Reading about Search

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May 2, 2019

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Operational Programme Research,
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Outline

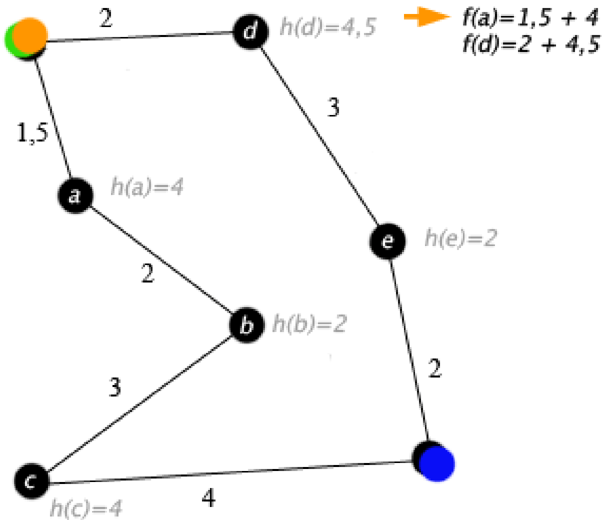
- Intro: Dijskra and A* search.
- MT is NP-hard.
- Fast and optimal decoding.
- Stacks and future cost.
- Cube pruning.
- Hypergraph decoding.

Dijkstra and A* Search

- Dijkstra's algorithm for shortest path:
  - Always extend the cheapest/shortest option.
- A* (A-Star) Search:
  - Always extend the cheapest/shortest option.
  - Include a CONSISTENT (optimistic) heuristic estimate of the remaining distance (also called "future cost").

Key data structure: stack of open hypotheses.

A* Search



Dijkstra		A*	
a	1.5	a	$+4 = 5.5$
d	2.0	b	$+2 = 5.5$
b	3.5	d	$+4.5 = 6.5$
e	5.0	e	$+2 = 7.0$
c	5.5	goal	$+0 = 7.0$
goal	7.0	c	$+4 = 9.5$

MT is NP-Hard

NP-hard problem:

- To solve the task of size n, strictly more than n^k steps (for any fixed k) have to be made.
- Usually this means, there are exponetially (k^n) solutions to consider.

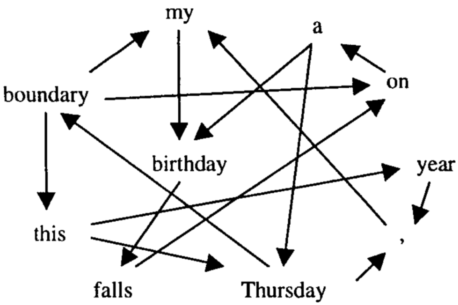
Knight (1999) shows word-based MT is NP-hard for two reasons:

- Selecting source word order ($\rightarrow$ Hamilton circuit).
- Grouping source words to form multi-word dictionary entries ($\rightarrow$ Minimum set cover).

- These are worst-case constructions.

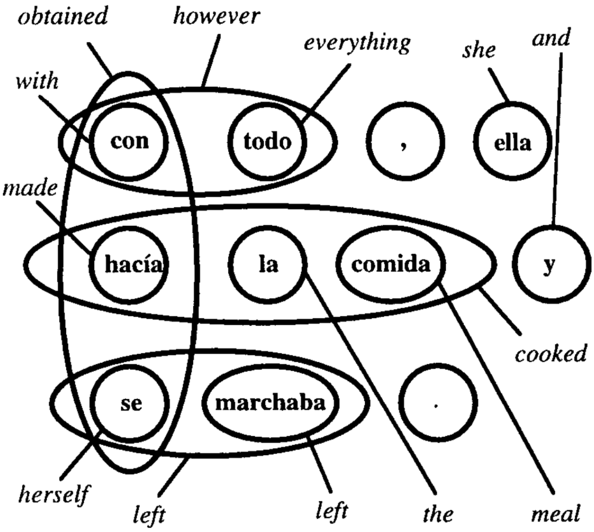
MT is NP-Hard (2/3)

- Remember the NP-hardness proof strategy:
  - Use MT as a black box to solve an NP-complete task.



With a 2-gram language model, finding the best word ordering solves the Hamilton Circuit or Travelling Salesman Problem. (Knight, 1999)

MT is NP-Hard (3/3)



Selecting a set of multi-word translations to cover the whole sentence solves Minimum Set Cover Problem. (Knight, 1999)

Input: However, she cooked and left.

Fast and Optimal Decoding

Germann et al. (2004) implement three word-based decoders:

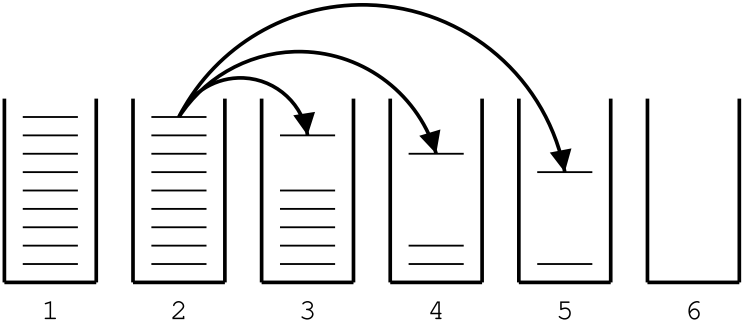
- Stack-based.
  - Similar to Moses but 2^n stacks instead of n stacks.
- Greedy.
  - Start with the cheapest gloss.
  - Modify alignment and translation to improve probability.
- Optimal ($\sim$Traveling Salesman).
  - Finding a tour through all source cities gives us target translation by noting owners of hotels where we stayed.

Observations:

- Many pure modelling errors.
- Greedy decoding viable option.

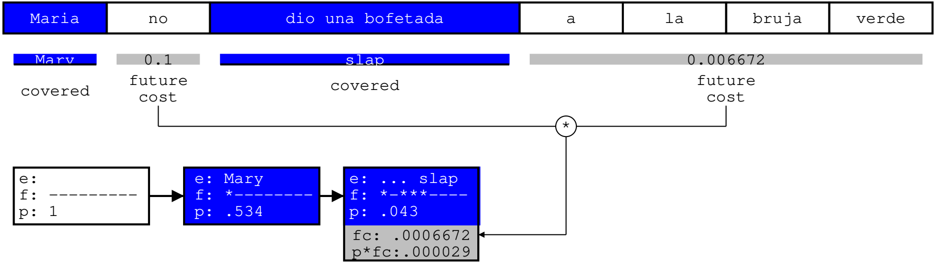
Stacks and Future Cost (1)

Remember Moses/Pharaoh stack-based decoding:



- n stacks based on number of words covered.
- A stack contains hypotheses regardless which words were covered.
  $\Rightarrow$ Not a fair comparison.

Stacks and Future Cost (2)



- Future cost to make the competition fair.
- Future cost = consistent heuristic estimate.
  Optimistic, because LM will make attachments more expensive.
- No future cost would be needed, if stacks were infinite.

Reranking

"Feature engineering":

- Choosing the most promising hypotheses based on local observations.

Some features need more context of output hypotheses, e.g.:

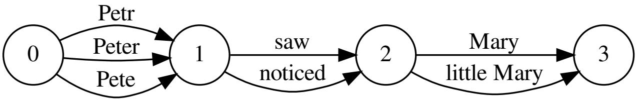
- Is the output hypothesis syntactically correct?
  $\Rightarrow$ Need full parsing.

Reranking example:

1. Generate n-best list of hypotheses.
2. Parse all of them.
3. Prefer hypotheses with likely parses.

Local vs. Non-local Features

Non-local features facilitate reranking of partial hyps. (Lopez, 2009)
While building partial hypotheses, decisions multiply:



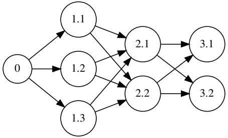
$3 \cdot 2 \cdot 2 = 12$ hyps.
$\Rightarrow$ n-best lists inevitably too short.

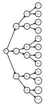
Local features access only **input** and **current edge**:

- Do we prefer to translate "Petr" as "Peter" or leave non-translated?

Non-local features access **partial history**:

- Do we prefer "Pete saw" or "Peter noticed"?
- Can be seen as **state splitting** depending on the relevant past context.





Reranking can access **full history**.

Weighted Deduction

Lopez (2009) summarizes several decoders in a unified framework of weighted deduction:

- Left-to-right, phrase-based, CKY.
- A HYPERGRAPH (see e.g. Huang (2008)) represents the deductions: combining items according to deduction rules.

Non-local features:

- Accommodated by state splitting ("product" of logics).

See the slides by Adam Lopez.

Cube Pruning

- Only a fraction of hypotheses constructed will escape pruning.
- Let's not construct them at all!
- Instead: Construct elements of the product starting from the (approximately) cheapest until the target stack is full.
- More details in Huang and Chiang (2007).

Summary

- MT is NP hard.
- Sub-optimal algorithms (stack-based, greedy, ...) used.
    - Modelling errors are an issue.
    - Future cost to reduce search errors.
- Local and non-local features.
- Unified view: translation as weighted deduction:
    - State splitting.
    - Cube pruning for stack-based decoding.

References

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