

Engineering Part IIB: Module 4F11

Speech and Language Processing

Lecture 11: Introduction to Statistical Machine Translation

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Lent 2014



Cambridge University Engineering Department

Machine Translation

Machine Translation is the full or partial automation of translation as carried out by humans. This is a difficult objective to define in absolute terms, since human translation often involves multiple overlapping tasks, for example

- ▶ Translation
- ▶ Interpretation
- ▶ Summarization
- ▶ Transliteration
- ▶ Glossing
 - ▶ Syntactic and Semantic Analysis
 - ▶ Commentary

All of these tasks require human intelligence, sensitivity, and understanding clearly beyond the state-of-the-art in NLP and artificial intelligence.

However translated texts are readily available in a variety of domains

- ▶ Religious texts
- ▶ Governmental proceedings:
EU, UN, multilingual countries ...
- ▶ Business documents:
localization of product manuals, ...
- ▶ Literary texts
- ▶ News sources:
multilingual and multinational
- ▶ Consumer: tourism, shopping, ...
- ▶ Military and humanitarian efforts

For example ...

The Eadwine Psalter, Canterbury, Mid-Twelfth Century



...Three Latin versions of the Psalms laid in parallel columns are integrated with a Latin commentary, Old English and Anglo-Norman translations written between the lines and in the margins. Each Psalm opens with a magnificent drawing inspired by its text the waters of Babylon, illustrates Psalm 136 shown here...

The Cambridge Illuminations,
The Fitzwilliam Museum ¹

¹<http://www.fitzmuseum.cam.ac.uk/gallery/CambridgeIlluminations>

European Union Parliamentary Proceedings

Rules of Procedure of the European Parliament – Rule 138

01/02/2006 09:55 PM



▶ TITLE VI : SESSIONS

CHAPTER 3 : GENERAL RULES FOR THE CONDUCT OF SITTINGS

Rule 138 : Languages

1. All documents of Parliament shall be drawn up in the official languages.
2. All Members shall have the right to speak in Parliament in the official language of their choice. Speeches delivered in one of the official languages shall be simultaneously interpreted into the other official languages and into any other language the Bureau may consider necessary.
3. Interpretation shall be provided in committee and delegation meetings from and into the official languages used and requested by the members and substitutes of that committee or delegation.
4. At committee and delegation meetings away from the usual places of work interpretation shall be provided from and into the languages of those members who have confirmed that they will attend the meeting. These arrangements may exceptionally be made more flexible where the members of the committee or delegation so agree. In the event of disagreement, the Bureau shall decide.

Where it has been established after the result of a vote has been announced that there are discrepancies between different language versions, the President shall decide whether the result announced is valid pursuant to Rule 164(5). If he declares the result valid, he shall decide which version is to be regarded as having been adopted. However, the original version cannot be taken as the official text as a general rule, since a situation may arise in which all the other languages differ from the original text.

Last updated: 17 October 2005

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European Union Parliamentary Proceedings

German

Offensichtlich bedeutet die Erklärung von Herrn Fischler vom Wochenende eine Änderung der Haltung der Kommission.

Ich begrüße diese Änderung, denn er sagte, daßer британisches Rindfleisch essen würde und daßdas Einfuhrverbot insbesondere aus wirtschaftlichen und politischen Gründen verhängt wurde.

English

It would appear that a speech made at the weekend by Mr Fischler indicates a change of his position.

I welcome this change because he has said that he will eat British beef and that the ban was imposed specifically for economic and political reasons.

French

Il semblerait en effet que M. Fischler ait changé de position dans un discours prononcé au cours de ce week-end.

Je me félicite de ce changement, car il a dit qu'il mangerait du boeuf britannique et que l'interdiction avait été décrétée spécifiquement pour des raisons économiques et politiques.



The DGT Multilingual Translation Memory of the Acquis Communautaire: DGT-TM

As of November 2007, the European Commission's Directorate General for Translation (DGT) made publicly accessible its multilingual Translation Memory for the Acquis Communautaire (the body of EU law) - a collection of parallel texts (texts and their translation, also referred to as bi-texts) in 22 languages. (<http://langtech.jrc.it/DGT-TM.html>)

4) Statistics for the DGT Translation Memory

The *DGT Translation Memory* is currently available in 22 languages. The following table shows the coverage, expressed in the total number of translation units available for each language:

Language	Language code	Number of units
English	EN	2 187 504
Bulgarian	BG	708 658
Czech	CS	890 025
Danish	DA	433 871
German	DE	532 668
Greek	EL	371 039
Spanish	ES	509 054
Estonian	ET	1 047 503
Finnish	FI	514 868
French	FR	1 106 442
Hungarian	HU	1 159 975
Italian	IT	542 873
Lithuanian	LT	1 126 255
Latvian	LV	1 120 835
Maltese	MT	1 021 855
Dutch	NL	502 557
Polish	PL	1 052 136
Portuguese	PT	945 203
Romanian	RO	650 735
Slovakian	SK	1 065 399
Slovene	SL	1 026 668
Swedish	SV	555 362

Size of DGT's Translation Memory expressed as the total number of translation units per language for each of the 22 official EU languages.

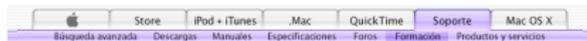
The number of *aligned translation units* differs for each language pair.



Product Localization

Apple - Formación

01/02/2006 10:23 PM



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<p>Formación para técnicos AppleCare</p> <p>Prepárate para los exámenes de certificación de Apple y aprende a resolver problemas de software y hardware de Apple.</p> <p>Más detalles</p>	<p>Instructor profesional</p> <p>Los cursos de desarrollo y formación profesional te ayudan a aprovechar al máximo las tecnologías en el aula y a motivar a tus alumnos hacia el éxito.</p> <p>Más detalles</p>

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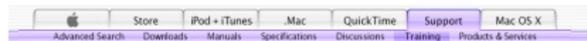
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News Sources with Multilingual and Multinational Audiences

26/02/2008 17:19

Home News Sport Radio TV Weather Languages

BBC RUSSIAN.com

Ваш график | О сайте | Обратная связь.

В мире
Обновлено: вторник, 26 февраля 2008 г., 17:05 GMT 20:05 MCK

В мире
Россия
Экономика
Наука и техника
Люди
Культура
Британия
Аналитика
Ваше мнение
Мир в картe
Learn English
Радио
Видео
Партнеры

В Пакистане снят запрет на доступ к YouTube

Дни Голланда
Зачем же "Оксфорд" в дамах, платьях и украшениях

Шансы Хиллари
В борьбе за Белый дом Барак Обама уходят в отрыв

Федель Кастро
Ожидание кубинского лидера в рождество

Американец выиграл \$275 млн.

Анализ, комментарии
Пресса США: Удача косоварин не помешает
Мотивация свавласти с поставке газа Польше
Признание Косова вызвало юридическую бурю

Клуб блогеров
Клуб блогеров БС. Би. Си. Эс приглашает вас к дискуссии

Другие новости
Патриархальные поздравит в четверг
Рост экономики США "замедляется"
"Сандбу" объявил в Индии посетили тысячи

ИЗБРАННОЕ
Новый сервис BBC Russian Select: что это такое и зачем это нужно?

Наше видео
Самые свежие сюжеты BBCRussian.com

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26/02/2008 17:10

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BBC NEWS

Low graphics | Accessibility help

Europe Today
LIVE

One-Minute World News

UK
Last Updated: Tuesday, 26 February 2008, 17:16 GMT

Top terror recruiter found guilty
A man said to be one of the most influential recruiters for Islamist extremism in the UK is found guilty at a major trial.
The radicaliser and the bombers
Nata suspect: What they said
UK 'terror camps' revealed

Lib Dem ordered out of EU debate
Lib Dem frontbencher Ed Davey is ordered out of the Commons after protest over EU treaty debate.

Bus stop killer gets whole life term
A man who killed two students and tried to kill a third must spend the rest of his life in prison, a judge orders.

Nick Robinson
OH dear, it seems I've angered a growing number of MPs.

Anti-depressants 'do not work'
Jersey 'abuse cover-up' claim
Marsh vehicle model tested

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FEATURES, VIEWS, ANALYSIS
Farer recruiter East London man trained with would-be suicide bombers

Hugh Grant: Help people die at home

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MORE FROM THE UK
Iraq minutes 'should be released'
UK work applicants near 800,000
Hospital staff 'sued in porn probe'
Average water bill rising by 5.8%
Truancy rate 'highest since 1997'
Egg complaints come to the boil
100,000 miss first-choice school
Materialism 'damages' children
Cash plea for die-at-home plan
Two quizzer over fatal stabbing

WALS
Concerns over school performance
E.coli butcher 'was allowed time'

MAGAZINE
For the love of bricks
How can a dog sniff through concrete?
My baby just loves to dance

UK NEWSPAPERS
Papers say 'the drugs don't work'

OTHER TOP STORIES
Super-casino proposal is ditched
Jersey 'abuse cover-up' is denied
Anti-depressants' 'little effect'
MPs' expenses review speeded up
ME 'did not keep files on Diana'
Missing girl police 'fear worst'
Bank warns of economic risks

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Small factory owl turns heads after being rescued from pipe

SPORT HEADLINES
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Football: Moyes' European focus
Athletics: Williamson makes team

HAVE YOUR SAY
6 Companies know that the gateway to your money is through your children
Emma, Katterling

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MONDAY
Pist sacked after fly-by stunt
TUESDAY
Active in first biofuel film
SATURDAY
Mandatory DNA database rejected
FRIDAY
Claim UK troops 'executed' Iraqis
THURSDAY
New airport fly paths proposed
UK WEATHER
Select a city: GO

RETURN TO THE UK WEATHER PAGE

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These Sources Suggest Both a Demand and an Opportunity for MT

Government and commercial bodies are producing ever increasing amounts of translated speech and text.

- ▶ Production is driven by political and economic necessity
- ▶ Dissemination is aided by the internet and other broadcast media

This is good for research and development in MT technology

- ▶ Useful products are needed
- ▶ Technology can be put to use – and evaluated – in real applications
- ▶ Data is being produced for use in system development

There is clearly a market for translation services

- ▶ Demand is currently met by (relatively) well-paid professional translators
- ▶ High-quality translation are very expensive and can be difficult to obtain
- ▶ Even low-quality translation services are expensive
 - ▶ Partial automation - *Computer Aided Translation* - may have economic value
- ▶ Commercial translation services are ubiquitous on the web

Why is Machine Translation Difficult ² ?

Variations within language pairs and translations domains challenge even bilingual humans

- ▶ Domain and Genre
- ▶ Word sense
- ▶ Morphology
- ▶ Word Order
- ▶ Idiomatic expressions
- ▶ Language Specific Issues:
 - Chinese - word segmentation
 - Arabic - tokenization
- ▶ Translation vs. Transliteration
 - named entity identification

Constructing models for use in statistical machine translation is computationally difficult

- ▶ Translation does not proceed in left-to-right fashion (as in automatic speech recognition) due to word reordering between language pairs
- ▶ Large amounts of monolingual and bilingual text are needed for parameter estimation

²Much of the material in this section was taken from Jurafsky and Martin, Chapter 21 



Translation Should Respect Document Domain and Genre

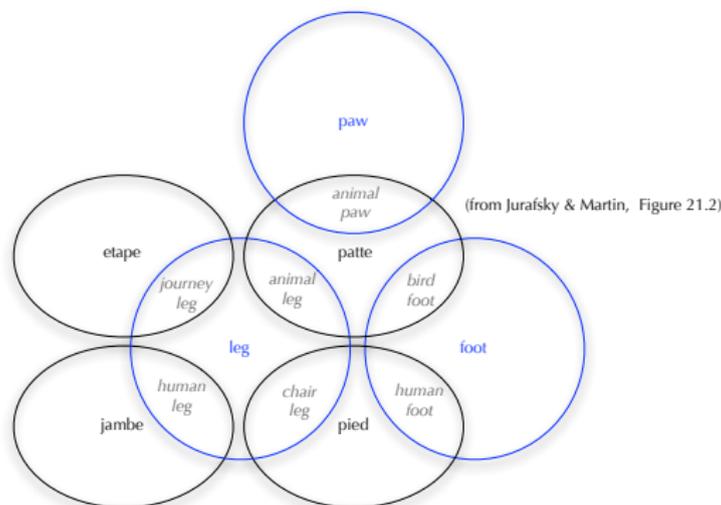
Religious texts, legal documents, business correspondence, technical documents, news sources, etc. are sometimes referred to as *sublanguages*

- ▶ Sublanguage domains differ across any of a range of dimensions
 - ▶ Specialized vocabularies
 - ▶ Stylistic differences, e.g. active vs. passive voice
 - ▶ Use of headlines, passage and chapter numbers, web addresses, proper names, ...
 - ▶ Variable sentence lengths, e.g. weather forecasts vs. news stories
- ▶ The same translation system cannot be used for all genres
- ▶ Text from one genre may not be suitable for building systems in another genre

Word Sense and Context: Translation Must Depend on Word Sense

Ambiguous words should be translated based on their *sense* : e.g. bank, plant, leg, ...

- ▶ Should an instance of *leg* be translated as *etape* , *pied* , *patte* , or *jambe* ?



Fortunately word sense is often (easily) determined by *context*, even for idioms

... *you're just pulling my leg* ... (English) ⇔ ... *mi stai prendeno per il naso* ... (Italian)

Morphology

Morphological variation across languages leads to modeling difficulties in translation

- ▶ Morphological analysis must be applied prior to processing
- ▶ Surface variability leads to sparsity of individual tokens in text translations

Example of Arabic tokenization and morphological analysis

. وينتج المفاعل البلوتونيوم اللازم لتصنيع القنبلة الذرية .

[and-produces] [the-reactor] [the-plutonium] [the-required] [to-build] [the-bomb] [the-atomic] . ← gloss

wyntj AlmfAEI Alblwtwnywm AllAzM ItSnyE AlqnbIp Al*ryp . ← Romanized text

w+ yntj AlmfAEI Alblwtwnywm AllAzM l+ tSnyE AlqnbIp Al*ryp . ← MADA Morphological Analyzer

- ▶ longer sentences, but fewer distinct tokens

Sources of variation

- ▶ Polysynthetic languages – *Siberian*
A single word might correspond to a single English sentence
- ▶ Agglutinative languages – *Turkish*
Morphemes are segmentable
- ▶ Fusion languages – *Russian*
affixes and prefixes carry syntactic meaning

Movement – Variations in Word Order

Languages are often classified by the ordering of their subject, verb, and object clauses .

- ▶ S-V-O – *English*
- ▶ S-O-V – *Japanese*
- ▶ V-S-O – *Arabic*

For example, in translating from Arabic into Japanese, the verb might have to be ‘moved’ from a sentence initial position to a sentence final position.

Movement leads to computational difficulties in machine translation

- ▶ Ordering changes in translation are not deterministic
- ▶ The number of possible reorderings grows exponentially with sentence length
- ▶ Considering arbitrary reorderings in automatic translation can be an NP-Complete problem³

³K. Knight, "Decoding Complexity in Word-Replacement Translation Models," *Computational Linguistics*, 25(4), 1999

Names Are Often Transliterated Rather Than Translated

Transliteration is writing a word from one language using the *closest* corresponding orthography of a different language

- ▶ *Closeness* is often defined ‘phonetically’, i.e. the transliteration attempts to describe the pronunciation of a foreign word
- ▶ Transliteration of English into Chinese finds the syllables corresponding to a Chinese approximation to the English name ⁴
 - ▶ “Bush” → /bu shu/
 - ▶ “Clinton” → /kk lin dun/

- ▶ A written form with that pronunciation is then chosen

Transliterations are rarely unique and are often difficult to spot in “foreign” text

- ▶ As another example, “Kosovo” can be transliterated into Chinese in several ways

科索沃 /ke-suo-wo/, 科索佛 /ke-suo-fo/,
 科索夫 /ke-suo-fu/, 科索伏 /ke-suo-fu/, or
 柯索佛 /ke-suo-fo/.

and all of the above should be translated back into English as “Kosovo”

- ▶ Machine Translation systems must
 - ▶ Identify names that are to be transliterated rather than translated
 - ▶ Identify transliterations found in the foreign text and normalize them prior to translation

⁴Meng *et al.*, “Generating Phonetic Cognates to Handle Named Entities in English-Chinese Cross-Language Spoken Document Retrieval”, ASRU 2001

Statistical Machine Translation and Automatic Speech Recognition

Like ASR, SMT can be formulated using a Source-Channel model.



For a given English sentence E , the Translation Model $P(F|E)$

- ▶ provides the likelihood that any foreign sentence F is a valid translation
- ▶ 'generates' foreign sentences F probabilistically from 'E'

Both the transcription and the translation are found as Maximum A Posterior estimates.

Transcription

Input - an English utterance A

Output - an English transcription \hat{W}

$$\begin{aligned} \hat{W} &= \operatorname{argmax}_W P(W|A) \\ &= \operatorname{argmax}_W \frac{P(A|W) P(W)}{P(A)} \\ &= \operatorname{argmax}_W \underbrace{P(A|W)}_{\text{Acoustic Model}} \underbrace{P(W)}_{\text{Source Language Model}} \end{aligned}$$

Translation

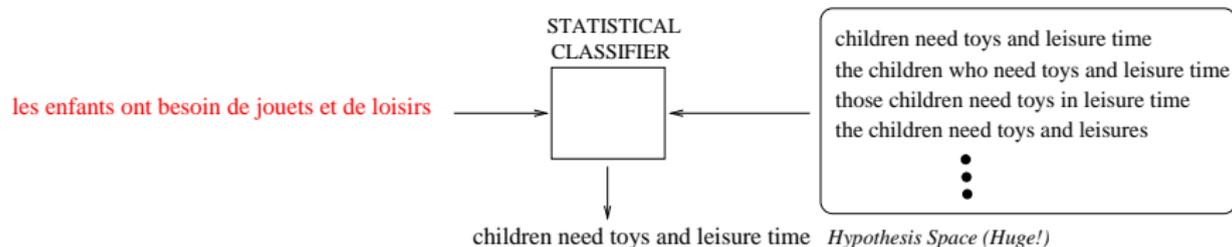
Input - a foreign sentence F

Output - an English sentence \hat{E}

$$\begin{aligned} \hat{E} &= \operatorname{argmax}_E P(E|F) \\ &= \operatorname{argmax}_E \frac{P(F|E) P(E)}{P(F)} \\ &= \operatorname{argmax}_E \underbrace{P(F|E)}_{\text{Translation Model}} \underbrace{P(E)}_{\text{Source Language Model}} \end{aligned}$$



Statistical Machine Translation and Pattern Recognition



Source-Channel Formulation: Input - a Foreign sentence F , Output - an English sentence \hat{E}

$$\hat{E} = \operatorname{argmax}_E P(E|F) = \operatorname{argmax}_E \frac{P(F|E) P(E)}{P(F)} = \operatorname{argmax}_E \underbrace{P(F|E)}_{\text{Translation Model}} \underbrace{P(E)}_{\text{Source Language Model}}$$

- ▶ The Source Language Model $P(E)$ can be estimated using *monolingual text* using the same techniques developed for use in speech recognition
- ▶ The next lecture will focus on the Translation Model $P(F|E)$
 - ▶ How should the model be formulated to capture the linguistic phenomena discussed earlier?
 - ▶ How can the model be formulated so that its parameters can be estimated from collections of translations, known as *Parallel Texts*?

Parallel Texts for Training and Evaluation of SMT Systems

A parallel text corpora consists of translations in two (or more) languages.

Parallel text can be **aligned** to identify **translation equivalence**

Translation (and therefore alignment) is a multi-level, hierarchical process

- ▶ Documents are aligned within collections ...
- ▶ Paragraphs are aligned with documents ...
- ▶ Sentences are aligned within paragraphs ...
- ▶ Words are aligned within sentences ...

Aligned elements in parallel texts are translations of each other.

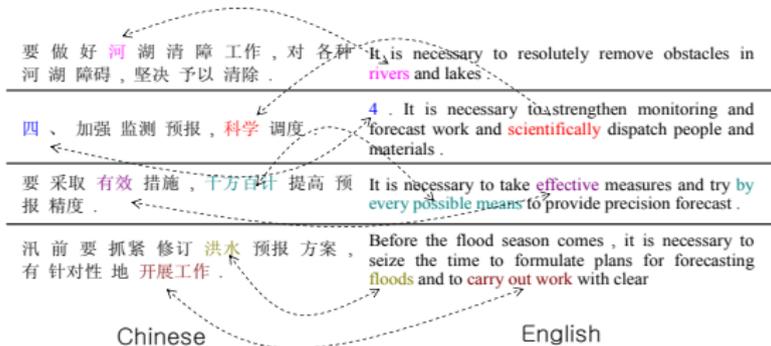
Alignments can be obtained in several ways

- ▶ Manually – Human translators mark alignment at the appropriate level
- ▶ Semiautomatically - Monolingual texts contain information that can be easily identified and used in alignment across languages, e.g. Chapter Headings, Verse Numbering, etc.
- ▶ Automatically – using statistical models, as will be discussed

Parallel text collections can be quite large – millions of words

- ▶ Parameters of statistical translation models can be estimated from these collections
- ▶ SMT systems can be **scored** against known translations

Chinese and English Text Aligned at the Sentence and Word Levels



Sentence Aligned French-English Parallel Text

Parallel documents with alignment information inserted :

[1] Perhaps the Commission or you could clarify a point for me. [2] It would appear that a speech made at the weekend by Mr Fischler indicates a change of his position. [3] I welcome this change because he has said that he will eat British beef [4] and that the ban was imposed specifically for economic and political reasons.

[1] La Commission ou vous-même pourriez peut-être m'expliquer un point. [2] Il semblerait en effet que M. Fischler ait changé de position dans un discours prononcé au cours de ce week-end. [3] Je me félicite de ce changement, car il a dit qu'il mangerait du boeuf britannique [4] et que l'interdiction avait été décrétée spécifiquement pour des raisons économiques et politiques.

- ▶ 'Markers' are inserted into the text to indicate the start and end of translation segments
- ▶ Translation segments can be sub-sentence units, e.g. at [4]