Data Intensive Linguistics — Lecture 18
Machine translation (V): Syntax-Based Models

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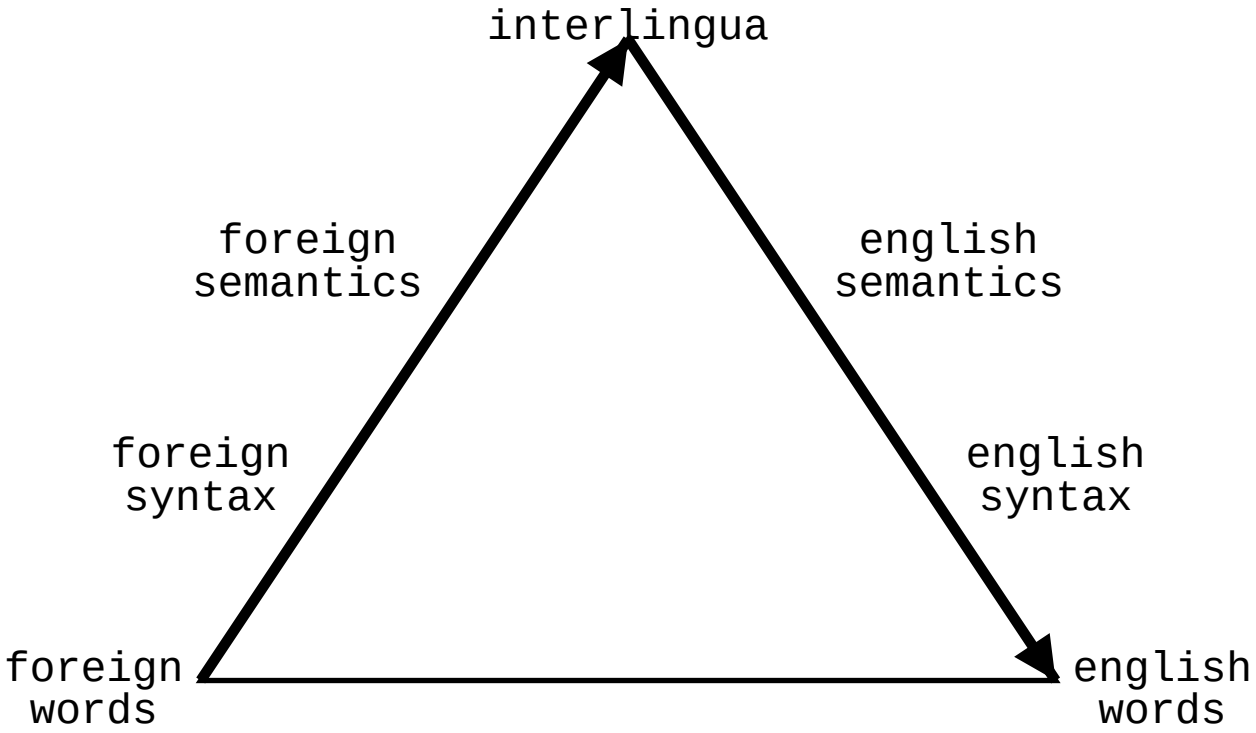
School of informatics

Syntax-based SMT

- Why Syntax?
- Yamada and Knight: *translating into trees*
- Wu: *tree-based transfer*
- Chiang: *hierarchical transfer*
- Collins, Kucerova, and Koehn: *clause structure*
- Other approaches

The Challenge of Syntax



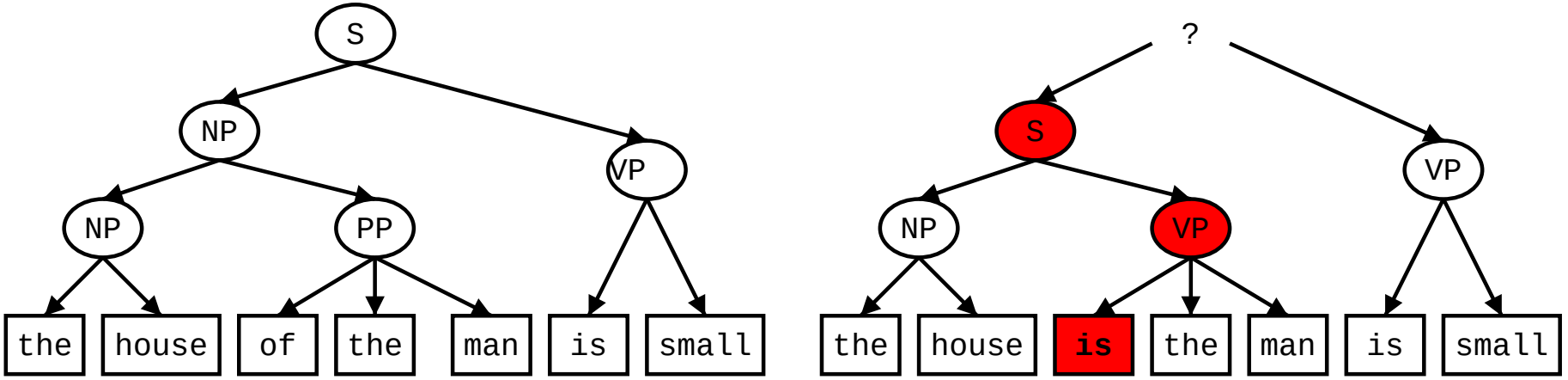
- The classical machine translation *pyramid*

Advantages of Syntax-Based Translation

- *Reordering* for syntactic reasons
  - e.g., move German object to end of sentence
- Better explanation for *function words*
  - e.g., prepositions, determiners
- Conditioning to *syntactically related words*
  - translation of verb may depend on subject or object
- Use of *syntactic language models*
  - ensuring grammatical output

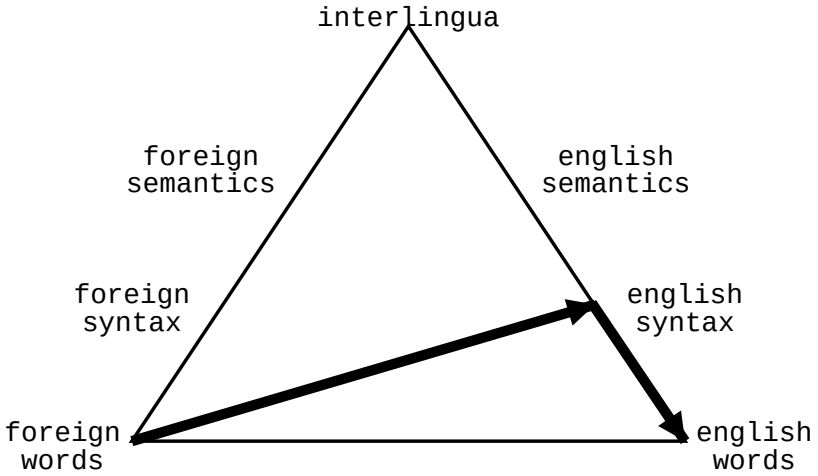
Syntactic Language Model

- *Good syntax tree* → good English
- Allows for *long distance constraints*



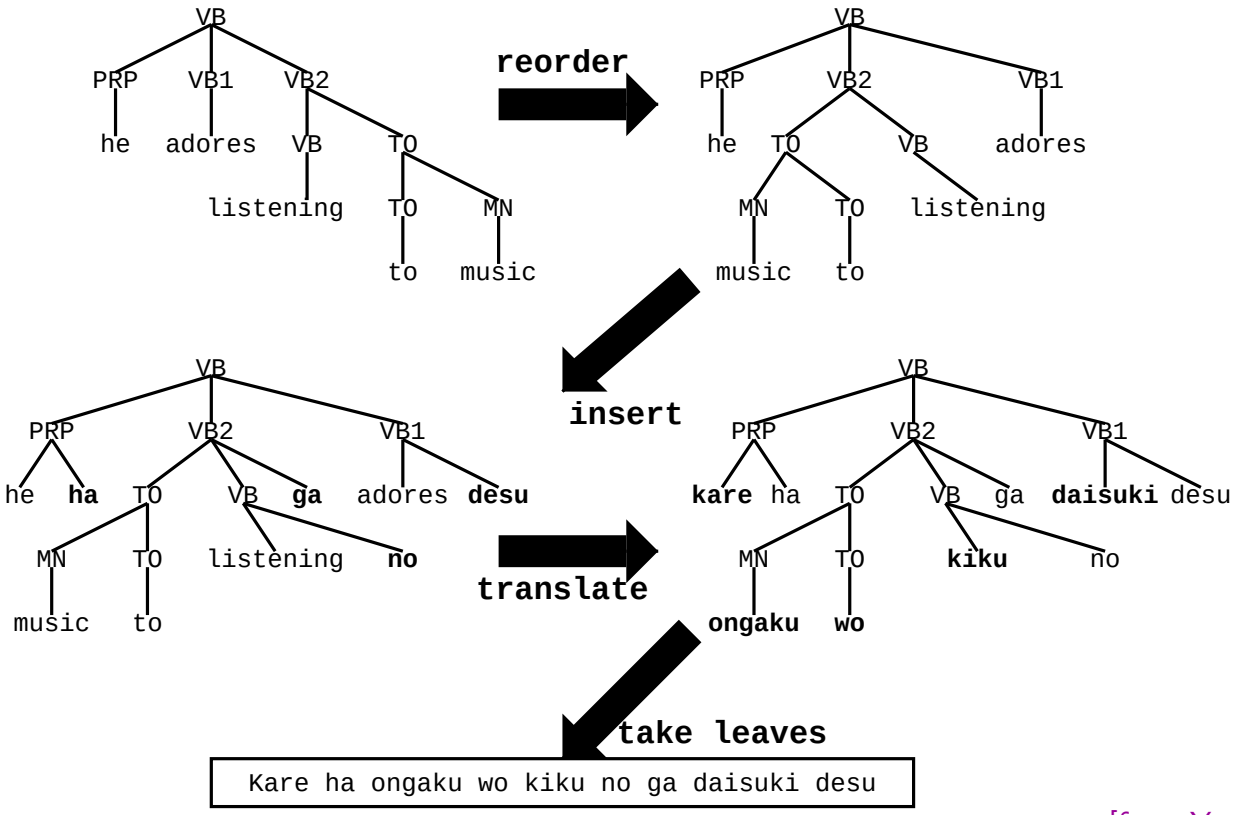
- Left translation preferred by syntactic LM

String to Tree Translation



- Use of English *syntax trees* [Yamada and Knight, 2001]
  - exploit *rich resources* on the English side
  - obtained with statistical parser [Collins, 1997]
  - *flattened tree* to allow more reorderings
  - works well with syntactic language model

Yamada and Knight [2001]



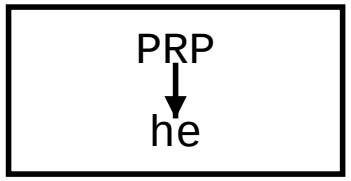
[from Yamada and Knight, 2001]

Reordering Table

Original Order	Reordering	p(reorder|original)
PRP VB1 VB2	PRP VB1 VB2	0.074
PRP VB1 VB2	**PRP VB2 VB1**	**0.723**
PRP VB1 VB2	VB1 PRP VB2	0.061
PRP VB1 VB2	VB1 VB2 PRP	0.037
PRP VB1 VB2	VB2 PRP VB1	0.083
PRP VB1 VB2	VB2 VB1 PRP	0.021
VB TO	VB TO	0.107
VB TO	**TO VB**	**0.893**
TO NN	TO NN	0.251
TO NN	**NN TO**	**0.749**

Decoding as Parsing

- **Chart Parsing**

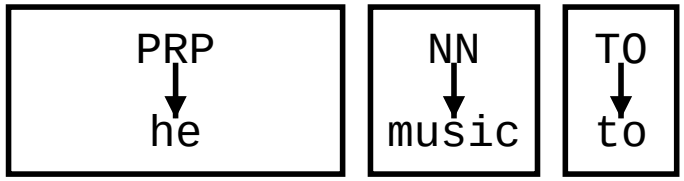


kare ha ongaku wo kiku no ga daisuki desu

- Pick Japanese *words*
- Translate into *tree stumps*

Decoding as Parsing

- Chart Parsing



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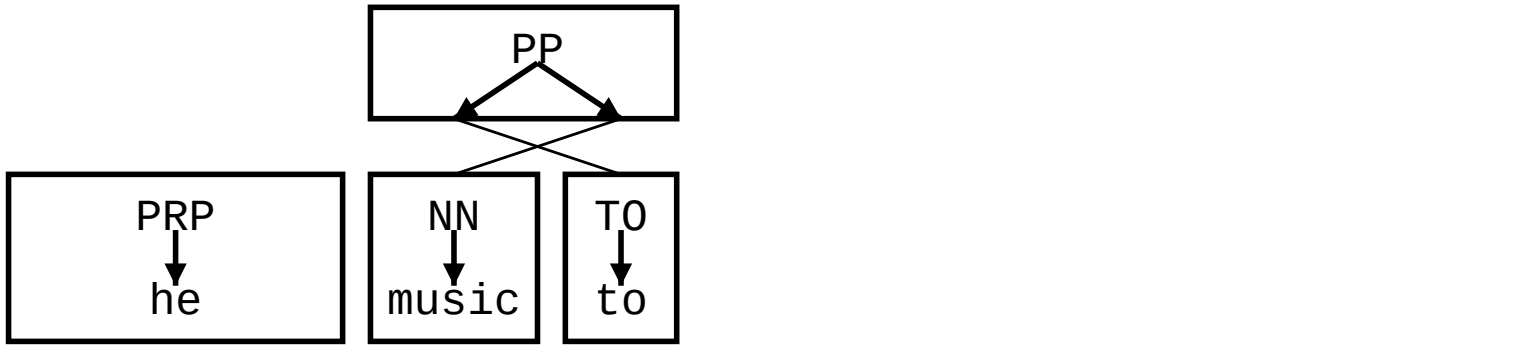
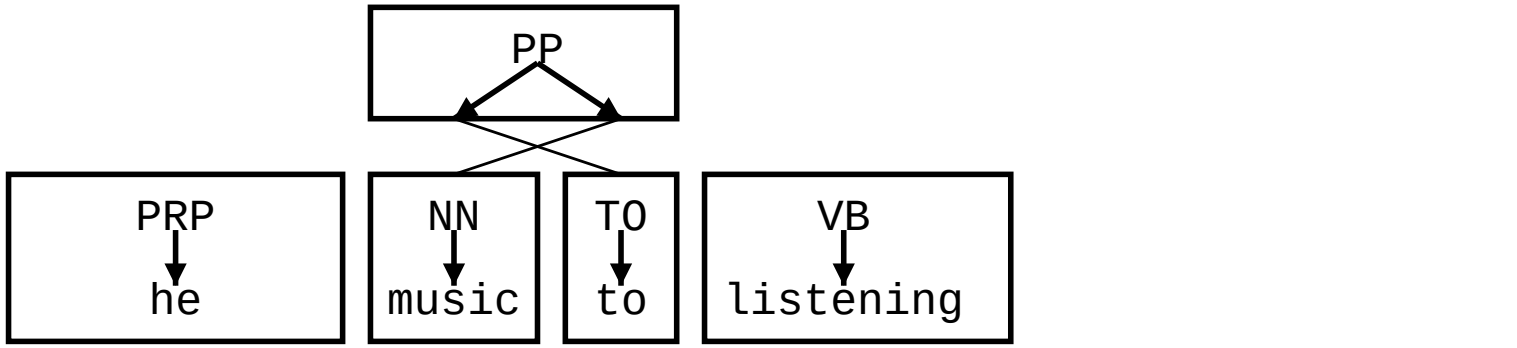


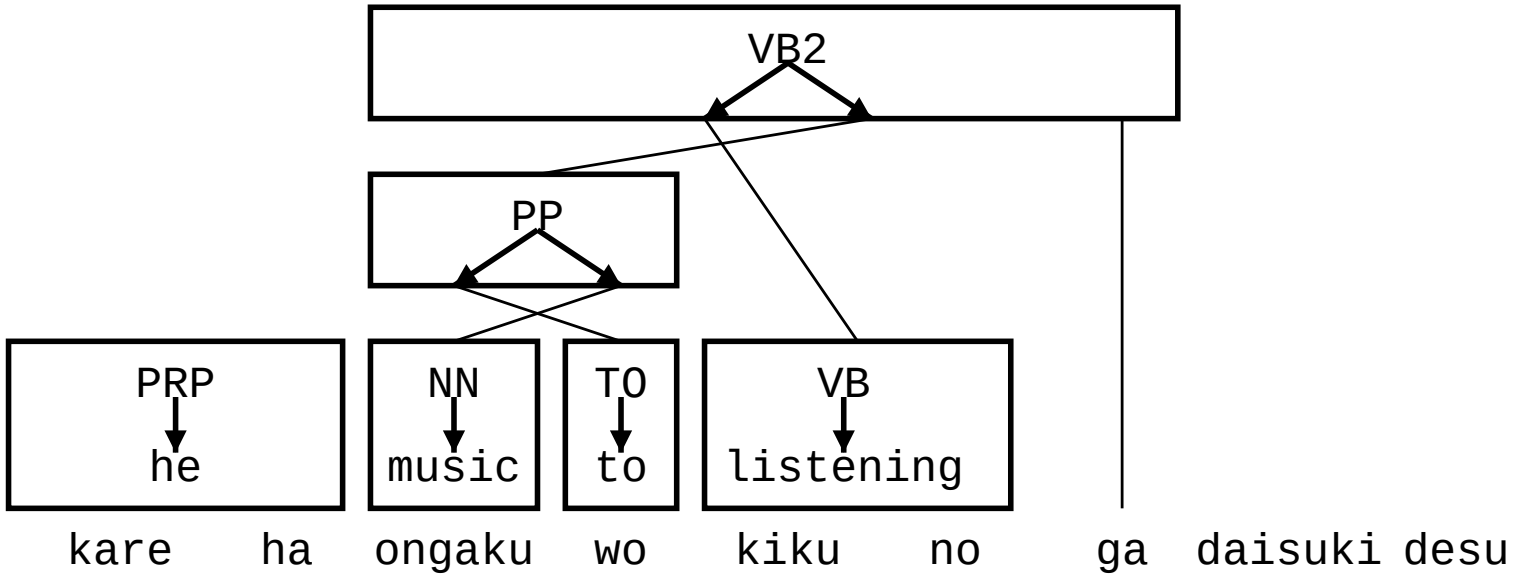
- Adding some *more entries*...

Decoding as Parsing

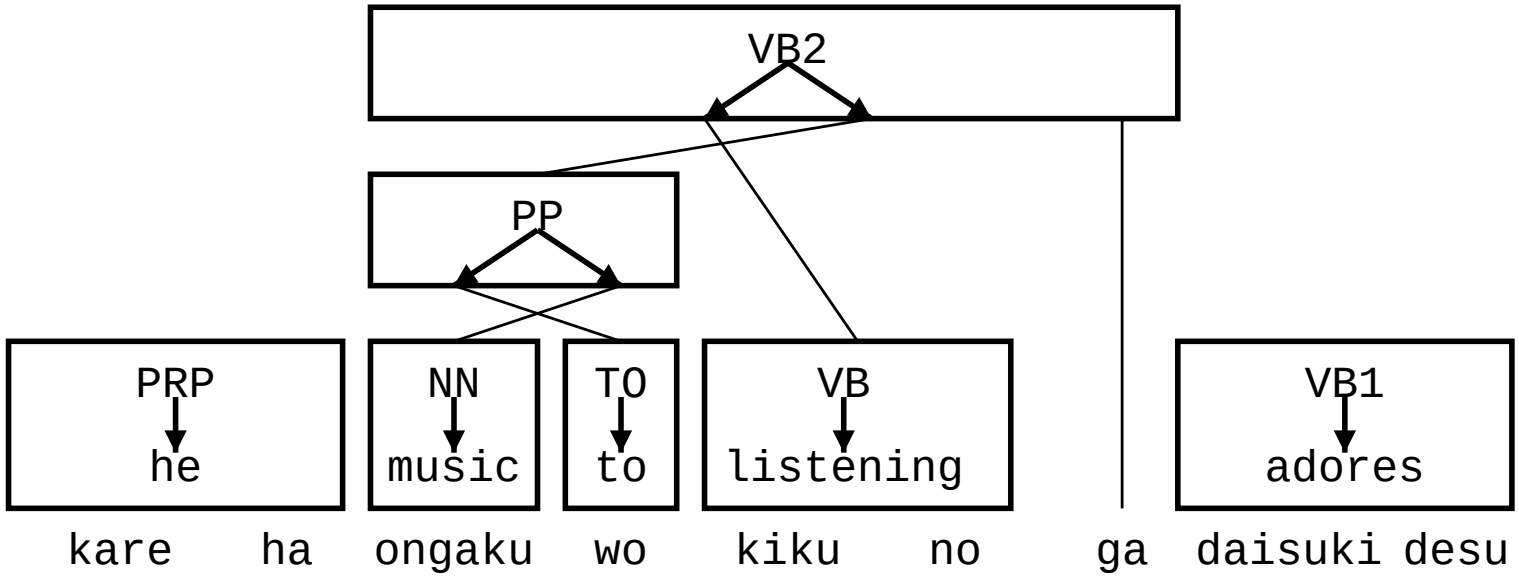


- *Combine entries*

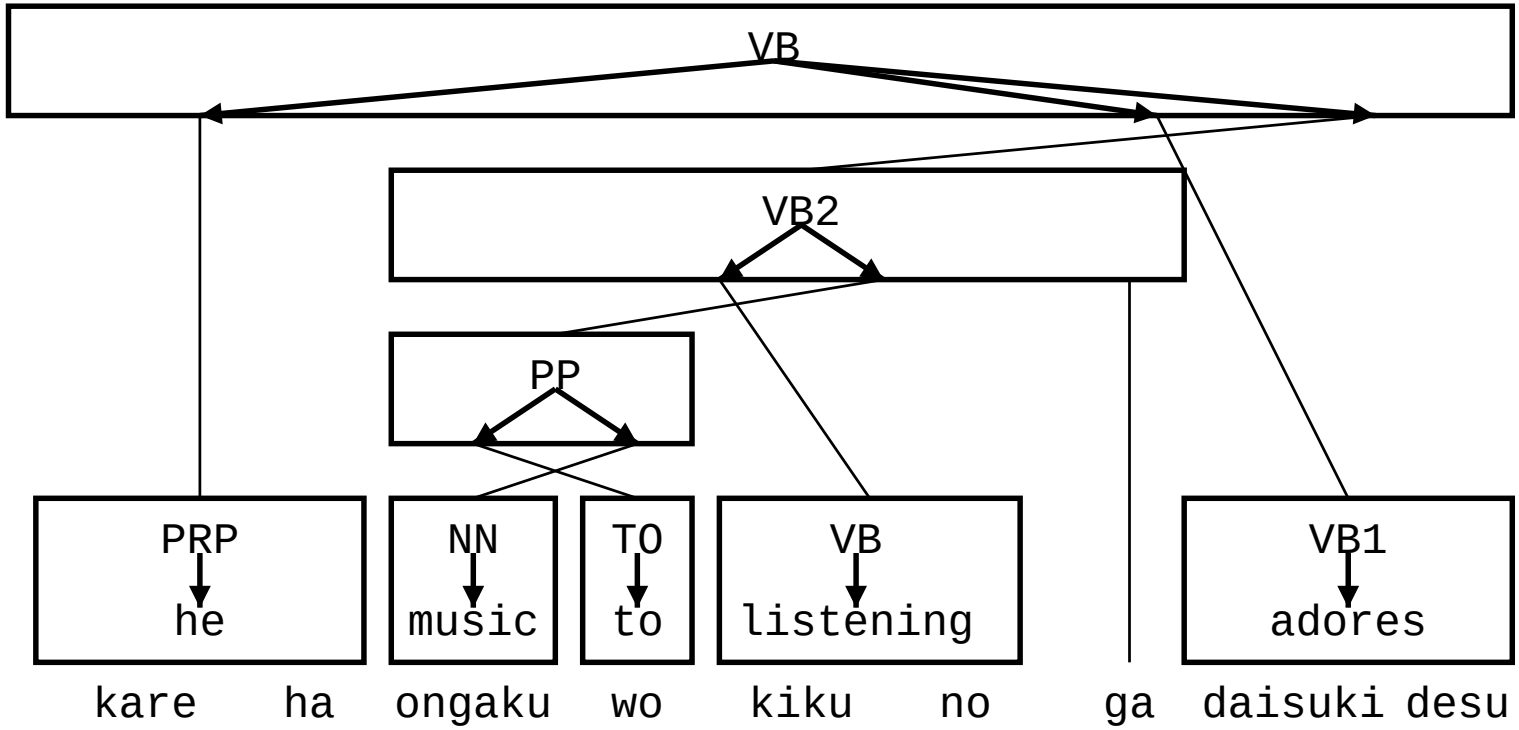
Decoding as Parsing



Decoding as Parsing



Decoding as Parsing



- *Finished* when all foreign words covered

Yamada and Knight: Training

- *Parsing* of the English side
  - using Collins statistical parser
- *EM training*
  - translation model is used to map training sentence pairs
  - EM training finds low-perplexity model

  → *unity of training and decoding* as in IBM models

Is the Model Realistic?

- Do English trees *match* foreign strings?
- Crossings between French-English [Fox, 2002]
  - 0.29-6.27 per sentence, depending on how it is measured
- Can be reduced by
  - *flattening tree*, as done by [Yamada and Knight, 2001]
  - detecting *phrasal* translation
  - *special treatment* for small number of constructions
- Most coherence between **dependency structures**

Inversion Transduction Grammars

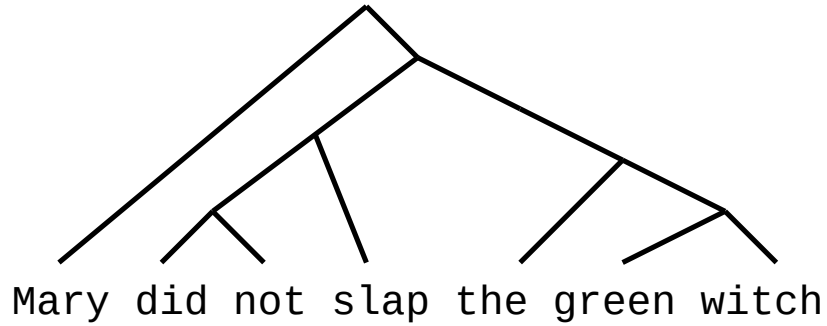
- Generation of *both* English and foreign trees [Wu, 1997]

- Rules (binary and unary)
  - $A \rightarrow A_1 A_2 \| A_1 A_2$
  - $A \rightarrow A_1 A_2 \| A_2 A_1$
  - $A \rightarrow e \| f$
  - $A \rightarrow e \| *$
  - $A \rightarrow * \| f$

$\Rightarrow$ *Common binary tree* required

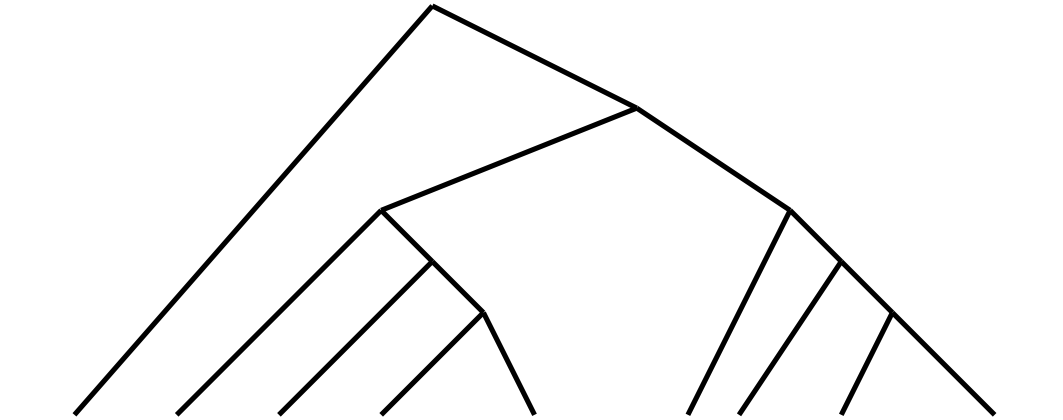
  - limits the complexity of reorderings

Syntax Trees



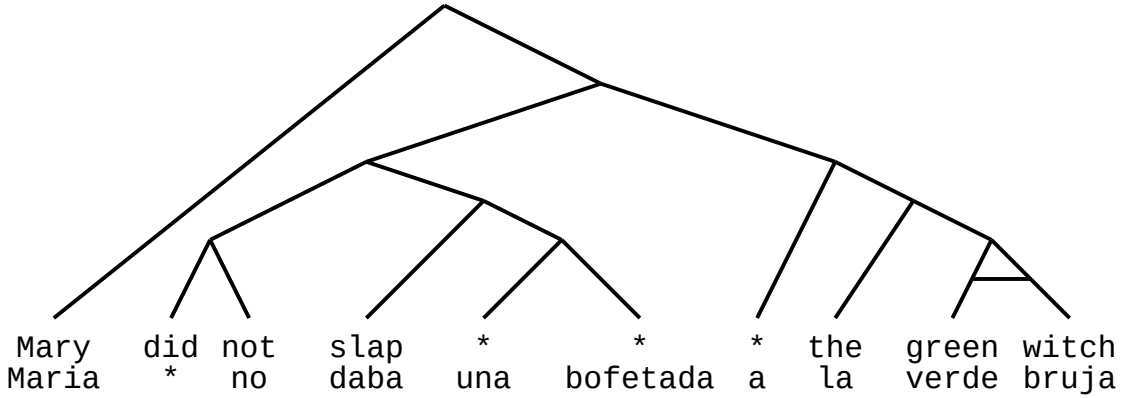
- English binary tree

Syntax Trees



- Spanish binary tree

Syntax Trees



- *Combined tree* with reordering of Spanish

Inversion Transduction Grammars

- Decoding by parsing (as before)
- Variations
  - may use *real syntax* on either side or both
  - may use *multi-word* units at leaf nodes

Chiang: Hierarchical Phrase Model

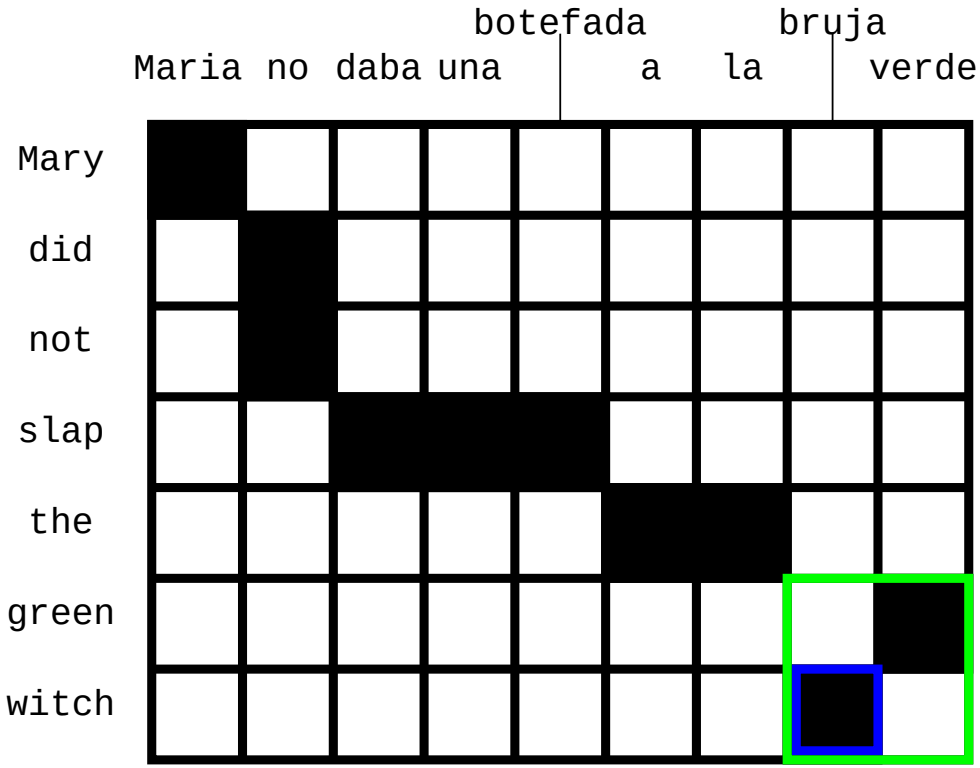
- **Chiang** [ACL, 2005] (best paper award!)
  - context free bi-grammar
  - *one non-terminal* symbol
  - right hand side of rule may include non-terminals and terminals

- *Competitive* with phrase-based models in 2005 DARPA/NIST evaluation

Types of Rules

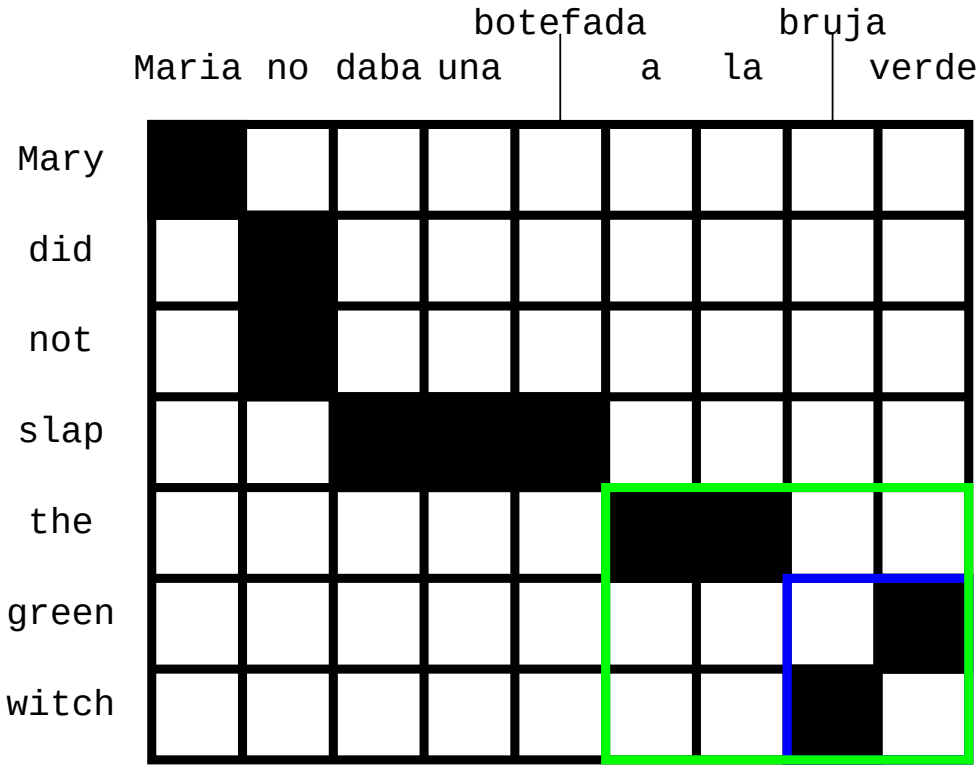
- *Word* translation
  - $X \rightarrow maison \parallel house$
- *Phrasal* translation
  - $X \rightarrow daba\ una\ bofetada \mid slap$
- *Mixed* non-terminal / terminal
  - $X \rightarrow X\ bleue \parallel blue\ X$
  - $X \rightarrow ne\ X\ pas \parallel not\ X$
  - $X \rightarrow X1\ X2 \parallel X2\ of\ X1$
- Technical rules
  - $S \rightarrow S\ X \parallel S\ X$
  - $S \rightarrow X \parallel X$

Learning Hierarchical Rules



X → X verde ‖ green X

Learning Hierarchical Rules



X → a la X ‖ the X

Details of Chiang's Model

- Too many rules

  → *filtering* of rules necessary

- *Efficient* parse decoding possible
  - hypothesis stack for each span of foreign words
  - only *one non-terminal* → hypotheses comparable
  - *length limit* for spans that do not start at beginning

Clause Level Restructuring [Collins et al.]

- Why **clause structure**?
  - languages *differ vastly* in their clause structure
    (English: SVO, Arabic: VSO, German: fairly *free order*;
    a lot details differ: position of adverbs, sub clauses, etc.)
  - large-scale restructuring is a *problem* for phrase models

- **Restructuring**
  - *reordering* of constituents (main focus)
  - add/drop/change of *function words*

- Details see [Collins, Kucerova and Koehn, ACL 2005]

Clause Structure

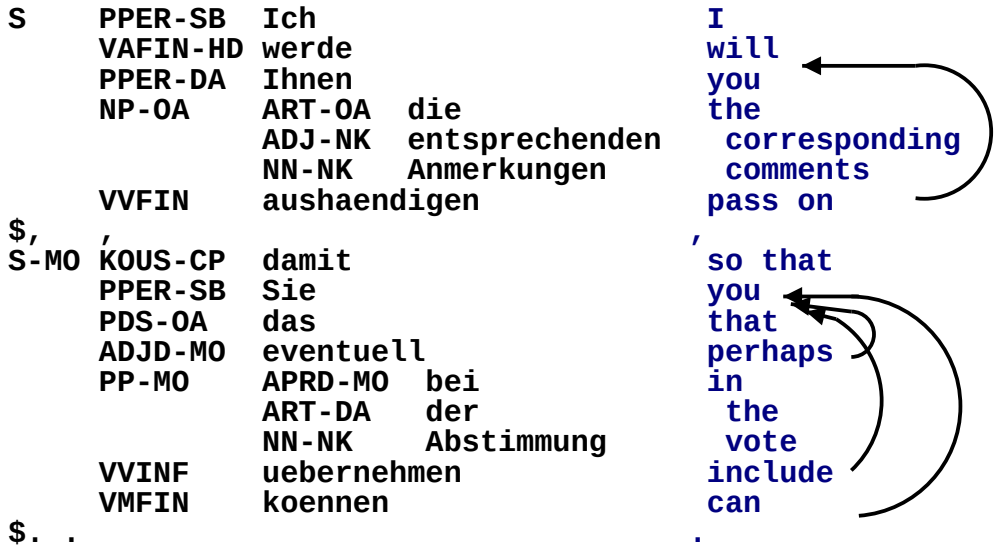
```
S   PPER-SB   Ich     I
    VAFIN-HD  werde    will
    VP-OC     PPER-DA Ihnen   you
              NP-OA   ART-OA  die   the
                      ADJ-NK  entsprechenden   corresponding
                      NN-NK   Anmerkungen  comments
              VVFIN   aushaendigen     pass on
              $,      ,    ,
              S-MO    KOUS-CP damit   so that
                      PPER-SB Sie    you
                      VP-OC   PDS-OA  das   that
                              ADJD-MO eventuell    perhaps
                              PP-MO   APRD-MO  bei   in
                                      ART-DA   der   the
                                      NN-NK    Abstimmung  vote
                              VVINF   uebernehmen    include
                      VMFIN   koennen   can
$. .              .
```

MAIN CLAUSE

SUB-ORDINATE CLAUSE

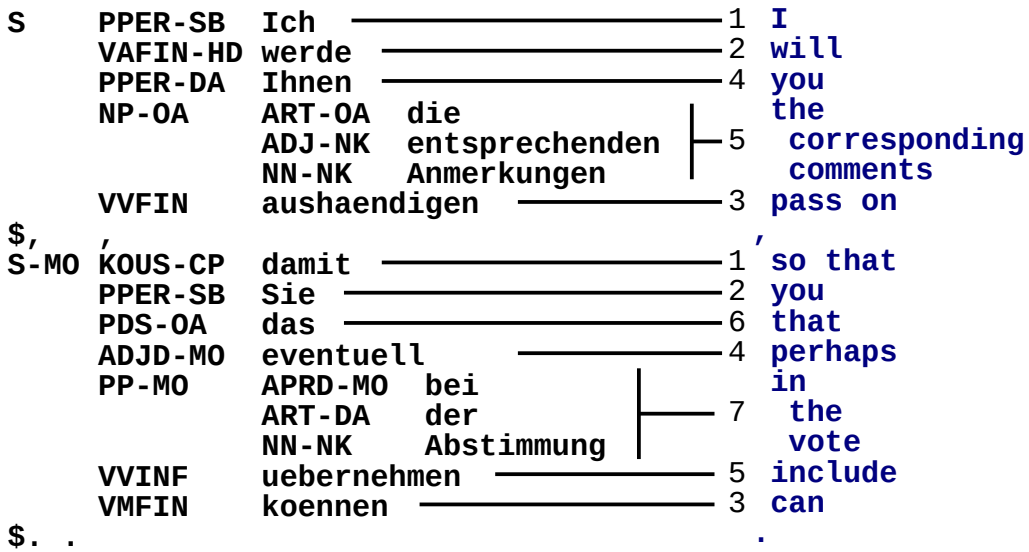
- *Syntax tree* from German parser
  - statistical parser by Amit Dubay, trained on TIGER treebank

Reordering When Translating



- *Reordering* when translating into English
  - tree is *flattened*
  - clause level constituents line up

Clause Level Reordering



- Clause level reordering is a *well defined task*
  - label German constituents with their *English order*
  - done this for 300 sentences, two annotators, high agreement

Systematic Reordering German → English

- Many types of reorderings are **systematic**
  - *move verb group together*
  - *subject - verb - object*
  - *move negation in front of verb*

⇒ *Write rules by hand*
  - apply rules to test and training data
  - train standard *phrase-based* SMT system

System	BLEU
baseline system	25.2%
with manual rules	26.8%

Improved Translations

- we must also this criticism should be taken seriously .

→ we must also take this criticism seriously .

- i am with him that it is necessary , the institutional balance by means of a political revaluation of both the commission and the council to maintain .

→ i agree with him in this , that it is necessary to maintain the institutional balance by means of a political revaluation of both the commission and the council .

- thirdly , we believe that the principle of differentiation of negotiations note .

→ thirdly , we maintain the principle of differentiation of negotiations .

- perhaps it would be a constructive dialog between the government and opposition parties , social representative a positive impetus in the right direction .

→ perhaps a constructive dialog between government and opposition parties and social representative could give a positive impetus in the right direction .

Other Syntax-Based Approaches

- ISI: extending work of Yamada/Knight
  - more *complex rules*
  - performance approaching phrase-based
- Prague: Translation via *dependency structures*
  - parallel Czech–English dependency treebank
  - tecto-grammatical translation model [EACL 2003]
- U.Alberta/Microsoft: *treelet translation*
  - translating from English into foreign languages
  - using dependency parser in English
  - project *dependency tree* into foreign language for training
  - map parts of the dependency tree ("treelets") into foreign languages

Other Syntax-Based Approaches

- *Reranking* phrase-based SMT output with syntactic features
  - create n-best list with phrase-based system
  - POS tag and parse candidate translations
  - rerank with syntactic features
  - see [Koehn, 2003] and JHU Workshop [Och et al., 2003]

- JHU Summer workshop 2005
  - **Genpar**: tool for syntax-based SMT

Syntax: Does it help?

- *Not yet*
  - best systems still phrase-based, treat words as tokens
- *Well, maybe...*
  - work on reordering German
  - ISI: better for short sentences Chinese–English
  - automatically trained tree transfer systems promising
- Why not yet?
  - if real syntax, we need *good parsers* — are they good enough?
  - syntactic annotations add a level of *complexity*

  $\rightarrow$ difficult to handle, slow to train and decode
  - few researchers good at statistical modeling and syntactic theories