Lecture 5:
Machine Translation
(phrases, decoding, evaluation)

Intro to NLP, CS585, Fall 2014

http://people.cs.umass.edu/~brenocon/inlp2014/

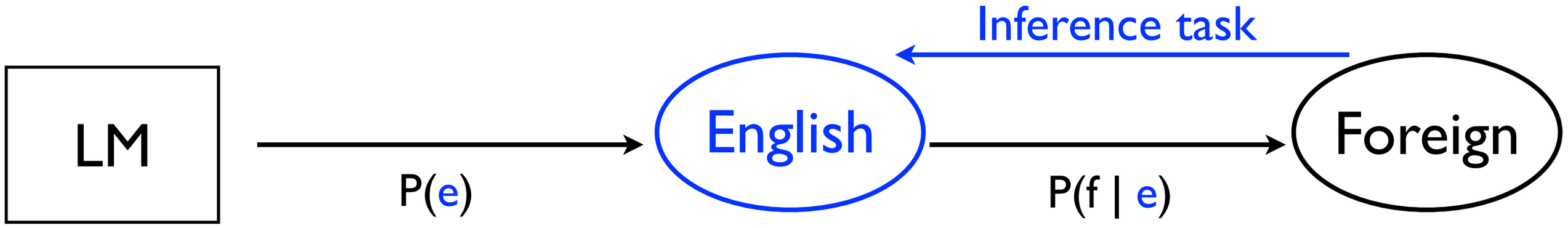
Brendan O'Connor (http://brenocon.com)

Material borrowed from Adam Lopez, Chris Manning, some combination of {Dyer,Callison-Burch,Lopez,Post}, and maybe others

- Review EM for Model 1
- Machine translation: phrase-based methods, decoding, evaluation

(Collins f,e notation)

Word alignment models



$$p(\mathbf{f}, \mathbf{a} \mid \mathbf{e}) = p(\mathbf{f} \mid \mathbf{e}, \mathbf{a})\ p(\mathbf{a} \mid \mathbf{e})$$

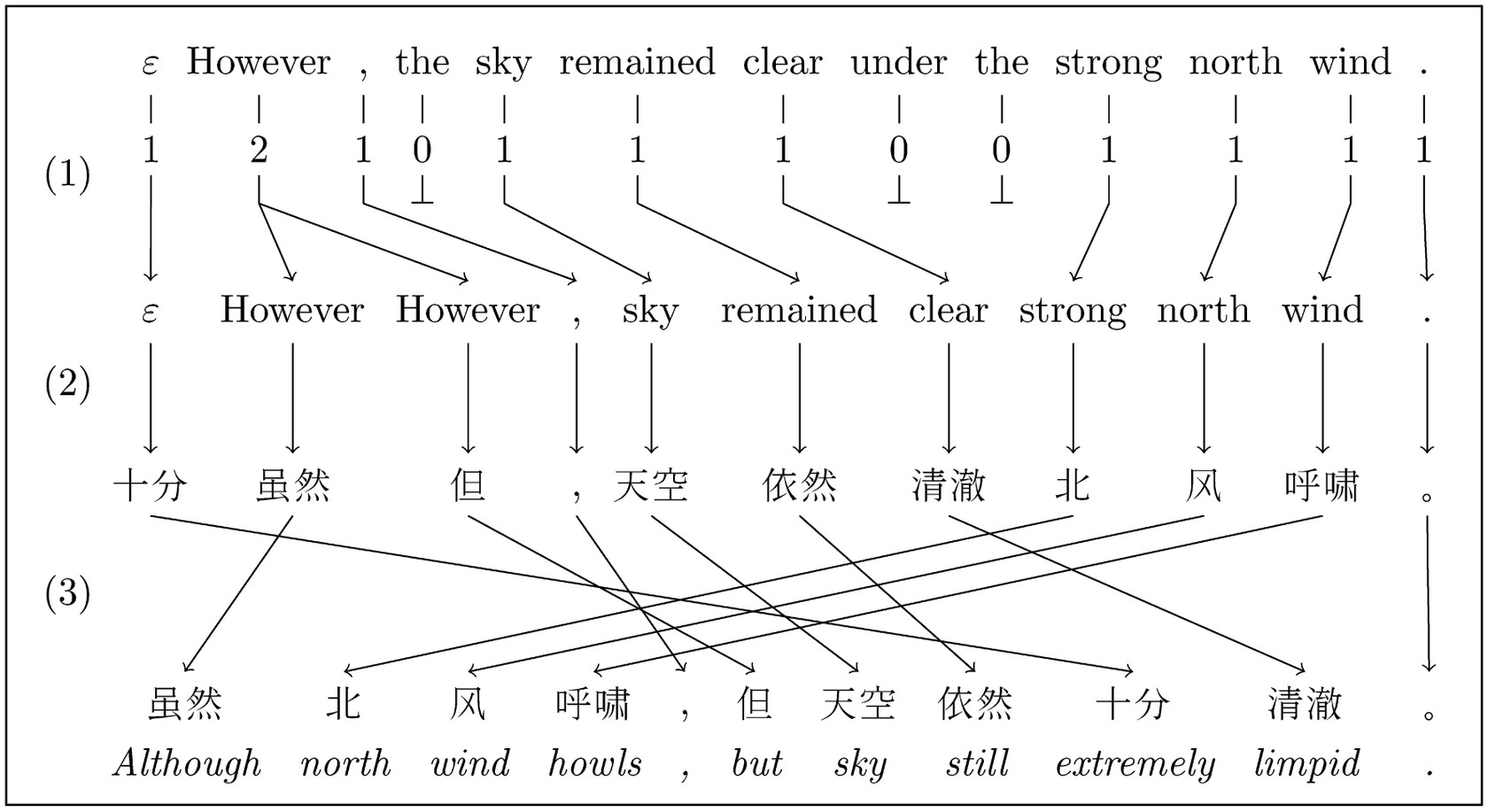
Lexical translations
(All IBM Models)

Alignment model: ordering

- Model 1: uniform and independent
- Position movement (Model 2)
- Constraining neighboring alignments (HMM)
- One-to-many/zero/n tendencies (fertility)

Fancier word alignment models

$$p(\mathbf{f}, \mathbf{a} \mid \mathbf{e}) = p(\mathbf{f} \mid \mathbf{e}, \mathbf{a})\ p(\mathbf{a} \mid \mathbf{e})$$



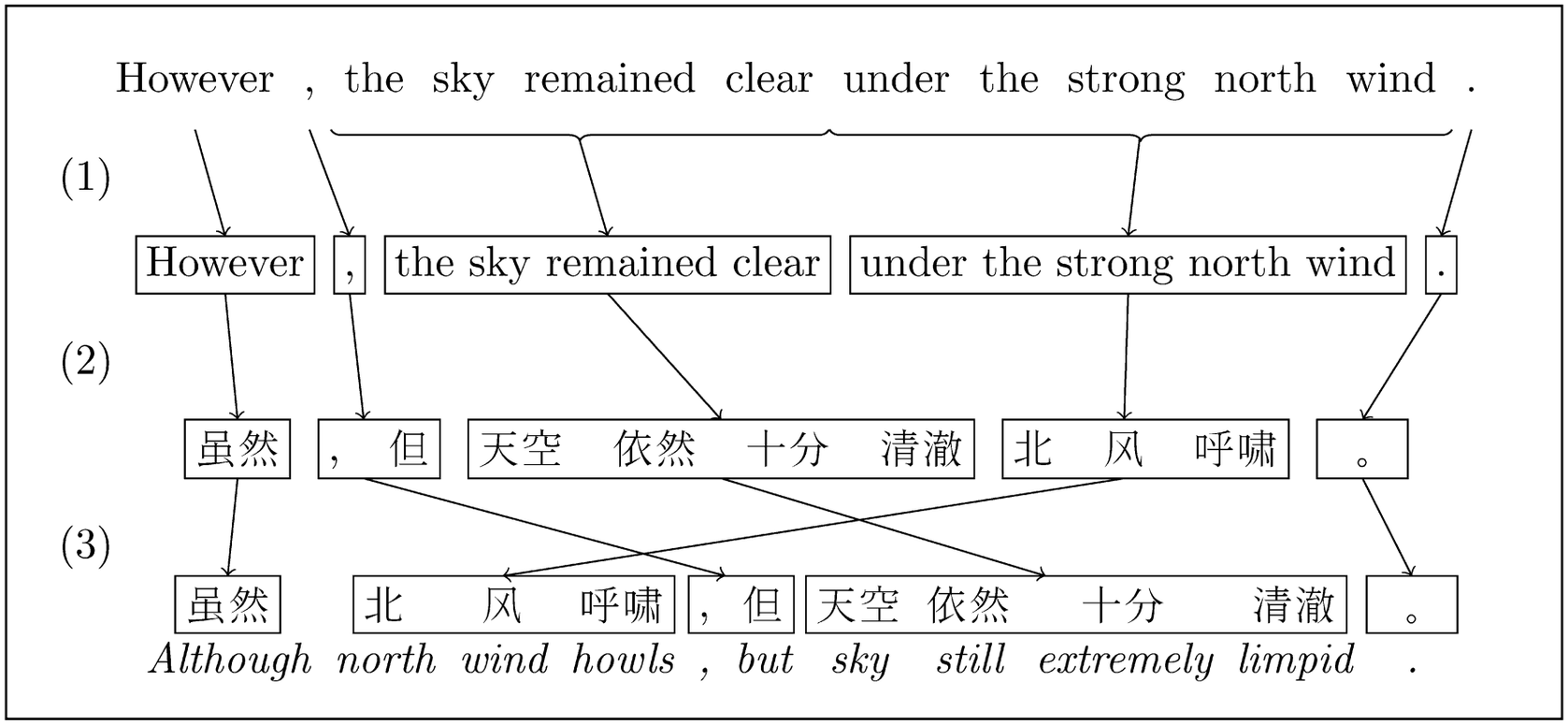
- IBM Model 4
  - Models *fertility*: p(num **e** translations | ***f*** word)

Phrase-based MT

$$p(\mathbf{f}, \mathbf{a} \mid \mathbf{e}) = p(\mathbf{f} \mid \mathbf{e}, \mathbf{a})\ p(\mathbf{a} \mid \mathbf{e})$$

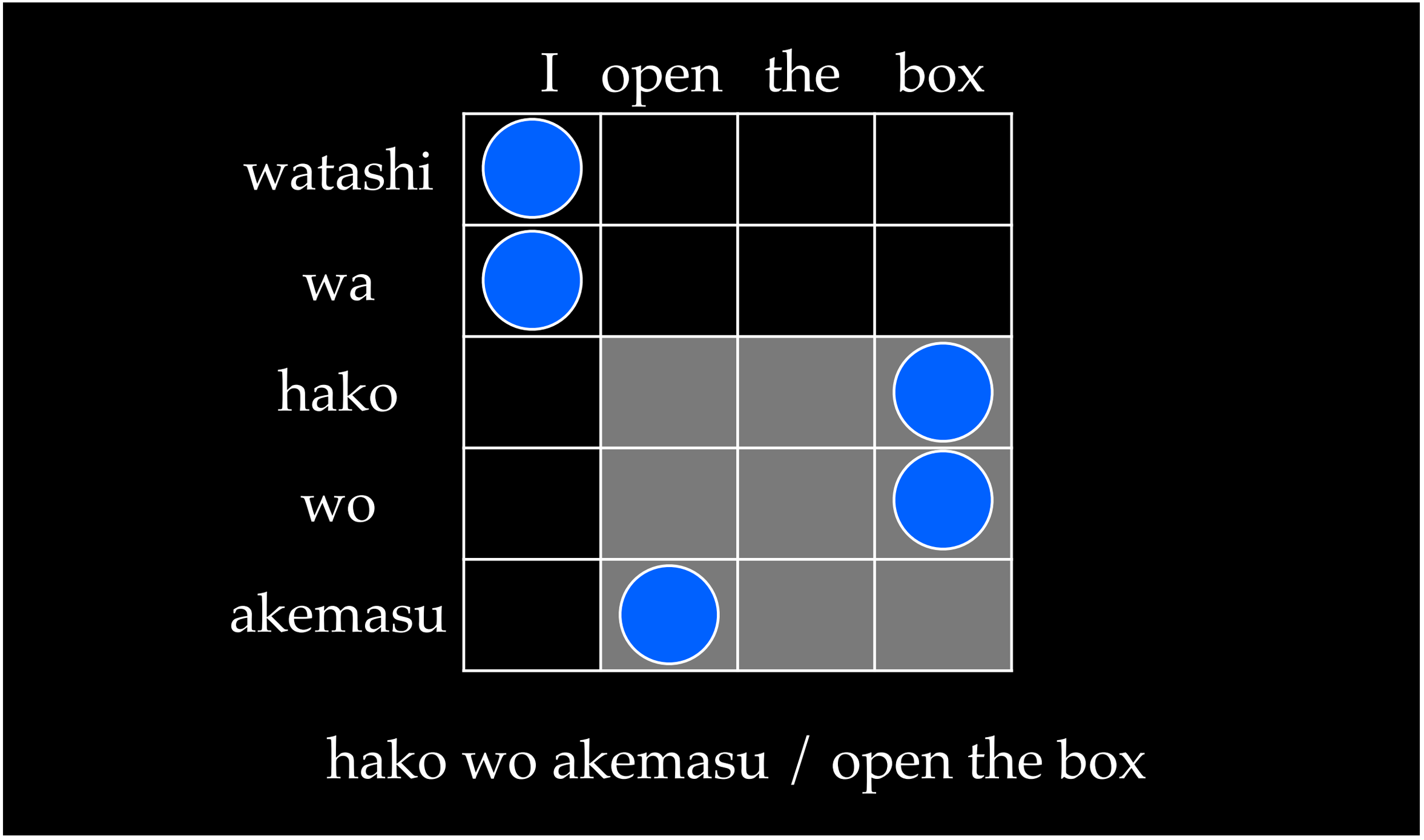
↓

Phrase-to-phrase translations



- Phrases can memorize local reorderings
- State-of-the-art (currently or very recently) in industry, e.g. Google Translate

Phrase extraction for training:
Preprocess with IBM Models to predict alignments



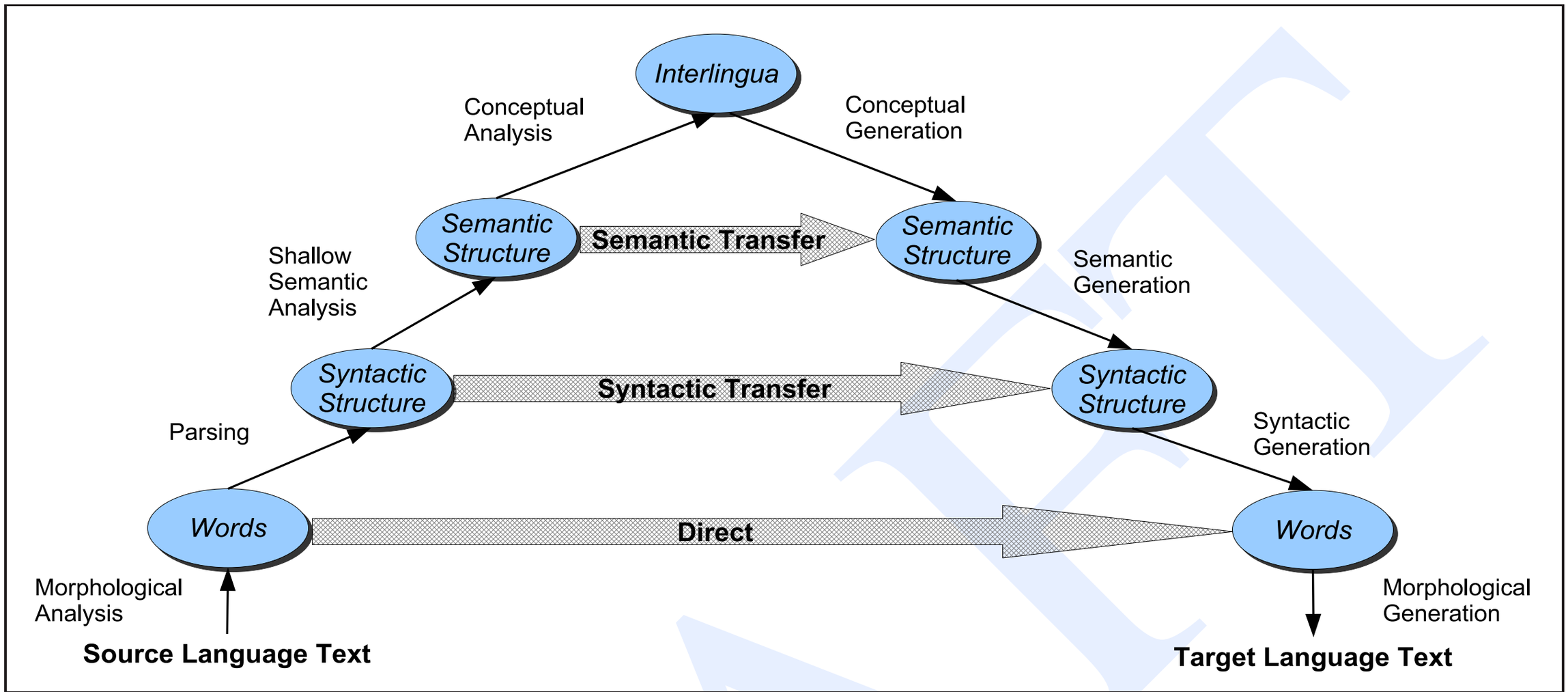
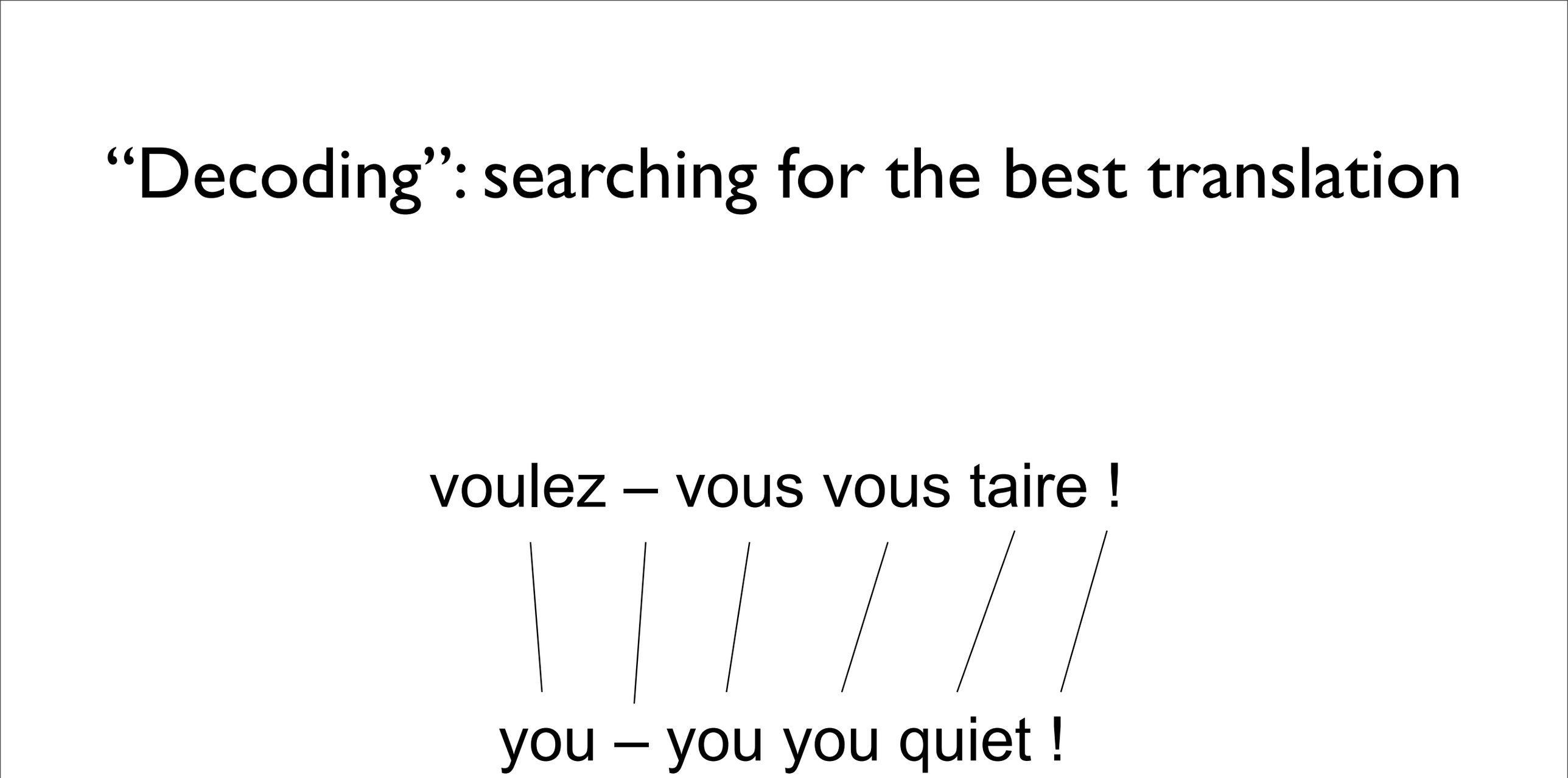


Figure 25.3 The Vauquois triangle.

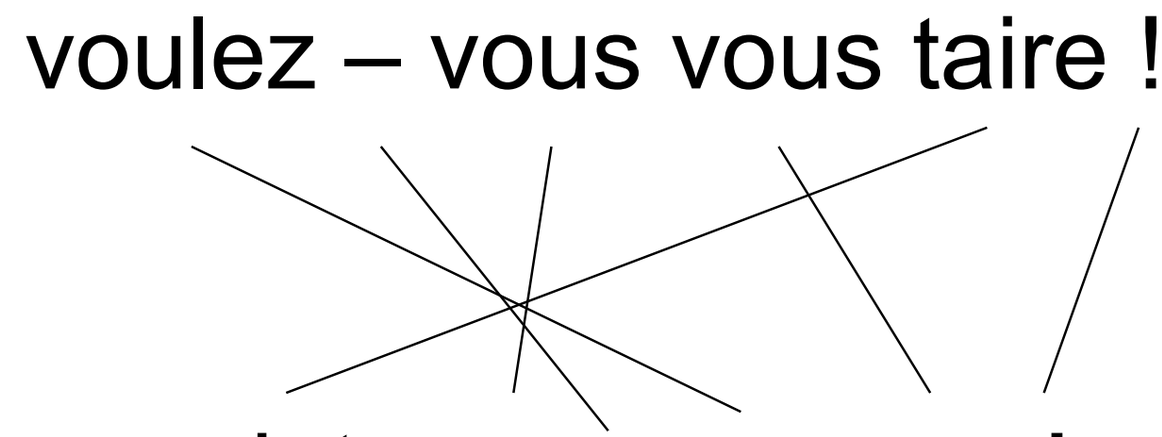
“Decoding”: searching for the best translation

voulez – vous vous taire !

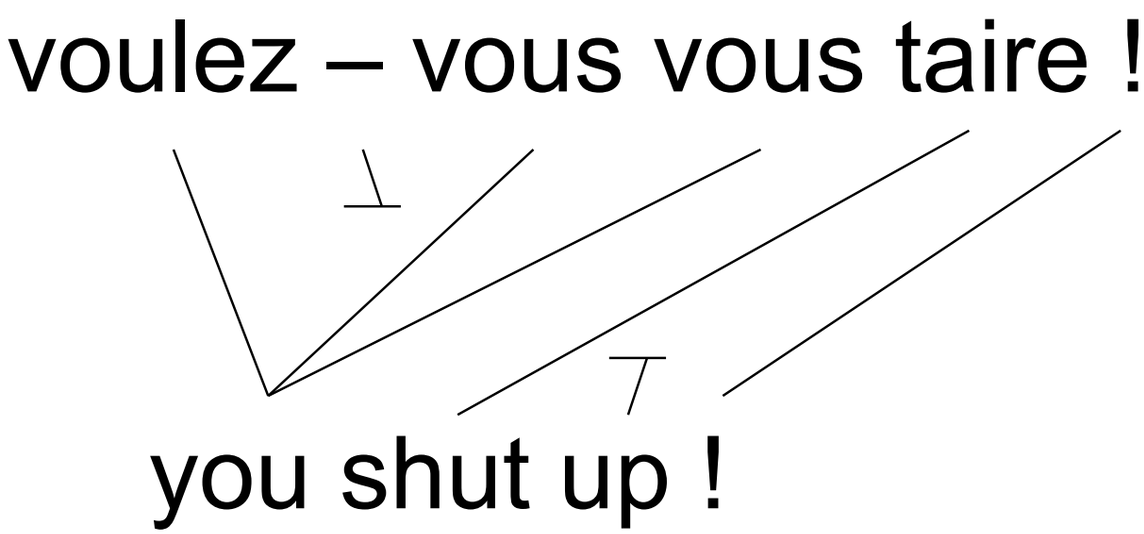
“Decoding”: searching for the best translation



“Decoding”: searching for the best translation



“Decoding”: searching for the best translation



"Decoding": searching for the best translation

Of all conceivable English word strings, we want the one maximizing P(e) x P(f | e)

Exact search

- Even if we have the right words for a translation, there are **n!** permutations.
- We want the translation that gets the highest score under our model
- Finding the argmax with a n-gram language model is NP-complete [Germann et al. 2001].
- Equivalent to Traveling Salesman Problem

“Decoding”: searching for the best translation

- Several search strategies are available
  - Usually a beam search where we keep multiple stacks for candidates covering the same number of source words
  - Or, we could try “greedy decoding”, where we start by giving each word its most likely translation and then attempt a “repair” strategy of improving the translation by applying search operators (Germann et al. 2001)

- Each potential English output is called a *hypothesis*.

Maria no dio una bofetada a la bruja verde

Mary	not	give	a	slap	to	the	witch	green
did not			a slap		by		hag	bawdy
no		slap			to the		green witch	
did not give					the			
						the witch		

Maria	no	dio	una	bofetada	a	la	bruja	verde
Mary	not	give	a	slap	to	the	witch	green
did not			a slap		by		hag	bawdy
no	slap				to the		green witch	
did not give					the			
						the witch		

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no	slap				to the		green witch	
did not give					the			
						the witch		

这	7人	中包括	来自	法国	和	俄罗斯	的	宇航	员	.

the	7 people	including	by some		**and**	the russian	**the**	the astronauts		,
it	7 people included		by france		and the	the russian		international astronautical	of rapporteur .	
this	7 out	including the	**from**	the french	and the russian		the fifth		.	
these	7 among	including from		the french and		of the russian	of	space	members	.
that	7 persons	including from the		of france	and to	russian	of the	aerospace	members	
	7 include		from the	of france and		russian		**astronauts**		. the
	7 numbers include		**from france**		and russian		of astronauts who			. ”
	7 populations include		those from france		and russian			astronauts .		
	7 deportees included		come from	**france**	**and russia**		in	astronautical	personnel	;
	7 philtrum	including those from		**france and**		**russia**	a space		**member**	
		including representatives from		france and the		**russia**		astronaut		
		include	came from	**france and russia**			by cosmonauts			
		include representatives from		french	**and russia**			cosmonauts		
		include	came from france		and russia 's			cosmonauts .		
		includes	coming from	french and		russia 's		cosmonaut		
				french and russian			's	astronavigation	member .	
				french	**and russia**		**astronauts**			
					and russia 's				special rapporteur	
					, and	**russia**			rapporteur	
					, and russia				rapporteur .	
					, and russia					
					or	russia 's				

Table 1: #11# the seven - member crew includes astronauts from france and russia .

Scoring: Try to use phrase pairs that have been frequently observed.
Try to output a sentence with frequent English word sequences.

这	7人	中包括	来自	法国	和	俄罗斯	的	宇航	员	.

the	7 people	including	by some		**and**	the russian	**the**	the astronauts		,
it	7 people included		by france		and the	the russian		international astronautical	of rapporteur .	
this	7 out	including the	**from**	the french	and the russian		the fifth		.	
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that	7 persons	including from the		of france	and to	russian	of the	aerospace	members	
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	7 philtrum	including those from		**france and**		**russia**	a space		**member**	
		including representatives from		france and the		**russia**		astronaut		
		include	came from	**france and russia**			by cosmonauts			
		include representatives from		french	**and russia**			cosmonauts		
		include	came from france		and russia 's			cosmonauts .		
		includes	coming from	french and		russia 's		cosmonaut		
				french and russian			's	astronavigation	member .	
				french	**and russia**		**astronauts**			
					and russia 's				special rapporteur	
					, and	**russia**			rapporteur	
					, and russia				rapporteur .	
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MT Evaluation

Illustrative translation results

- *la politique de la haine .* *(Foreign Original)*
- politics of hate . (Reference Translation)
- the policy of the hatred . (IBM4+N-grams+Stack)

- *nous avons signé le protocole .* *(Foreign Original)*
- we did sign the memorandum of agreement . (Reference Translation)
- we have signed the protocol . (IBM4+N-grams+Stack)

- *où était le plan solide ?* *(Foreign Original)*
- but where was the solid plan ? (Reference Translation)
- where was the economic base ? (IBM4+N-grams+Stack)

对外经济贸易合作部今天提供的数据表明，今年至十一月中国实际利用外资四百六十九点五九亿美元，其中包括外商直接投资四百点零七亿美元。

the Ministry of Foreign Trade and Economic Cooperation, including foreign direct investment 40.007 billion US dollars today provide data include that year to November china actually using foreign 46.959 billion US dollars and

MT Evaluation

- Manual (the best!?):
  - SSER (subjective sentence error rate)
  - Correct/Incorrect
  - **Adequacy and Fluency** (5 or 7 point scales)
  - Error categorization
  - **Comparative ranking of translations**

- Testing in an application that uses MT as one sub-component
  - E.g., question answering from foreign language documents
    - May not test many aspects of the translation (e.g., cross-lingual IR)

- Automatic metric:
  - WER (word error rate) – why problematic?
  - **BLEU (Bilingual Evaluation Understudy)**

BLEU Evaluation Metric

(Papineni et al, ACL-2002)

Reference (human) translation:

The U.S. island of Guam is maintaining a high state of alert after the Guam airport and its offices both received an e-mail from someone calling himself the Saudi Arabian Osama bin Laden and threatening a biological/ chemical attack against public places such as the airport .

Machine translation:

The American [?] international airport and its the office all receives one calls self the sand Arab rich business [?] and so on electronic mail , which sends out ; The threat will be able after public place and so on the airport to start the biochemistry attack , [?] highly alerts after the maintenance.

- N-gram precision (score is between 0 & 1)
  - What percentage of machine n-grams can be found in the reference translation?
    - An n-gram is an sequence of n words
  - Not allowed to match same portion of reference translation twice at a certain n-gram level (two MT words *airport* are only correct if two reference words *airport;* can't cheat by typing out "the the the the the")
  - Do count unigrams also in a bigram for unigram precision, etc.
- Brevity Penalty
  - Can't just type out single word "the" (precision 1.0!)
- It was thought quite hard to "game" the system (i.e., to find a way to change machine output so that BLEU goes up, but quality doesn't)

BLEU Evaluation Metric

(Papineni et al, ACL-2002)

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- BLEU is a weighted geometric mean, with a brevity penalty factor added.
  - Note that it's precision-oriented
- BLEU4 formula

  (counts n-grams up to length 4)

exp (1.0 * log p1 +
0.5 * log p2 +
0.25 * log p3 +
0.125 * log p4 –
max(words-in-reference / words-in-machine – 1, 0)

p1 = 1-gram precision
P2 = 2-gram precision
P3 = 3-gram precision
P4 = 4-gram precision

Note: only works at corpus level (zeroes kill it); there's a smoothed variant for sentence-level

BLEU in Action

枪手被警方击毙。 (Foreign Original)

the gunman was shot to death by the police . (Reference Translation)

the gunman was police kill .	#1
wounded police jaya of	#2
the gunman was shot dead by the police .	#3
the gunman arrested by police kill .	#4
the gunmen were killed .	#5
the gunman was shot to death by the police .	#6
gunmen were killed by police ?SUB>0 ?SUB>0	#7
al by the police .	#8
the ringer is killed by the police .	#9
police killed the gunman .	#10

green = 4-gram match (good!)
red = word not matched (bad!)

Multiple Reference Translations

Reference translation 1:
The U.S. island of Guam is maintaining a high state of alert after the Guam airport and its offices both received an e-mail from someone calling himself the Saudi Arabian Osama bin Laden and threatening a biological/chemical attack against public places such as the airport .

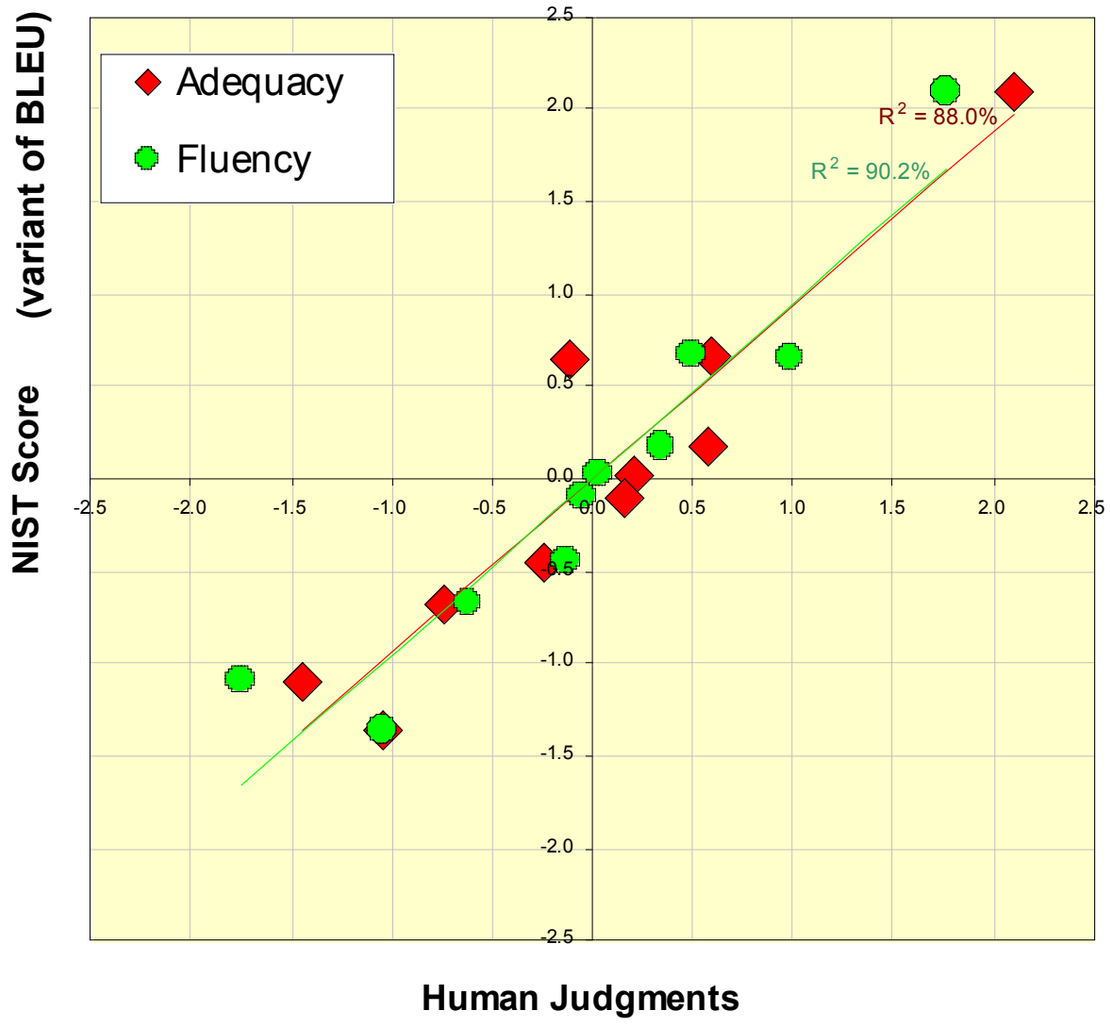
Reference translation 2:
Guam International Airport and its offices are maintaining a high state of alert after receiving an e-mail that was from a person claiming to be the wealthy Saudi Arabian businessman Bin Laden and that threatened to launch a biological and chemical attack on the airport and other public places .

Machine translation:
The American [?] international airport and its the office all receives one calls self the sand Arab rich business [?] and so on electronic mail , which sends out ; The threat will be able after public place and so on the airport to start the biochemistry attack , [?] highly alerts after the maintenance.

Reference translation 3:
The US International Airport of Guam and its office has received an email from a self-claimed Arabian millionaire named Laden , which threatens to launch a biochemical attack on such public places as airport . Guam authority has been on alert .

Reference translation 4:
US Guam International Airport and its office received an email from Mr. Bin Laden and other rich businessman from Saudi Arabia . They said there would be biochemistry air raid to Guam Airport and other public places . Guam needs to be in high precaution about this matter .

Initial results showed that BLEU predicts human judgments well



slide from G. Doddington (NIST)

Automatic evaluation of MT

- People started optimizing their systems to maximize BLEU score
  - BLEU scores improved rapidly
  - The correlation between BLEU and human judgments of quality went way, way down
  - StatMT BLEU scores now approach those of human translations but their true quality remains far below human translations
- Coming up with automatic MT evaluations has become its own research field
  - There are many proposals: TER, METEOR, MaxSim, SEPIA, our own RTE-MT
  - TERpA is a representative good one that handles some word choice variation.
- MT research **requires** *some* automatic metric to allow a rapid development and evaluation cycle.