CSCI 5832
Natural Language Processing

Lecture 25
Jim Martin

Machine Translation

Slides stolen from Kevin Knight (USC/ISI)

Today 4/24

- Machine translation framework
- State of the art
- Evaluation methods
- Word-based models

Recent Progress

2002

insistent Wednesday may recurred her trips to Libya tomorrow for flying

Cairo 6-4 (AFP) - An official announced today in the Egyptian lines company for flying Tuesday is a company "insistent for flying" may resumed a consideration of a day Wednesday tomorrow her trips to Libya of Security Council decision trace international the imposed ban comment.

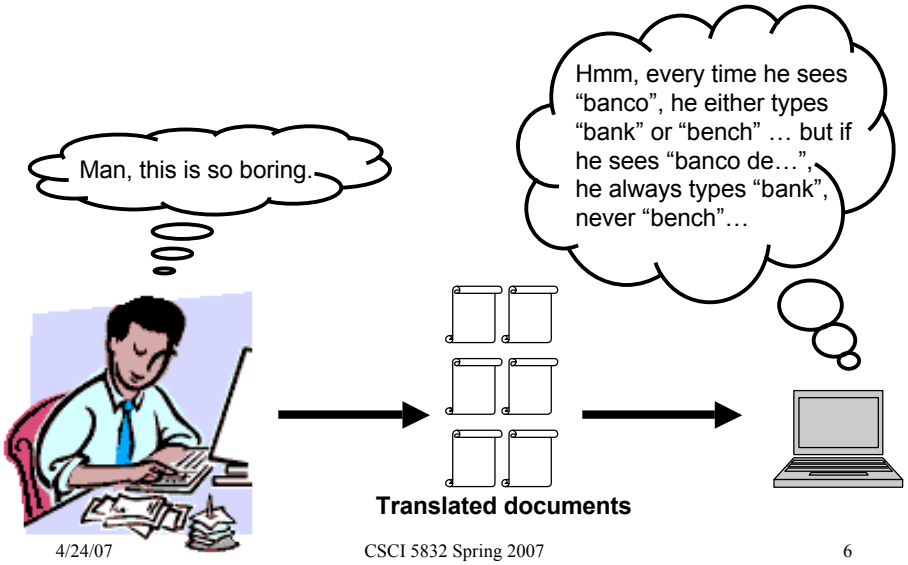
2003

Egyptair Has Tomorrow to Resume Its Flights to Libya

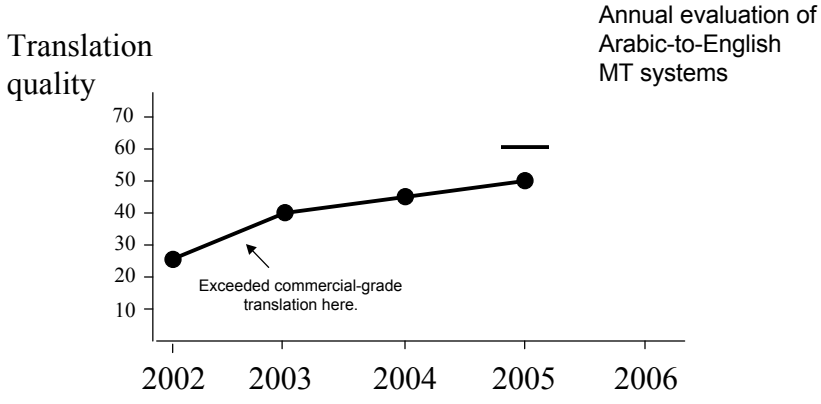
Cairo 4-6 (AFP) - Said an official at the Egyptian Aviation Company today that the company egyptair may resume as of tomorrow, Wednesday its flights to Libya after the International Security Council resolution to the suspension of the embargo imposed on Libya.

Commercial Applications

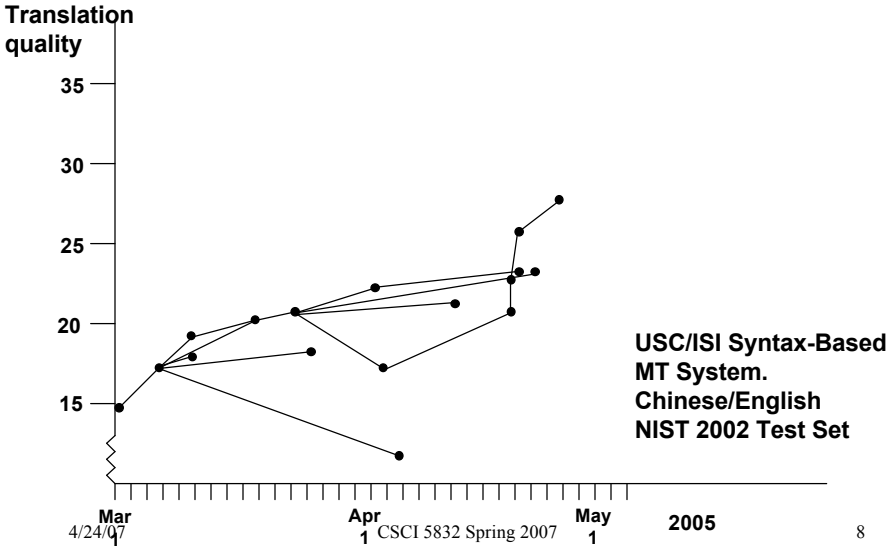
Statistical Machine Translation



Things are Consistently Improving



Progress Driven by Experiments with Empirical Measures of Success

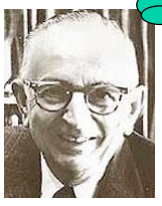


Current Approaches

- Same old noisy channel model…
- If we're translating French to English the French we're seeing is just a weird garbled version of English
- There must have been some process that generated the French from the original English
- The key is to decode the garbles back into the original English by…
- Argmax P(E | F) by Bayes
- A very old idea

Warren Weaver (1947)

When I look at an article in Russian, I say to myself: This is really written in English, but it has been coded in some strange symbols. I will now proceed to decode.



MT History

- **Earliest applications of NLP/AI**
- **Didn't work for a lot of reasons**
- **Led to an NLP/AI winter where funding was hard to come by for a long time.**
- **MT was a topic no one would touch in respected circles…**

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: farok crrrok hihok yorok clok kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
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3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
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process of elimination

Centauri/Arcturan [Knight, 1997]

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cognate?

Centauri/Arcturan [Knight, 1997]

Your assignment, put these words in order: **{ jjat, arrat, mat, bat, oloat, at-yurp }**

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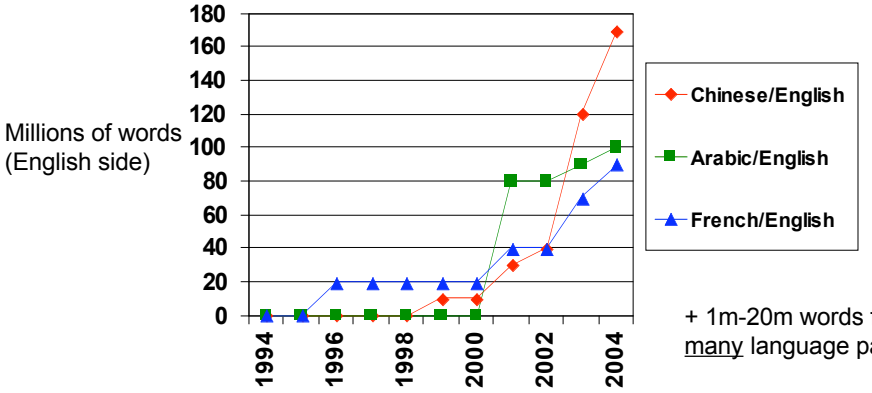
Spanish/English text

Translate: Clients do not sell pharmaceuticals in Europe.

1a. Garcia and associates . 1b. Garcia y asociados .	7a. the clients and the associates are enemies . 7b. los clients y los asociados son enemigos .
2a. Carlos Garcia has three associates . 2b. Carlos Garcia tiene tres asociados .	8a. the company has three groups . 8b. la empresa tiene tres grupos .
3a. his associates are not strong . 3b. sus asociados no son fuertes .	9a. its groups are in Europe . 9b. sus grupos estan en Europa .
4a. Garcia has a company also . 4b. Garcia tambien tiene una empresa .	10a. the modern groups sell strong pharmaceuticals . 10b. los grupos modernos venden medicinas fuertes .
5a. its clients are angry . 5b. sus clientes estan enfadados .	11a. the groups do not sell zenzanine . 11b. los grupos no venden zanzanina .
6a. the associates are also angry . 6b. los asociados tambien estan enfadados .	12a. the small groups are not modern . 12b. los grupos pequenos no son modernos .

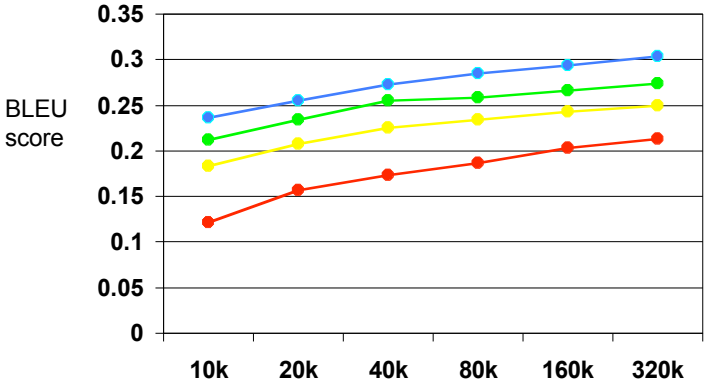
Bilingual Training Data



+ 1m-20m words for many language pairs

(Data stripped of formatting, in sentence-pair format, available from the Linguistic Data Consortium at UPenn).

Sample Learning Curves



Swedish/English
French/English
German/English
Finnish/English

Experiments by Philipp Koehn

MT Evaluation

Traditionally difficult because there is no "right answer".

20 human translators will translate the same sentence 20 different ways.

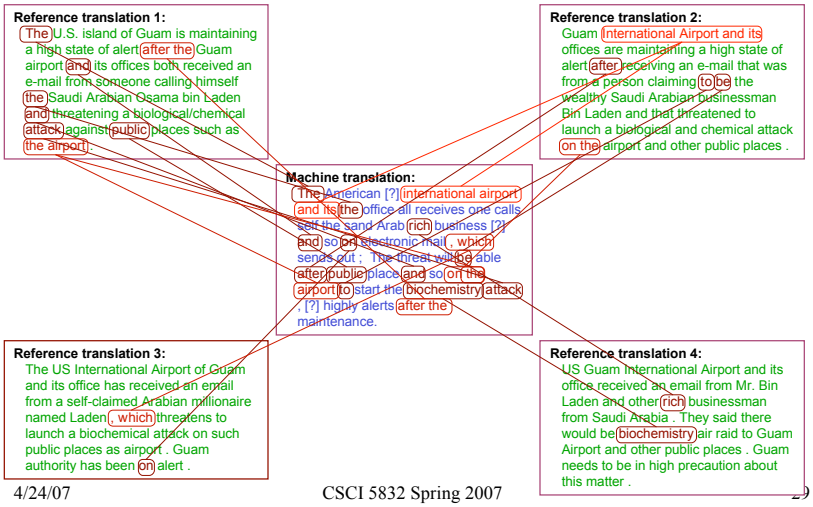
Evaluation Metric (BLEU)

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 use same portion of reference translation twice (can't cheat by typing out "the the the the the")
- **Brevity penalty**
  - Can't just type out single word "the" (precision 1.0!)
- **Amazingly hard to "game" the system (i.e., find a way to change machine output so that BLEU goes up, but quality doesn't)**
  - Contra doesn't hold. Can find perfectly good translations that hurt, or don't help, BLEU

Multiple Reference Translations



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	**#7**
al by the police .	**#8**
the ringer is killed by the police .	**#9**
police killed the gunman .	**#10**

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police killed the gunman .	#10

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

NIST 2006 Results

Arabic-to-English Results

Large Data Track

NIST Subset

Overall BLEU Scores

Site ID	BLEU-4
google	0.4281
ibm	0.3954
isi	0.3908
rwth	0.3906
apptek*#	0.3874
lw	0.3741
bbn	0.3690
ntt	0.3680
itcirst	0.3466
cmu-uka	0.3369
umd-jhu	0.3333
edinburgh*#	0.3303
sakhr	0.3296

Chinese-to-English Results

Large Data Track

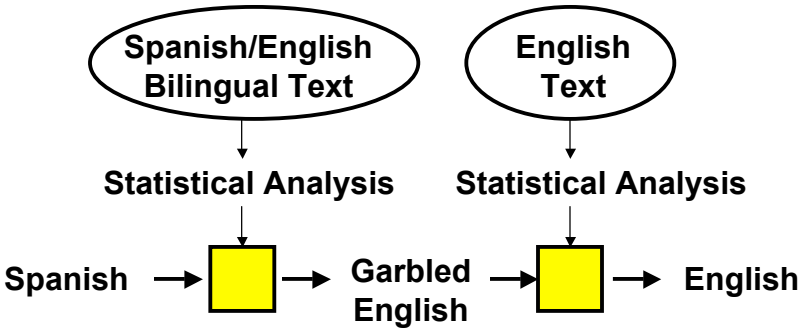
NIST Subset

Overall BLEU Scores

Site ID	BLEU-4
isi	0.3393
google	0.3316
lw	0.3278
rwth	0.3022
ict	0.2913
edinburgh*#	0.2830
bbn	0.2781
nrc	0.2762
itcirst	0.2749
umd-jhu	0.2704

Word-Based Statistical MT

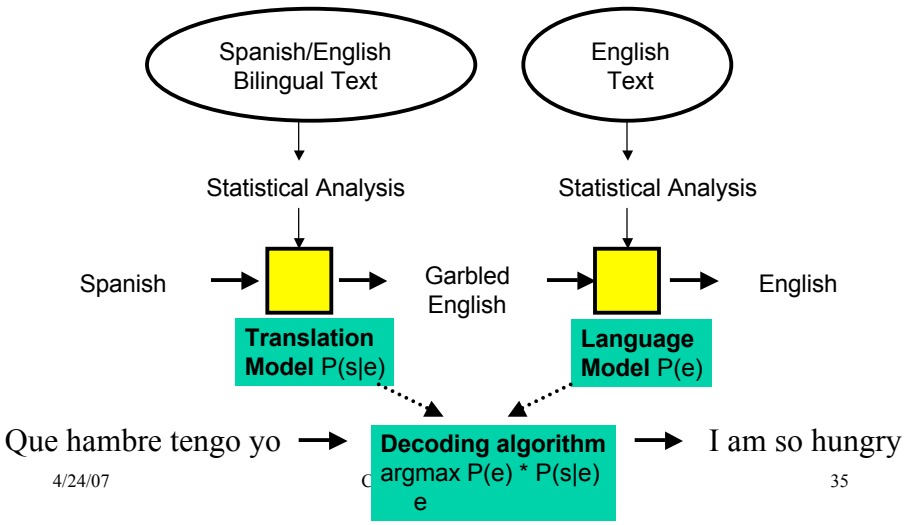
Statistical MT Systems



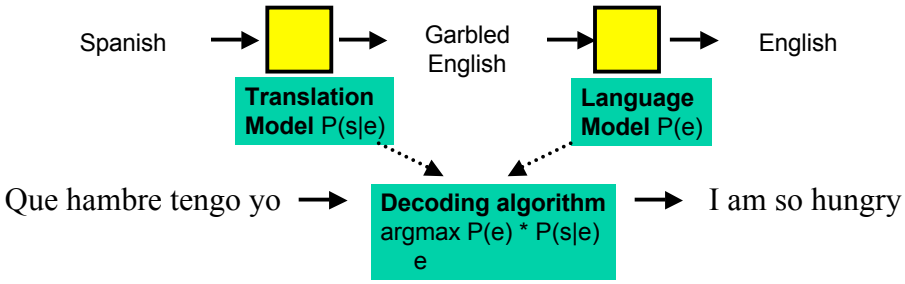
What hunger have I,
Hungry I am so,
I am so hungry,
Have I that hunger …

Que hambre tengo yo → → I am so hungry

Statistical MT Systems



Bayes Rule/Noisy Channel



Given a source sentence s, the decoder should consider many possible translations … and return the target string e that maximizes

P(e | s)

By Bayes Rule, we can also write this as:

P(e) x P(s | e) / P(s)

and maximize that instead. P(s) never changes while we compare different e's, so we can equivalently maximize this:

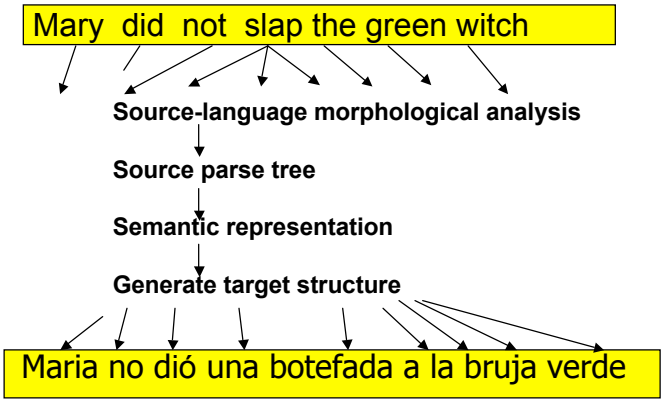
P(e) x P(s | e)

Three Sub-Problems of Statistical MT

- **Language model**
  - Given an English string e, assigns P(e) by formula
  - good English string -> high P(e)
  - random word sequence -> low P(e)
- **Translation model**
  - Given a pair of strings <f,e>, assigns P(f | e) by formula
  - <f,e> look like translations -> high P(f | e)
  - <f,e> don't look like translations -> low P(f | e)
- **Decoding algorithm**
  - Given a language model, a translation model, and a new sentence f … find translation e maximizing P(e) * P(f | e)

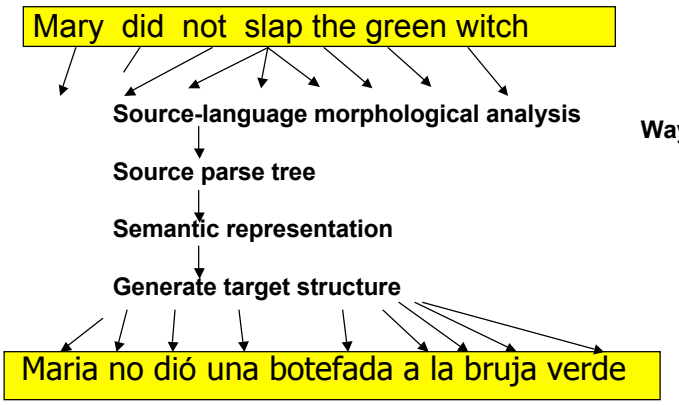
Translation Model

Generative story:



Translation Model?

Generative story:

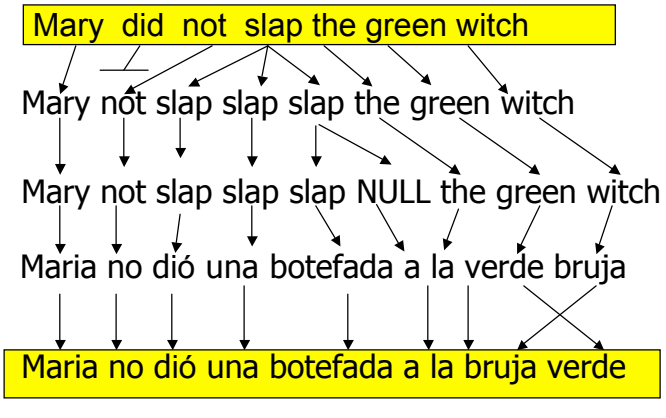


Way too hard.

The Classic Translation Model

Word Substitution/Permutation [IBM Model 3, Brown et al., 1993]

Generative story:



n(3|slap)

p-Null

t(la|the)

d(j|i)

Parts List

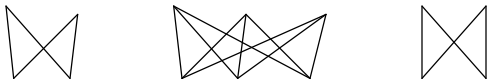
- We need probabilities for
  - n (x|y) The probability that word y will yield x outputs in the translation… (fertility)
  - p The probability of a null insertion
  - t The actual word translation probability table
  - d(j|i) the probability that a word at position i will make an appearance at position j in the translation

Parts List

- Every one of these can be learned from a sentence aligned corpus…
  - Ie. A corpus where sentences are paired but nothing else is specified
- And the EM algorithm

Word Alignment

… la maison … la maison bleue … la fleur …



… the house … the blue house … the flower …

- **Assume that All word alignments equally likely.**
- **Ie.that all P(french-word | english-word) are equal**
- **Recall that we want P(f|e)**

Word Alignment

… la maison … la maison bleue … la fleur …

… the house … the blue house … the flower …

"la" and "the" observed to co-occur frequently,
so P(la | the) is increased.

Word Alignment

… la maison … la maison bleue … la fleur …

… the house … the blue house … the flower …

Word Alignment

… la maison … la maison bleue … la fleur …

… the house … the blue house … the flower …

settling down after another iteration

Word Alignment

… la maison … la maison bleue … la fleur …

… the house … the blue house … the flower …

Inherent hidden structure revealed by EM training

Parts List

- **Given a sentence alignment we can induce a word alignment**
- **Given that word alignment we can get the p, t, d and n parameters we need for the model.**
- **Ie. We can argmax P(e|f) by maxing over P(f|e)*P(e)… and we can do that by iterating over some large space of f possibilities.**

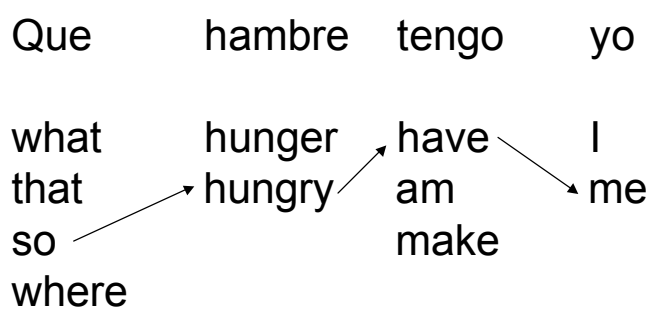
Decoding

- **Remember Viterbi? Just a fancier Viterbi**
  - **Given foreign sentence f, find English sentence e that maximizes P(e) x P(f | e)**

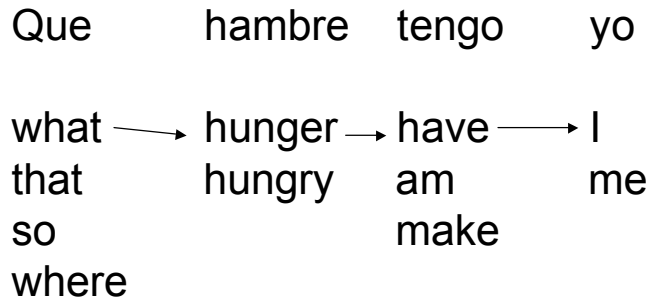
Decoding

Que	hambre	tengo	yo
what	hunger	have	I
that	hungry	am	me
so		make	
where			

Decoding



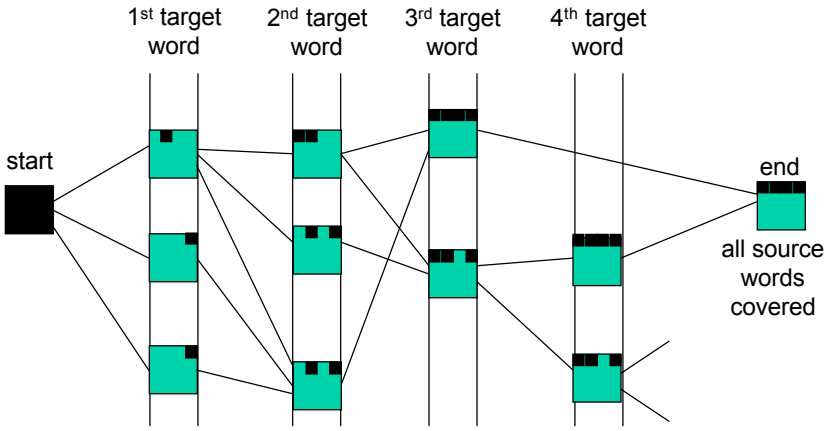
Decoding



Decoding

Que	hambre	tengo	yo
what	hunger	have	I
that	hungry	am	me
so		make	
where			

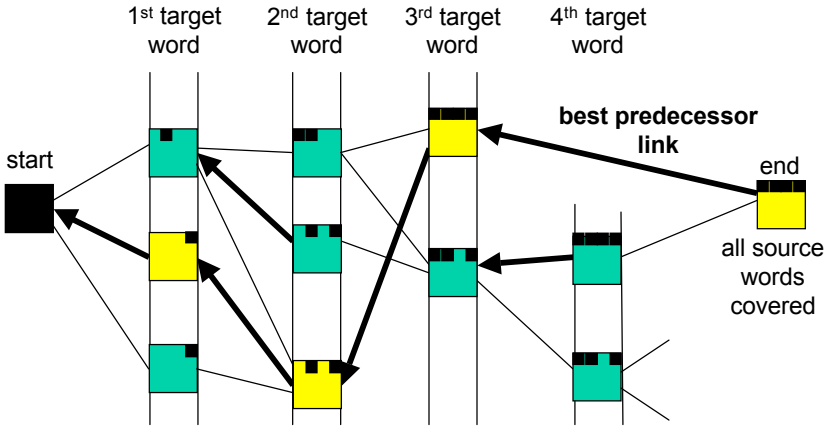
Decoder: Actually Translates New Sentences



Each partial translation hypothesis contains:
- Last English word chosen + source words covered by it
- Next-to-last English word chosen
- Entire coverage vector (so far) of source sentence
- Language model and translation model scores (so far)

[Jelinek, 1969;
Brown et al, 1996 US Patent;
(Och, Ueffing, and Ney, 2001]

Dynamic Programming Beam Search



Each partial translation hypothesis contains:
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- Language model and translation model scores (so far)

[Jelinek, 1969;
Brown et al, 1996 US Patent;
(Och, Ueffing, and Ney, 2001]

55

Classic 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

Flaws of Word-Based MT

- Multiple English words for one foreign word
  - IBM models can do one-to-many (fertility) but not many-to-one
- Phrasal Translation
  - "real estate", "note that", "interest in"
- Syntactic Transformations
  - Verb at the beginning in Arabic
  - Translation model penalizes any proposed re-ordering
  - Language model not strong enough to force the verb to move to the right place

Next Time

- EM alignment example
- Phrase-based translation