Machine translation: Decoding

Chris Callison-Burch
Slides borrowed from Philipp Koehn

December 4, 2007

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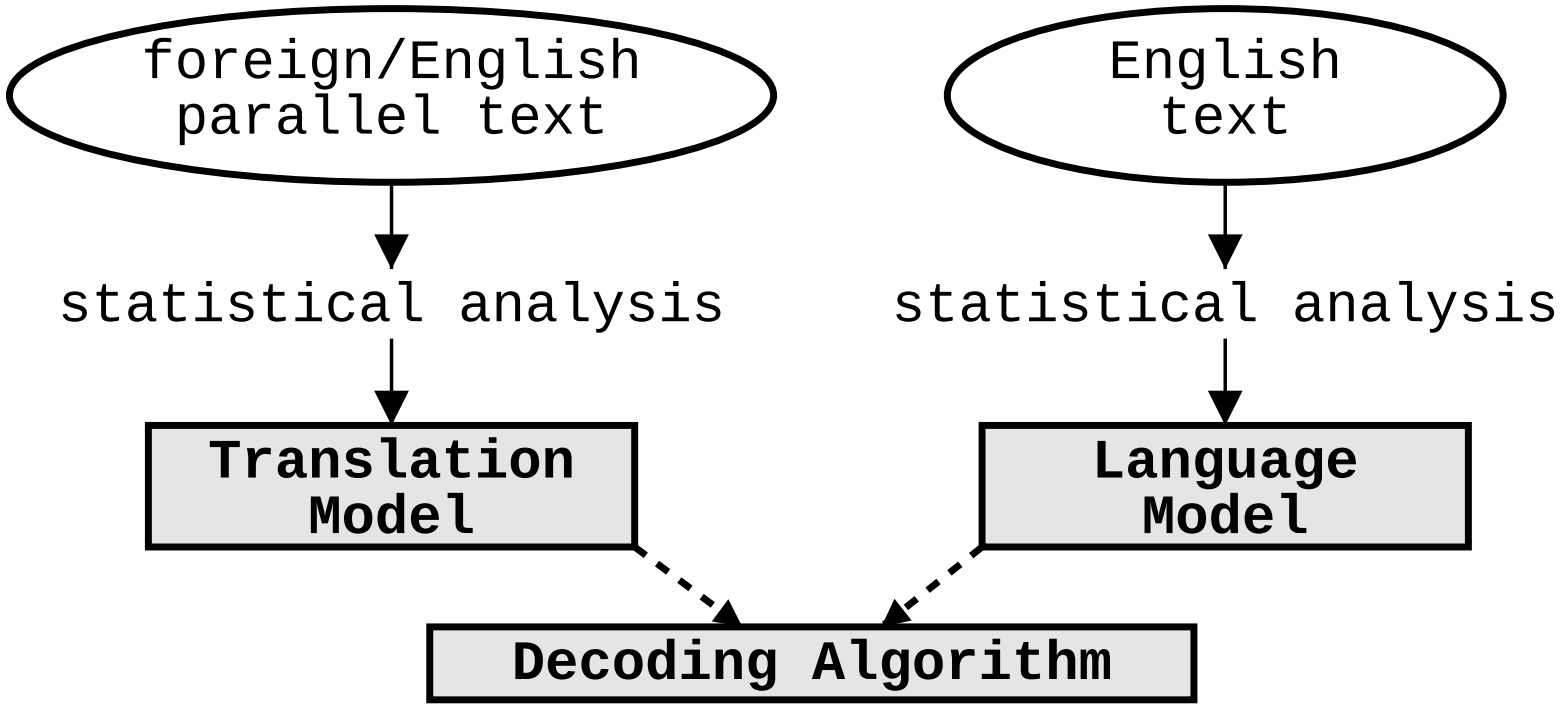
Statistical Machine Translation

- Components: Translation model, language model, decoder



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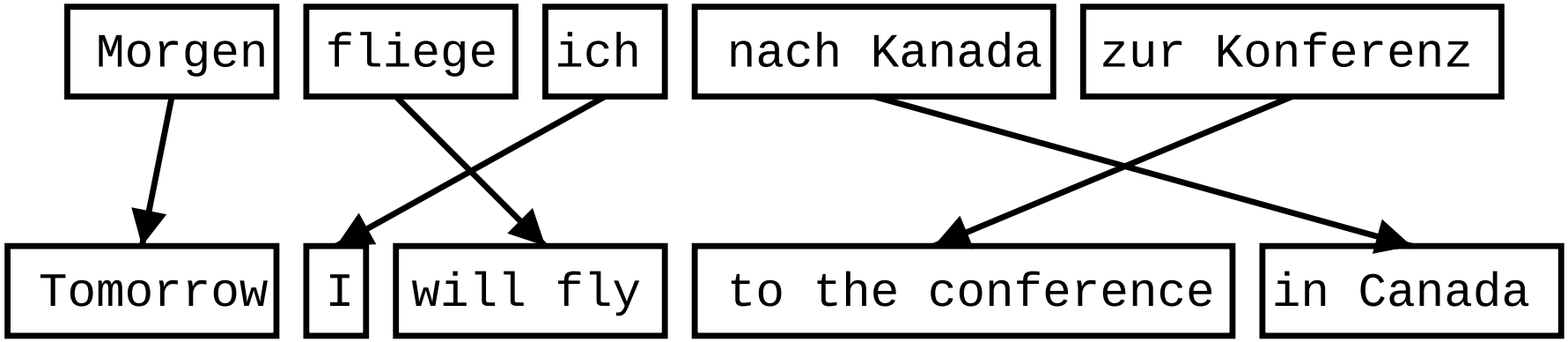
Phrase-Based Translation



- Foreign input is segmented in phrases
  - any sequence of words, not necessarily linguistically motivated
- Each phrase is translated into English
- Phrases are reordered

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Phrase Translation Table

- Phrase Translations for "den Vorschlag":

English	ϕ**(e|f)**	**English**	ϕ**(e|f)**
the proposal	0.6227	the suggestions	0.0114
's proposal	0.1068	the proposed	0.0114
a proposal	0.0341	the motion	0.0091
the idea	0.0250	the idea of	0.0091
this proposal	0.0227	the proposal ,	0.0068
proposal	0.0205	its proposal	0.0068
of the proposal	0.0159	it	0.0068
the proposals	0.0159	...	...

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Decoding Process

Maria	no	dio	una	bofetada	a	la	bruja	verde

- Build translation left to right
  - *select foreign* words to be translated

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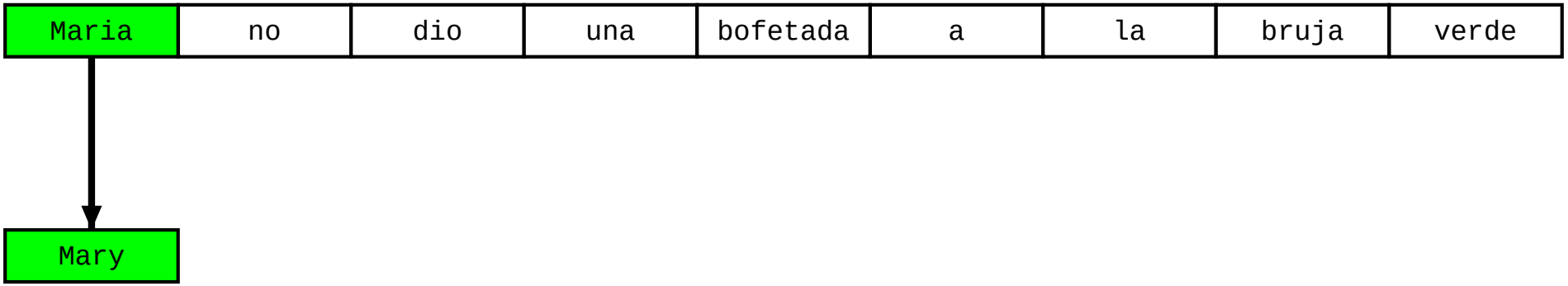
Decoding Process



- Build translation *left to right*
  - select foreign words to be translated
  - *find English* phrase translation
  - *add English* phrase to end of partial translation

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Decoding Process

Maria	no	dio	una	bofetada	a	la	bruja	verde

Mary

- Build translation left to right
  - select foreign words to be translated
  - find English phrase translation
  - add English phrase to end of partial translation
  - *mark foreign* words as translated

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Decoding Process

- *One to many* translation

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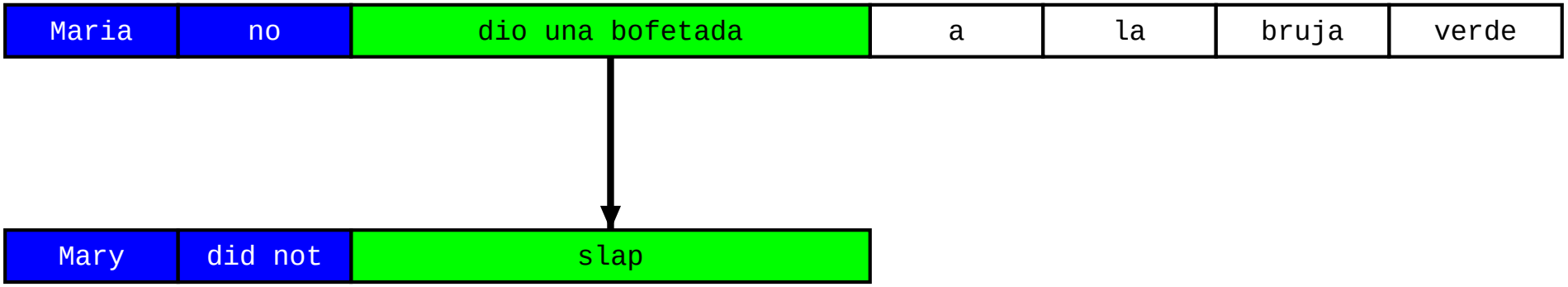
Decoding Process



- Many to one translation

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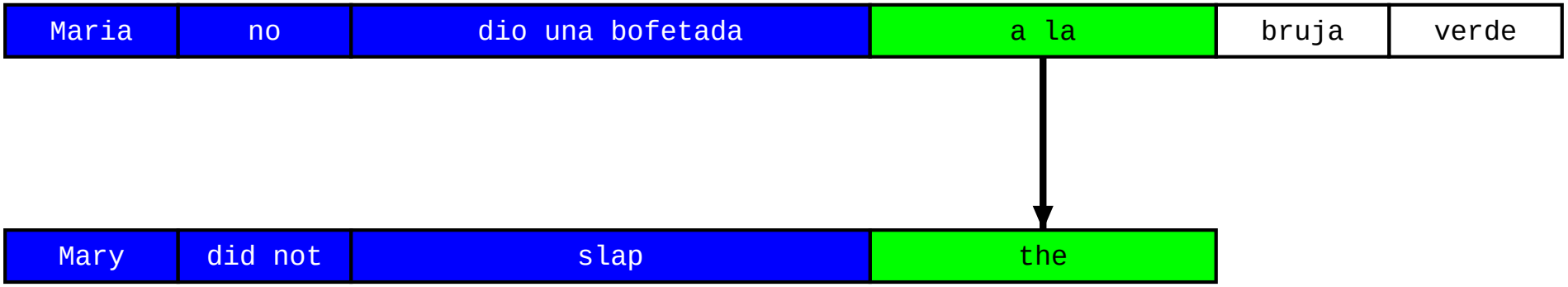
Decoding Process



- *Many to one* translation

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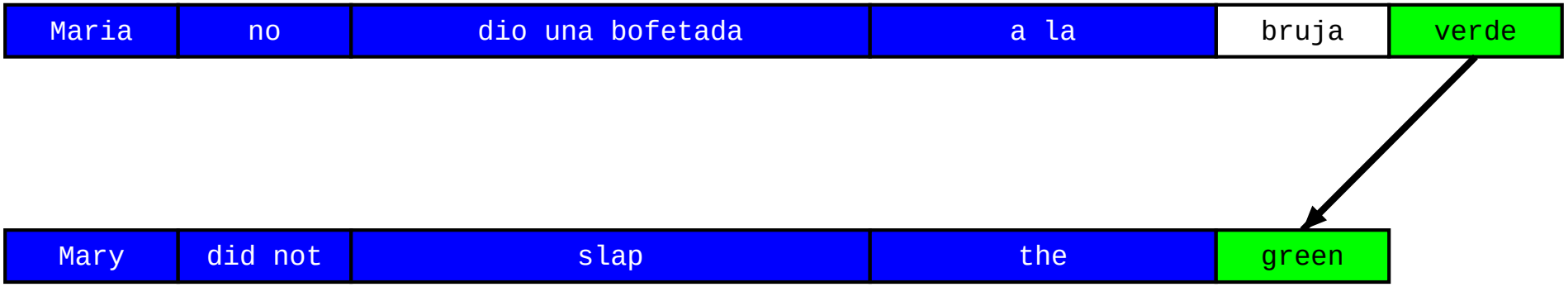
Decoding Process



- *Reordering*

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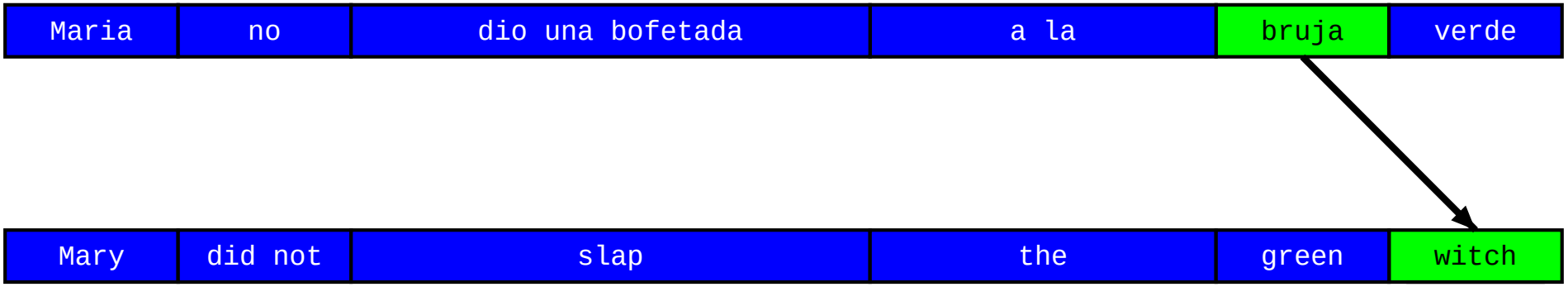
Decoding Process



- Translation *finished*

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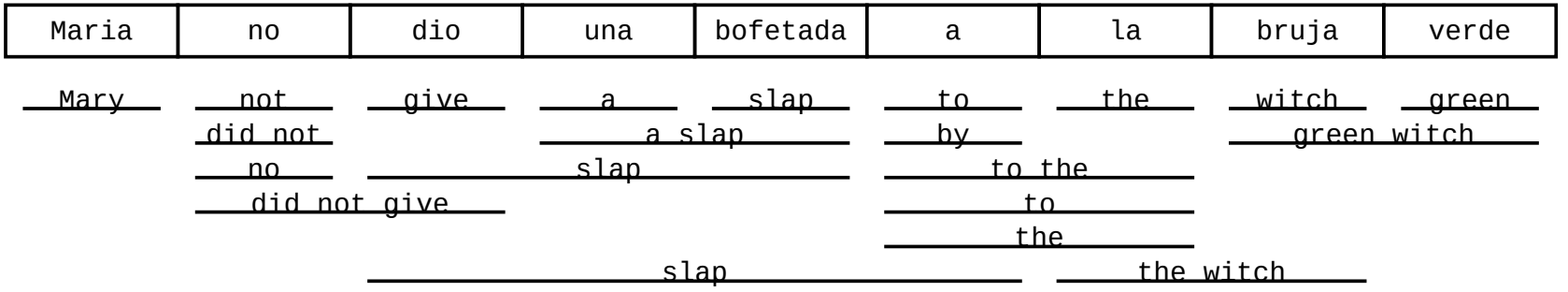
Translation Options



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

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Hypothesis Expansion

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

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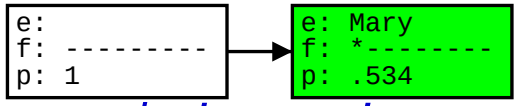
Hypothesis Expansion



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

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A Quick Word on Probabilities

- Not going into detail here, but...
- *Translation Model*
  - phrase translation probability p(Mary|Maria)
  - reordering costs
  - phrase/word count costs
  - ...
- *Language Model*
  - uses trigrams:
  - p(Mary did not) = p(Mary|START) $\times p$(did|Mary,START) $\times$ p(not|Mary did)

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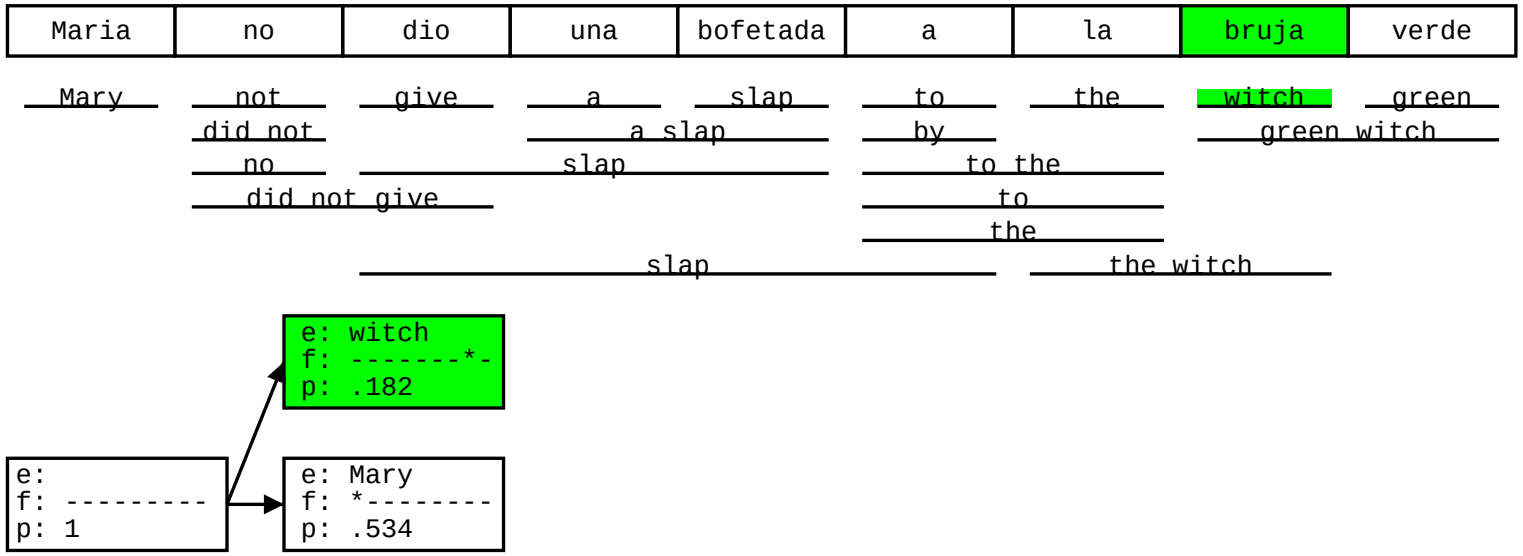
Hypothesis Expansion



- Add another *hypothesis*

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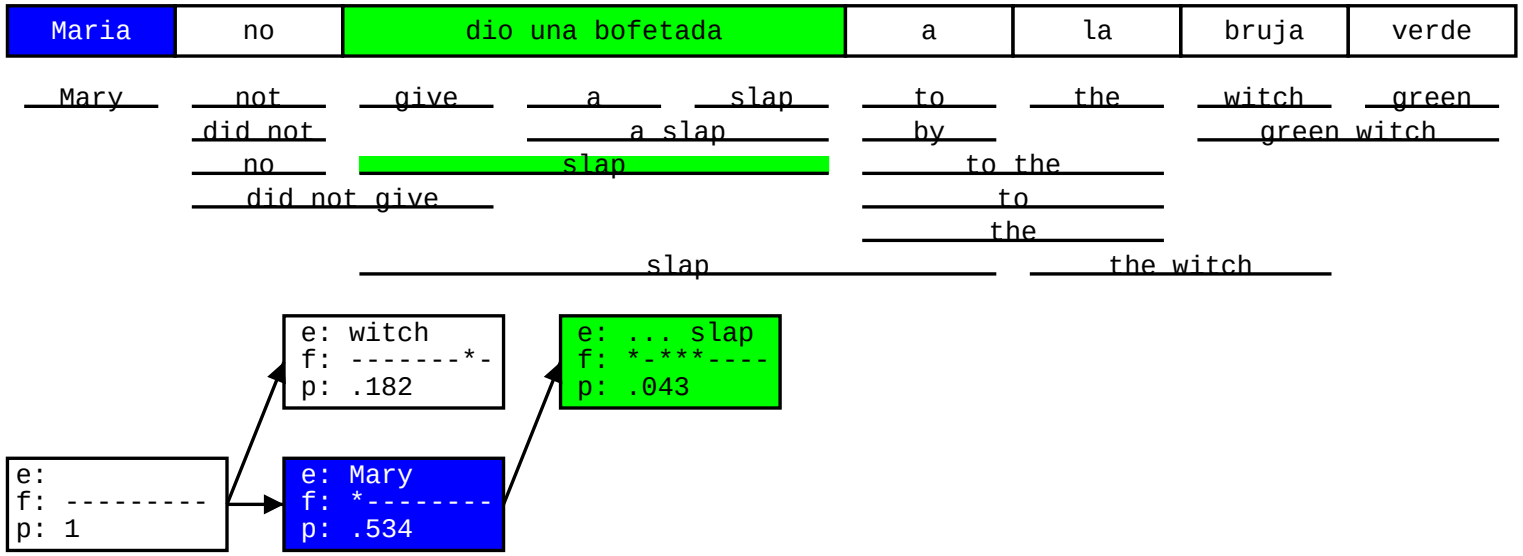
Hypothesis Expansion



- Further *hypothesis expansion*

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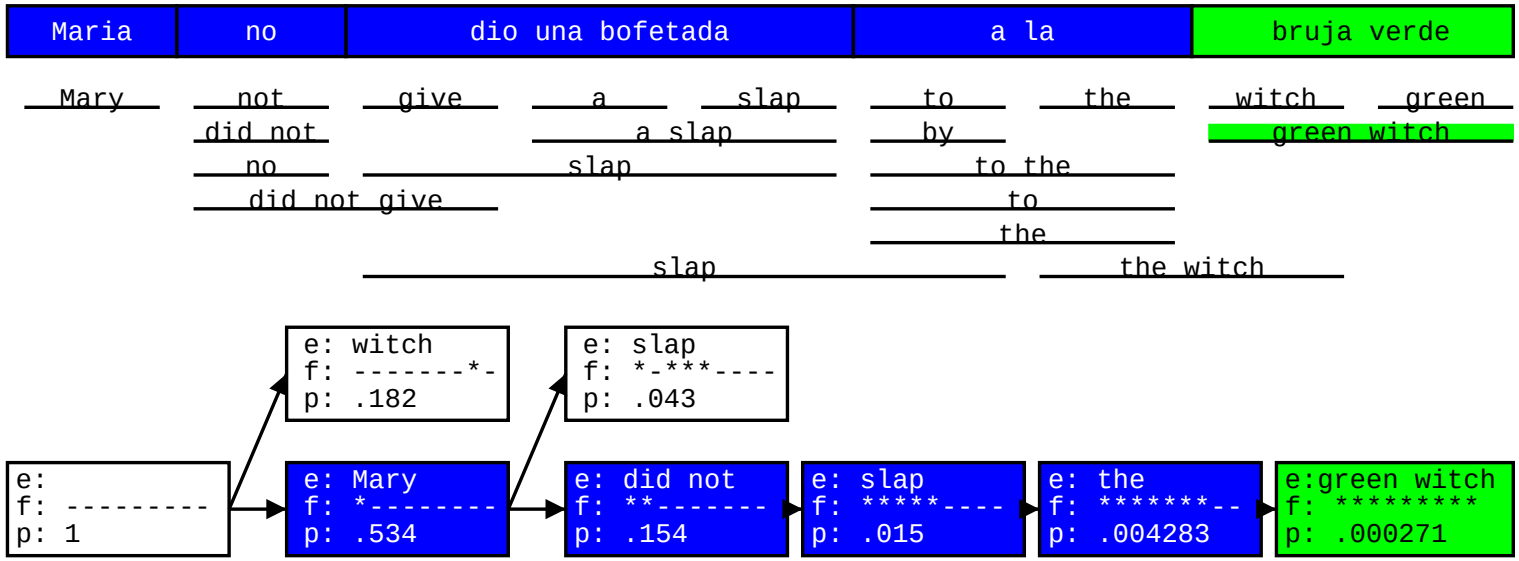
Hypothesis Expansion



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

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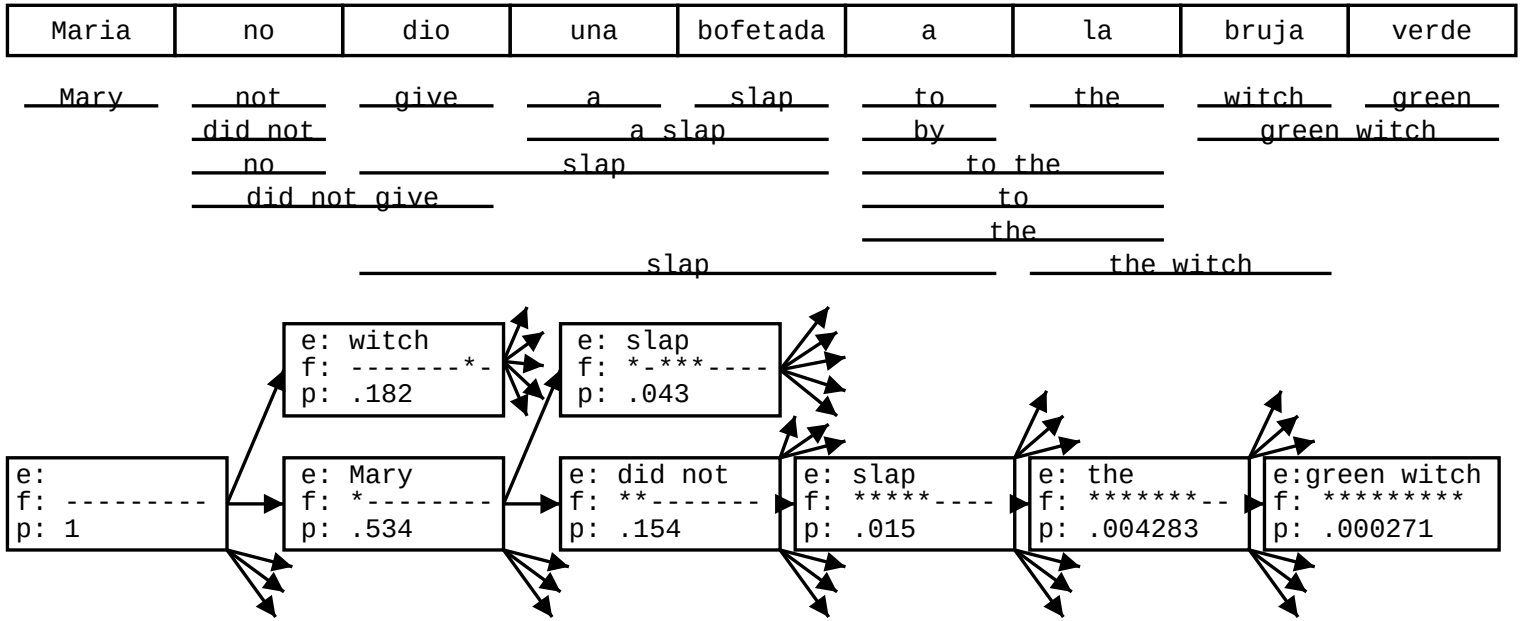
Hypothesis Expansion



- Adding more hypothesis

$\Rightarrow$ *Explosion* of search space

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Explosion of Search Space

- Number of hypotheses is *exponential* with respect to sentence length

$\Rightarrow$ Decoding is NP-complete [Knight, 1999]

$\Rightarrow$ Need to *reduce search space*

  - risk free: hypothesis **recombination**
  - risky: **histogram/threshold pruning**

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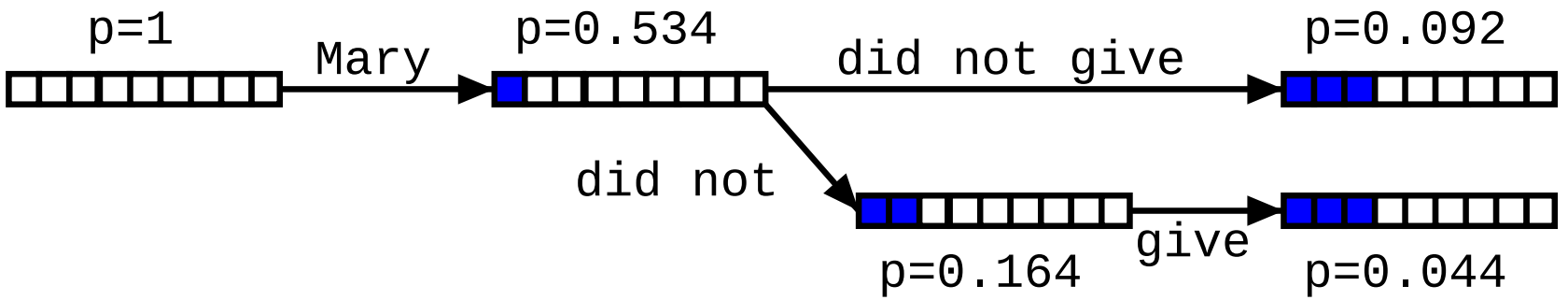
Hypothesis Recombination



- Different paths to the *same* partial translation

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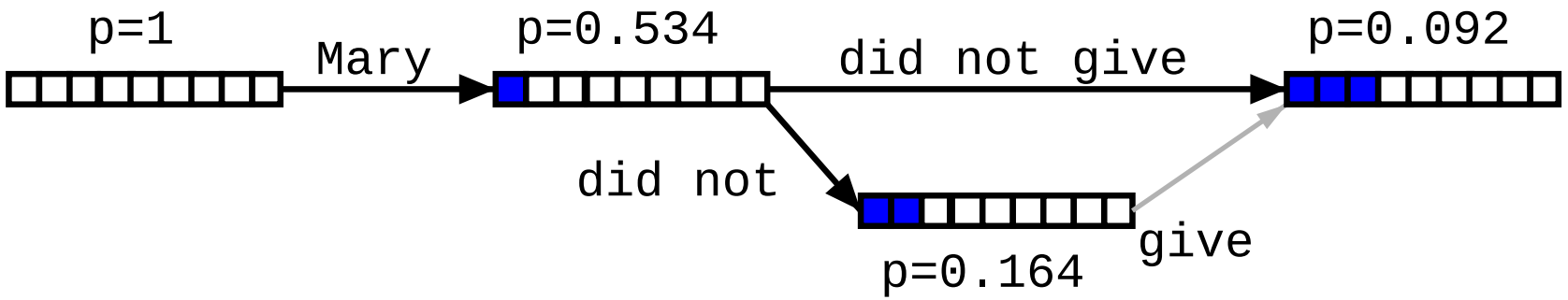
Hypothesis Recombination



- Different paths to the same partial translation

⇒ *Combine paths*

  - *drop weaker* path
  - keep pointer from weaker path (for lattice generation)

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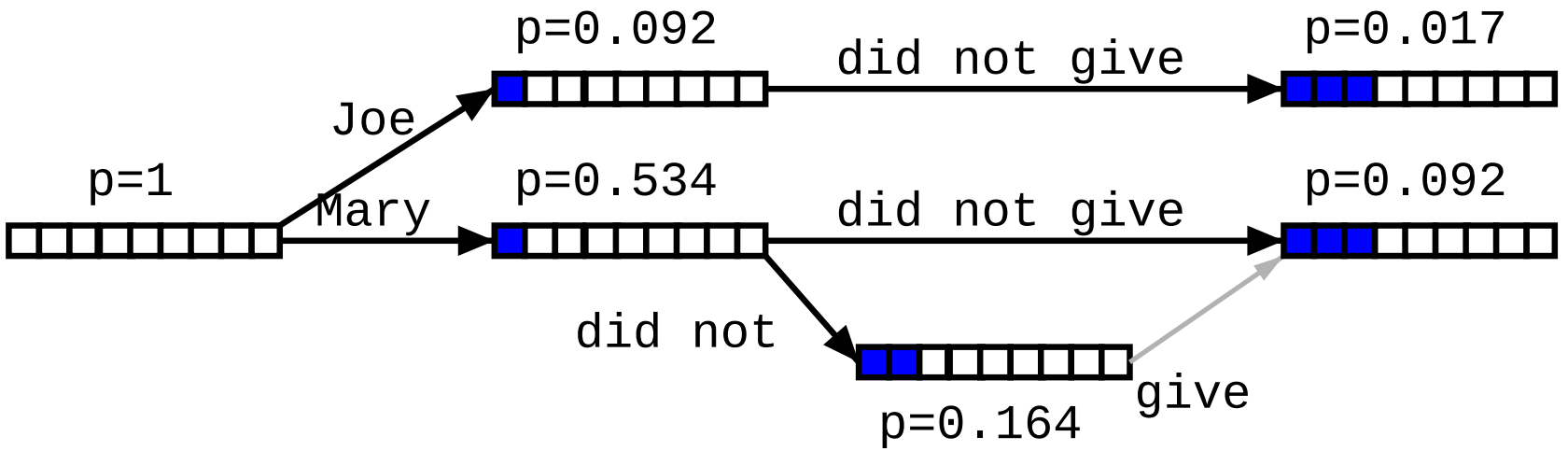
Hypothesis Recombination



- 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)

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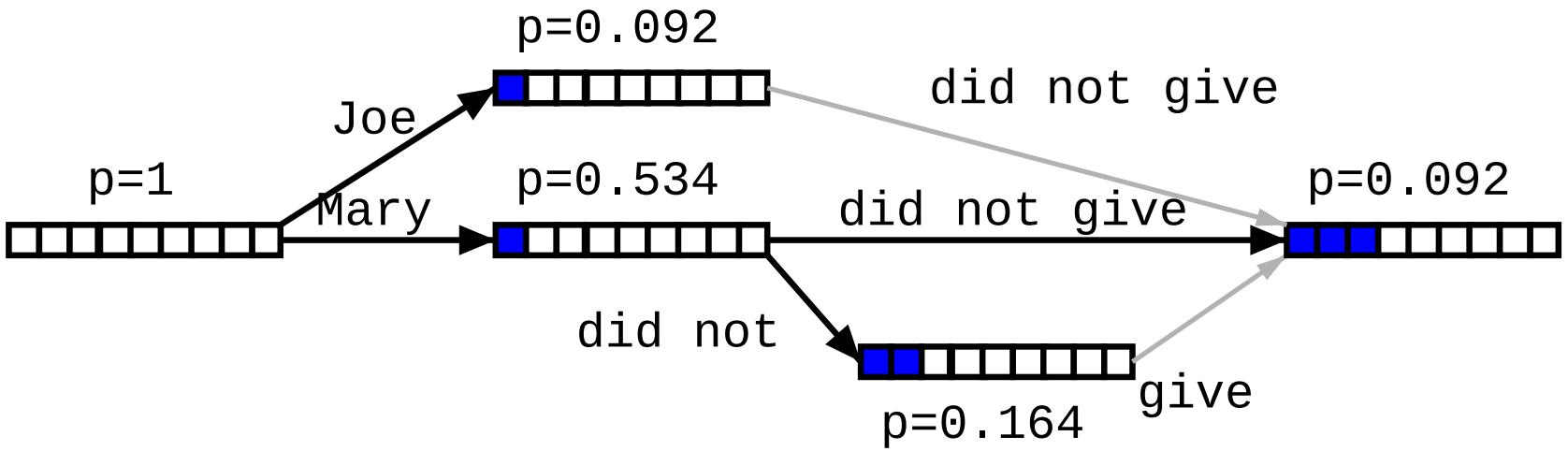
Hypothesis Recombination



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⇒ *Combine paths*

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Pruning

- Hypothesis recombination is *not sufficient*

⇒ Heuristically *discard* weak hypotheses early

- Organize Hypothesis in **stacks**, e.g. by
  - *same* foreign words covered
  - *same number* of foreign words covered
  - *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., $\alpha = 0.001$)

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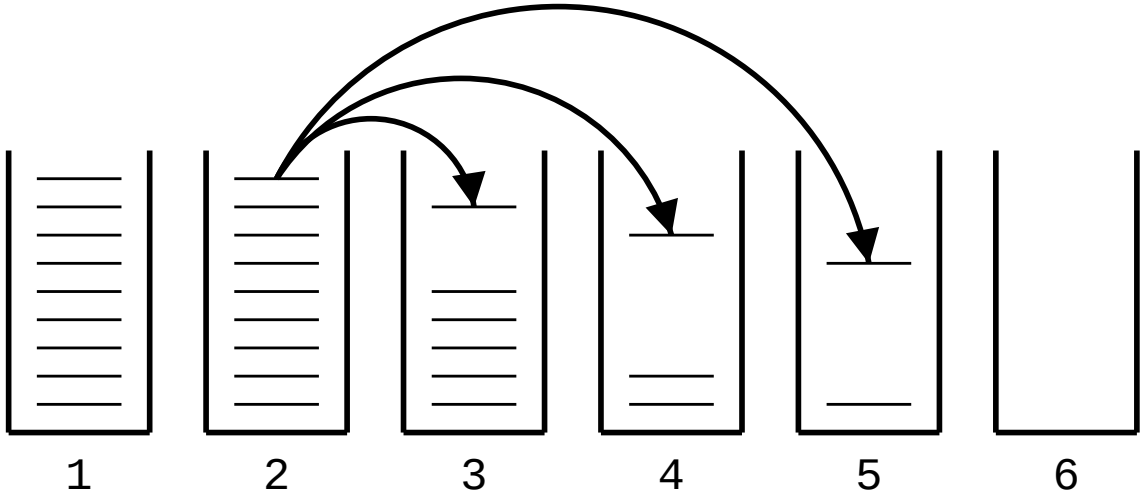
Hypothesis Stacks



- Organization of hypothesis into stacks
  - here: based on *number of foreign words* translated
  - during translation all hypotheses from one stack are expanded
  - expanded Hypotheses are placed into stacks

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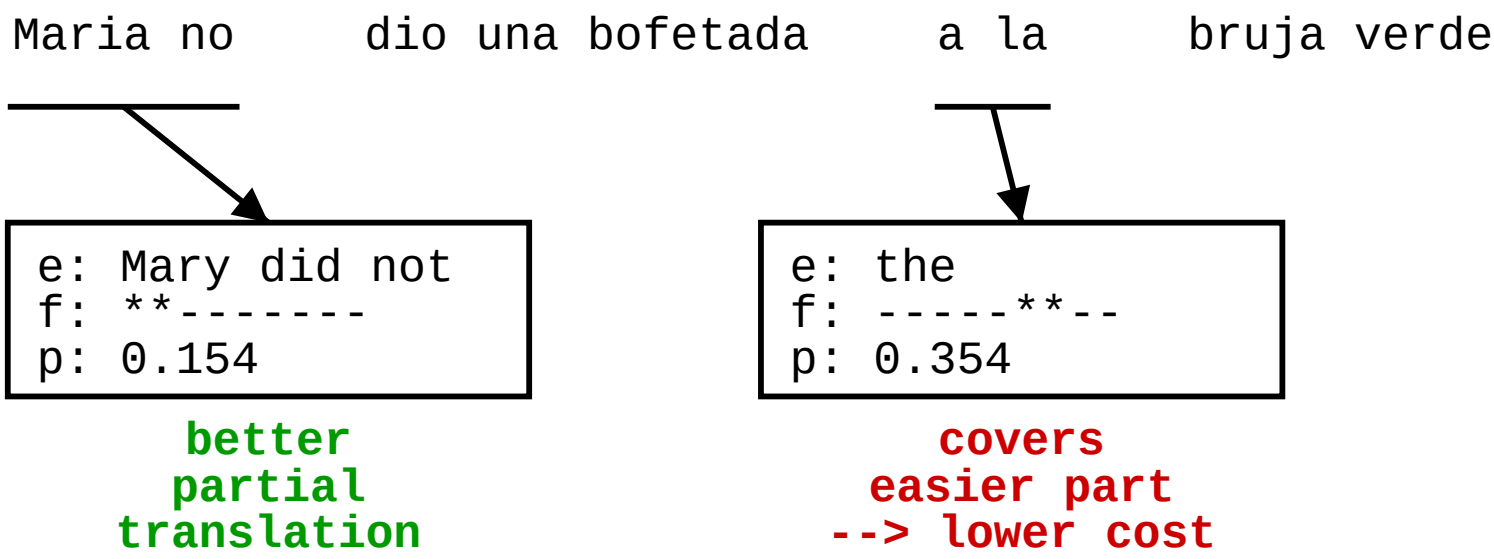
Comparing Hypotheses

- Comparing hypotheses with *same number of foreign words* covered



- Hypothesis that covers *easy part* of sentence is preferred

$\Rightarrow$ Need to consider **future cost** of uncovered parts

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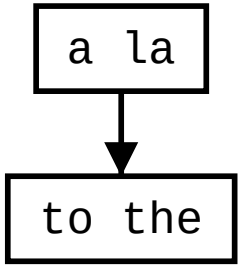
Future Cost Estimation



- *Estimate cost* to translate remaining part of input
- Step 1: estimate future cost for each *translation option*
  - look up translation model cost
  - estimate language model cost (no prior context)
  - ignore reordering model cost

  → LM * TM = p(to) * p(to the|a la)

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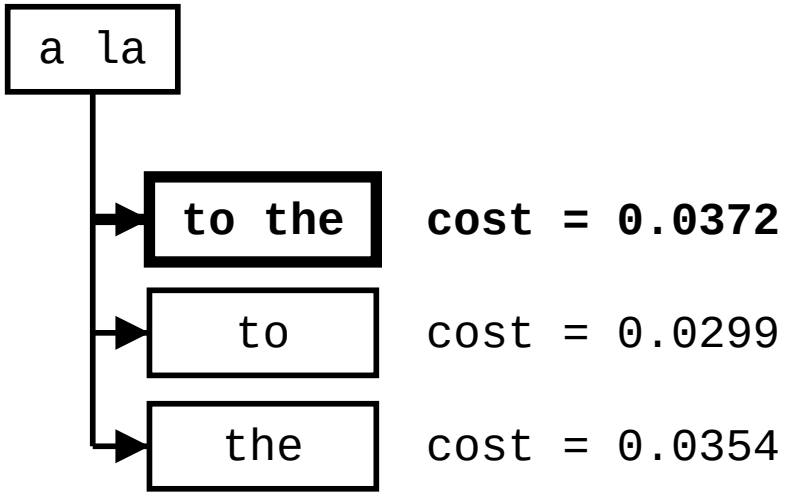
Future Cost Estimation: Step 2



- Step 2: find *cheapest cost* among translation options

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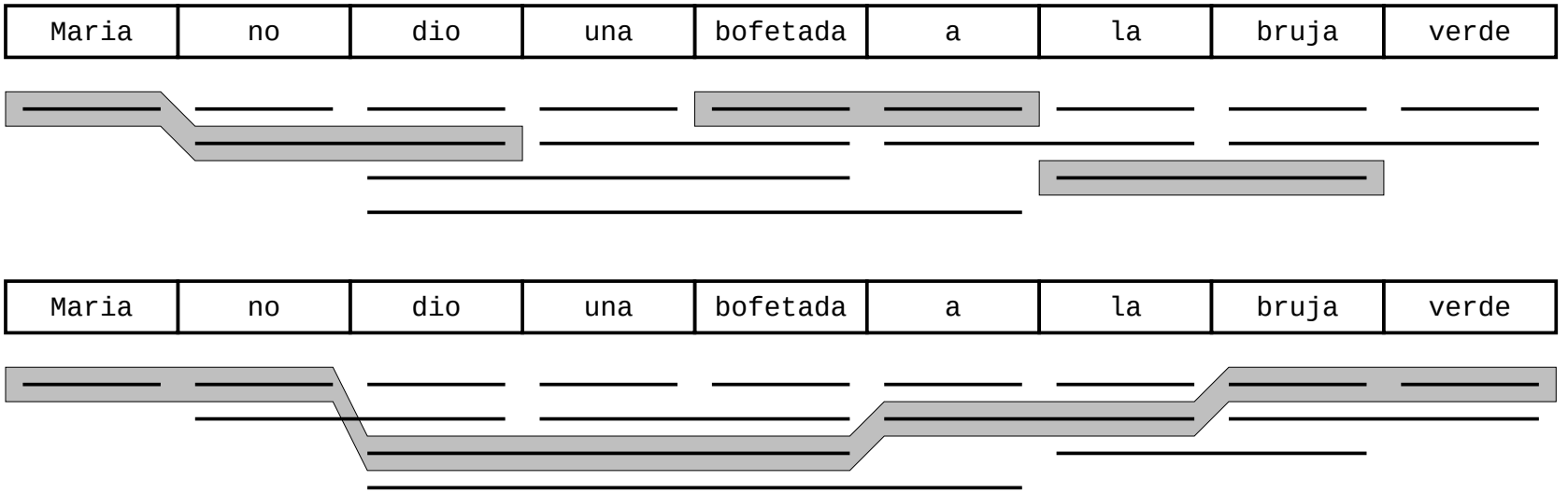
Future Cost Estimation: Step 3



- Step 3: find *cheapest future cost path* for each span
  - can be done *efficiently* by dynamic programming
  - future cost for every span can be *pre-computed*

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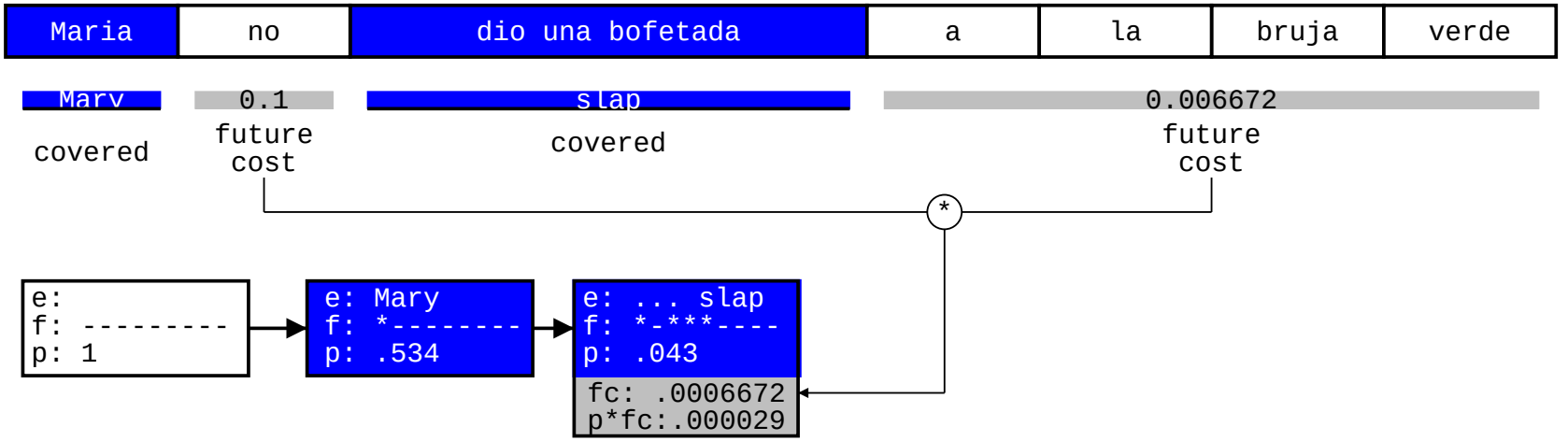
Future Cost Estimation: Application



- Use future cost estimates when *pruning* hypotheses
- For each *uncovered contiguous span*:
  - look up *future costs* for each maximal contiguous uncovered span
  - *add* to actually accumulated cost for translation option for pruning

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A* search

- Pruning might drop hypothesis that lead to the best path (**search error**)
- **A* search**: safe pruning
  - future cost estimates have to be accurate or underestimates
  - **lower bound** for probability is established early by **depth first search**: compute cost for one complete translation
  - if cost-so-far and future cost are worse than *lower bound*, hypothesis can be safely discarded
- Not commonly done, since not aggressive enough

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Limits on Reordering

- Reordering may be **limited**
  - **Monotone** Translation: No reordering at all
  - Only phrase movements of at most n words
- Reordering limits *speed* up search (polynomial instead of exponential)
- Current reordering models are weak, so limits *improve* translation quality

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Automatic evaluation

- Why **automatic evaluation** metrics?
  - Manual evaluation is *too slow*
  - Evaluation on large test sets *reveals minor improvements*
  - **Automatic tuning** to improve machine translation performance
- History
  - Word Error Rate
  - **BLEU** since 2002
- BLEU in short: *Overlap with reference* translations

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Automatic evaluation

- Reference Translation
  - the gunman was shot to death by the police .
- System Translations
  - **the gunman was police kill .**
  - **wounded police jaya of**
  - **the gunman was shot dead by the police .**
  - **the gunman arrested by police kill .**
  - **the gunmen were killed .**
  - **the gunman was shot to death by the police .**
  - **gunmen were killed by police ?SUB>0 ?SUB>0**
  - **al by the police .**
  - **the ringer is killed by the police .**
  - **police killed the gunman .**
- Matches
  - green = 4 gram match (good!)
  - red = word not matched (bad!)

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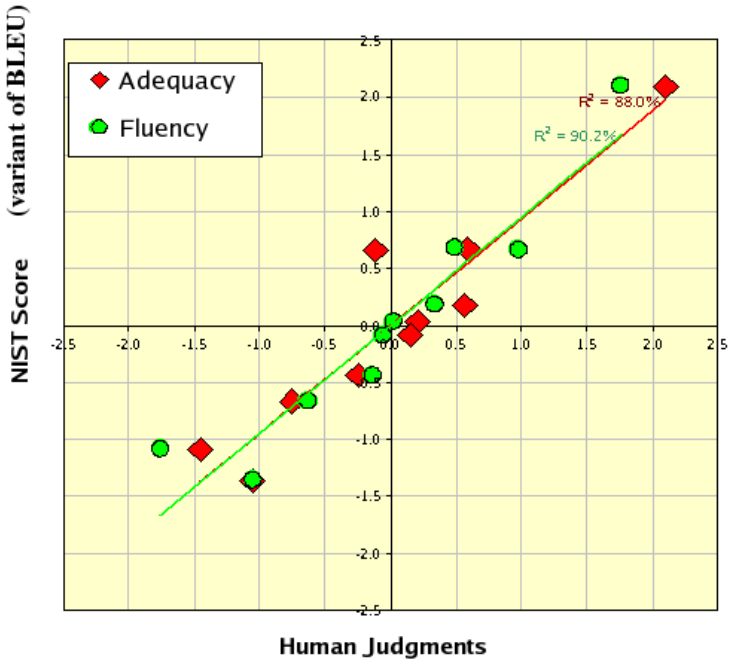
Automatic evaluation



- BLEU **correlates** with human judgement
  - **multiple reference translations** may be used

[from George Doddington, NIST]

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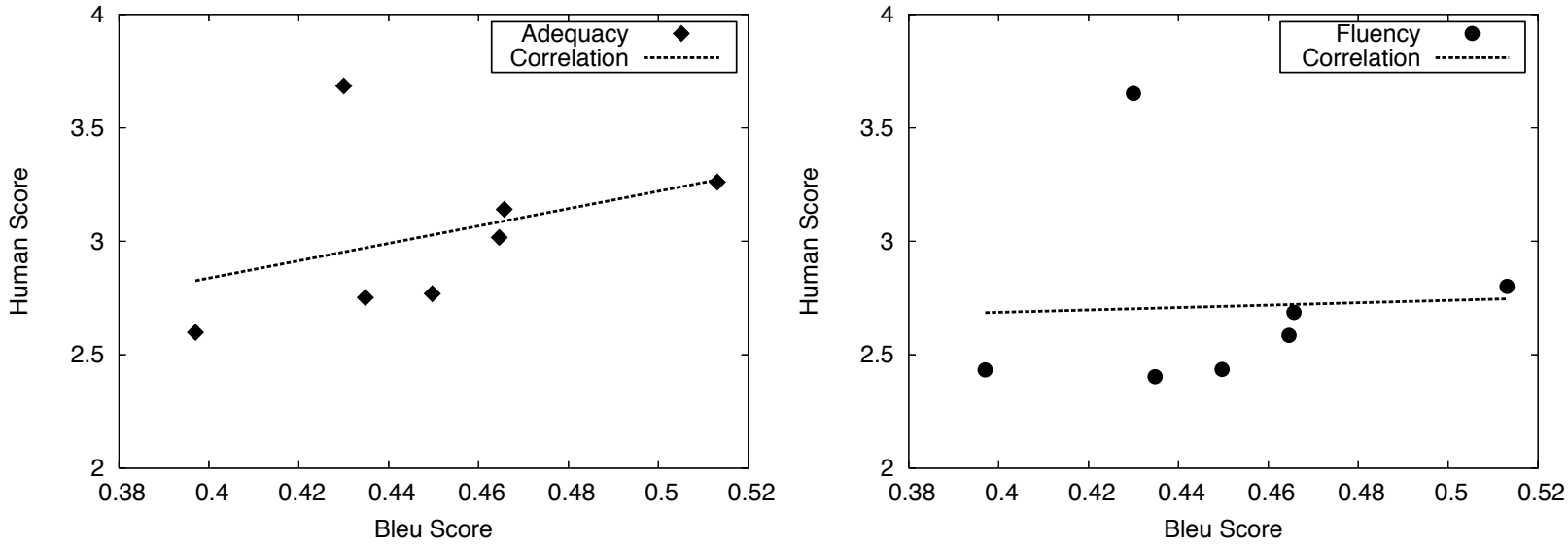
Correlation? [Callison-Burch et al., 2006]



[from Callison-Burch et al., 2006, EACL]

- DARPA/NIST MT Eval 2005
  - Mostly statistical systems (all but one in graphs)
  - One submission **manual post-edit** of statistical system's output

  → Good adequacy/fluency scores *not reflected* by BLEU

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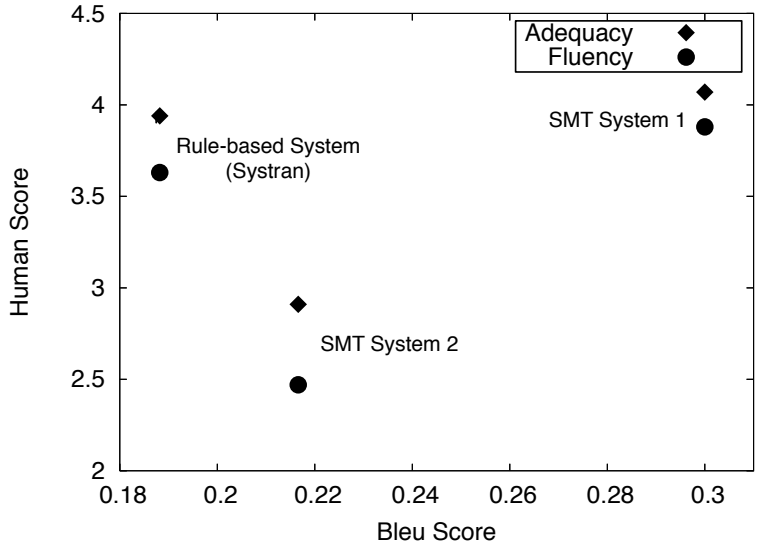
Correlation? [Callison-Burch et al., 2006]



[from Callison-Burch et al., 2006, EACL]

- Comparison of
  - *good statistical* system: high BLEU, high adequacy/fluency
  - *bad statistical* sys. (trained on less data): low BLEU, low adequacy/fluency
  - *Systran*: lowest BLEU score, but high adequacy/fluency

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Automatic evaluation: outlook

- Research questions
  - why does BLEU *fail* Systran and manual post-edits?
  - how can this *overcome* with novel evaluation metrics?
- Future of automatic methods
  - automatic metrics too *useful* to be abandoned
  - evidence still supports that during *system development*, a better BLEU indicates a better system
  - *final assessment* has to be human judgement

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Output of Chinese-English system

In the First Two Months Guangdong's Export of High-Tech Products 3.76 Billion US Dollars

Xinhua News Agency, Guangzhou, March 16 (Reporter Chen Jizhong) - The latest statistics show that between January and February this year, Guangdong's export of high-tech products 3.76 billion US dollars, with a growth of 34.8% and accounted for the province's total export value of 25.5%. The export of high-tech products bright spots frequently now, the Guangdong provincial foreign trade and economic growth has made important contributions. Last year, Guangdong's export of high-tech products 22.294 billion US dollars, with a growth of 31 percent, an increase higher than the province's total export growth rate of 27.2 percent; exports of high-tech products net increase 5.270 billion us dollars, up for the traditional labor-intensive products as a result of prices to drop from the value of domestic exports decreased.

In the Suicide explosion in Jerusalem

Xinhua News Agency, Jerusalem, March 17 (Reporter bell tsui flower nie Xiaoyang) - A man on the afternoon of 17 in Jerusalem in the northern part of the residents of rammed a bus near ignition of carry bomb, the wrongdoers in red-handed was killed and another nine people were slightly injured and sent to hospital for medical treatment.

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Partially excellent translations

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Mangled grammar

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