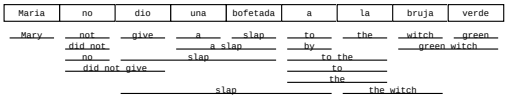
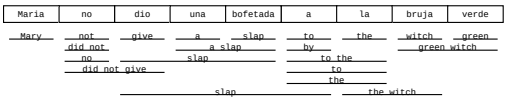
Translation Options



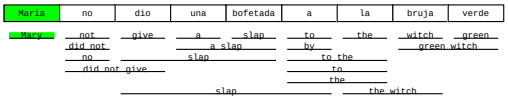
- Look up possible phrase translations
  - many different ways to segment words into phrases
  - many different ways to translate each phrase

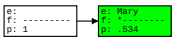
Hypothesis Expansion



- Start with empty hypothesis
  - e: no English words
  - f: no foreign words covered
  - p: probability 1

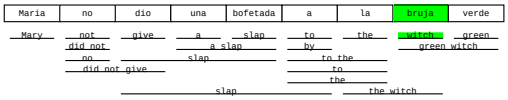
Hypothesis Expansion

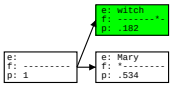




- Pick translation option
- Create hypothesis
  - e: add English phrase `Mary`
  - f: first foreign word covered
  - p: probability 0.534

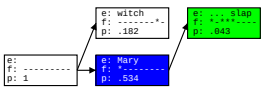
Hypothesis Expansion





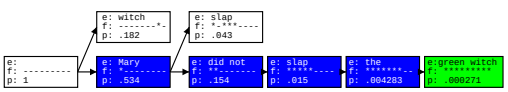
- Add another hypothesis

Hypothesis Expansion



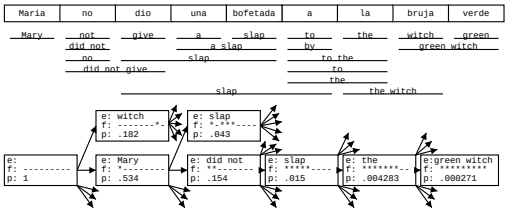
- Further hypothesis expansion

Hypothesis Expansion



- ... until all foreign words covered
  - find best hypothesis that covers all foreign words
  - backtrack to read off translation

Hypothesis Expansion



- Adding more hypothesis

⇒ Explosion of search space

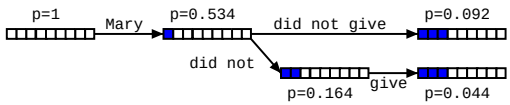
Explosion of Search Space

- Number of hypotheses is exponential with respect to sentence length

⇒ Decoding is NP-complete [Knight, 1999]

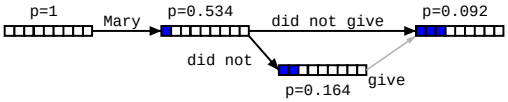
⇒ Need to reduce search space
  - risk free: hypothesis recombination
  - risky: histogram/threshold pruning

Hypothesis Recombination



- Different paths to the same partial translation

Hypothesis Recombination

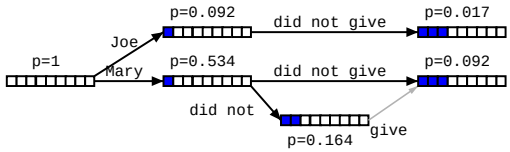


- Different paths to the same partial translation

$\Rightarrow$ Combine paths

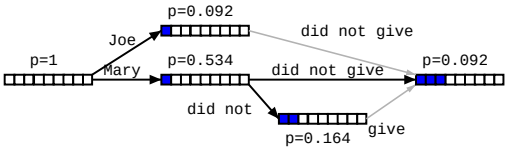
- drop weaker hypothesis
- keep pointer from worse path

Hypothesis Recombination



- Recombined hypotheses do not have to match completely
- No matter what is added, weaker path can be dropped, if:
  - last two English words match (matters for language model)
  - foreign word coverage vectors match (effects future path)

Hypothesis Recombination



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  - last two English words match (matters for language model)
  - foreign word coverage vectors match (effects future path)

$\Rightarrow$ Combine paths

Pruning

- Hypothesis recombination is not sufficient

$\Rightarrow$ Heuristically discard weak hypotheses

- Organize Hypothesis in stacks, e.g. by
  - same foreign words covered
  - same number of foreign words covered (Pharaoh does this)
  - same number of English words produced
- Compare hypotheses in stacks, discard bad ones
  - histogram pruning: keep top n hypotheses in each stack (e.g., n=100)
  - threshold pruning: keep hypotheses that are at most α times the cost of best hypothesis in stack (e.g., α = 0.001)