Weighted posets

Learning surface order from dependency trees

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Oracle Corp

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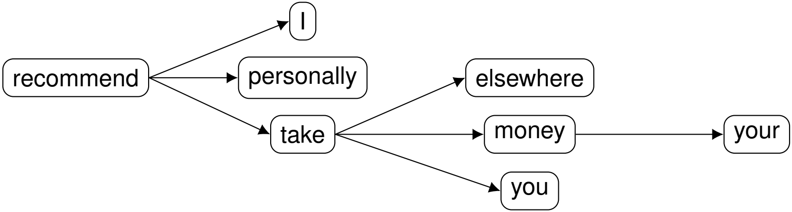
Outline

1. Task
   - Syntactic tree to surface realization
   - Previous work
2. Methodology
   - Weighted posets (sorted)
   - Syntactic embeddings
   - Graph neural network
   - Example
3. Results
4. Discussion

Outline

From syntactic tree to surface realization

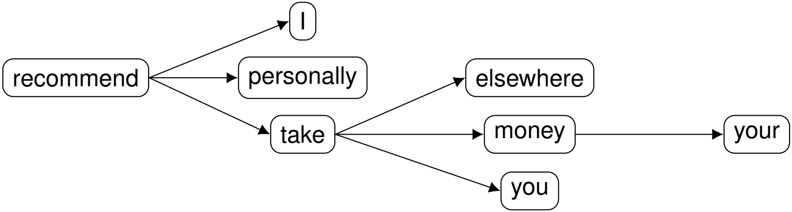
(a) syntactic tree (DAG)



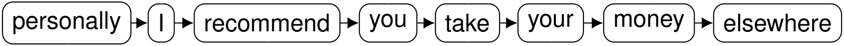
(b) surface realization

From syntactic tree to surface realization

(a) syntactic tree (DAG)



(b) surface realization



From syntactic tree to surface realization

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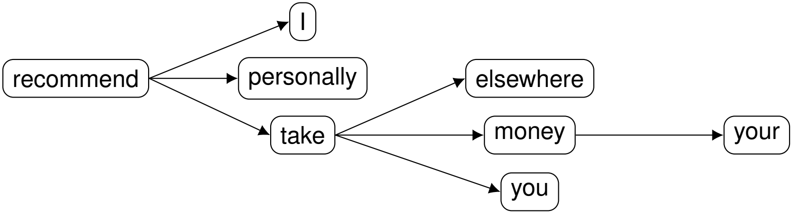
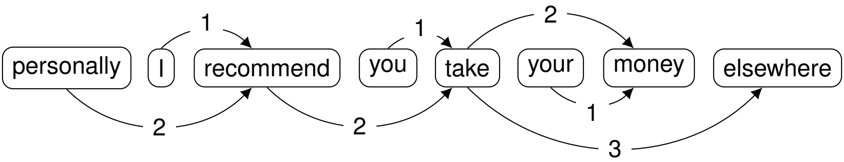


(b′) surface realization (poset)



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Previous linguistic work

- Specific constituents
  - demonstratives, numerals, adjectives (Greenberg, 1963)
  - manner, place, time (Boisson, 1981)
  - adjective order restrictions (Scott, 2002)
  - complements and adjuncts
- General tree principles
  - "what belongs together semantically is also placed close together" (Behaghel, 1932)
  - projectivity (Marcus, 1965)
  - Head Proximity (Rijkhoff, 1986)
  - Early Immediate Constituents (Hawkins, 1994)
  - Dependency Distance Minimization (Hudson, 1995)
  - Dependency Locality Theory (Gibson, 2000)
  - Minimize Domains (Hawkins, 2004)
  - Uniform Information Density (Jaeger and R. Levy, 2006)

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Previous linguistic work

- Sequential order
  - "old concepts come before new ones" (Behaghel, 1932)
  - "most important information first" (cf. Gundel, 1988)
  - precedence relations (Gerdes and Kahane, 2001; Kahane and Lareau, 2016)
  - extend DDm with info-theoretic measures (Dyer, 2018; Hahn et al., 2018)

Previous NLG work

- Bag of words
  - "for language is not merely a bag of words but a tool with particular properties which have been fashioned in the course of its use" (Harris, 1954)
- SR '18: First Multilingual Surface Realisation Shared Task (Mille et al., 2018)
  - determine word order and inflections
  - bigram language model with binary neural-net classification (Puzikov and Gurevych, 2018)
  - seq-to-seq MT model augmented with synthetic/outside data (Elder and Hokamp, 2018)
  - sort dependents into preceding or following groups, then by syntactic category or using max entropy classifier (Castro Ferreira et al., 2018)
  - incrementally linearize words based on dependency structure and distance (King and White, 2018)

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- partially ordered set (poset)
  - *for* $\prec$ *trip*, *your* $\prec$ *trip*, *trip* $\prec$ *Canada*, *to* $\prec$ *Canada*

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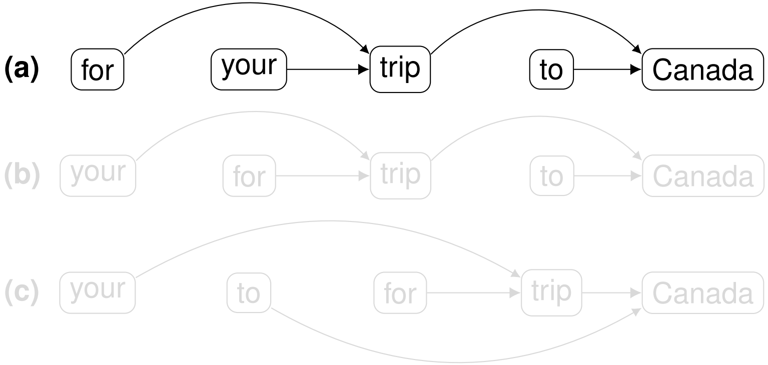

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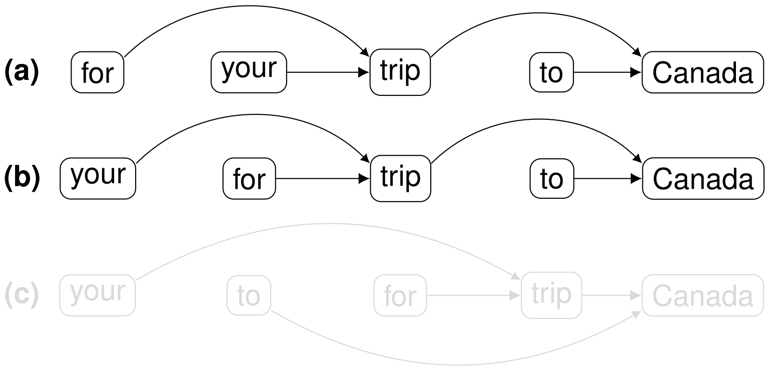

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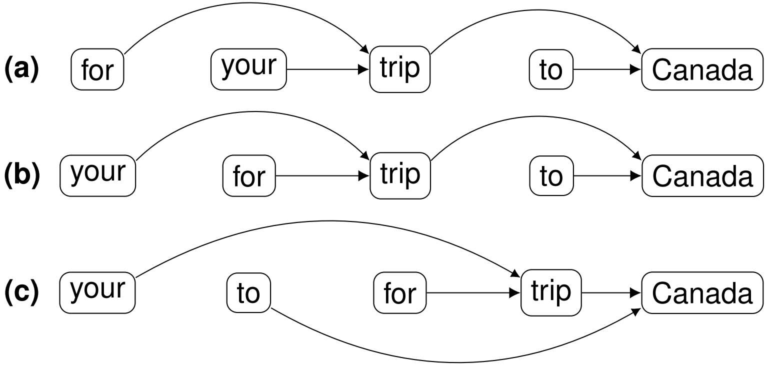

Weighted poset

- edge-weighted poset
  - *for* $\overset{2}{\prec}$ *trip*, *your* $\overset{1}{\prec}$ *trip*, *trip* $\overset{2}{\prec}$ *Canada*, *to* $\overset{1}{\prec}$ *Canada*

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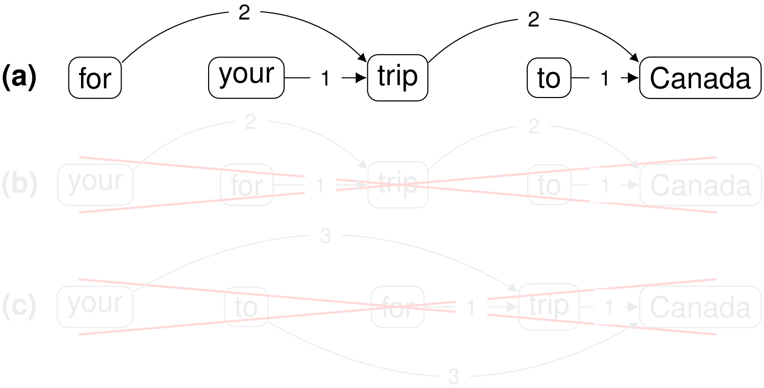

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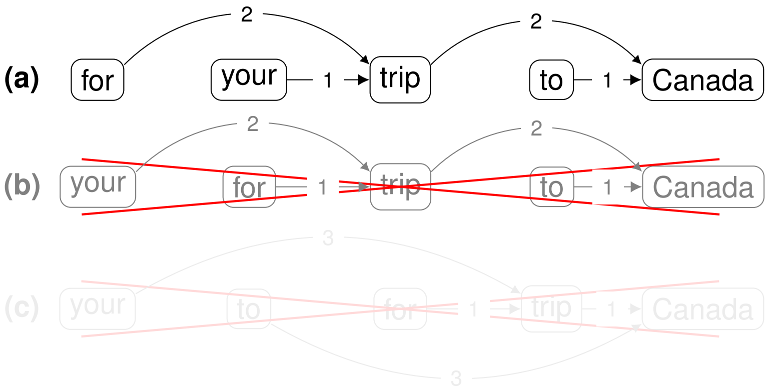

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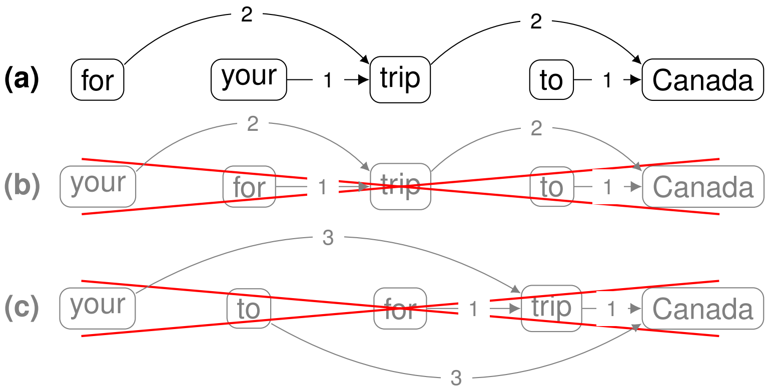

Topologically sorting a weighted poset

Algorithm 1: Given an edge-weighted *poset*, construct a total order such that nodes with smallest weights are adjacent.

```
function WEIGHTED_TOPO_SORT(poset)
    order ← ∅                                          ▷ empty directed graph to hold totally ordered set
    for (u, v, w_uv) ∈ poset do
        w_sum ← 0                                      ▷ a sum of traversed weights
        if u ∈ order then
            while w_uv > w_sum do                      ▷ traverse successors of u
                s ← order.u.successor
                w_us ← order[u][s].weight
                w_sum ← w_sum + w_us
                if w_uv < w_sum then
                    u ← s                              ▷ u becomes its successor s
            w_vs ← w_sum − w_uv                        ▷ w_vs is how much w_sum overshot w_uv
            order.UPDATE_EDGE(u, s, _) ←               ▷ change existing (u, s)...
                [(u, v, w_us − w_vs), (v, s, w_vs)]    ▷ ... to (u, v) and (v, s) and update weights
        else if v ∈ order then
            while w_uv > w_sum do                      ▷ traverse predecessors of v
                p ← order.v.predecessor
                w_pv ← order[p][v].weight
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        else
            order.ADD_EDGE(u, v, w_uv)
    return TOPO_SORT(order)                            ▷ return topological sort of order graph
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Syntactic embeddings

- Distributional hypothesis
  - “you shall know a word by the company it keeps” (Firth, 1957)
- Represent words as dense vectors (via NN)
  - `dancing [0.43 1.91 -0.22 0.95 -0.89 ...]`
  - similar words have cosine-similar vectors
- Context
  - linear (continuous bag-of-words) – `word2vec` (Mikolov et al., 2013)
  - `dancing` similar to `singing`, `dance`, `dances`, `dancers`
  - syntactic – `word2vecf` (O. Levy and Goldberg, 2014)
  - `dancing` similar to `singing`, `rapping`, `miming`, `busking`

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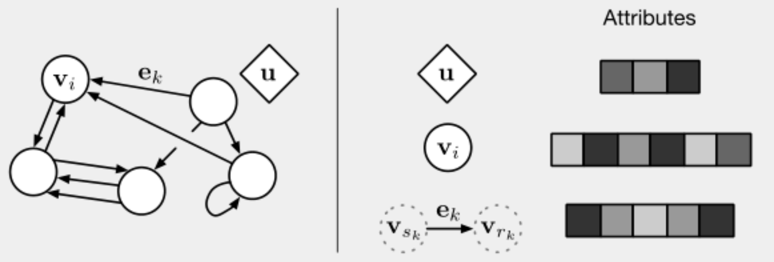
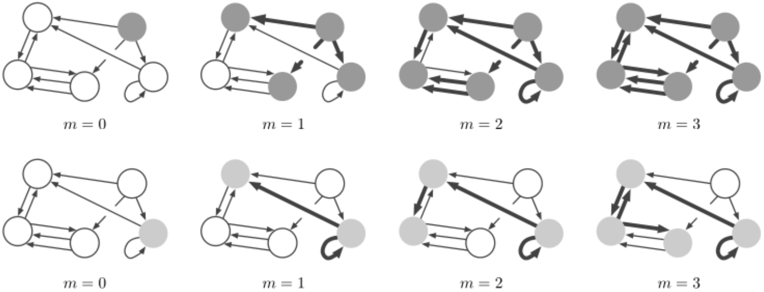
Graph neural network (GNN)

- Graph Nets (GN) framework (Battaglia et al., 2018)



Graph neural network (GNN)

- Graph Nets (GN) framework (Battaglia et al., 2018)
- Message-passing neural network (MPNN) (Gilmer et al., 2017)
- Spatial-based graph convolutions and pooling (Wu et al., 2019)



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Example - `word2vecf`

(a) *[input] conllu file (abridged)*

9	for	for	ADP	11	case
10	your	you	PRON	11	nmod:poss
11	trip	trip	NOUN	3	obl
12	to	to	ADP	13	case
13	Canada	Canada	PROPN	11	nmod

(b) *[output] syntactic embeddings*

for|ADP|case	[1.69 -0.51 ...]
your|PRON|nmod:poss	[0.92 -0.61 ...]
trip|NOUN|obl	[0.17 -0.11 ...]
to|ADP|case	[1.24 -0.59 ...]
canada|PROPN|nmod	[0.05 -0.05 ...]
ADP|case	[0.12 -0.80 ...]
ADP	[0.10 -0.07 ...]

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for|ADP|case              [1.69  -0.51  ...]
your|PRON|nmod:poss       [0.92  -0.61  ...]
trip|NOUN|obl             [0.17  -0.11  ...]
to|ADP|case               [1.24  -0.59  ...]
canada|PROPN|nmod         [0.05  -0.05  ...]
ADP|case                  [0.12  -0.80  ...]
ADP                       [0.10  -0.07  ...]
```
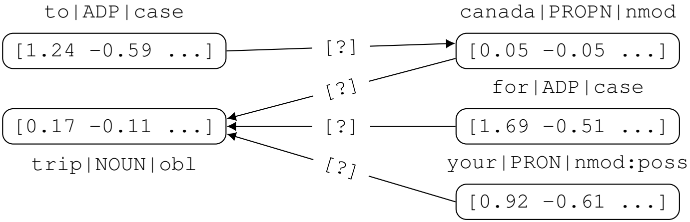

Example - GNN

(c) *[input] directed* `networkx` *graph of dependency tree*



(d) *[output] directed graph with learned edge attributes*

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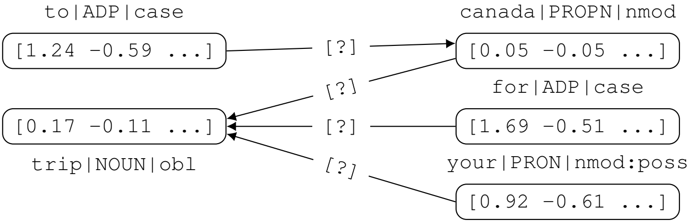

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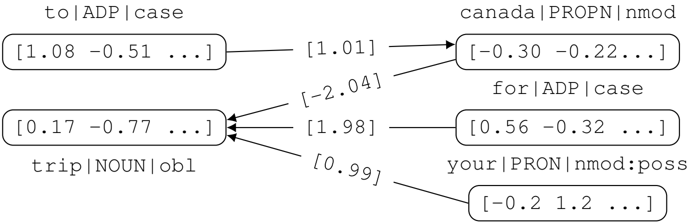
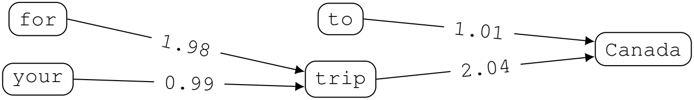


Example - topological sort

(e) *[input] edge-weighted poset*



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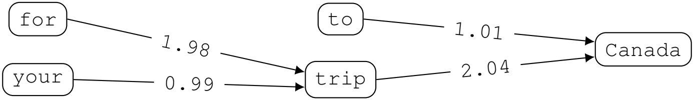

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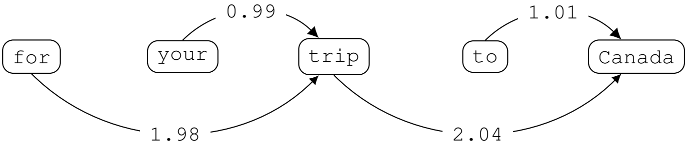

Baseline

- Average dependency distance
  - for|ADP|case $\overset{1.74}{\prec}$ trip|NOUN|obl
  - your|PRON|nmod:poss $\overset{1.06}{\prec}$ trip|NOUN|obl
  - trip|NOUN|obl $\overset{1.83}{\prec}$ PROPN|nmod
  - to|ADP|case $\overset{1.89}{\prec}$ PROPN|nmod

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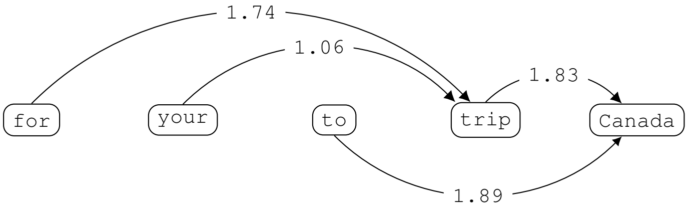
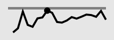
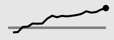
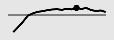
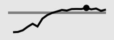
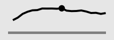
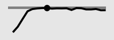


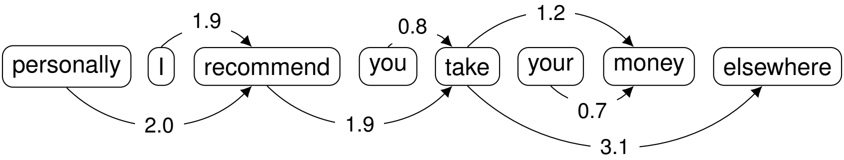
Results

	SPEARMAN'S ρ [-1,1]			PROJECTIVITY [0,1]			
	AVG		GNN	AVG		GNN	UD
Afrikaans	0.707		**0.773**	0.530		**0.650**	0.939
Armenian	0.628		**0.672**	0.413		**0.585**	0.987
Czech	0.665		0.659	0.359		**0.469**	0.982
English	0.634		**0.775**	0.496		**0.680**	0.995
French	0.677		**0.729**	0.531		**0.669**	0.998
Greek	0.731		**0.754**	0.503		**0.651**	0.996
Hungarian	0.635		0.609	0.440		**0.598**	0.969

Results

	SPEARMAN'S ρ [-1,1]			PROJECTIVITY [0,1]			
	AVG		GNN	AVG		GNN	UD
Irish	0.674		**0.753**	0.461		**0.603**	0.978
Italian	0.657		**0.796**	0.482		**0.651**	0.996
Latin	0.614		0.582	0.613		**0.729**	0.855
Maltese	0.729		**0.750**	0.498		**0.682**	0.995
Slovenian	0.549		**0.567**	0.663		**0.798**	0.967
Telugu	0.916		**0.931**	0.925		**0.971**	0.997
Uyghur	0.728		0.727	0.629		**0.762**	0.976

Discussion



- Engineering
  - not E2E, but using ML to address parts of problem
  - useful data structure for representing surface realizations
  - entirely within dependency framework
- What is GNN learning?
  - relative individual dependency-distance **tolerances** ...
  - based on **context** of words (embeddings) and structure (MPNN)
- Emergent projectivity rate
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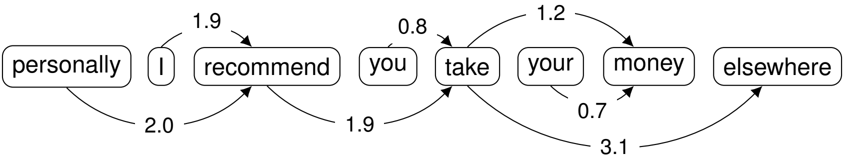
  - rate reflects (approaches) that of training data

Discussion



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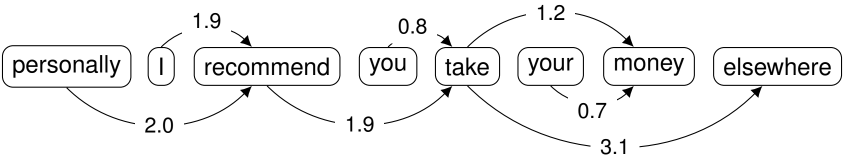

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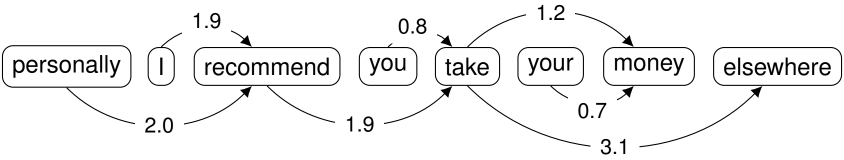

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Future study

- improve design of GNN
- customize hyperparameters based on corpus
- use newer embedding frameworks
- develop/find efficient algorithm for sorting weighted posets
- apply weighted posets to study graph-theoretic measures

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Thank you!

Weighted posets
Learning surface order from dependency trees

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