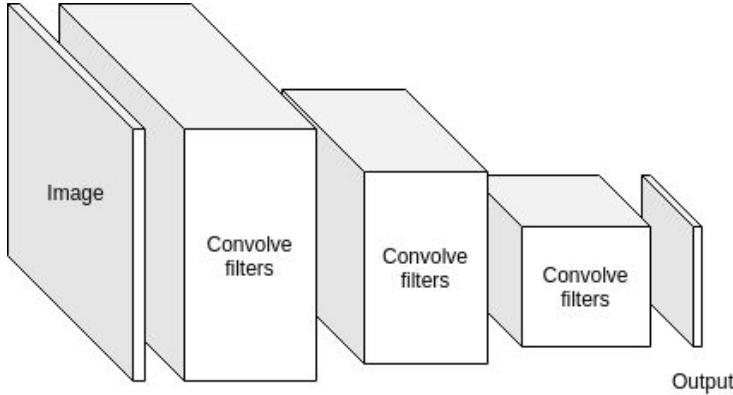
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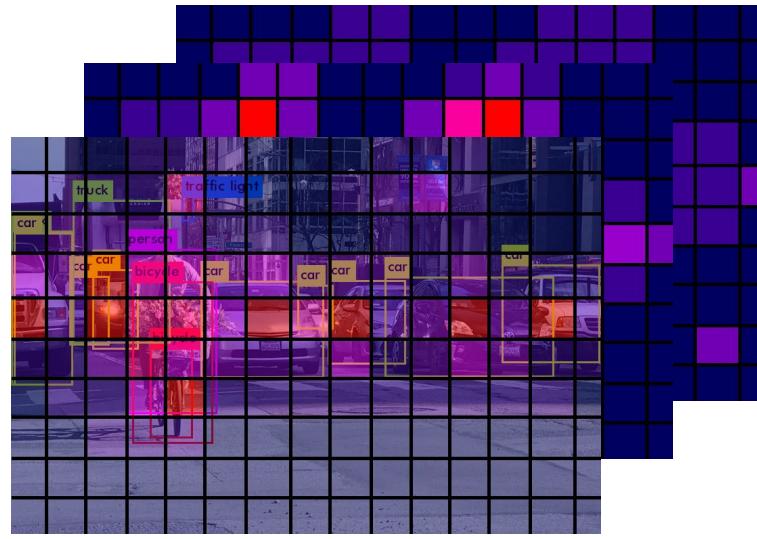
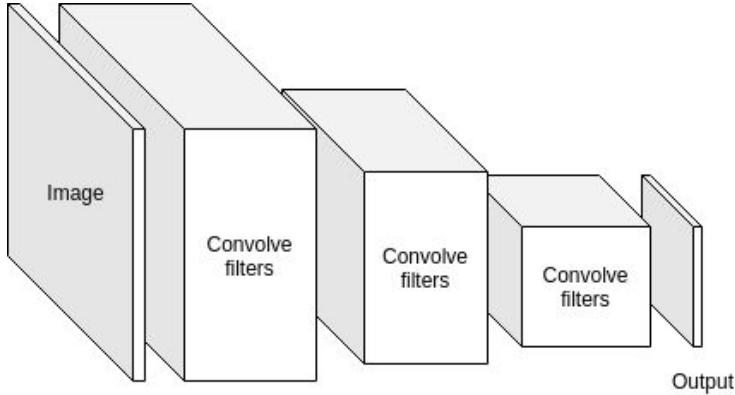
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# Detection

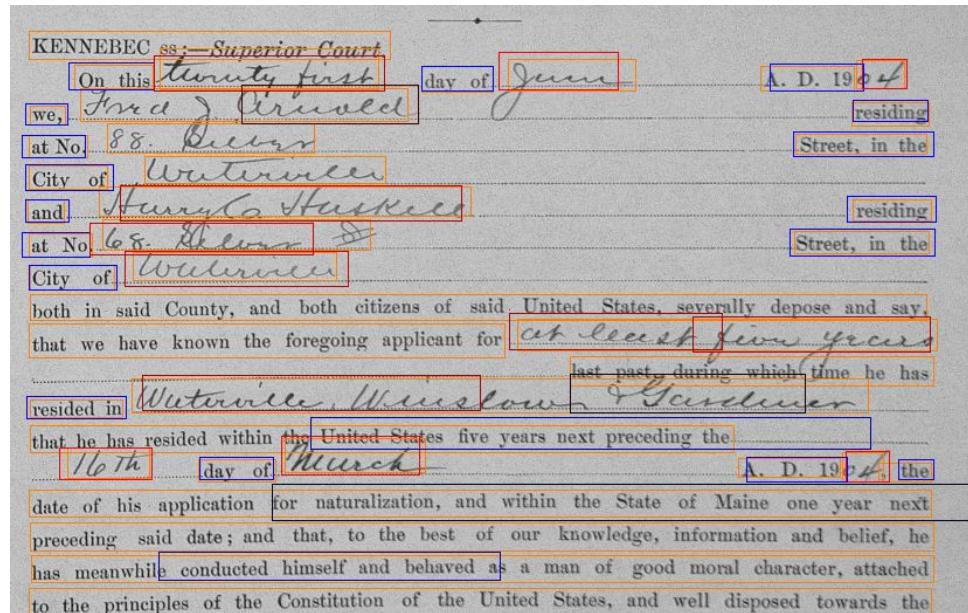
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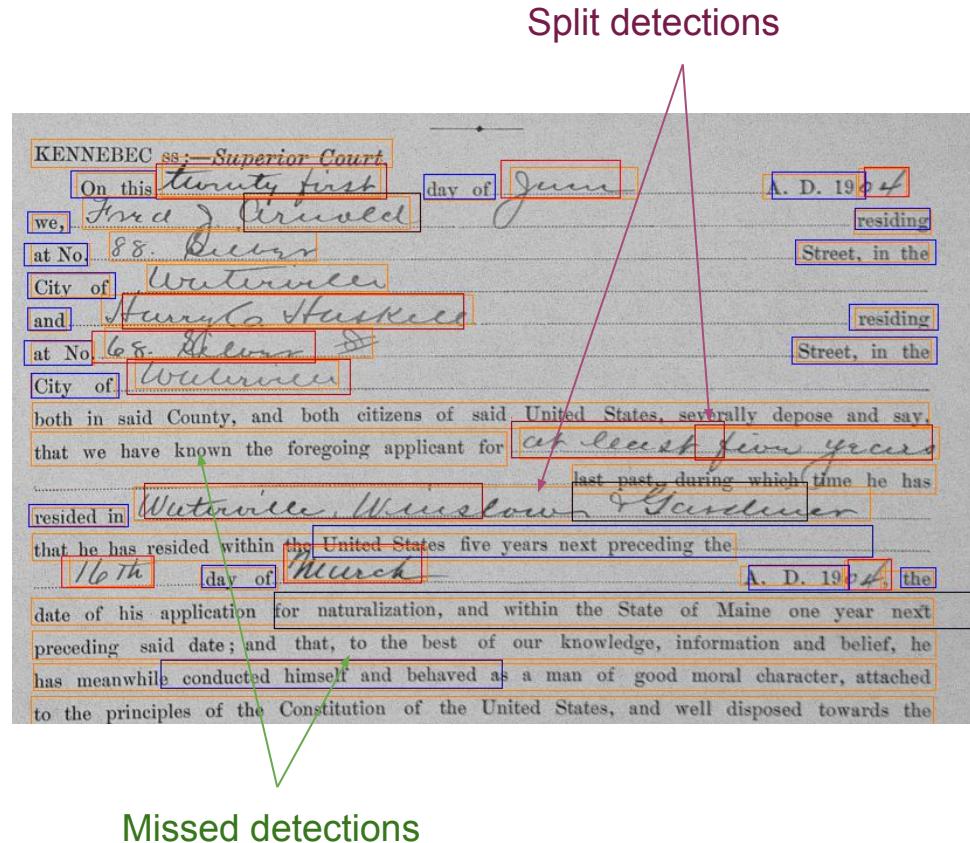
However, a normal convolutional net architecture does not handle very long text/writing lines.



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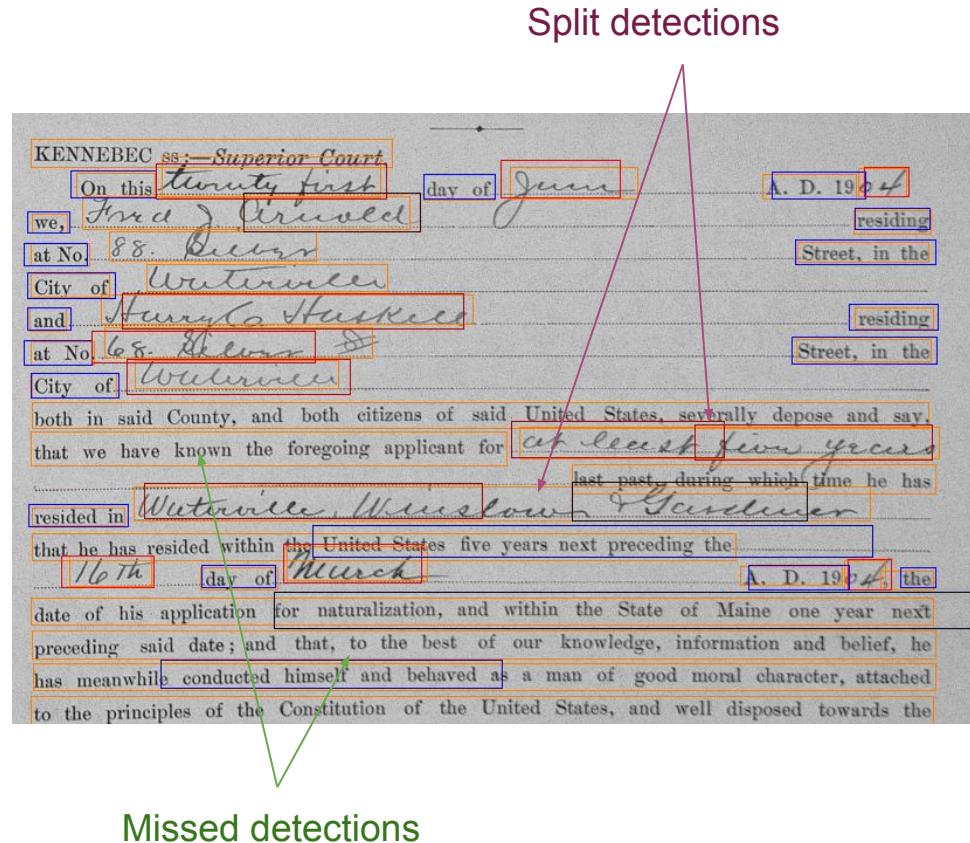


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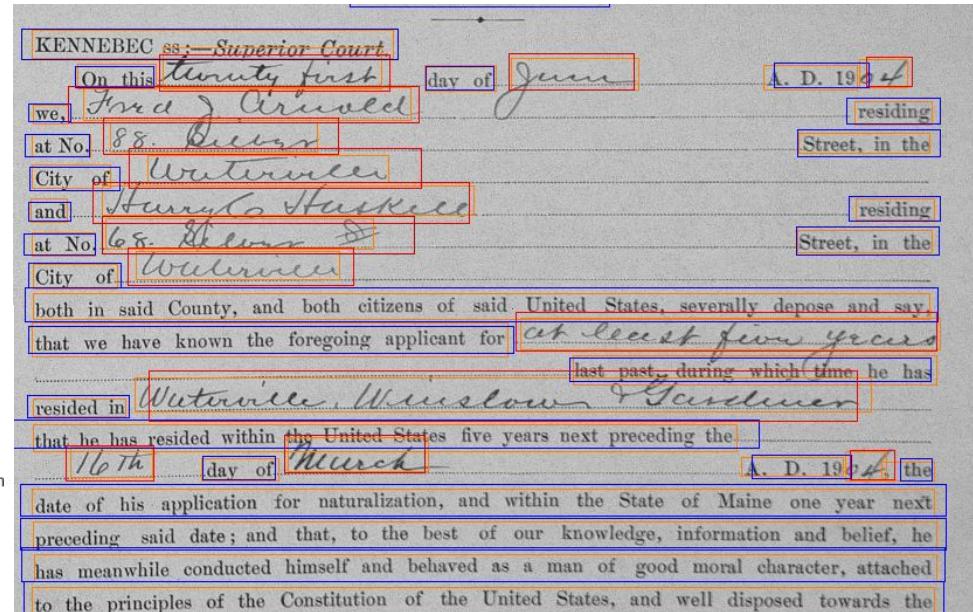
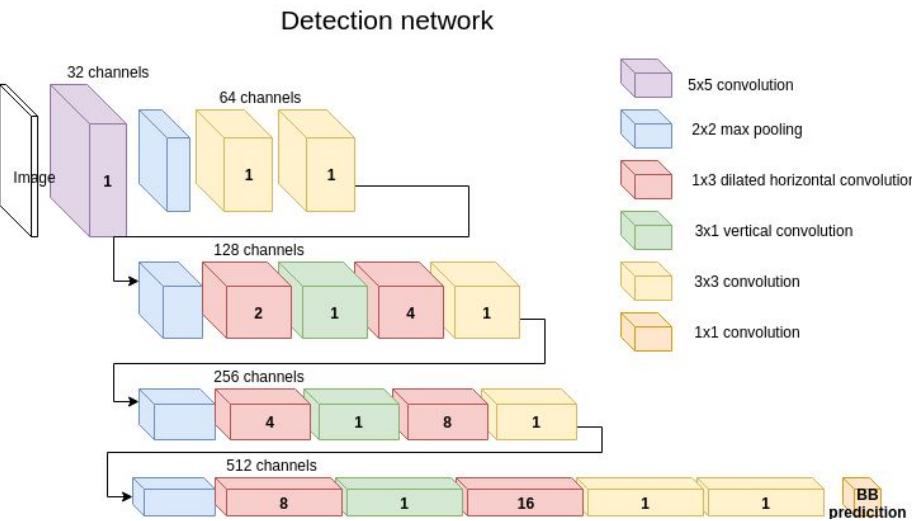
However, a normal convolutional net architecture does not handle very long text/writing lines.

YOLO handles this with multi-resolution detection.



# Detection

We increase the horizontal receptive field of our network by introducing dilated 1x3 convolutions.



# Detection Results

Mean average precision (measures both precision and recall)

Normal convolutional network: 0.397 mAP

With dilatations (our architecture): 0.453 mAP

I, Jas H. Mitchell, do solemnly, sincerely and truly, swear that the within List contains the Names of the Crew of the  
Places of their Birth and Residence, as far as I can ascertain the same  
from this 18th day of November 1834  
Before me (Signed) W. M. Morris Collector

Signal  
Jas H. Mitchell

I do certify, that the within is a true Copy of a List of the Crew of the

of Brig Palin, whereof I H. Mitchell  
is Master, taken from the Original, on file in this office.

Given under my hand and Seal of Office, at the Customs House,  
this 18th day of November  
in the Year of our Lord one thousand eight hundred and thirty four

Milling Cole  
COO

I do hereby further certify, That the within named

John W. Andrews  
Sam'l Lewis 3<sup>d</sup>  
Charles Booth  
Sam'l Blaylock  
James Kenny  
George Taylor

do severally be the company of the above mentioned Brig Palin, whereof I H. Mitchell is at present Master, have produced to me proof in the manner directed in the Act entitled "An Act for the Relief and Protection of American Seamen," And pursuant to the said Act and to the Act Supplementary to the Act concerning Consuls and Vice-Consuls, and for the further protection of American Seamen,

I do hereby certify, that the said

Persons  
above named

John H. Miller  
Collector

are citizens of the United States of America.

Given under my hand and Seal of Office, this

18th day of

Novr 1834

Milling Cole  
COO

Brig Palin  
Sept 15th  
1835

1834

EP NOTE PARTICULARLY—For use of aliens who admitted BEFORE June 20, 1906.

FACTS FOR PETITION FOR NATURALIZATION

Clerk of court and applicant should read these instructions carefully.

Clerk of court should refer to specific petition for alien so admitted in the United States after June 20, 1906, until certificate of arrival is furnished the clerk by the Bureau of Immigration and Customs, or the alien so admitted arrives at Portland, Maine, (see note at the beginning.)  
A copy of this form may be had from the Clerk of Court, or by application for petition for naturalization who arrived in this country on or before June 20, 1906, as that he can get his license to fill out the questions.

The alien should file his petition for of him before he commences to fill out the petition.

No fee is charged for this blank or for the expenses incurred by the cost of stamping.

Witness must be citizen of the United States. If any witness is a natural citizen, he must take his certificate of citizenship, or so-called second paper, to the court when the petition is filed, and also when it is heard by the court.

My name is Robert Stobie, also known as Robert Stobie.

1. My place of residence is 83-1/2 Deers, Bar Harbor, County, State, Territory, or District.

2. My present occupation is Seal hunter.

3. I was born on the 29 day of October, 1855 at Doroshis grodno, Russia.

4. I emigrated to the United States from Premar (country) on or about the 18 (day of August, 1865) and arrived in the United States at the port of Castro, Jamaica.

5. On the 10 day of September, 1905, on the vessel Widmaw, (name of vessel when she left), Switzerland, (place of birth) my certificate of immigration was issued to me.

6. I declared my intention No. 193 to become a citizen of the United States on the 15 day of December, 1905.

at Bar Harbor in the Court of In the name entered above.

(The petitioner certifies that he was of age when above signed, whereupon he shall sign his name in this space. He may file his petition for naturalization at any time.)

7. I am married. My wife's name is Gied. (Whether it is known, shall the name of wife when born, and state place of birth and fact of her death if deceased, be entered "not" in first column.)

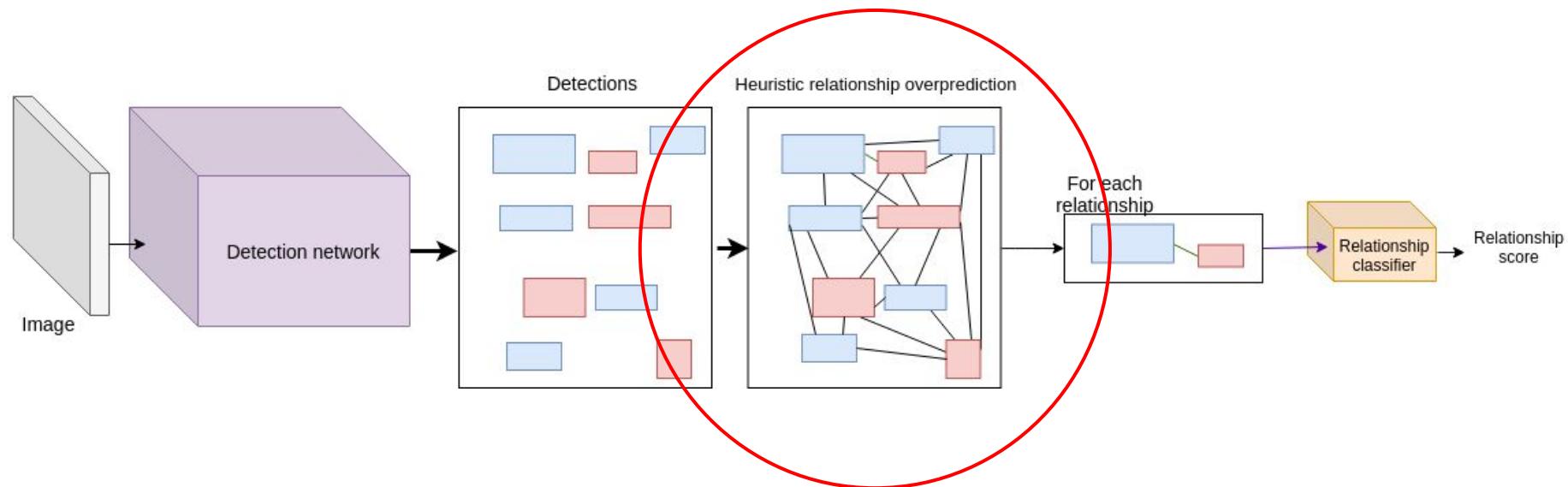
She was born in Prussia on the 18 day of January, 18, and now resides at Bar Harbor. County (State and street). (City or town) (State or country).

I have 1 children, and the name is John Stobie. Date and place of birth, and place of residence of each said children is as follows:

born day of 1 at ; resides at

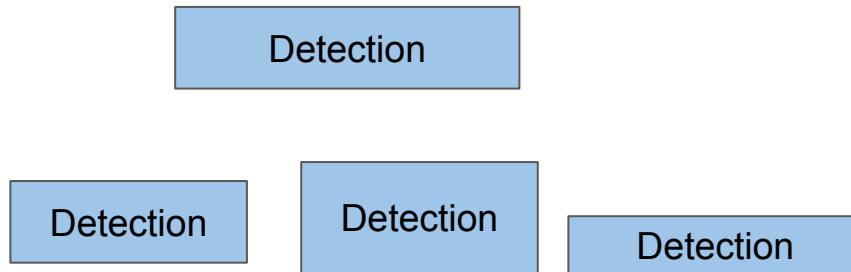
</div

# Method



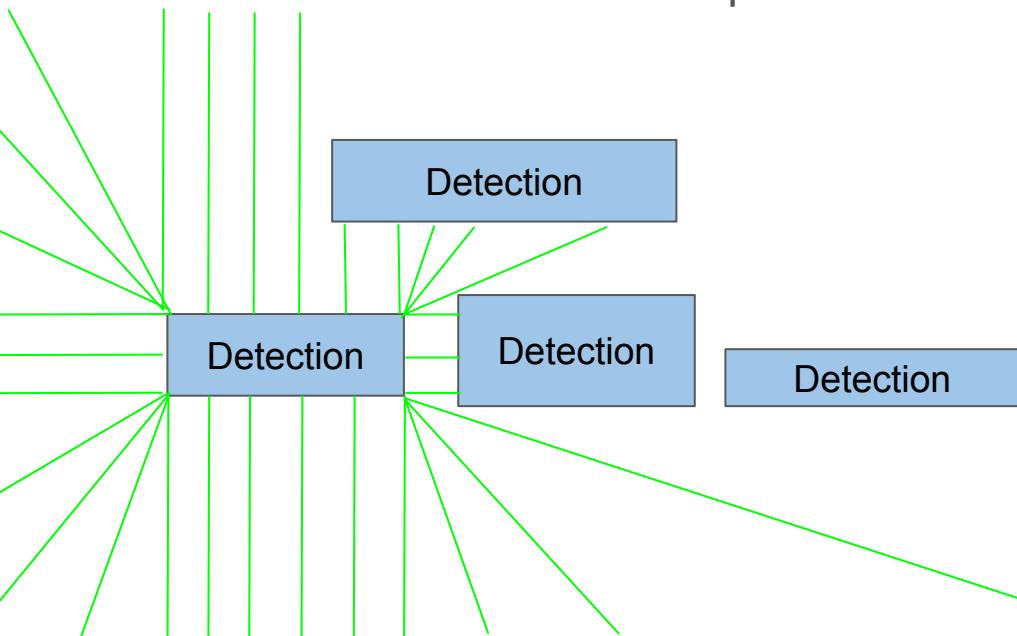
# Heuristic over pairing

- Rather than considering every possible pairing, we only consider a pair between detections that are within line-of-sight.
- +0.99 recall on relationships



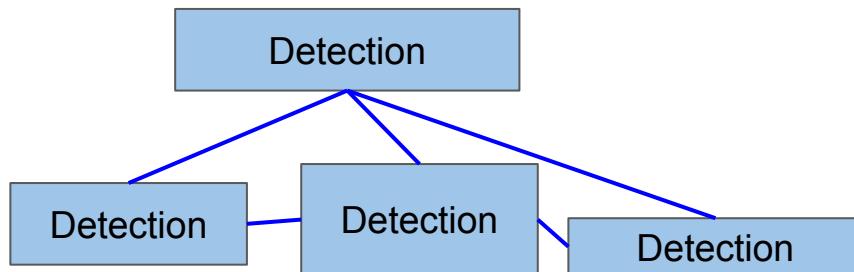
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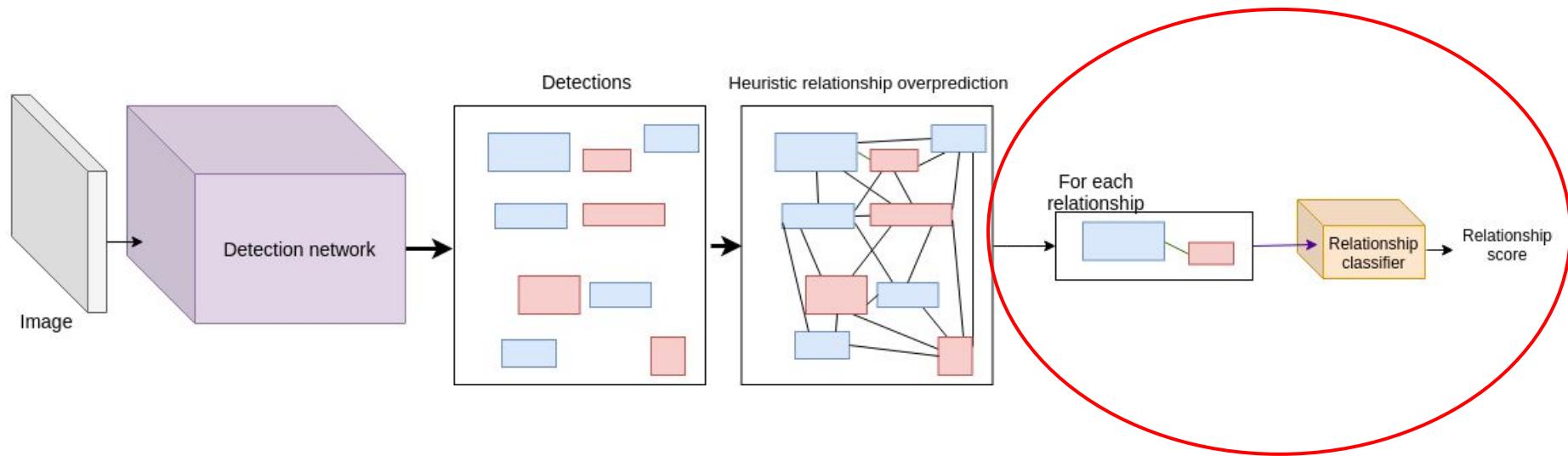


# Heuristic over pairing

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# Method



# How to determine relationships?

- Nearest neighbor of opposite class
  - Simple, but definitely not optimal

# How to determine relationships?

- Nearest neighbor of opposite class
- Heuristic scoring functions (borrowed from Hirayama et al. “Development of template-free form recognition system”)
  - Average of three functions
    - It's too the left
    - Same height
    - Not too far apart
  - Better, but still not optimat

# How to determine relationships?

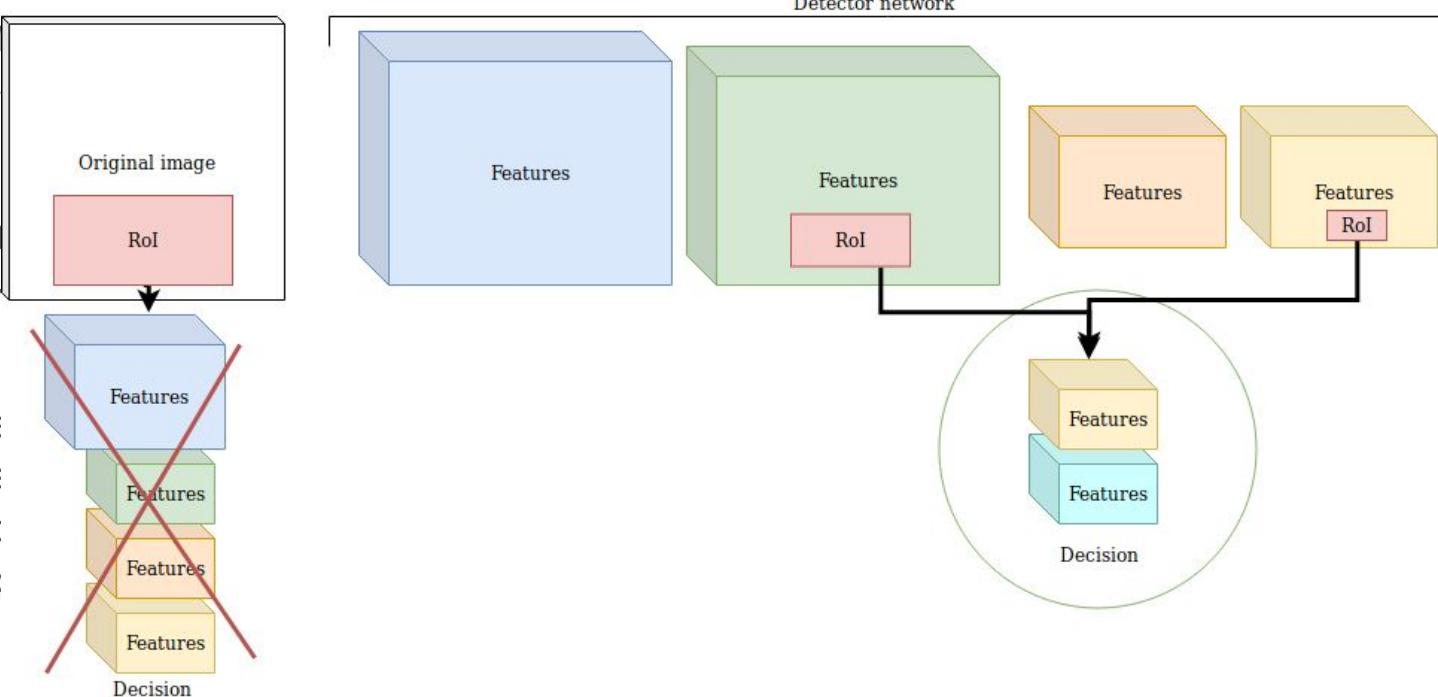
- Nearest neighbor of opposite class
- Heuristic scoring functions(borrowed from Hirayama et al. “Development of template-free form recognition system”)
- Why not learn heuristic rules? Give shapes and distances as features to machine learning classifier (neural network)
  - Heights, widths, x-offset, y-offset, distances of each corner
  - Two hidden fully connected layers, ReLU, batch norm
  - Trained from detector output

# How to determine relationships?

- Nearest neighbor of opposite class
- Heuristic scoring functions(borrowed from Hirayama et al. “Development of template-free form recognition system”)
- Why not learn heuristic rules? Give shapes and distances as features to machine learning classifier (neural network)
- Let us see!
  - Why not use a convolutional network look at the potential relationships?
  - RoIAlign features from detector network (reusing features)
  - Small convolutional network trained with binary cross entropy
  - Detector is pre-trained, them fine-tuned as classifying network trains.

# How to determine relationships?

- Nearest neighbor
- Heuristic scoring
- template-free
- Why not learn
- machine learning
- Let us see!
  - Why not use
  - ROIAlign feature
  - Small convc
  - Detector is p



# Optimization

Pairing decisions should depend on each other.

We frame this as an optimization over all relationships, given a prior of how many neighbors/relationships each detection should have

## Venenatis tellus in metus vulputate

Cras semper auctor neque vitae tempus quam pellentesque nec nam. Adipiscing elit  
duis tristique sollicitudin nibh sit amet.  
Faucibus a pellentesque sit amet porttitor  
eget dolor morbi. Ipsum suspendisse  
ultrices gravida dictum fusce.

Ut enim:

Lorum ipsum dolor

ad minim:

Excepteur

Veniam:

Quis nostrud:

Cius sed felis

Semper:

Excepteur

Feugiat nibh:

Velit aliquet

Pulvinar proin:

1998

Gravida hendrerit:

Nulla 25<sup>th</sup>

Volutpat:

At auctor urna 2019

Vivamus at augue eget arcu dictum varius  
duis at. Sit amet dictum sit amet justo donec  
enim diam. Id donec ultrices tincidunt arcu  
non sodales neque sodales. Mi proin sed  
libero enim. Sit amet cursus sit amet dictum  
sit amet justo donec. Sodales neque  
sodales ut etiam. Morbi leo urna molestie at  
elementum eu facilisis. Tristique sollicitudin  
nibh sit amet commodo nulla. Sed egestas  
egestas fringilla phasellus faucibus  
scelerisque eleifend. Risus pretium quam  
vulputate dignissim. In ante metus dictum at  
tempor commodo ullamcorper a. Sed risus  
ultricies tristique nulla aliquet enim tortor at.  
Duis ut diam quam nulla. Auctor eu augue  
ut lectus. Ullamcorper morbi tincidunt ornare  
massa eget. Platea dictumst quisque  
sagittis purus sit amet volutpat consequat.

Lacinia Quis

Viverra

Sed egestas

Hendrerit Grinda

Sed egestas

Vestibulum

Sed egestas

Clement Justo

X

Feugiat

Sed egestas

# Optimization

Intuition: We want to pick relationships ( $x_r$ ) with high probability ( $p_r > 0.5$ ), but we don't want more relationships (sum  $x_r$ ) than we think a text instance has ( $n_i$ ).

$c$  is a constant indicating how much we trust  $n_i$

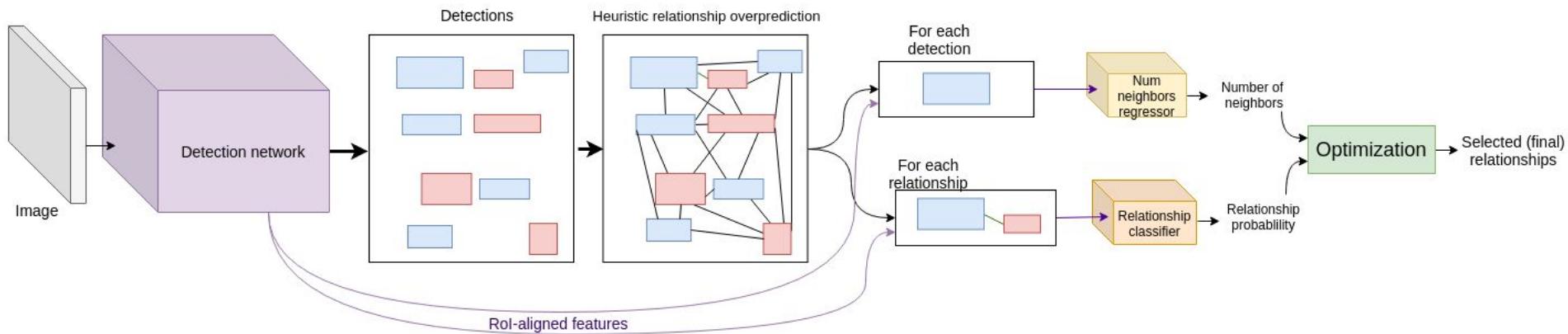
$$\begin{aligned} \underset{X}{\text{maximize}} \quad & \sum_{r=1}^R (2p_r - 1)x_r - c \sum_i^B (n_i - \sum_{x_r \in R_i} x_r)^2 \\ \text{subject to} \quad & x_r \in \{0, 1\}, \end{aligned}$$

# Optimization

We need a prediction of the number of neighbors (generally 0 or 1)

- We can have the detector network predict the number of neighbors (along with class, etc.)
- We can have an additional convolutional network (parallel to relationship classifier) predict the number of neighbors

# Method



# Results for Label-Value pair finding

	mAP	mAP with optimization
Nearest neighbor	0.197	0.243
Heuristic rules	0.244	0.243
Blind network	0.325	0.349
Full/visual network	0.566	0.566

True positive occurs when both detections have  $>0.5$  IoU with ground truth bounding boxes and there is a true relationship between them.

TREASURY DEPARTMENT,  
U. S. Public Health Service  
Form 1979.

MEDICAL CERTIFICATE.

Port of	Boston	1879
Name,	Oliver Kundi	
Age,	33	Sex, m
Nat.,	Norway	Native 15
Date arrival,	11-11-19	
S. S.	Wamanda	
Class,	Passenger manifest No.	

This is to certify that the above-described person has this day been examined and is found to be afflicted with:

Sacral disease  
Arthritis may  
require treatment  
which may affect ability  
to earn a living.

Surgeon.  
G. J. Murphy Surgeon.  
Surgeon.

2-1630

Admitted U.S.A.

PRIMARY INSPECTION MEMORANDUM  
REGD. NO. \_\_\_\_\_  
Department of Commerce and Labor  
U. S. IMMIGRATION SERVICE

Date \_\_\_\_\_  
Name \_\_\_\_\_ Murphy  
Age 33 Sex Married Single  
Occupation Locomotive  
Able to read? Yes  
Nationality Norwegian  
Race White

Last permanent residence Canada  
Name and complete address of nearest relative or friend in country of last permanent residence  
Alphonse Godfrey  
Destination Boston  
Ticket No. \_\_\_\_\_  
Amount of money carried 1000 Dollars  
Breath test \_\_\_\_\_  
Date of last departure from U.S. 1908

Going to join whom?  
Relative Name Friend  
Address Street

Whether under contract 70  
Condition of health Good  
Landing:  
Port \_\_\_\_\_  
Date \_\_\_\_\_  
Steamship \_\_\_\_\_

New York Branch Freedmen's Union Commission

TEACHER'S SCHOOL REPORT,  
For the Month of May 1869

Name and Location of School "Brunswick Co" - Lawrenceville, Ga.  
When opened September 25th 1865 to close June 30th 1869  
Number of Teachers Four White 2 Black 0 Northern 2 Southern 0  
By whom the Teachers are employed by New York Branch Freedmen's Union Commission  
Number of Days Kept Twenty Sessions per day Two Length of Sessions Six hours  
Number of Pupils enrolled 67 Boys 42 Girls 56 White 1  
Number of Pupils enrolled at last report One hundred & two (102) Boys 42 Girls 56 White 1  
Number left School and removed eight (8)  
Number of new Pupils this month three (3)  
Number always present 34 Always Present 26 Average Attendance 66  
Number over 10 years of age 11 Under 10 2  
Number of Pupils paying tuition 26 Amount paid to you this month 736  
Number in Reading and Penmanship 16 In 1st or 2nd 21 3rd 16 4th 20 5th 11  
Number in Mental Arithmetic 181 eighty one  
Number in Written Arithmetic 60 In 2d or 3d 60 In 4th 0  
Number in Geography 61 In 3d or 4th 14 In 5th 8  
Number in Grammar 144 forty four  
Number who write on Slates 61 In Books 20  
Number at Needwork 0  
Is your School graded? This How many grades? Two  
Have you a Sunday School Yes Number of Pupils 112 Of Teachers 6  
Have you a Class in Sunday School Yes Number of Pupils 35  
Have you a High School No Number of Pupils 0 Of Teachers 0  
Have you a Class in High School No Number of Pupils 0

Each blank should be filled with a number or cipher, and the Report forwarded as soon after the first of the Month as possible. Remarks, in letter form, to be made by the teacher on the third page of this sheet.

# Conclusion

- Trainable method for detecting pre-printed text and input writing
- Trainable method for determining relationships
  - Outperforms heuristic baselines
- Method is language agnostic
  - Reading text may help in pairing
- This is one piece of a bigger problem

# Thank you!

Questions?