Lecture 07:
Machine Translation

OVERVIEW

1. Introduction to machine translation
2. Statistical machine translation
3. Why is machine translation hard
4. Evaluation of machine translation

MACHINE TRANSLATION (MT)

Machine Translation (MT) is the task of translating a sentence *x* from one language (the source language) to another sentence *y* in another language (the target language).

source: L'homme est né libre, et partout il est dans les fers.

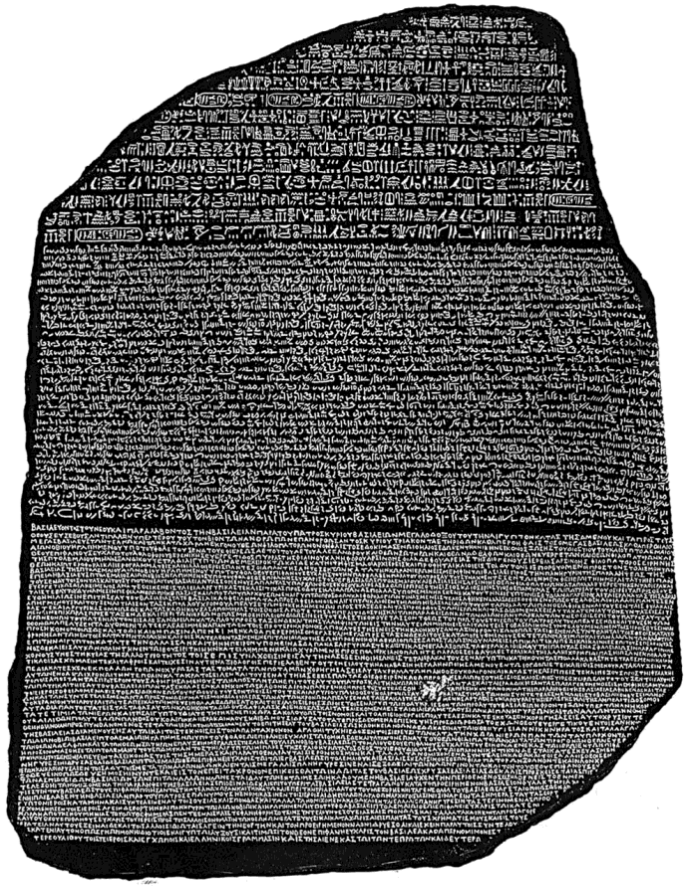
target: Man is born free, but everywhere he is in chains.

- Rousseau

The Rosetta Stone

First known historical evidence of translation

First instance of parallel text: Greek inscription allowed scholars to decipher the hieroglyphs



Hieroglyphic: used by priest in ancient Egypt

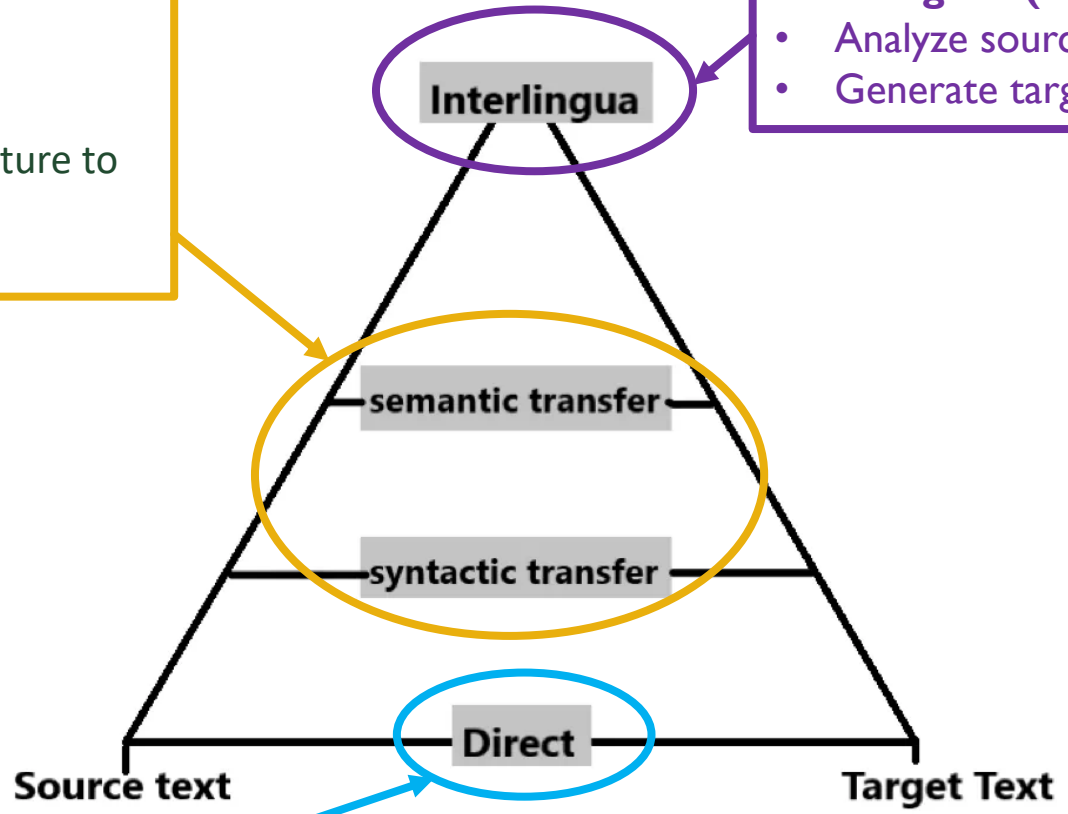
Demotic: used for daily purposes in Egypt

Ancient Greek: used by the administration

EVOLUTION OF MACHINE TRANSLATION - VAUQUOIS TRIANGLE

Transfer-based:
- parse source language
- determine its structure
- apply rules to transfer structure to target language

Interlingual: (language independent representation)
- Analyze source language and represent as interlingual
- Generate target from interlingual



depth of analysis

Amount of transfer knowledge

Direct transfer:
Word-by-word (no language structure)

https://towardsdatascience.com/the-vauquois-triangle-mystery-solved-420ca995e70b

STATISTICAL MACHINE TRANSLATION (SMT)

- Suppose we want to translate a text from *French* to *English*
- We need to find the *best English sentence* y, given a *French sentence* x $\quad P(y|x), \forall y \in \Omega$

$$\underset{y}{\operatorname{argmax}}\, P(y|x) = \underset{y}{\operatorname{argmax}}\, P(x|y)P(y)$$

Bayes Rule

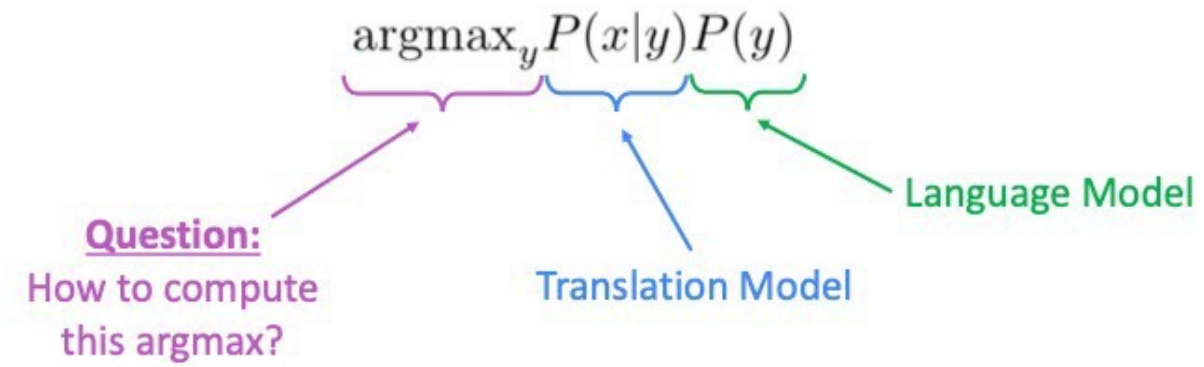
Translation Model

Models how words and phrases should be translated (*fidelity*). Learnt from parallel data.

Language Model

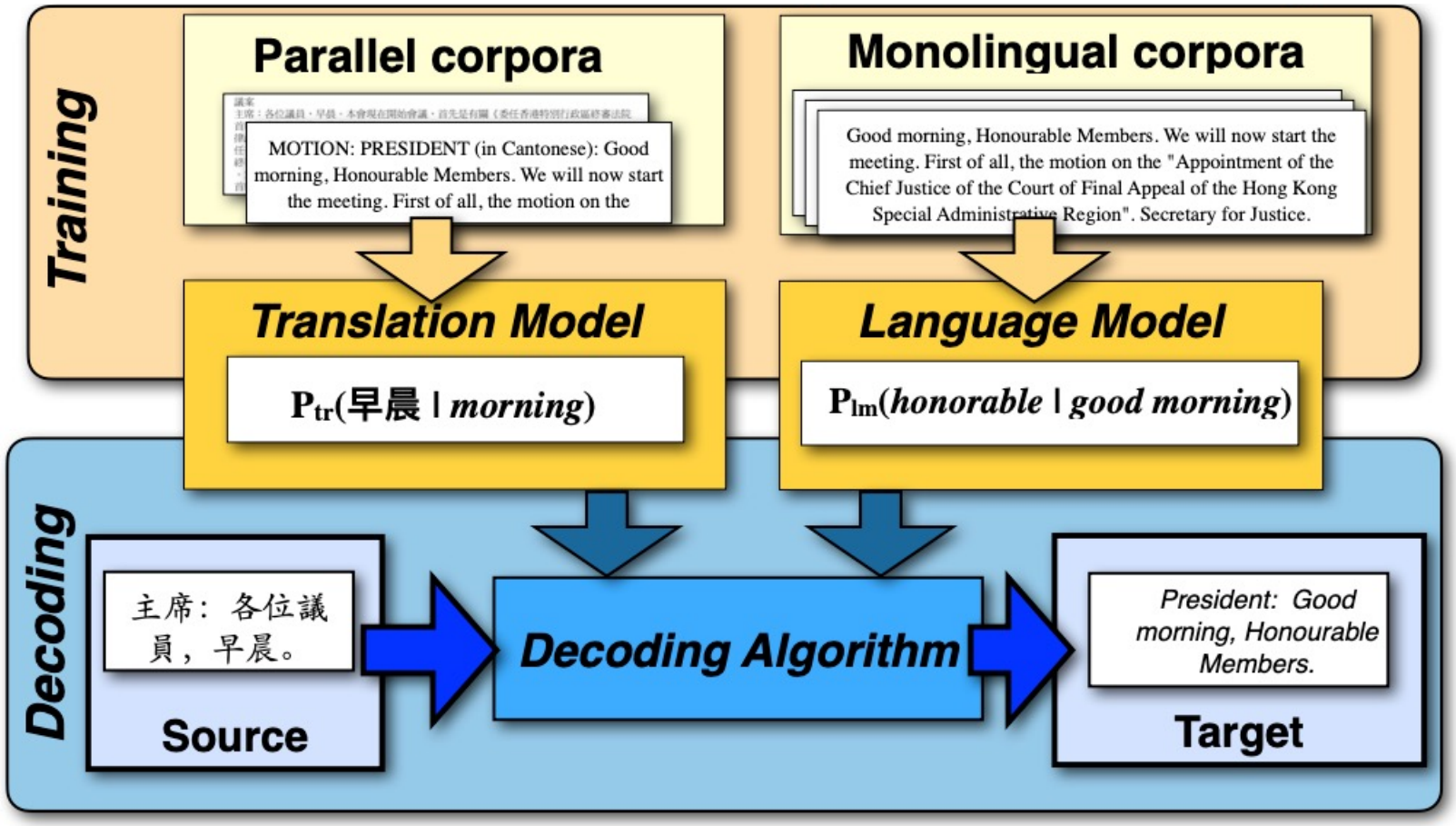
Models how to write good English (*fluency*). Learnt from monolingual data.

LEARNING ALIGNMENT FOR SMT



- Enumerate every possible *y* and calculate the probability? **too expensive!**
- **Solution (decoding):** Use a heuristic search algorithm to search for the best translation, discarding hypotheses with very low-probability
- Decoder maps words/pharses/sentence from one language to another

SMT training and decoding



STATISTICAL MACHINE TRANSLATION (SMT)

How do we learn the translation model $P(x|y)$?

- large corpus of parallel text (French/English)
- Rewrite the translation model

$$P(x|y) \approx P(x, a|y)$$

where *a* is an alignment or correspondence

- an alignment is a correspondence between target (French) sentence x and source (English) sentence y

alignment ⇔ *decoder*

DECODING IN SMT

Find translation that maximizes $P(y \mid x)$

- Exhaustive search decoding
  - Try computing all possible sequences y (too expensive)
  - At each time step we are tracking V possible partial translations

- Beam search decoding
  - On each step of decoder keep track of the k most probable partial translation, with K the beam size
  - Beam search is not guaranteed to find optimal solution
  - More efficient than exhaustive search!

STATISTICAL MACHINE TRANSLATION

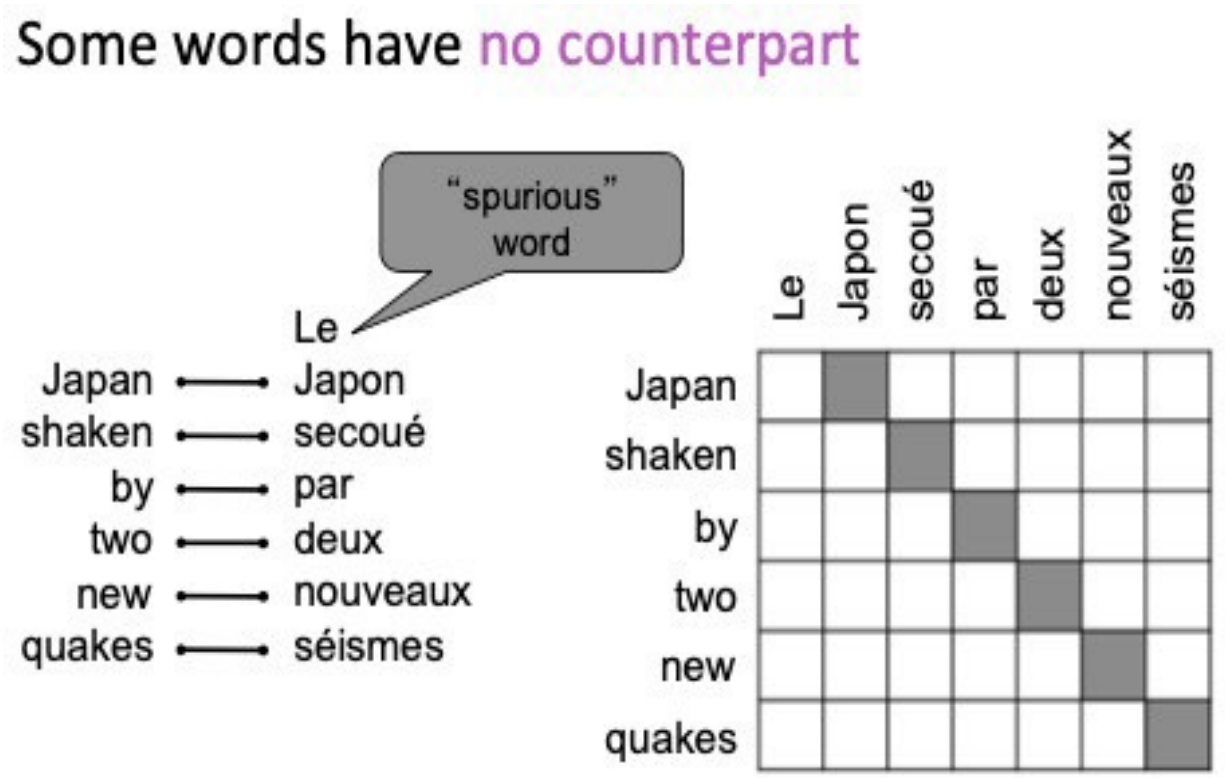
We learn the alignment $P(x, a|y)$ as a combination of many factors

- Probability of particular words aligning, can depend on position in the sentence
- Probability of particular words having specific fertility

Question of interest:

- What's the probability of a French word having a corresponding English word?
- Obtaining and alignment decoder in SMT is not trivial task

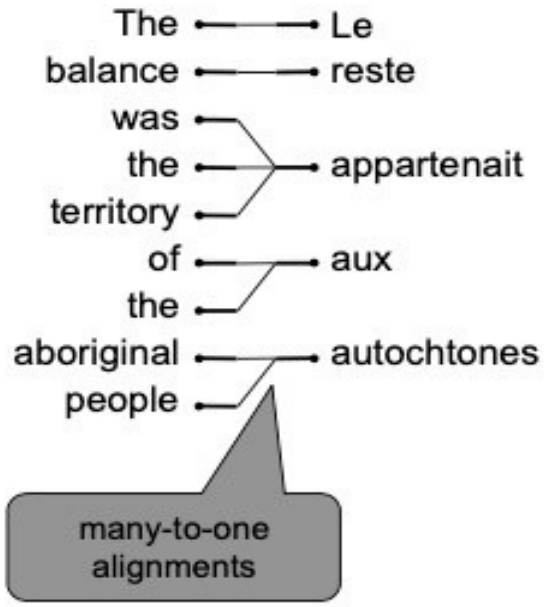
WHY IS MACHINE TRANSLATION HARD?

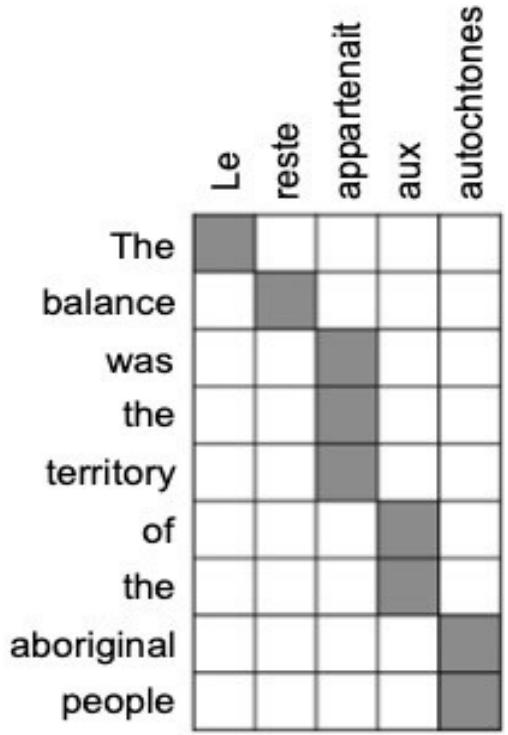


Examples from: "The Mathematics of Statistical Machine Translation: Parameter Estimation", Brown et al, 1993. http://www.aclweb.org/anthology/J93-2003

WHY IS MACHINE TRANSLATION HARD?

Alignment can be many-to-one





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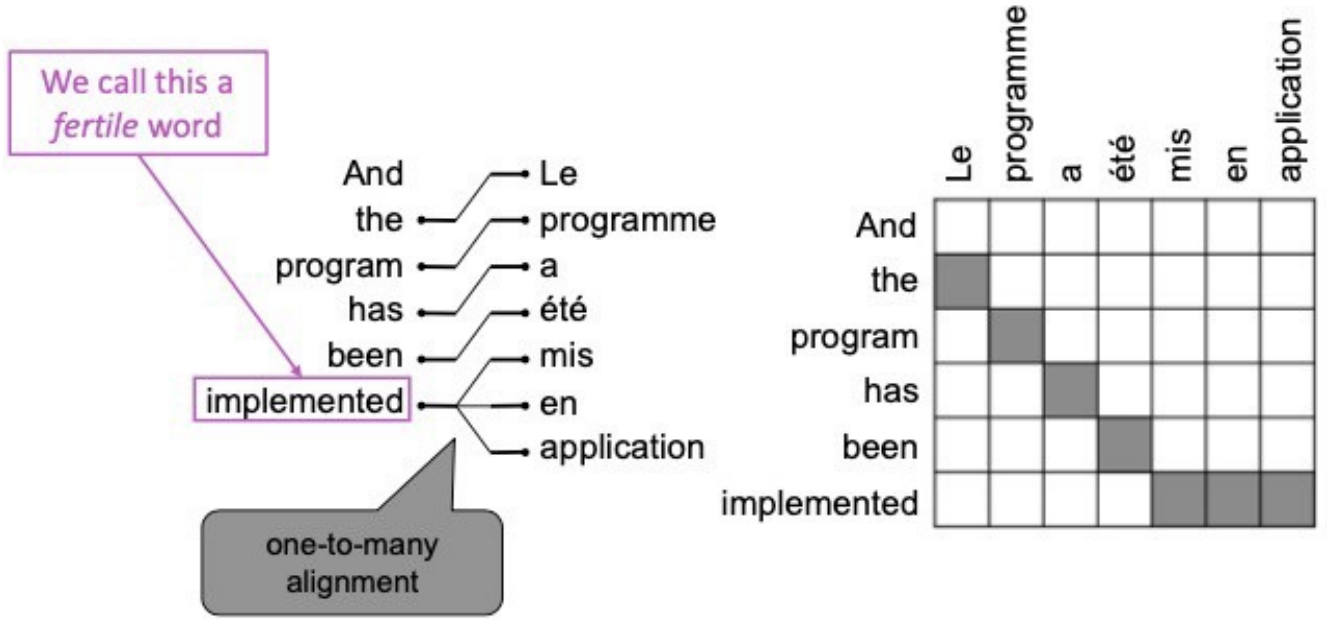
Alignment can be one-to-many



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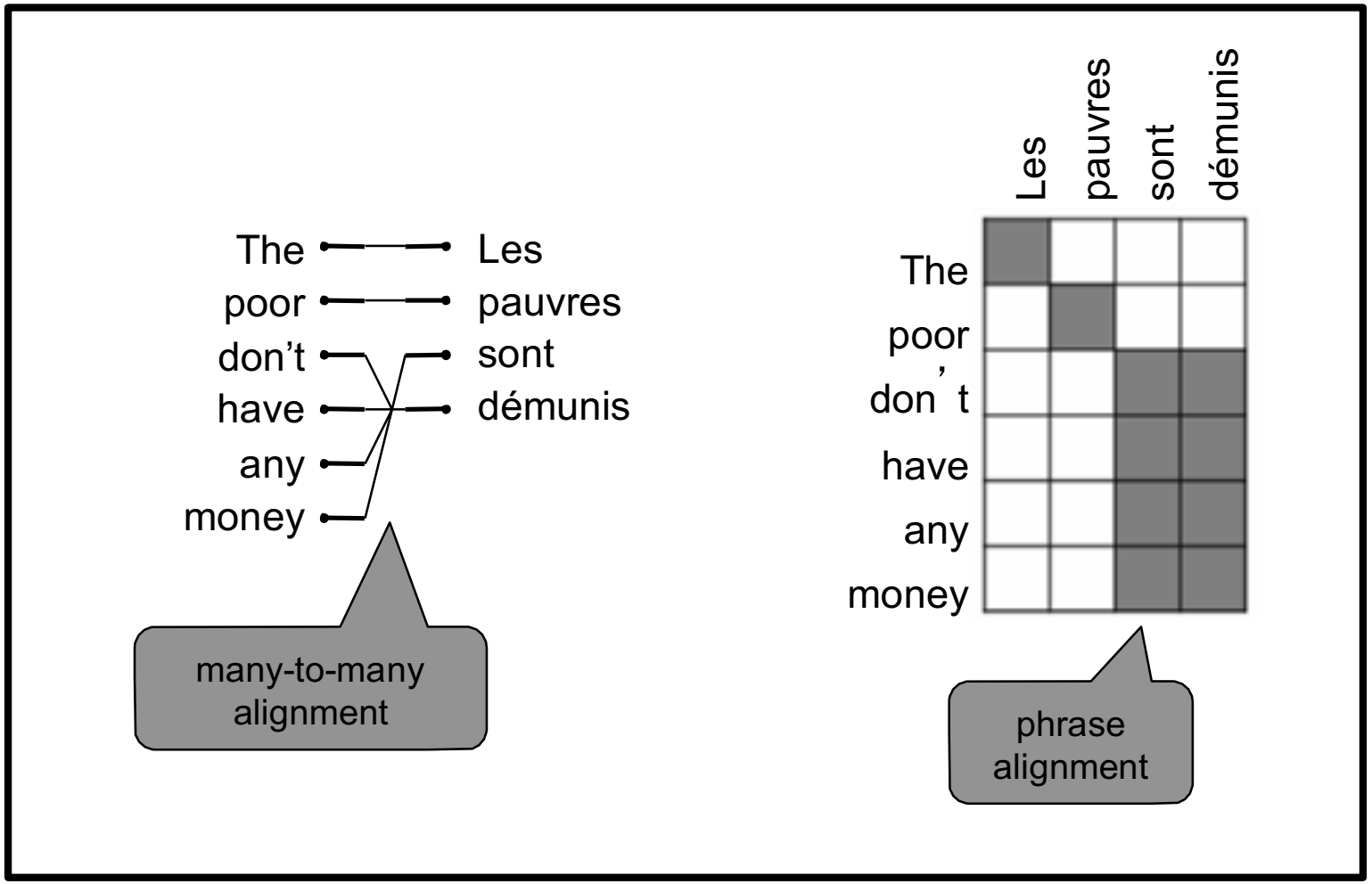

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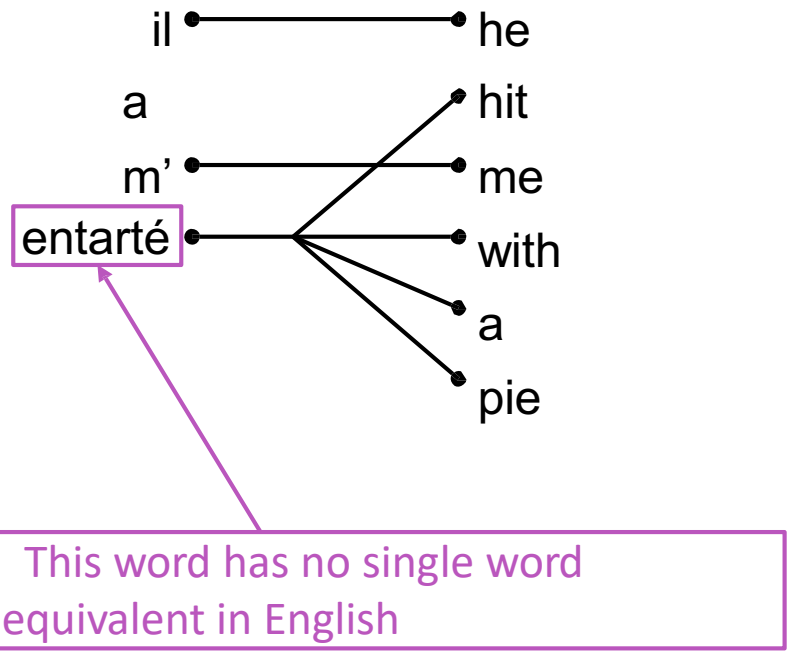
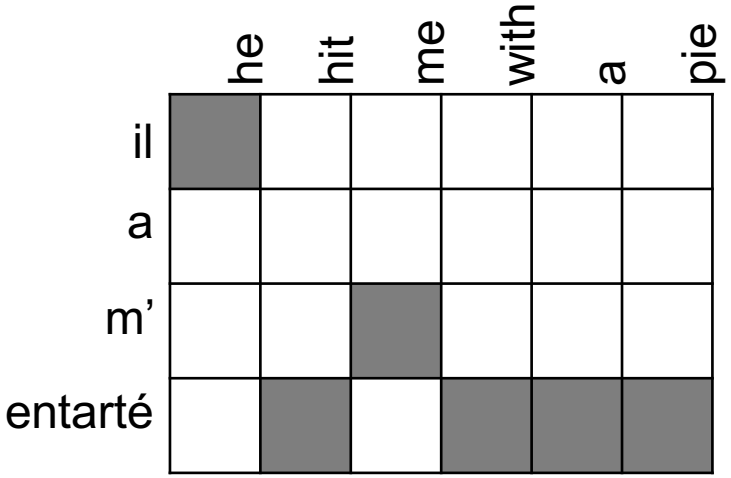


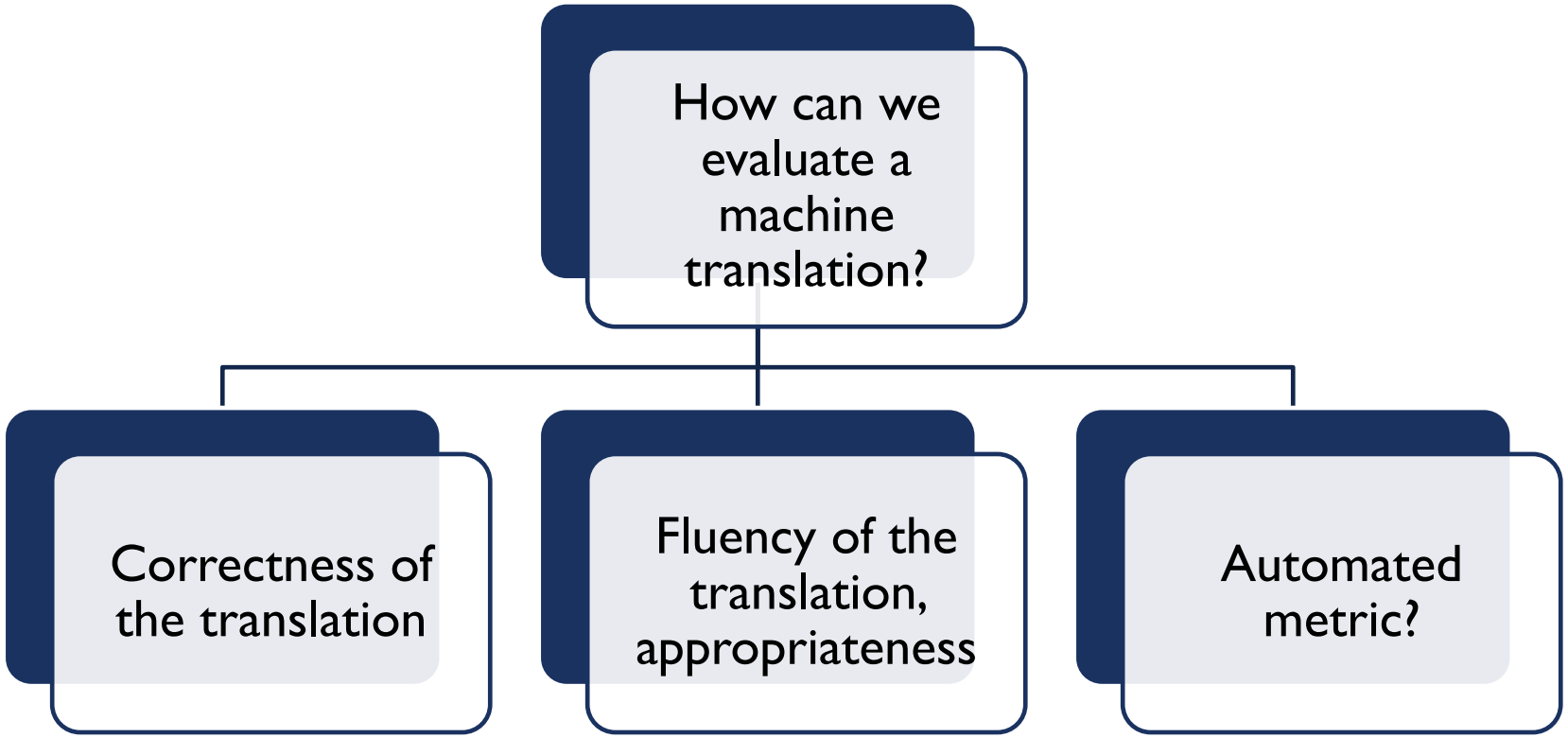


Some words are very fertile! Can map multiple words in the same sentence

SMT SYSTEMS ARE VERY COMPLEX

- A lot of language structure to consider
- Systems had many separately-designed subcomponents
- Lots of feature engineering
  - Need to design features to capture a language phenomena
- Require compiling and maintaining extra resources
  - Like tables of equivalent phrases
- Lots of human effort to maintain
  - Repeated effort for each language pair!

MACHINE TRANSLATION EVALUATION



MACHINE TRANSLATION EVALUATION

Automatic:

- metrics to assess the quality of machine translation e.g. BLUE
- not as reliable as human evaluation
- good scalable option when evaluating the overall quality of translation on multiple documents
- Inexpensive but may not capture what we want to evaluate.

Human:

- assessment of translation quality is done by human professional translators.
- not easily reproducible or comparable across evaluators (different judges, different questions, ...)
- more costly and time consuming.

AUTOMATIC EVALUATION: BLUE

Bilingual Evaluation Understudy Score (BLUE): score is based on **n-gram** precisions

- evaluate candidate translations against several reference translations.
- the How many n-grams in the candidate translation occur also in one of the reference translation

C1: It is a guide to action which ensures that the military always obeys the commands of the party.
C2: It is to insure the troops forever hearing the activity guidebook that party direct

R1: It is a guide to action that ensures that the military will forever heed Party commands.
R2: It is the guiding principle which guarantees the military forces always being under the command of the Party.
R3: It is the practical guide for the army always to heed the directions of the party.

AUTOMATIC EVALUATION: BLUE

C1: It is a guide to action which ensures that the military always obeys the commands of the party.
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BLUE - Unigram = 17/18

BLUE: ISSUE OF N-GRAM PRECISION

- What if some words are over-generated?
- An extreme example
  - Candidate: *the the the the the the the.*
  - Reference 1: *The cat is on the mat.*
  - Reference 2: *There is a cat on the mat.*
  - N-gram Precision: 7/7

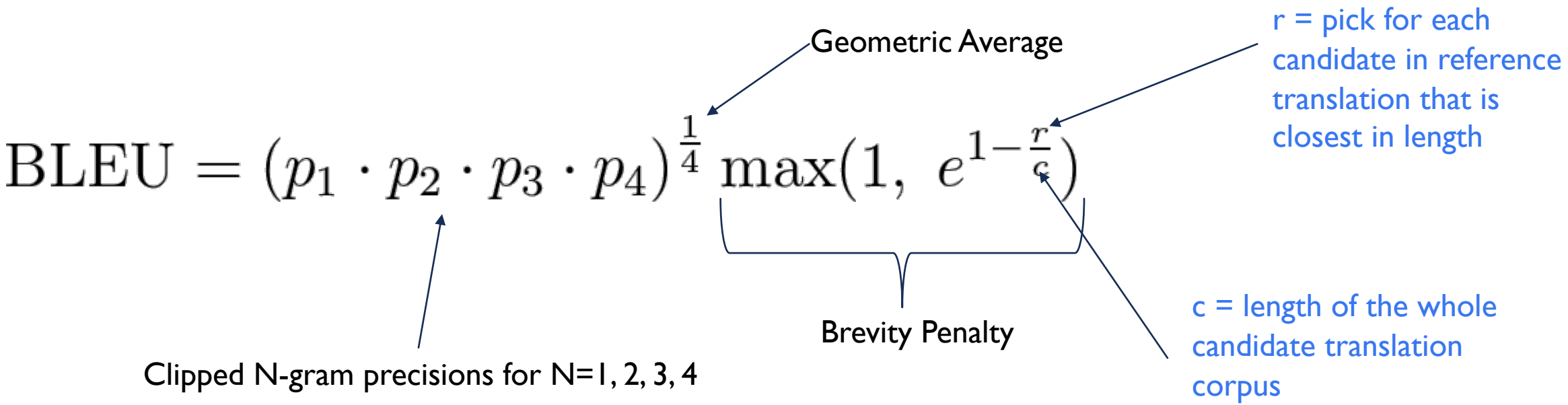
- **Solution:** reference word should be exhausted after it is matched.

BLUE: ISSUE OF N-GRAM PRECISION

- Another extreme example
  - Candidate: *the.*
  - Reference 1: *My mom likes the blue flowers.*
  - Reference 2: *My mother prefers the blue flowers.*
  - N-gram Precision: 1/1

- **Solution:** add a penalty if the candidate is too short.

BLEU - EQUATION



Ranges from 0.0 to 1.0, but usually shown multiplied by 100

An increase of +1.0 BLEU is usually a conference paper

MT systems usually score in the 10s to 30s

Human translators usually score in the 70s and 80s

BLUE ADVANTAGES

- Quick and inexpensive to calculate
- It is easy to understand
- It is language independent
- It correlates highly with human evaluation

HUMAN EVALUATION

We want to know whether the translation is **"good" and accurate** of the original.

- Ask humans to judge the **fluency** and the **adequacy** of the translation (e.g., on a scale of 1 to 5)
- Correlated with fluency is accuracy on **close task**:
  - Give evaluators the sentence with one word replaced by blank.
  - Ask evaluators to guess the missing word in the blank.
- adequacy is **informativeness**
  - Can you use the translation to perform some task (e.g., answer multiple-choice questions about the text)

REFERENCES

- A Survey on Evaluation Metrics for Machine Translation (https://www.mdpi.com/2227-7390/11/4/1006)