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FONDAZIONE  
BRUNO KESSLER

# Introduction to Machine Translation

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**Ninth Machine Translation Marathon**  
**Trento, September 8th-13th, 2014**

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# Outline

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- Motivation
  - Why Machine Translation?
  - Do we need research in Machine Translation?
  - Why is Machine Translation so Difficult?
- Approaches to MT
- Machine Translation Evaluation

# Why Machine Translation?

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- Information society and production of multilingual content
  - 7 billion people - 193 countries - over 150 official languages

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  - > 1,000 global companies operating in at least 160 countries
- Size of worldwide translation market
  - 12.5 billion \$ per year ≈ 34 million \$ per day

# Why Machine Translation?

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- Size of translation industry
  - > 3,000 translation companies
  - > 250,000 translators

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  - competitive quality-cost-speed trade-off
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Source: Common Sense Advisory, 2010

# Do we need research in Machine Translation?

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# Do we need research in Machine Translation?

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Chinglish examples,  
some of which  
resulting from MT  
errors.



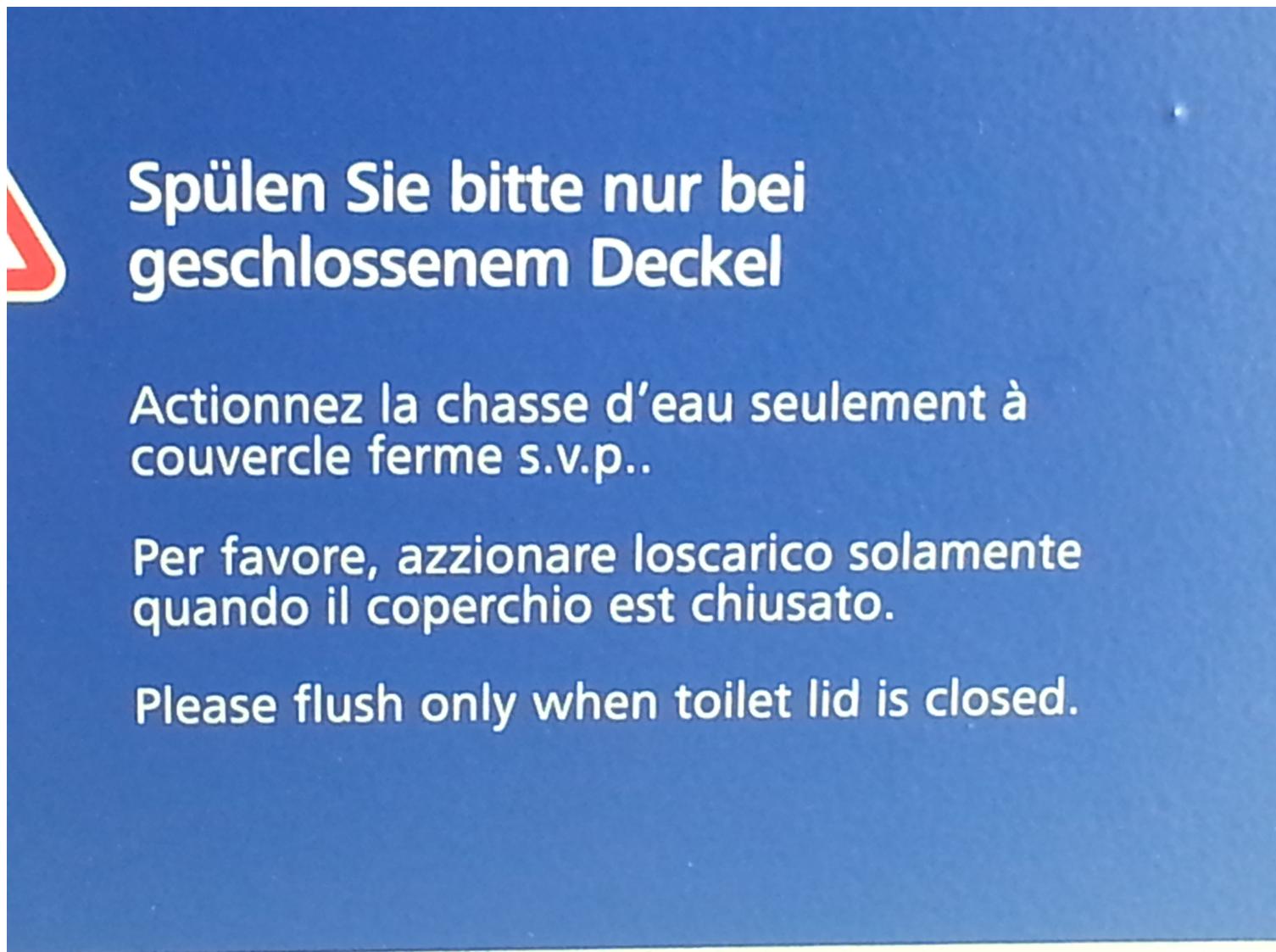
# Do we need research in Machine Translation?

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- Chinese – English
  - difficult translation direction
  - different alphabet
  - several Chinese dialects
  - less resources than other directions
  - ...

# Do we need research in Machine Translation?

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# Why is Machine Translation so Difficult?

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  - sophisticated and creative command of **target language**

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  - even approximate translation are helpful (**gist translation**)
  - professional translators can take advantage of it (**computer assisted translation**)
  - linguistic domain is very focused and limited (**apps for travelers**)

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  - linguistic domain is very focused and limited (**apps for travelers**)
- Difficulty of translating depends on how similar the target and source languages are in their **vocabulary**, **grammar**, and **conceptual structure**.

# Some Applications

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## Stora problem efter helgens regn

Articles : 17 | Last update : Sep 1, 2014 9:53:00 AM | Start : Sep 1, 2014 6:54:00 AM | Sources : 11 | Peak : 1 | Current rank : 1

### Stora problem efter helgens regn

 aftenbladet Monday, September 1, 2014 9:53:00 AM CEST | info [EN](#) [\[en\]](#) [\[other\]](#)

Malmö. Det råder begränsad framkomlighet på flera skånska vägar efter det kraftiga regnovädret i helgen. Även tågtrafiken påverkas i dag. Och i Malmö är hundratals hushåll utan el. Många fastigheter drabbades av stora översvämningar under gården. I Malmös skyskrapa Kronprinsen har bortåt.....

### Major problems after weekend's rain

Malmö. There is limited access to several skånska roads after the heavy regno weather at the weekend. Also trains are affected today. And in Malmö is hundreds of households without electricity. Many real estate was affected by major flooding yesterday. The crown prince has some Malmös skyskrapa in....

[More articles...](#)

## Gist translation for social media

# Some Applications

Traduzione automatica  Originale in inglese

Il tuo giudizio su questa traduzione: Cattiva  Buona

  
andyhg  
Pittsburgh, Pennsylvania

Recensore super  
 77 recensioni  
 Recensioni in 38 città  
 24 voti utili

**"Nice little breakfast"**  
 Recensito il 30 giugno 2012  
Our motel had no breakfast, so we stopped here and were pleased that we could find a nice light breakfast. And the coffee was GREAT!

[Problemi con questa recensione?](#)

[Mostra altre 2 recensioni di andyhg su Monticello](#)

Originale in inglese

Tradotto da:   
Language Weaver

zione: Cattiva  Buona

**"Bella colazione scarsa"**  
 Recensito il 30 giugno 2012  
Il nostro motel aveva senza colazione, così ci siamo fermati qui e siamo stati contenti che siamo riusciti a trovare una leggera colazione buona. E il caffè era FANTASTICO!

[Problemi con questa recensione?](#)

[Mostra altre 2 recensioni di andyhg su Monticello](#)

Traduzione automatica  Originale in inglese

Il tuo giudizio su questa traduzione: Cattiva  Buona

  
forket  
1 recensione

**"A relaxing place"**  
 Recensito il 23 giugno 2012  
We enjoyed a light dinner at the Peace Tree yesterday night. The service was very friendly and the quality of the food was very good, although the choice is not large. Prices are absolutely reasonable. We definitely recommend it. Notice that the restaurant closes at 9pm.

Originale in inglese

Tradotto da:   
Language Weaver

zione: Cattiva  Buona

**"Un posto rilassante"**  
 Recensito il 23 giugno 2012  
Ci siamo goduti una cena leggera presso la Pace Tree ieri notte. Il servizio era molto cordiale e la qualità del cibo era molto buono, anche se la scelta non è molto grande. I prezzi sono assolutamente ragionevoli. Lo consigliamo vivamente. Si noti che il ristorante chiude alle 21.00 .

## Gist translation for social media

# Some Applications

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Speech Translation app.

# Some Applications

The screenshot shows the matecat software interface for translating legal texts between English and French. The top navigation bar includes the logo, project name (LegalText.txt), language pairs (en-US > fr-FR), and tabs for ORIGINAL and PREVIEW. A search icon and a help button are also present.

The main window displays two parallel text blocks:

**Original (Left):** Member States shall, in accordance with this Decision, submit intermediate and final reports as regards programmes approved pursuant to Article 27 of Decision 2009/470/EC.

**Translated (Right):** Les États membres prennent, conformément aux dispositions de la présente décision, de présenter des rapports intermédiaire et final en ce qui concerne les programmes approuvés conformément à l'article 27 de la décision 2009 / 470 / CE.

Below the main text blocks, there are sections for Translation matches, Concordance, and Glossary. The Translation matches section contains several entries, with one entry highlighted by a blue rectangle. This entry shows the source text "Member States shall, in accordance with this Decision, submit intermediate and final reports as regards programmes approved pursuant to Article 27 of Decision 2009/470/EC." and its translation "Les États membres prennent, conformément aux dispositions de la présente décision, de présenter des rapports intermédiaire et final en ce qui concerne les programmes approuvés conformément à l'article 27 de la décision 2009 / 470 / CE." The status bar indicates the source is "MT-FBK Legal (EN>FR) - Ad." and the quality is 44%, with a yellow "MT" button.

At the bottom of the interface, there are progress indicators (Progress: 0%, Payable Words: 451, To-do: 451), management links (Manage, Editing Log, Anonymous (login)), and a page number (12813539, Article 2, 12813540).

Integration of MT into computer assisted translation

# Differences and Similarities of Languages

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- Universal communicative role of language
  - names for people, words for talking about women, men, children
  - every language seems to have nouns and verbs

# Differences and Similarities of Languages

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- Differences/similarities across large classes of languages:
  - Morphology:  
one vs. many morphemes per words, agglutination vs. fusion
  - Syntax:  
Subj-Verb-Obj structure (E) vs. SOV (J) vs. VSO (Irish)
  - Semantics:  
mapping of semantic roles and meaning of words  
e.g. direction/manner of motion indicated by verb/satellite in  
the bottle floated out (E) → la botella salio flotando (S)

# Differences and Similarities of Languages

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- Lexical divergence between languages:
  - **Semantics:**  
there is no corresponding word with the same meaning  
wall (E) → Wand/Mauer (D, inside/outside)
  - **Syntax:**  
a word is better translated into another part-of-speech  
she likes to sing (E,v) → sie singt gerne (D,adv)

# Lexical Divergence

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English	brother	Japanese	otooto (younger) oniisan (older)
English	is	Japanese	isu (subj animate) aru (subj not animate)
English	know	French	connaître (be acquainted with) savoir (know a proposition)
English	they	French	ils (masculine) elles (feminine)
German	Berg	English	hill mountain

---

- Some languages make distinctions that other languages don't
  - Difficulty to translate from less specific into more specific information
-

# Outline

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- Approaches to MT
- Machine Translation Evaluation

# Approaches to MT

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- How is knowledge and linguistic information acquired by the system?
  - Hand-crafted
  - Machine-learned

# Approaches to MT

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- Hand-crafted:
  - knowledge for analysis, transfer, generation, meaning representation, or direct translation is **manually developed**
    - most of commercial MT systems fall into this category
    - requires lots of human labor and expertise
    - includes: rule-based MT

# Approaches to MT

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- Machine-learned:
  - representations are implemented by mathematical models learnable from data
    - much less human effort is needed
    - requires huge amounts of data (parallel corpora of human translations), the more, the better!
    - includes: statistical MT and example-based MT

# History of Machine Translation

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- before 1900 - various suggestions about “mechanic” translation
  - 1940s – computers used to crack the German Enigma code in World War II
  - **1947** - Weaver letter outlining translation as a problem in cryptography
  - 1954 - Georgetown Experiments showed “promise” of Russian-English MT
  - 1966 - ALPAC report shifts funding to basic research in computational linguistics
  - **1968** - MT company SYSTRAN founded (still in existence)
  - 1970s - advances in formal languages and automata theory; development of *statistical speech recognition* techniques at IBM and Princeton
  - **1993** - Weaver’s model of translation prototyped by IBM; *statistical revolution*
  - 1999 - Open source reimplementations of IBM models
  - 2000s - Major modeling advances, rediscovery of syntax, large scale funding
  - **2006** - Open source Moses decoder development begins
  - **2006** - Google Translate launches
  - 2010 - SDL acquires Language Weaver
-

# Warren Weaver to Norbert Wiener, March, 1947

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One naturally wonders if the problem of translation could conceivably be treated as a problem in cryptography. 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.*'



# Noisy Channel Model

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Claude Shannon. “A Mathematical Theory of Communication” 1948.

# Noisy Channel Model

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$M$   
→

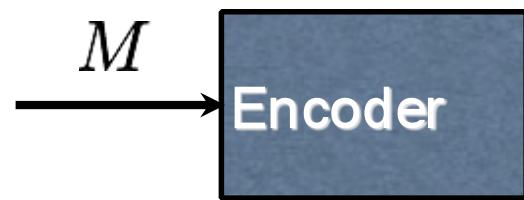
Message



Claude Shannon. “A Mathematical Theory of Communication” 1948.

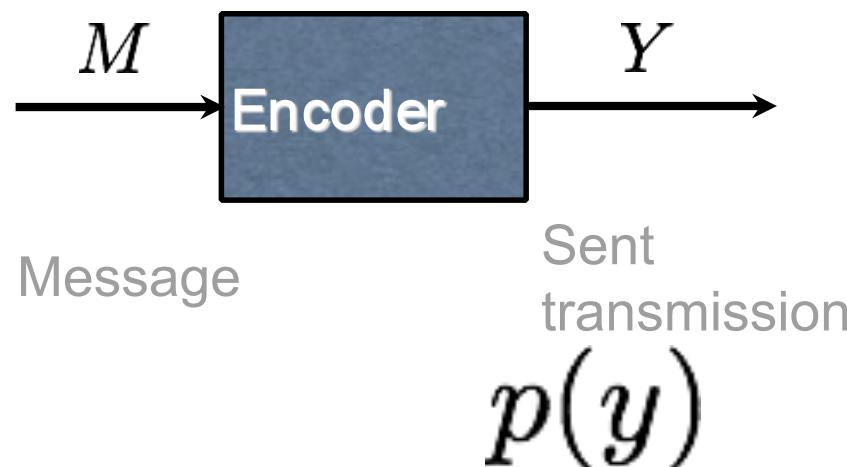
# Noisy Channel Model

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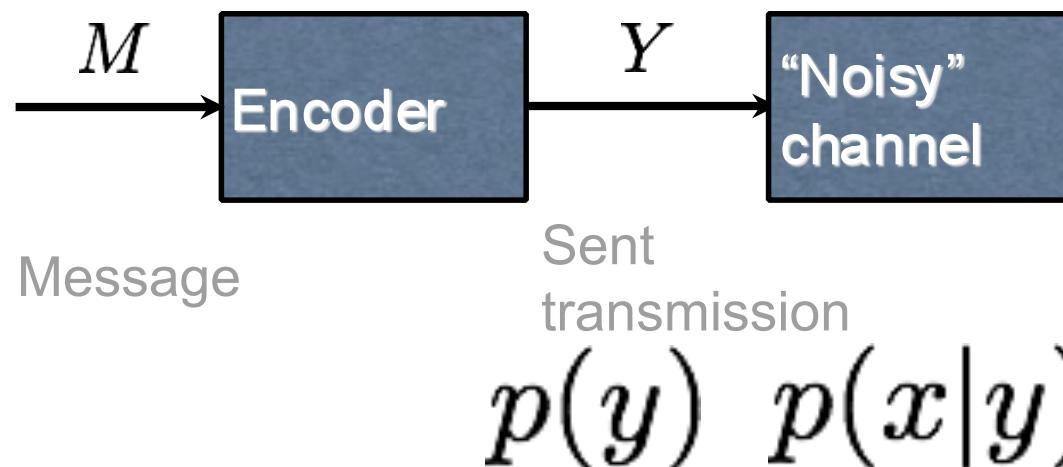
Claude Shannon. “A Mathematical Theory of Communication” 1948.

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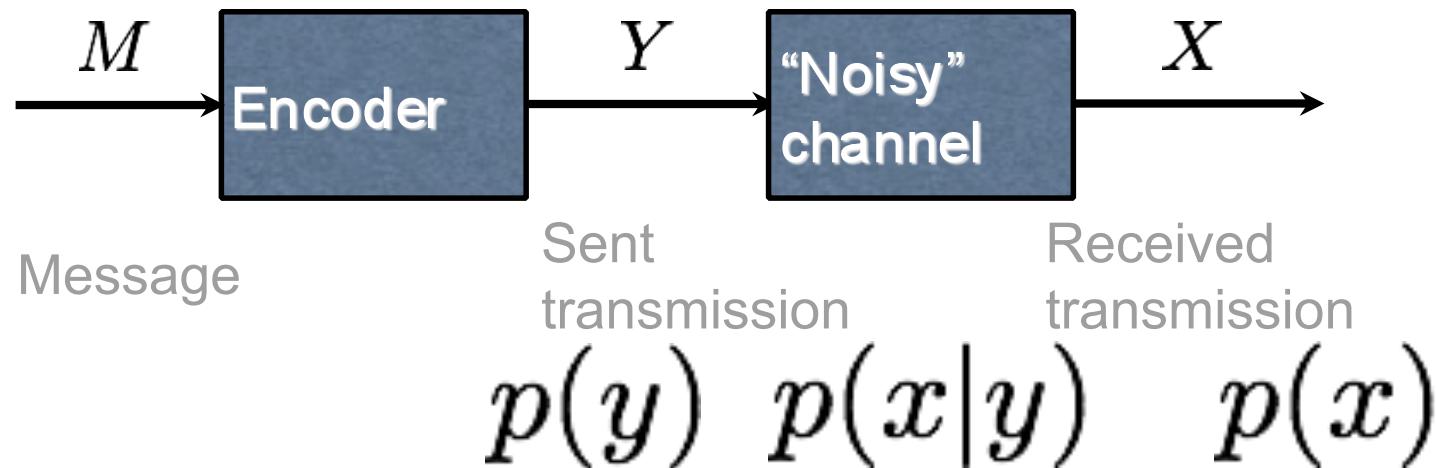
Claude Shannon. “A Mathematical Theory of Communication” 1948.

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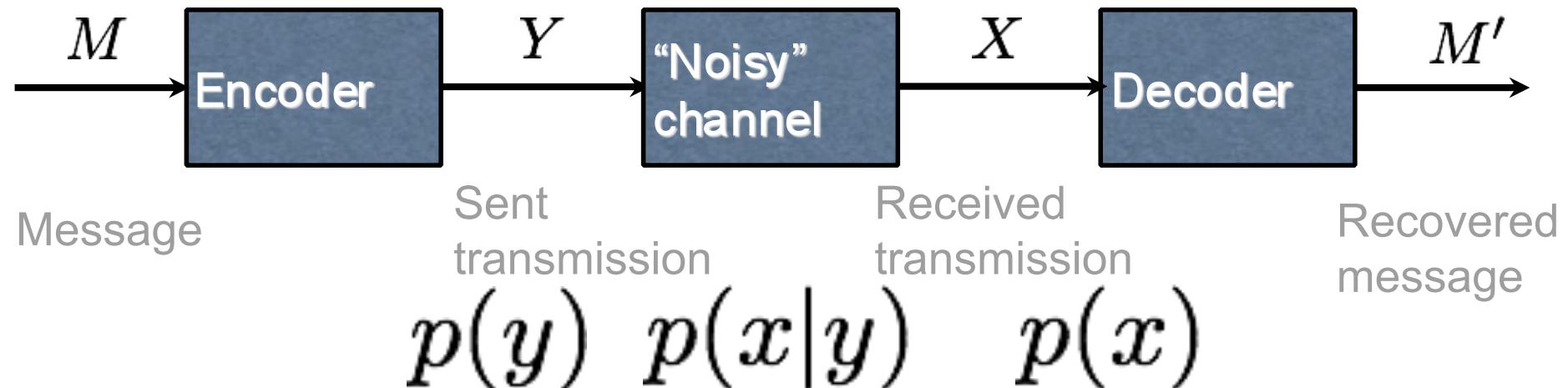
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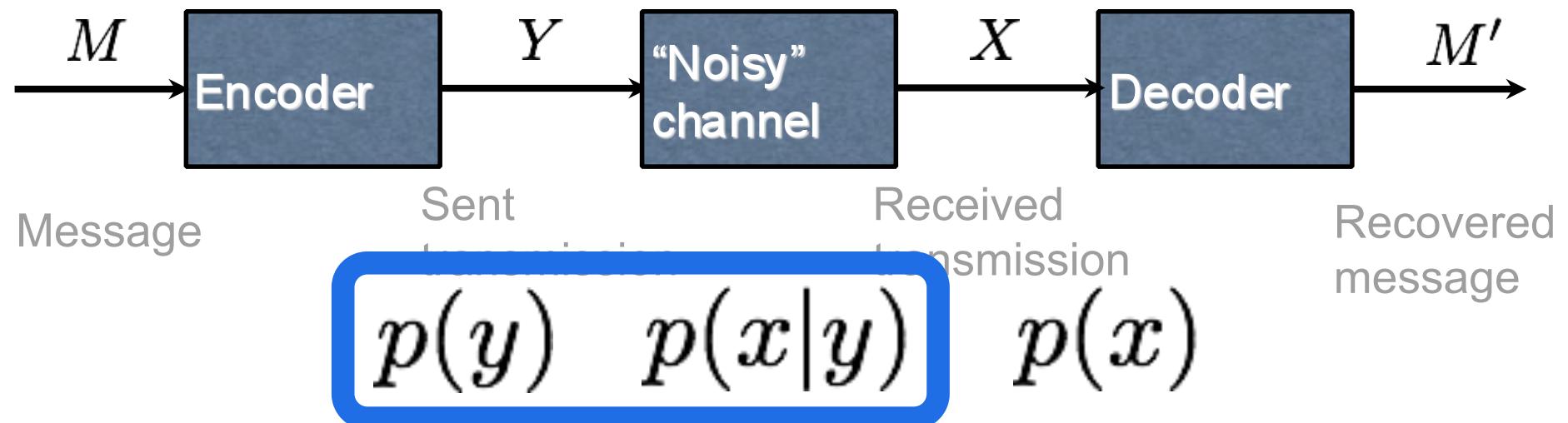
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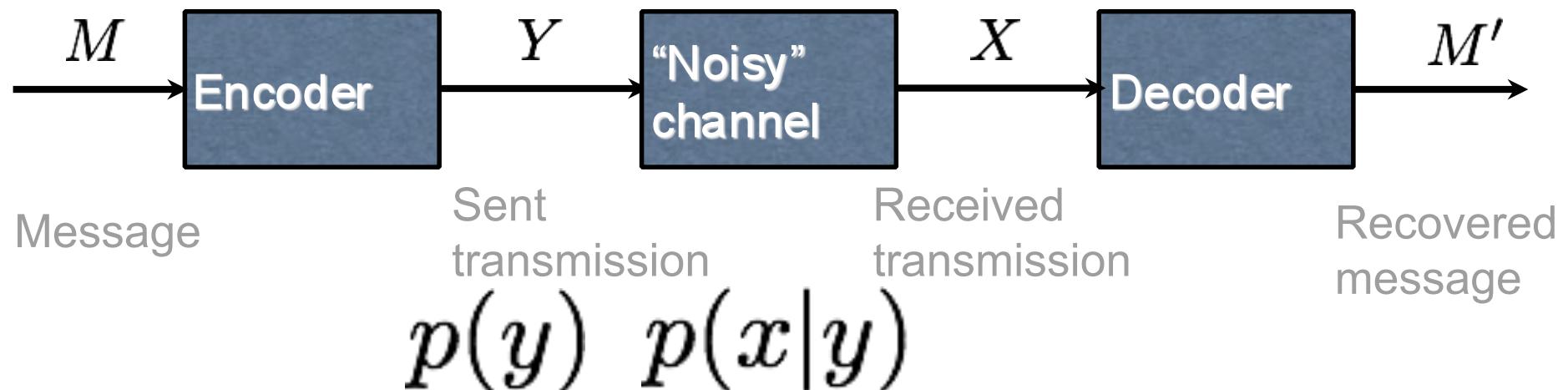
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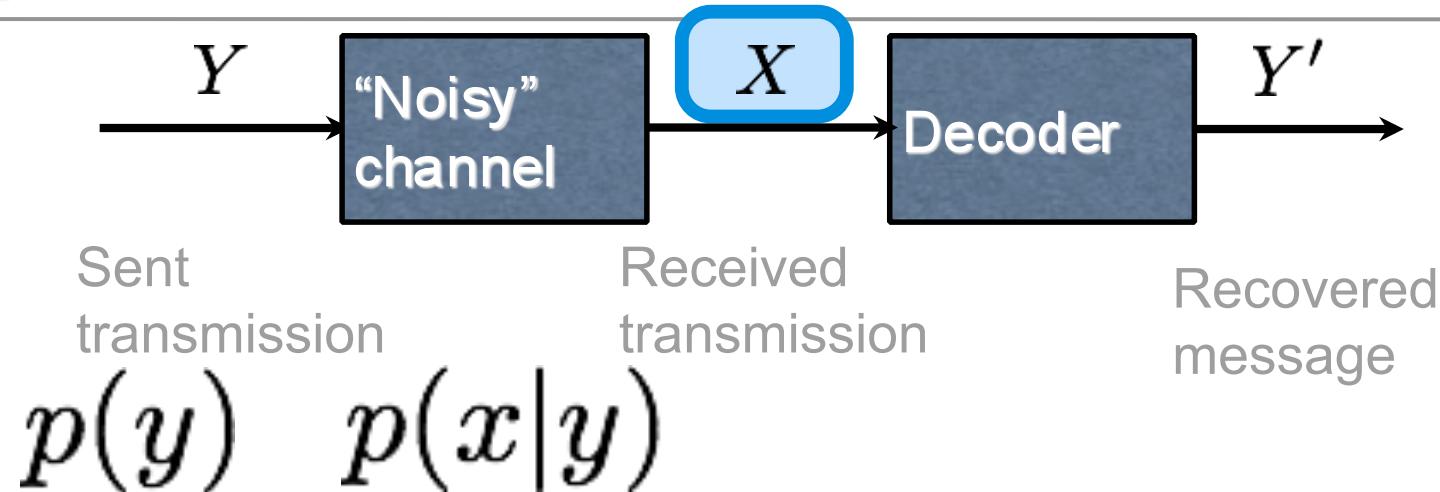


**Shannon's theory tells us:**

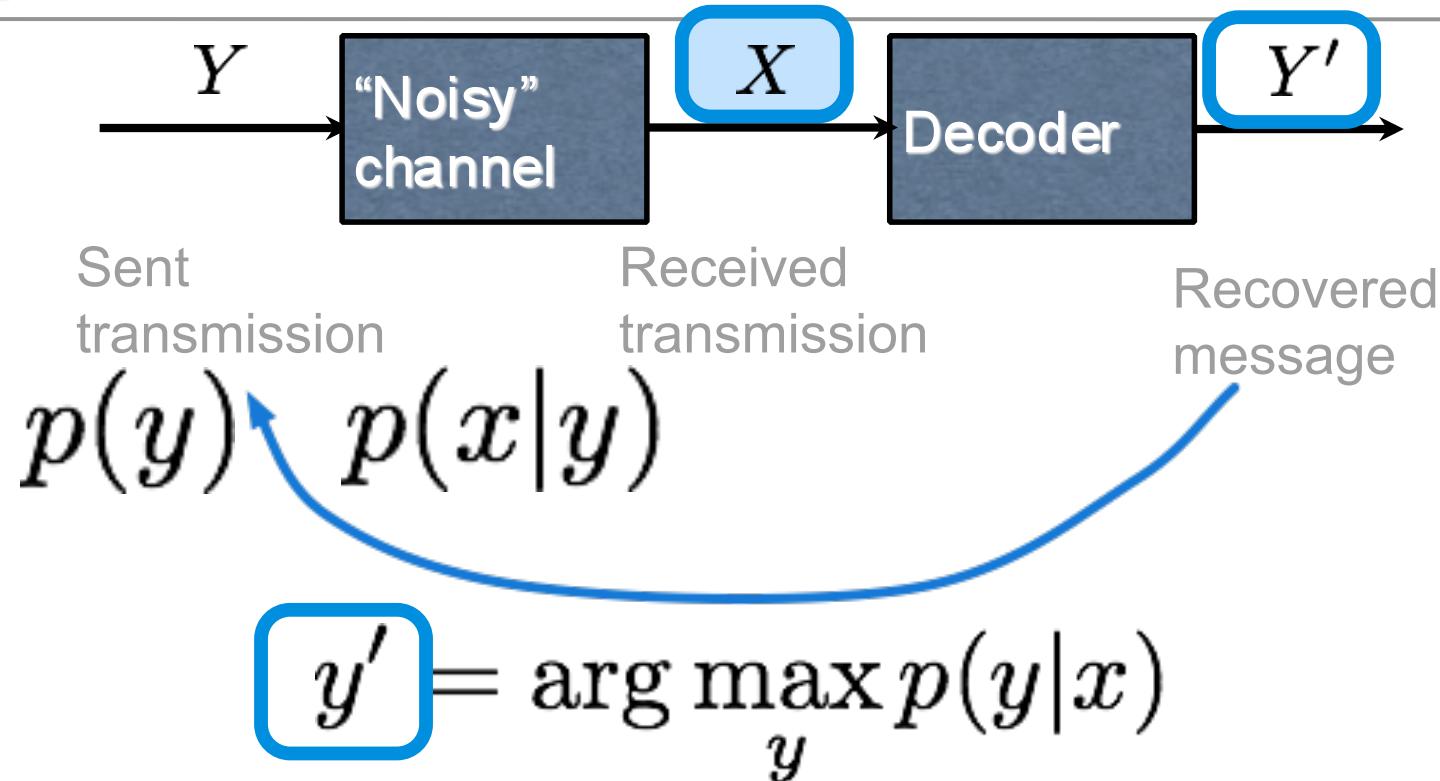
1. how much data you can send
2. the limits of compression
3. why your download is so slow
4. how to translate

Claude Shannon. “A Mathematical Theory of Communication” 1948.

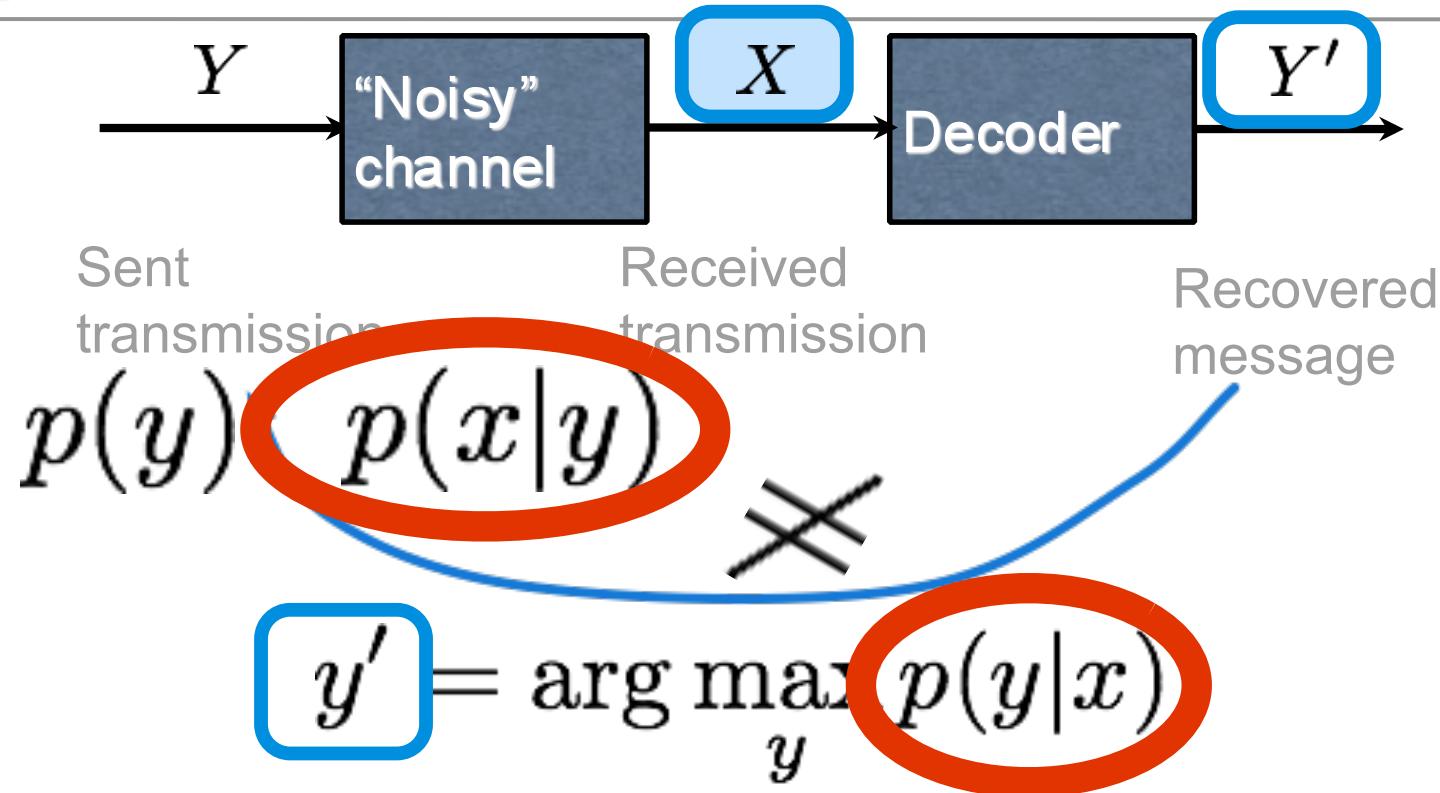
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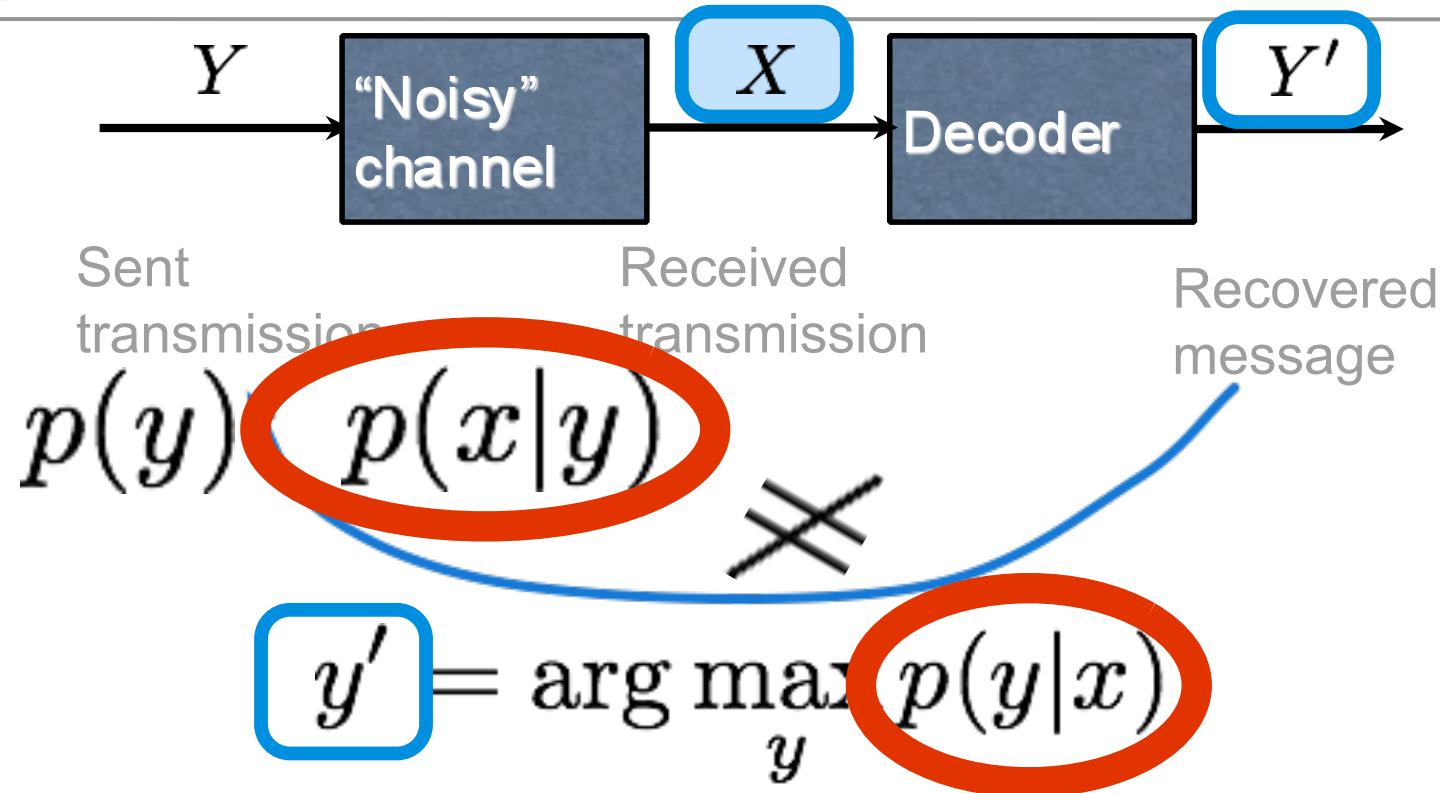
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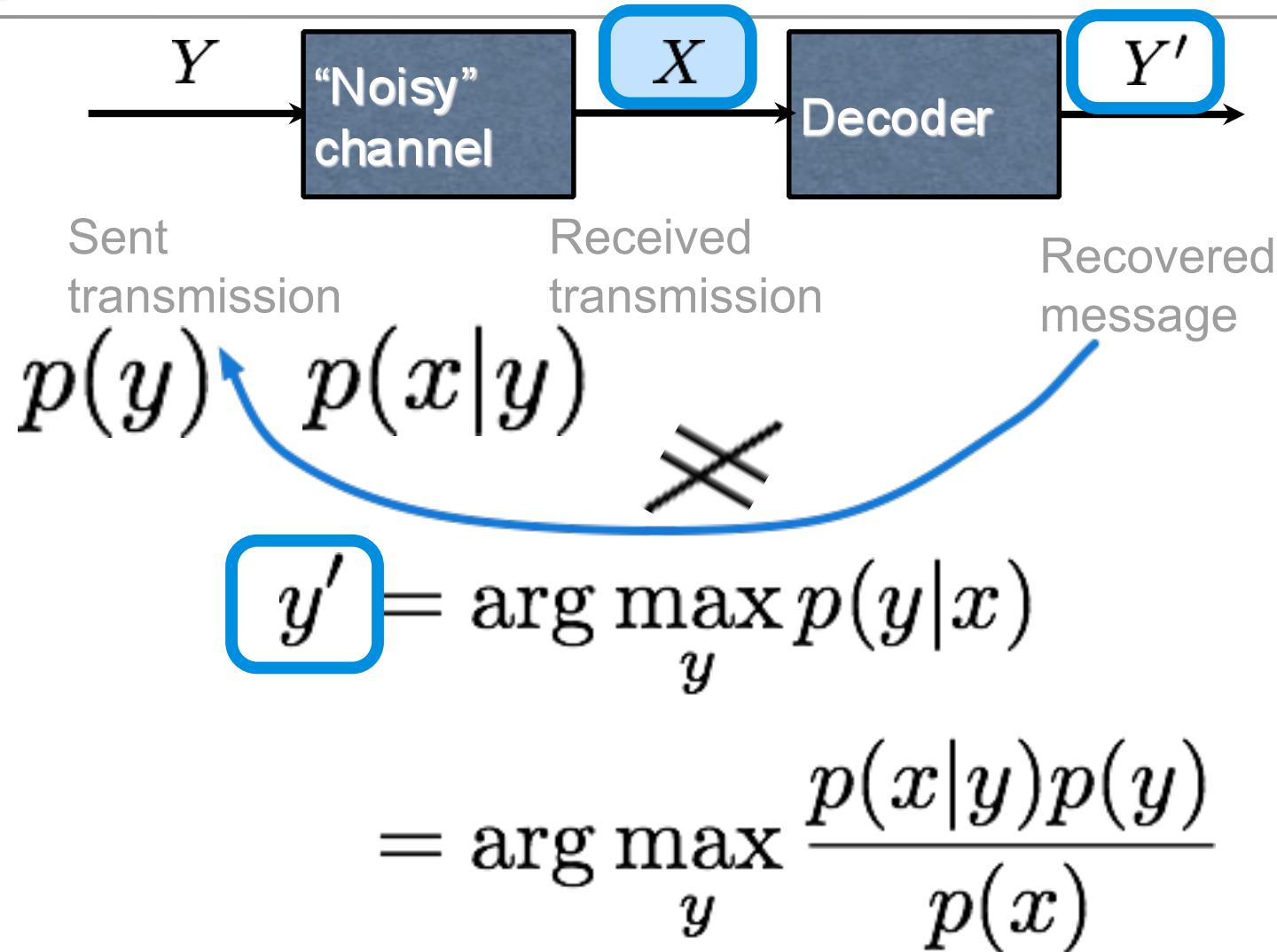


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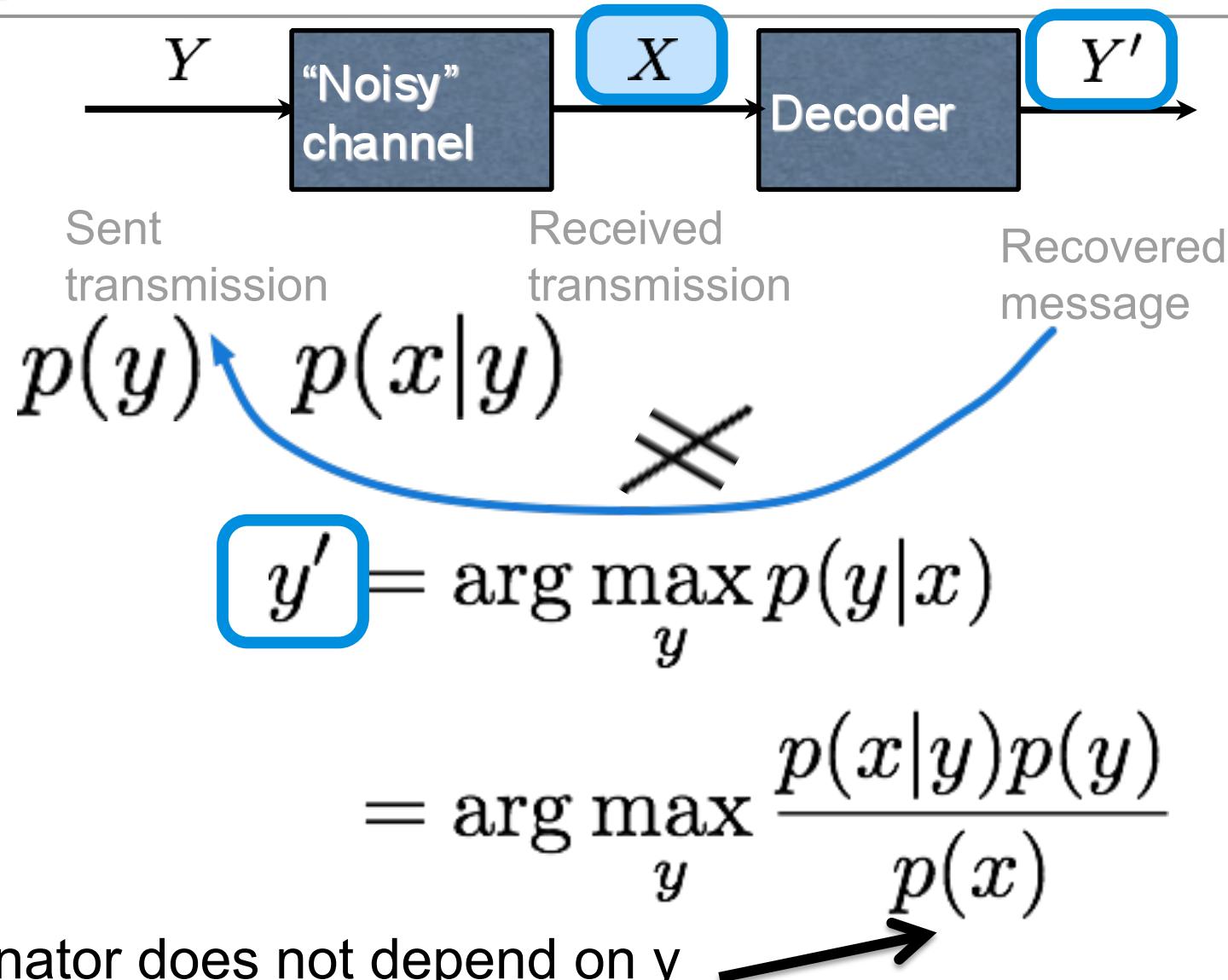


I can help

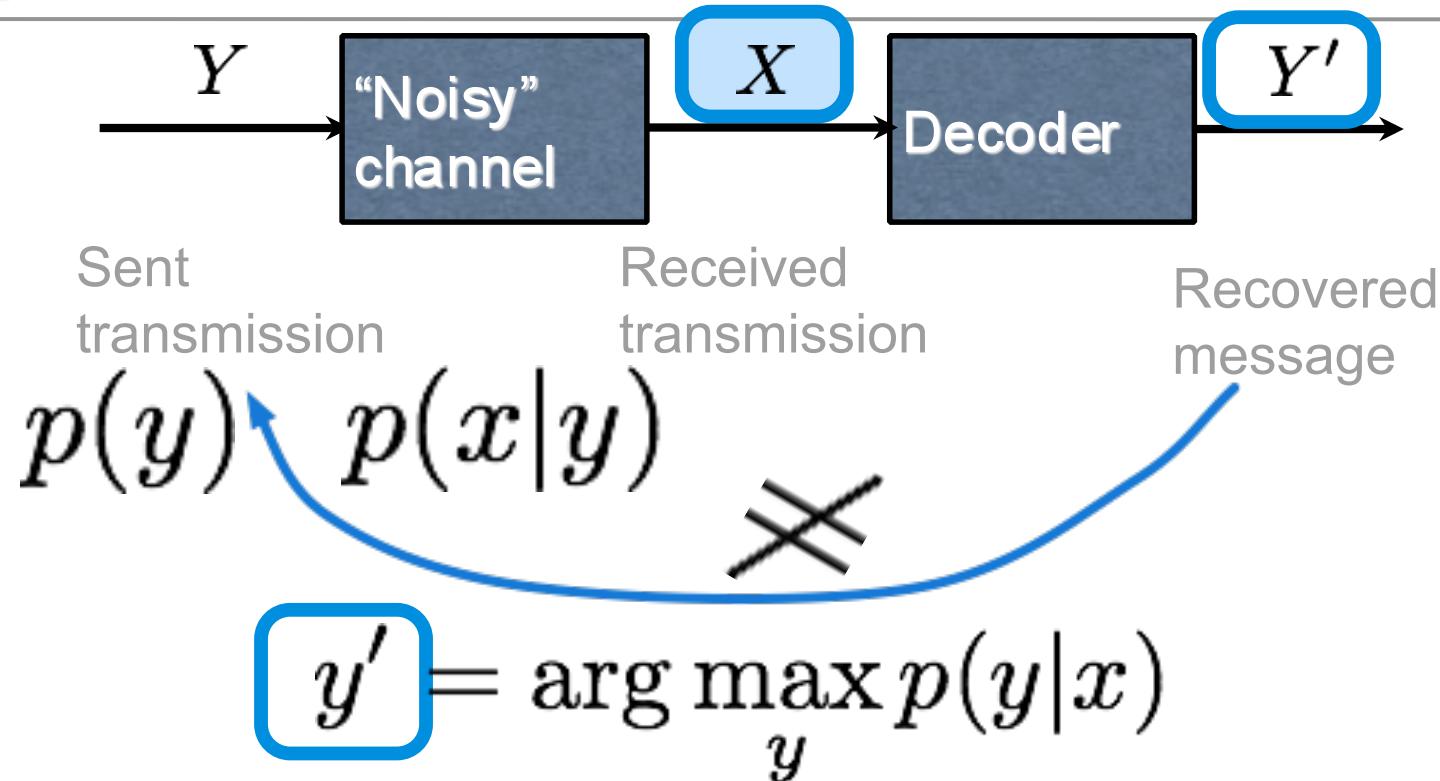
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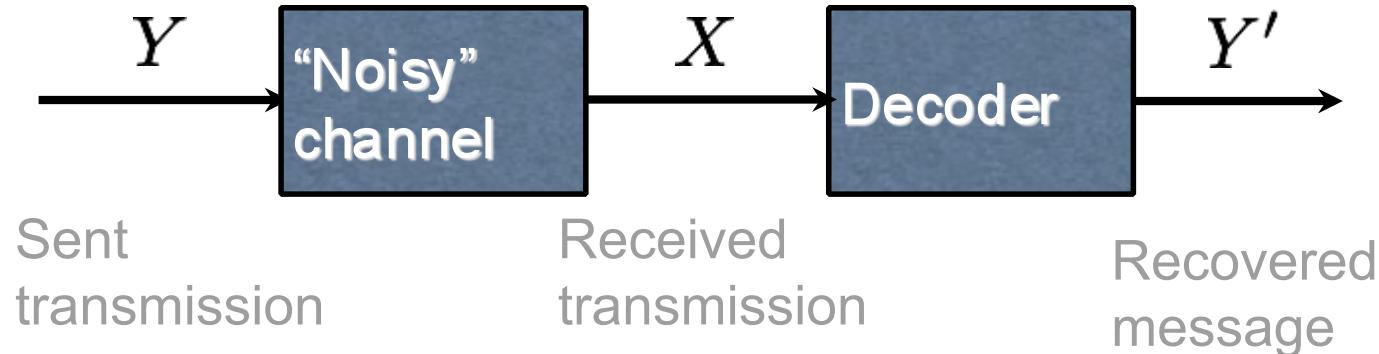


$$= \arg \max_y \frac{p(x|y)p(y)}{p(x)}$$

$$= \arg \max_y p(x|y)p(y)$$

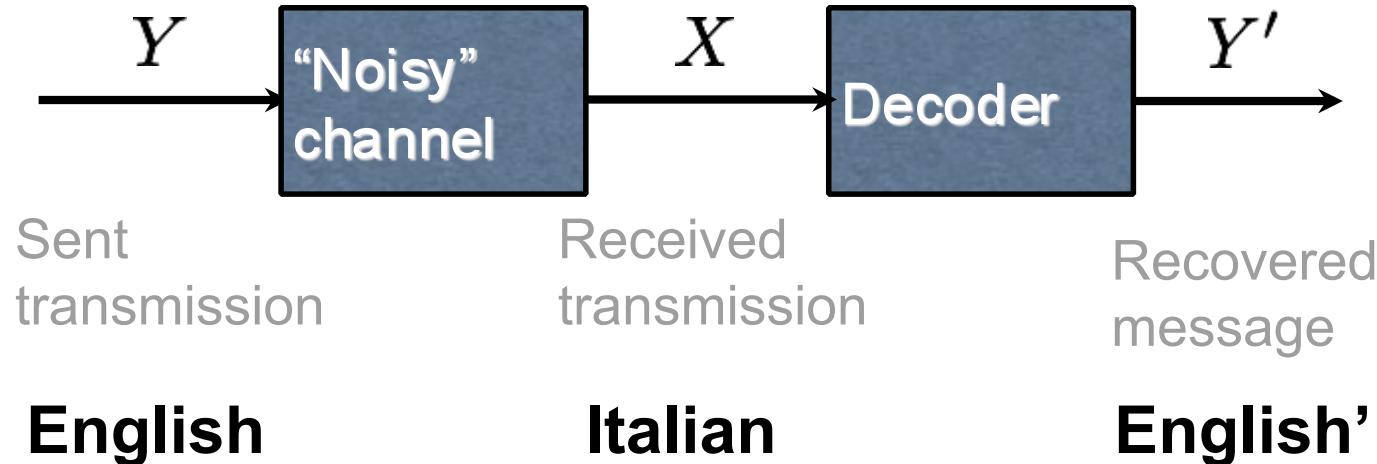
# Noisy Channel Model

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$$y' = \arg \max_y p(x|y)p(y)$$

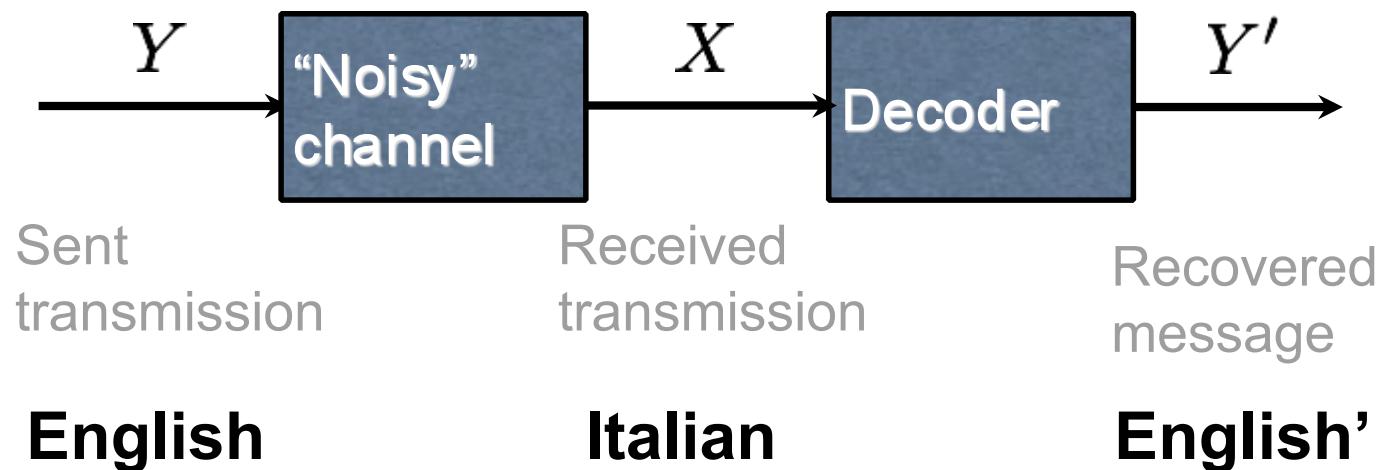
# Noisy Channel Model



$$y' = \arg \max_y p(x|y)p(y)$$

$$\mathbf{e}' = \arg \max_{\mathbf{e}} p(\mathbf{f}|\mathbf{e})p(\mathbf{e})$$

# Noisy Channel Model

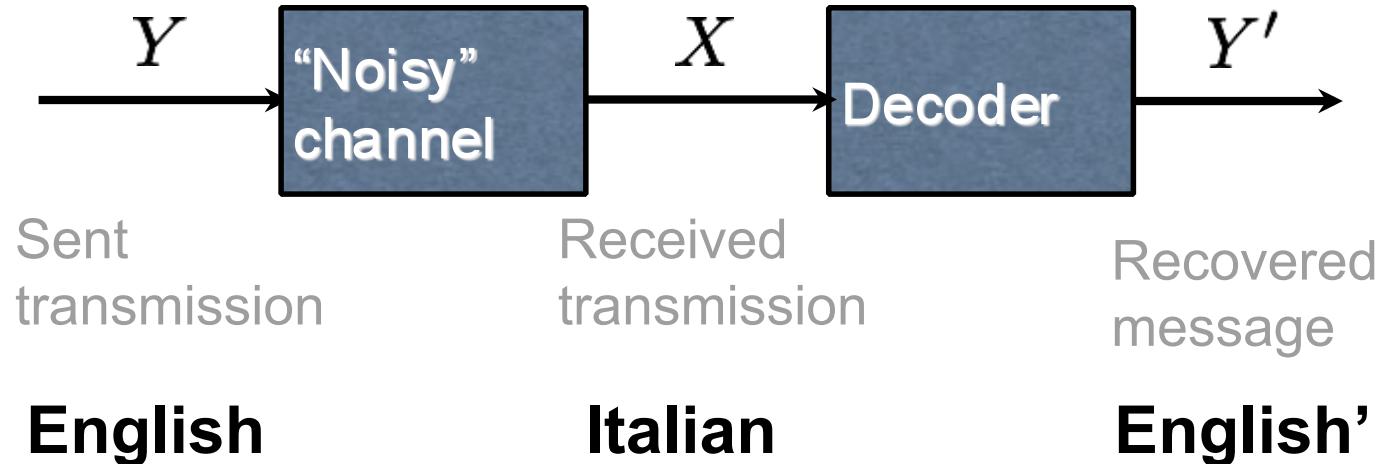


$$y' = \arg \max_y p(x|y)p(y)$$

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translation model

# Noisy Channel Model



$$y' = \arg \max_y p(x|y)p(y)$$

$$\mathbf{e}' = \arg \max_{\mathbf{e}} p(\mathbf{f}|\mathbf{e})p(\mathbf{e})$$

translation model

language model

# Translation Model

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- provides translation *back* into the source
- learned from parallel data
  - target literally translation of the source
- guarantees **adequacy** of translation

# Language Model

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- probability of finding a sequence of words in the target language
  - guarantees **fluency** of translation
- supports difficult decisions in word order and word translation
- learned from *any* target language corpus
- *Tues., 9<sup>th</sup> Kenneth Heafield - Language modelling*

# Parallel Data

www.un.org  
http://www.un.org/english/

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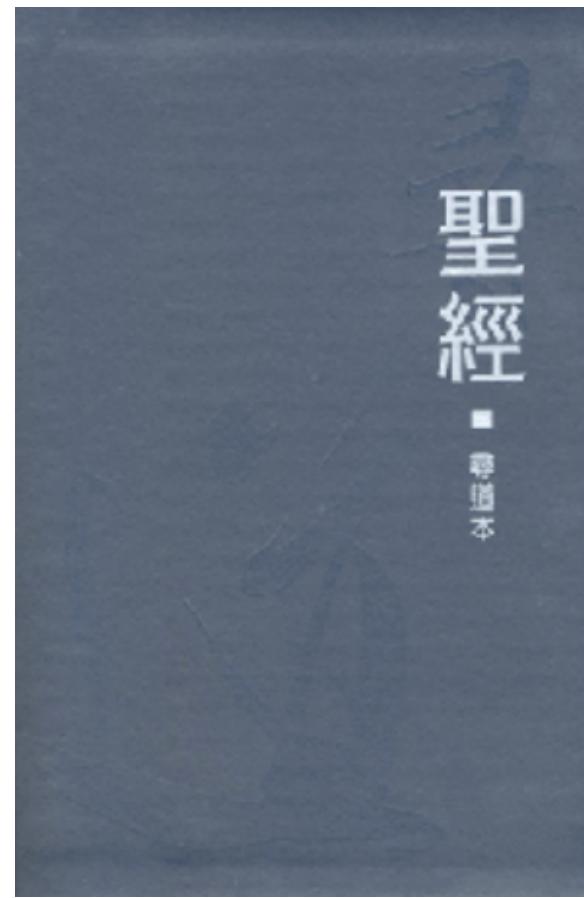
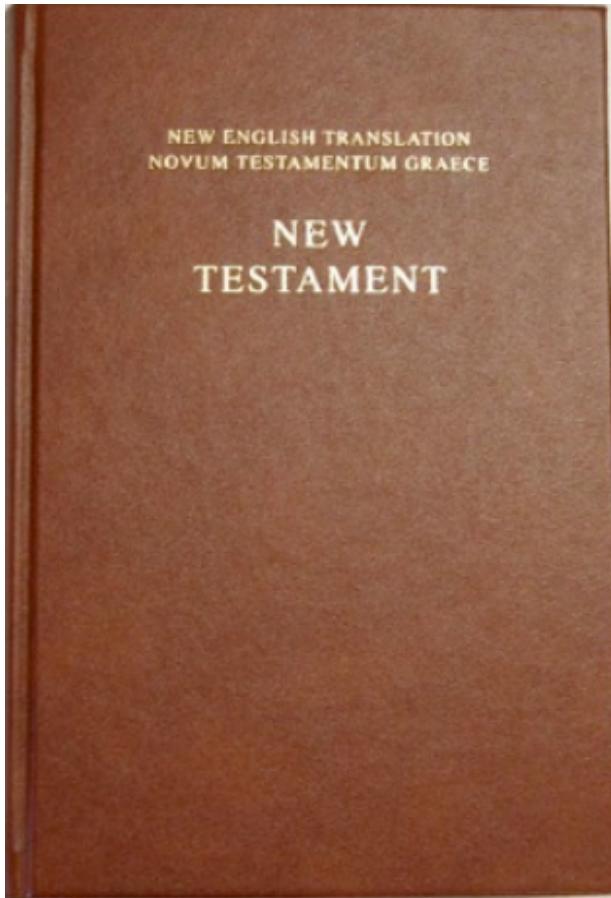
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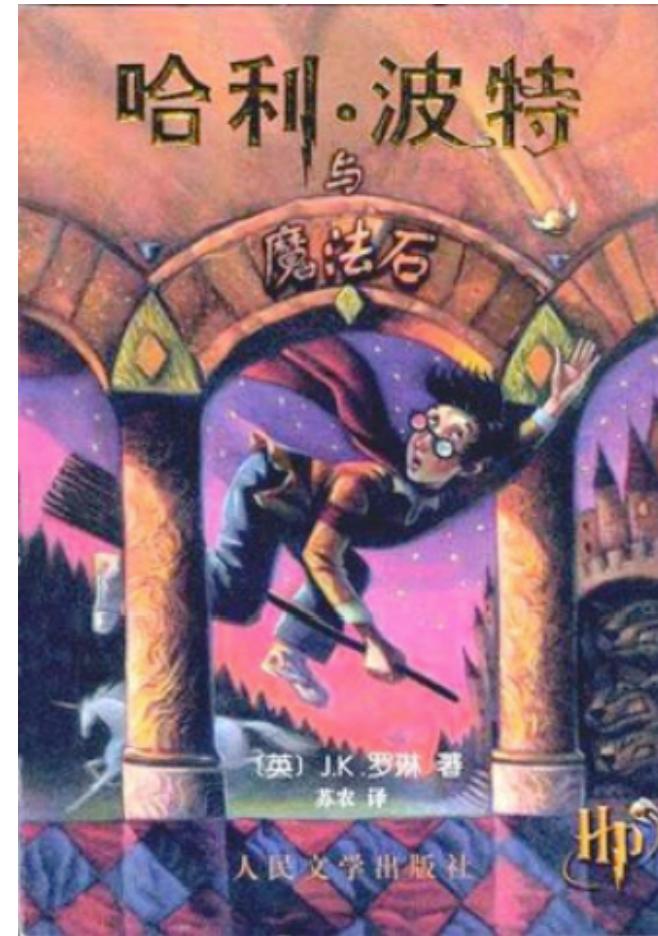
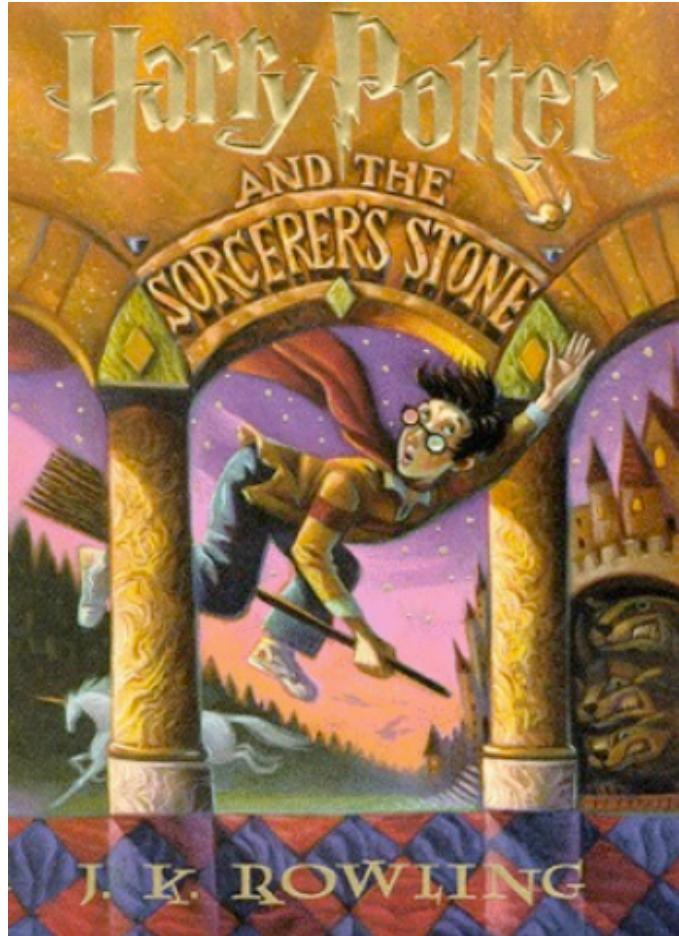
# Parallel Data

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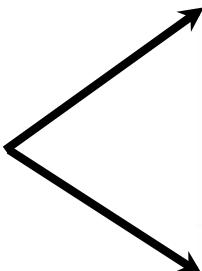
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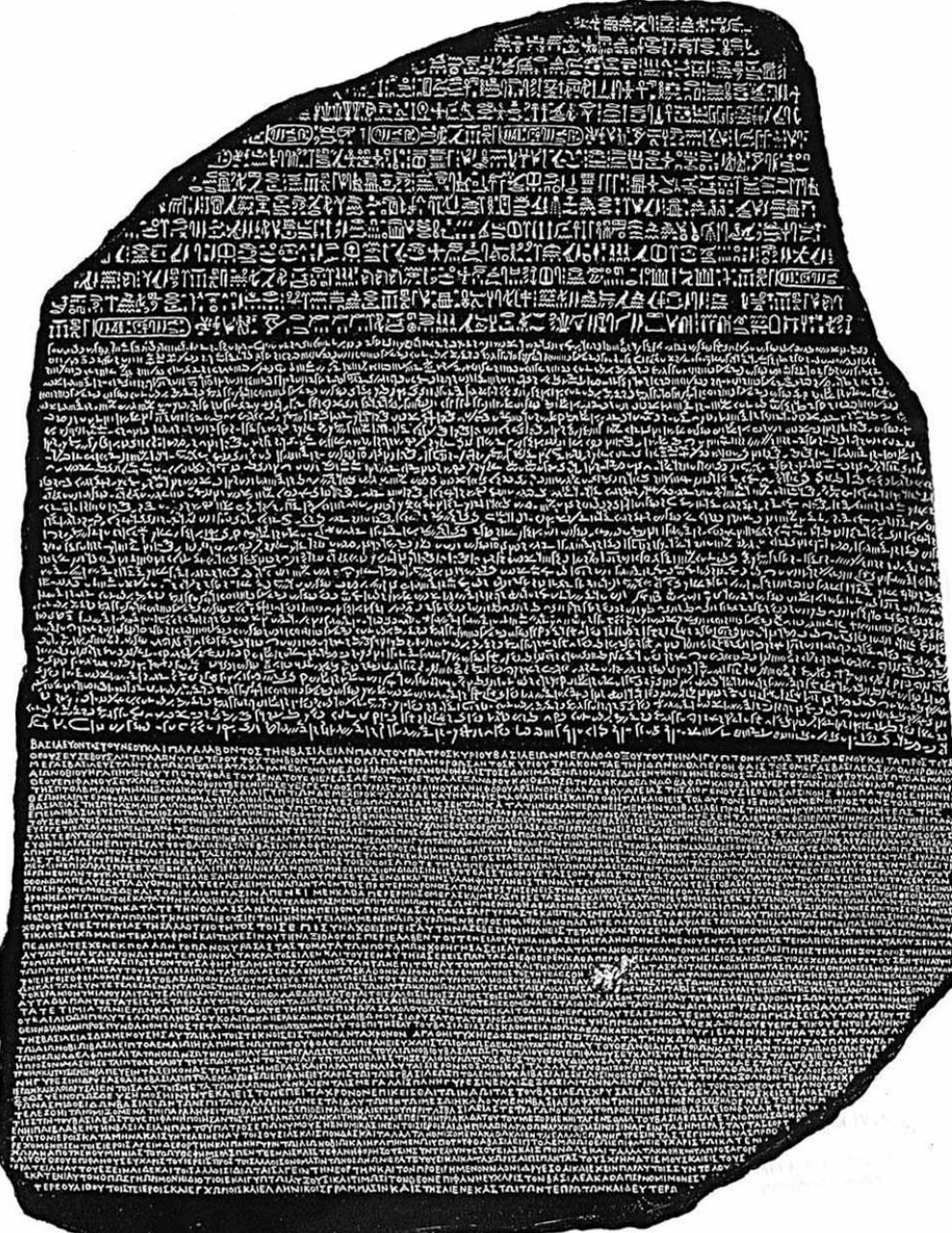
# Parallel Data

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Egyptian



Greek →



Introduction to Machine Translation – Turcini



HLT  
HUMAN LANGUAGE  
TECHNOLOGY

# Statistical Machine Translation

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- Parallel sentences

dalla serata di domani soffierà un freddo vento orientale  
since tomorrow evening an eastern chilly wind will blow

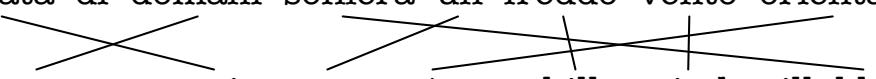
un vento freddo da est interessa le Alpi  
an eastern cool breeze affects the Alps

# Statistical Machine Translation

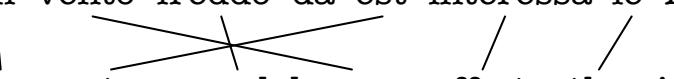
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- Parallel sentences and word alignment

dalla serata di domani soffierà un freddo vento orientale  
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un vento freddo da est interessa le Alpi  
an eastern cool breeze affects the Alps



- Mon., 8<sup>th</sup> Mark Fishel - Word Alignment

# Statistical Machine Translation

---

- Parallel sentences and word alignment

dalla serata di domani soffierà un **freddo** vento orientale  
since tomorrow evening an eastern **chilly** wind will blow

un vento **freddo** da est interessa le Alpi  
an eastern **cool** breeze affects the Alps

- Word translation probabilities

translations of <b>freddo</b>	counts	probs
chill	15	0.15
chilly	10	0.10
cold	43	0.43
cool	28	0.28
...	...	...

# Statistical Machine Translation

---

- Parallel sentences and word alignment

dalla serata di domani soffierà un **freddo** vento orientale  
| ~~since tomorrow evening~~ ~~an eastern~~ ~~chilly~~ ~~wind~~ ~~will blow~~

un vento **freddo** da est interessa le Alpi  
| ~~an eastern~~ ~~cool~~ ~~breeze~~ ~~affects~~ ~~the~~ ~~Alps~~

- Word translation probabilities

translations of <b>freddo</b>	counts	probs
chill	15	0.15
chilly	10	0.10
cold	43	0.43
cool	28	0.28
...	...	...

translations of <b>vento</b>	counts	probs
wind	59	0.59
breeze	26	0.26
...	...	...

# Statistical Machine Translation

---

- Parallel sentences

dalla serata di domani soffierà un **freddo** vento orientale  
since tomorrow evening an eastern **chilly** wind will blow

un vento **freddo** da est interessa le Alpi  
an eastern **cool** breeze affects the Alps

- Word translation probabilities

translations of <b>freddo</b>	counts	probs
chill	15	0.15
chilly	10	0.10
cold	43	0.43
cool	28	0.28
...	...	...

translations of <b>vento</b>	counts	probs
wind	59	0.59
breeze	26	0.26
...	...	...

- Word concatenation probabilities

bigrams with <b>eastern</b>	counts	probs
eastern cool	5	0.05
eastern chilly	10	0.10
eastern wind	12	0.12
eastern breeze	7	0.07
eastern ...	...	...

# Statistical Machine Translation

---

- Given word translation and concatenation probabilities

translations of <b>freddo</b>	counts	probs	translations of <b>vento</b>	counts	probs	bigrams with <b>eastern</b>	counts	probs
chill	15	0.15	wind	59	0.59	eastern cool	5	0.05
chilly	10	0.10	breeze	26	0.26	eastern chilly	10	0.10
cold	43	0.43	...	...	...	eastern wind	12	0.12
cool	28	0.28	...	...	...	eastern breeze	7	0.07
...	...	...				eastern ...	...	...

- generate possible translations of the source sentence

un freddo vento da est

# Statistical Machine Translation

---

- Given word translation and concatenation probabilities

translations of <b>freddo</b>	counts	probs	translations of <b>vento</b>	counts	probs	bigrams with <b>eastern</b>	counts	probs
chill	15	0.15	wind	59	0.59	eastern cool	5	0.05
chilly	10	0.10	breeze	26	0.26	eastern chilly	10	0.10
cold	43	0.43	...	...	...	eastern wind	12	0.12
cool	28	0.28	...	...	...	eastern breeze	7	0.07
...	...	...	...	...	...	eastern ...	...	...

- generate possible translations of the source sentence

un freddo vento da est	a cool eastern breeze	0.08
	an eastern chilly wind	0.10
	a eastern cool wind	0.09
	a cold eastern wind	0.12
	an eastern chilly breeze	0.05
	...	...

# Statistical Machine Translation

---

- Given word translation and concatenation probabilities

translations of <b>freddo</b>	counts	probs	translations of <b>vento</b>	counts	probs	bigrams with <b>eastern</b>	counts	probs
chill	15	0.15	wind	59	0.59	eastern cool	5	0.05
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cool	28	0.28	...	...	...	eastern breeze	7	0.07
...	...	...	...	...	...	eastern ...	...	...

- generate possible translations of the source sentence

un freddo vento da est	a cool eastern breeze	0.08
	an eastern chilly wind	0.10
	a eastern cool wind	0.09
	<b>a cold eastern wind</b>	<b>0.12</b>
	an eastern chilly breeze	0.05
	...	...

- return the best scoring translation

# Phrase-based Model

---

- Phrase:
  - sequence of words without any linguistic notion
- Phrases as atomic elements
  - words not be the best atomic units, due to many to many mapping.
- Advantages:
  - translating word groups helps to resolve translation ambiguities
  - given a large training corpora, longer and longer phrases can be learnt.
- *Wed., 10<sup>th</sup> Ulrich Germann - Phrase based model*

# Hierarchical Phrase-based Model

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- Discontinuous phrases, i.e. phrases with gaps
- Long-range reordering rules
- Formalized as synchronous context-free grammars
- no linguistic syntax, just a formally syntactic model
- The model is fully machine learnable!

# Syntax-based Model

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- Linguistic syntax
- Non-terminals for words and phrases: np, vp, pp, adj, ...
- Corpus annotated with syntactic parsers
- *Thurs., 11<sup>th</sup> Marcello Federico - Hierarchical and Syntactic Models*

# Outline

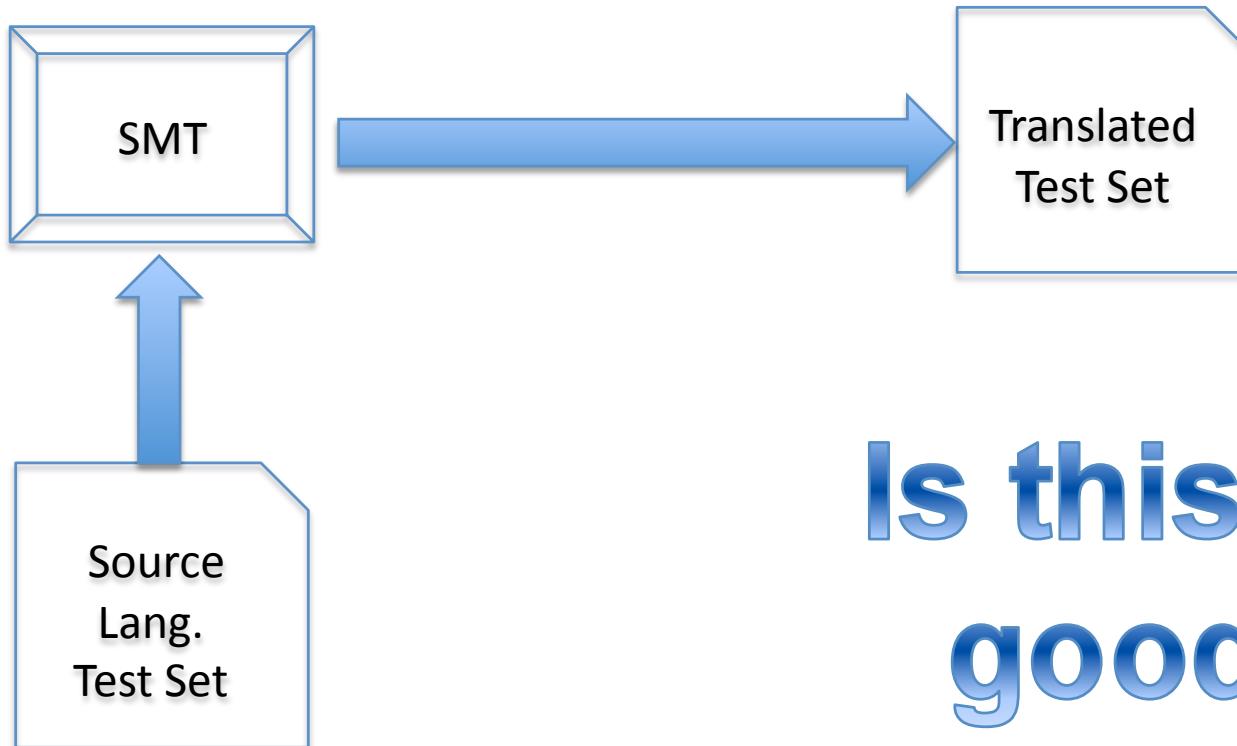
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- Motivation
  - Why Machine Translation?
  - Do we need research in Machine Translation?
  - Why is Machine Translation so Difficult?
- Approaches to MT
- Machine Translation Evaluation

# Machine Translation Evaluation

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- Automatic Evaluation of MT output

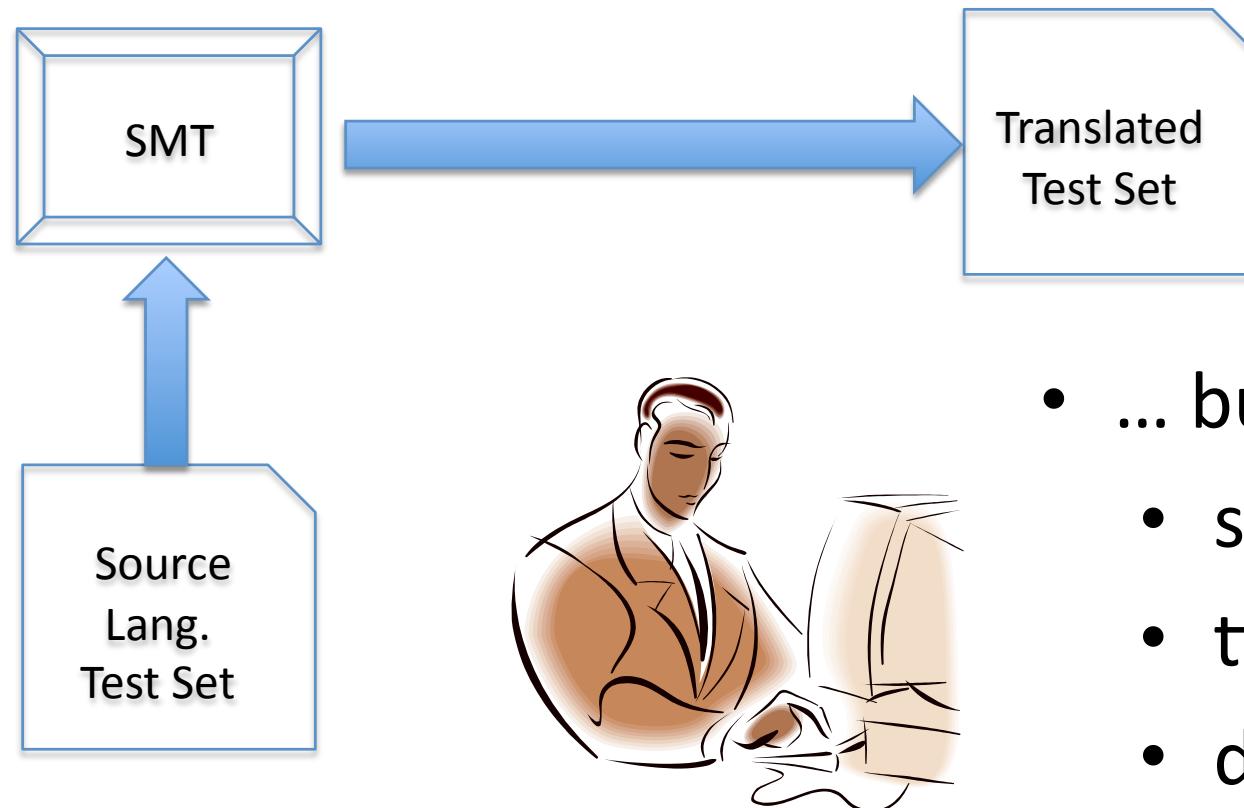


Is this a  
good  
translation?

# Machine Translation Evaluation

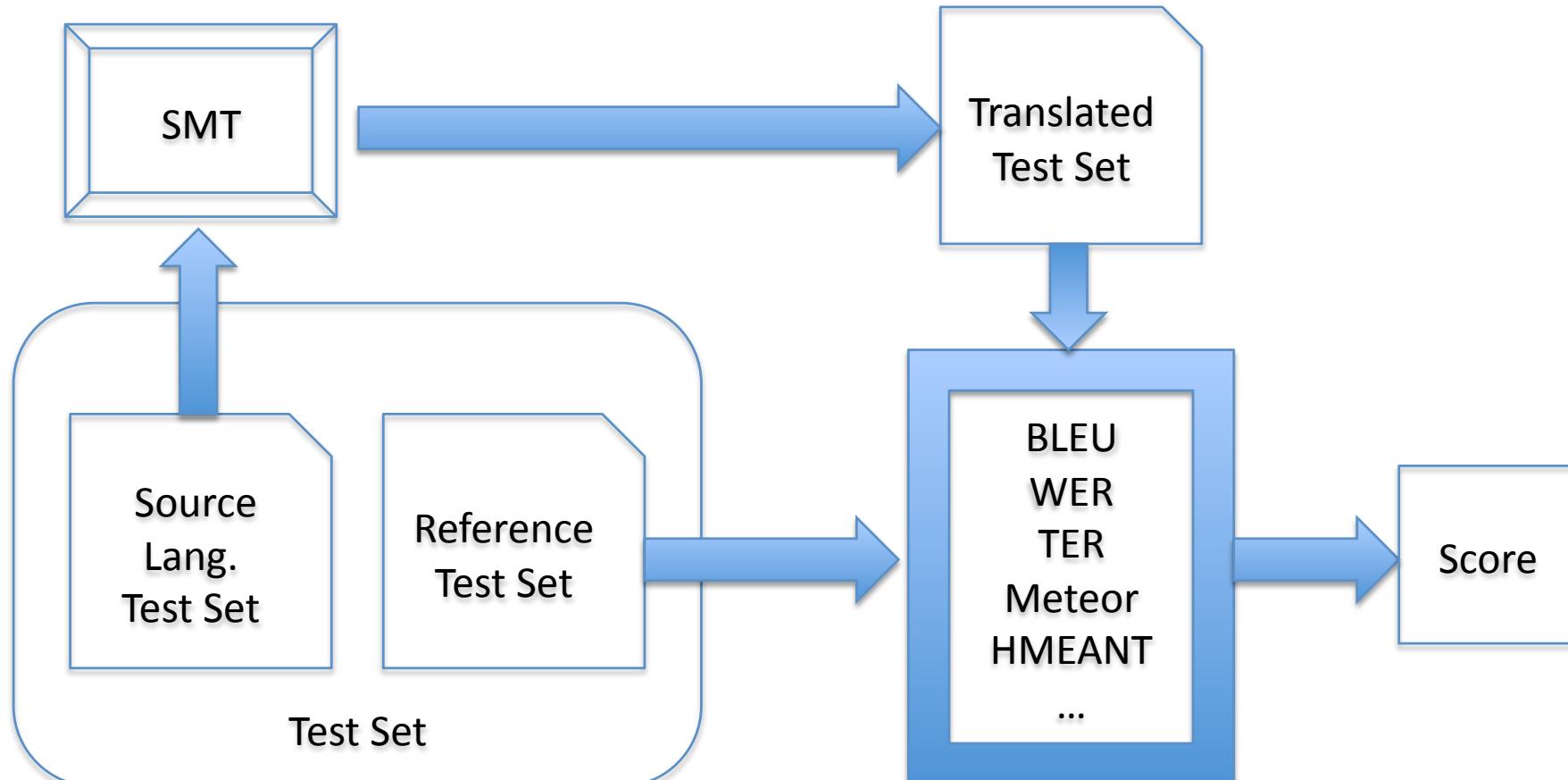
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- Human presence



- ... but it is:
  - subjective
  - time consuming
  - difficult
  - not replicable

# Machine Translation Evaluation



- Reference Test set: human translation of the source language test set into the target language.

# Machine Translation Evaluation

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- Large amount of parallel test sets in different languages
- Automatic Scoring Methods (Bleu, TER, WER, Meteor):
  - low cost (wrt human evaluation)
  - objective (unbiased)
  - informative (for system developers): to profile system behavior
  - discriminative: to tell if and where improvements are
  - effective and replicable: to be computed quickly and often
- *Tues., 9<sup>th</sup> Maja Popovic - MT evaluation, QE*

# Challenges

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- Translation into and from morphologically rich languages
  - Philip Williams - Morphology in SMT
- Training and test data sampled for different domains
  - Marine Carpuat - Domain adaptation in MT
- Model able to better generalize from training data
  - Holger Schwenk - Deep Learning for MT
- Translation of specific texts
  - Bruno Pouliquen - Patent translation

# Challenges

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- Document translation
    - Bonnie Webber - Discourse in SMT
  - Translation from the crowd
    - Joao Graca - Crowdsourcing for MT
  - Interaction between Human and Machine Translation System
    - Francisco Casacuberta - Interactive MT
  - Post-editing Machine Translated Output
    - Sharon O'Brien - Post-editing
    - Marco Trombetti - CAT tools
-

# Questions

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FONDAZIONE  
BRUNO KESSLER

# Introduction to Machine Translation

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**Fondazione Bruno Kessler – Trento, Italy**  
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**Ninth Machine Translation Marathon**  
**Trento, September 8th-13th, 2014**

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