Fully Convolutional Neural Networks for Page Segmentation

Seth Stewart, BYU

Overview

1. **What is Page Segmentation?**
2. Neural Network Architectures for Page Segmentation
    a. (How to build your own Neural Network for a Document Pixel Labeling task)
3. Handling overlapping content in document images
4. A natural extension to OCR
5. Challenges and Frontiers

Page Segmentation

The novel that launched the Beats, the hippies and designer jeans turns 50. But this legendary 'joyride' is actually the saddest book you'll ever read—even with God on every page. Time for another look.

Rules

BY DAVID GATES

JACK KEROUAC'S "ON THE ROAD" GETS THE FULL 50TH anniversary treatment next month, and both cheerleaders and hand-wringers acknowledge that it radically changed American culture—somehow or other. True, the National Quiet Desperation Index has only risen since 1957, and if the book's exaltation of junker cars and diner food had really taken hold, we''d have fewer SUVs and fast-food franchises. But "On the Road" showed, and continues to show, generations of young readers a more intense, more passionate—and more closely examined—life. Some who've busted out to live it themselves died on the streets. Others have refreshed the American sensibility, in music, art, fashion, or in simply learning to kick back and take pleasure in pleasure. This book has stayed as one of its early readers would say, forever young.

Yet when the novel—which might now be called "creative nonfiction"—appeared, its events were already 10 years in the past. And in 1947, when Kerouac (Sal Paradise in the book) hit the road, the America that obsessed him was already dwindling. Even bebop—apparently the only worthwhile product of modernity—was in decline, from Charlie Parker hot to West Coast cool. Kerouac mostly loved the vestiges of the Great Depression of the '30s: the hobos, hitchhikers, migrant workers and good pals Eddie just trying to get by. "In those days," a cowboy tells Sal, "you'd see hundreds of men riding a flatcar ... all kinds of men out of work and going from one place to another and some of them just wandering ... Brakemen never used to bother you in those days. ... I don't know about today." Paradise lost, in both senses.

America's archetypal literary joyride might be the saddest novel you'll ever read. If you're young enough, "On the Road" can be a liberating, life-changing blast of energy. But its brief years of pure joy and pleasure simply add piquancy to the general lamentation. Near the end of the novel, an apparition with long white hair (maybe a vision, maybe a crazed wanderer) gives Sal the Word: "Go mani for man." He didn't say *German* so.

I've been moaning, too, about this 50th anniversary nonsense. What neat, the 50th anniversary of the 50th anniversary marketing ploy? But I have to admit that, thanks entirely to the publishing industry, "On the Road" once again has my total attention. Viking, the book's original publisher, has issued a "50th Anniversary Edition," which reads just like the edition you could've bought on the 49th anniversary, except for its reproduction of Gilbert Millstein's prescient review in The New York Times of Sept. 5, 1957. Millstein called the novel's publication "an historic occasion"—back then, such an assertion in the paper of record guaranteed it would be preacher—and saw that the book was a search for "affirmation" and "belief." On the other hand, neocon-to-be Norman Podhoretz wrote in Partisan Review that the implicit message of "On the Road" was "Kill the intellectuals who can talk coherently, kill the people who can sit still for five minutes at a time, kill those inconsiderable characters who are capable of getting seriously involved with a woman, a job, a cause." (Was he smoking "tea"?) Over the years, Podhoretz has probably done more for Kerouac's career than Millstein.

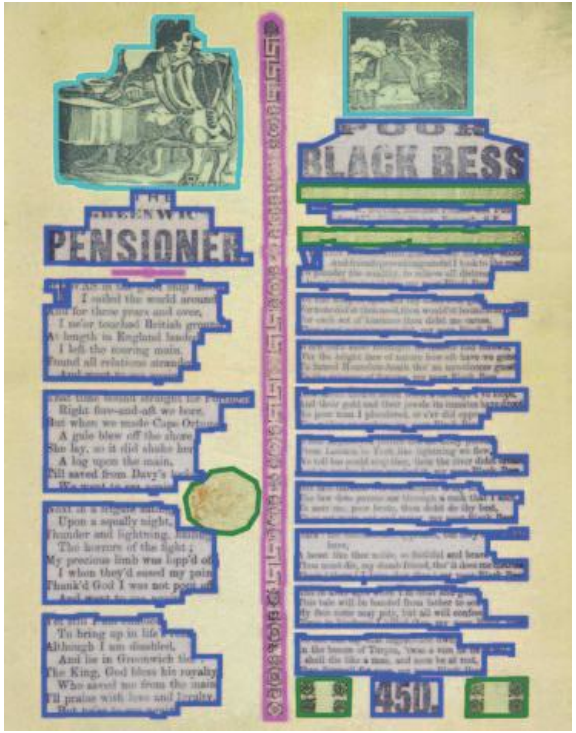
The Library of America will observe the anniversary with a volume of five "road novels": "On the Road" "The Dharma Bums," "The Subterraneans," "Tristessa" and "Lonesome Traveler," as well as a selection of journal entries. (But not the powerful, terrifyingly depressing "Big Sur" compared with which "On the Road" is a joyride.) City Lights Books, the original publisher of Allen Ginsberg's "Howl"—which had its 50th anniversary last year—is putting out "You'll Be Okay," a posthumous memoir by Edie Kerouac-Parker, who served a brief term as Kerouac's first wife—his "life's wife," he said. As usual with his wives, she got time off for good behavior.

Kerouac-Parker never got over "the fulfillment and nemesis of my youth," and she kept memories of the young man who liked to make love in the morning and carried a copy for his erection—"it was the scourge of his vanity." She also had a front-row seat for the previews of the Sal-and-Dean show, which became the front of "On the Road." Neal Cassady, Dean Moriarty in the novel, was the con man, sociopath and holy fool who inspired Kerouac to take to the road, and became Kerouac's own fulfillment and nemesis: the doppelgänger who finally abandoned him and had to be abandoned.

But Viking has the real goods—not just "On the Road" itself, but the hitherto-

SIDE BY SIDE: The author (above, right) once described himself and Cassady as "Catholic buddies."

AUGUST 13, 2007 NEWSWEEK 53



TECHNOLOGIST
Andreas Tzortzis

Steal These Books Online

Paulo Coelho is championing a book-promotion model that is gaining momentum among fellow, if lesser known, authors.

HOLOGRAMS

Pictures That Move In 3-D

To Our Readers

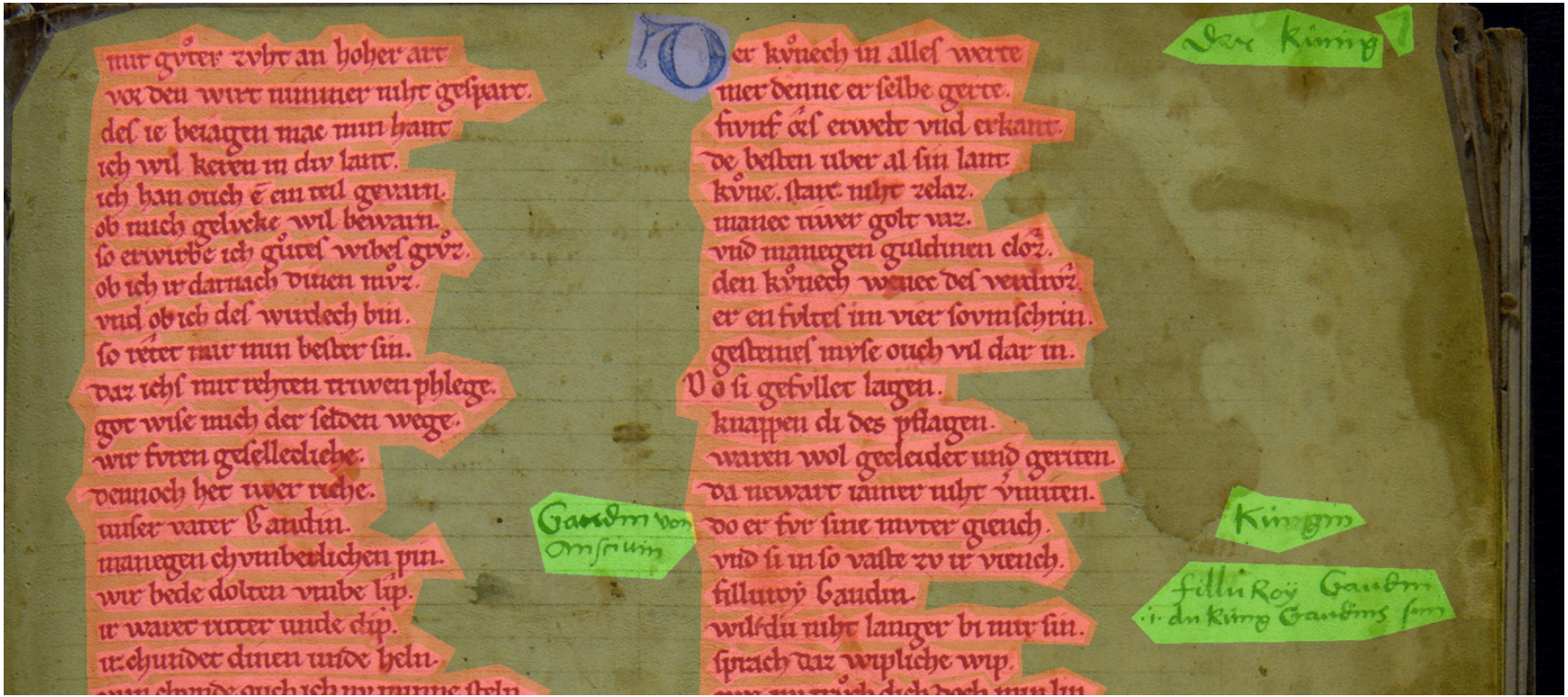
Our Eyes and Ears. One veteran correspondent returns to Baghdad to evaluate the war, and we honor another as she prepares to take her final bow

ICDAR 2009
http://www.cse.salford.ac.uk/prima/ICDAR2009_pscomp/

ICDAR 2011
http://www.primaresearch.org/ICDAR2011_competition/

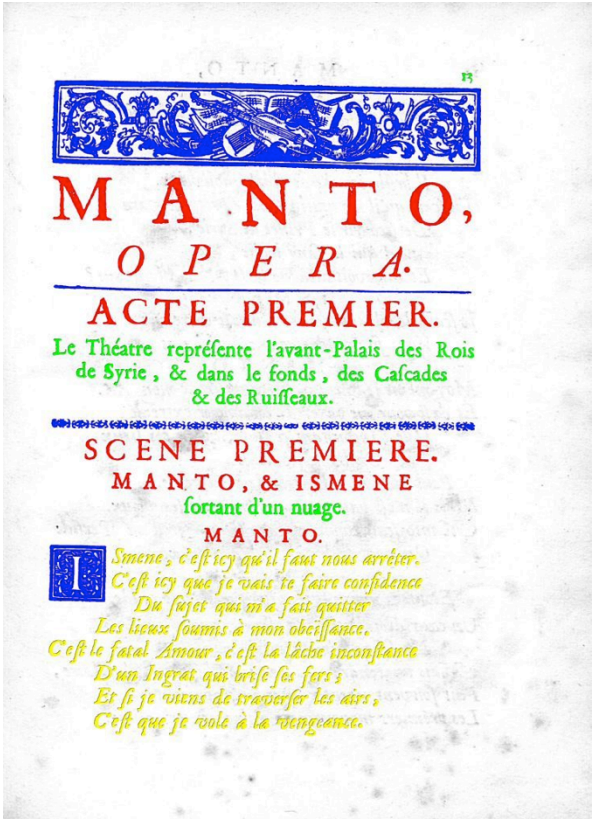
ICDAR 2015
http://www.primaresearch.org/RDCL2015/

Page Segmentation



K. Chen, M. Seuret, H. Wei, M. Liwicki, J. Hennebert, and R. Ingold, “Ground truth model, tool, and dataset for layout analysis of historical documents,” in IS&T/ SPIE Electronic Imaging. International Society for Optics and Photonics, 2015, pp. 940 204–940 204.

Superpixel & Pixel Labeling

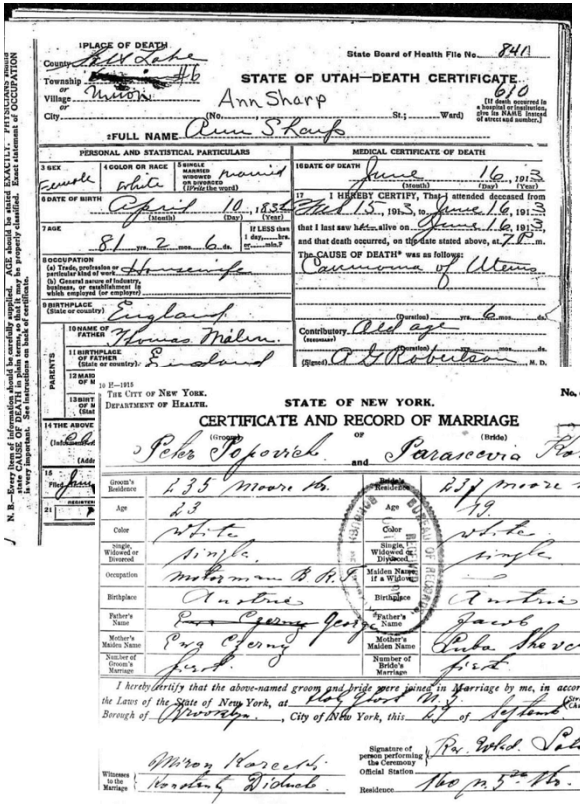


Maroua Mehri, Pierre Héroux, Petra Gomez-Krämer, and Rémy Mullot. 2017. Texture feature benchmarking and evaluation for historical document image analysis. *Int. J. Doc. Anal. Recognit.* 20, 1 (March 2017), 1-35. DOI: https://doi.org/10.1007/s10032-016-0278-y

Maroua Mehri, Pierre Héroux, Rémy Mullot, Jean-Philippe Moreux, Bertrand Coüasnon, and Bill Barrett. 2017. Historical Book Analysis Competition. Organization website. http://icdar2017hba.litislab.eu/index.php/dataset/. Accessed 9 Oct 2017.

Pixels in the Wild

1 billion images @ 12 MP each = 12×10^{16} pixels (**12 Petapixels**)



1919 Ohio Death Record

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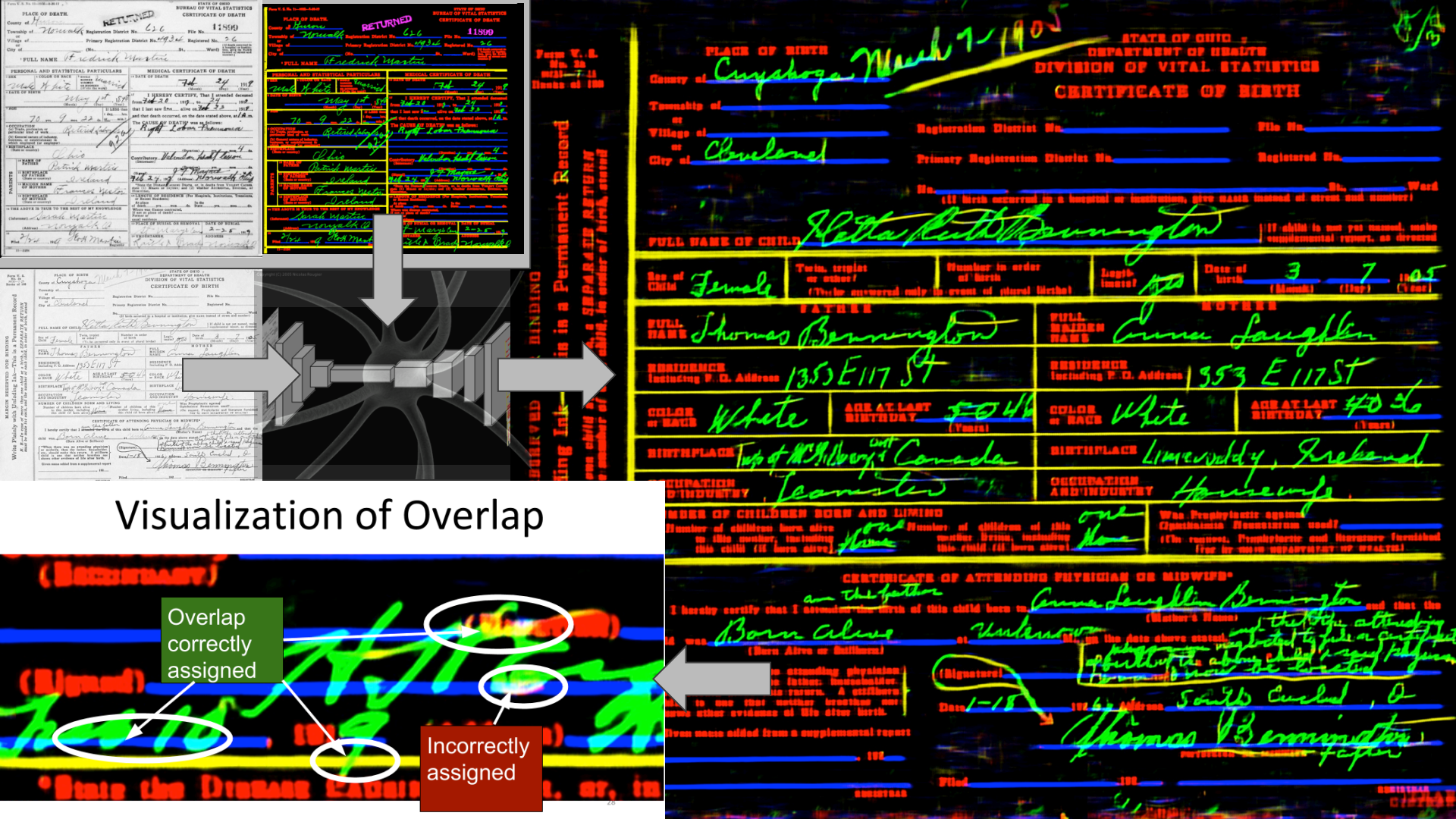
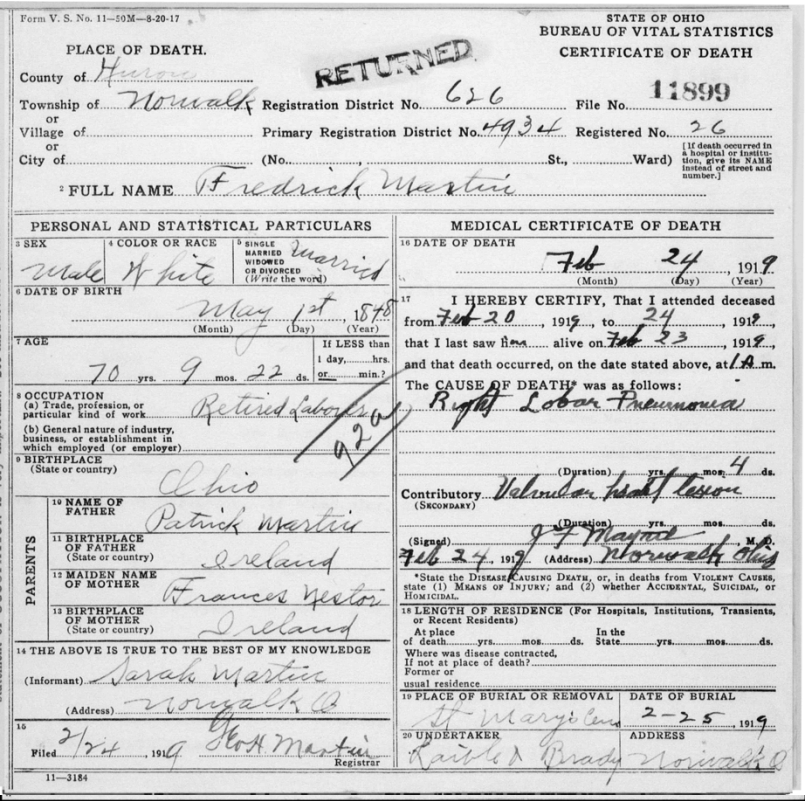

Visualization of Overlap
Overlap correctly assigned
Incorrectly assigned

Ground-Truthing



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.

RETURNED

County of Huron
Township of Norwalk Registration District No. 626 File No. 11899
or
Village of Primary Registration District No. 4934 Registered No. 26
or
City of (No. , St., Ward)

[If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Fredrick Martin

PERSONAL AND STATISTICAL PARTICULARS

3 SEX: Male
4 COLOR OR RACE: White
5 SINGLE, MARRIED, WIDOWED OR DIVORCED (Write the word): Married
6 DATE OF BIRTH: May 1st (Month) (Day) 1848 (Year)
7 AGE: 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.?
8 OCCUPATION (a) Trade, profession, or particular kind of work: Retired Labor
(b) General nature of industry, business, or establishment in which employed (or employer):
9 BIRTHPLACE (State or country): Ohio

PARENTS
10 NAME OF FATHER: Patrick Martin
11 BIRTHPLACE OF FATHER (State or country): Ireland
12 MAIDEN NAME OF MOTHER: Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country): Ireland

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Sarah Martin
(Address) Norwalk O

Filed 2/24 1919 Fred Martin Registrar

11—3184

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH: Feb (Month) 24 (Day) 1919 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 20, 1919, to 24, 1919, that I last saw him alive on Feb 23, 1919, and that death occurred, on the date stated above, at 1A m.

The CAUSE OF DEATH* was as follows:
Right Lobar Pneumonia

(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Voluntary Insufficient Nourishment

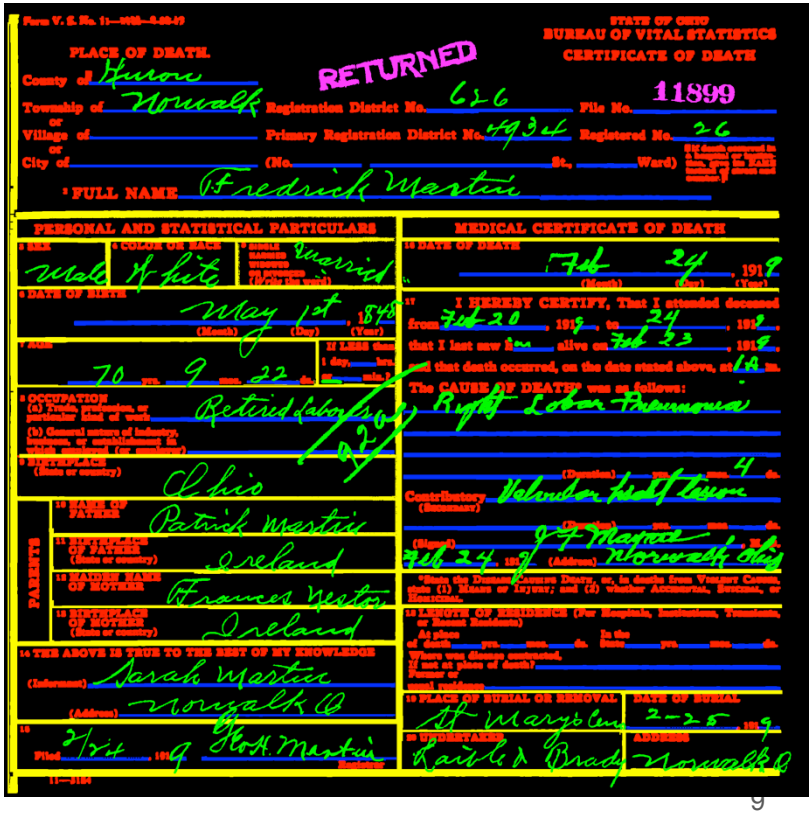
(Signed) J F Maynard M.D.
Feb 24, 1919 (Address) Norwalk Ohio

*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, if not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL: St Marys Cem
DATE OF BURIAL: 2-25, 1919

20 UNDERTAKER: Kaible & Brady
ADDRESS: Norwalk O



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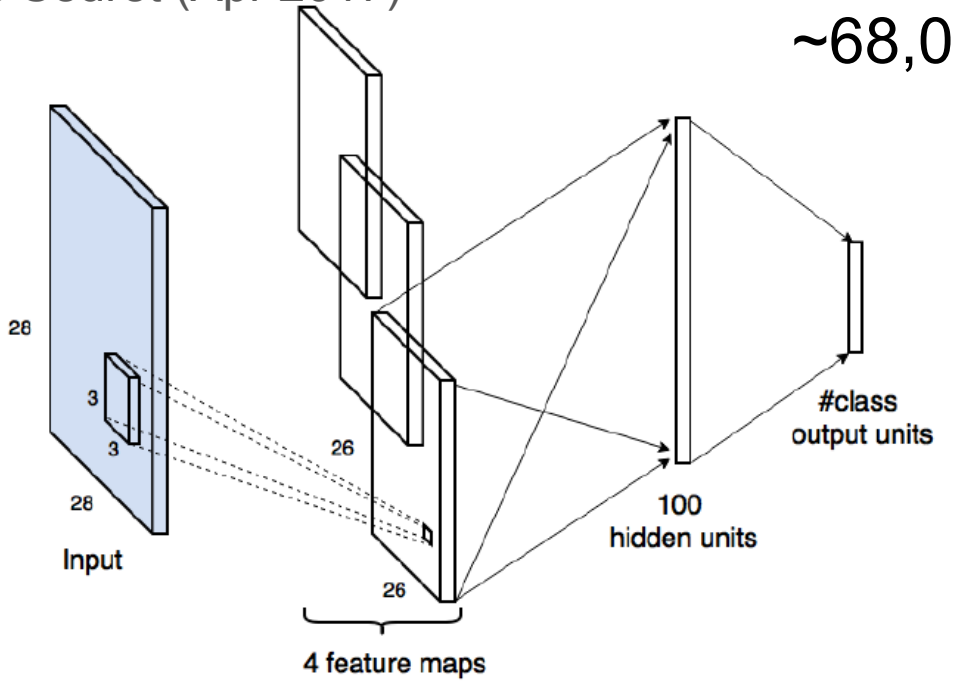
Architectures

By Lorie Shaull (Own work) [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons

Convolutional Neural Networks for Page Segmentation of Historical Document Images

Kai Chen, Mathias Seuret (Apr 2017)

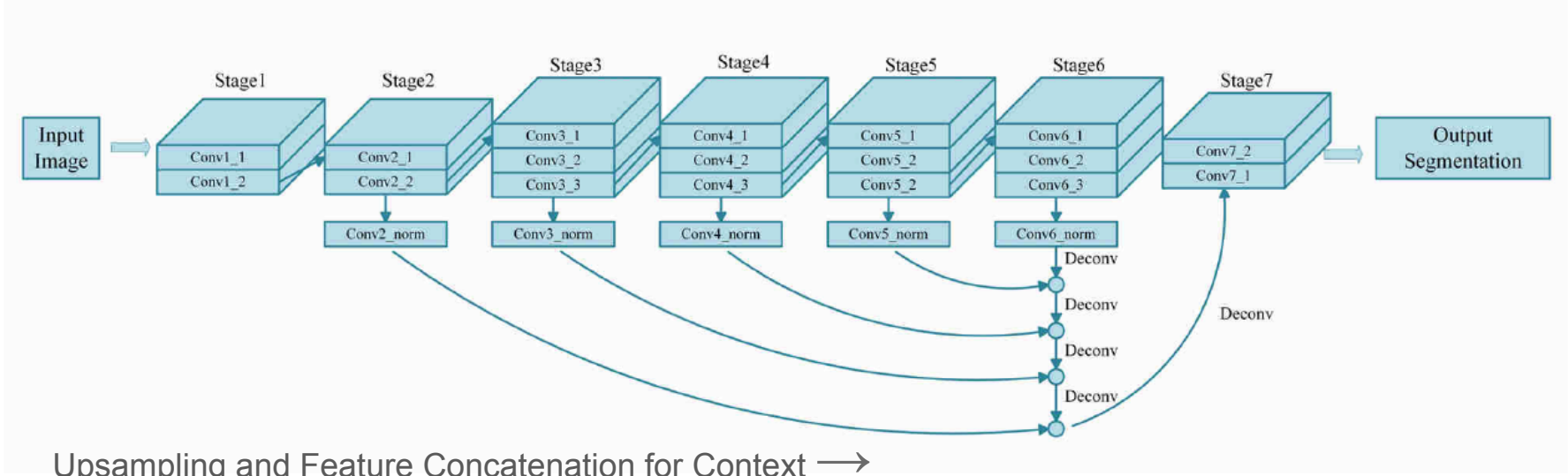
~68,000 parameters



Winners of the ICDAR2017 Competition on Layout Analysis for Challenging Medieval Manuscripts

Based on VGG-16

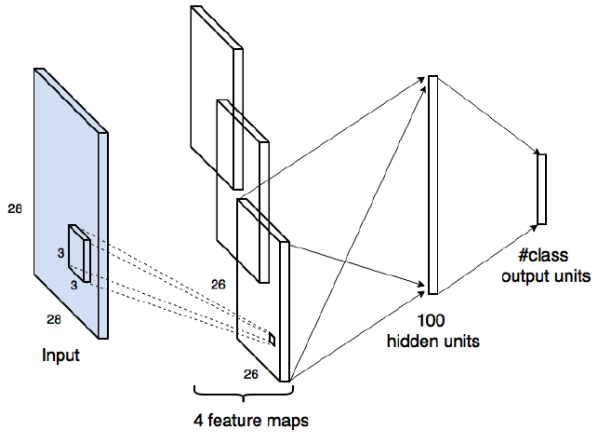
~138 Million parameters!

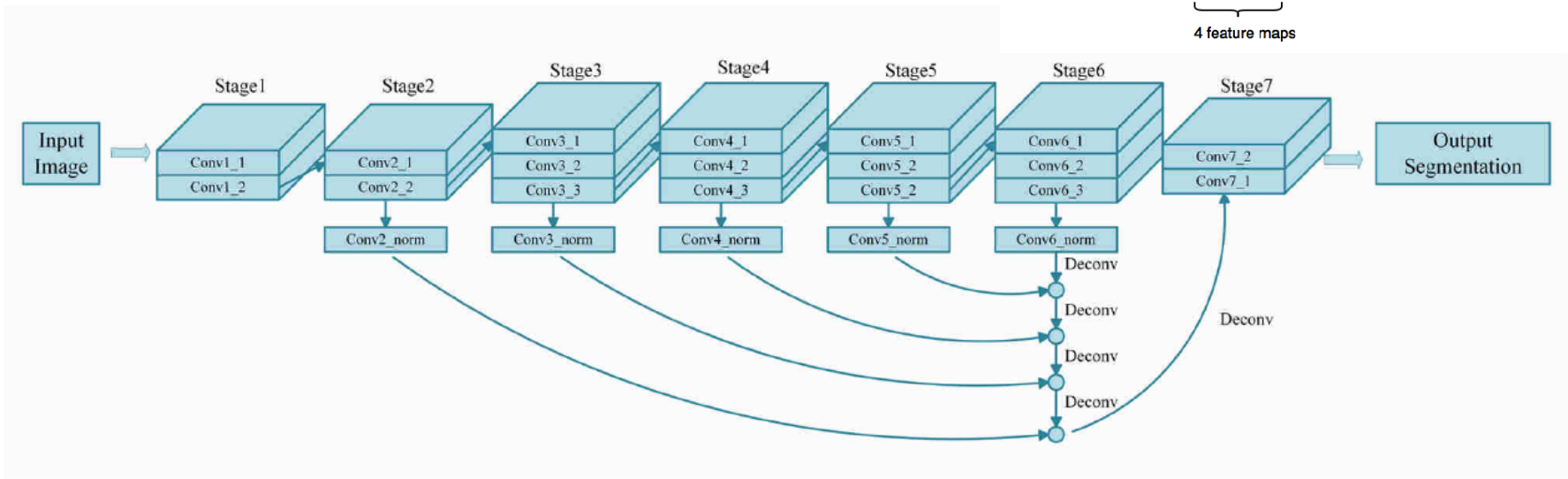


Upsampling and Feature Concatenation for Context ⟶

Which way to go?

138M vs 68K:
2000x difference in # of parameters





We’re caught in a net

DenseNets
https://arxiv.org/abs/1608.06993

ResNets
https://arxiv.org/abs/1611.08323

SqueezeNets
https://arxiv.org/abs/1711.05491

ShuffleNets

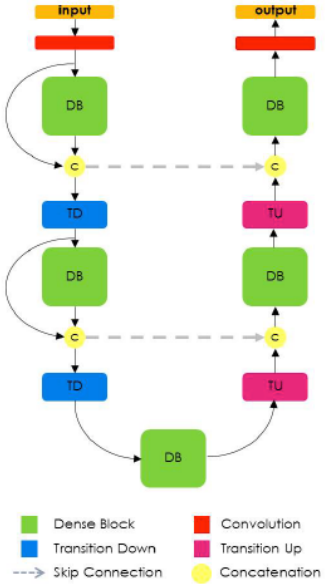
InceptionNets

XceptionNets

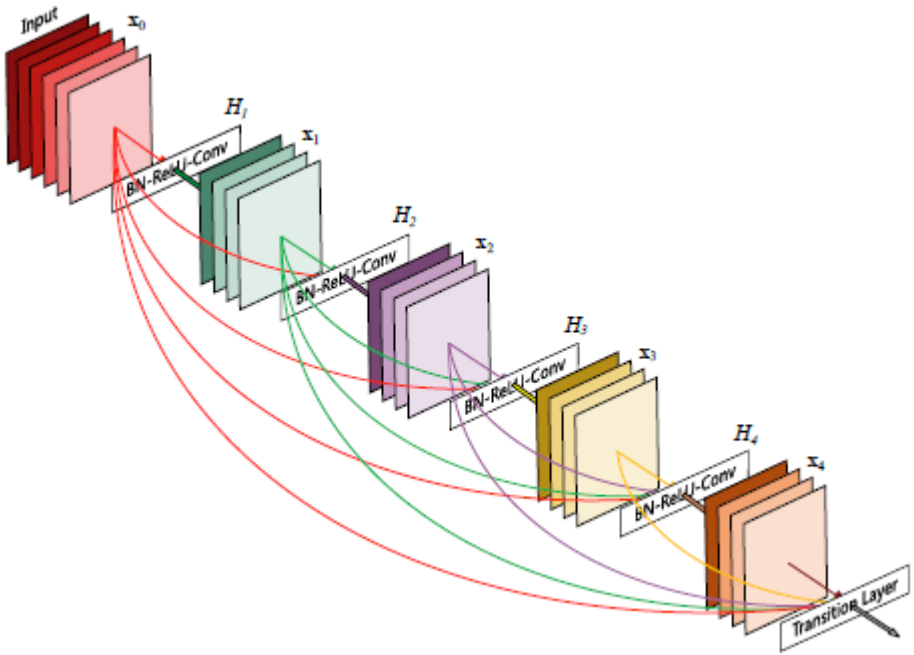
Densely Connected Convolutional Networks

The One Hundred Layers Tiramisu: Fully Convolutional DenseNets for Semantic Segmentation

Layers: Params
56: 1.5M,
67: 3.5M,
103: 10M



10x Reduction!



https://arxiv.org/abs/1611.09326

https://arxiv.org/abs/1608.06993

Historical Book Analysis Competition

Two competitors,

One neural and one not.

Neural method outperformed

Non-neural by

4.79% Weighted F-Measure

11 Books,

61-98% WFM per book

https://dl.acm.org/citation.cfm?id=3151528

PRIMO.

Fermar sentono i moti a poco a poco,
E l'onde ritornar a esser equali,
Sperdesi i mostri, ogni suo furor fioco
Restar, venti fuggir con placid'ali,
Rassenerar il Ciel, mostrar il fuoco,
Ch'il mondo adorna, e tutti noi mortali,
Chinando al basso il ben bagnato crine,
Gratie rendean a Dio del lieto fine.

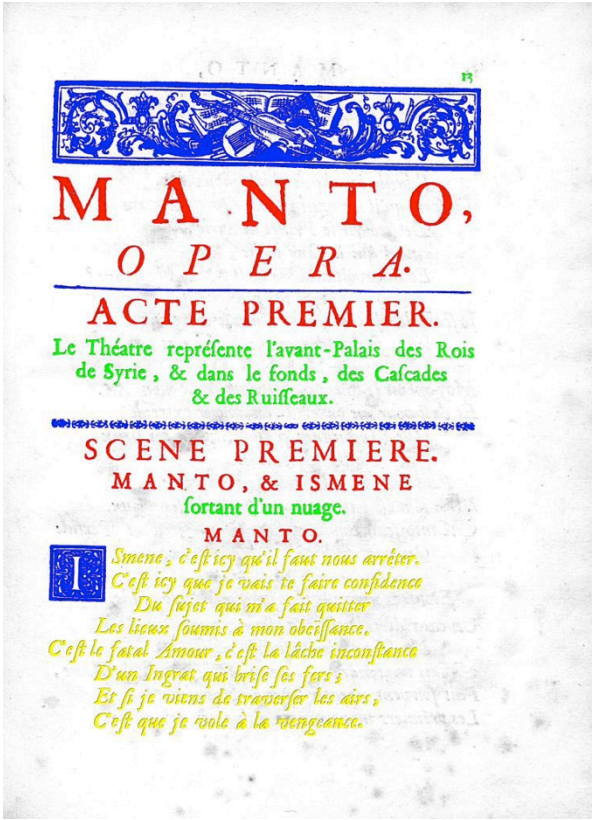
IL FINE DEL PRIMO CANTO.

ARGOMENTO.

Consola la sua madre, e li promette
Christo quel mondo, e a la Spagnuola addotto
Il buon Rè doloroso, & ansio stette,
Che quattro naui a lui mancar fu dotto:
Cleante ritrouò il Colombo, e strette
Pugne oprò co i Caribi, e al mar ridotto,
Pietro, e Martin, e Vasco vede, e al fiume
E tratto pel mancar d'Illithia il lume.

ARGOMENTO DEL SECONDO CANTO

Si lamenta la Beata Vergine col suo Figlio, che i Christiani siano tanto trauagliati, a cui ridendo il Figlio, li promette liberamente, che quel Mondo serrà suo; & giunto a capo dell'Isola Spagnola lo Rè, ritroua mancar quattro naui, per cui cercar spedisce il Colombo, qual andando uers' Austro, ritroua Cleante col Padre morto andar notando per lo mare sopra un'asse, Dipoi combatte con i Caribi, e sonno molti uccisi, & li uarra uno, che in spiaggia della lor Isola hauea trouato la natura loro, ch'era di mangiar gl'huomini. Di poi ritroua Pietro d'Auila e compagni in un legnetto. Scopre l'isola delle perle, & il modo di pescarle. Ritroua Martin di Vergara nel Isola della Trinità. Scopre Vasco di Nugnes sopra un legnetto, quale con li compagni era risoluto mangiarsi l'un l'altro per fame, e giunti al fiume Maragnõ, fu discacciato da gl'Indiani, a quali fa intendere, che in quella notte uedrãno segno nel Cielo di tal delitto, quali uedendo Eclissar la Luna, lo richiamano con gran timore.



13

MANTO,

OPERA.

ACTE PREMIER.

Le Théatre représente l'avant-Palais des Rois de Syrie, & dans le fonds, des Cascades & des Ruisseaux.

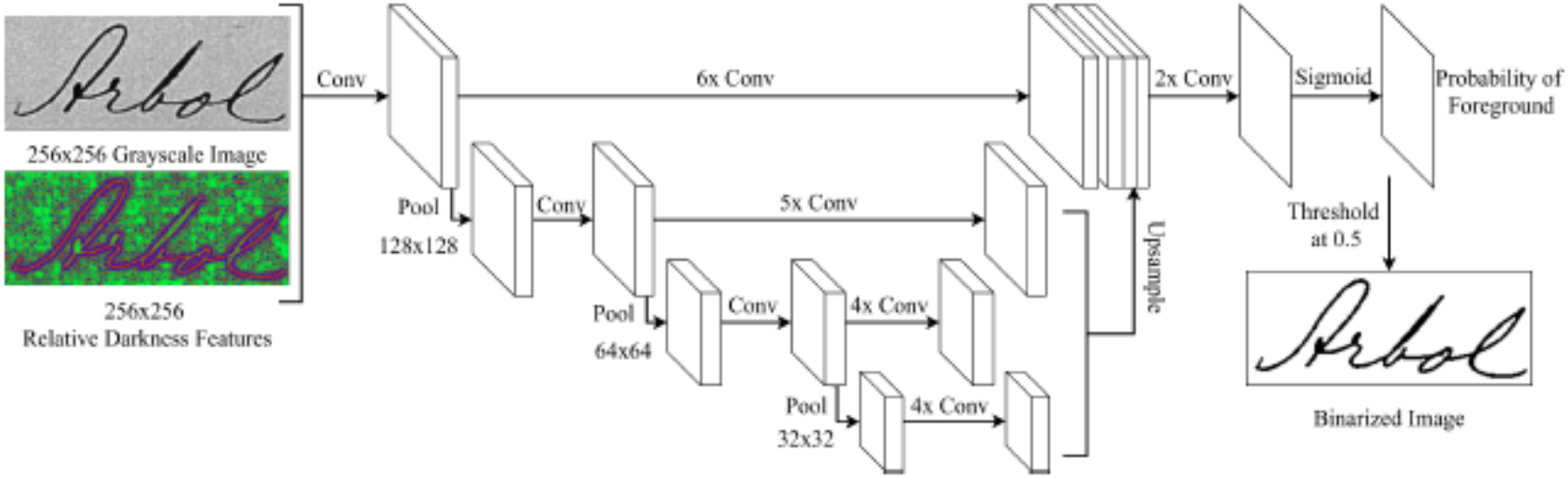
SCENE PREMIERE.

MANTO, & ISMENE sortant d'un nuage.

MANTO.

Ismene, c'est icy qu'il faut nous arrêter.
C'est icy que je vais te faire confidence
Du sujet qui m'a fait quitter
Les lieux soumis à mon obeïssance.
C'est le fatal Amour, c'est la lâche inconstance
D'un Ingrat qui brise ses fers;
Et si je viens de traverser les airs,
C'est que je vole à la vengeance.

Multi-Scale network architecture

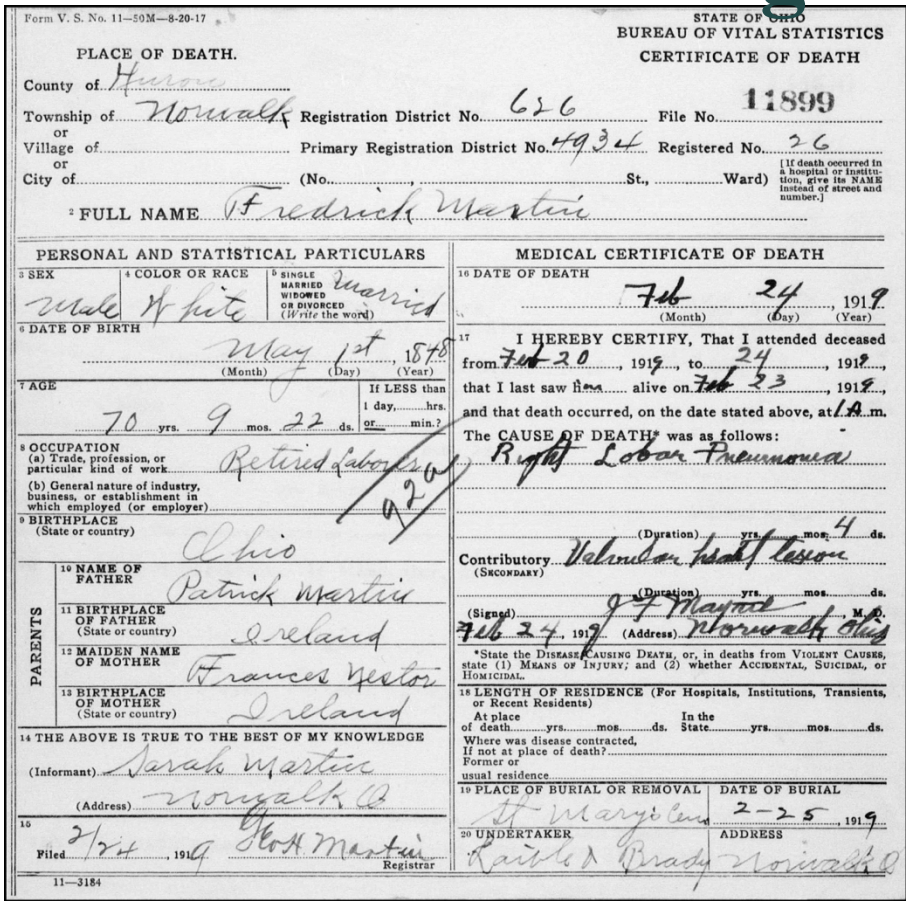


Document Image Binarization with Fully Convolutional Neural Networks

Chris Tensmeyer, Tony Martinez

https://arxiv.org/abs/1708.03276

Back to Form Images



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4 COLOR OR RACE: White
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7 AGE: 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.

8 OCCUPATION
(a) Trade, profession, or particular kind of work: Retired Laborer
(b) General nature of industry, business, or establishment in which employed (or employer):

9 BIRTHPLACE (State or country): Ohio

PARENTS

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11 BIRTHPLACE OF FATHER (State or country): Ireland
12 MAIDEN NAME OF MOTHER: Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country): Ireland

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(Informant): Sarah Martin
(Address): Norwalk O

15 Filed 2/24, 1919 Scott Martin Registrar

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The CAUSE OF DEATH* was as follows:
Right Lobar Pneumonia
(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Valvular heart disease
(Duration) yrs. mos. ds.

(Signed) J F Mayne M. D.
Feb 24, 1919 (Address) Norwalk Ohio

*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

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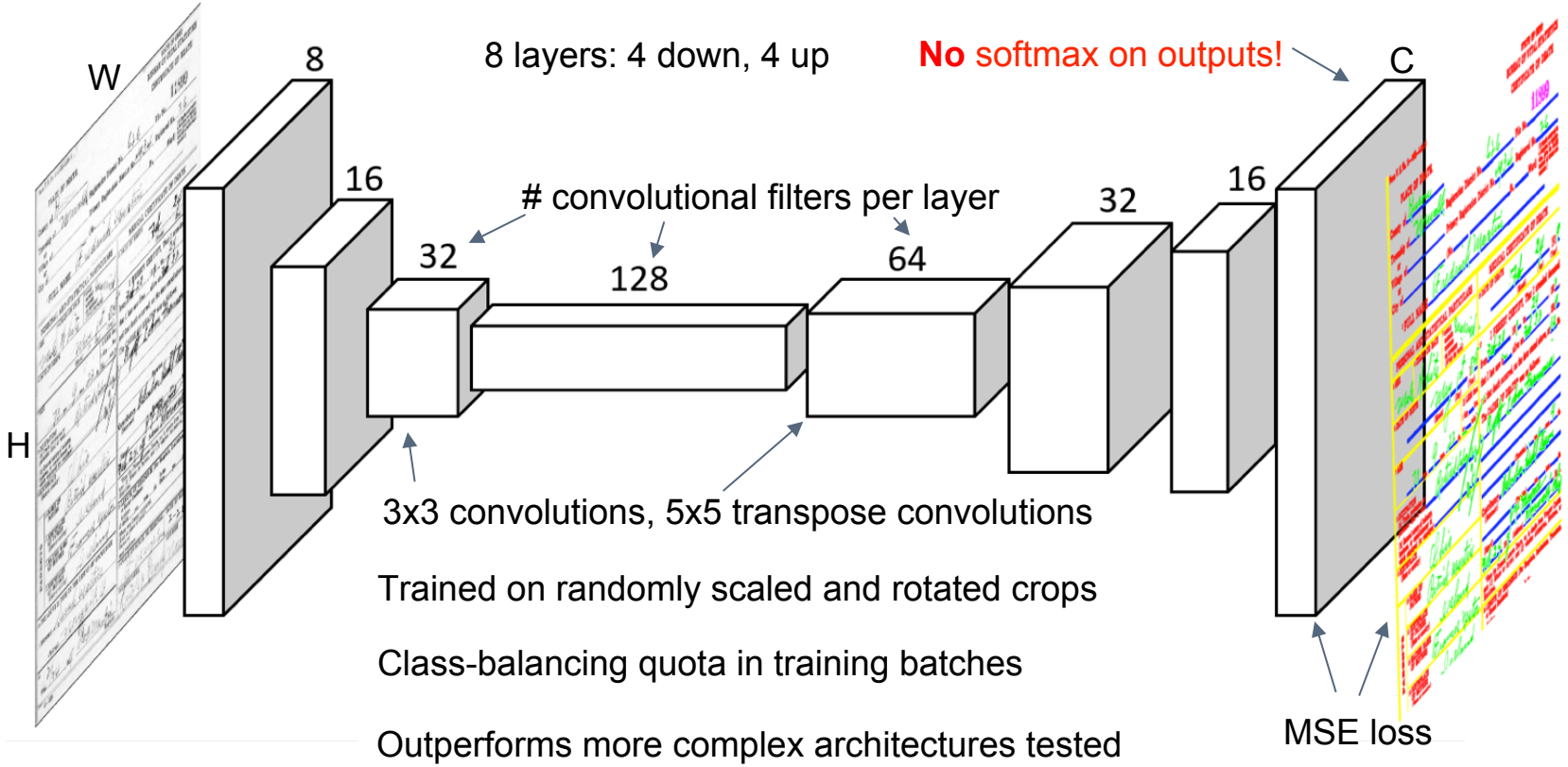
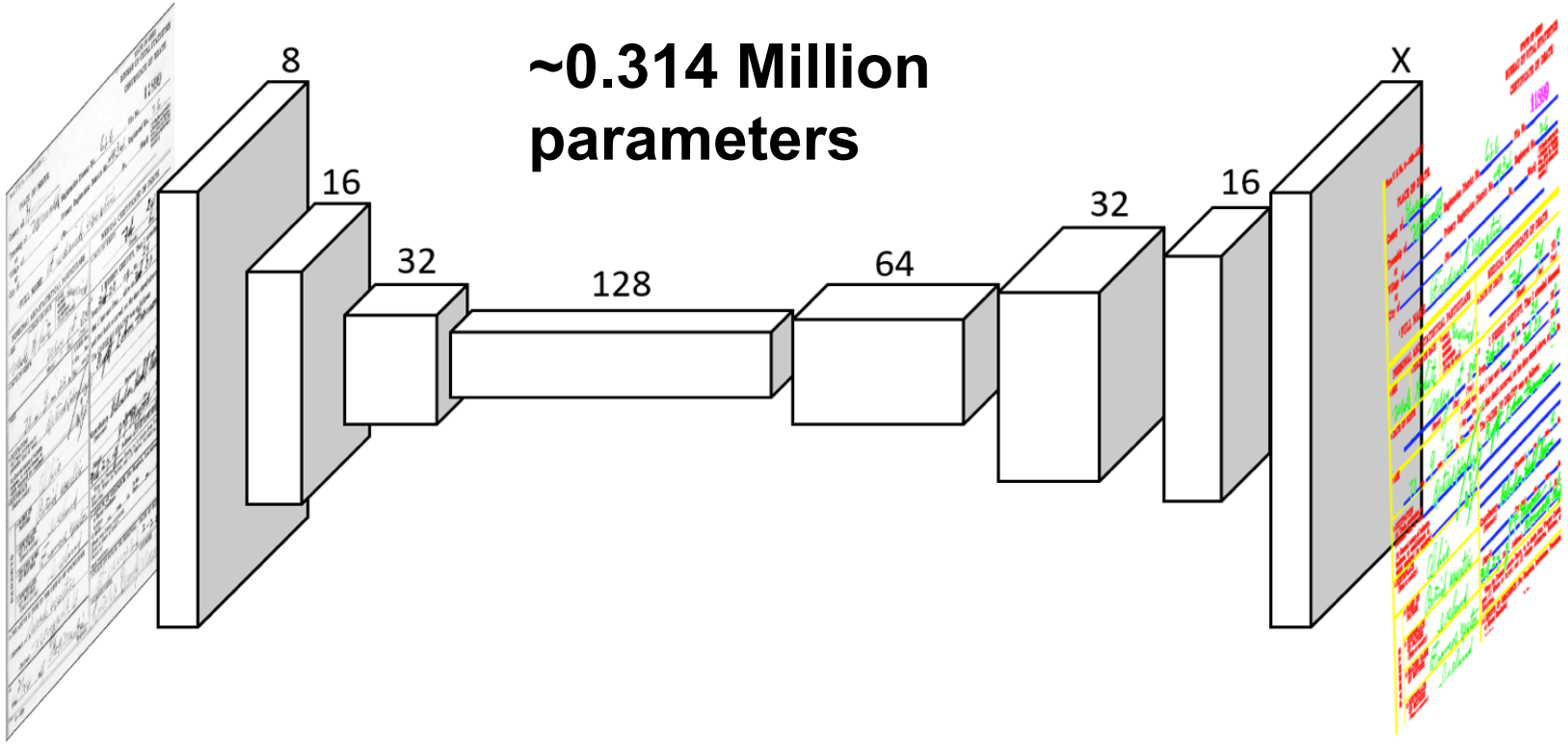
1919 Ohio Death Record

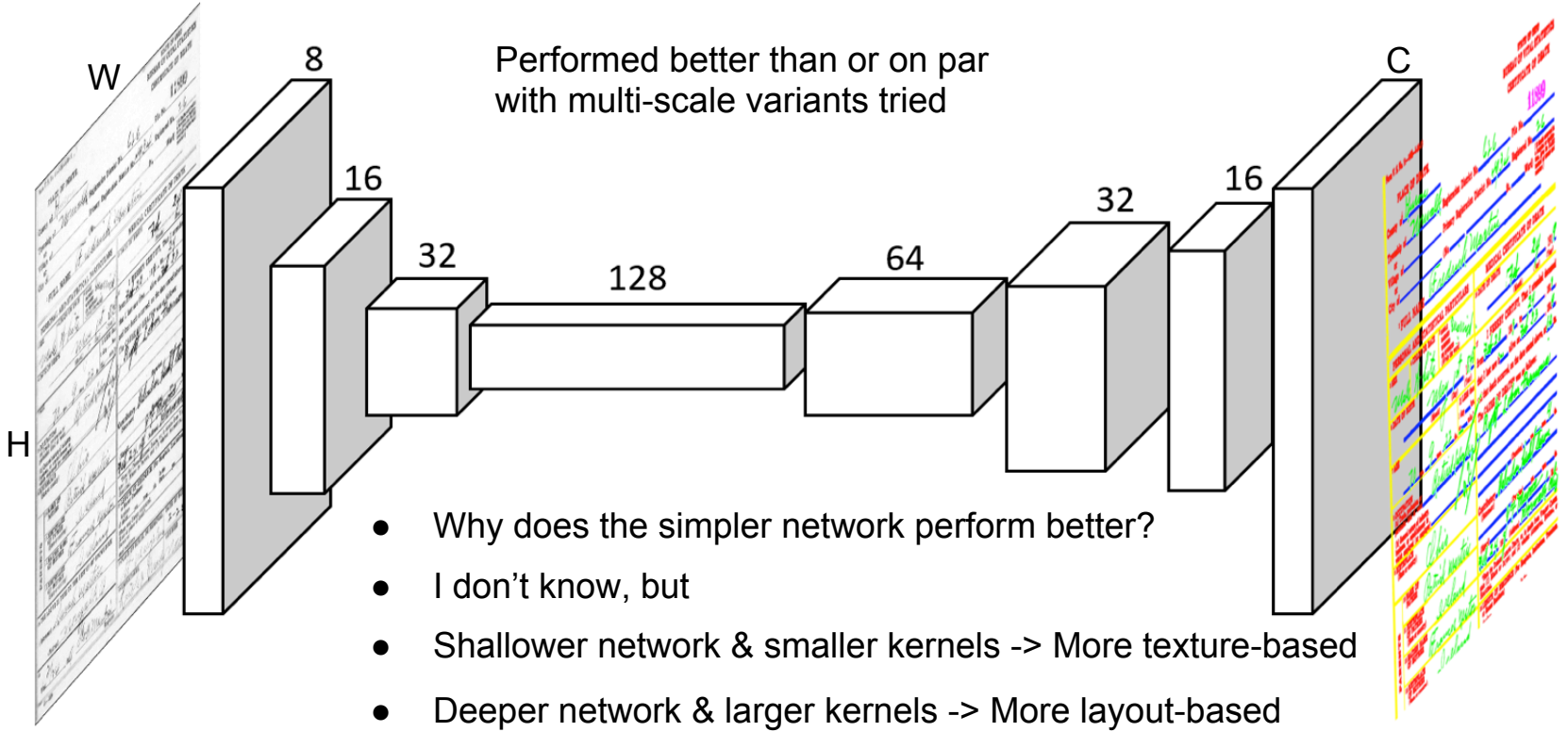
Convolutional Neural Network Architecture



Convolutional Neural Network Architecture



Convolutional Neural Network Architecture



Performed better than or on par with multi-scale variants tried

- Why does the simpler network perform better?
- I don't know, but
- Shallower network & smaller kernels -> More texture-based
- Deeper network & larger kernels -> More layout-based
- Smaller architecture -> Fewer parameters -> Less ability to overfit

Architecture Takeaways

1. Think about the target variables: Do I want Long-term context (logical layout) or local/textural analysis (graphical layout)?
    a. Smaller context can be better for textural, and larger context may be needed for logical, high-level labelings.
2. Document images are very high resolution. Prepare for high throughput.
3. Loss function matters -- you get what you optimize for
4. Training balancing: Include more of what you are worse at, within reason

Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS

CERTIFICATE OF DEATH

PLACE OF DEATH.

County of

Township of
or
Village of
or
City of

Registration District No.

Primary Registration District No.

(No. , St., Ward)

File No.

Registered No.

[If death occurred in a hospital or institution, give its NAME instead of street and number.]

[2] FULL NAME

PERSONAL AND STATISTICAL PARTICULARS

[3] SEX

[4] COLOR OR RACE

[5] SINGLE
MARRIED
WIDOWED
OR DIVORCED
(*Write* the word)

[6] DATE OF BIRTH

(Month) (Day) , 18 (Year)

[7] AGE

yrs. mos. ds.

If LESS than 1 day, hrs. or min.?

[8] OCCUPATION
(a) Trade, profession, or particular kind of work

(b) General nature of industry, business, or establishment in which employed (or employer)

[9] BIRTHPLACE
(State or country)

PARENTS

[10] NAME OF FATHER

[11] BIRTHPLACE OF FATHER
(State or country)

[12] MAIDEN NAME OF MOTHER

[13] BIRTHPLACE OF MOTHER
(State or country)

[14] THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE

(Informant)

(Address)

[15]

Filed , 191

Registrar

11—3184

MEDICAL CERTIFICATE OF DEATH

[16] DATE OF DEATH

(Month) (Day) , 191 (Year)

[17] I HEREBY CERTIFY, That I attended deceased from , 191 , to , 191 , that I last saw h alive on , 191 , and that death occurred, on the date stated above, at m.

The CAUSE OF DEATH* was as follows:

(Duration) yrs. mos. ds.

Contributory
(SECONDARY)

(Duration) yrs. mos. ds.

(Signed) , M. D.

, 191 (Address)

*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

[18] LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)

At place of death yrs. mos. ds. In the State yrs. mos. ds.

Where was disease contracted, if not at place of death?

Former or usual residence

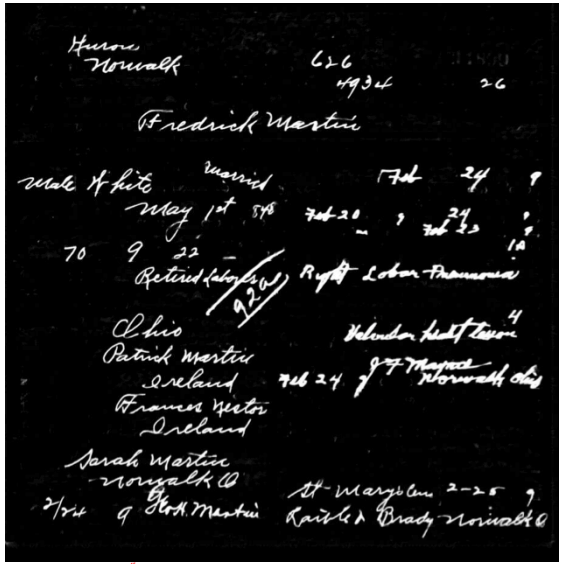
[19] PLACE OF BURIAL OR REMOVAL DATE OF BURIAL

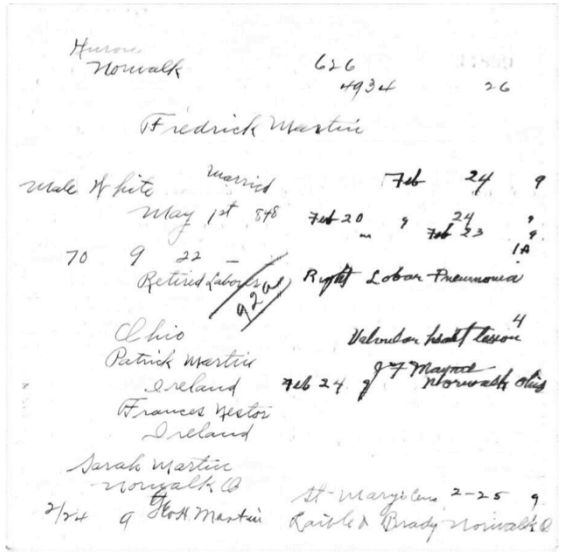
, 191

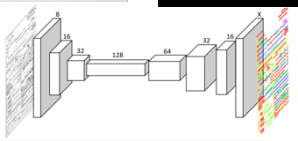
[20] UNDERTAKER ADDRESS

Masking Content Channels

Input * Mask + (255 * 1-Mask) = Masked Image

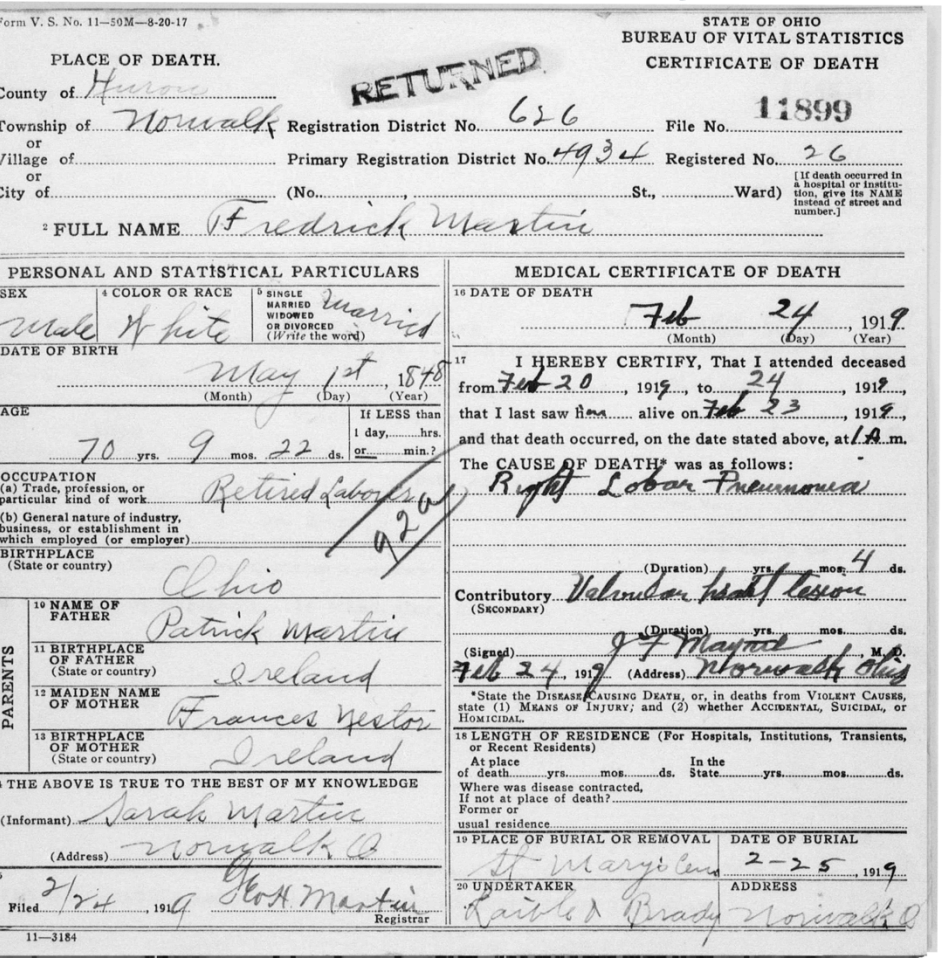






Results

Single Training Image



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.

RETURNED

County of Huron
Township of Norwalk Registration District No. 626 File No. 11899
or
Village of Primary Registration District No. 4934 Registered No. 26
or
City of (No. St., Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Fredrick Martin

PERSONAL AND STATISTICAL PARTICULARS

3 SEX: Male
4 COLOR OR RACE: White
5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word): Married

6 DATE OF BIRTH: May 1st, 1848 (Month) (Day) (Year)

7 AGE: 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.?

8 OCCUPATION
(a) Trade, profession, or particular kind of work: Retired Laborer
(b) General nature of industry, business, or establishment in which employed (or employer):

9 BIRTHPLACE (State or country): Ohio

PARENTS
10 NAME OF FATHER: Patrick Martin
11 BIRTHPLACE OF FATHER (State or country): Ireland
12 MAIDEN NAME OF MOTHER: Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country): Ireland

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Sarah Martin
(Address) Norwalk O

15 Filed 2/24, 1919 Geo H. Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH: Feb 24, 1919 (Month) (Day) (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 20, 1919, to 24, 1919, that I last saw him alive on Feb 23, 1919, and that death occurred, on the date stated above, at 1A m.
The CAUSE OF DEATH* was as follows:
Right Lobar Pneumonia
(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Valvular heart lesion
(Duration) yrs. mos. ds.
(Signed) J F Maynie, M.D.
Feb 24, 1919 (Address) Norwalk Ohio

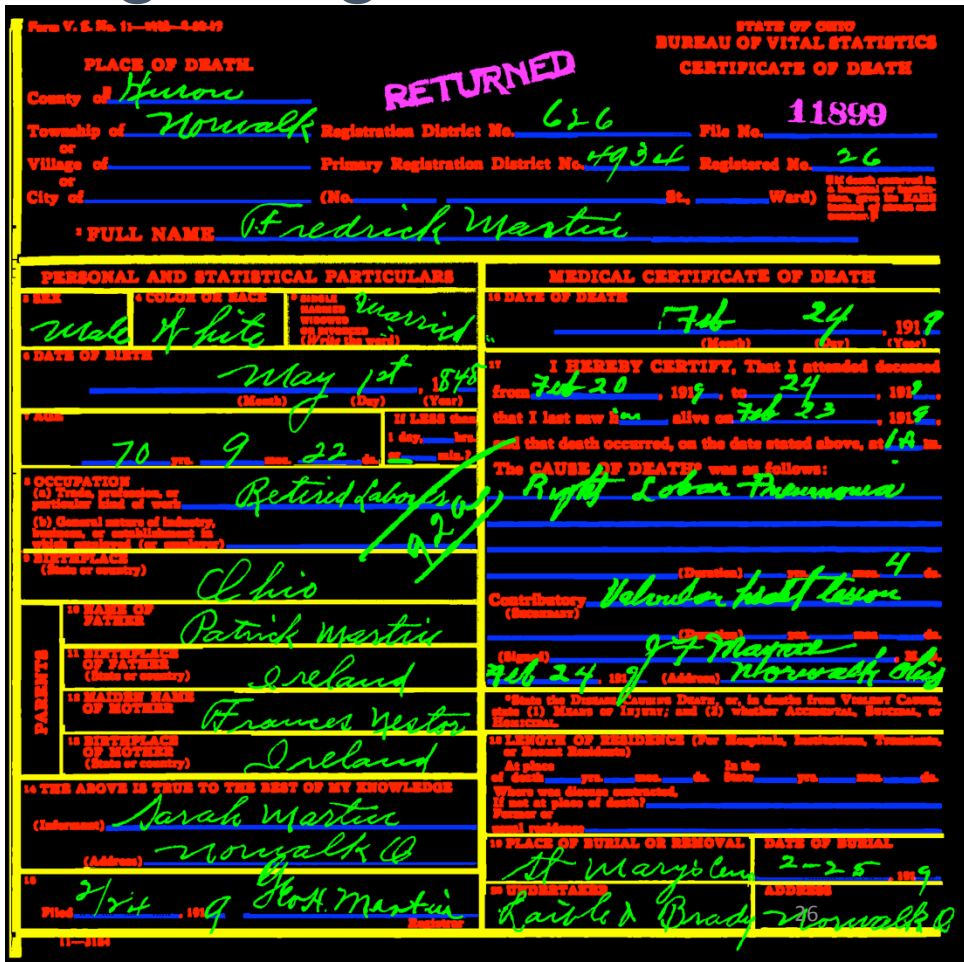
*State the Disease Causing Death, or, in deaths from Violent Causes, state (1) Means of Injury; and (2) whether Accidental, Suicidal, or Homicidal.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, If not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL: St Mary's Cem
DATE OF BURIAL: 2-25, 1919

20 UNDERTAKER: Raible & Brady
ADDRESS: Norwalk O

11—3184



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.

RETURNED

County of Huron
Township of Norwalk Registration District No. 626 File No. 11899
or
Village of Primary Registration District No. 4934 Registered No. 26
or
City of (No. St., Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Fredrick Martin

PERSONAL AND STATISTICAL PARTICULARS

3 SEX: Male
4 COLOR OR RACE: White
5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word): Married

6 DATE OF BIRTH: May 1st, 1848 (Month) (Day) (Year)

7 AGE: 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.?

8 OCCUPATION
(a) Trade, profession, or particular kind of work: Retired Laborer
(b) General nature of industry, business, or establishment in which employed (or employer):

9 BIRTHPLACE (State or country): Ohio

PARENTS
10 NAME OF FATHER: Patrick Martin
11 BIRTHPLACE OF FATHER (State or country): Ireland
12 MAIDEN NAME OF MOTHER: Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country): Ireland

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Sarah Martin
(Address) Norwalk O

15 Filed 2/24, 1919 Geo H. Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH: Feb 24, 1919 (Month) (Day) (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 20, 1919, to 24, 1919, that I last saw him alive on Feb 23, 1919, and that death occurred, on the date stated above, at 1A m.
The CAUSE OF DEATH* was as follows:
Right Lobar Pneumonia
(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Valvular heart lesion
(Duration) yrs. mos. ds.
(Signed) J F Maynie, M.D.
Feb 24, 1919 (Address) Norwalk Ohio

*State the Disease Causing Death, or, in deaths from Violent Causes, state (1) Means of Injury; and (2) whether Accidental, Suicidal, or Homicidal.

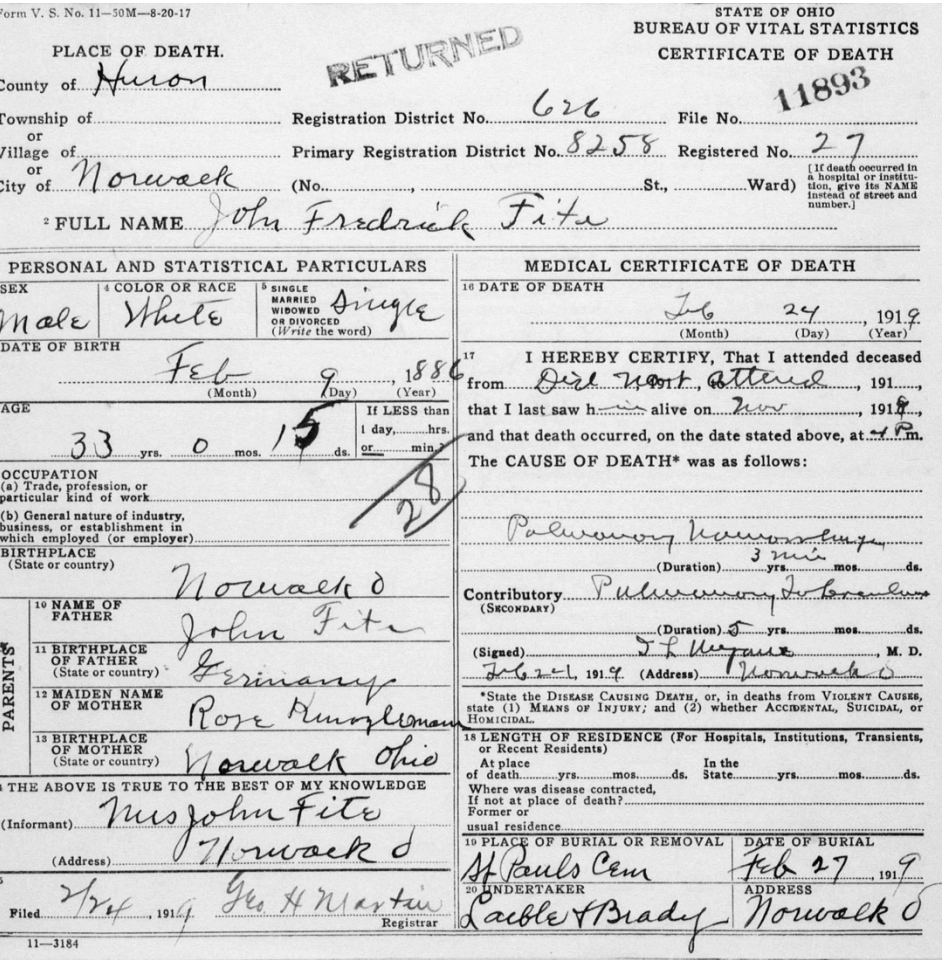
18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, If not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL: St Mary's Cem
DATE OF BURIAL: 2-25, 1919

20 UNDERTAKER: Raible & Brady
ADDRESS: Norwalk O

11—3184

Same Writers



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.

RETURNED

County of Huron

Township of ..... Registration District No. 626 File No. 11893
or
Village of ..... Primary Registration District No. 8258 Registered No. 27
or
City of Norwalk (No. ....., ... St., ... Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME John Fredrick Fite

PERSONAL AND STATISTICAL PARTICULARS

SEX Male | 4 COLOR OR RACE White | 5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word) Single

DATE OF BIRTH Feb (Month) 9 (Day) 1886 (Year)

AGE 33 yrs. 0 mos. 15 ds. If LESS than 1 day, ... hrs. or ..... min.?

OCCUPATION
(a) Trade, profession, or particular kind of work
(b) General nature of industry, business, or establishment in which employed (or employer)

BIRTHPLACE (State or country) Norwalk O

PARENTS
10 NAME OF FATHER John Fite
11 BIRTHPLACE OF FATHER (State or country) Germany
12 MAIDEN NAME OF MOTHER Rose Kunzleman
13 BIRTHPLACE OF MOTHER (State or country) Norwalk Ohio

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Mrs John Fite
(Address) Norwalk O

Filed 2/24, 1919 Geo H Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH Feb (Month) 24 (Day) 1919 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Dec 1917, to Feb 24, 1919, that I last saw him alive on Nov, 1918, and that death occurred, on the date stated above, at 4 P.m.

The CAUSE OF DEATH* was as follows:

Pulmonary Hemorrhage (Duration) 3 mos. yrs. mos. ds.

Contributory (SECONDARY) Pulmonary Tuberculosis (Duration) 5 yrs. mos. ds.

(Signed) T L Wyane, M. D.
Feb 24, 1919 (Address) Norwalk O

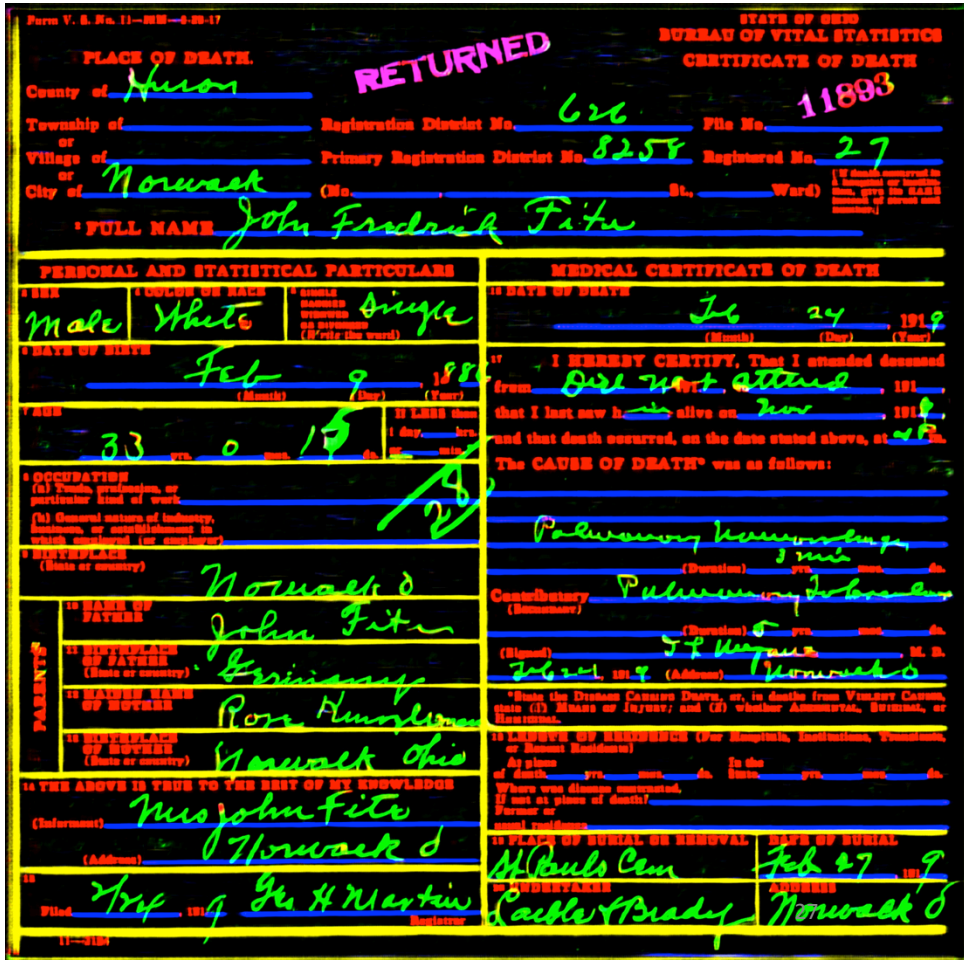
*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death ..... yrs. ..... mos. ..... ds. In the State ..... yrs. ..... mos. ..... ds.
Where was disease contracted, If not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL St Pauls Cem | DATE OF BURIAL Feb 27, 1919

20 UNDERTAKER Laible & Brady | ADDRESS Norwalk O

11—3184



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.

RETURNED

County of Huron

Township of ..... Registration District No. 626 File No. 11893
or
Village of ..... Primary Registration District No. 8258 Registered No. 27
or
City of Norwalk (No. ....., ... St., ... Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME John Fredrick Fite

PERSONAL AND STATISTICAL PARTICULARS

SEX Male | 4 COLOR OR RACE White | 5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word) Single

DATE OF BIRTH Feb (Month) 9 (Day) 1886 (Year)

AGE 33 yrs. 0 mos. 15 ds. If LESS than 1 day, ... hrs. or ..... min.?

OCCUPATION
(a) Trade, profession, or particular kind of work
(b) General nature of industry, business, or establishment in which employed (or employer)

BIRTHPLACE (State or country) Norwalk O

PARENTS
10 NAME OF FATHER John Fite
11 BIRTHPLACE OF FATHER (State or country) Germany
12 MAIDEN NAME OF MOTHER Rose Kunzleman
13 BIRTHPLACE OF MOTHER (State or country) Norwalk Ohio

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Mrs John Fite
(Address) Norwalk O

Filed 2/24, 1919 Geo H Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH Feb (Month) 24 (Day) 1919 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Dec 1917, to Feb 24, 1919, that I last saw him alive on Nov, 1918, and that death occurred, on the date stated above, at 4 P.m.

The CAUSE OF DEATH* was as follows:

Pulmonary Hemorrhage (Duration) 3 mos. yrs. mos. ds.

Contributory (SECONDARY) Pulmonary Tuberculosis (Duration) 5 yrs. mos. ds.

(Signed) T L Wyane, M. D.
Feb 24, 1919 (Address) Norwalk O

*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

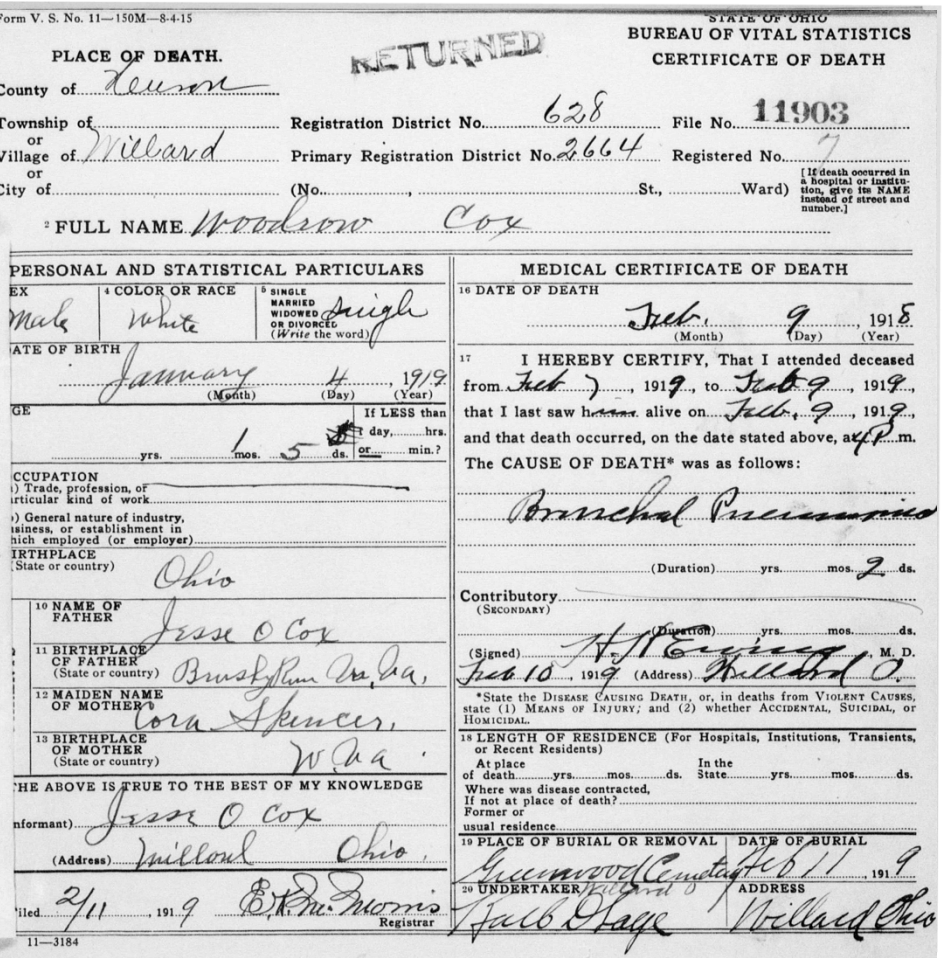
18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death ..... yrs. ..... mos. ..... ds. In the State ..... yrs. ..... mos. ..... ds.
Where was disease contracted, If not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL St Pauls Cem | DATE OF BURIAL Feb 27, 1919

20 UNDERTAKER Laible & Brady | ADDRESS Norwalk O

11—3184

Different Writers



Form V. S. No. 11—150M—8-4-15

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

RETURNED

PLACE OF DEATH.

County of Huron

Township of ..... Registration District No. 628 File No. 11903
or
Village of Willard Primary Registration District No. 2664 Registered No. 7
or
City of ..... (No. ..... St., ... Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Woodrow Cox

PERSONAL AND STATISTICAL PARTICULARS

EX	4 COLOR OR RACE	5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word)
Male	White	Single

ATE OF BIRTH January (Month) 4 (Day) 1919 (Year)

GE ..... yrs. 1 mos. 5 ds. If LESS than 1 day, ... hrs. or ..... min.?

CCUPATION
) Trade, profession, or rticular kind of work
) General nature of industry, siness, or establishment in hich employed (or employer)

IRTHPLACE (State or country) Ohio

10 NAME OF FATHER Jesse O Cox

11 BIRTHPLACE OF FATHER (State or country) Brushy Run Va. Va.

12 MAIDEN NAME OF MOTHER Cora Spencer

13 BIRTHPLACE OF MOTHER (State or country) W Va

HE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE

nformant) Jesse O Cox

(Address) Willard Ohio

iled 2/11 1919 E. R. McMorris Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH Feb. (Month) 9 (Day) 1918 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 7, 1919, to Feb 9, 1919, that I last saw him alive on Feb. 9, 1919, and that death occurred, on the date stated above, at 4 P.M.

The CAUSE OF DEATH* was as follows:

Bronchial Pneumonia

(Duration) ..... yrs. ..... mos. 2 ds.

Contributory (SECONDARY) ..... (Duration) ..... yrs. ..... mos. ..... ds.

(Signed) H. N. Ewing, M. D.

Feb 10, 1919 (Address) Willard O.

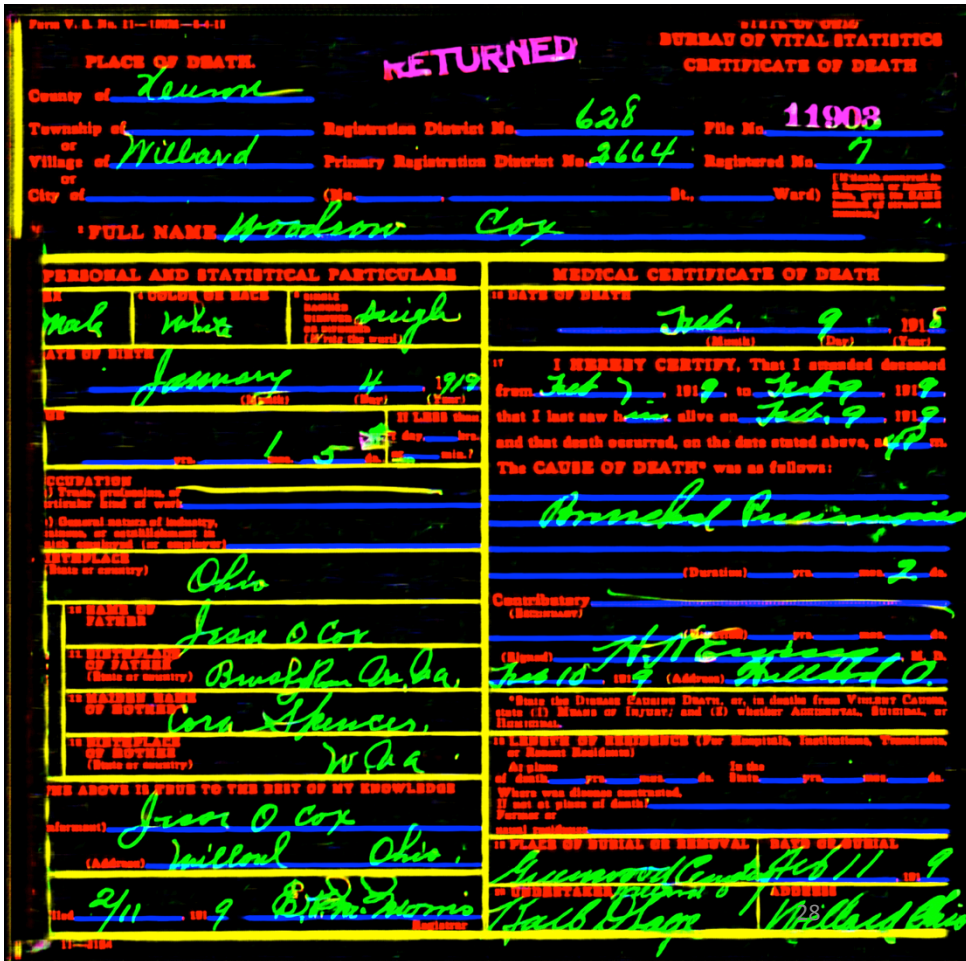
*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death ..... yrs. ..... mos. ..... ds. In the State ..... yrs. ..... mos. ..... ds.
Where was disease contracted, If not at place of death? .....
Former or usual residence .....

19 PLACE OF BURIAL OR REMOVAL Greenwood Cemetery DATE OF BURIAL Feb 11, 1919

20 UNDERTAKER Willard O. Ralb D Lage ADDRESS Willard Ohio

11—3184



Form V. S. No. 11—150M—8-4-15

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

RETURNED

PLACE OF DEATH.

County of Huron

Township of ..... Registration District No. 628 File No. 11903
or
Village of Willard Primary Registration District No. 2664 Registered No. 7
or
City of ..... (No. ..... St., ... Ward) [If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Woodrow Cox

PERSONAL AND STATISTICAL PARTICULARS

EX	4 COLOR OR RACE	5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word)
Male	White	Single

ATE OF BIRTH January (Month) 4 (Day) 1919 (Year)

GE ..... yrs. 1 mos. 5 ds. If LESS than 1 day, ... hrs. or ..... min.?

CCUPATION
) Trade, profession, or rticular kind of work
) General nature of industry, siness, or establishment in hich employed (or employer)

IRTHPLACE (State or country) Ohio

10 NAME OF FATHER Jesse O Cox

11 BIRTHPLACE OF FATHER (State or country) Brushy Run Va. Va.

12 MAIDEN NAME OF MOTHER Cora Spencer

13 BIRTHPLACE OF MOTHER (State or country) W Va

HE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE

nformant) Jesse O Cox

(Address) Willard Ohio

iled 2/11 1919 E. R. McMorris Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH Feb. (Month) 9 (Day) 1918 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 7, 1919, to Feb 9, 1919, that I last saw him alive on Feb. 9, 1919, and that death occurred, on the date stated above, at 4 P.M.

The CAUSE OF DEATH* was as follows:

Bronchial Pneumonia

(Duration) ..... yrs. ..... mos. 2 ds.

Contributory (SECONDARY) ..... (Duration) ..... yrs. ..... mos. ..... ds.

(Signed) H. N. Ewing, M. D.

Feb 10, 1919 (Address) Willard O.

*State the DISEASE CAUSING DEATH, or, in deaths from VIOLENT CAUSES, state (1) MEANS OF INJURY; and (2) whether ACCIDENTAL, SUICIDAL, or HOMICIDAL.

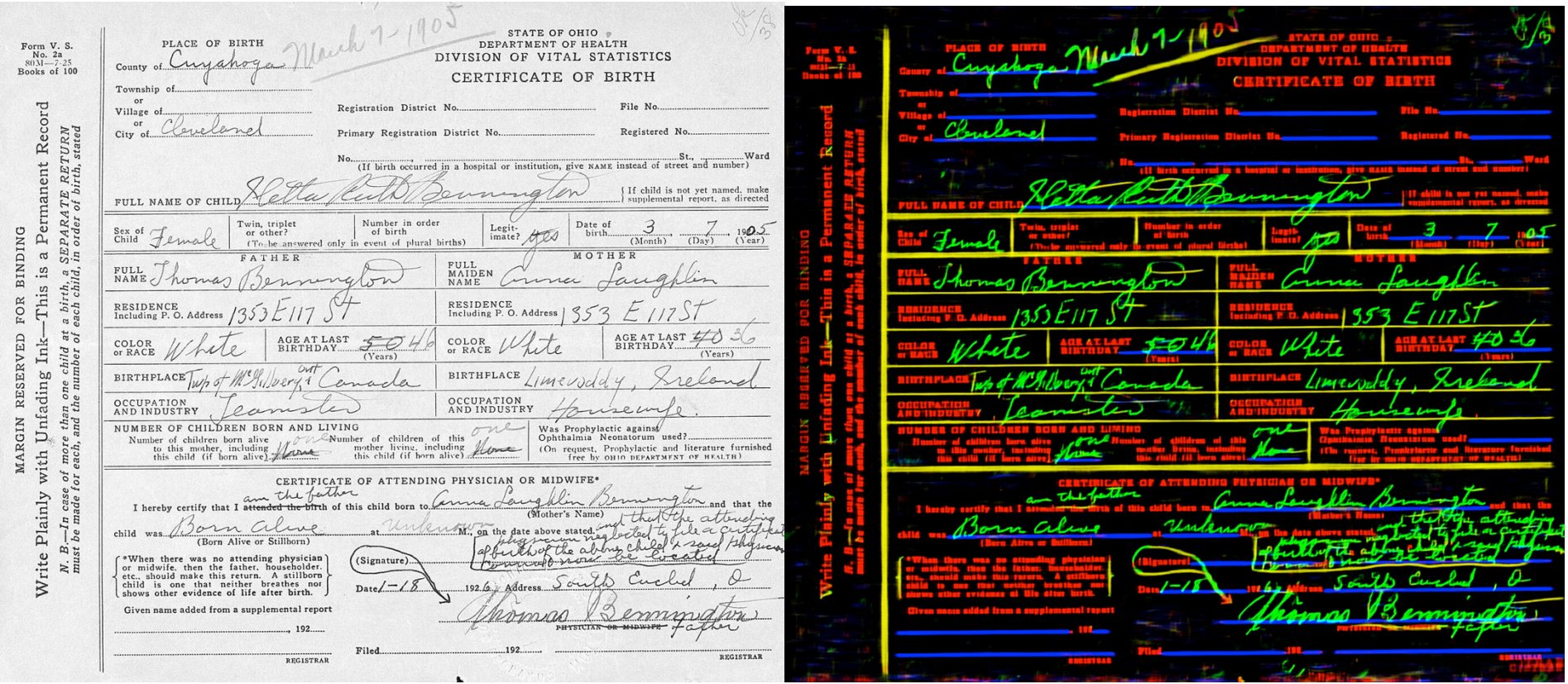
18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death ..... yrs. ..... mos. ..... ds. In the State ..... yrs. ..... mos. ..... ds.
Where was disease contracted, If not at place of death? .....
Former or usual residence .....

19 PLACE OF BURIAL OR REMOVAL Greenwood Cemetery DATE OF BURIAL Feb 11, 1919

20 UNDERTAKER Willard O. Ralb D Lage ADDRESS Willard Ohio

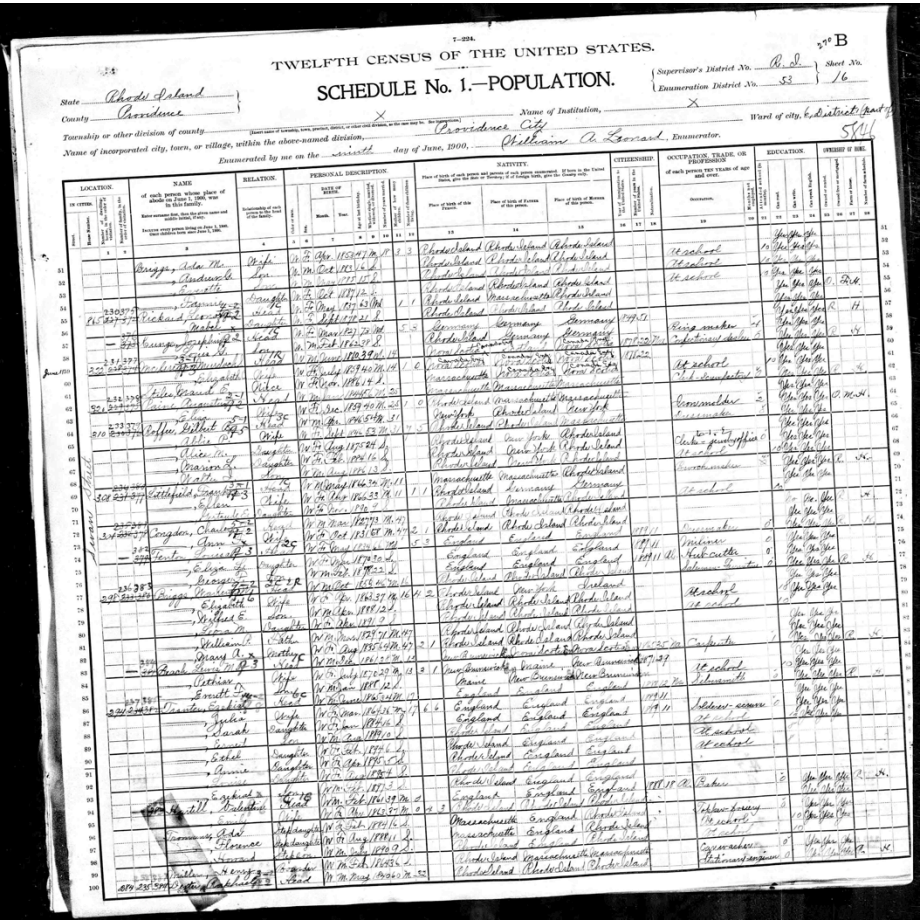
11—3184

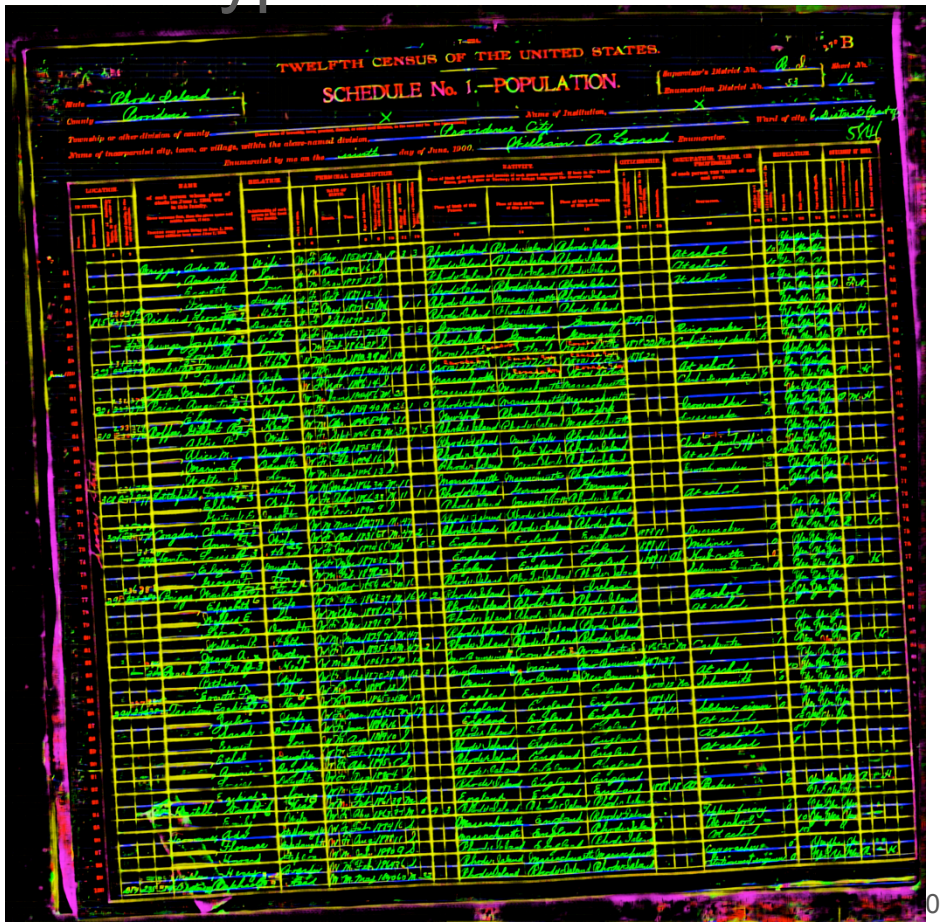
Different Form Types



1905 Ohio Birth Certificate

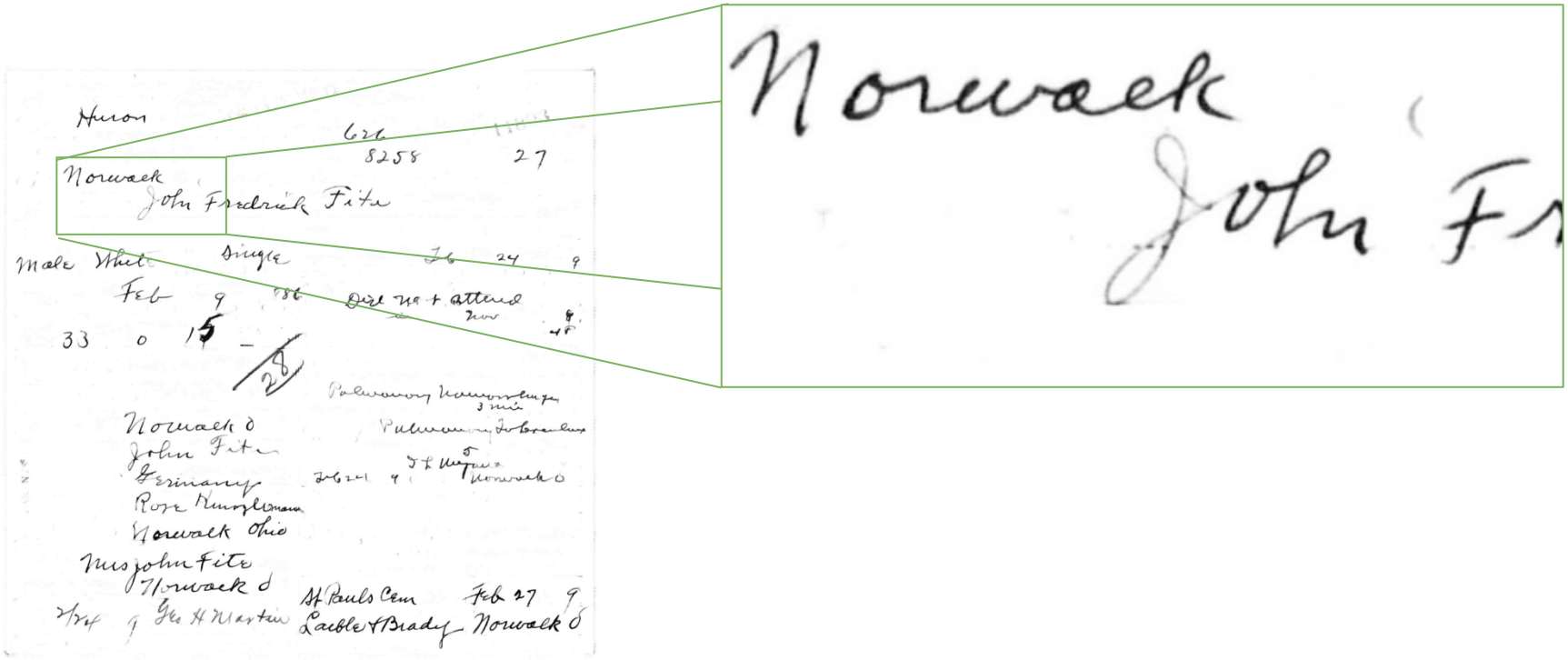
Different Form Types





1900 U.S. Census

Handwriting Channel



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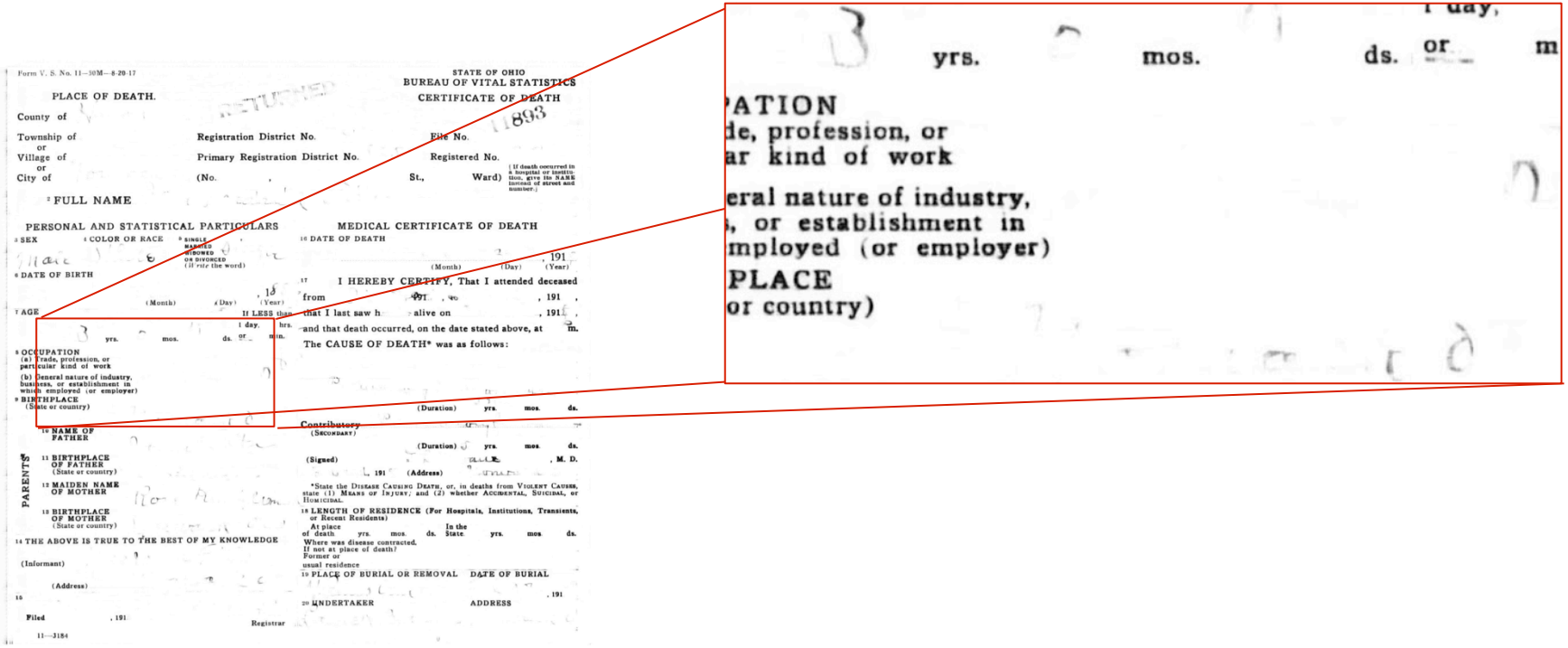
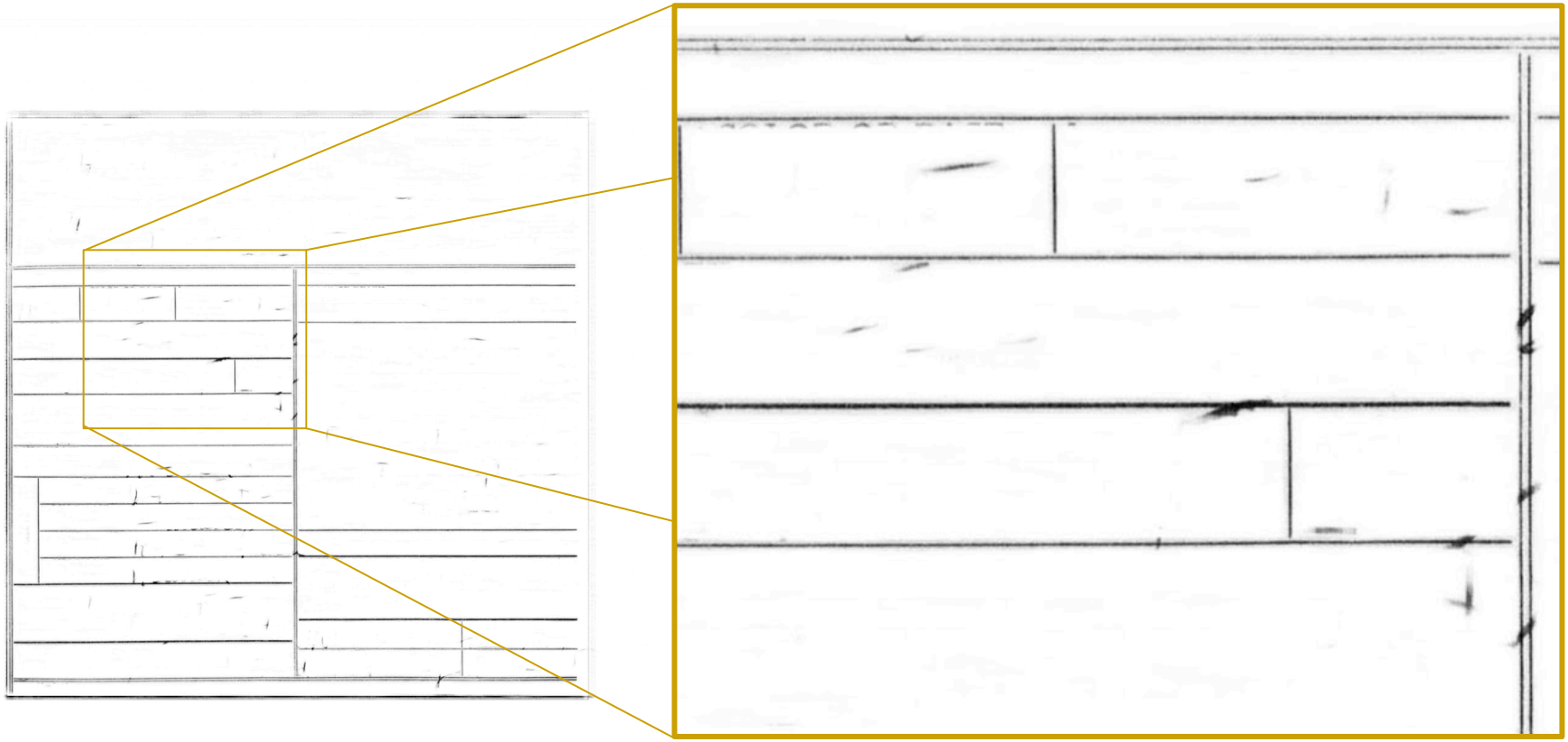
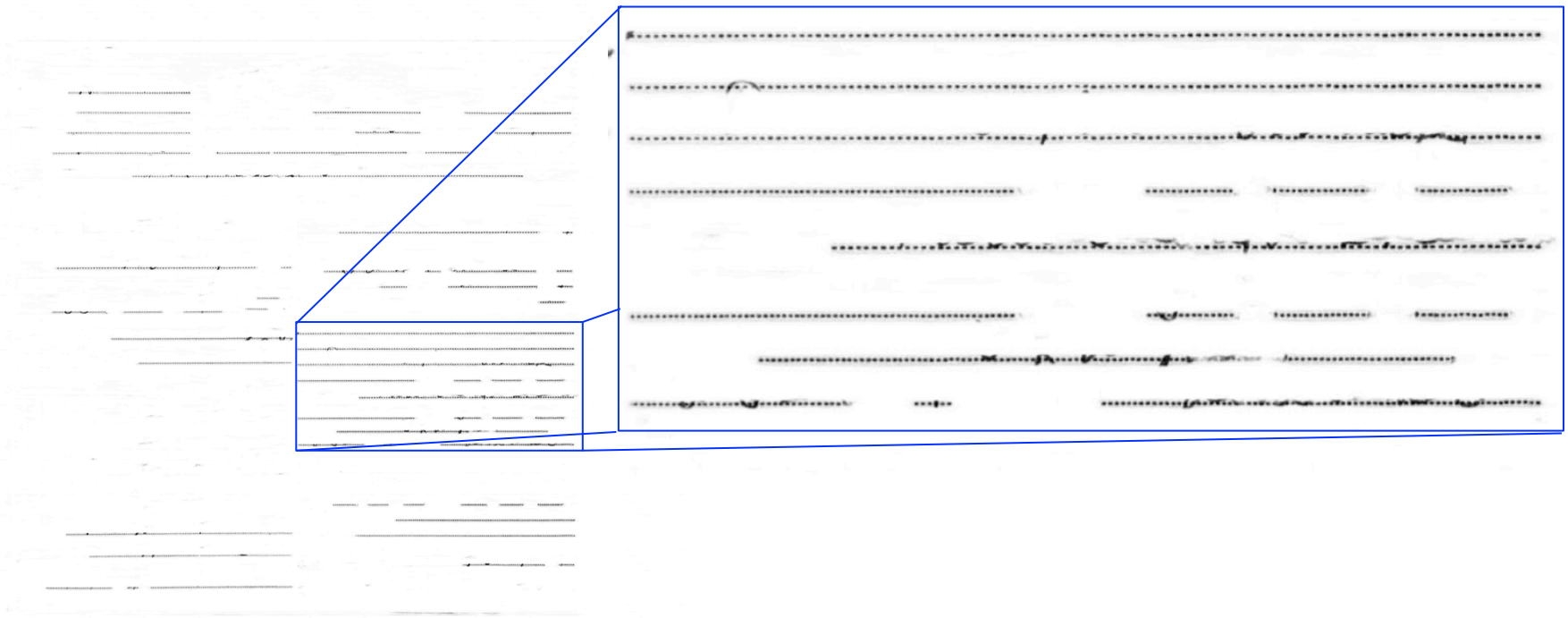


Solid Lines Channel



Dotted Lines Channel



Stamp/Decoration Channel

Open Problems

Have We Forgotten about Geometry in Computer Vision?

https://alexgkendall.com/computer_vision/have_we_forgotten_about_geometry_in_computer_vision/

Alex Kendall

Computer Vision & Robotics Researcher

Deep learning has revolutionised computer vision. Today, there are not many problems where the best performing solution is not based on an end-to-end deep learning model. In particular, convolutional neural networks are popular as they tend to work fairly well out of the box. However, these models are largely big black-boxes. There are a lot of things we don't understand about them.

Dense Layers

https://www.google.com/search?safe=active&biw=1366&bih=633&tbm=isch&sa=1&ei=V2WMWovJF-PX0gKZ1azIAQ&q=dense+cake+recipe+site%3Awikimedia.org&oq=dense+cake+recipe+site%3Awikimedia.org&gs_l=psy-ab.3...9304.12238.0.12375.19.16.0.0.0.0.223.1716.3j7j2.12.0....0...1c.1.64.psy-ab..7.1.125...0i30k1j0i8i30k1j0i24k1.0.v5TK6hZEBi4

https://www.google.com/imgres?imgurl=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F3%2F3f%2FDobos_cake_%2528Gerbeaud_Confectionery_Budapest_Hungary%2529.jpg&imgrefurl=https%3A%2F%2Fcommons.wikimedia.org%2Fwiki%2FFile%3ADobos_cake_(Gerbeaud_Confectionery_Budapest_Hungary).jpg&docid=HkdgsiVJfgckuM&tbnid=0QWLllor-2j60M%3A&vet=10ahUKEwjR54HyirXZAhXKqVQKHW5RAhYQMwiPAigIMAg..i&w=1280&h=853&safe=active&bih=633&biw=1366&q=layer%20cake%20site%3Awikimedia.org&ved=0ahUKEwjR54HyirXZAhXKqVQKHW5RAhYQMwiPAigIMAg&iact=mrc&uact=8

Where to Go from Here

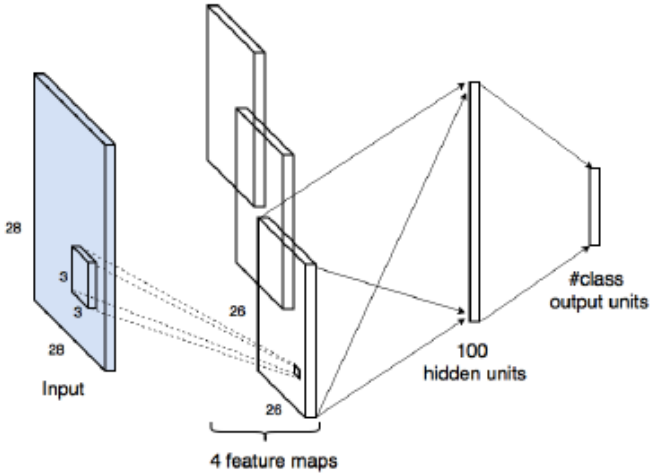
Marriage of Computer Vision and Deep Learning

Resource-Efficient Processing (ms/image)

Document Image Page Segmentation and Character Recognition as Semantic Segmentation

Seth Stewart and Bill Barrett
Brigham Young University
stewart.seth.a@gmail.com

Chen and Seuret CNN for Page Segmentation



Single convolutional layer with only 4 feature maps performs as well as more layers/maps

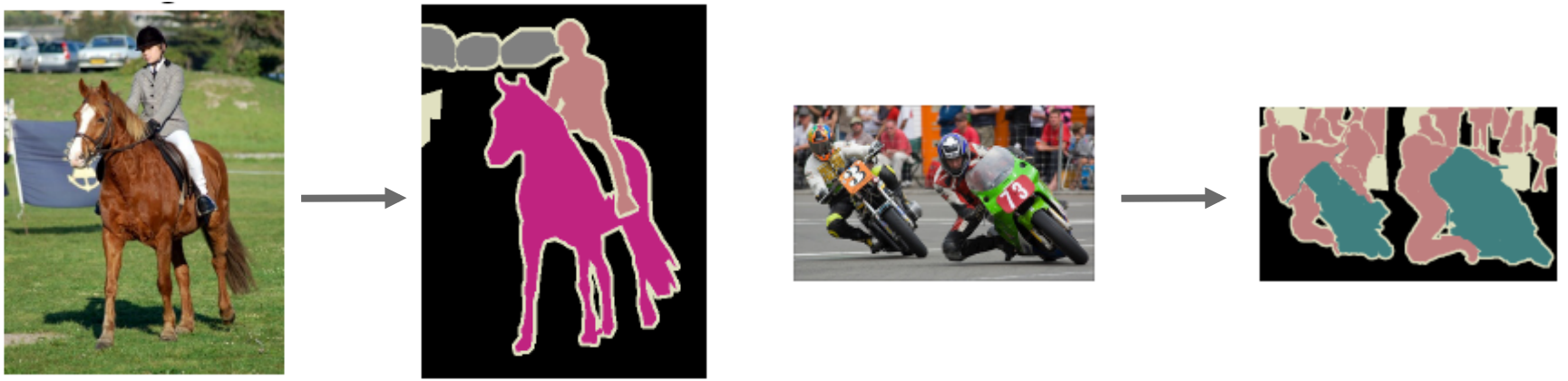
Performs ~99% as well with **only 2 training images** as with many more

Single-Layer Convolutional Neural Network for page segmentation by Chen and Seuret

K. Chen and M. Seuret. 2017. Convolutional Neural Networks for Page Segmentation of Historical Document Images. ArXiv e-prints (April 2017). arXiv:cs.CV/1704.01474

Semantic Segmentation

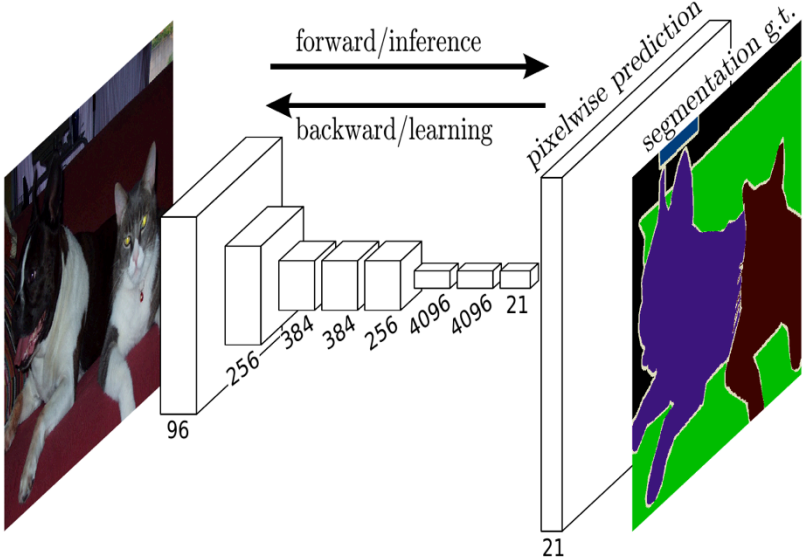
Pixel-wise labeling of images



M. Everingham, L. Van Gool, C. K. Williams, J. Winn, and A. Zisserman. The pascal visual object classes (voc) challenge. IJCV, 88(2):303–338, 2010

Semantic Segmentation Convolutional Neural Network Architectures

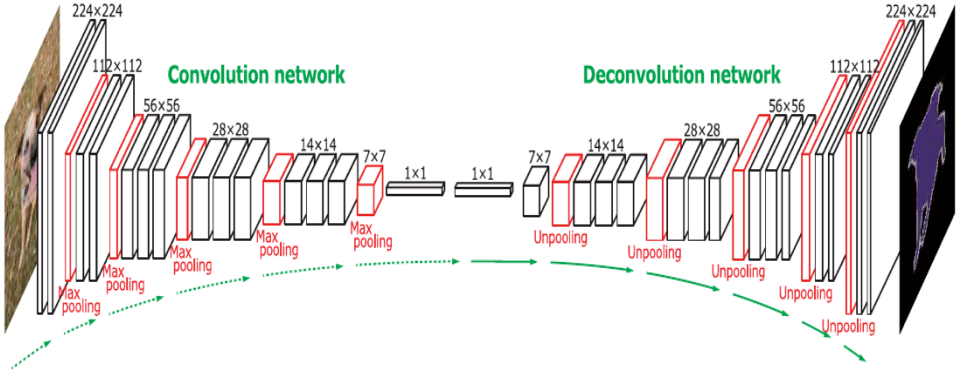
Fully Convolutional Network [Long and Shelhamer, 2014]



Fully Convolutional Models for Semantic Segmentation. Evan Shelhamer, Jonathan Long, Trevor Darrell. PAMI 2016. arXiv:1605.06211

Downsampling-upsampling Network [Noh, et al. 2015]

- Learned upsampling allows for denser predictions given modest additional computation



H. Noh, S. Hong, and B. Han, "Learning deconvolution network for semantic segmentation," in The IEEE International Conference on Computer Vision (ICCV), December 2015

The Problem

Many documents have heterogeneous content consisting of

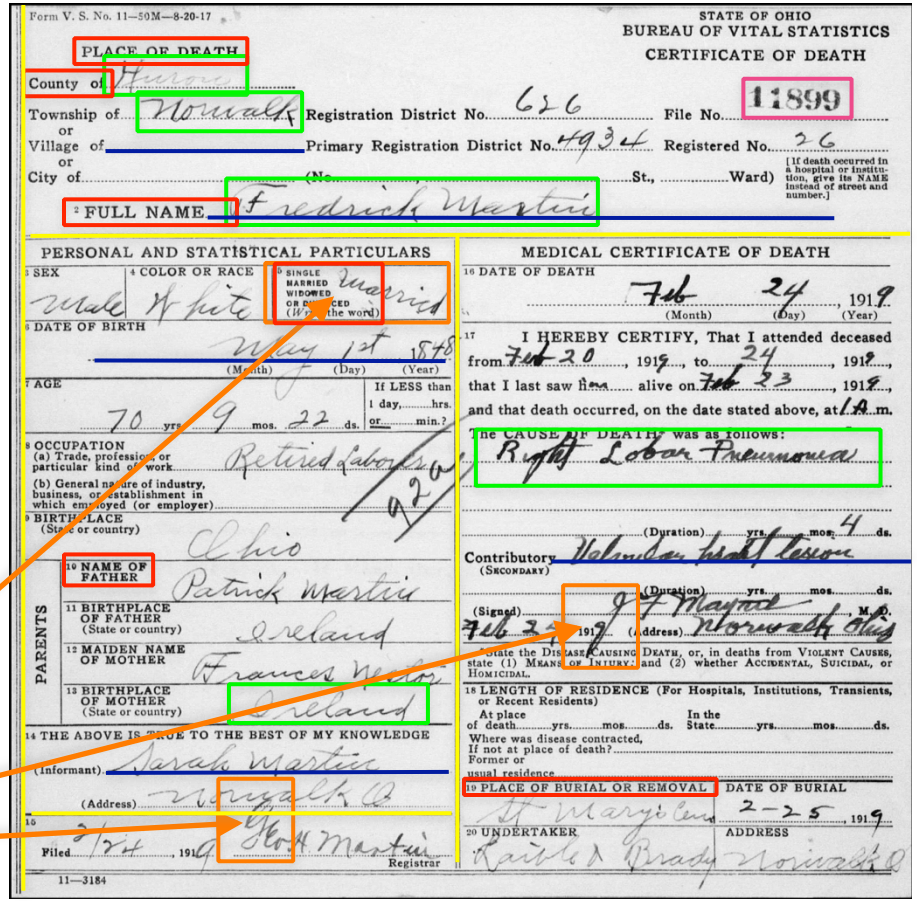
- handwriting
- machine print
- solid lines
- dashed lines
- stamps

that are

- interleaved

and frequently

- overlap



1919 Ohio Death Record

10 H—1915

THE CITY OF NEW YORK.
DEPARTMENT OF HEALTH.

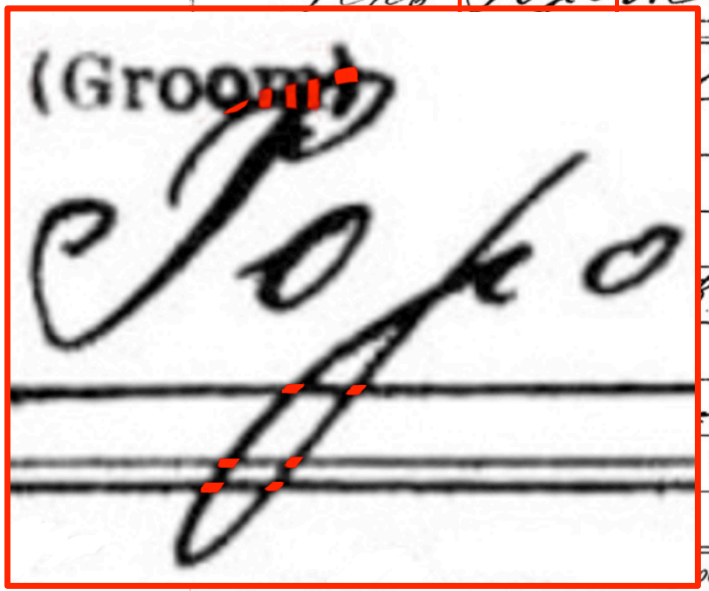
No. of Certificate

STATE OF NEW YORK.

CERTIFICATE AND RECORD OF MARRIAGE

13525

(Groom) Peter Popovich OF (Bride) and Parascevia Korecka



...tr.	Bride's Residence	237 Moore St.
	Age	19.
	Color	white
	Single, Widowed or Divorced	single
...R. T.	Maiden Name, if a Widow	—
	Birthplace	Austria
...George	Father's Name	Jacob
	Mother's Maiden Name	Luba Shevchuk
	Number of Bride's Marriage	first

BUREAU OF RECORDS
RECEIVED
BOROUGH OF BROOKLYN

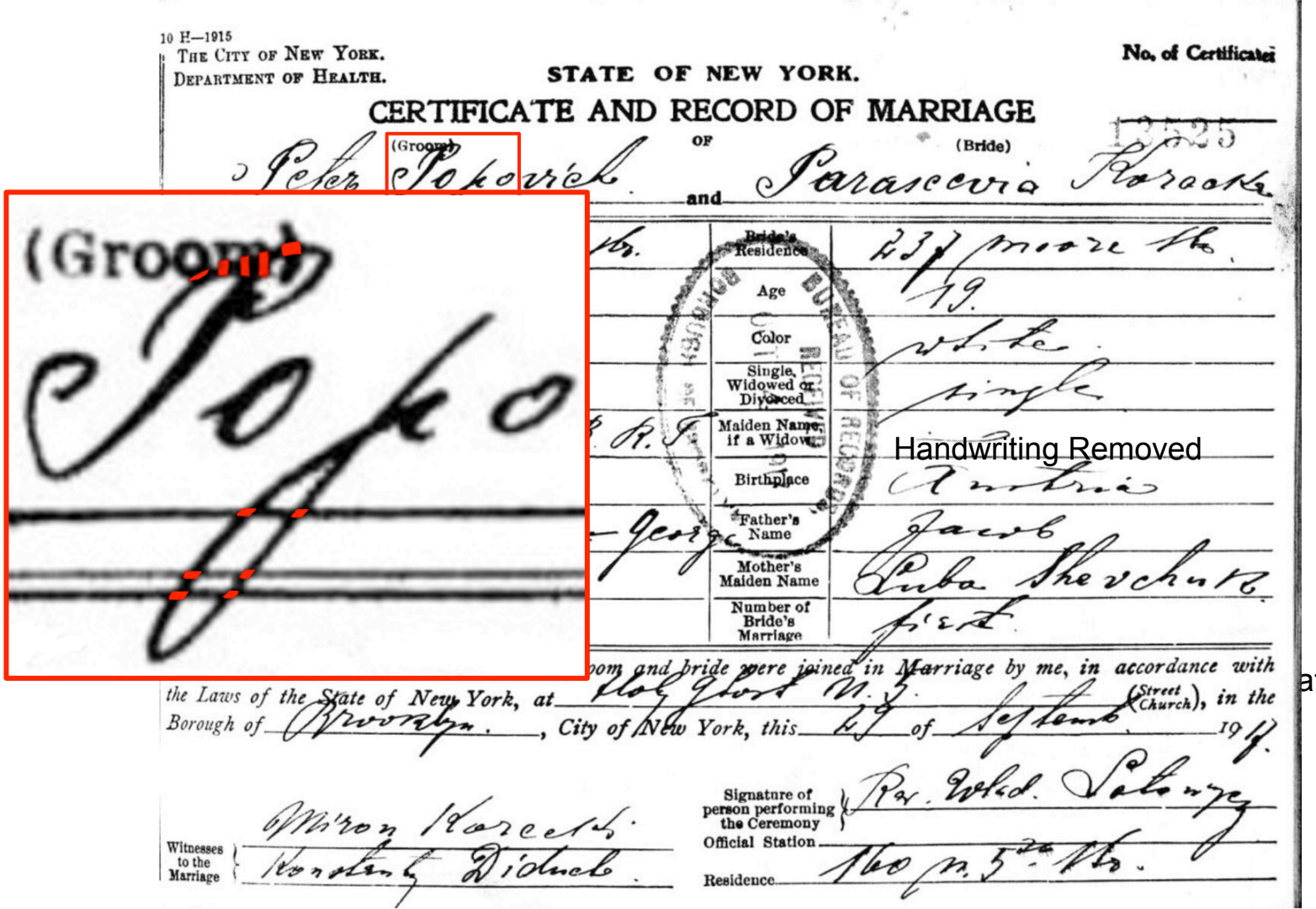
...oom and bride were joined in Marriage by me, in accordance with the Laws of the State of New York, at Holy Ghost N. 5 (Street Church), in the Borough of Brooklyn, City of New York, this 29 of Septemb. 1917.

Witnesses to the Marriage: Miron Korecki, Konstanty Diduch

Signature of person performing the Ceremony: Rev. Wład. Sołowyj

Official Station

Residence: 160 N. 5th St.



10 H—1915

THE CITY OF NEW YORK.
DEPARTMENT OF HEALTH.

No. of Certificate

STATE OF NEW YORK.

CERTIFICATE AND RECORD OF MARRIAGE

(Groom) Peter Popovich OF (Bride) Parascevia Korecka

and

Bride's Residence	237 Moore St.
Age	19.
Color	white
Single, Widowed or Divorced	single
Maiden Name, if a Widow	
Birthplace	Austria
Father's Name	Jacob
Mother's Maiden Name	Luba Shevchuk
Number of Bride's Marriage	first

BUREAU OF RECORDS RECEIVED

Handwriting Removed

...oom and bride were joined in Marriage by me, in accordance with the Laws of the State of New York, at Holy Ghost N.Y. (Street Church), in the Borough of Brooklyn, City of New York, this 29 of September 1917.

Signature of person performing the Ceremony: Rev. Wlad. Latonycz

Official Station

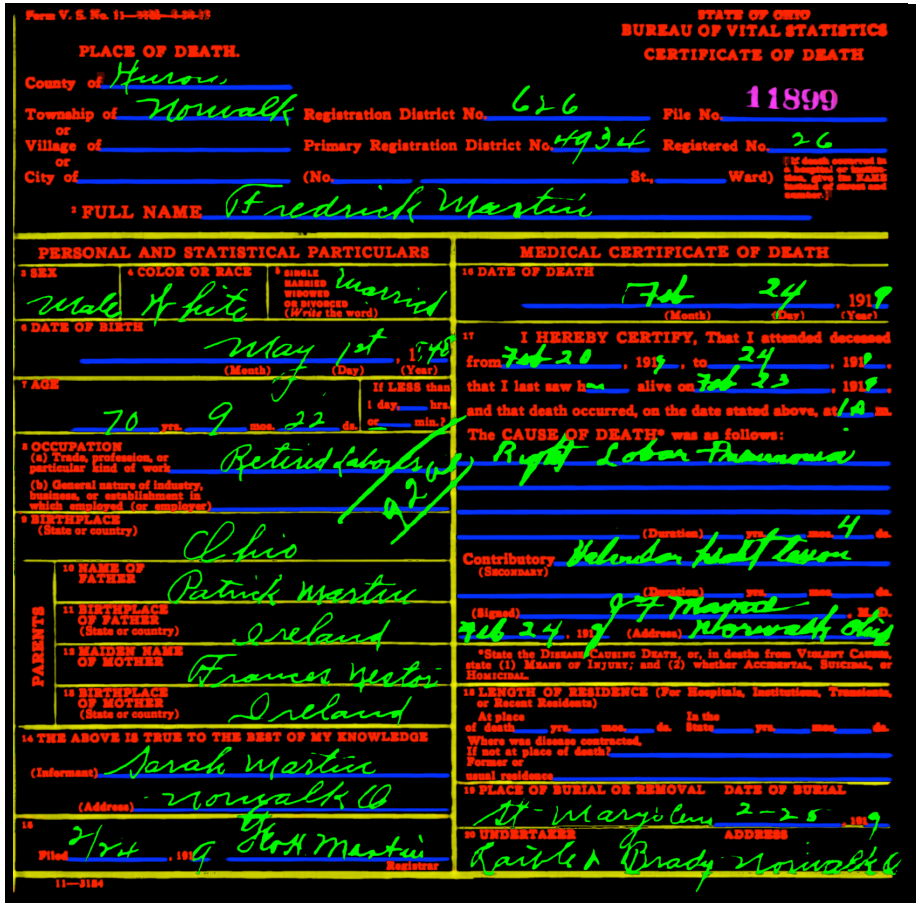
Residence: 160 N. 5th St.

Witnesses to the Marriage: Miron Korecki, Konstanty Diduch

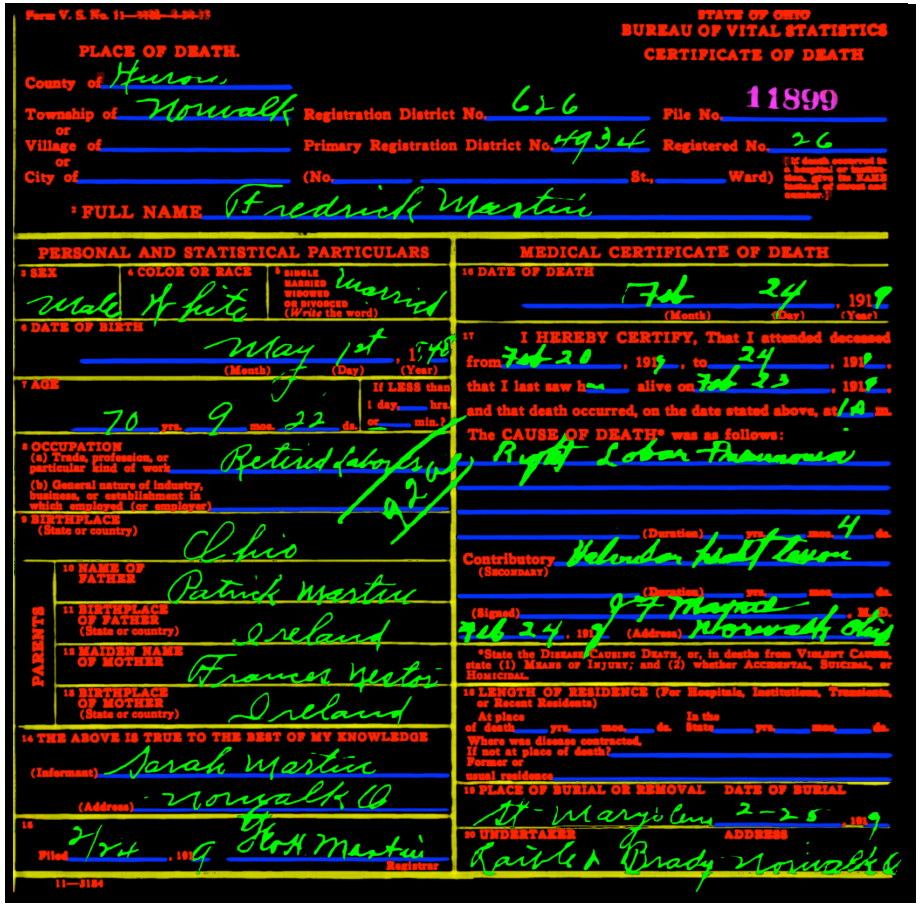
(Groom) Popo

ation)

We use a **Convolutional Neural Network** to Semantically label each document component at the **pixel level**



...allowing each component to be peeled off into a separate layer and processed selectively



STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.
County of Huron
Township of Norwalk Registration District No. 626 File No. 11899
or
Village of Primary Registration District No. 4934 Registered No. 26
or
City of (No. St., Ward) [If death occurred in a hospital or institution, give the FARM instead of street and number.]

1 FULL NAME Fredrick Martin

PERSONAL AND STATISTICAL PARTICULARS

3 SEX Male
4 COLOR OR RACE White
5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word) Married
6 DATE OF BIRTH May 1st, 1848 (Month) (Day) (Year)
7 AGE 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.?
8 OCCUPATION (a) Trade, profession, or particular kind of work Retired Laborer
(b) General nature of industry, business, or establishment in which employed (or employer)
9 BIRTHPLACE (State or country) Ohio

PARENTS
10 NAME OF FATHER Patrick Martin
11 BIRTHPLACE OF FATHER (State or country) Ireland
12 MAIDEN NAME OF MOTHER Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country) Ireland

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Sarah Martin
(Address) Norwalk O

15 Filed 2/24, 1919 Geo H. Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH Feb 24, 1919 (Month) (Day) (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 20, 1919, to 24, 1919, that I last saw him alive on Feb 23, 1919, and that death occurred, on the date stated above, at 10 a.m.
The CAUSE OF DEATH* was as follows: Right Lobar Pneumonia
(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Valvular heart lesion
(Duration) yrs. mos. ds.
(Signed) J F Mayne, M.D.
Feb 24, 1919 (Address) Norwalk Ohio
*State the Disease Causing Death, or, in deaths from Violent Causes, state (1) Means of Injury; and (2) whether Accidental, Suicidal, or Homicidal.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, If not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL St. Marys Cem DATE OF BURIAL 2-25, 1919
20 UNDERTAKER Raible & Brady ADDRESS Norwalk O

11—3184

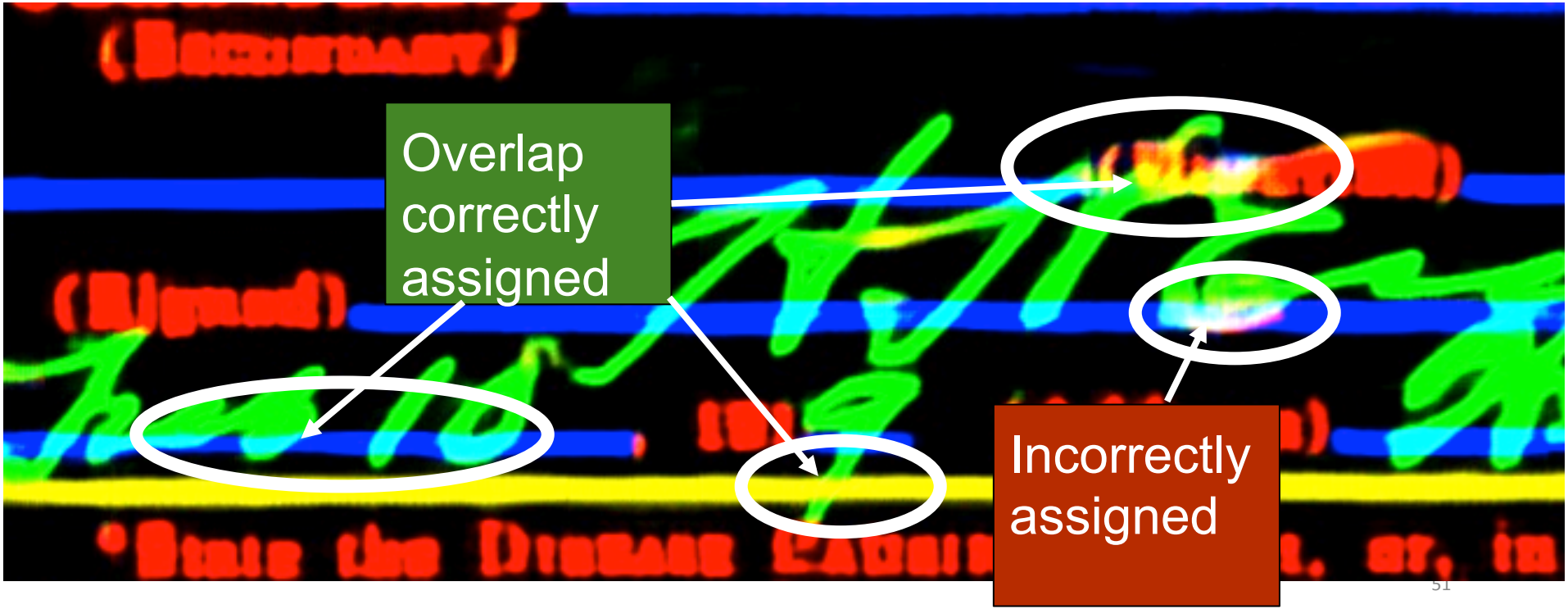
1919 Ohio Death Record

Methods

Overview

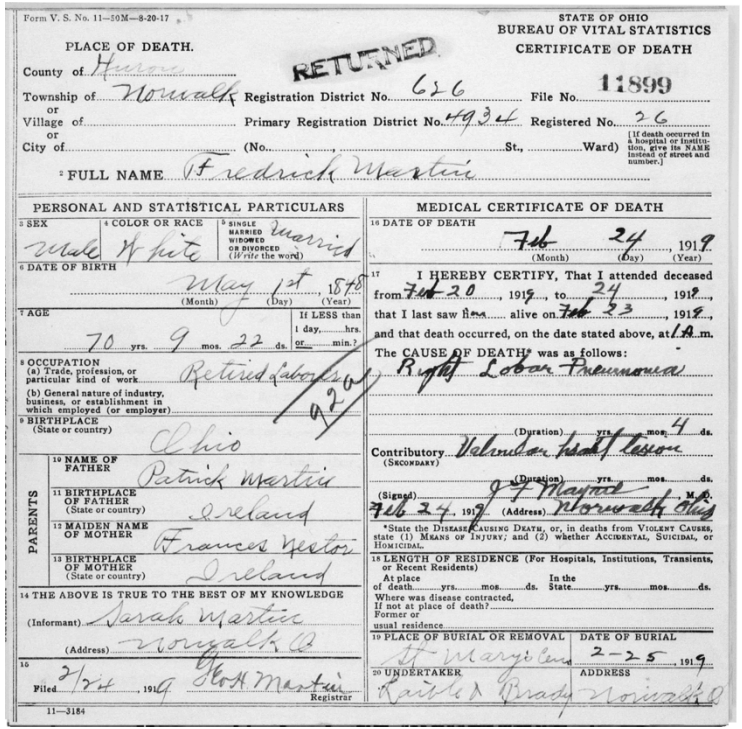
1. What is Page Segmentation?
2. Neural Network Architectures for Page Segmentation
    a. (How to build your own Neural Network for a Document Pixel Labeling task)
3. **Handling overlapping content in document images**
4. A natural extension to OCR
5. Challenges and Frontiers

Visualization of Overlap



RTH
January
(Mon(b)

Two-form cross-validation



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH

PLACE OF DEATH.
County of Huron
RETURNED
Township of Norwalk Registration District No. 626 File No. 11899
or
Village of Primary Registration District No. 4934 Registered No. 26
or
City of (No. , St., Ward)
[If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Frederick Martin

PERSONAL AND STATISTICAL PARTICULARS

3 SEX: Male | 4 COLOR OR RACE: White | 5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word): Married

6 DATE OF BIRTH: May 1st (Month) (Day) 1848 (Year)

7 AGE: 70 yrs. 9 mos. 22 ds. If LESS than 1 day, hrs. or min.

8 OCCUPATION
(a) Trade, profession, or particular kind of work: Retired Laborer
(b) General nature of industry, business, or establishment in which employed (or employer):

9 BIRTHPLACE (State or country): Ohio

PARENTS

10 NAME OF FATHER: Patrick Martin
11 BIRTHPLACE OF FATHER (State or country): Ireland
12 MAIDEN NAME OF MOTHER: Frances Nestor
13 BIRTHPLACE OF MOTHER (State or country): Ireland

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) Sarah Martin
(Address) Norwalk O.

15 Filed 2/24 1919 Fred K. Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH: Feb 24 (Month) (Day) 1919 (Year)

17 I HEREBY CERTIFY, That I attended deceased from Feb 20, 1919, to Feb 24, 1919, that I last saw him alive on Feb 23, 1919, and that death occurred, on the date stated above, at 1A m.

The CAUSE OF DEATH* was as follows:
Right Lobar Pneumonia
(Duration) yrs. mos. 4 ds.
Contributory (Secondary) Valvular heart lesion
(Duration) yrs. mos. ds.

(Signed) J F Mayer M. D.
2/24 1919 (Address) Norwalk Ohio

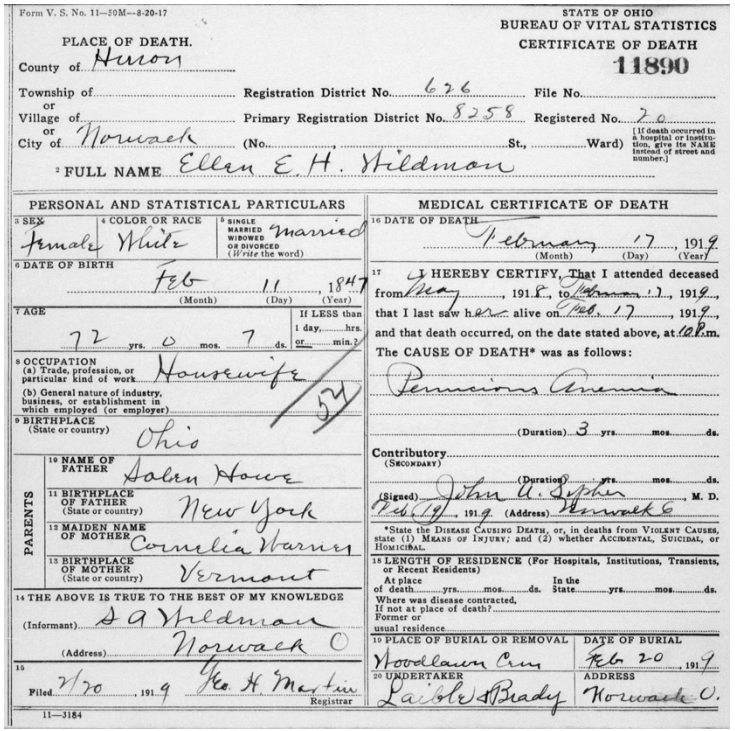
*State the Disease Causing Death, or, in deaths from Violent Causes, state (1) Means of Injury; and (2) whether Accidental, Suicidal, or Homicidal.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, if not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL: St. Mary's Cem. DATE OF BURIAL: 2-25 1919

20 UNDERTAKER: Laible & Brady ADDRESS: Norwalk O.

11—3184



Form V. S. No. 11—50M—8-20-17

STATE OF OHIO
BUREAU OF VITAL STATISTICS
CERTIFICATE OF DEATH
11890

PLACE OF DEATH.
County of Huron
Township of Registration District No. 626 File No.
or
Village of Primary Registration District No. 8258 Registered No. 20
or
City of Norwalk (No. , St., Ward)
[If death occurred in a hospital or institution, give its NAME instead of street and number.]

2 FULL NAME Ellen E. H. Hildman

PERSONAL AND STATISTICAL PARTICULARS

3 SEX: Female | 4 COLOR OR RACE: White | 5 SINGLE MARRIED WIDOWED OR DIVORCED (Write the word): Married

6 DATE OF BIRTH: Feb 11 (Month) (Day) 1847 (Year)

7 AGE: 72 yrs. 0 mos. 7 ds. If LESS than 1 day, hrs. or min.

8 OCCUPATION
(a) Trade, profession, or particular kind of work: Housewife
(b) General nature of industry, business, or establishment in which employed (or employer):

9 BIRTHPLACE (State or country): Ohio

PARENTS

10 NAME OF FATHER: Solon Howe
11 BIRTHPLACE OF FATHER (State or country): New York
12 MAIDEN NAME OF MOTHER: Cornelia Warner
13 BIRTHPLACE OF MOTHER (State or country): Vermont

14 THE ABOVE IS TRUE TO THE BEST OF MY KNOWLEDGE
(Informant) A A Hildman
(Address) Norwalk O

15 Filed 2/20 1919 Geo. H. Martin Registrar

MEDICAL CERTIFICATE OF DEATH

16 DATE OF DEATH: February 17 (Month) (Day) 1919 (Year)

17 I HEREBY CERTIFY, That I attended deceased from May 1, 1918, to February 17, 1919, that I last saw her alive on Feb. 17, 1919, and that death occurred, on the date stated above, at 12P m.

The CAUSE OF DEATH* was as follows:
Pernicious Anemia
(Duration) 3 yrs. mos. ds.
Contributory (Secondary)
(Duration) yrs. mos. ds.

(Signed) John A. Spohn M. D.
Feb 19, 1919 (Address) Norwalk O

*State the Disease Causing Death, or, in deaths from Violent Causes, state (1) Means of Injury; and (2) whether Accidental, Suicidal, or Homicidal.

18 LENGTH OF RESIDENCE (For Hospitals, Institutions, Transients, or Recent Residents)
At place of death yrs. mos. ds. In the State yrs. mos. ds.
Where was disease contracted, if not at place of death?
Former or usual residence

19 PLACE OF BURIAL OR REMOVAL: Woodlawn Cem DATE OF BURIAL: Feb 20 1919

20 UNDERTAKER: Laible & Brady ADDRESS: Norwalk O.

11—3184

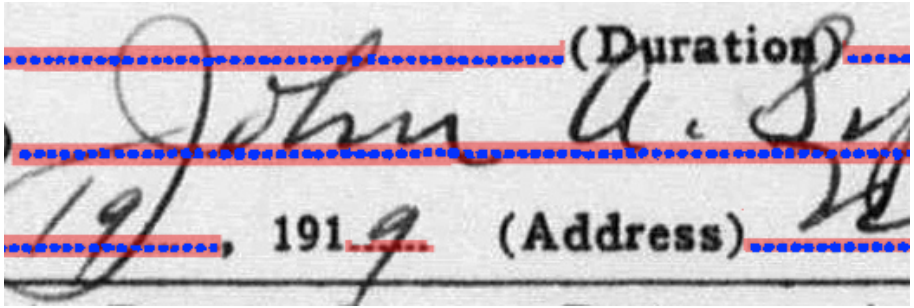
Two-form cross-validation

Form Instance A validated against Form Instance B				
Class	Training		Validation	
	Precision	Recall	Precision	Recall
Machine Print	0.927	0.783	0.812	0.891
Handwriting	0.930	0.868	0.842	0.929
Solid Lines	0.815	0.912	0.574	0.996
Dotted Lines	0.857	0.923	0.735	0.927
Stamps	0.794	0.885	0.199	0.282

Trained on Form Instance B				
Class	Training		Validation	
	Precision	Recall	Precision	Recall
Machine Print	0.967	0.945	0.869	0.703
Handwriting	0.935	0.940	0.897	0.734
Solid Lines	0.906	0.916	0.743	0.530
Dotted Lines	0.930	0.920	0.885	0.777
Stamps	0.682	0.979	0.279	0.235

The Effect of Ground Truth*

Average F-scores	GT to preds	3 GTs
Machine Print	0.813	0.888
Handwriting	0.845	0.889
Solid Lines	0.673	0.844
Dotted Lines	0.824	0.753
Stamps	0.244	0.933



Conclusions:

- HW and MP transfer in the 80-90% range
- Lines are more subjective
- Stamps transfer relatively poorly
- Needs more training data

RETURNED

11899

*Elisa H. Barney Smith. 2010. An analysis of binarization ground truthing. In *Proceedings of the 9th IAPR International Workshop on Document Analysis Systems* (DAS '10). ACM, New York, NY, USA, 27-34. DOI=http://dx.doi.org/10.1145/1815330.1815334

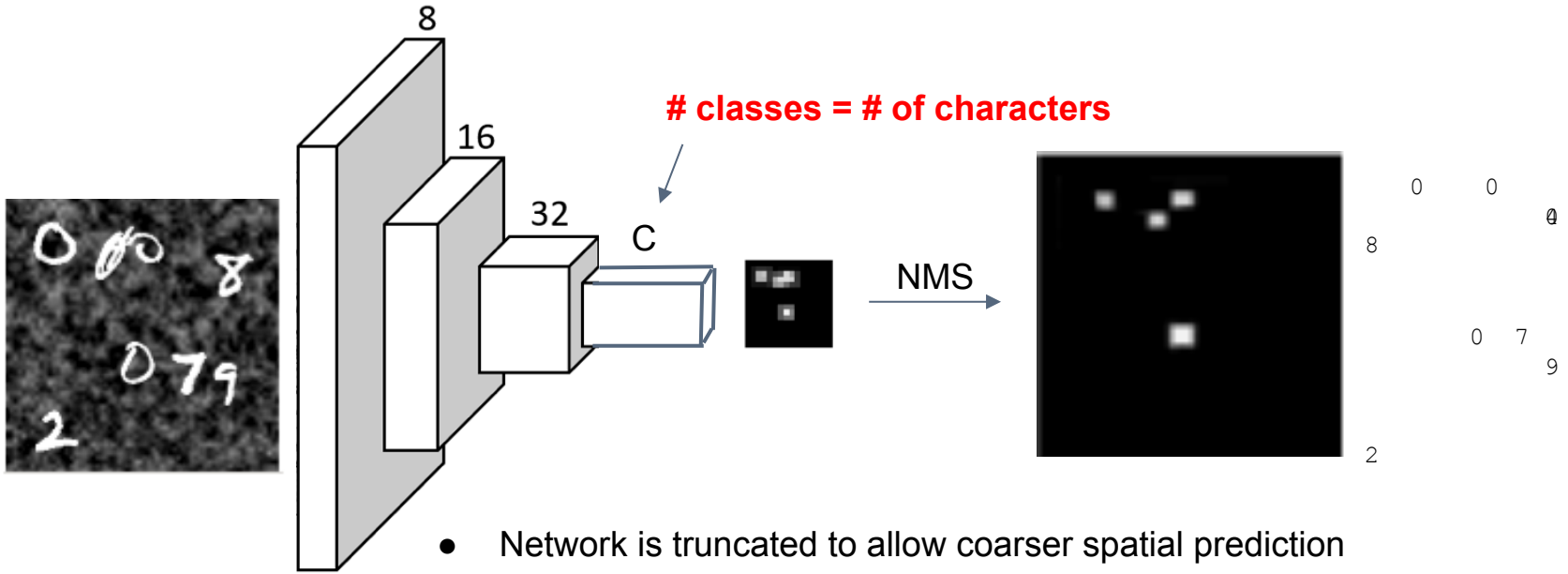
Overview

1. What is Page Segmentation?
2. Neural Network Architectures for Page Segmentation
    a. (How to build your own Neural Network for a Document Pixel Labeling task)
3. Handling overlapping content in document images
4. **A natural extension to OCR**
5. Challenges and Frontiers

What if I could tell you...

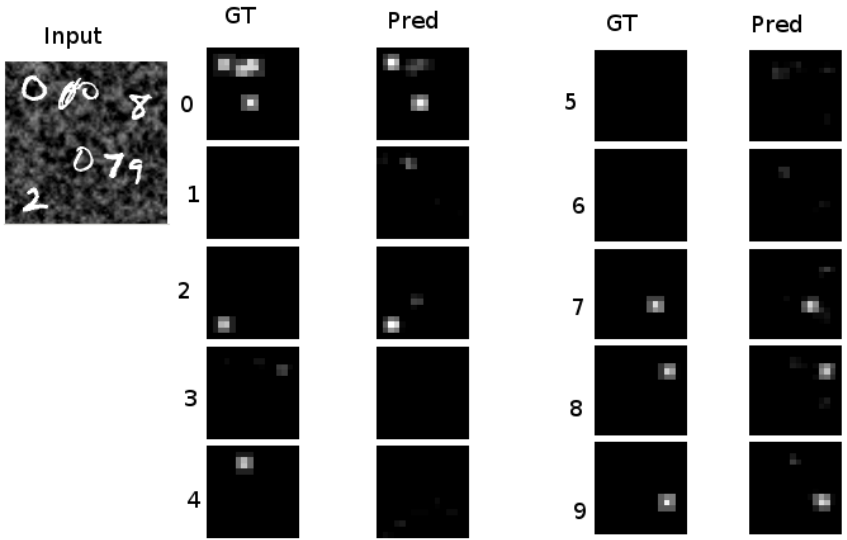
Not only is it machine print, it’s a “9”

Modification for character prediction



- Network is truncated to allow coarser spatial prediction
- Threshold + Non-Maximal Suppression can be used to identify characters directly

Segmentation-free character recognizer

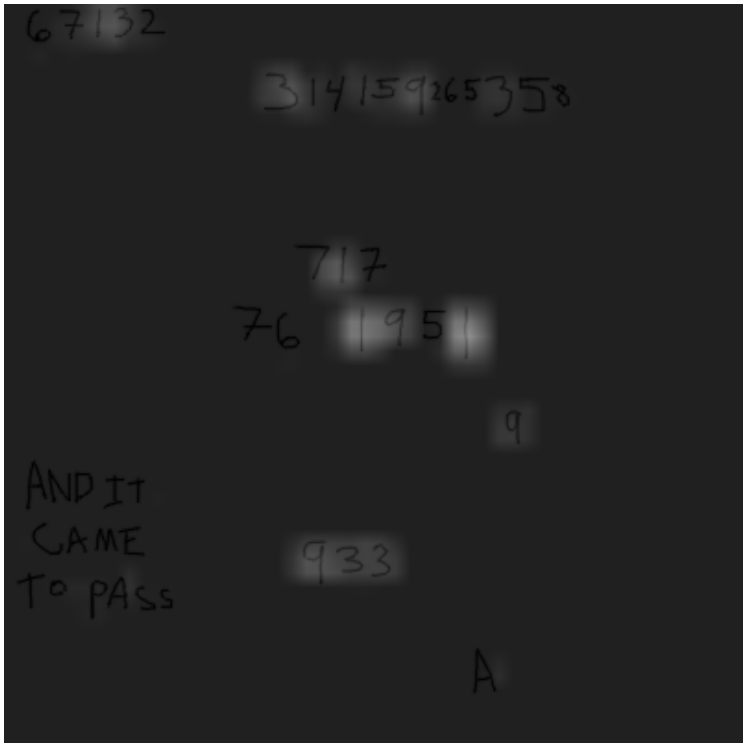


- Semantic Segmentation is performed to produce character heatmaps
- Easy to ground-truth
- Without tuning, a shallow network is 95% accurate at regressing MNIST digits at arbitrary locations

Segmentation-free character recognizer

Not constrained to words or lines in predetermined read order

Eliminates the need for any *a priori* word, character, or line segmentation algorithm.



Words, lines, and paragraphs can be recovered post-recognition

Overview

1. What is Page Segmentation?
2. Neural Network Architectures for Page Segmentation
    a. (How to build your own Neural Network for a Document Pixel Labeling task)
3. Handling overlapping content in document images
4. A natural extension to OCR
5. **Challenges and Frontiers**

Open challenges / Future Work

-Network architecture search is still inefficient

(but maybe a small network can be good enough for some tasks?)

-Pixel labeling is still not integrated with downstream tasks (OCR, Handwriting recognition, region pairing)

-Fuse character recognition with other document processing tasks

Semantic Segmentation web demo

http://bit.ly/2tgbo2G

Acknowledgements

Special thanks to:

Lucas Pinto, Allen Liao, Zhihan Tsai, Curtis Wigington
Brigham Young University

Pat Schone, Jon Morrey
FamilySearch

Scott Cohen and Brian Price
Adobe Research

Seth Stewart and Bill Barrett
Brigham Young University
stewart.seth.a@gmail.com

Questions?

Document Image Page Segmentation and Character Recognition
as Semantic Segmentation

Seth Stewart and Bill Barrett
Brigham Young University
stewart.seth.a@gmail.com

Future/Ongoing Work

Two-form cross-validation

Form Instance A validated against Form Instance B				
Class	Training		Validation	
	Precision	Recall	Precision	Recall
Machine Print	0.927	0.783	0.812	0.891
Handwriting	0.930	0.868	0.842	0.929
Solid Lines	0.815	0.912	0.574	0.996
Dotted Lines	0.857	0.923	0.735	0.927
Stamps	0.794	0.885	0.199	0.282

Trained on Form Instance B				
Class	Training		Validation	
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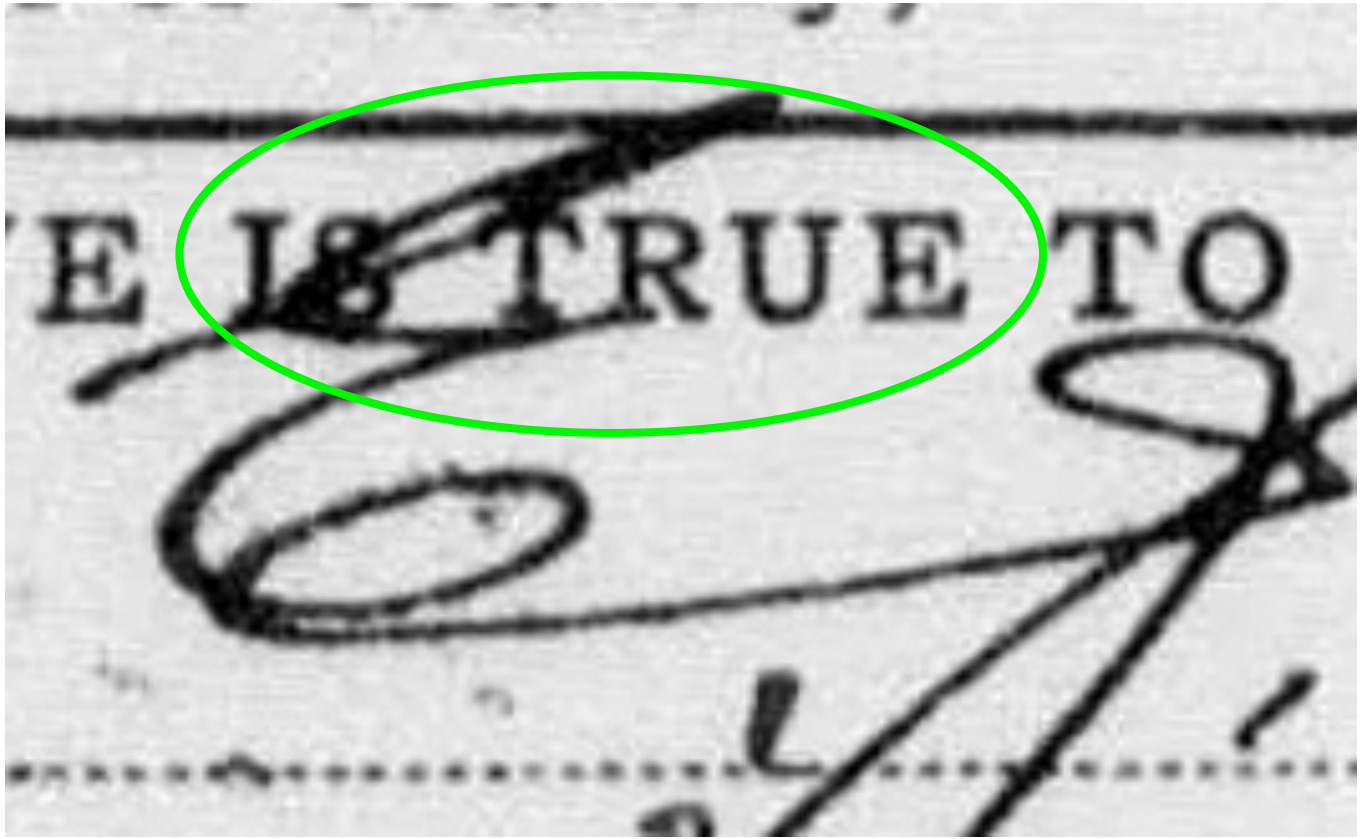
Machine Print	0.967	0.945	0.869	0.703
Handwriting	0.935	0.940	0.897	0.734
Solid Lines	0.906	0.916	0.743	0.530
Dotted Lines	0.930	0.920	0.885	0.777
Stamps	0.682	0.979	0.279	0.235

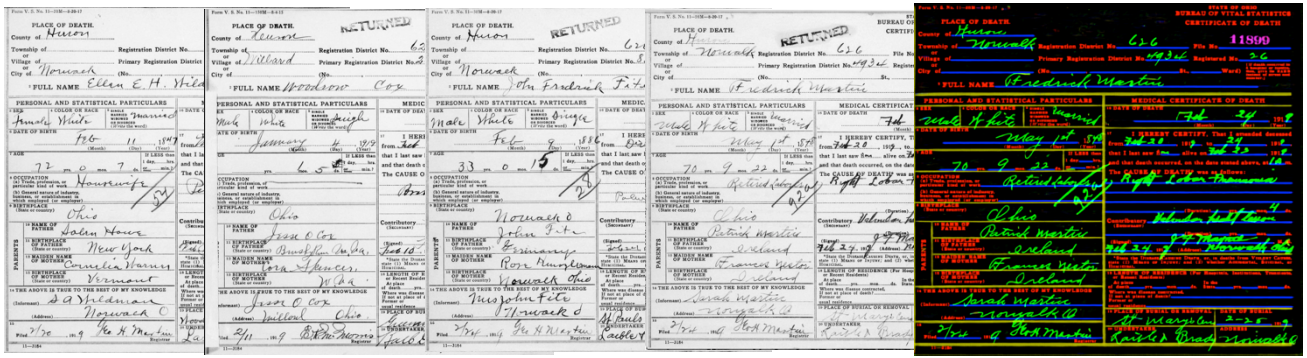
Compare to Chen and Seuret's
77-96 f.w. IU on Parzival, Washington, and Saint Gall databases
IU can be seen as symmetric precision & recall.
It is bounded as pessimistic, score-wise, relative to Prec & Rec. In other words, it will always be lower than either of these.
IU is a lower bound on Prec & Rec.

But these are against arbitrary pixel-level ground truth
TODO: Compare to HBA results

Handling Class Overlap



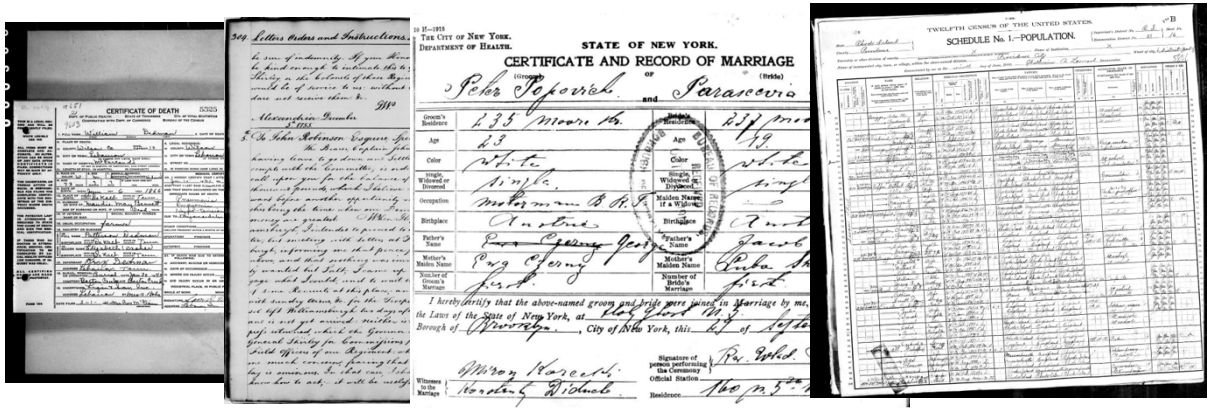
Larger Dataset Creation



Early 20th Century Death Records

Similar layouts

Answers the question:
How well do classes transfer to similar images?

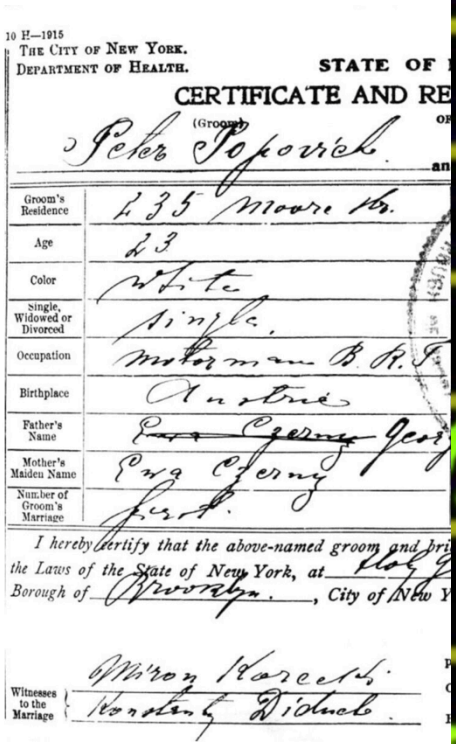


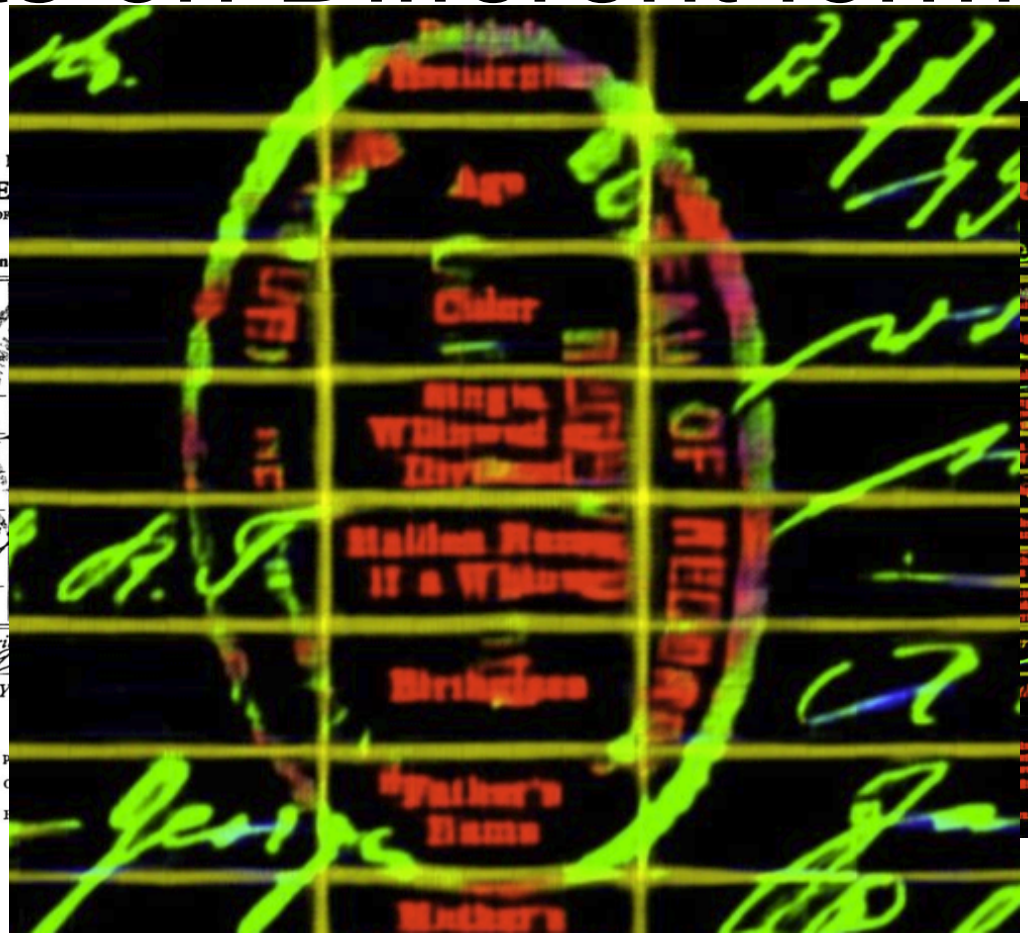
1800s-1900s Birth Certificates, Marriage Records, Wills, Census Records, etc.

Different layouts

Answers the question:
How well do classes transfer across different layouts?

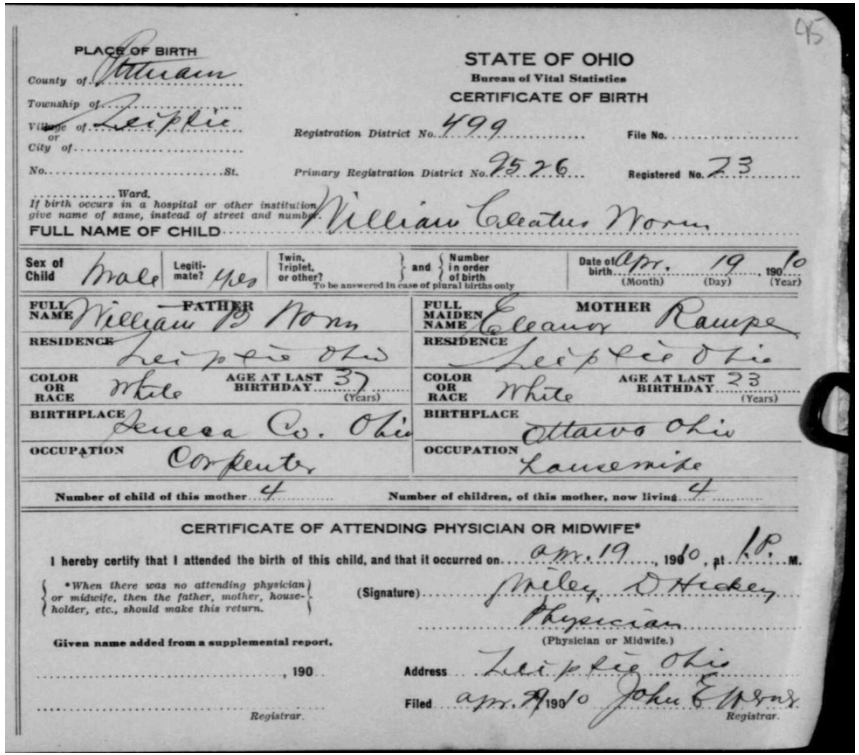
Results on Different form types


10 H—1915
THE CITY OF NEW YORK.
DEPARTMENT OF HEALTH.
STATE OF
CERTIFICATE AND RE
(Groom)
Peter Topovich
Groom's Residence: 235 Moore St.
Age: 23
Color: White
Single, Widowed or Divorced: Single.
Occupation: Motorman B.R.T.
Birthplace: Austria
Father's Name: [illegible]
Mother's Maiden Name: Eva Czerny
Number of Groom's Marriage: first
I hereby certify that the above-named groom and bri
the Laws of the State of New York, at
Borough of Brooklyn, City of New Y
Witnesses to the Marriage: Miron Karcetich, Karolina Didulich



YORK.
D OF MARRIAGE
(Bride)
Paraseovia Topovich
235 Moore St.
23.
White.
Single.
Austria
Farm
Eva Skevchuta
first
Rev. Rafael Sabuza
Brooklyn

Results on Different form types



PLACE OF BIRTH
County of Putnam
Township of
Village of Leipsic
or
City of
No. St.
Ward.
If birth occurs in a hospital or other institution give name of same, instead of street and number

STATE OF OHIO
Bureau of Vital Statistics
CERTIFICATE OF BIRTH

Registration District No. 499 File No.
Primary Registration District No. 9526 Registered No. 73

FULL NAME OF CHILD William Chester Norris

Sex of Child: Male | Legitimate? Yes | Twin, Triplet, or other? | and Number in order of birth (To be answered in case of plural births only) | Date of birth Apr. (Month) 19 (Day) 10 (Year)

FATHER	MOTHER
FULL NAME William B Norris	FULL MAIDEN NAME Eleanor Rampe
RESIDENCE Leipsic Ohio	RESIDENCE Leipsic Ohio
COLOR OR RACE White	COLOR OR RACE White
AGE AT LAST BIRTHDAY 37 (Years)	AGE AT LAST BIRTHDAY 23 (Years)
BIRTHPLACE Juneau Co. Ohio	BIRTHPLACE Ottawa Ohio
OCCUPATION Carpenter	OCCUPATION Housewife

Number of child of this mother 4
Number of children, of this mother, now living 4

CERTIFICATE OF ATTENDING PHYSICIAN OR MIDWIFE*

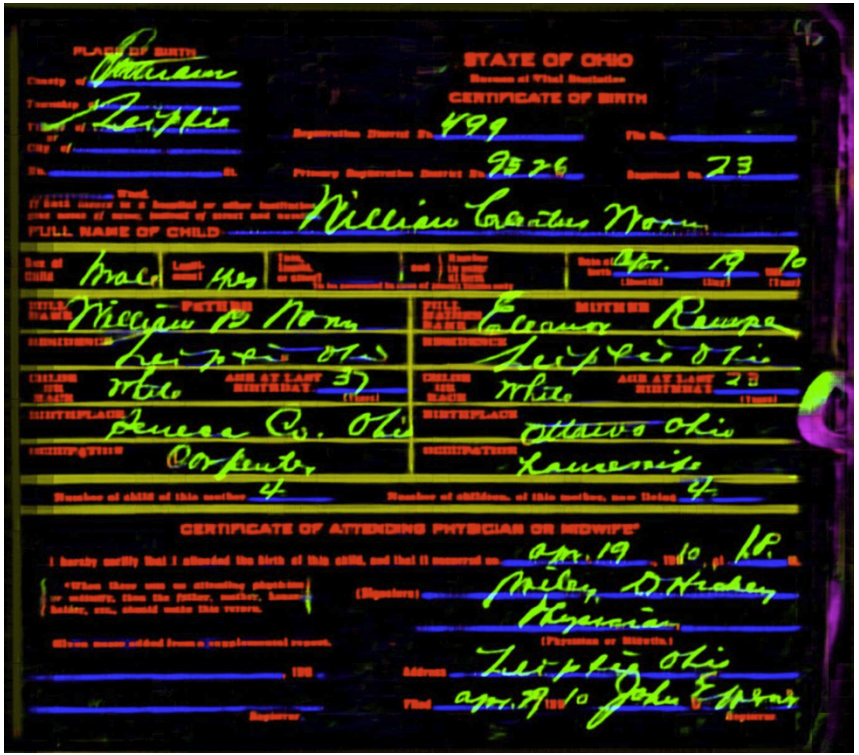
I hereby certify that I attended the birth of this child, and that it occurred on Apr. 19 1910, at 1P. M.

*When there was no attending physician or midwife, then the father, mother, householder, etc., should make this return.

(Signature) Miley D Hickey
Physician
(Physician or Midwife.)

Given name added from a supplemental report.
, 190
Registrar.

Address Leipsic Ohio
Filed Apr. 19 1910 John E Myers
Registrar.



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Validation

Performance Measures

Precision $P_i = \frac{n_{ii}}{\sum_j n_{ji}}$

Recall $R_i = \frac{n_{ii}}{\sum_j n_{ij}}$

F-Score $F_{score,i} = 2 \times \frac{P_i \times R_i}{P_i + R_i}$

Accuracy $acc = \frac{\sum_i n_{ii}}{\sum_i t_i}$

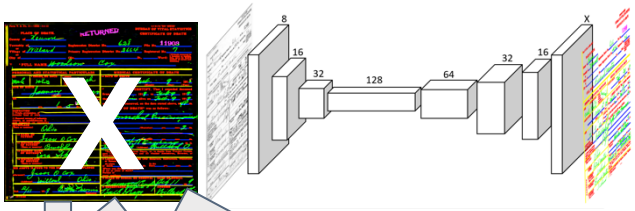
Mean Accuracy $acc_{mean} = \frac{1}{n_c} \frac{\sum_i n_{ii}}{\sum_i t_i}$

Intersection Over Union $IoU_{freqwt} = \frac{1}{n_c} \sum_i \frac{t_i \times n_{ii}}{t_i + \sum_j n_{ji} - n_{ii}}$

Mean Intersection Over Union $IoU_{mean} = \frac{1}{n_c} \sum_i \frac{n_{ii}}{t_i + \sum_j n_{ji} - n_{ii}}$

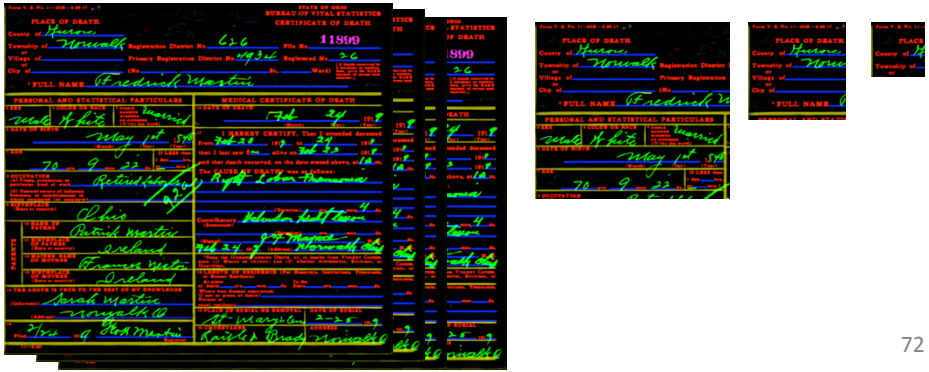
1. Similar Layouts

2. Similar Contents



3. Human-to-Human vs. Machine-to-Human

4. Dataset size analysis: How much is too little?



How to get crisp upsampling?

Train the network at multiple scales, and then at inference time…

Inflate the resolution of the image you are predicting on!