# Engineering Part IIB: Module 4F11

# Speech and Language Processing

# Lecture 11: Introduction to Statistical Machine Translation

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Lent 2016

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# 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

EUROPEAN PARLIAMENT

es cs da de et el en fr it lv lt hu mt nl pl pt sk sl fi sv

**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 **Legal notice**

# European Union Parliamentary Proceedings

| German | English | French |
|---|---|---|
| Offensichtlich bedeutet die Erklärung von Herrn Fischler vom Wochenende eine Änderung der Haltung der Kommission. | It would appear that a speech made at the weekend by Mr Fischler indicates a change of his position. | Il semblerait en effet que M. Fischler ait changê de position dans un discours prononcê au cours de ce week-end. |
| Ich begrüße diese Änderung , denn er sagte , daßer britisches Rindfleisch essen würde und daßdas Einfuhrverbot insbesondere aus wirtschaftlichen und politischen Gründen verhängt wurde. | 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. | 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. |

Directorate-General for Translation (DGT)

**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


# News Sources with Multilingual and Multinational Audiences

Би-би-си | В мире 26/02/2008 17:19

BBC Home News Sport Radio TV Weather Languages ПОИСК

BBC RUSSIAN.com

Без графики | О сайте | Обратная связь

Главная
В мире
Россия
Экономика
Наука и техника
Люди
Культура
Британия

Аналитика
Ваше мнение
Мир в кадре
Learn English
Радио
Видео
Партнеры

Что такое RSS?

БИ-БИ-СИ НА ДРУГИХ ЯЗЫКАХ
УКРАЇНСЬКА
AZƏRBAYCAN
ЎЗБЕК
КЫРГЫЗ
ОСТАЛЬНЫЕ >

## В мире

Обновлено: вторник, 26 февраля 2008 г., 17:05 GMT 20:05 МСК

**Британия: экстремист-проповедник признан виновным**

В Британии признан виновным человек, которого считают одним из главных создателей экстремистской сети на территории королевства.

ВИДЕО >>

Китай нацелился на виноградники Бордо
СМОТРЕТЬ

Видеопоездка по США: четыре сюжета
СМОТРЕТЬ

ДРУГИЕ ВИДЕОСЮЖЕТЫ >>

**В Пакистане снят запрет на доступ к YouTube**

**Оркестр из США дал концерт в Пхеньяне**

**Американец выиграл $275 млн.**

АКТУАЛЬНО

**Дивы Голливуда**
Церемония "Оскаров" в дамах, платьях и украшениях

**Шансы Хиллари**
В борьбе за Белый дом Барак Обама уходит в отрыв

**Фидель Кастро**
Жизнь кубинского лидера в фотографиях

ДРУГИЕ НОВОСТИ

Патаркацишвили похоронят в четверг
Рост экономики США "прекратился"
"Свадьбу" обезьян в Индии посетили тысячи
Козулин сможет проститься с женой
Белый тюрбан сенатора Обамы вызвал скандал
Новые сведения о ядерной программе Ирана

АНАЛИЗ, КОММЕНТАРИИ

Пресса США: Удача косоварам не помешает
Могилевича связали с поставками газа Польше
Признание Косова вызвало юридическую бурю

ИЗБРАННОЕ

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

**Наше видео**
Самые свежие сюжеты BBCRussian.com

**Клуб блоггеров**
Клуб блоггеров Би-би-си приглашает вас к дискуссии

Русская служба Би-би-си – Информационные услуги

Новости по почте | Для мобильных устройств | Новостной канал (RSS)

Вернуться ^^

О сайте | Обратная связь | Партнеры | Погода | Конфиденциальность

Liveinternet СЕРВИС СТАТИСТИКИ | УЧАСТНИК Rambler's TOP 100

http://news.bbc.co.uk/hi/russian/international/default.stm Page 1 of 1

BBC NEWS | UK 26/02/2008 17:19

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## 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
Hate speech: What they said
UK 'terror camps' revealed

**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.

**Lib Dem ordered out of EU debate**

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

FEATURES, VIEWS, ANALYSIS

**Terror recruiter**
East London man trained with would-be suicide bombers

**Nick Robinson**
Oh dear, it seems I've angered a growing number of MPs

VIDEO AND AUDIO NEWS HIDE

Hugh Grant: Help people die at home
WATCH

LISTEN One-minute summary

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

More Video / Audio News

TV AND RADIO PROGRAMMES SHOW
MOST POPULAR VIDEO AND AUDIO SHOW

MORE FROM THE UK

Iraq minutes 'should be released'
UK work applicants near 800,000
Hospital staff axed 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 quizzed over fatal stabbing

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'

ENGLAND
Man 'stabbed daughter 13 times'
Brothers found guilty of murder

NORTHERN IRELAND
Review follows legal papers find
Donaldson takes up minister post

SCOTLAND
Cheap island ferry plan launched
Gun attack 'like gangster film'

WALES
Concern over school performance
E.coli butcher 'was allowed time'

OTHER TOP STORIES
Super-casino proposal is ditched
Jersey 'abuse cover-up' is denied
Anti-depressants' 'little effect'
MPs' expenses review speeded up
MI6 'did not keep files on Diana'
Missing girl police 'fear worst'
Bank warns of economic risks

ALSO IN THE NEWS

Small tawny owl turns heads after being rescued from pipe

SPORT HEADLINES

**Hicks denies Liverpool sale claim**

Football: Moyes' European focus
Athletics: Williamson makes team

**Six-year mystery**
What happened to bright, vivacious Milly Dowler?

HAVE YOUR SAY

**Companies know that the gateway to your money is through your children**
Emma, Kettering

MOST POPULAR STORIES
From UK

MONDAY
Pilot sacked after fly-by stunt

SUNDAY
Airline in first biofuel flight

SATURDAY
Mandatory DNA database rejected

FRIDAY
Claim UK troops 'executed' Iraqis

THURSDAY
New airport flight paths proposed

UK WEATHER
Select a city: Go

http://news.bbc.co.uk/2/hi/uk_news/default.stm Page 1 of 2

# 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

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

# Translation Should Respect Document Domain and Genre

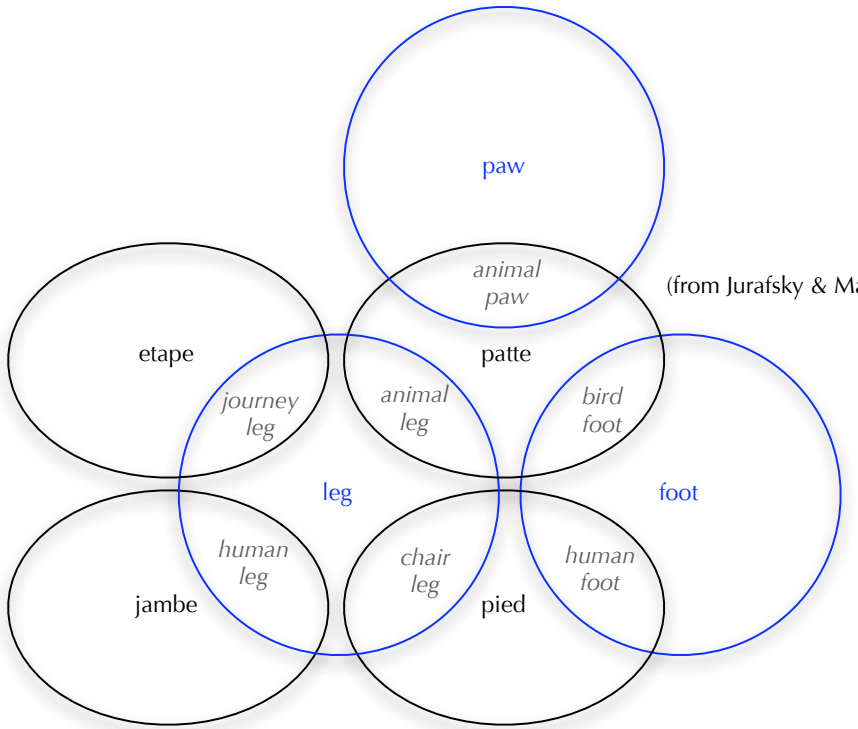
Religious texts, legal documents, business correspondence, technical documents, news sources, etc. are sometimes referred to as *sublanguages*

- 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* ?




(from Jurafsky & Martin, Figure 21.2)

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 AlmfAEl Alblwtwnywm AllAzm ltSnyE Alqnblp Al*ryp . ⇐ Romanized text

w+ yntj AlmfAEl Alblwtwnywm AllAzm l+ tSnyE Alqnblp Al*ryp . ⇐ MADA Morphological Analyzer

- longer sentences, but fewer distinct tokens

Sources of variation

- Polysnthetic 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 problem[3]

[3] K. 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

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

# Discourse and Meaning

This sentence has five words

В этом предложении пять слов ✓

Это предложение состоит из пяти слов ✗

# Social Media

Spanish

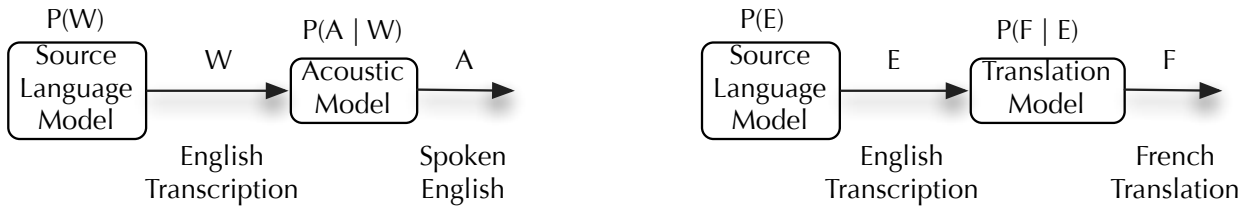
- ahhhhhhhhhhhhhhhhhhhhh siiiiill omg omg omg por diooooooos no lo puedes creer!!! espaa es tan pero tan chipadrevere!!!! y algo mas... me quedo hasta el savadoooo :D :D :D nena cuidate oiste... ojala la estes pasando super bien ok??? ha
- su musica es muy hermosalos adoro
- aww qe lindo0 esteban io tmb te qiero baby :)
- ellos practicaron duro aller
- me duele saber ke nunca te importe
- muy difisil
- hola,com estas?

English

- iam off tomarrow
- Eh! Waiter servame a beer more
- HI AS THESE? My name is EDUARDO I'm FROM MEXICO AND I wanted THANK YOU FOR AGREGARME..HAVE MSN? AH if it did not understand WAS THE FAULT OF THE TRANSLATOR. 34 AND I HOPE KNOW YOU SOON.KISSES
- im trying to write in korean
- he's def a cutie!!

# 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 $\widehat{W}$

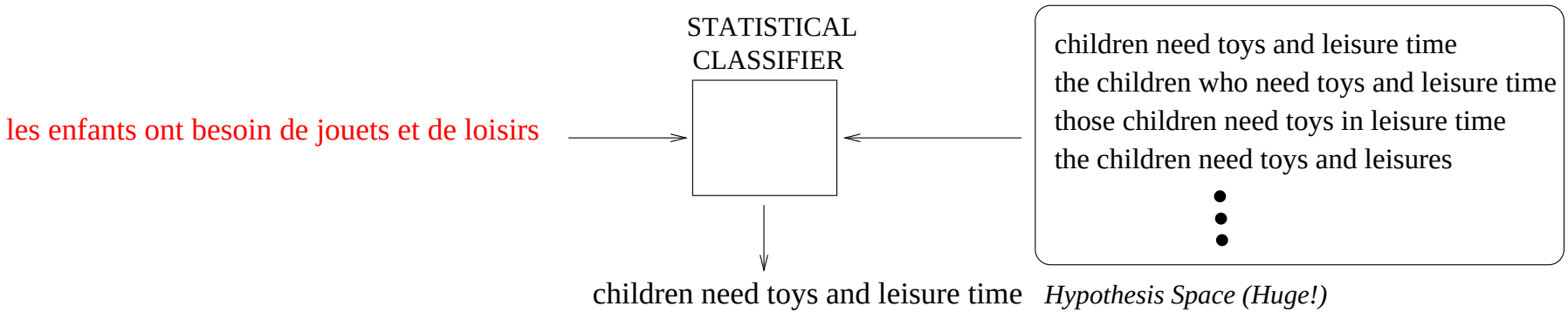
$$\begin{aligned}\widehat{W} &= \text{argmax}_W\, P(W|A) \\ &= \text{argmax}_W\, \frac{P(A|W)\,P(W)}{P(A)} \\ &= \text{argmax}_W\, \underbrace{P(A|W)}_{\textit{Acoustic Model}}\ \underbrace{P(W)}_{\textit{Source Language Model}}\end{aligned}$$

**Translation**

Input - a foreign sentence $F$
Output - an English sentence $\widehat{E}$

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

# Statistical Machine Translation and Pattern Recognition




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

$$\widehat{E} = \underset{E}{\text{argmax}}\, P(E|F) = \underset{E}{\text{argmax}}\, \frac{P(F|E)\,P(E)}{P(F)} = \underset{E}{\text{argmax}}\, \underbrace{P(F|E)}_{\substack{\textit{Translation}\\ \textit{Model}}}\ \underbrace{P(E)}_{\substack{\textit{Source}\\ \textit{Language Model}}}$$

- 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.*

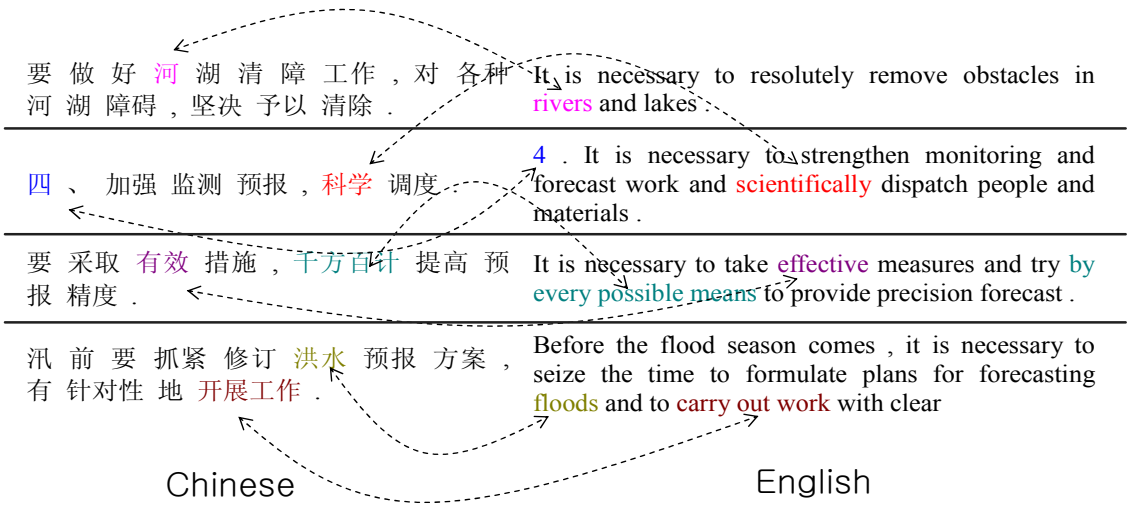
Alignments can be obtained in several ways

- 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]