Introduction to Statistical Machine Translation

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Some slides adapted from

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Admin

Assignment 5

Quiz #2
- Mean 26.5 (88%)
- Median 26.5

Language translation

MT Systems

Where have you seen machine translation systems?

Machine Translation

美国关岛国际机场及其办公室均接获一名自称沙地阿拉伯富商拉登等发出的电子邮件，威胁将会向机场等公众地方发动生化袭击後，关岛经保持高度戒备。

➡

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 .

The classic acid test for natural language processing.

Requires capabilities in both interpretation and generation.

“People around the world stubbornly refuse to write everything in English.” ☺

Machine Translation

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Machine translation is becoming very prevalent

Even PowerPoint has translation built into it!

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 .

United States Office of the Guam International Airport and were received by a man claiming to be Saudi Arabian businessman Osama bin Laden, sent emails, threats to airports and other public places will launch a biological or chemical attack, remain on high alert in Guam.

Warren Weaver (1947)

ingcmpnqsnwf cv fpn owoktvcv

hu ihgzsnwfv rqcffnw cw owgcnwf

kowazoanv ...

Warren Weaver (1947)

e e e e

ingcmpnqsnwf cv fpn owoktvcv

e e e

hu ihgzsnwfv rqcffnw cw owgcnwf

e

kowazoanv ...

Warren Weaver (1947)

```
 e    e  e      the
ingcmpnqsnwf cv fpn owoktvcv
        e         e         e
hu ihgzsnwfv rqcffnw cw owgcnwf
       e
kowazoanv ...
```

Warren Weaver (1947)

```
 e   he  e      the
ingcmpnqsnwf cv fpn owoktvcv
        e         e         e t
hu ihgzsnwfv rqcffnw cw owgcnwf
       e
kowazoanv ...
```

Warren Weaver (1947)

```
 e   he  e   of the
ingcmpnqsnwf cv fpn owoktvcv
        e         e         e t
hu ihgzsnwfv rqcffnw cw owgcnwf
       e
kowazoanv ...
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```
 e   he  e   of the      fof
ingcmpnqsnwf cv fpn owoktvcv
        e  f   o  e  o    oe t
hu ihgzsnwfv rqcffnw cw owgcnwf
       ef
kowazoanv ...
```

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e he e ~~o~~ the
ingcmpnqsnwf cv fpn owoktvcv
e e e t
hu ihgzsnwfv rqcffnw cw owgcnwf
e
kowazoanv ...

Warren Weaver (1947)

e he e is the sis
ingcmpnqsnwf cv fpn owoktvcv
e s i e i ie t
hu ihgzsnwfv rqcffnw cw owgcnwf
es
kowazoanv ...

Warren Weaver (1947)

decipherment is the analysis
ingcmpnqsnwf cv fpn owoktvcv
of documents written in ancient
hu ihgzsnwfv rqcffnw cw owgcnwf
languages ...
kowazoanv ...

Warren Weaver (1947)

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

- Warren Weaver, March 1947

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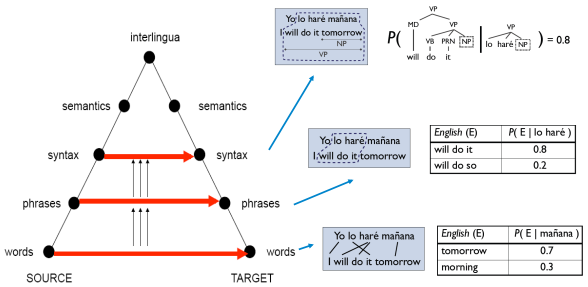
"... as to the problem of mechanical translation, I frankly am afraid that the [semantic] boundaries of words in different languages are too vague ... to make any quasi-mechanical translation scheme very hopeful."

- Norbert Wiener, April 1947

Levels of Transfer



World-Level MT: Examples

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)

Phrasal / Syntactic MT: Examples

Le président américain Barack Obama doit annoncer lundi de nouvelles mesures en faveur des constructeurs automobile. General motors et Chrysler avaient déjà bénéficié fin 2008 d'un prêt d'urgence cumulé de 17,4 milliards de dollars, et ont soumis en février au Trésor un plan de restructuration basé sur un total de 22 milliards de dollars d'aides publiques supplémentaires.

Interrogé sur la chaîne CBS dimanche, le président a toutefois clairement précisé que le gouvernement ne preterait pas d'argent sans de fortes contreparties. *"Il faudra faire des sacrifices à tous les niveaux"*, a-t-il prévenu. *"Tout le monde devra se réunir autour de la table et se mettre d'accord sur une restructuration en profondeur"*.

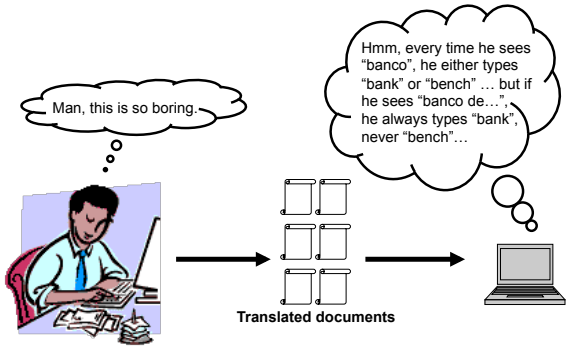
General Motors et Chrysler sont engagés dans des négociations avec le principal syndicat de l'automobile. Les constructeurs souhaitent diminuer leurs cotisations aux caisses de retraites, et accorder en échange des actions aux syndicats. Ils souhaiteraient également négocier des baisses des salaires.

U.S. President Barack Obama to announce Monday new measures to help automakers. General Motors and Chrysler had already received late in 2008 a cumulative emergency loan of 17.4 billion dollars, and submitted to the Treasury in February in a restructuring plan based on a total of 22 billion dollars in additional aid .

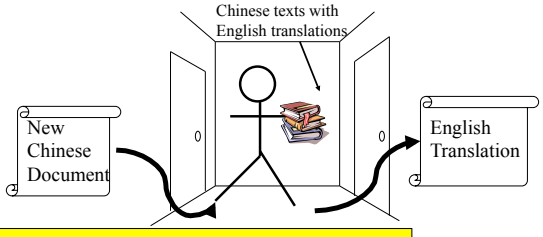
Interviewed on CBS Sunday, the president has clearly stated that the government does not lend money without strong counterparts. *"We must make sacrifices at all levels,"* he warned. *"Everyone should gather around the table and agree on a profound restructuring. "*

General Motors and Chrysler are engaged in negotiations with the major union of the car. Manufacturers wishing to reduce their contributions to pension funds, and give in exchange for the shares to trade unions. They would also negotiate lower wages.

Data-Driven Machine Translation



Welcome to the Chinese Room



You can teach yourself to translate Chinese using *only* bilingual data (without grammar books, dictionaries, any people to answer your questions…)

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 .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
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 .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
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process of elimination

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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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zero fertility

It's Really Spanish/English

Clients do not sell pharmaceuticals in Europe => Clientes no venden medicinas en Europa

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 .

Data available

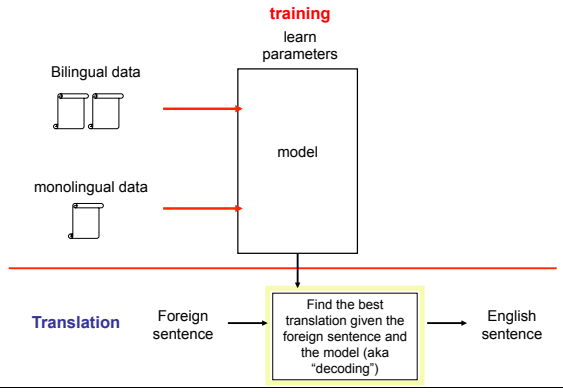
Many languages
- Europarl corpus has all European languages
  - http://www.statmt.org/europarl/
  - From a few hundred thousand sentences to a few million
- French/English from French parliamentary proceedings
- Lots of Chinese/English and Arabic/English from government projects/ interests
  - Chinese-English: 440 million words (15-20 million sentence pairs)
  - Arabic-English: 790 million words (30-40 million sentence pairs)
- Smaller corpora in many, many other languages

Lots of monolingual data available in many languages

Even less data with multiple translations available

Available in limited domains
- most data is either news or government proceedings
- some other domains recently, like blogs

Statistical MT Overview



Statistical MT

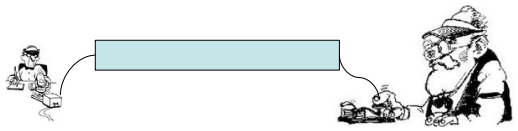
We will model the translation process probabilistically

Given a foreign sentence to translate, for any possible English sentence, we want to know the probability that the sentence is a translation of the foreign sentence

If we can find the most probable English sentence, we're done

p(english sentence | foreign sentence)

Noisy channel model



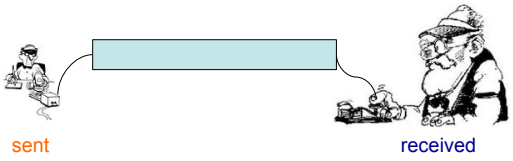
some message is sent

along the way the message gets messed up

What was originally sent?

We have the mutated message, but would like to recover the original

Noisy channel model



sent received

model: p(sent | received)

Noisy channel model

Probabilistic model: $p(e \mid f)$

p(English | Foreign)

p(text | audio)

p(simplified | unsimplified)

p(compressed | uncompressed)

Given sentence pairs, gives us the probability

Translation

Probabilistic model: $p(e \mid f)$ p(English | Foreign)

What is the translation problem then?

$$translation(f) = \arg_e \max p(e \mid f)$$

Noisy channel model

$$p(e \mid f) = \frac{p(f \mid e)p(e)}{p(f)}$$ Bayes' rule

$p(f)$ probability of the foreign sentence

$p(e)$ language model: what are likely English word sequences?

$p(f \mid e)$ translation model: how does the translation process happen? probability of the translated English sentence given the foreign sentence

Noisy channel model

$p(e \mid f) = p(f \mid e)p(e)$ Bayes' rule

~~$p(f)$~~ ~~probability of the foreign sentence~~ why?

$p(e)$ language model: what are likely English word sequences?

$p(f \mid e)$ translation model: how does the translation process happen? probability of the translated English sentence given the foreign sentence

Noisy channel model

$p(e \mid f) = p(f \mid e)p(e)$ Bayes' rule

~~$p(f)$~~ ~~probability of the foreign sentence~~ why?

$$translation(f) = \arg_e \max \frac{p(f \mid e)p(e)}{p(f)} = \arg_e \max p(f \mid e)p(e)$$

this is a constant for any given *f*

Noisy channel model

model $p(e \mid f) \propto p(f \mid e)p(e)$

translation model: how do English sentences get translated to foreign?

language model: what do English sentences look like?

Translation model

The models define probabilities over inputs

$p(f \mid e)$

Morgen fliege ich nach Kanada zur Konferenz

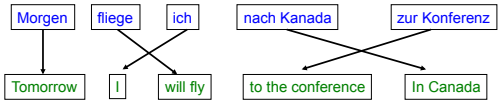
Tomorrow I will fly to the conference in Canada

What is the probability that the English sentence is a translation of the foreign sentence?

Translation model

The models define probabilities over inputs

$$p(f \mid e)$$



- What is the probability of a foreign word being translated as a particular English word?
- What is the probability of a foreign foreign phrase being translated as a particular English phrase?
- What is the probability of a word/phrase changing ordering?
- What is the probability of a foreign word/phrase disappearing?
- What is the probability of a English word/phrase appearing?

Translation model

The models define probabilities over inputs

$$p(f \mid e)$$

p(Morgen fliege ich nach Kanada zur Konferenz | Tomorrow I will fly to the conference in Canada) = 0.1

p(Morgen fliege ich nach Kanada zur Konferenz | I like peanut butter and jelly) = 0.0001

Language model

The models define probabilities over inputs

$$p(e)$$

Tomorrow I will fly to the conference in Canada

What is a probability distribution?

A probability distribution defines the probability over a space of possible inputs

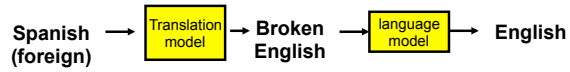
For the language model, what is the space of possible inputs?

- A language model describes the probability over **ALL** possible combinations of English words

For the translation model, what is the space of possible inputs?

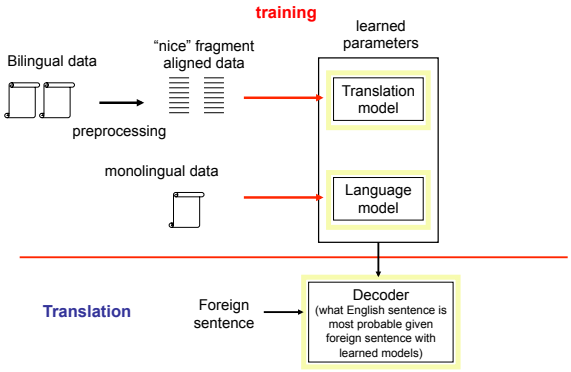
- **ALL** possible combinations of foreign words with **ALL** possible combinations of English words

One way to think about it…



Que hambre tengo yo → What hunger have I, Hungry I am so, I am so hungry, Have I that hunger … → I am so hungry

Statistical MT Overview



Basic Model, Revisited

$$\underset{e}{\text{argmax}}\ P(e \mid f) =$$

$$\underset{e}{\text{argmax}}\ P(e) \times P(f \mid e) / P(f) =$$

$$\underset{e}{\text{argmax}}\ P(e) \times P(f \mid e)$$

Basic Model, Revisited

$$\underset{e}{\text{argmax}}\ P(e \mid f) =$$

$$\underset{e}{\text{argmax}}\ P(e) \times P(f \mid e) / P(f) =$$

$$\underset{e}{\text{argmax}}\ P(e)^{2.4} \times P(f \mid e)$$ … works better!

Basic Model, Revisited

$$\underset{e}{\text{argmax}}\ P(e \mid f) =$$

$$\underset{e}{\text{argmax}}\ P(e) \times P(f \mid e) / P(f)$$

$$\underset{e}{\text{argmax}}\ P(e)^{2.4} \times P(f \mid e) \times \text{length}(e)^{1.1}$$

Rewards longer hypotheses, since these are unfairly punished by P(e)

Basic Model, Revisited

$$\underset{e}{\text{argmax}}\ P(e)^{2.4} \times P(f \mid e) \times \text{length}(e)^{1.1} \times KS^{3.7} \ldots$$

Lots of knowledge sources vote on any given hypothesis.

"Knowledge source" = "feature function" = "score component".

A feature function simply scores a hypothesis with a real value.

(May be binary, as in "e has a verb").

Problems for Statistical MT

Preprocessing
- How do we get aligned bilingual text?
- Tokenization
- Segmentation (document, sentence, word)

Language modeling
- Given an English string e, assigns P(e) by formula

Translation modeling
- Given a pair of strings <f,e>, assigns P(f | e) by formula

Decoding
- Given a language model, a translation model, and a new sentence f … find translation e maximizing P(e) * P(f | e)

Parameter optimization
- Given a model with multiple feature functions, how are they related? What are the optimal parameters?

Evaluation
- How well is a system doing? How can we compare two systems?