Graph neural networks for information extraction

EuroPython 2021

Augusto Stoffel

dida Machine Learning

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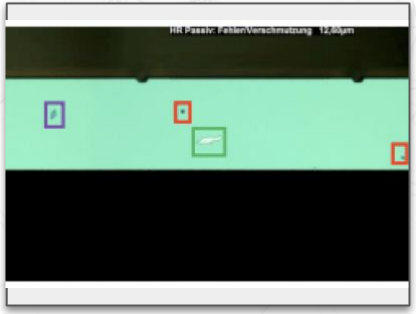
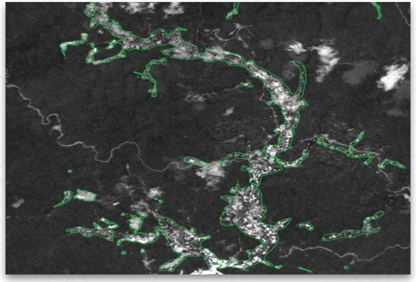
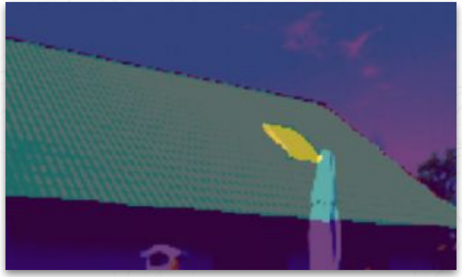
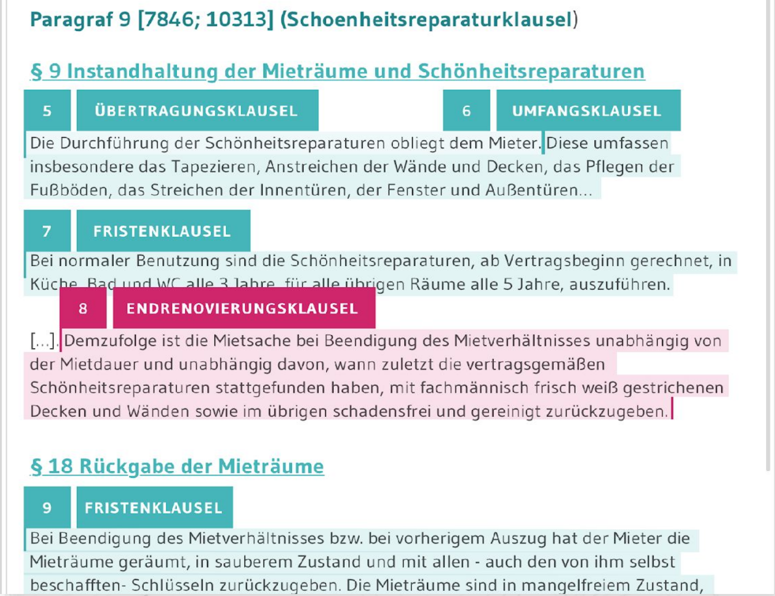
Deep learning landscape



Computer Vision

Example Project



Natural Language Processing (NLP)

Example Project

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Sample GNN use case

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12345 Hobbshausen

Tel.: 0211 12345 67
E-Mail: accounting@hobbs.de
Internet: www.deweyhobbs.de

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Rechnung Nr. 2020-06-1001   Bestellung-Nr.: KA12345   Kunden-Nr.: 1001

Bitte bei Zahlungen und Schriftverkehr angeben!

Datum: 07.06.2020

Pos	Leistung	MwSt.	Einzelpreis	Anzahl	Gesamtpreis
1	Röntgenblitzröhre ZW 367 H 01G 12 120kV /28mm / 20 cm	19 %	11,00 EUR	2	22,00 EUR
2	50kg Seesand reinst	19 %	22,00 EUR	1	22,00 EUR
3	Salzsäure 1 mol / 10l , 20l Standardlösung 7647-01-0	19 %	33,00 EUR	2	66,00 EUR

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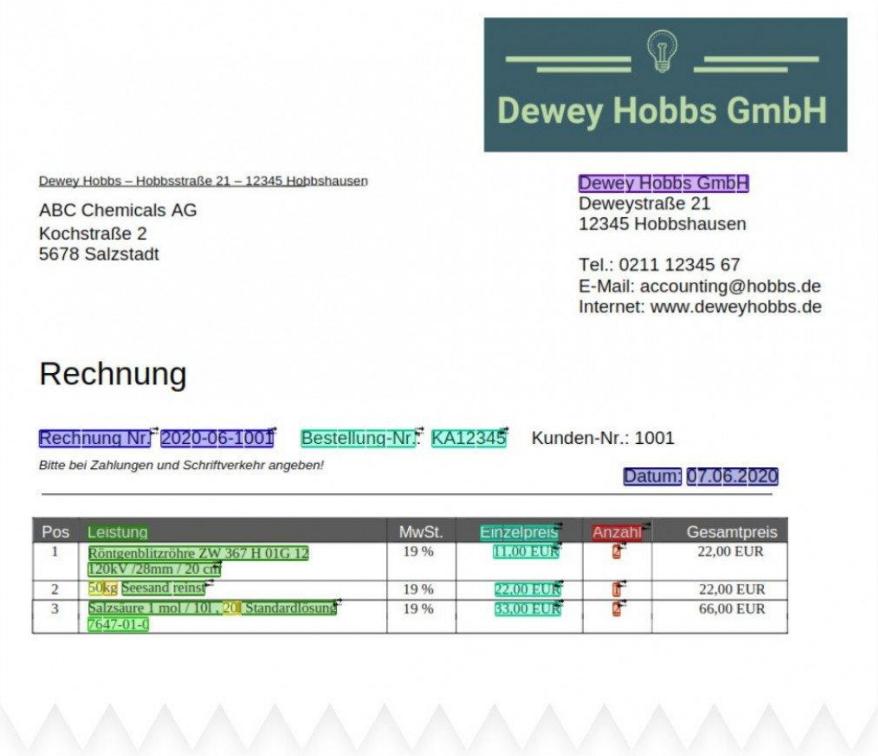
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A typical information extraction pipeline

Where do graphs enter in this picture?

- Encode information in a graph
- Use graph algorithms to process the information

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Agenda:

- Graphs and GNNs
- Comparison with convolutional networks
- Use case

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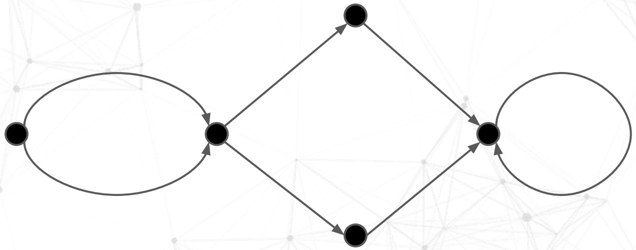
What is a graph?



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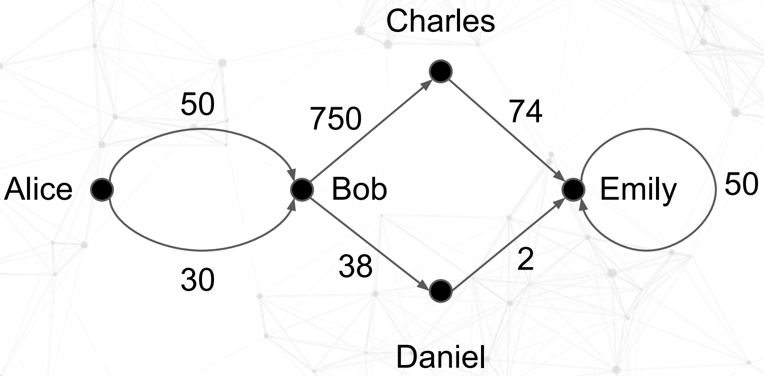
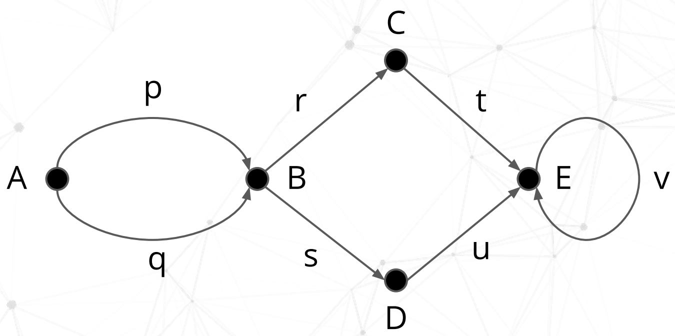


Variations: simple graph, multigraph, pseudograph; directed or not

What is a graph?

Definition: A *directed pseudograph*, or simply *graph*, is

- a set $\mathcal{V}$ of vertices
- a set $\mathcal{E}$ of edges
- functions source, target: $\mathcal{E} \rightarrow \mathcal{V}$



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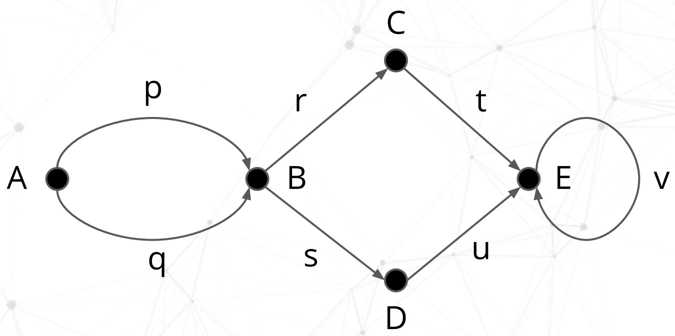

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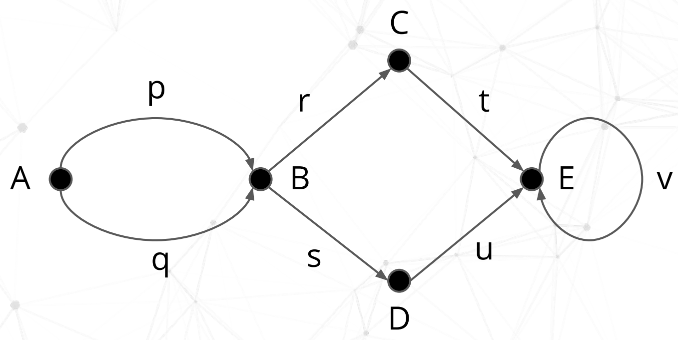
Example:

- $\mathcal{V}$ = {A, B, C, ..., E}
- $\mathcal{E}$ = {p, q, r, ..., v}
- source(p) = A
- target(p) = B
- source(v) = E
- target(v) = E

What is a graph?



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- target(v) = E

Note: Often there are labels associated to vertices and edges.

- L_0: $\mathcal{V} \rightarrow$ {vertice labels}
- L_1: $\mathcal{E} \rightarrow$ {edge labels}

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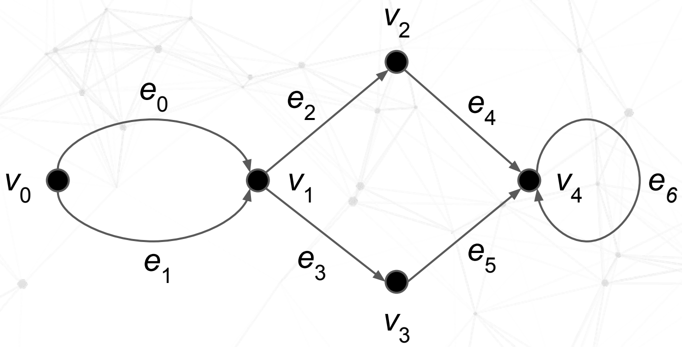
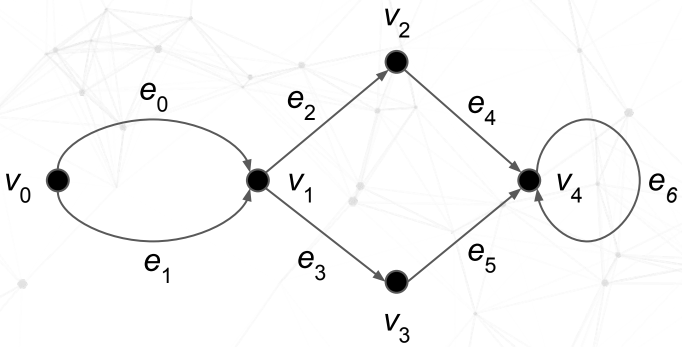
Representing graphs in Python

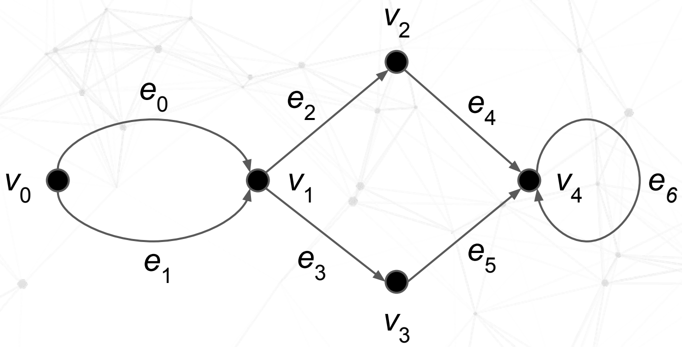


Representing graphs in Python




```
adjacencies = [
    (0, 1),  # e_0
    (0, 1),  # e_1
    (1, 2),  # e_2
    ...,
    (4, 4),  # e_6
]
```

Representing graphs in Python

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A graph with nodes labeled by NodeT and edges labeled by EdgeT can be modeled as follows:

```
class Graph(Generic[NodeT, EdgeT]):

    nodes: List[NodeT]
    edges: List[EdgeT]
    adjacencies: List[Tuple[int, int]]

    def source(self, k: int) -> int:
        """Source of the kth edge"""
        return self.adjacencies[k][0]

    def target(self, k: int) -> int:
        """Target of the kth edge"""
        return self.adjacencies[k][1]
```

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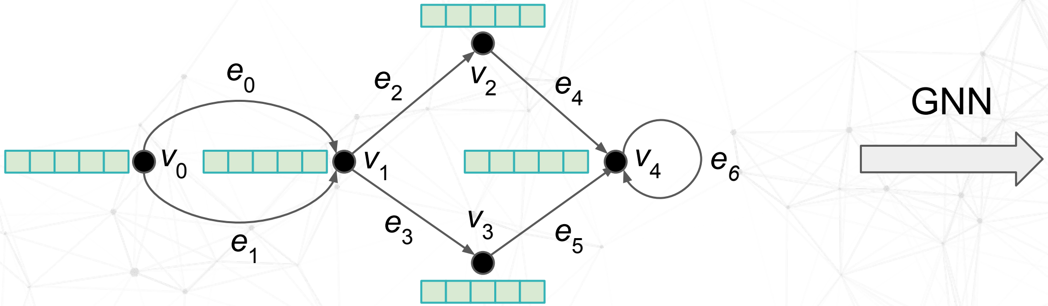
Graph neural networks

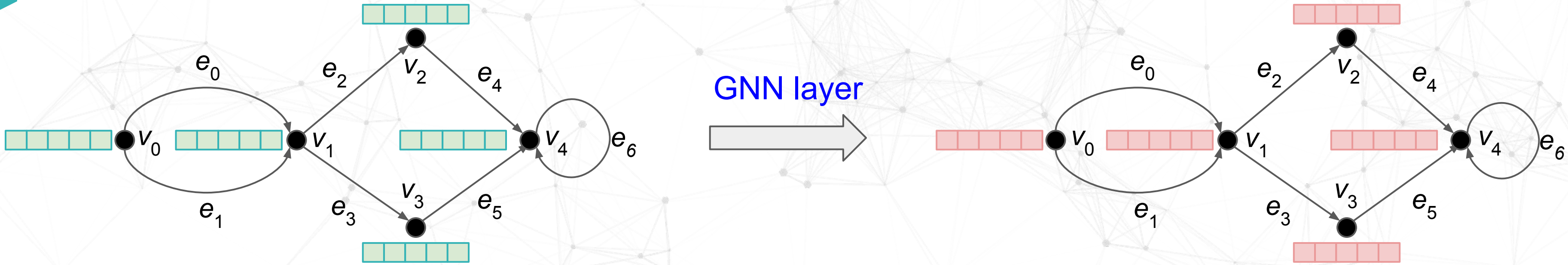
Let's consider the *node classification* problem:

- Input: a graph G of type `Graph[Tensor, EnumT]`
- Output: a labeling of its vertices, $L \colon \mathcal{V} \to \{0, 1\}$




```
labels = [
    0,  # v_0
    1,  # v_1
    0,  # v_2
    0,  # v_3
    1   # v_4
]
```

Graph neural networks



For instance: $y_v = \sigma\left(\sum_{w \xrightarrow{e} v} \frac{1}{\deg^{+}_{t(e)}(v)} W_{t(e)} x_w\right)$ where

- y_v is the output feature vector of node v
- x_w is the input feature vector of node w
- $t(e)$ is the type of the edge $e: v \rightarrow w$
- W_t is a learned weight matrix corresponding to edge type t
- $\deg_t^{+}(v)$ is the number of incoming edges of type t for node v
- σ is an activation function

Schlichtkrull et at, “Modeling Relational Data with Graph Convolutional Networks”, arxiv:1703.06103

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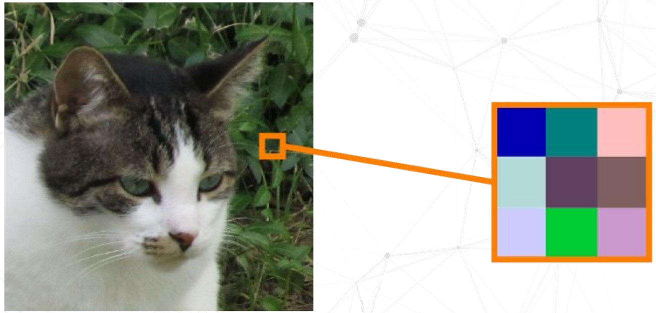
Comparison with convolutional networks

Graph (convolutional) networks generalize CNNs from computer vision



Original image   A 3×3 patch

$$y_{i,j} = \sigma\left(\sum_{\substack{k=-1,0,1 \\ l=-1,0,1}} W_{k,l}\, x_{i+k,j+l} \right)$$

where

- $y_{i,j}$ is the output feature vector of pixel (i, j)
- $x_{i,j}$ is the input feature vector of pixel (i, j)
- $W_{k,l}$ are learned weight matrices
- σ is an activation function

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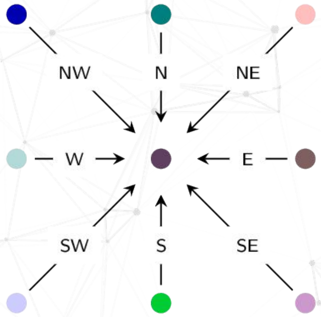

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A graph representing the 3 × 3 patch

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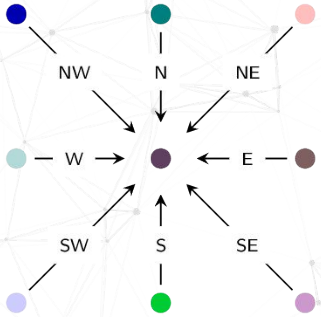


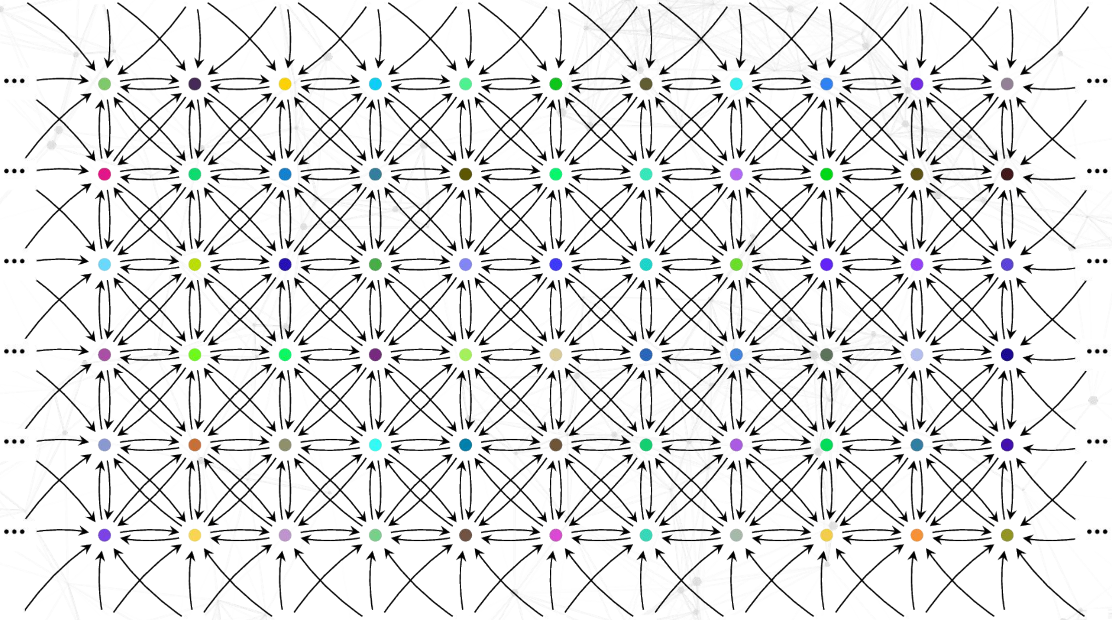
A graph representing the 3 × 3 patch

$$y_p = \sigma\left(W_0 x_p + \sum_{q \xrightarrow{t} p} W_t x_q \right)$$

where

- x_p is the input feature vector of pixel p
- y_p is the output feature vector of pixel p
- $t \in \{N, NW, W, \ldots\}$ is a cardinal direction
- W_t are learned weight matrices
- σ is an activation function

Comparison with convolutional networks

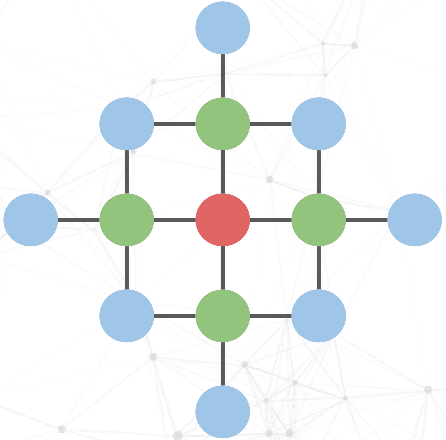


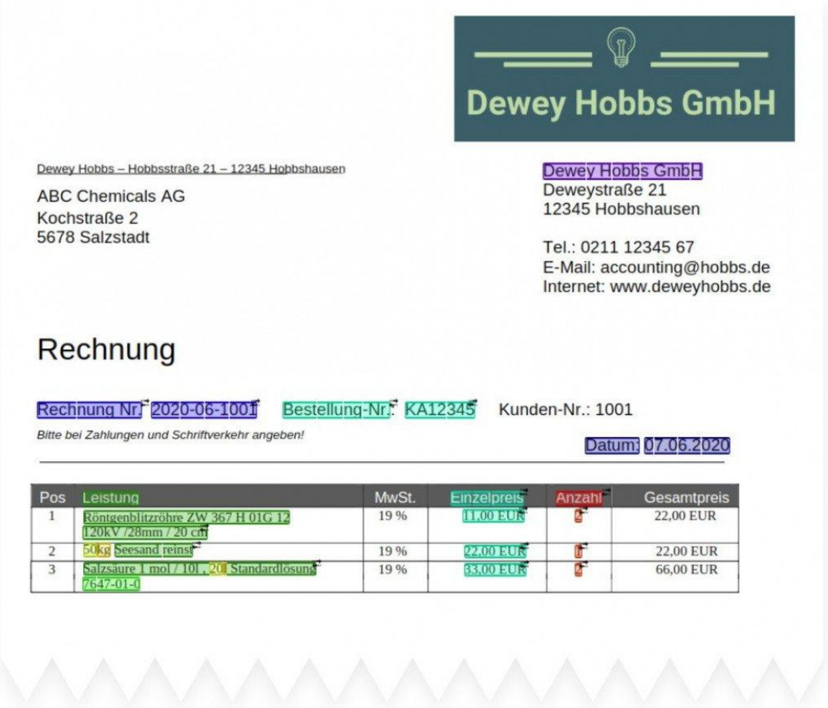
A graph representing the entire image

Use case: information extraction from tables

Idea: Model the document structure as a graph

- each word is a node in the graph
- neighbouring words are connected by edges





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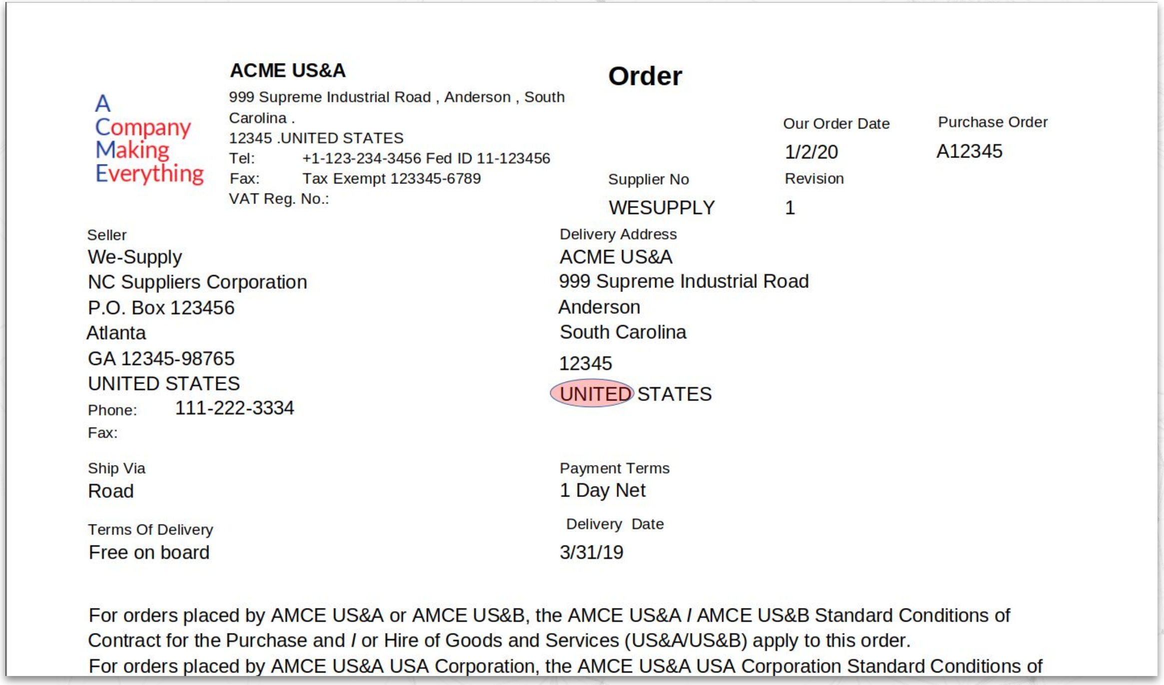
Prediction Result (example)

Use case: information extraction from tables



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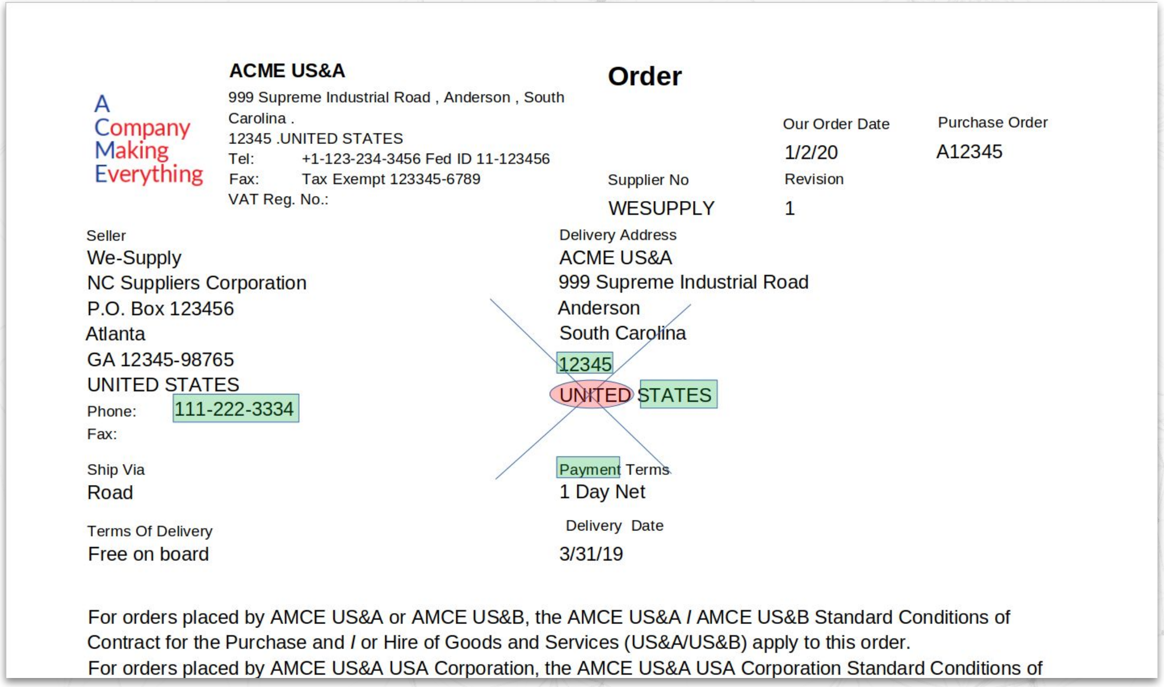
Use case: information extraction from tables



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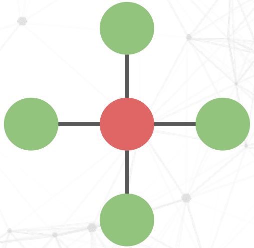

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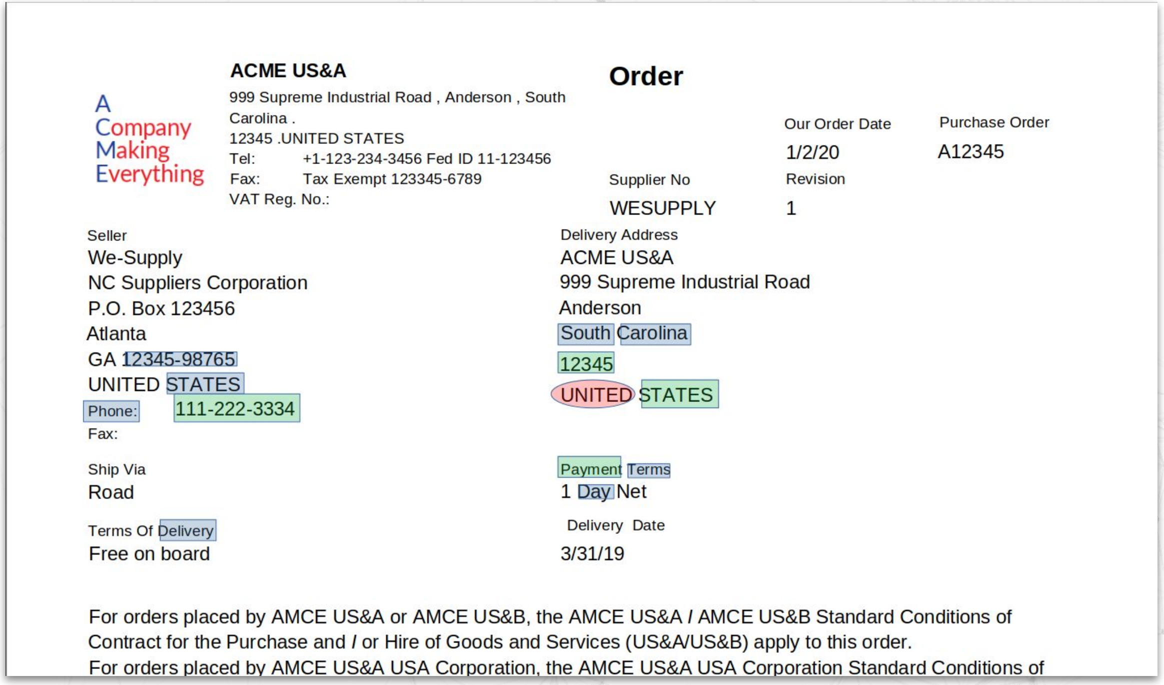

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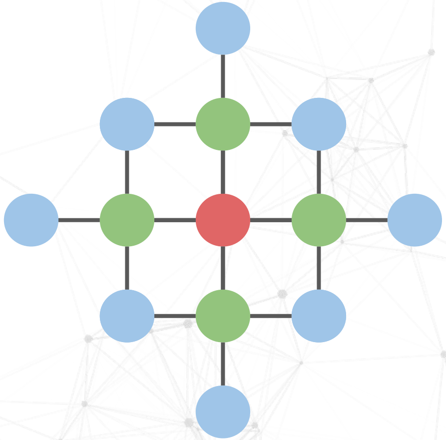
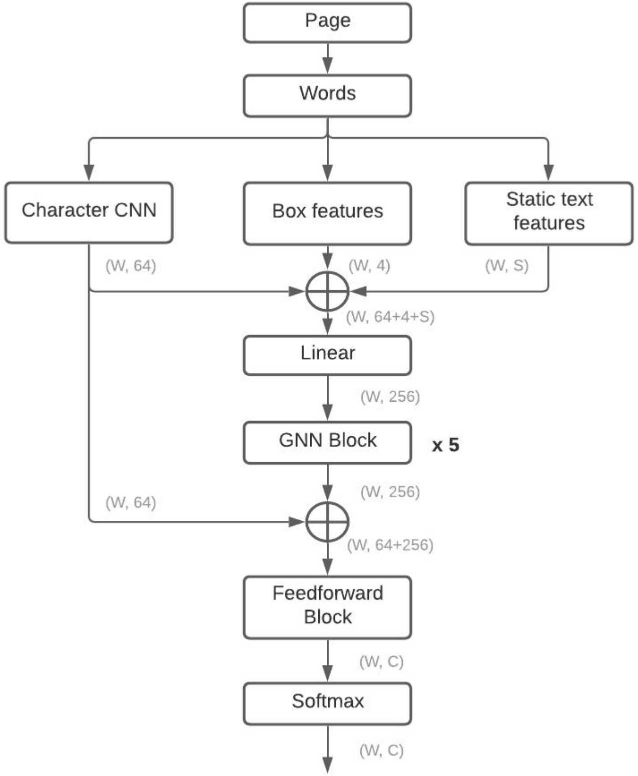


Use case: a possible model architecture



Legend

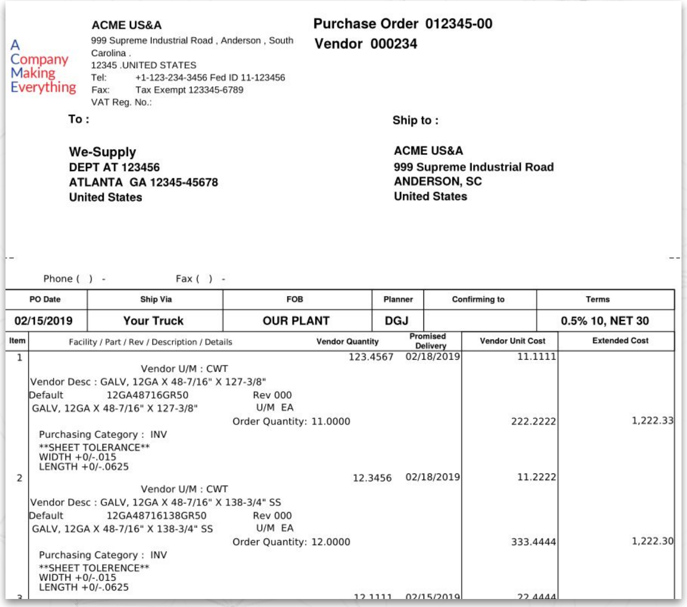
W: Number of words

S: Number of static text features

C: Number of classes

⊕: Concatenate tensors

Use case: results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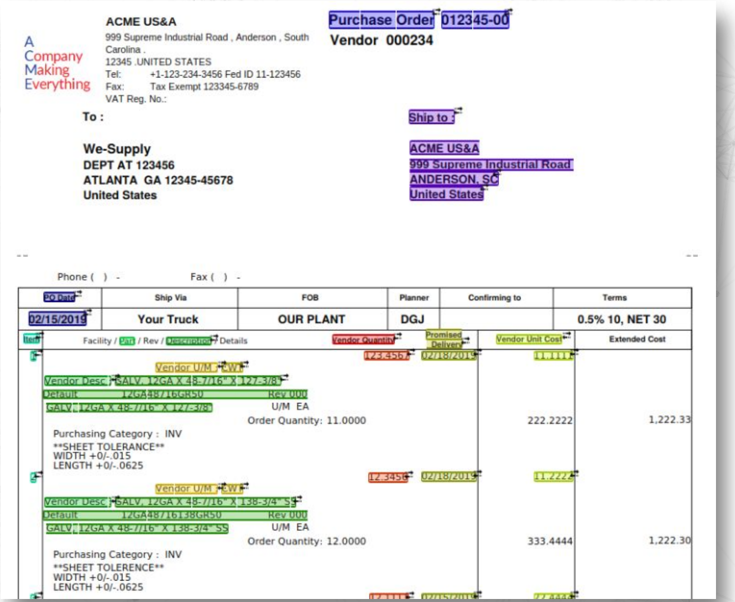
	Vendor U/M : CWT Vendor Desc : GALV, 12GA X 48-7/16" X 138-3/4" SS Default 12GA48716138GR50 Rev 000 GALV, 12GA X 48-7/16" X 138-3/4" SS U/M EA Order Quantity: 12.0000			333.4444	1,222.30
	Purchasing Category : INV **SHEET TOLERENCE** WIDTH +0/-.015 LENGTH +0/-.0625				
3		12.1111	02/15/2019	22.4444	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About 1000 training documents

Macro F1 score: 88%

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Implementations, literature

- PyTorch Geometric
    - "GNN Cheatsheet" in the docs contains an interesting list of papers
- Spektral for TensorFlow
- Deep Graph Library (framework agnostic)
- https://en.wikipedia.org/wiki/Graph_neural_network exists since 5 July 2021

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