Exploiting Graph Structure for Accelerating the Calculation of Shortest Paths in Wordnets

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Motivation

- Frequent criticism: The relations in wordnets are too sparse
- Extend GermaNet (the German wordnet) with new relations (Lemnitzer, Wunsch, Gupta; 2008)
  - Extraction of verb-object and verb-subject pairs from the automatically parsed German newspaper corpus TüPP-D/Z ($\approx$ 11.5 million sentences)
  - Ranking of the pairs according to mutual information and log-likelihood
  - Manual filtering (removal of nonsense pairs, support verb constructions, and words not present in GermaNet)
  - For each of the top 100 remaining pairs, a new relation is added to GermaNet (`arg1` and `arg2`)
- Hypothesis: The better of both measures brings semantic fields closer together

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- **But: How about repeatedly (semi-)automatically extending and evaluating the wordnet – with help of semantic similarity?**

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- Use **Structure Adapted Shortest Path Search**

Wordnets and Graphs

Wordnets	**Graphs**
synset	node
(directed) relation	(directed) edge

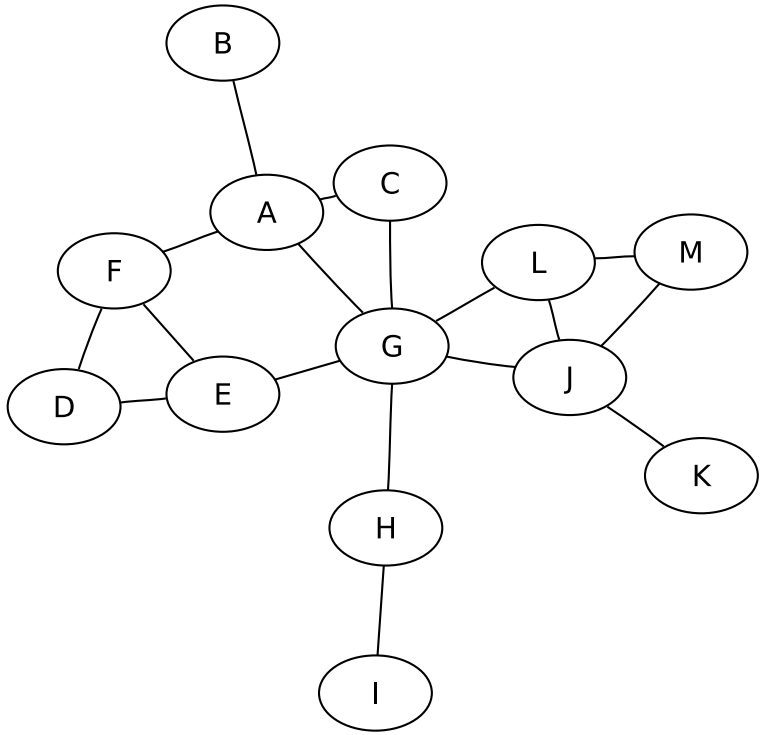
- A synset is a set of words that are synonymous.
- Two types of relations in wordnets:
  - directed relations
    specific terms vs. more general terms (hyponymy – hyperonymy)
  - undirected relations
    opposites (antonymy)

Shortest Paths in General Graphs

- In general graphs, there are *multiple* paths connecting two nodes
- A general algorithm for finding a shortest path must consider all possible alternatives

Algorithms for finding all shortest paths

- Dijkstra's algorithm (n^3)
- Floyd-Warshall algorithm (n^3)
  - Matrix-based (dynamic programming) approach
  - If there exists a shortest path between x and z, and one between z and y, then the shortest path between x and y is $x - z - y$.



Are Wordnets Graphs?

They are for sure, but...

- Wordnets are (still) sparse
- Relatively few nodes in a dense central graph
- Numerous and large tree structures (biological and medical taxonomies, ...) on the fringe

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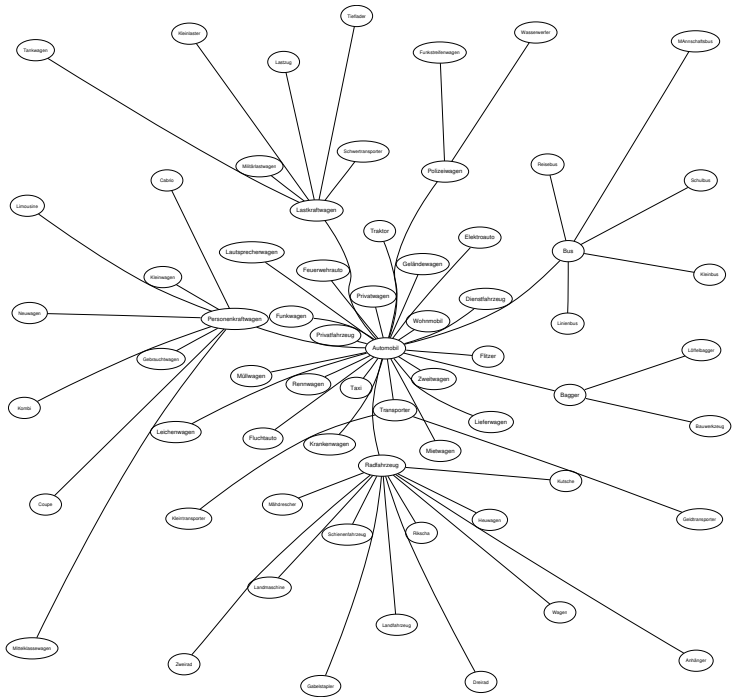
$\Rightarrow$ Wordnets are stars

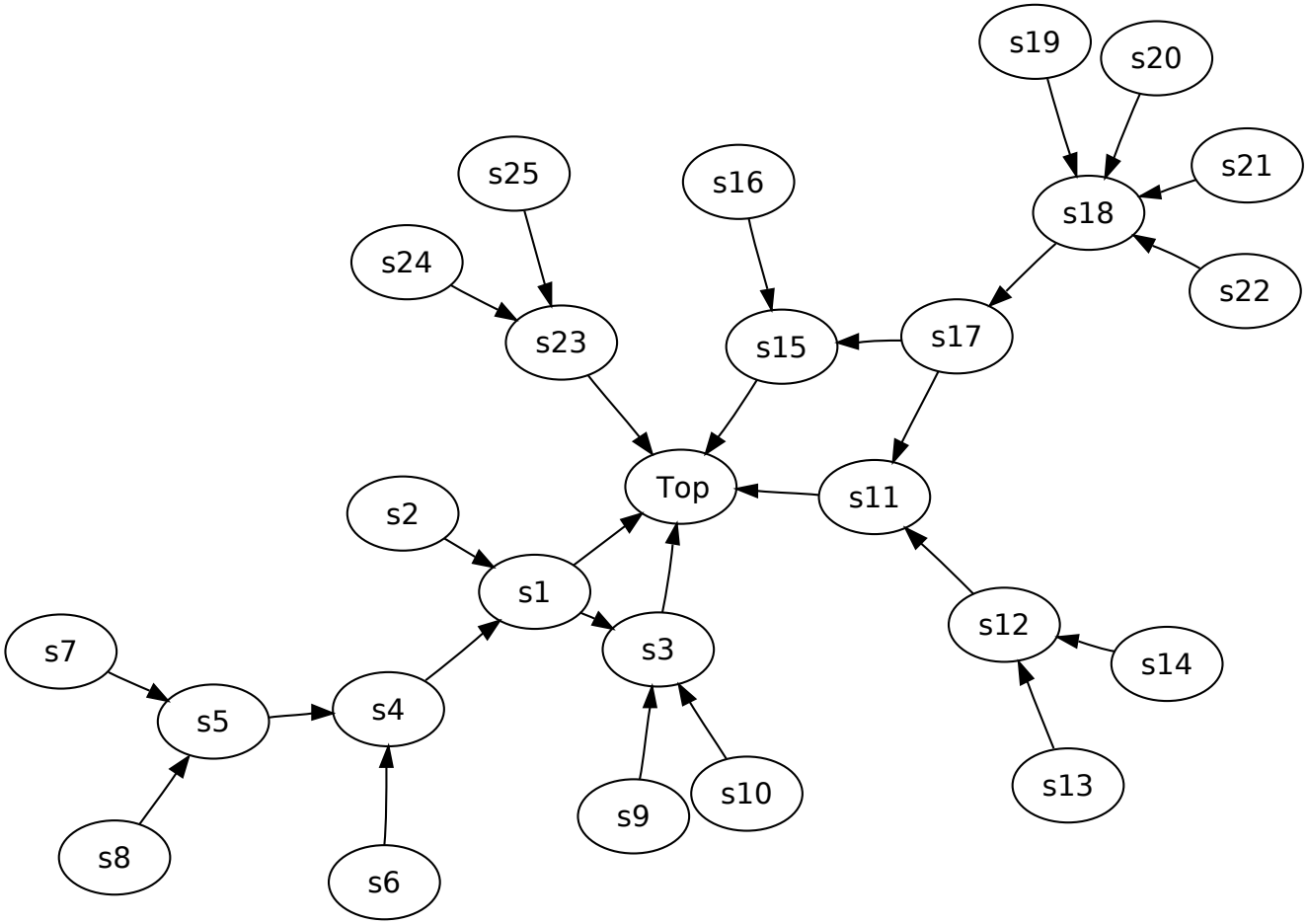


Two-step Approach to Calculating Shortest Paths

- First pre-classify nodes
- Then use specialized algorithms for calculating the shortest path between nodes depending on their type
- Within trees: the path connecting two nodes is unique
- Within the graph part: use general path search algorithm

Node Classification

- Inner nodes
- Root nodes
- Tree nodes
- Leaf nodes



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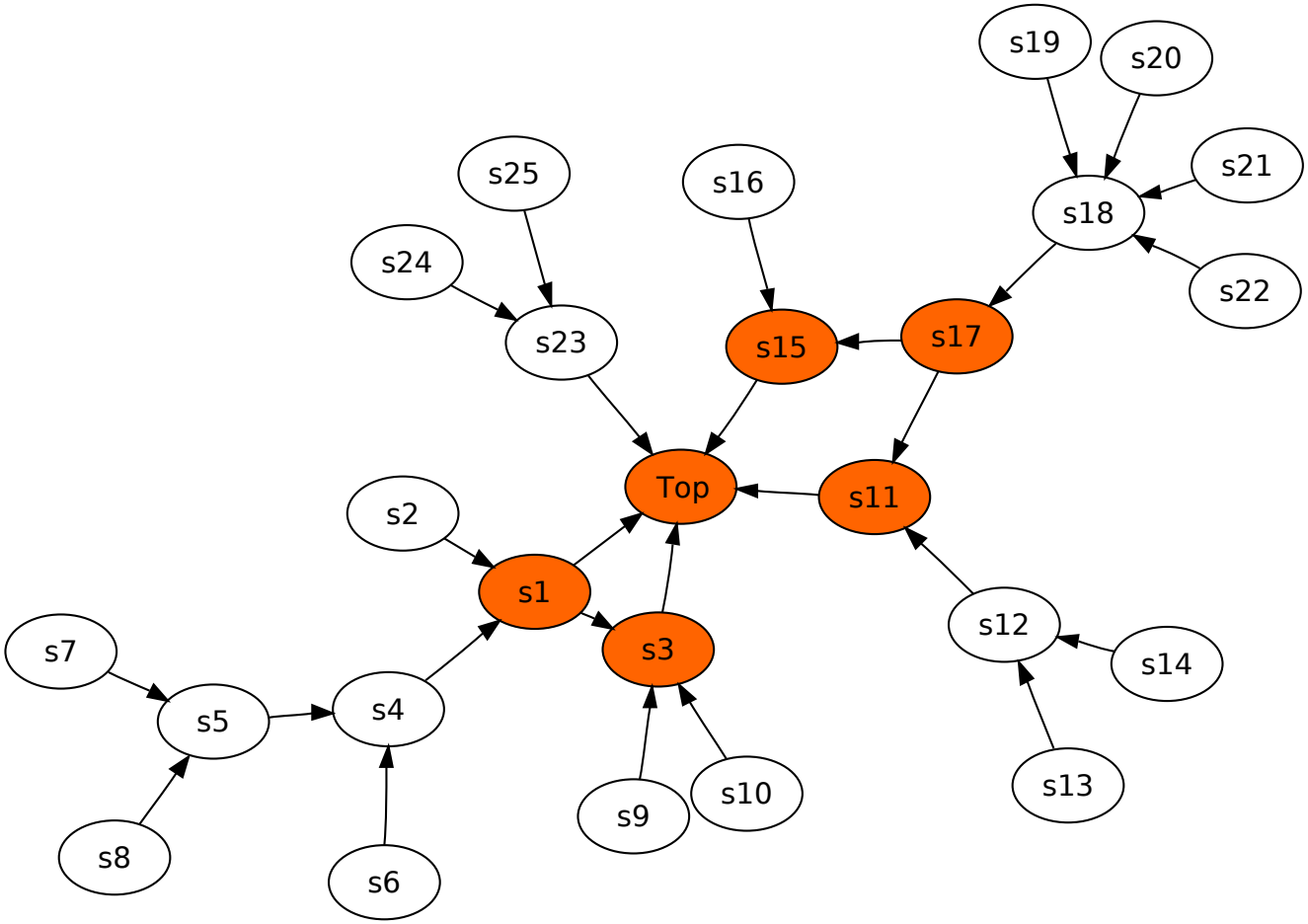

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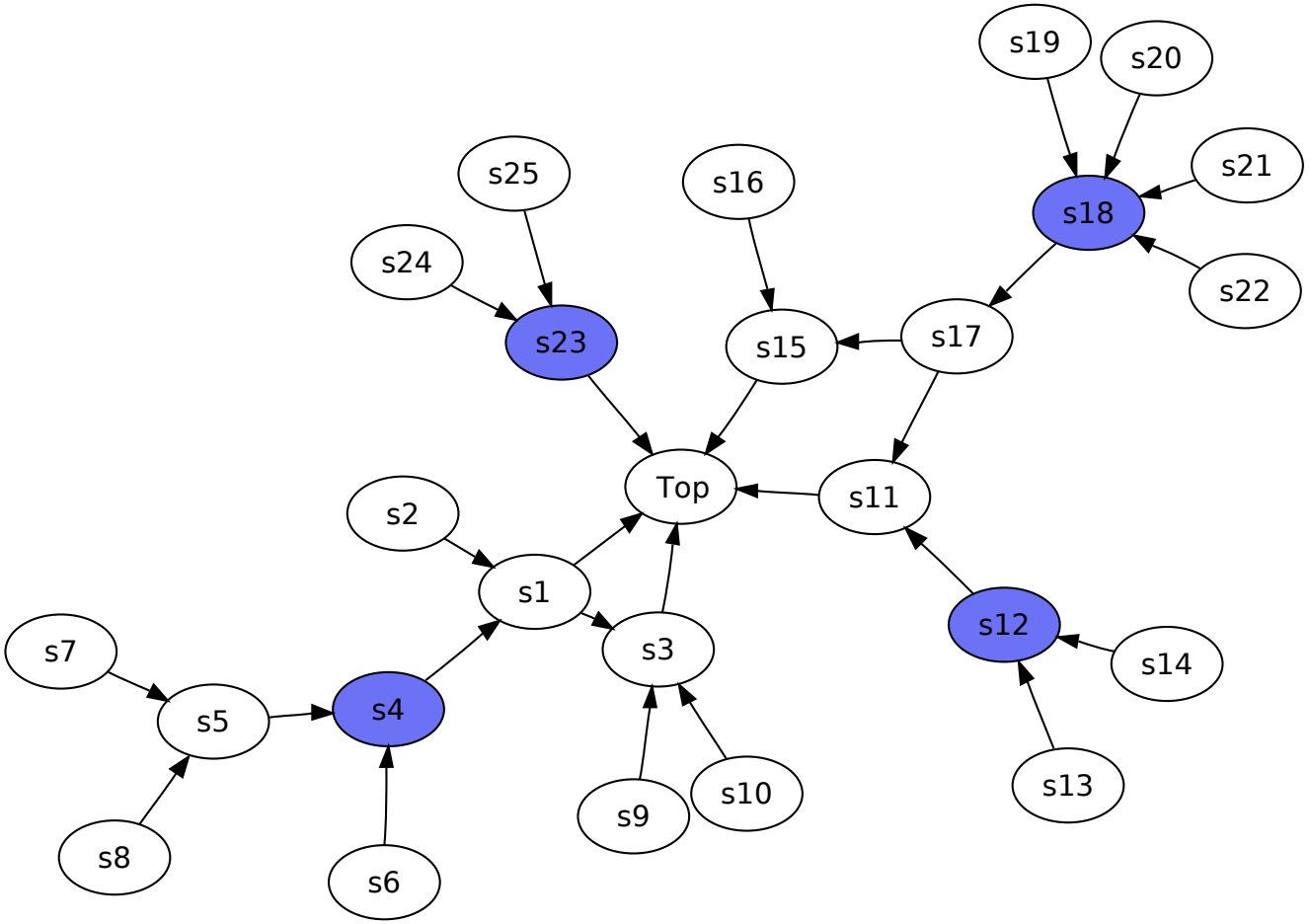

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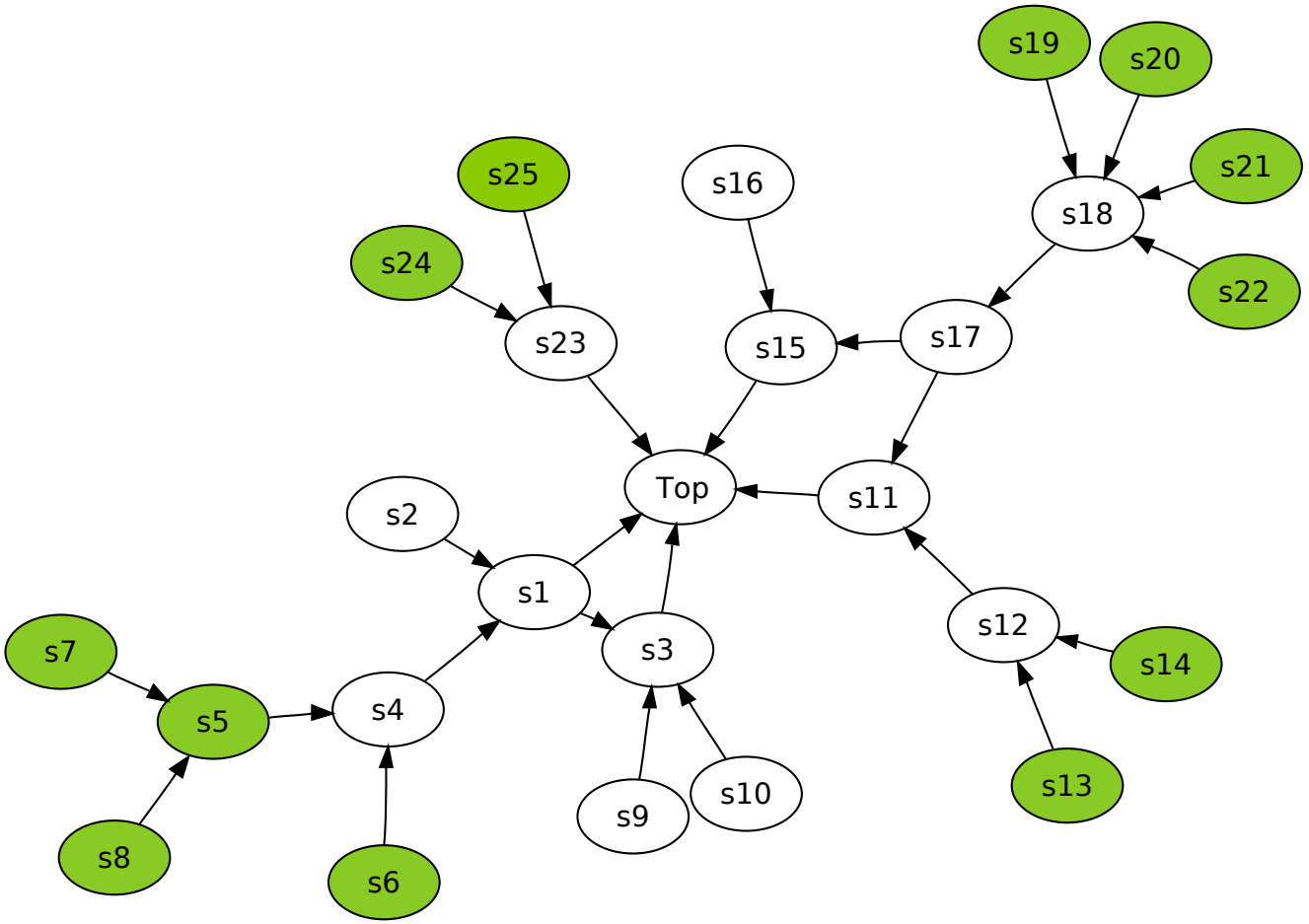

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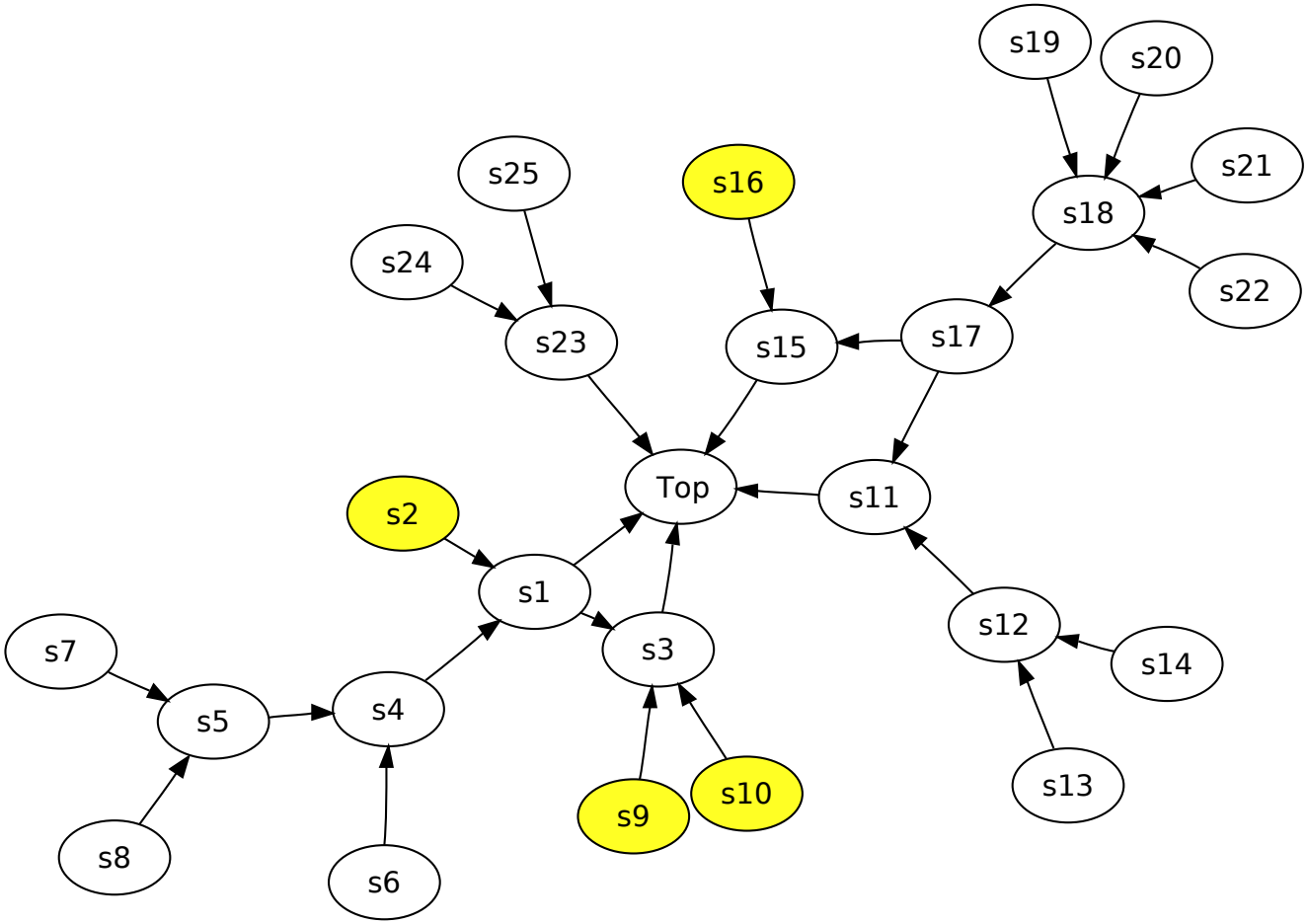

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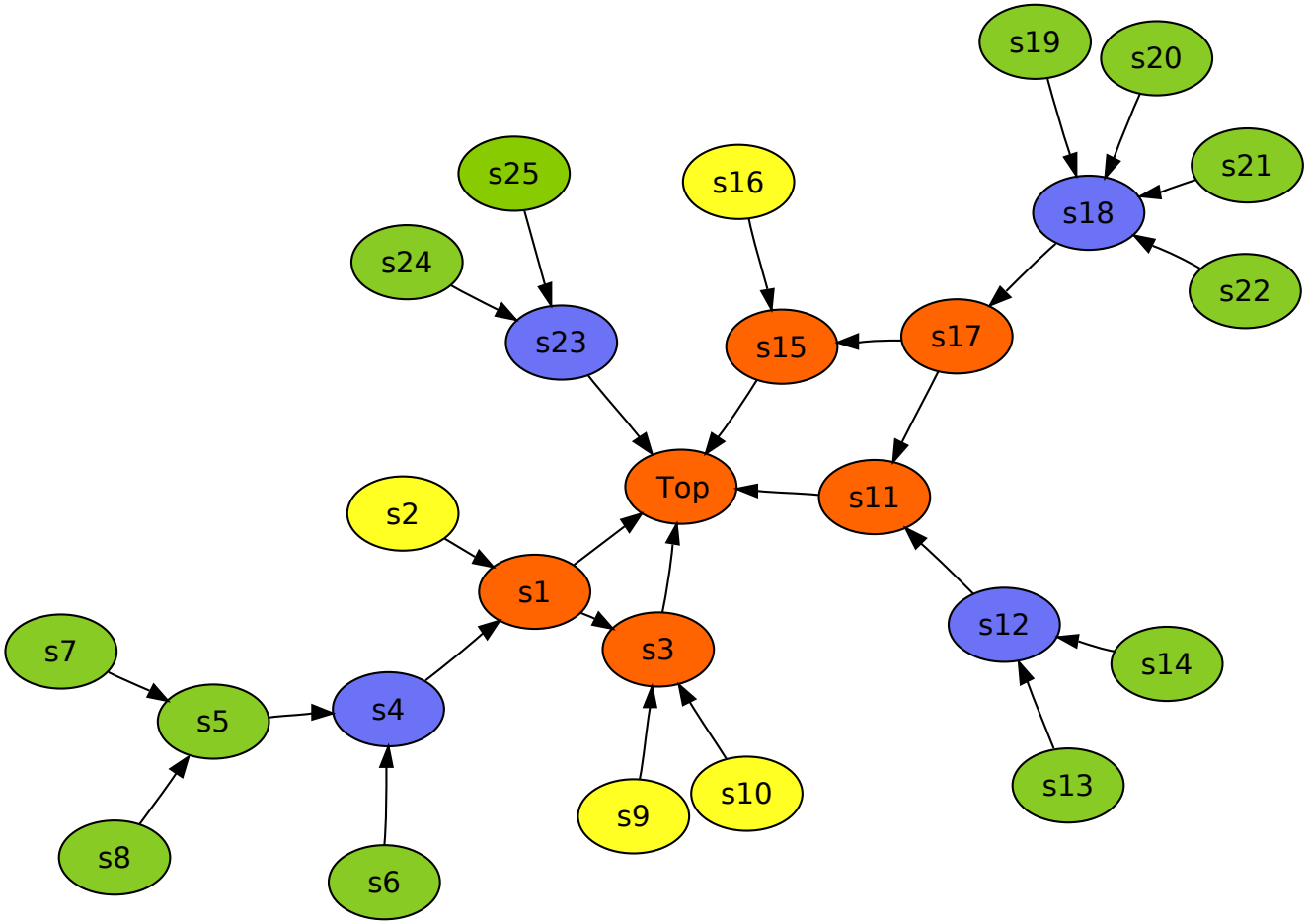

Path Calculation Proper

Path splitting

- From the start node...
- ...through the first tree...
- ...through the core graph...
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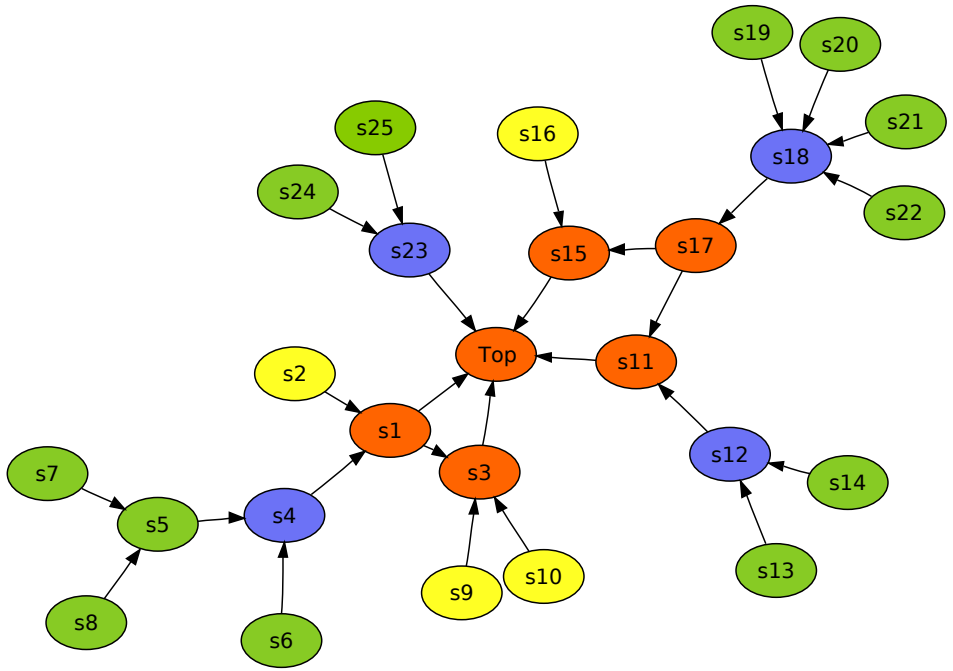
- ...to the target node



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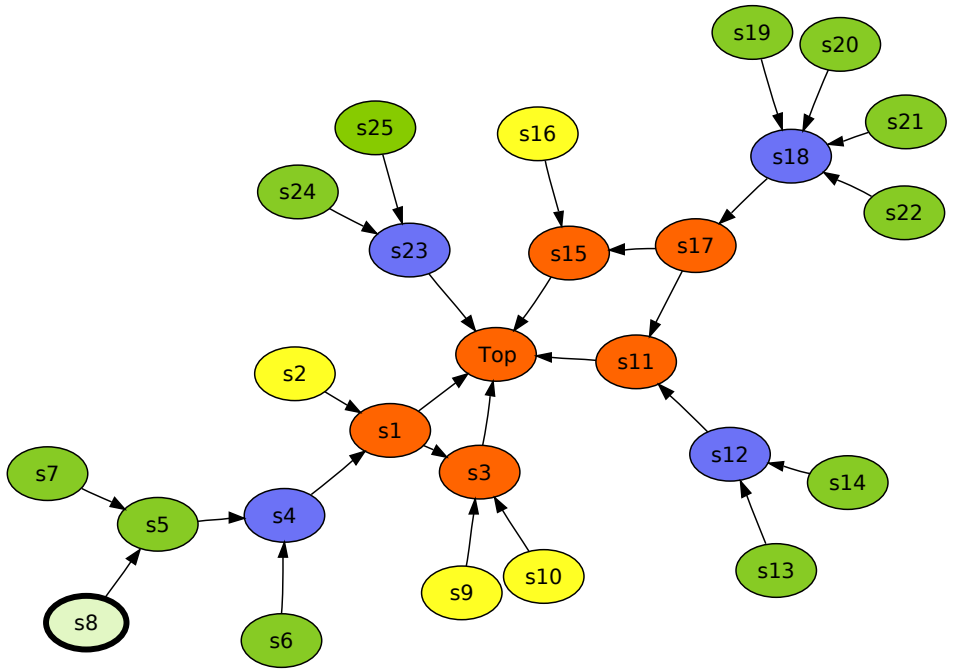

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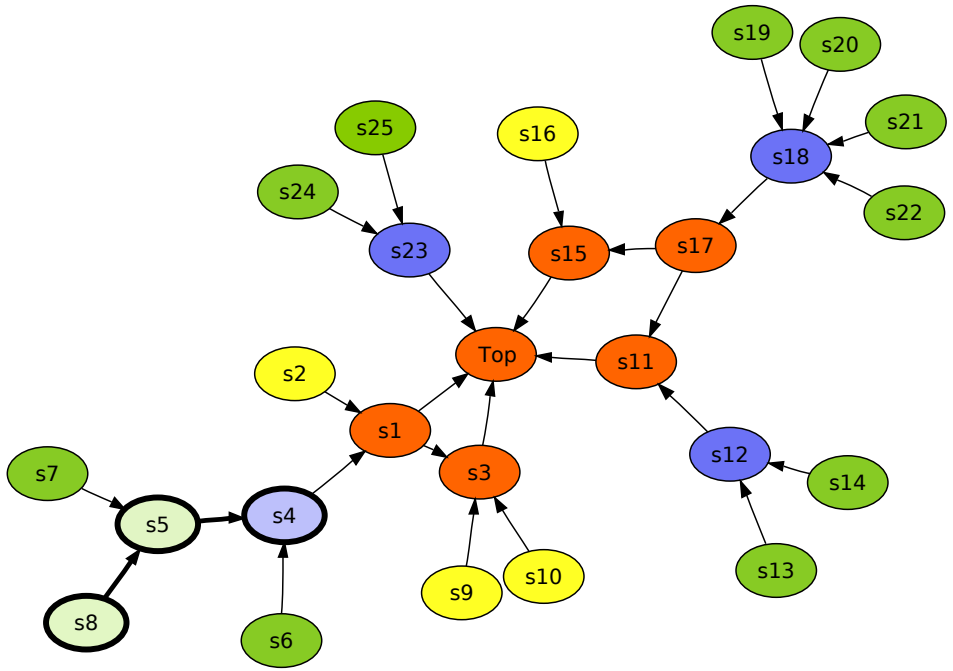

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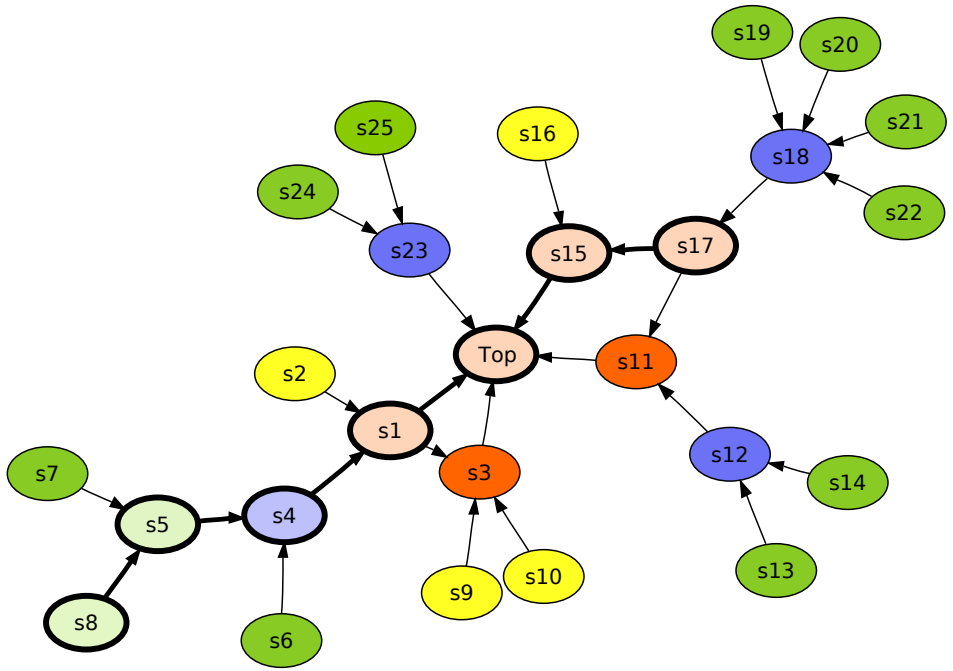

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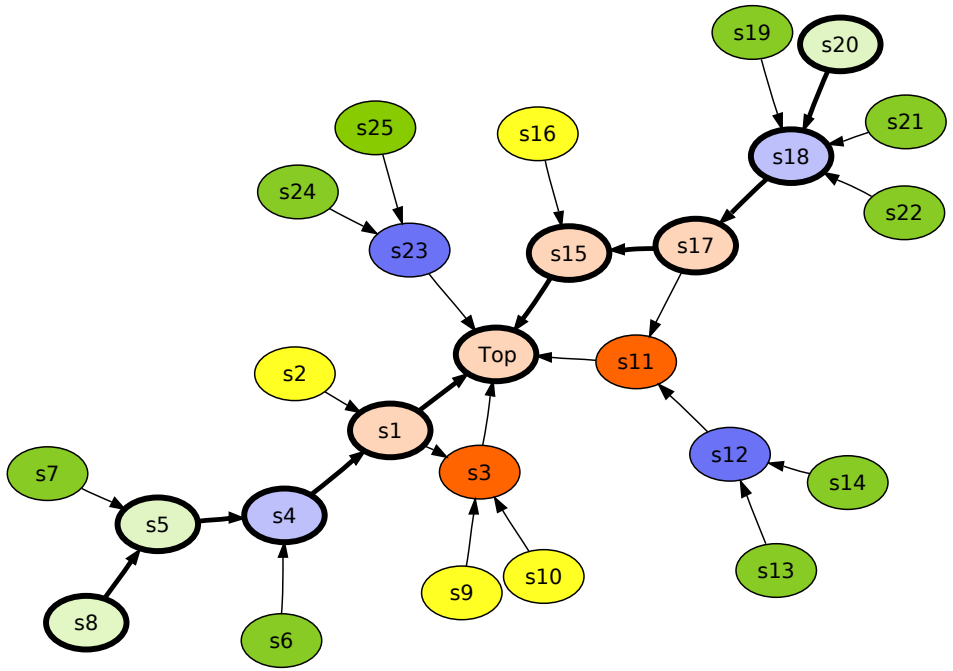
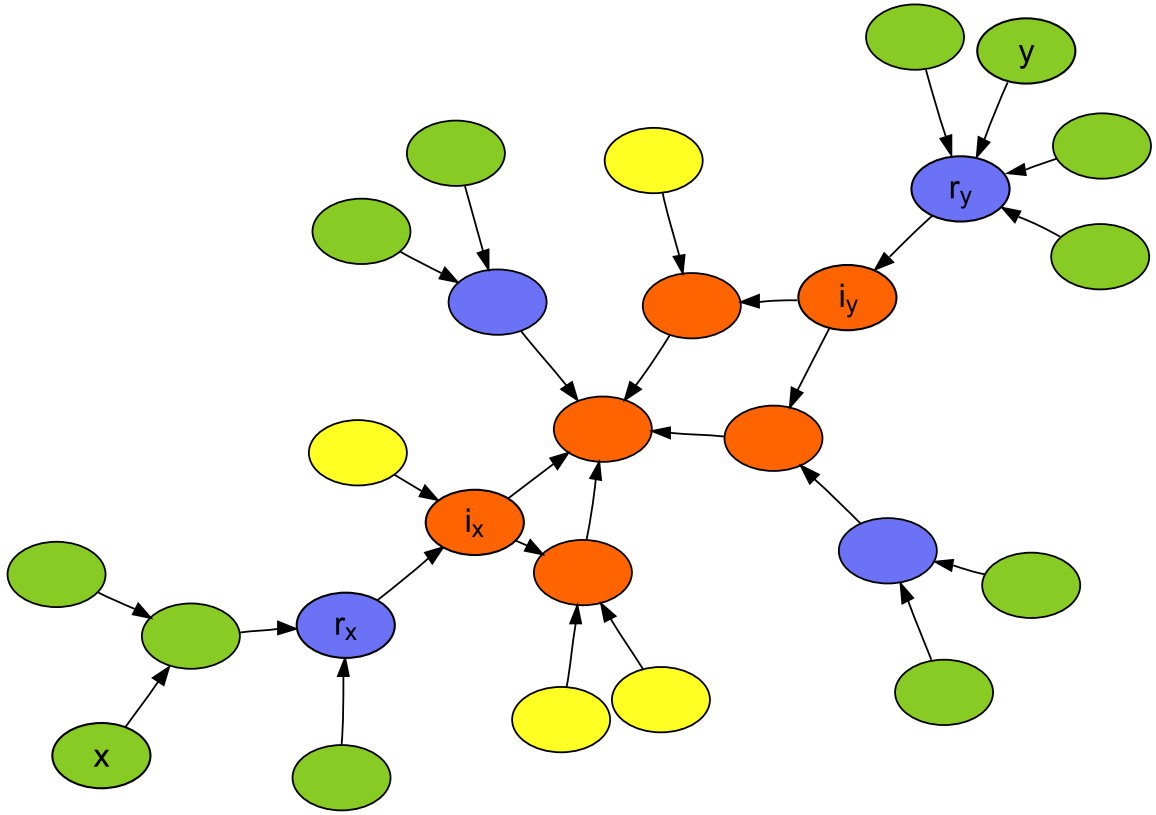


Structure Adapted Shortest Path Search



$$l_{xy} = l_{xr_x} + l_{r_x i_x} + l_{i_x i_y} + l_{i_y r_y} + l_{r_y y}$$

$$\text{with } l_{r_x i_x} = l_{i_y r_y} = 1$$

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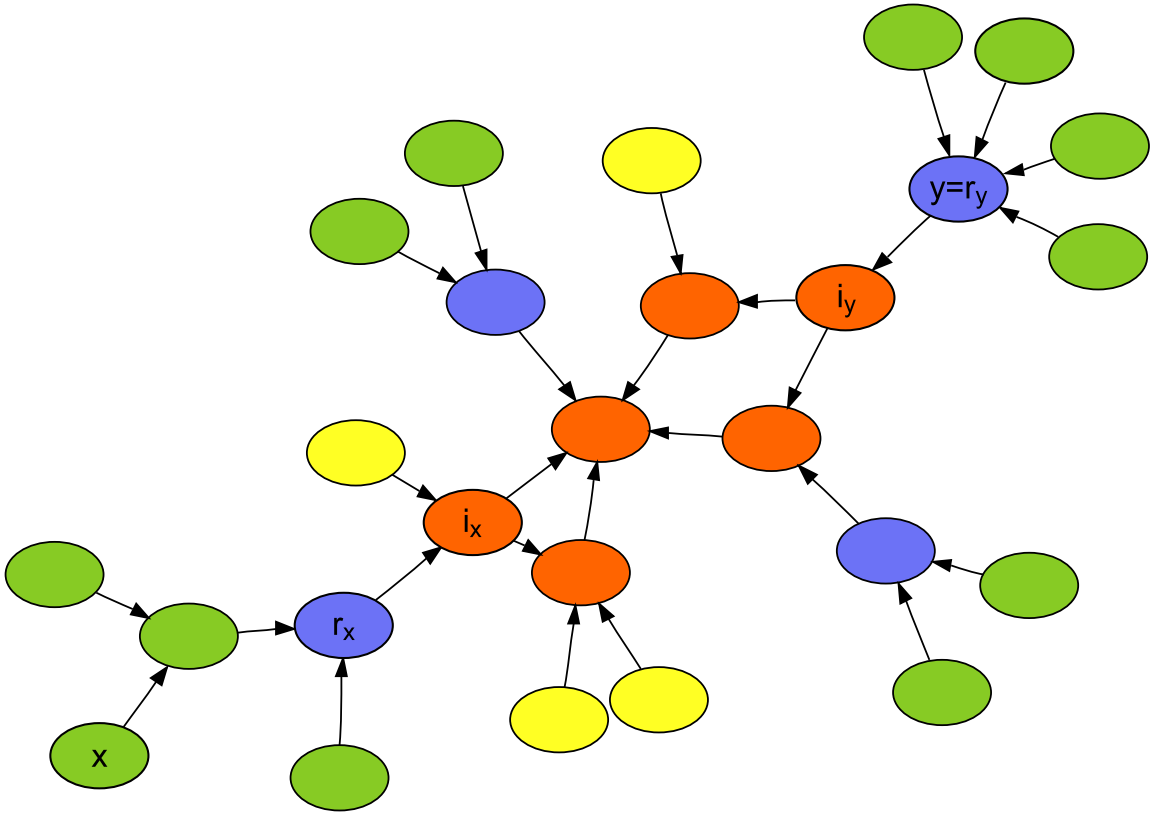

$$l_{xy} = l_{xr_x} + 1 + l_{i_x i_y} + 1$$

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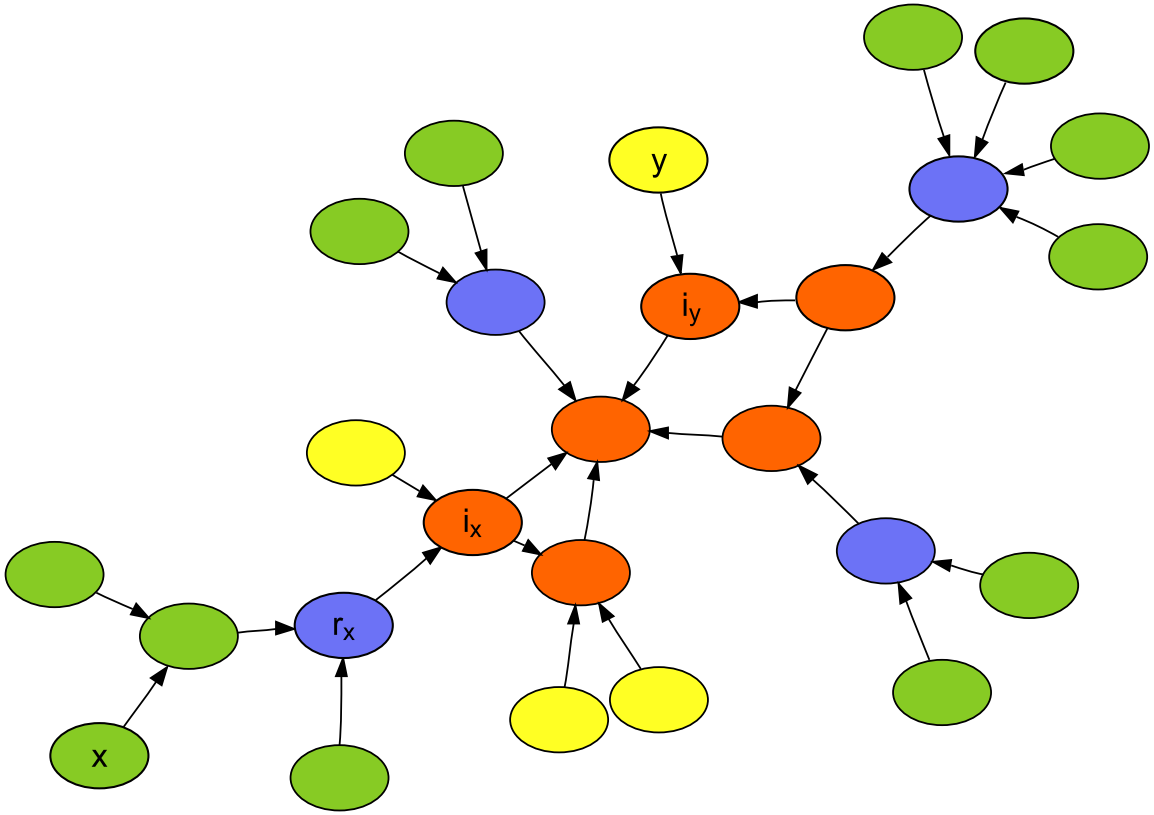

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Results

	Wordnet	**GermaNet**
Synsets	117659	53312
Inner nodes	4250	8728
Root nodes	7174	4641
Tree nodes	56532	18949
Leaf nodes	49704	20683
Classification time	$\approx$ 1 sec	1.2 sec
plain Floyd-Warshall	$>$ 35 days	120 hrs
Structure-adapted shortest path search	9 min	40 min

Discussion / Future Work

- Exploitation of wordnet-specific structure substantially reduces processing time
- Reduced memory overhead: Less housekeeping effort due to smaller graphs
- Replace greedy path search algorithm with heuristic ones

Thank You

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References

Lothar Lemnitzer, Holger Wunsch, Piklu Gupta (2008) : Enriching GermaNet with Verb-noun Relations – a Case Study of Lexical Acquisition. In: *Proceedings of LREC 2008*. Marrakech, Morocco, May 2008.