Data-Driven Deep Dependency Parsing

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Outline

The Covert Helps Parse the Overt

Semantic Dependency Parsing

Question

HPSG	PET, Enju, ACE, ...
CCG	C&C, ...
LFG	XLE, ...

PCFG	Collins, Charniark&Johnson, Berkeley, ...
Data-driven	MST, Mate, Malt, SyntaxNet, Stanford, ZPar, RNNG, ...

Question

HPSG	PET, Enju, ACE, ...
CCG	C&C, ...
LFG	XLE, ...

$\boxed{\text{Can deep syntactic information help surface parsing?}}$

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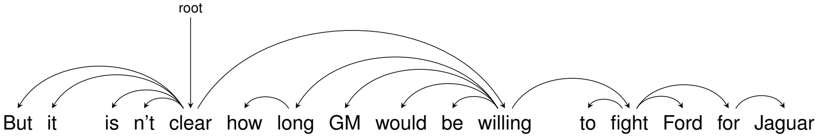
Syntactic analysis with empty categories



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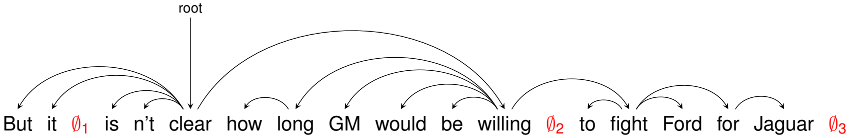

- $\emptyset_1$: expletive construction.
- $\emptyset_2$: the subject of *fight* is somehow missing because it is *controled* by the subject of *willing*.
- $\emptyset_3$: *wh*-movement in which an adjunct of *willing*, i.e. *how long* is moved to the front of the clause.

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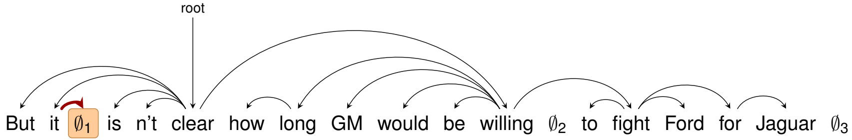

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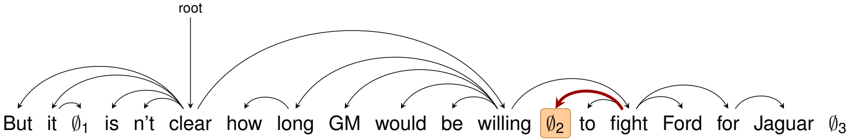

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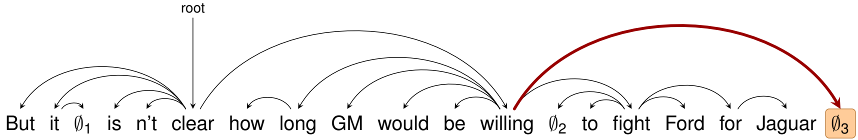

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Parsing with empty elements

But it is n't clear how long GM would be willing to fight Ford for Jaguar

Task

- Predicting empty elements
- Predicting dependencies, including dependencies between normal and empty elements

Parsing with empty elements

But it $\emptyset_1$ is n't clear how long GM would be willing $\emptyset_2$ to fight Ford for Jaguar $\emptyset_3$

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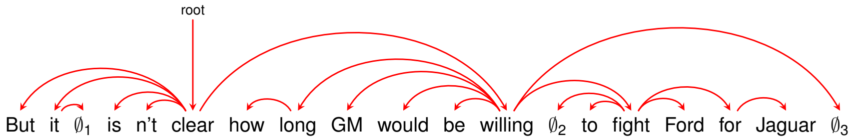
Parsing with empty elements



Task

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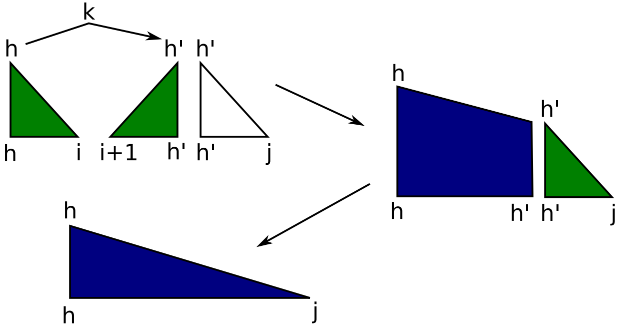
- Predicting dependencies, including dependencies between normal and empty elements

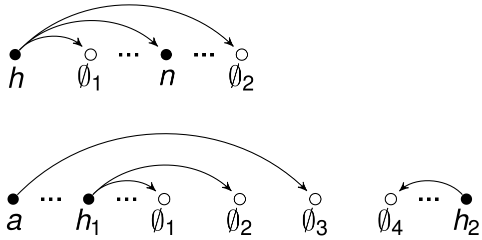
Parsing without empty elements



Prototypes of structures with empty categories

Assumption

Empty nodes can be only dependents.



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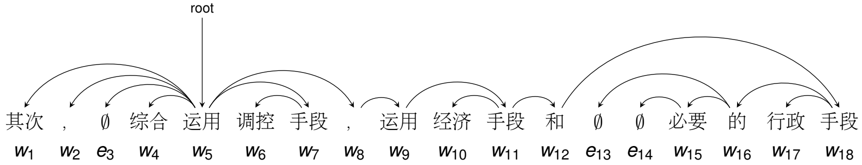
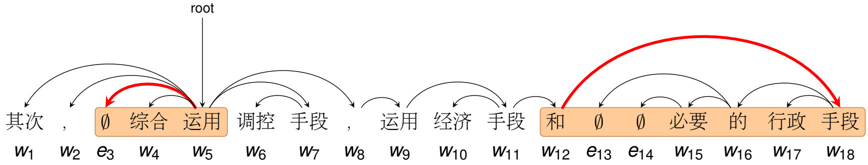
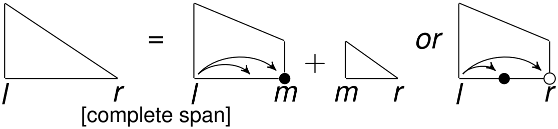


incomplete spans: a dependency and the region between the head and modifier.

Parsing with empty elements



complete spans: a head-word and its descendents on one side



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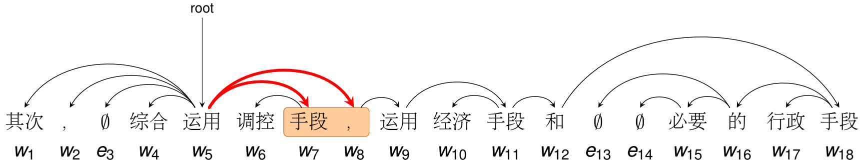
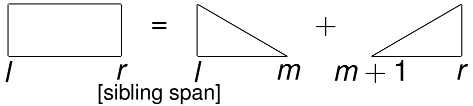


sibling span: the region between successive modifiers of same head.



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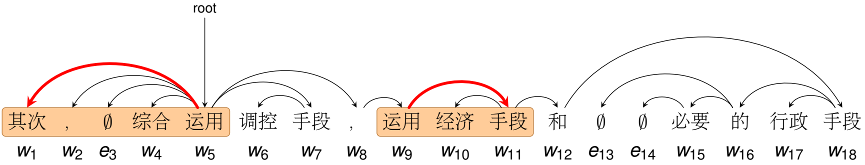
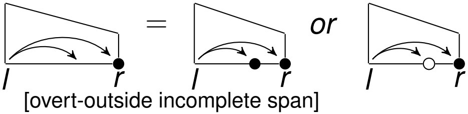


overt-outside incomplete span



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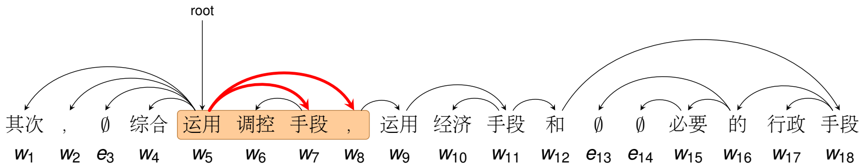
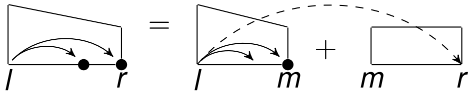


overt-both incomplete span



[overt-both incomplete span]

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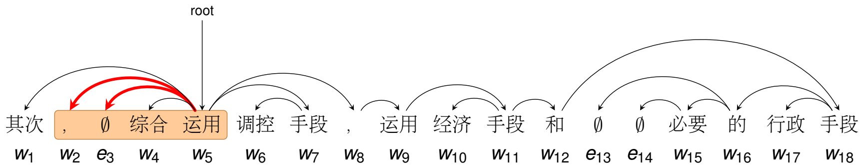
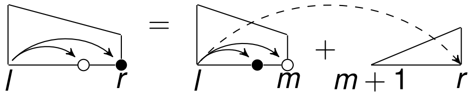


covert-inside incomplete span



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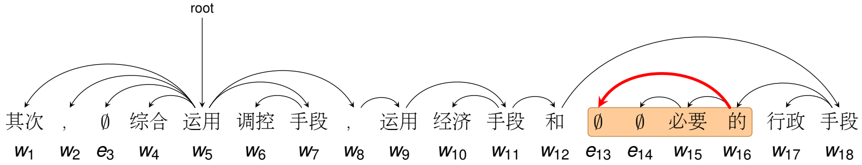
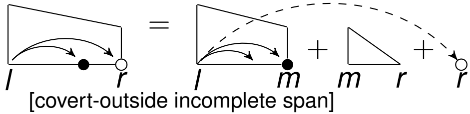


covert-ouside incomplete span



incomplete spans: a dependency and the region between the head and modifier.

Evaluation

Disambiguation: Global linear model

$$f(\boldsymbol{y}) = \sum_{p \in \boldsymbol{y}} \mathbf{w}_f^\top \phi_f(s, p)$$

Results: unlabeled attachment score for all overt words

Model	English	Chinese
second-order	91.73	89.16
$+\emptyset$ (partial)	91.70 (-0.03)	89.20 ($+0.04$)
$+\emptyset$ (full)	91.72 (-0.01)	89.28 ($+0.12$)
third-order	92.23	90.00
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Analysis

Two types of errors

- Approximation error
- Estimation error

Information about empty categories is helpful for reducing the approximation error, but brings new challenge for estimation.

Structure Regularization with joint decoding

$$\begin{array}{ll} \text{max.} & \lambda f(\boldsymbol{y}) + (1-\lambda) g(\boldsymbol{z}) \\ \text{s.t.} & \boldsymbol{y} \in \mathcal{Y}, \boldsymbol{z} \in \mathcal{Z} \\ & y(i,j) = z(i,j), \ \forall (i,j) \in \mathcal{I} \end{array}$$

Results

	Algo	English	Chinese
CM	1+3	91.94 (+0.21)	89.53 (+0.37)
	1+4	91.88 (+0.15)	89.44 (+0.28)
DD	1+3	91.96 (+0.23)	89.53 (+0.37)
	1+4	91.94 (+0.21)	89.53 (+0.37)
CM	2+5	92.60 (+0.37)	90.35 (+0.35)
DD	2+5	92.71 (+0.48)	90.38 (+0.38)

Two joint decoders

- **CM** Chart merging
- **DD** Dual decomposition

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Semantic Dependency Parsing

Yesterday

$\boxed{\text{They use our semantics, but don't use our grammar.}}$

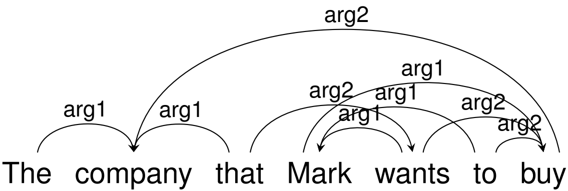
Yesterday

$\boxed{\text{They use our semantics, but don't use our grammar.}}$

$\boxed{\text{Grammar as an annotator.}}$

Semantic dependency parsing

Example



- Predicate–argument analysis, bi-lexical relations
- Long-distance dependencies
- Graph-structured representations, many crossing arcs
- Not a tree: single-headed (✗), cycle-free (✗)

Semantic dependency parsing

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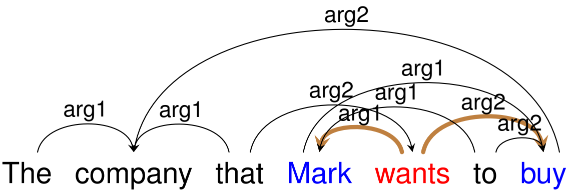

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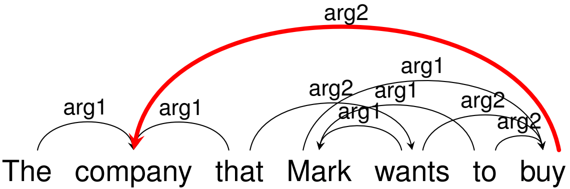

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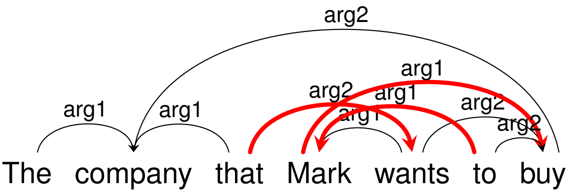

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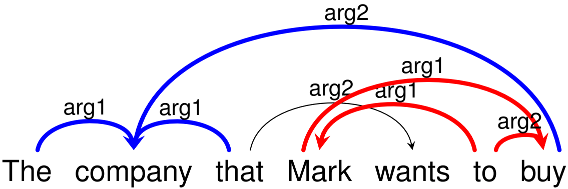

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Parsing approaches

Approaches

- Maximum Subgraph Parsing
- Transition-based Parsing
- Graph Merging

Maximum Subgraph

Input A directed graph $G = (V, A)$

Output Subgraph $G' = (V, A' \subseteq A)$ with maximum total weight such that G' belongs to $\mathcal{G}$

$$G'(s) = \arg\max_{H \in \mathcal{G}(s,G)} \sum_{p \in H} \textsc{ScorePart}(s, p)$$

Example When $\mathcal{G}$ is tree,

Maximum Subgraph = Maximum Spanning Tree

Complexity $\mathcal{G}$ and the order of $\textsc{ScorePart}$ determine the complexity of inference.

Complexity

$\mathcal{G}$	O	Algo	
Arbitrary	1	$O(n^2)$	
Arbitrary	2	NP-hard	ACL15
Acyclic	1	NP-hard	Kuhlmann & Jonsson
Noncrossing	1	$O(n^3)$	Kuhlmann & Jonsson
Noncrossing	2	$O(n^4)$	ACL17a
1-endpoint-crossing	1	$O(n^5)$	Ongoing work
1-endpoint-crossing pagenumber-2	1	$O(n^5)$	ACL17b
1-endpoint-crossing pagenumber-2, C-free	1	$O(n^4)$	ACL17b
1-endpoint-crossing pagenumber-2, C-free	2	$O(n^4)$	EMNLP17

Transition-based parsing

- Psycholinguistically motivated: Left-to-right, word-by-word
- Partially parsed results (parsing states) constrain parsing of subsequent words
- Usually, perform greedy search to get a *good* parse.

New transition systems

A naive idea

$\textsc{Parse}(x = (w_1, \ldots, w_n))$
1 **for** $j = 1..n$
2 **for** $k = j - 1..1$
3 $\texttt{Link}(j, k)$

New transition systems

$\mathcal{G}$	System
Arbitrary graphs	Two-stack-based
Arbitrary graphs	Non-incremental online reordering
Supersets of noncrossing graphs	Incremental K-permutation

Real running time

Naive spanning runs in time of $\Theta(n^2)$

$$
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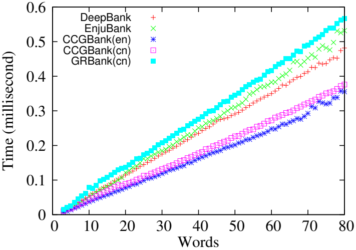
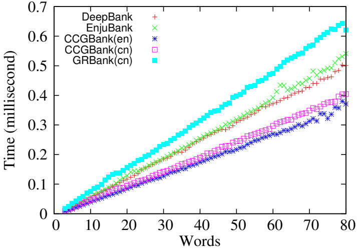
\quad\quad \texttt{Link}(j,k)
\end{array}
$$

New systems



Online re-ordering



Two stack based

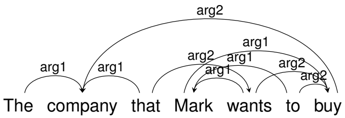
A new framework

Challenge of graph parsing

- Complex graphs are difficult to construct for its complex structure.
- Simple graphs can be solved more easily, but the coverage is not satisfactory.

Graph merging

Constructing a complex structure via constructing simple partial structures.



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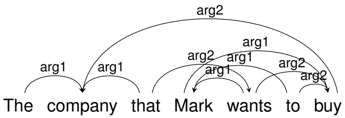

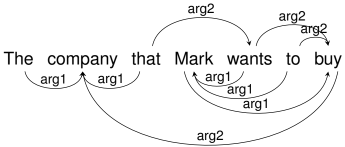

Workflow

Architecture

	Annotated graphs		**Output**
	↓		↑
Graph Transformation	**Graph-to-Subgraphs** (Graph Decomposition)		**Subgraphs-to-Graph** (Graph Merging)
	↓		↑
Parser	**Parameter Estimation**	→	**Disambiguation/Decoding**
			↑
			Input

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			↑ **Input**

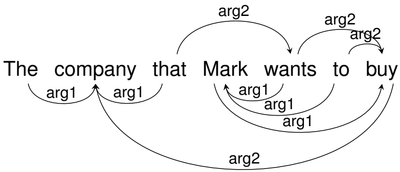
Three problems

Training How to decompose a complex graph into noncrossing graphs?

Parsing How to construct simple graphs?

Parsing How to merge subgraphs into a coherent complex graph?

Book embedding



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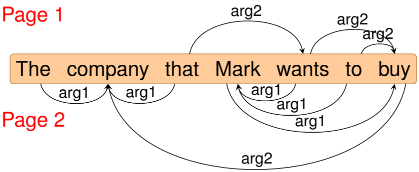
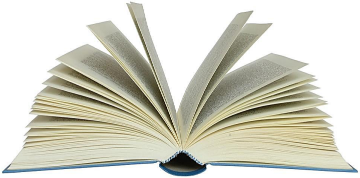


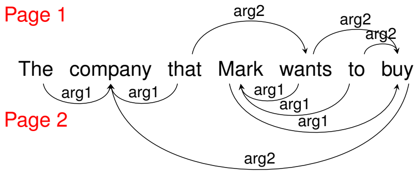


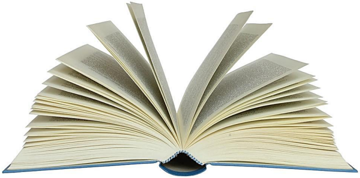
book embedding

A book embedding B of G satisfies the following conditions.

1. Every vertex of G is depicted as a point on the spine of B.
2. Every edge of G is depicted as a curve that lies within a single page of B.
3. Every page of B does not have any edge crossings.

Book embedding





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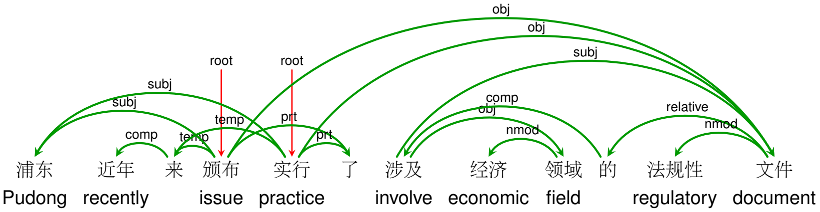
Tree + Tree + ...


obj
obj
subj
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comp
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relative
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浦东 Pudong
近年 recently
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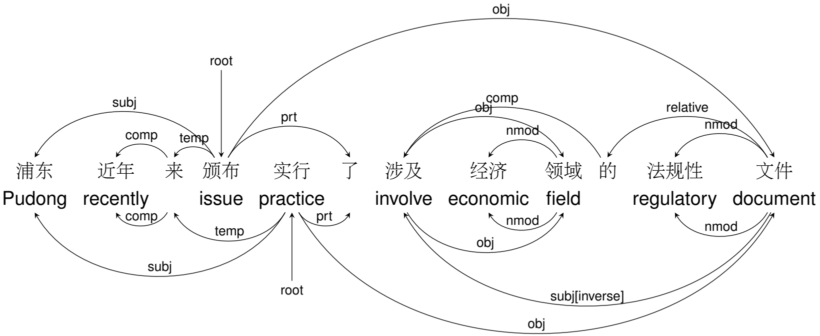
的
法规性 regulatory
文件 document

Tree + Tree + ...


obj
root
subj
comp
temp
prt
comp
obj
nmod
relative
nmod
浦东 近年 来 颁布 实行 了 涉及 经济 领域 的 法规性 文件
Pudong recently issue practice involve economic field regulatory document
comp
temp
prt
nmod
nmod
obj
subj
root
subj[inverse]
obj

Decomposing and combining subgraphs

Decomposition as Optimization

$$
\begin{array}{ll}
\text{max.} & \sum_k s_k(\boldsymbol{y}_k) \\
\text{s.t.} & \boldsymbol{y}_k \text{ belongs to } \mathcal{G}_k \\
 & \sum_k \boldsymbol{y}_k(i,j) \geq \boldsymbol{y}(i,j), \forall i,j
\end{array}
$$

Combination as Optimization

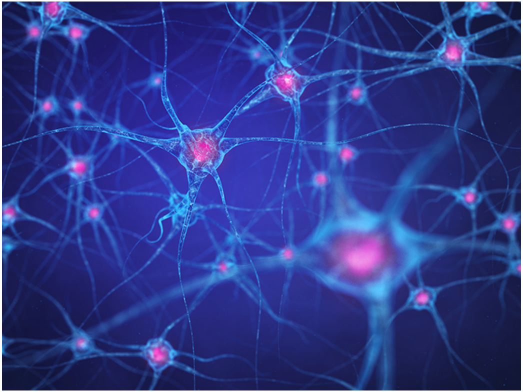
$$
\begin{array}{ll}
\text{min.} & -f_A(\mathbf{g}_A) - f_B(\mathbf{g}_B) \\
\text{s.t.} & \mathbf{g}_A \text{ belongs to } \mathcal{G}_A, \mathbf{g}_B \text{ belongs to } \mathcal{G}_B \\
 & A\mathbf{g}_A + B\mathbf{g}_B \leq 0
\end{array}
$$

Usually, we can employ Lagrangian Relaxation for solutions.

Lessons learned

Data-driven models can produce
high-quality deep dependency analysis.

Another experience



Game Over