

Chargrid: Towards Understanding 2D Documents

Christian Reisswig

Anoop R. Katti, Steffen Bickel, Sebastian Brarda, Cordula Guder, Johannes Höhne, Jean B. Faddoul, Ying Jiang, Stefan Baur, Alexander Dueck

SAP Deep Learning Center Of Excellence
January 28, 2019

PUBLIC

Problem Description: Key-Value Extraction

Input:

[pdf / image]

ABC Communications							Invoice
3451 NE Willoughby Blvd. Stuart, FL 54094 U.S.A Phone: (72) 288-2250 Fax: (72) 288-9631							Number: 174221 Date: 2/18/2016
E-Mail: dispatch@abcms.com Web: www.abcms.com							
Bill To Standard Products 3150 SW 7th Street Miami, FL 32127 U.S.A. Phone: (306) 461-003				Ship To Standard Products 6406 SW 7th St Suite 145 Miami, FL 32127 U.S.A. Phone: 306.41.0073		Source: S. O. # 687250	
Acct. #	A/R Cust. #	Acct. ID	Customer P.O.	Reference	Sales Rep	Ship Via	Terms
860	Std Products	Ft. Lauderdale	Ben	Ben	House .	Email	Due upon receipt
Work Requested: 02/01/2016 11:39 AM, Gary:							
Per phone call from Ben: Customer advised that the incoming phone calls now ring throughout the store over the speaker.							
Ben # 306.41.073 Ben cell # 052-005-691							
Work Performed: 2/16/16 Lines had programming glitch, ring over page to group 5011. Deleted Lisa out of MC 7224. Tested all lines incoming OK 711231-716. There should be no calls coming in on these lines//J							
Part Number	Description			Qty.	UOM	Ea. Price	Total
2001	Spot consulting sessions			2.00	HR	\$ 55.00	\$ 110.00
3001	Extra Fee 24h Service			1.00	HR	\$ 70.00	\$ 70.00
9001	Travel costs			1.00	TR	\$ 40.00	\$ 40.00
							Item Total: \$ 220.00
							Sales Tax \$ 0.00
							Total Amount Due: \$ 220.00

Output:

extracted tokens [json]



```
{  
    "InvoiceNumber": "xxxxx",  
    "InvoiceAmount": "xxx.xx",  
    "InvoiceDate": "xx-xx-xxxx",  
    "LineItems": {  
        "0": {  
            "Description": "xxxx xxxxxxxxxxxx xxxx xxxxxxxx",  
            "Quantity": "xx",  
            "TotalPrice": "xxx.xx"  
        },  
        "1": {  
            "Description": "xxxx xxxxxxxxxxxx xxxx xxxxxxxx",  
            "Quantity": "xx",  
            "TotalPrice": "xxx.xx"  
        }  
    }  
}
```

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3451 NE Willoughby Blvd.
Stuart, FL 54094 U.S.A.
Phone: (72) 288-2250 Fax: (72) 288-9631

E-Mail: dispatch@abcms.com Web: www.abcms.com

Invoice
Number: **174221**
Date: **2/18/2016**



= „Header Fields“

<u>Bill To</u>	<u>Ship To</u>	Source: S. O. # 687250
Standard Products 3150 SW 7th Street Miami, FL 32127 U.S.A. Phone: (306) 461-003	Standard Products 6406 SW 7th St Suite 145 Miami, FL 32127 U.S.A. Phone: 306.41.0073	

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Item Total: **\$ 220.00**
Sales Tax **\$ 0.00**
Total Amount Due: **\$ 220.00**

E.g.:

- Vendor Name
- Vendor Address
- Invoice Number
- Invoice Date
- Total Amount
- Subtotal

Problem Description: Key-Value Extraction

ABC Communications

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Stuart, FL 54094 U.S.A.
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E-Mail: dispatch@abcms.com Web: www.abcms.com

Invoice

174221

Number:
174221
Date:
2/18/2016



= „Line Item“



= „Line Item Column“

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E.g.:

- Line Item Total Price
- Line Item Quantity
- Line Item Description

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Challenge:

- Large variety of invoice layouts
- Multiple languages
- Not all fields are always present
- Tables / line items with irregular structure
- Documents exhibit „2D structure“

Problem Description: Dataset

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E-Mail: dispatch@abcms.com Web: www.abcms.com							
Bill To		Ship To	Source: S.O. # 687250				
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						Item Total:	\$ 220.00
						Sales Tax	\$ 0.00
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Available Ground Truth:

- Bounding box annotations

~ 10,000 samples in training set

~ 1,000 samples in validation set

~ 1,000 samples in test set

Approaches

Approach: Sequential Models

Input: invoice [pdf / image]

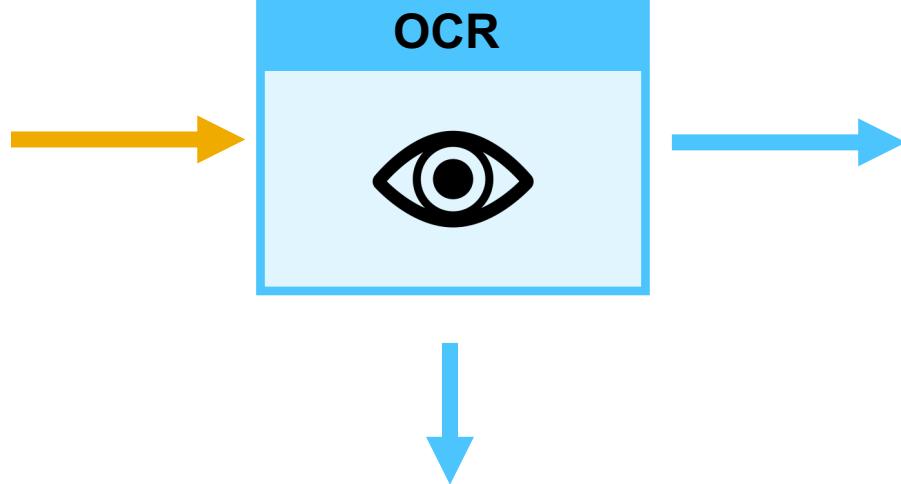
ABC Communications 3451 NE Willoughby Blvd. Stuart, FL 54094 U.S.A. Phone: (72) 288-2250 Fax: (72) 288-9631 E-Mail: dispatch@abcmis.com Web: www.abcmis.com		Invoice Number: 174221 Date: 2/18/2016																																										
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Approach: Sequential Models

Input: invoice [pdf / image]

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E-Mail: dispatch@abcmcs.com Web: www.abcmcs.com							
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Acct # 860	A/R Cust. # Std Products	Acct. ID Ft. Lauderdale	Customer P.O. Ben	Reference Ben	Sales Rep House.	Ship Via Email	Terms Due upon receipt
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String
Lorem ipsum dolor sit amet,
consectetur adipiscing elit,
sed do eiusmod tempor
incididunt ut labore et dolore
magna aliqua. Ut enim ad minim
veniam, quis nostrud
exercitation ullamco laboris
nisi ut aliquip ex ea commodo
consequat. Duis aute irure
dolor in reprehenderit in
voluptate velit esse cillum
dolore eu fugiat nulla
pariatur.

Approach: Sequential Models

Input: invoice [pdf / image]

ABC Communications
211 NE Washington Blvd.
Stuart, FL 34904 U.S.A.
Phone: (727) 288-2250 Fax: (727) 288-9631
E-Mail: dispatch@abcmcs.com Web: www.abcmcs.com

Invoice
Number: 174221
Date: 2/18/2016

Bill To: Standard Products
3150 SW 7th Street
Miami, FL 32127 U.S.A.
Phone: (305) 461-0033

Ship To: Standard Products
6406 SW 7th St
Suite 145
Miami, FL 32127 U.S.A.
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Source: S.O. # 687250

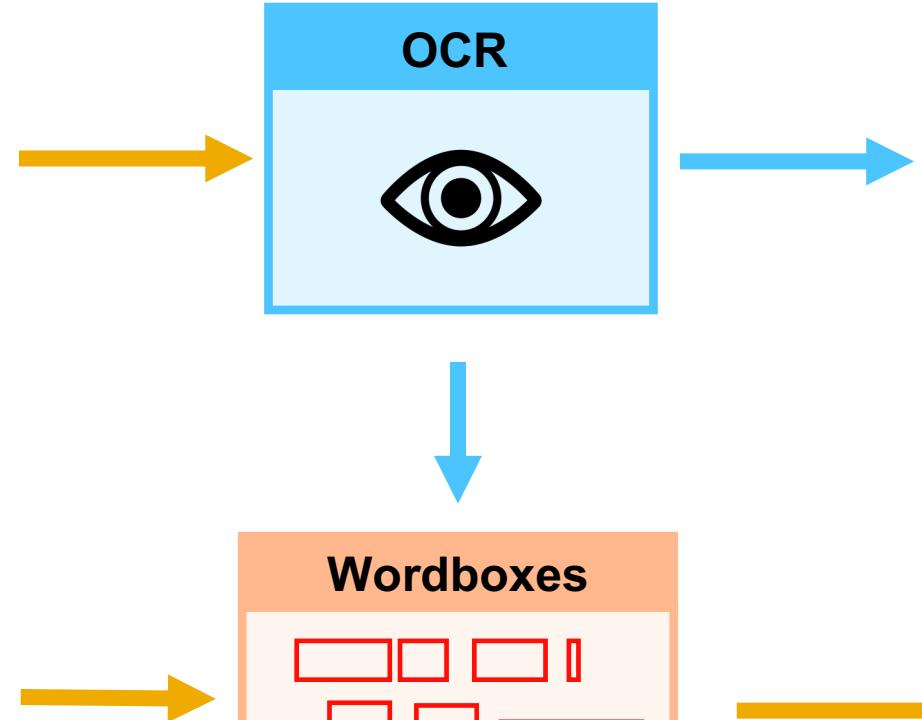
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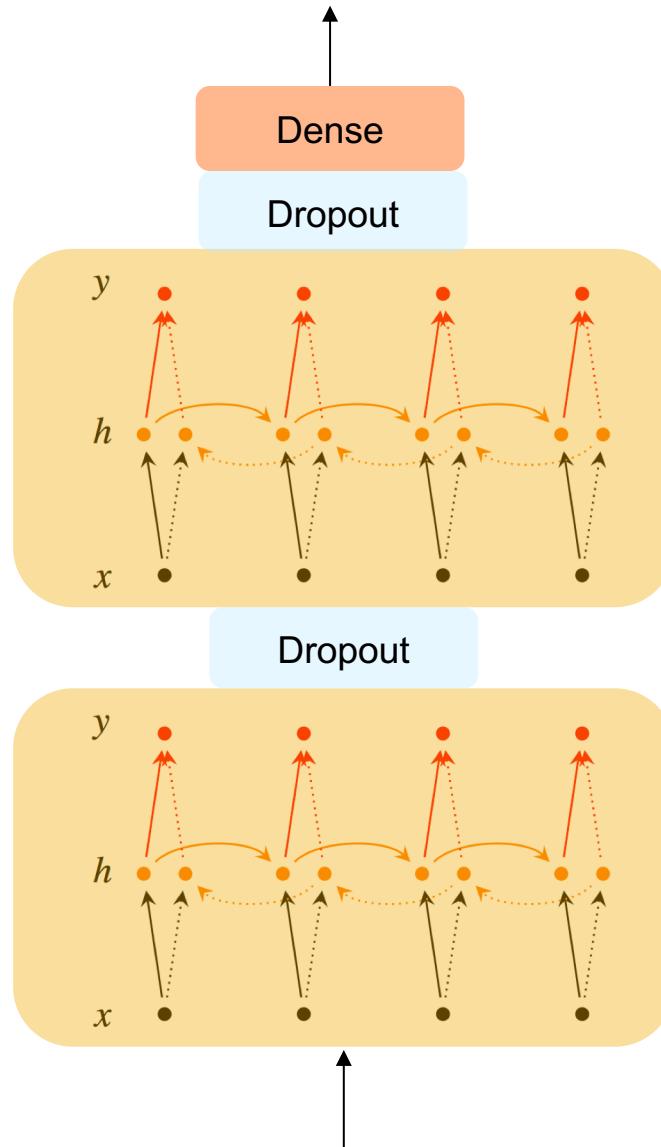
For each character in the input,
we know the class label!

Approach: Sequential Models

„Stacked Bidirectional Gated Recurrent Units (GRUs)“

Character-based Input

111101111100000000022200000003333333333



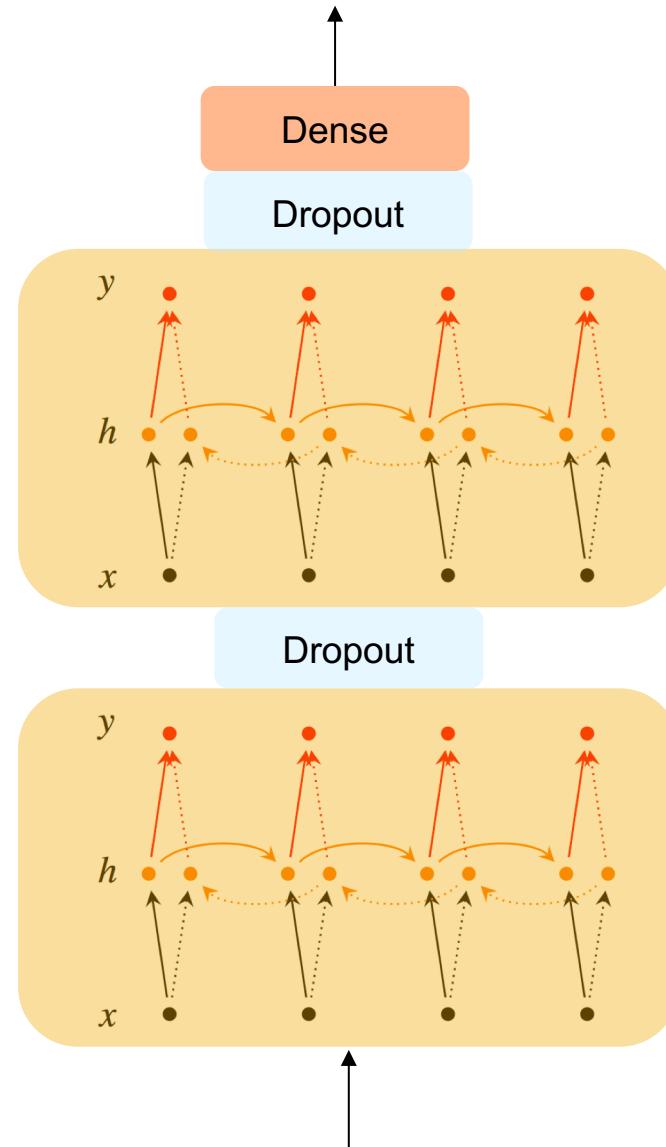
Approach: Sequential Models

„Stacked Bidirectional Gated Recurrent Units (GRUs)“

Great performance for „header fields“

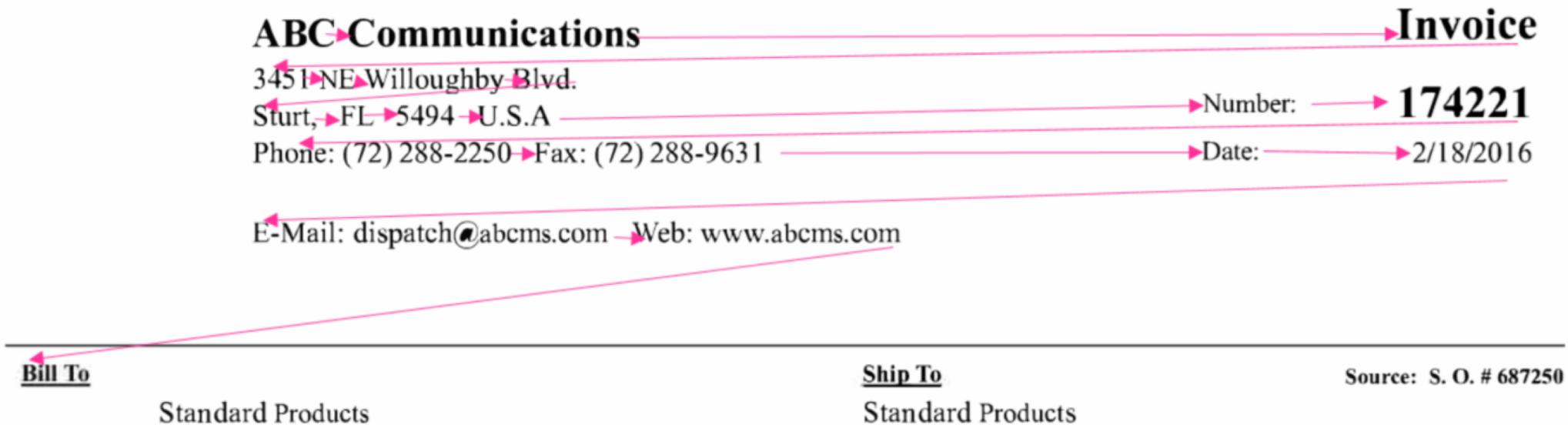
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111101111100000000022200000003333333333



Approach: Sequential Models

Drawback: RNN has a hard time capturing 2D relations in the text
(like a single column spanning multiple rows)



Approach: Sequential Models

Drawback: RNN has a hard time capturing 2D relations in the text
This is **problematic** especially for “line item” extraction!

Date	Description	Qty	Rate	Tax Amt	Amount
24/11/2015	Dry Hire 980II Loader- NWEII095 26/10/15 to 23/11/15 Start Hours- 5268 End Hours- 5626	358	80.00	2,864.00	28,640.00
	Dry Hire 980II Loader- NWEII096 26/10/15 to 23/11/15 Start Hours- 10608 End Hours- 10941	333	80.00	2,664.00	26,640.00

Approach: Computer Vision

- **Object Detection**
- Directly work on image (i.e. scanned document)
- Predict bboxes for fields of interest
- Some initial success with off-the-shelf “Single Shot Detector (SSD)”
- Results not yet satisfactory

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3001	Extra Fee 24h Service	1.00	HR	\$ 70.00	\$ 70.00
9001	Travel costs	1.00	TR	\$ 40.00	\$ 40.00
Item Total:				\$ 220.00	
Sales Tax				\$ 0.00	
Total Amount Due:					\$ 220.00

Approach: Computer Vision

- **Object Detection**

Drawback:

- Computationally very expensive
(3500x2500 pixel images)
- small font
- need to learn to interpret characters/words
from pixel level (like implicit OCR)

ABC Communications

3451 NE Willoughby Blvd.
Stuart, FL 54094 U.S.A.
Phone: (72) 288-2250 Fax: (72) 288-9631

E-Mail: dispatch@abcms.com Web: www.abcms.com

Invoice

Number:
174221
Date:
2/18/2016

Bill To					Ship To				Source: S. O. # 687250
Standard Products 3150 SW 7th Street Miami, FL 32127 U.S.A. Phone: (306) 461-003					Standard Products 6406 SW 7th St Suite 145 Miami, FL 32127 U.S.A. Phone: 306.41.0073				

Acct. #	A/R Cust. #	Acct. ID	Customer P.O.	Reference	Sales Rep	Ship Via	Terms
860	Std Products	Ft. Lauderdale	Ben	Ben	House .	Email	Due upon receipt

Work Requested: 02/01/2016 11:39 AM, Gary:

Per phone call from Ben: Customer advised that the incoming phone calls now ring throughout the store over the speaker.

Ben # 306.41.073
Ben cell # 052-005-691

Work Performed: 2/16/16
Lines had programming glitch, ring over page to group 5011. Deleted Lisa out of MC 7224. Tested all lines incoming OK 711231-716. There should be no calls coming in on these lines//J

Part Number	Description	Qty.	UOM	Ea. Price	Total
2001	Spot consulting sessions	2.00	HR	\$ 55.00	\$ 110.00
3001	Extra Fee 24h Service	1.00	HR	\$ 70.00	\$ 70.00
9001	Travel costs	1.00	TR	\$ 40.00	\$ 40.00
Item Total:				\$ 220.00	
Sales Tax				\$ 0.00	
Total Amount Due:					\$ 220.00

Idea: ‘Character Grid’ Representation

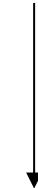
- We have OCR: word boxes + string
- We **want to retain 2D spatial relationship** of text (i.e. no serialization!)
- We want to **make use of character / word representation**
i.e. one-hot encoding / word embedding

SAP SE

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SAP SE

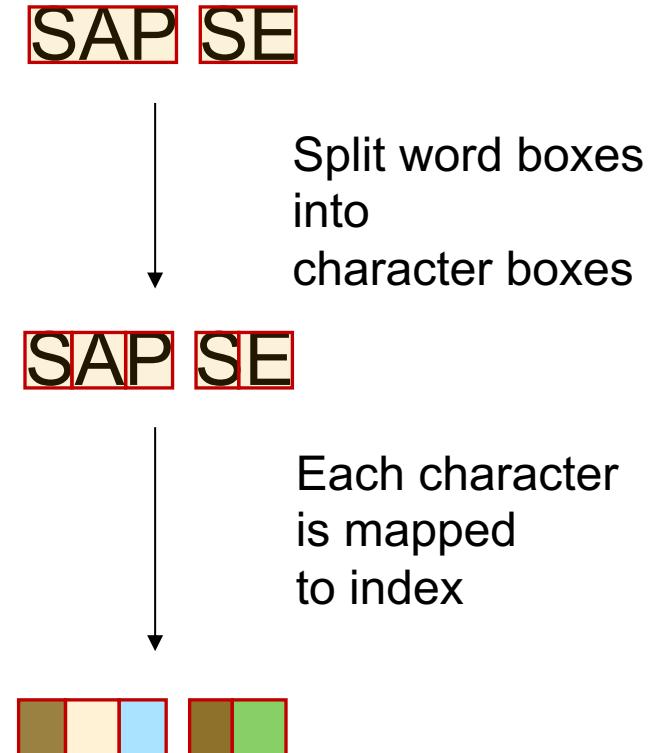


Split word boxes
into
character boxes

SAP SE

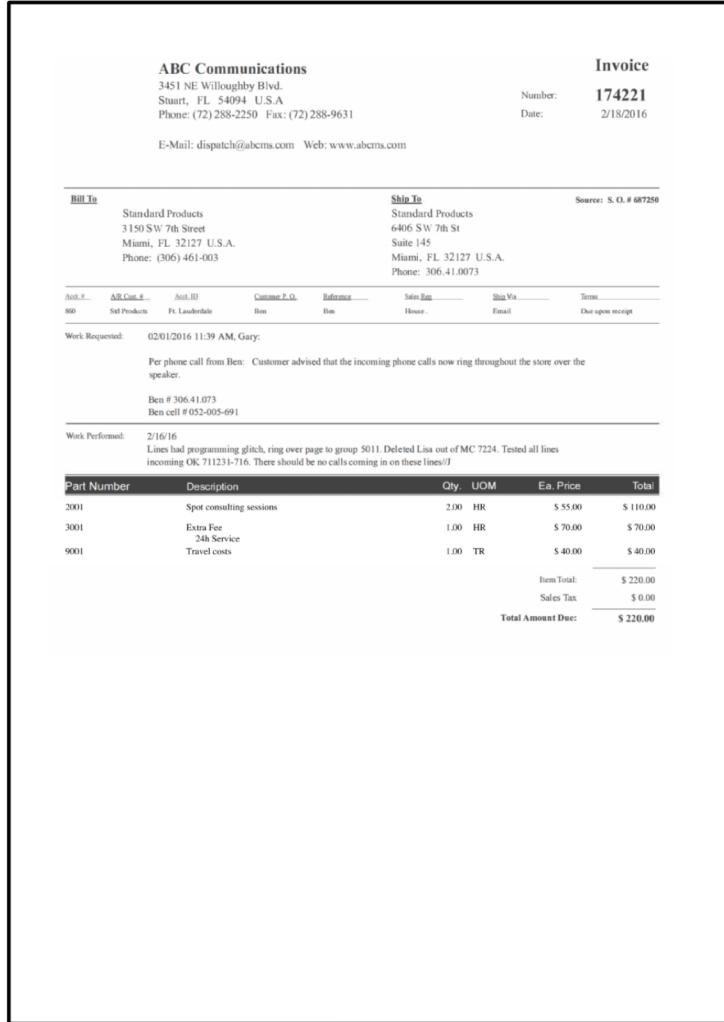
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Idea: ‘Character Grid’ Representation

Raw document



Chargrid



- 1) Run OCR: → Text, WordBoxes
- 2) Map Character → Index
- 3) WordBox, Character Index: → character grid

Advantage:

- We encode character information
- Retains spatial 2D relationship of text
- Allows us to aggressively downsample

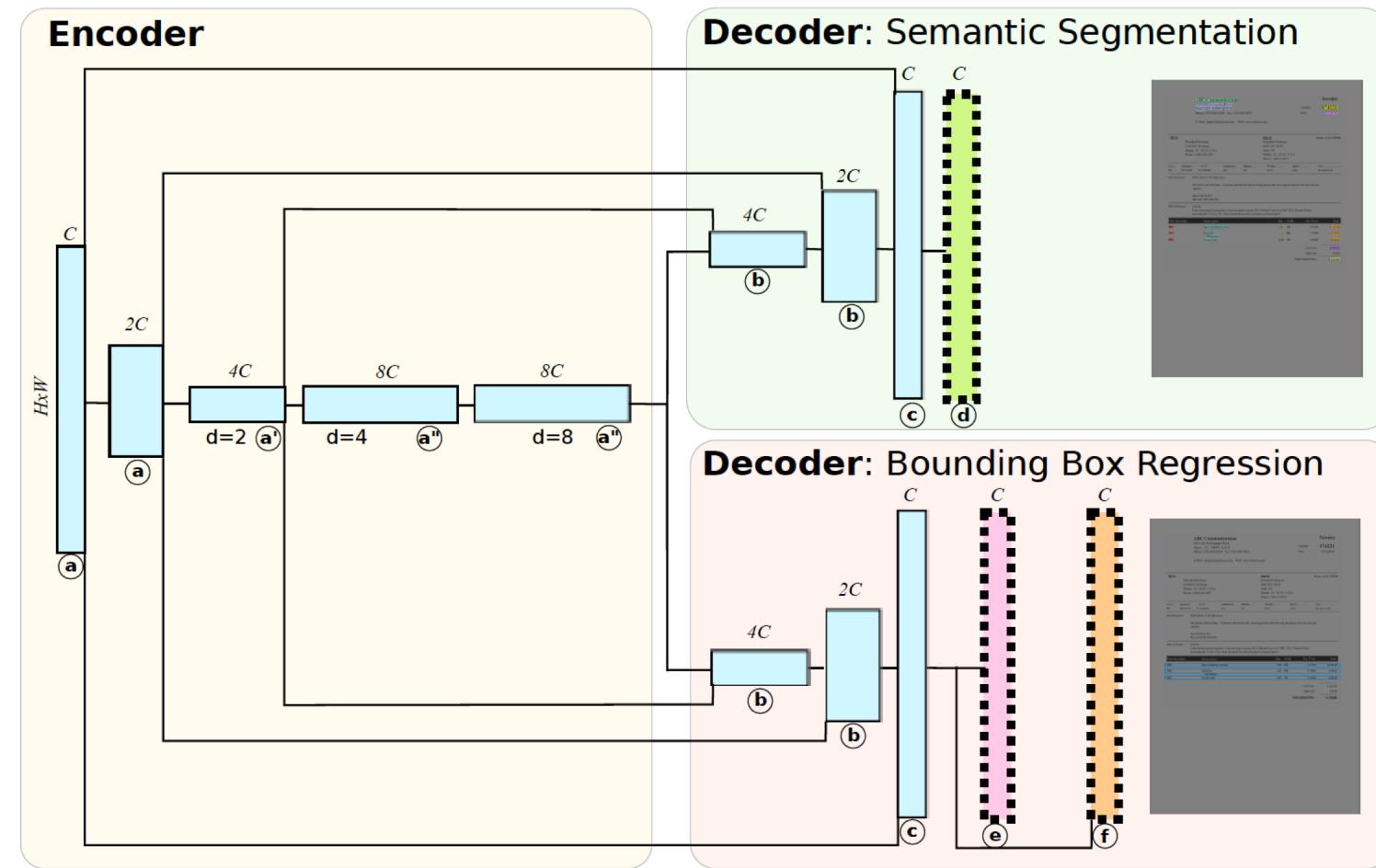
Model: Semantic Instance Segmentation

Fully Convolution Neural Network (Semantic Segmentation + Single-Stage Object Detection)

Raw data

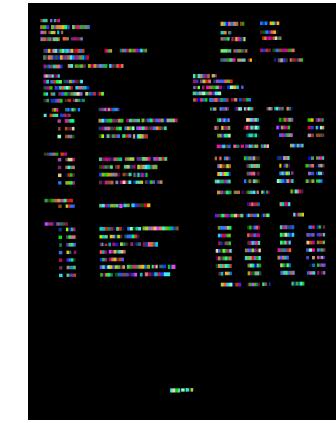
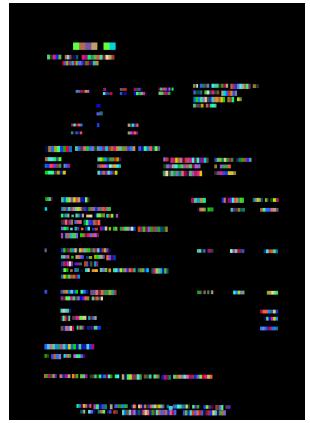


Chagrid

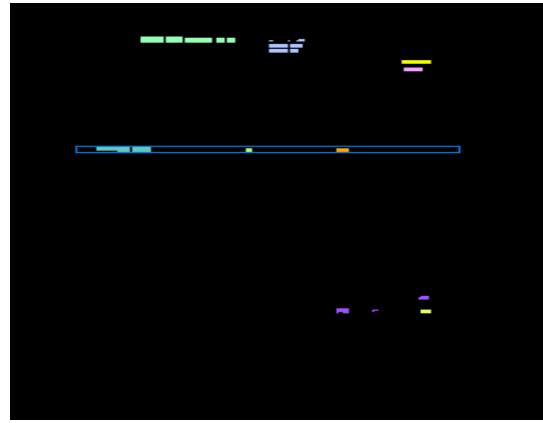
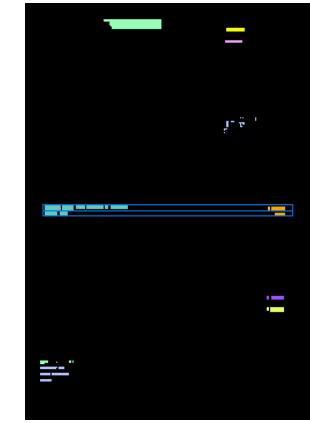
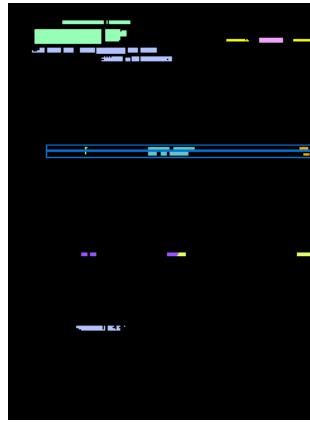
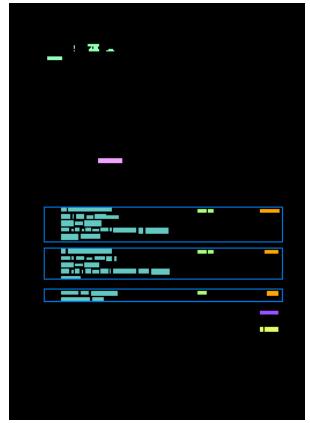


Example Outputs

chargrid



prediction
mask and boxes



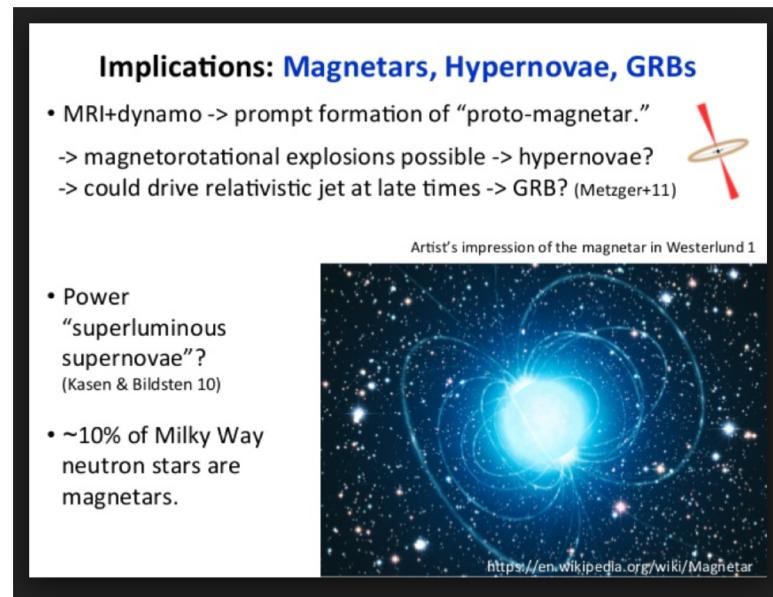
Results

Model/Field	Invoice Number	Invoice Amount	Invoice Date	Vendor Name	Vendor Address	Line-item Description	Line-item Quantity	Line-item Amount
sequential	80.98%	79.13%	83.98%	28.97%	16.94%	-0.01%	-0.18%	0.22%
image-only	47.79%	68.91%	45.67%	19.68%	13.99%	49.50%	46.79%	63.49%
chargrid-net	80.48%	80.74%	83.78%	36.00%	39.13%	52.80%	65.20%	65.57%
chargrid-hybrid-C32	74.85%	77.93%	80.40%	32.00%	31.48%	46.27%	64.04%	63.25%
chargrid-hybrid-C64	82.49%	80.14%	84.28%	34.27%	36.83%	48.81%	64.59%	64.53%

Beyond Invoices...

- Our method should be applicable to *any* rich document where 2D structure is important

- Named Entity Recognition
 - Document Semantic Structure
 - Key-Val Extraction



The Shared Office Printer
Instruction Manual

WWW.PHDCOMICS.COM

Quick Guide:

The Graveyard of Abandoned Documents

- Test Pages
- Computer Gibberish ↴ ↵ ↶ ↷ ↸ ↹ ↺ ↻
- A 200-page document somebody printed but never used (treekiller!)
- Your co-workers' personal correspondence you can use to extort them in the future

The Ether
Where 80% of the documents you send to print actually go.

Troubleshooting Guide:

Error Message	Action
'Low Ink'	Ignore. Just keep on printing...
'Out of Paper'	Default mode. Put in just enough paper to print your documents.
'Paper Jam'	Non-existent. Open and close the hatch, that usually works.
'Warming Up'	Count as precious minutes of your life are wasted.

Driver Installation

Choose from several frustratingly similar model numbers:

- Laserjet 4000dn
- Laserjet 4000ex 7
- Laserdeck 4000dnA
- Laserprint 4000 Series 7

Caution: choosing the wrong one will permanently damage your computer.

Personal Use

Is it appropriate to use this printer for personal use? Use this chart to find out:

Likelihood You'll Get Fired

Volume

Everyone does it

Maps, Directions to parties, totally ok

Fliers for your missing pet/garage sale/art event

Printing stuff for your side business

Danger Zone!

How to Load Special Paper (a.k.a. the "Print Sprint")

Step 1. Load your special paper

Step 2. Run as fast as you can to your desk!!

Step 3. Hit "Print"!

Step 4. Run back to the printer!!

Step 5. Watch someone else beat you to it.

WTH?? Aargh!!

JORGE CHAM © 2013

Conclusion

- New representation: ‘character grid’ (or likewise: ‘word grid’)
- Captures 2D relation of text
- Combine computer vision with natural language processing
- Superior performance compared to other methods that we tried (seq2mask, Image-based CNN) for line item extraction

Paper accepted at EMNLP 2018

<https://arxiv.org/abs/1809.08799>

Thank you.

Contact information:

Christian Reisswig

christian.reisswig@sap.com

Evaluation Metric

$$Metric = 1 - \frac{\#[\text{modifications}]+\#[\text{additions}]+\#[\text{deletions}]}{\#[\text{fields in ground truth}]}$$

Details:

#[modifications]: number of non-equal values for same index position for field X

#[additions]: number of field indices existing and non-zero in ground truth but missing in prediction

#[deletions]: number of field indices existing and non-zero in prediction but missing in ground truth

#[fields in ground truth]: number of non-empty (and non-zero) fields in ground truth

The metric is computed for each field separately.

Intuitive Meaning:

The metric counts the number of human actions (modify, add, or delete) that are required to convert the prediction values into the ground values.

This means the metric is the percentage of human work that is saved due to using the prediction model compared to manually entering the data entirely .