Machine Translation

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Language Technologies Institute
Machine Learning Department

MT Marathon 2013
September 9, 2013

Overview

- A Brief History of MT
- Modeling: Language & Translation
- Using MT
- Evaluating MT
- Coffee

MT Timeline

- 1940s - WW2 code breaking
- 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 reimplementation 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
- 2013 - Prague MT Marathon!

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.***'

Warren Weaver to Norbert Wiener, March, 1947

Claude Shannon. "A Mathematical Theory of Communication" 1948.

M

Message

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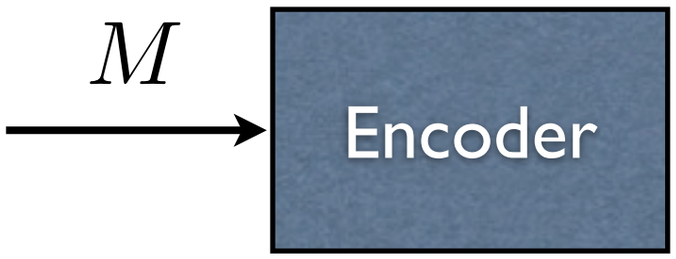

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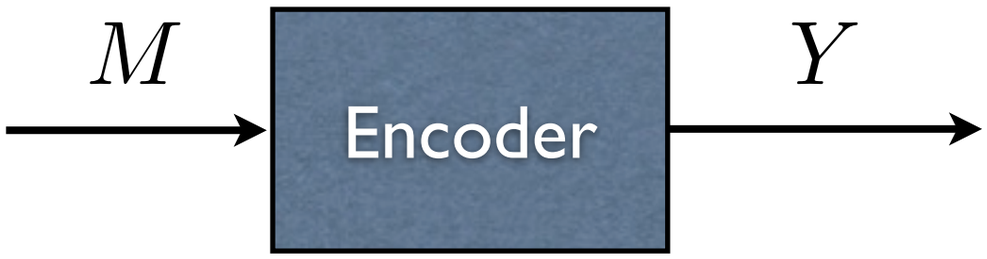

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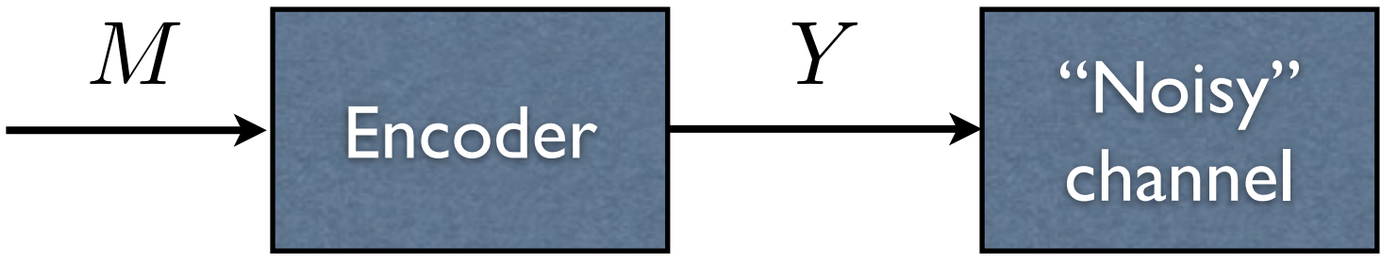

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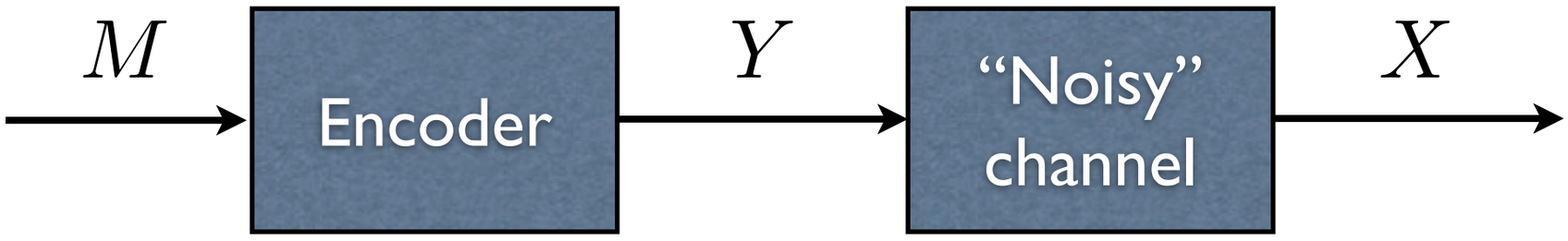

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$$p(y) \quad p(x|y) \quad p(x)$$

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$$p(y) \quad p(x|y)$$

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

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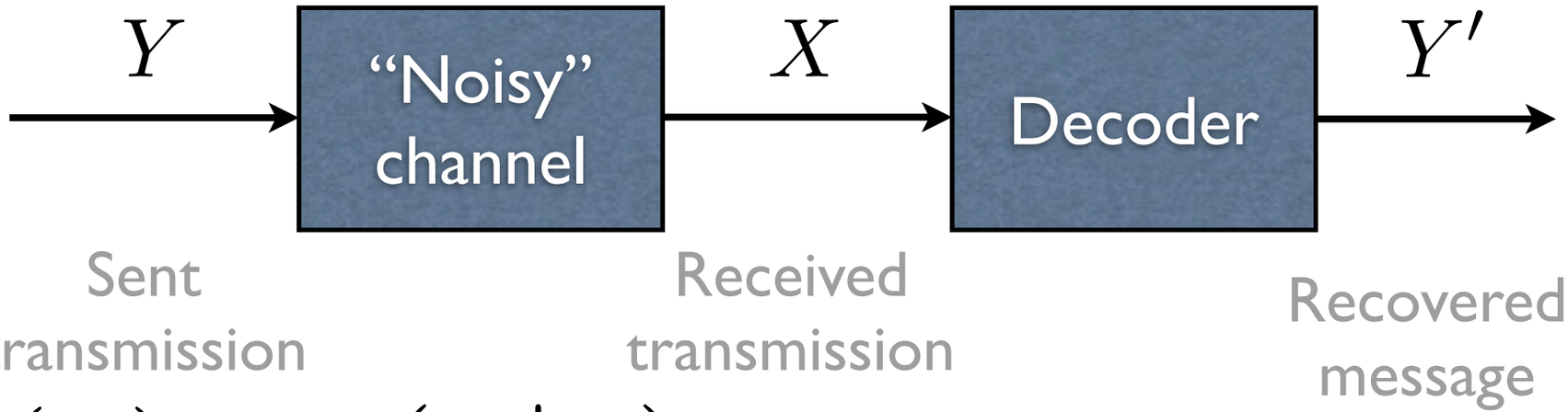
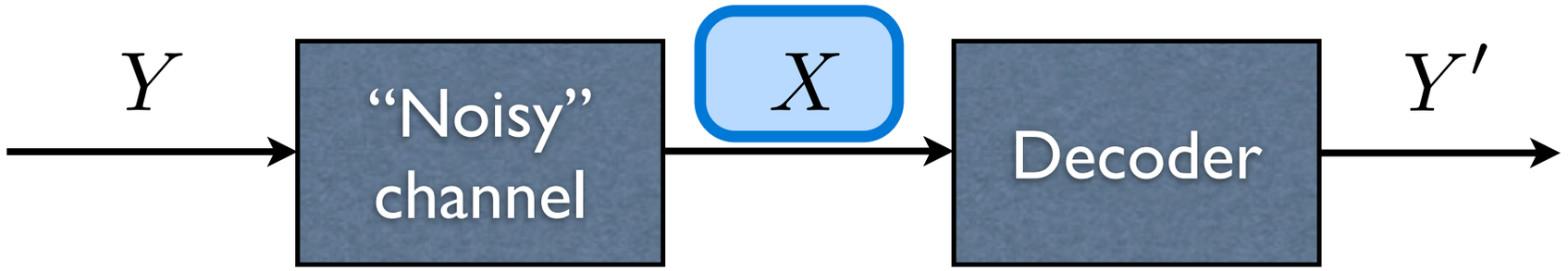

Y
"Noisy" channel
X
Decoder
Y'
Sent transmission
Received transmission
Recovered message

$$p(y) \quad p(x|y)$$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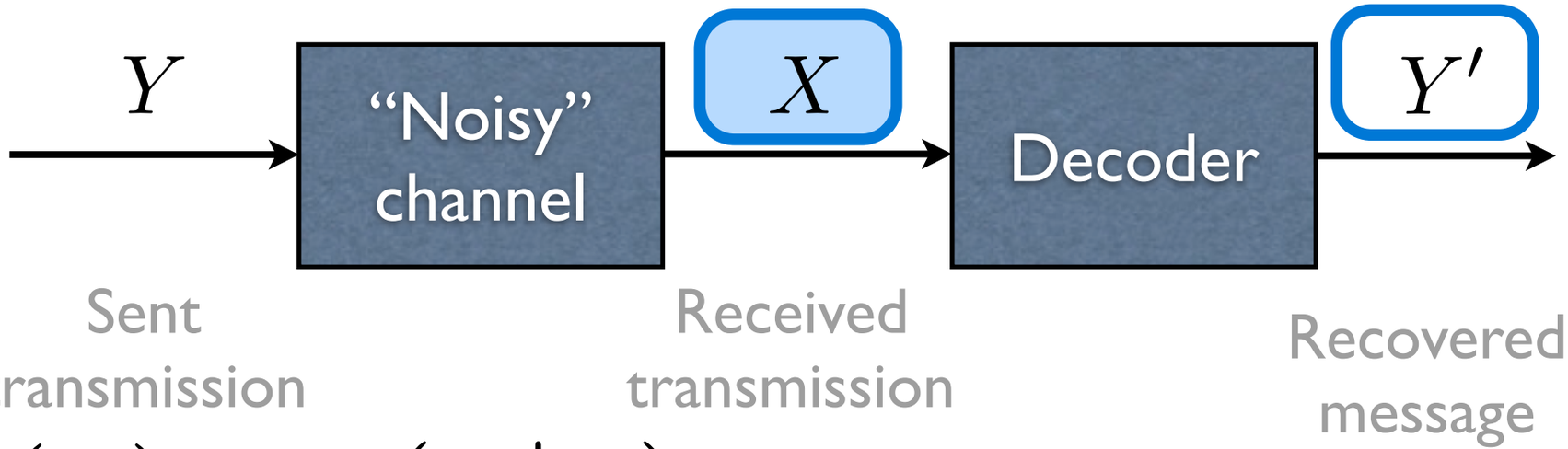
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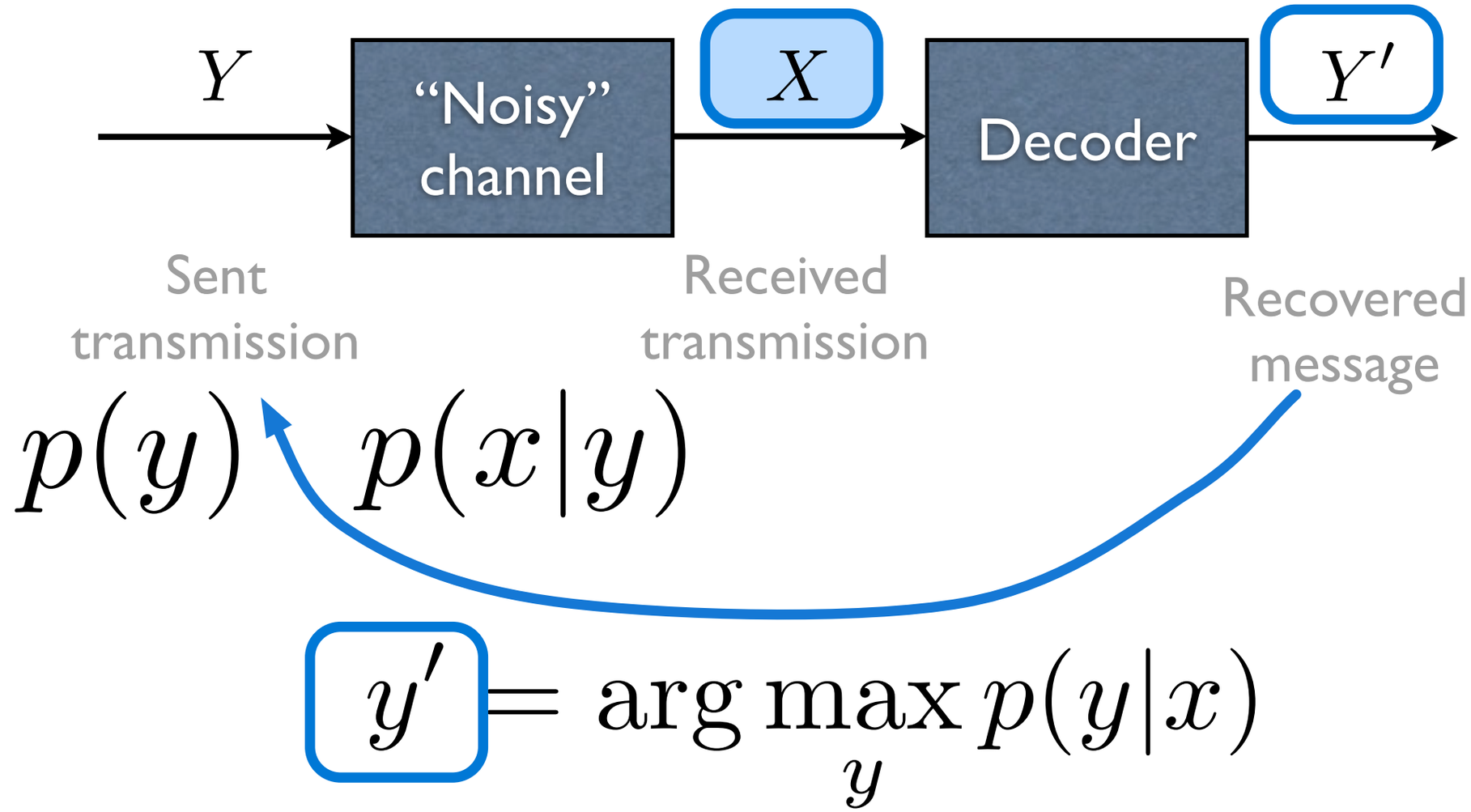
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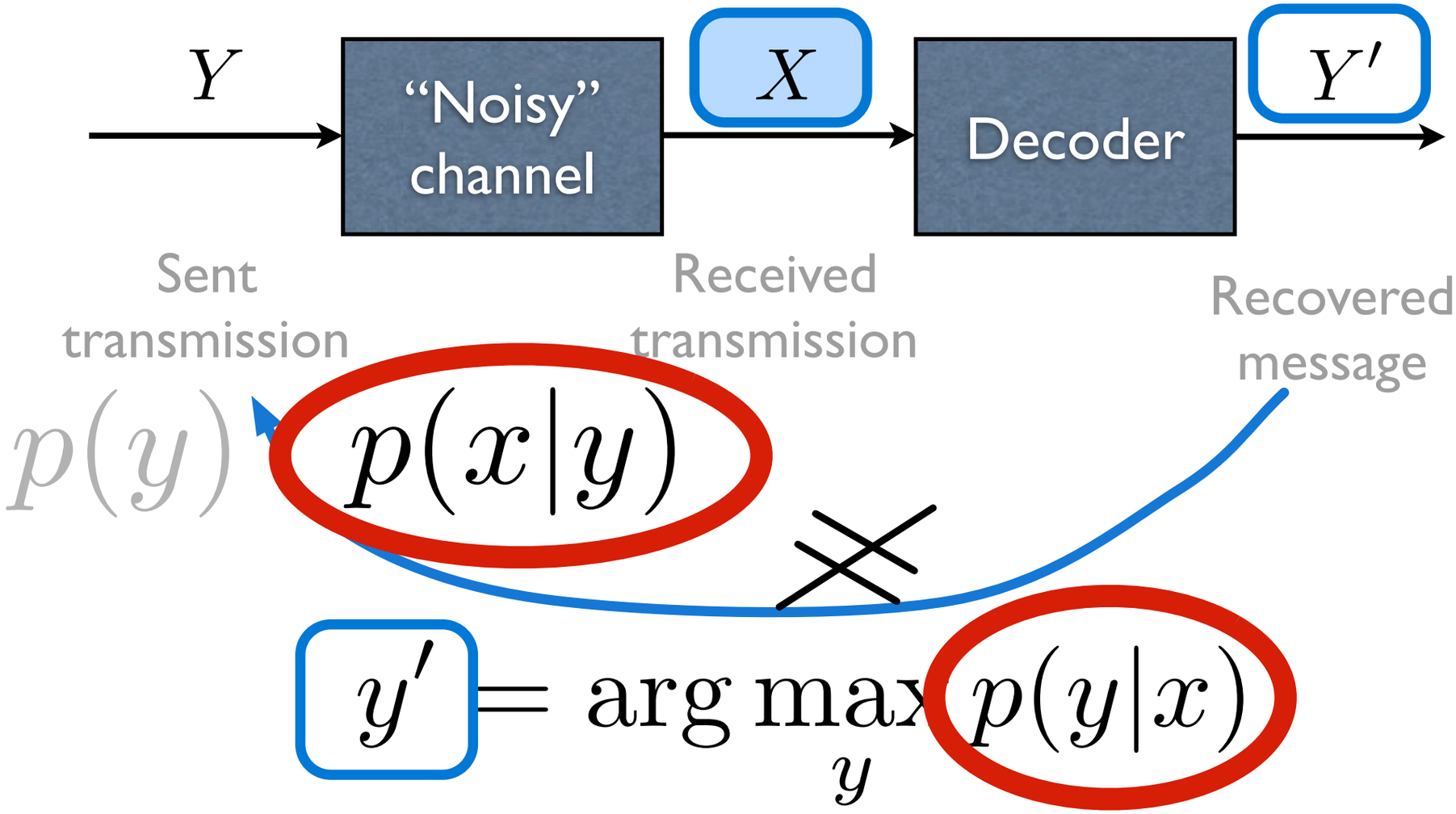
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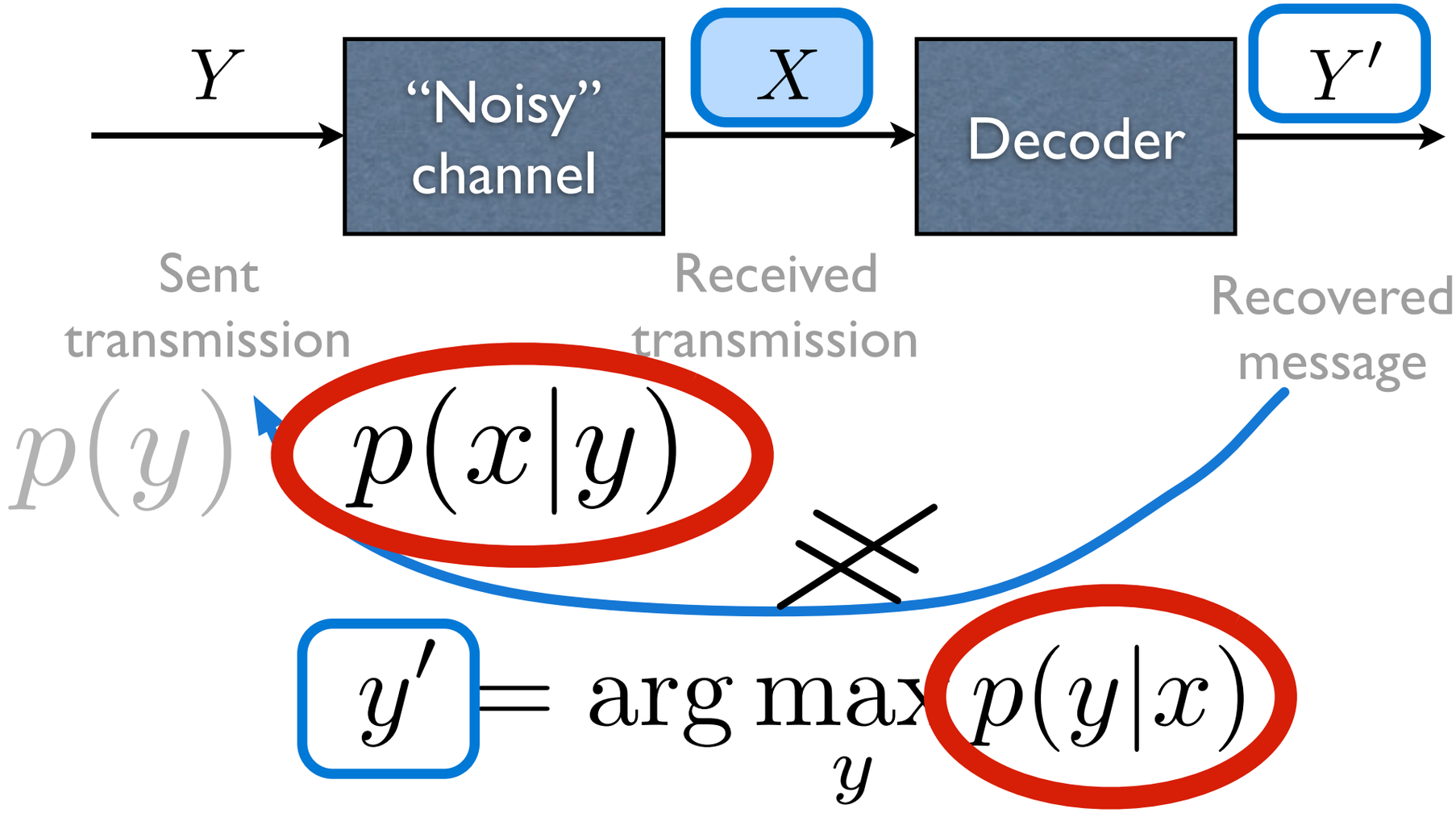
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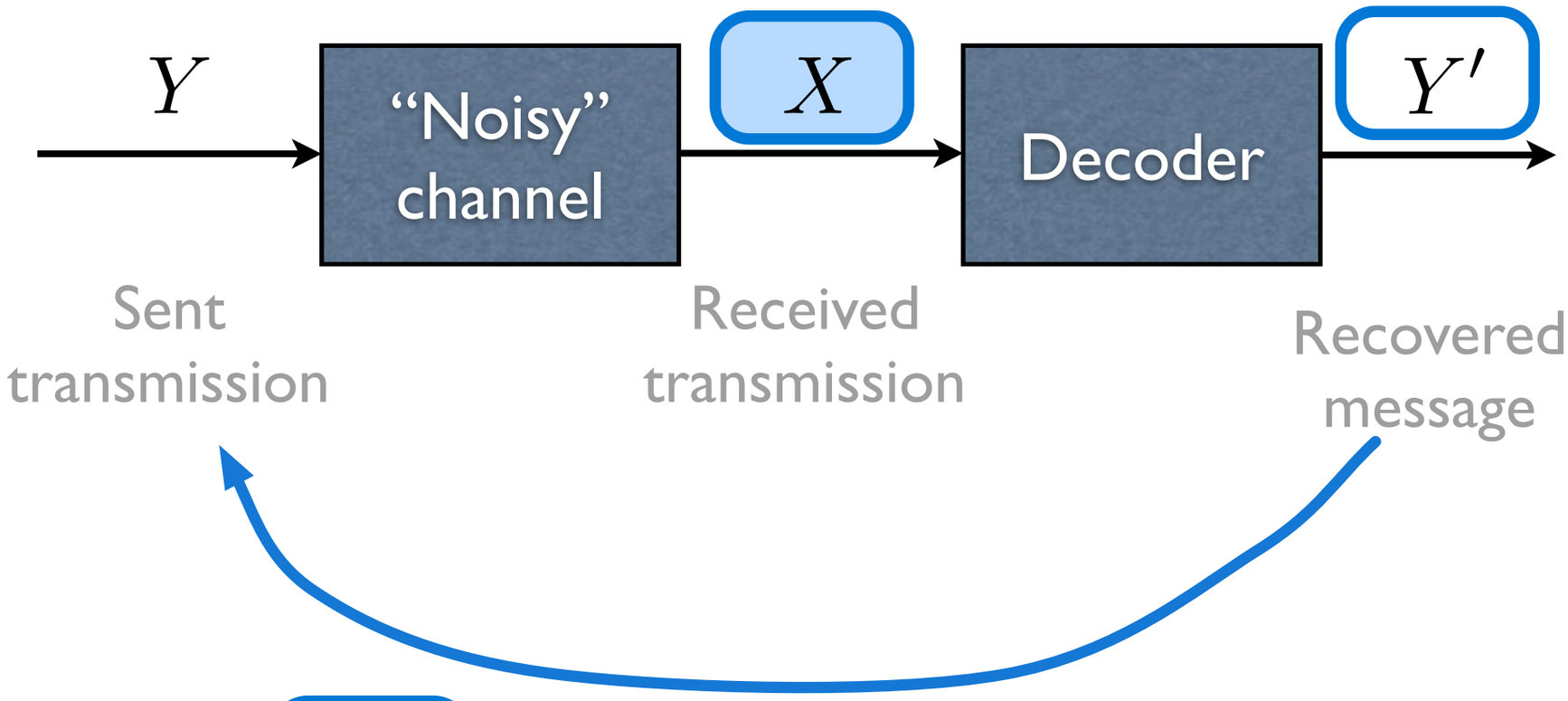
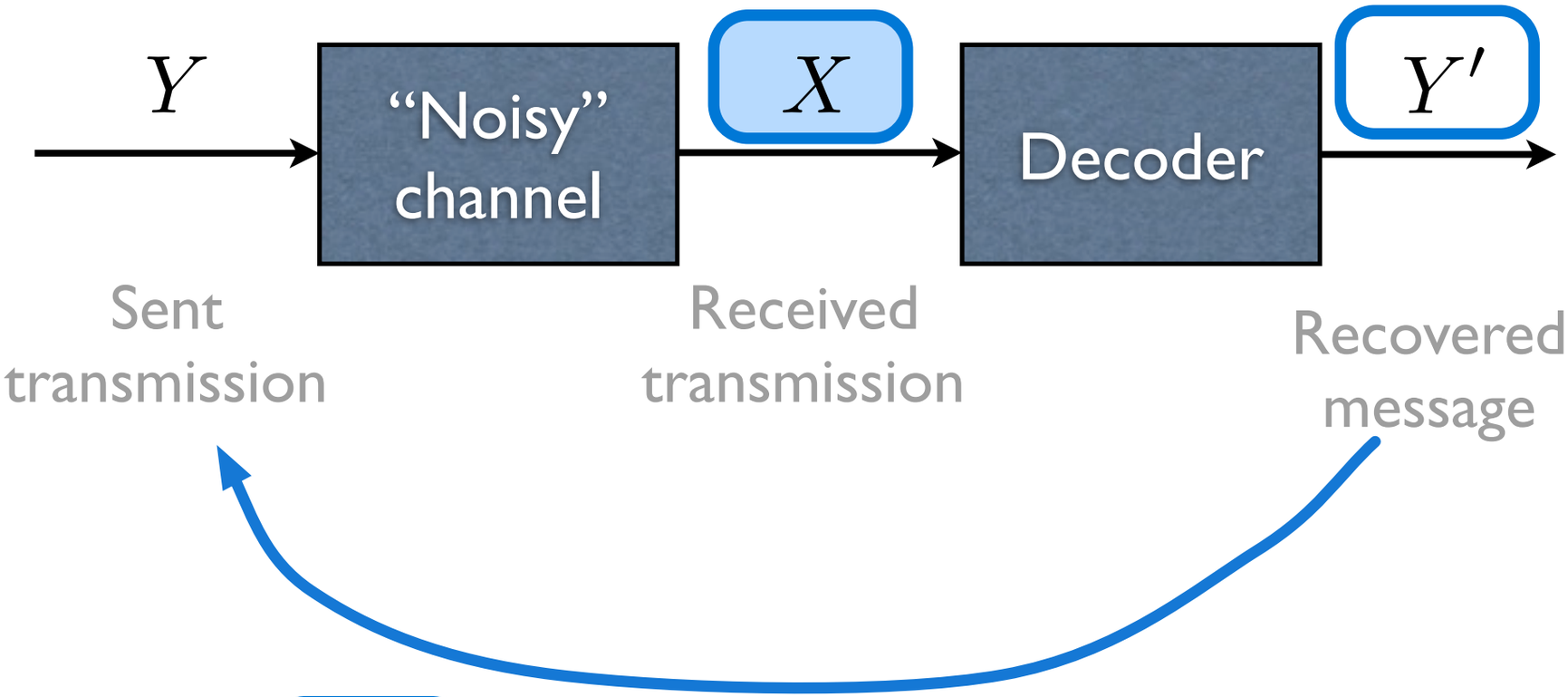
I can help.



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

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



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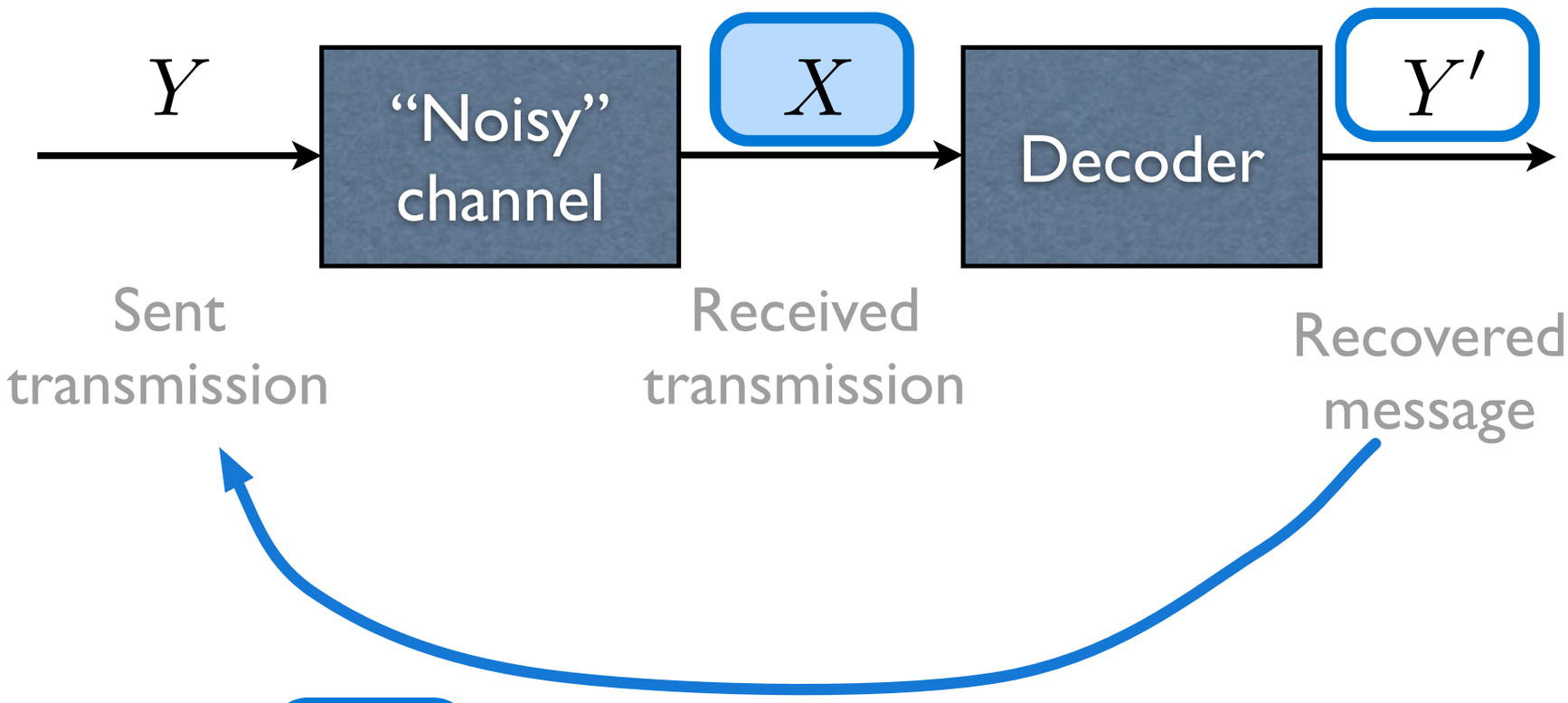
Denominator doesn't depend on y.



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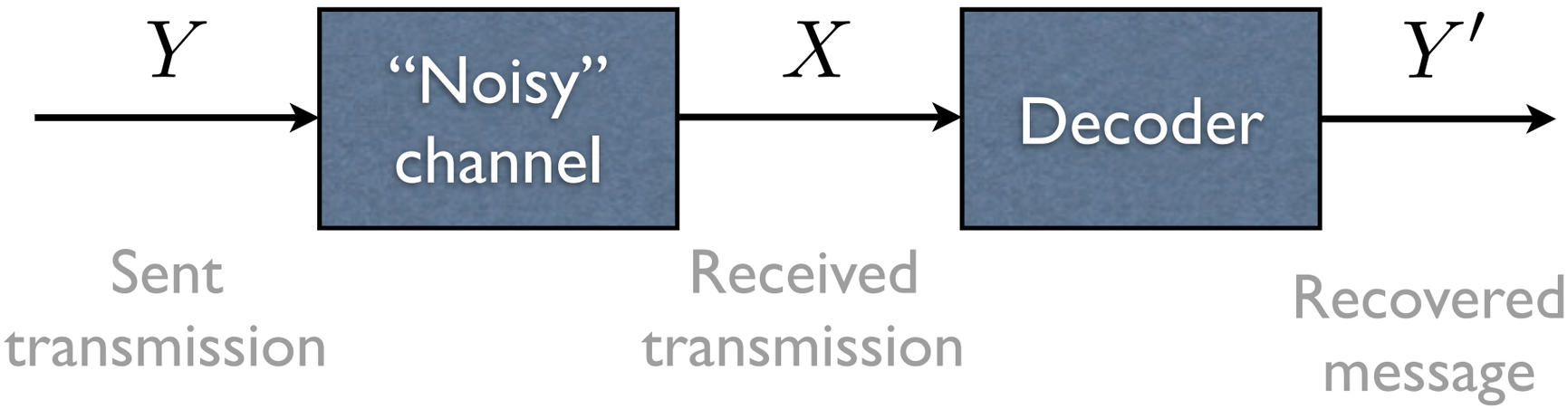

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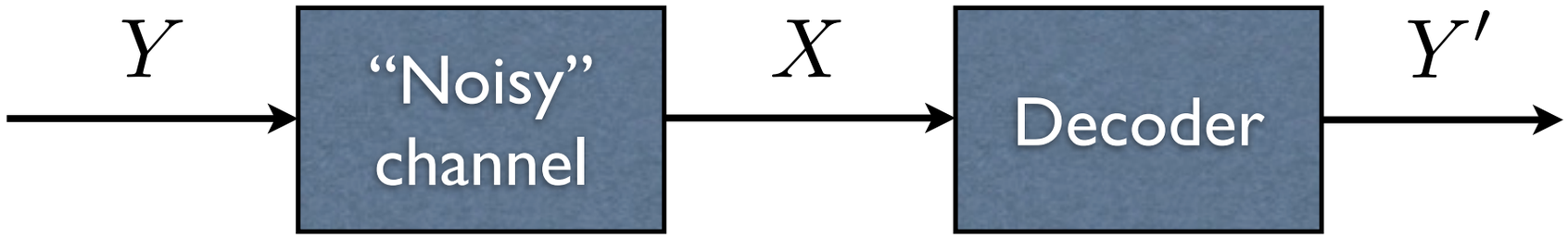
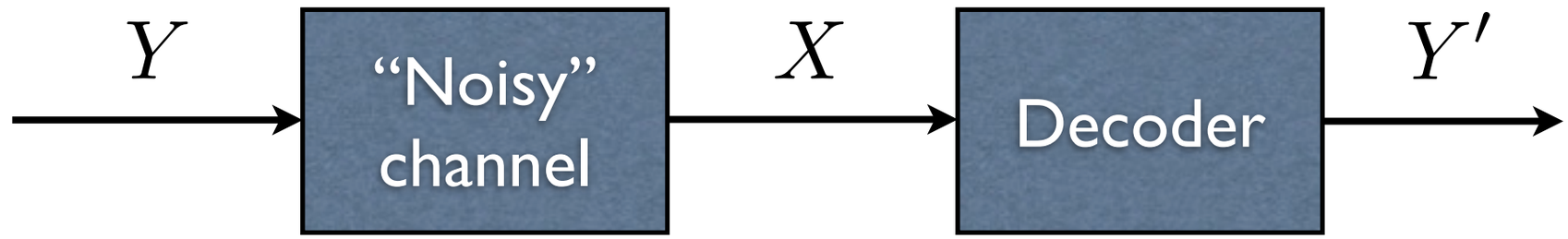


$$y' = \arg\max_{y} p(x|y)p(y)$$

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



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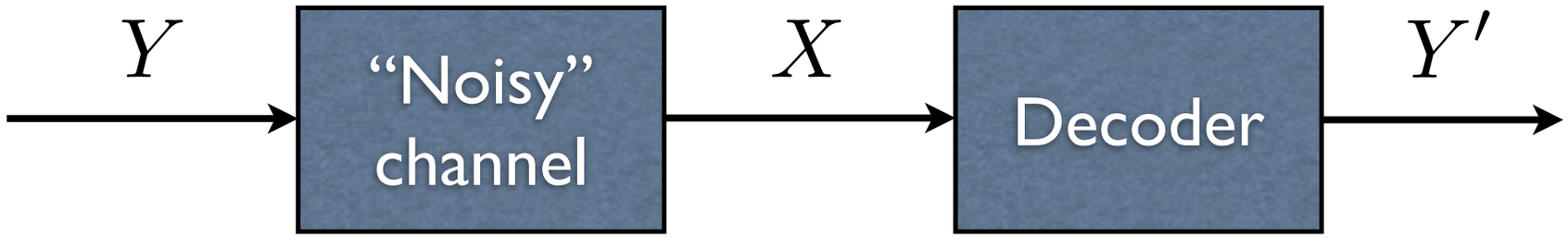
translation model



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English **Csesky** **English'**

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translation model

language model

Division of labor

- **Translation model**
  - translation *back* into the source
  - learned from (source, target) translations
    - **adequacy** of translation
- **Language model**
  - probability of the output sentence
  - learned from *any* target language corpus
  - **fluency** of translation

Intuition for Division of Labor

- Better use of data
  - We have parallel data
  - We also have (lots of) parallel data
    - ... use both
- Use weaker translation models
  - Language modeling is hard ...
  - Translation modeling is language modeling ++
- Language models are used in many applications

The Big Question in MT

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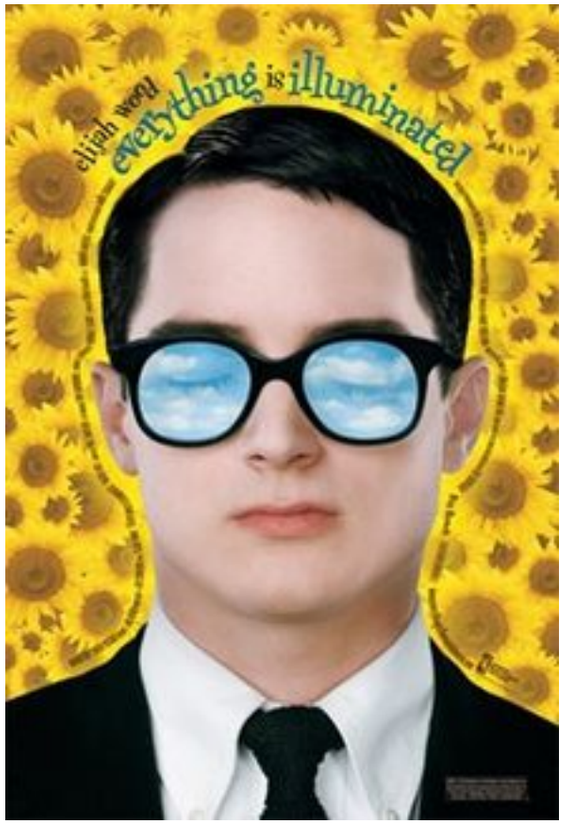
- **How do we *design* language and translation models?**

The Big Question in MT

- **How do we *design* language and translation models?**
- Considerations
  - Is the model ***correct***?
  - Is prediction (*inference*) ***tractable***?
  - Is there data to learn the parameters?

Language Models

- What is the **probability** of a sentence (in a particular language)?
  - There are an *infinite number* of grammatical sentences in any language
  - This is the era of Big Data...but infinity is bigger
- For machine translation
  - Naive model (model language)
  - Naive parameterization (no relationship between words like **walk walked walking walks**)
  - Clever estimation of parameters (Lecture later this week)



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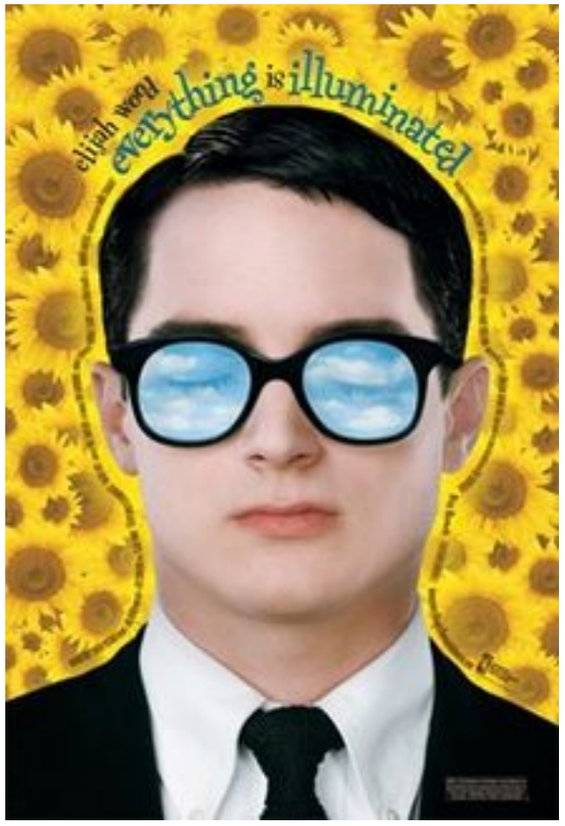

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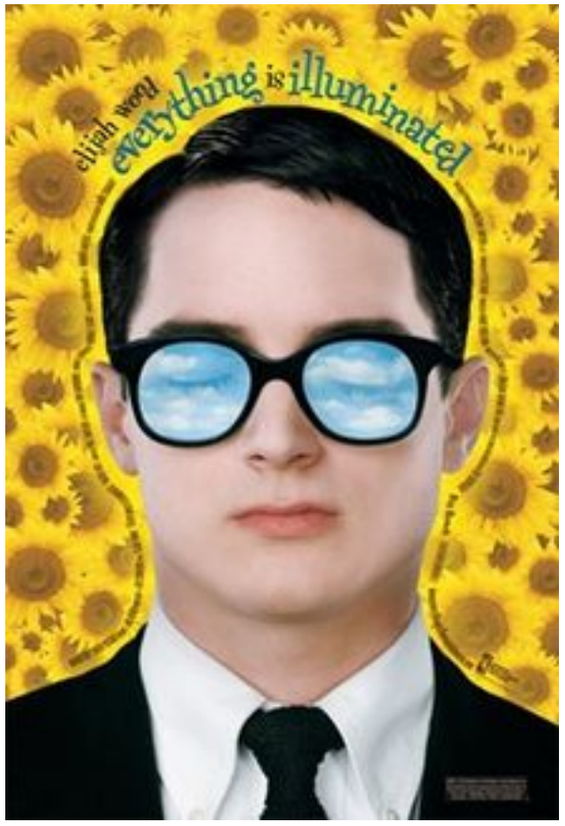

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Probability Models of Text

- Sequence of symbols (bytes, letters, characters, morphemes, words, ...)
  - Let Σ denote the set of symbols
- Lots of possible sequences (Σ^* is infinitely large!)
- Probability distributions over Σ^*?

Probability Models of Text

- How are probability models built?
  - Make some independence assumptions

$$P(x, y) = P(x) \times P(y) \iff x, y \text{ are independent}$$

  - Make assumptions about the (conditional) distributions of the events
  - Estimate parameters from a sample of data

I ^ want

I want a

I want a flight

I want a flight to

I want a flight to Prague

I want a flight to Prague STOP

I want a flight to Prague STOP

English:

I have a bad headache

Chukchi (Siberian language):

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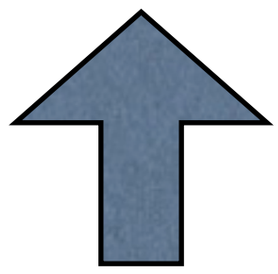

Aggultinative and polysynthetic languages have rich word-formation processes.

English:

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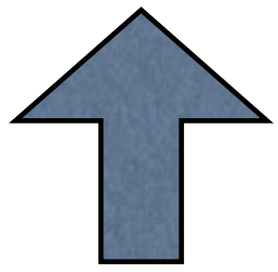
Chukchi (Siberian language):

Təmeyŋəlevtpəγtərkən



Aggultinative and polysynthetic languages have rich word-formation processes.

Translation Models

- Is a string of words **e** a meaning-preserving translation of a string of words **f**?
- Conditional model p(**f** | **e**)
- Challenges
  - There are an infinite number of sentences
  - How do we learn parameters of the models?

In der Innenstadt explodierte eine Autobombe

- **Make independence assumptions**

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  - Permute the source words into the target language order

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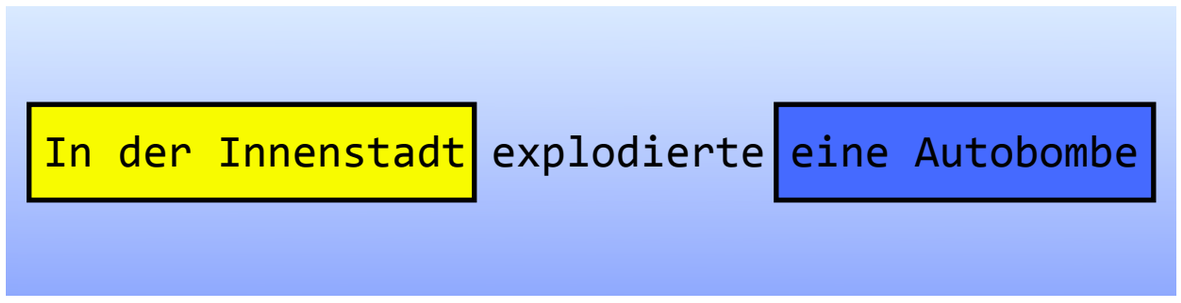

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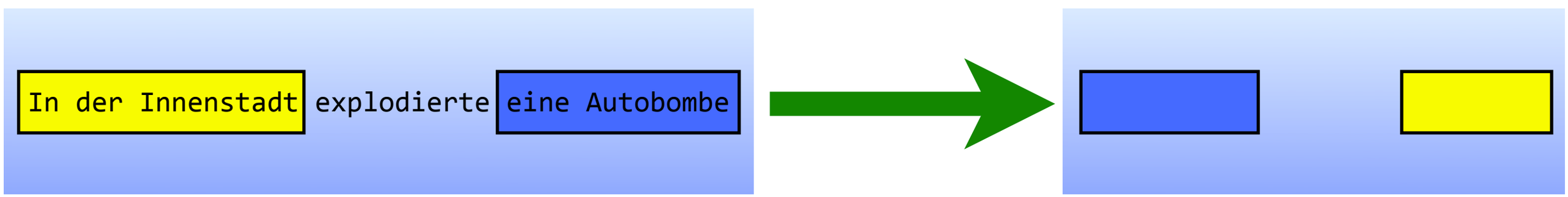
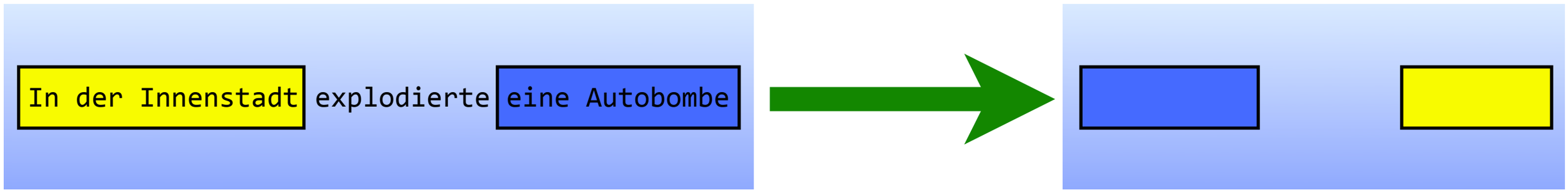


- **Make independence assumptions**
  - Permute the source words into the target language order
  - Pick translations for individual words / phrases
    - Probability of particular translations
    - Look at source context
    - Ensure that the output is fluent & idiomatic



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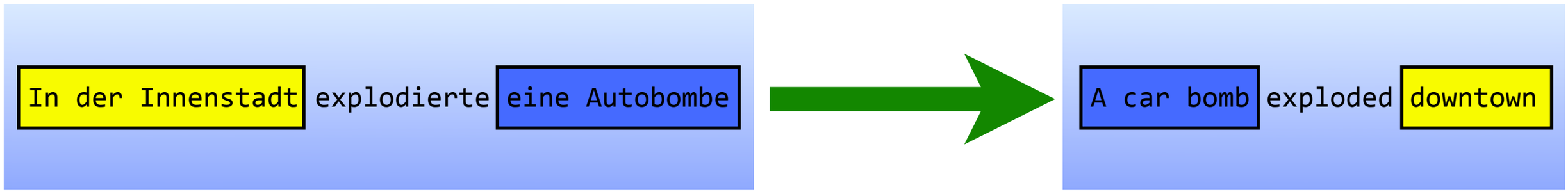

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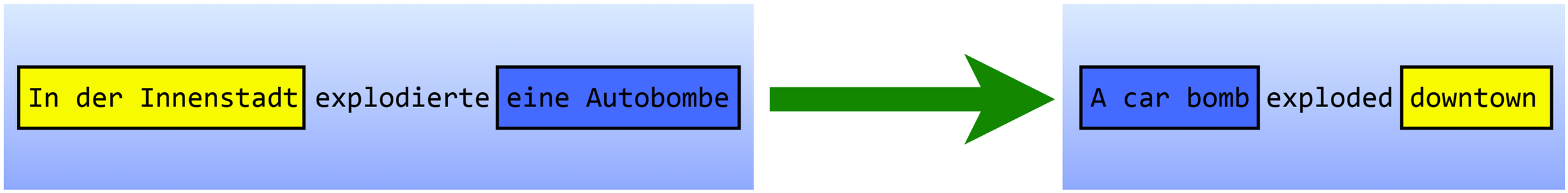
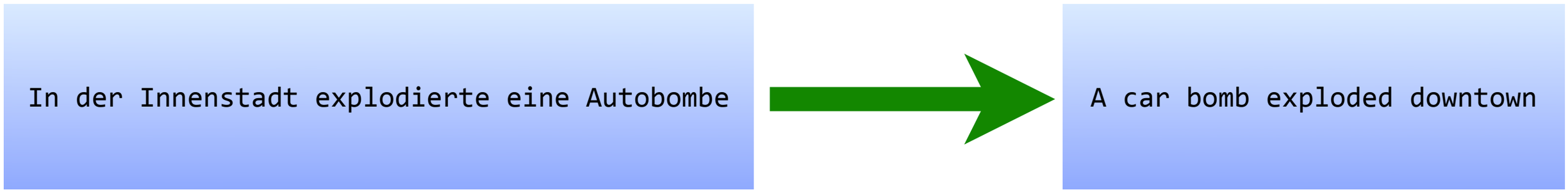
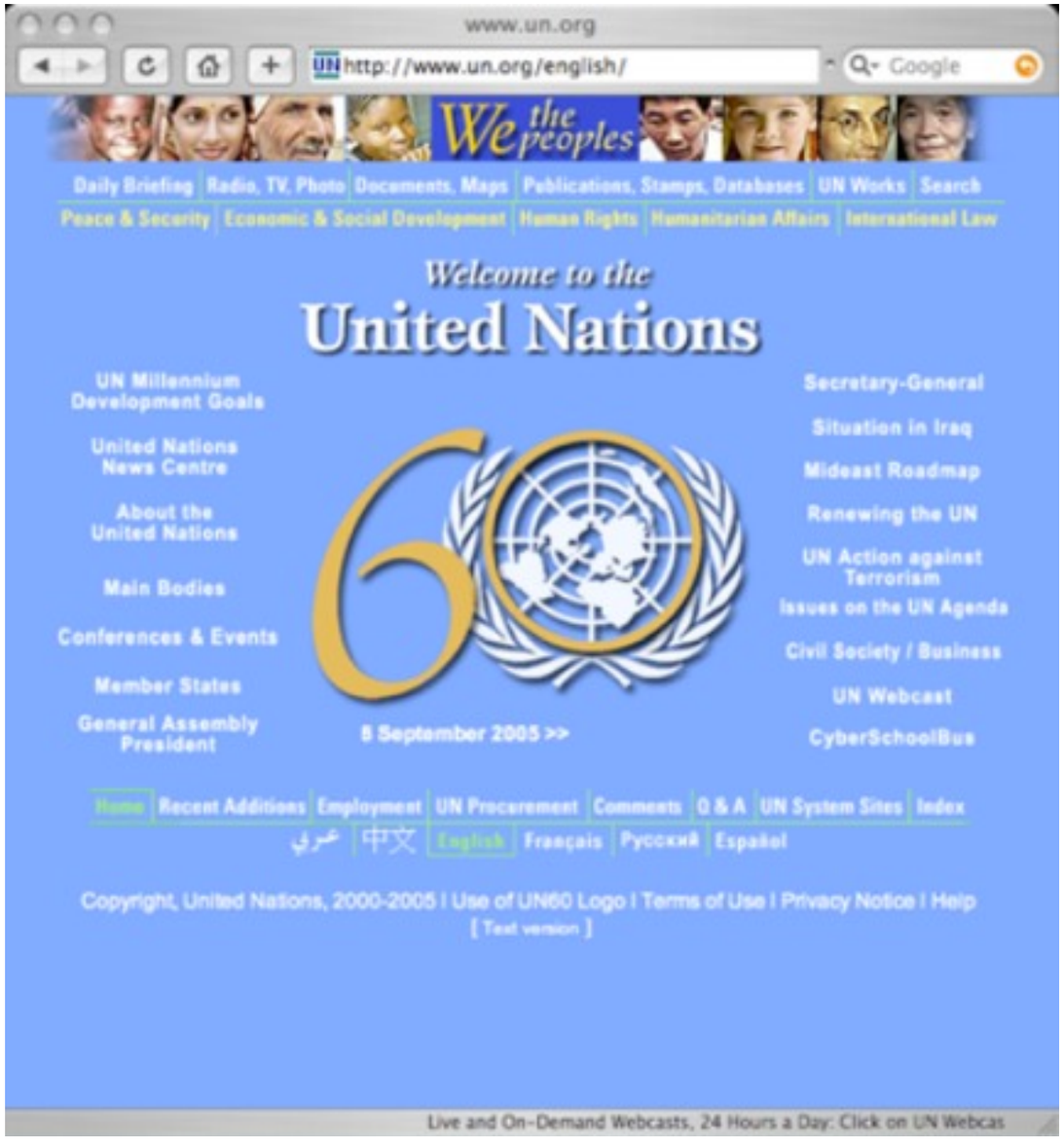
- **Computational challenges**
  - Searching all word permutations is NP-hard
  - Massive numbers of translation alternatives



- **String-to-string translation**
  - Became popular in the 1990's with *statistical MT*
  - State-of-the-art for many (most?) language pairs
    - Especially: Closely related language pairs
    - Especially: Typologically similar language pairs
    - ~ Google Translate / Bing Translator
  - Limitations
    - Independence assumptions are wrong (too strong *and* too weak)
    - No structural information available to improve modeling
  - **Models can be learned directly from *parallel data***

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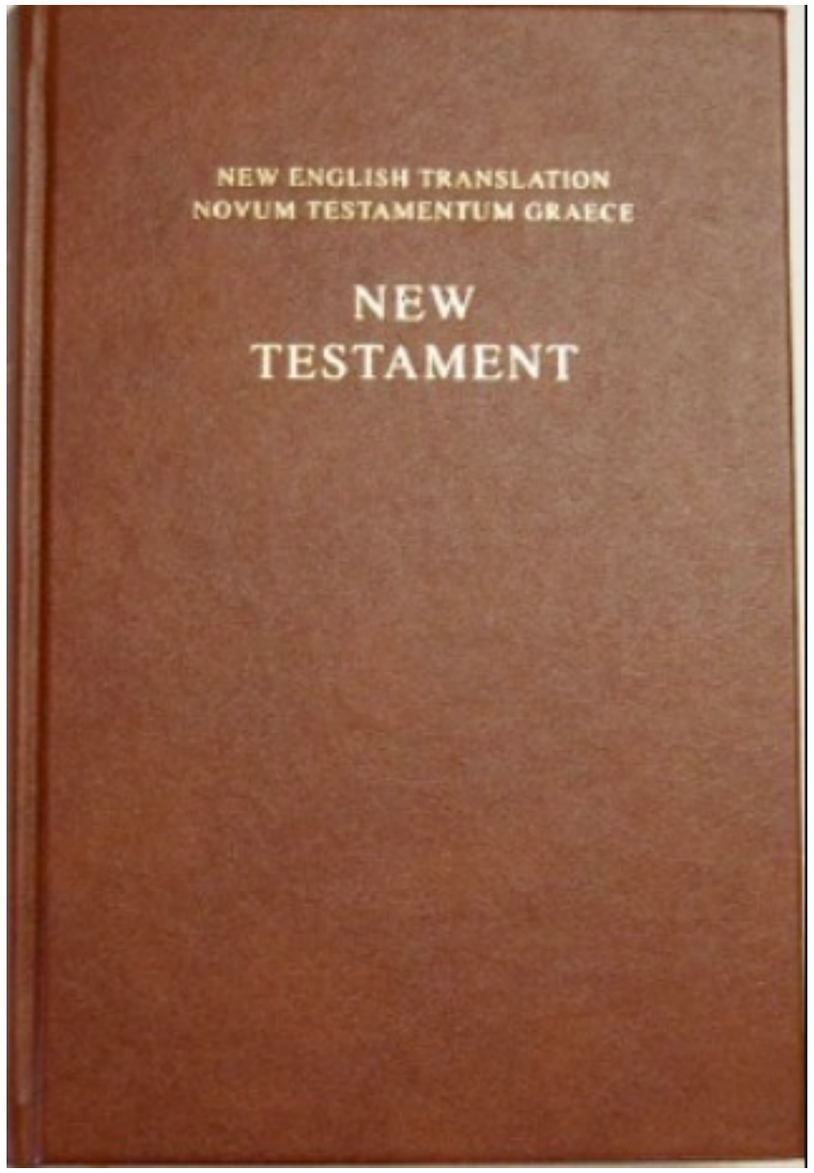
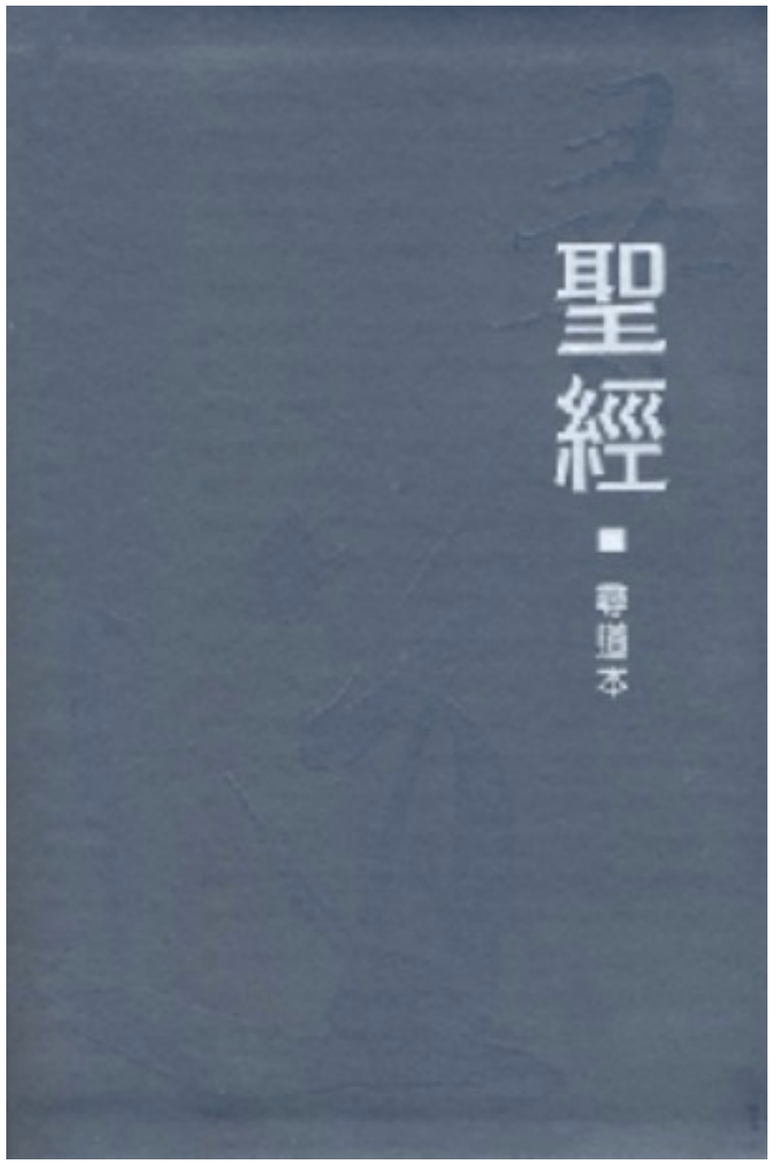
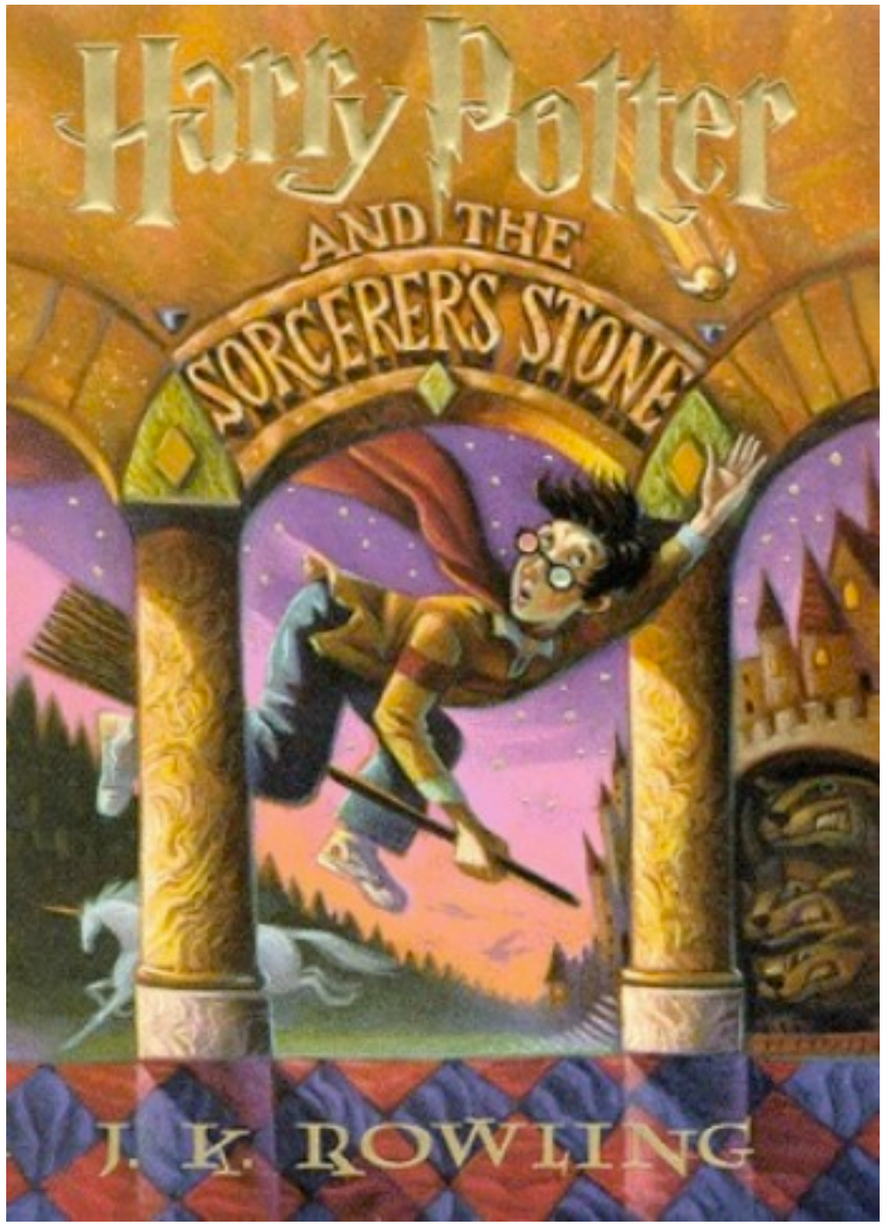
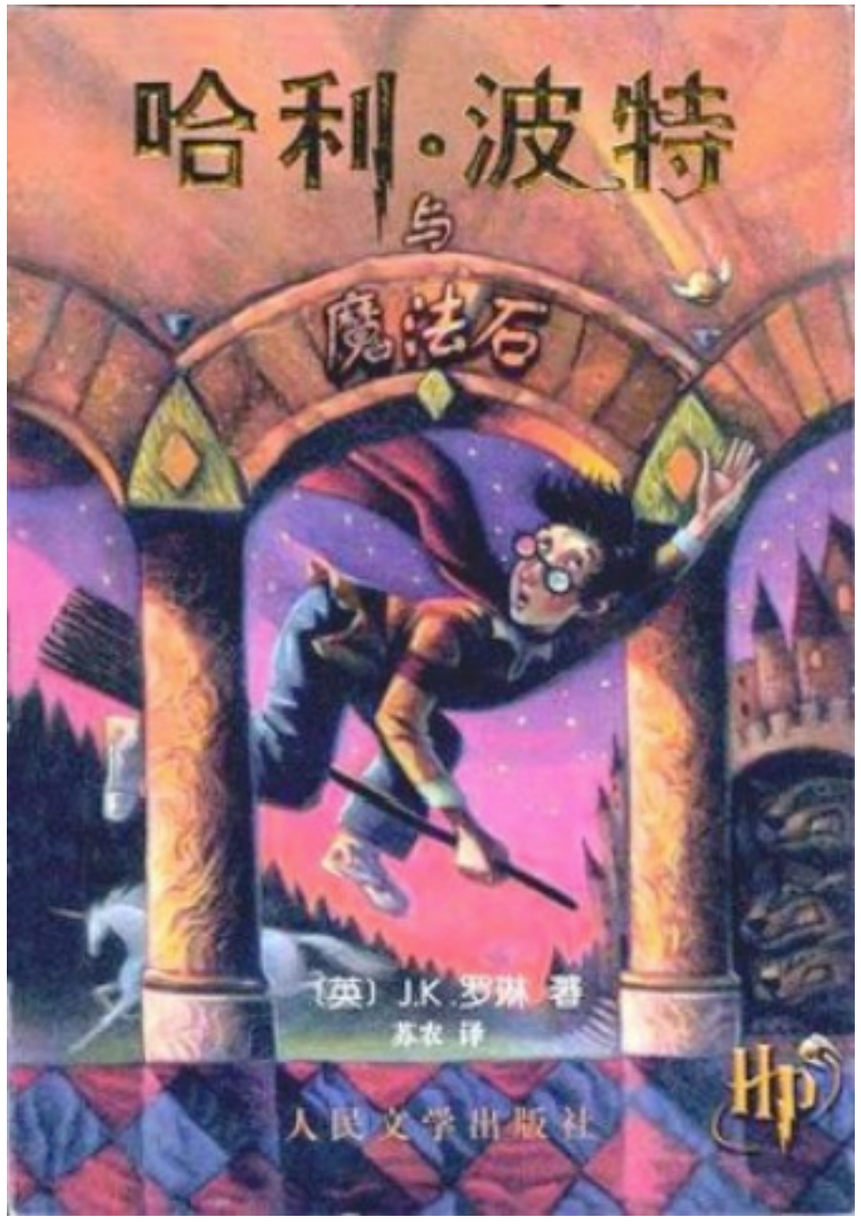

NEW ENGLISH TRANSLATION
NOVUM TESTAMENTUM GRAECE
NEW
TESTAMENT

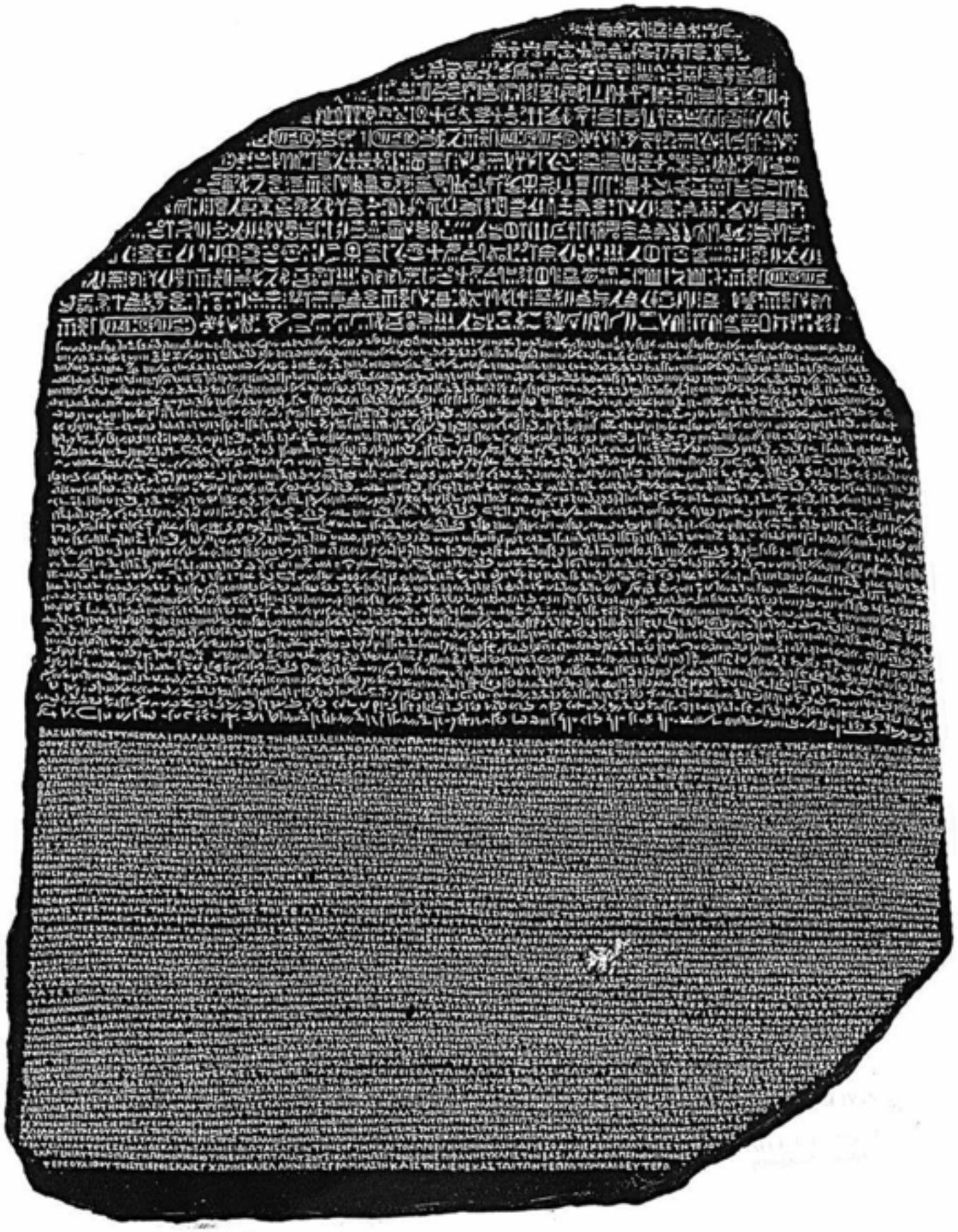

聖經


Harry Potter
AND THE
SORCERER'S STONE
J. K. ROWLING


哈利·波特
与
魔法石
〔英〕J.K.罗琳 著
苏农 译
人民文学出版社
Hp

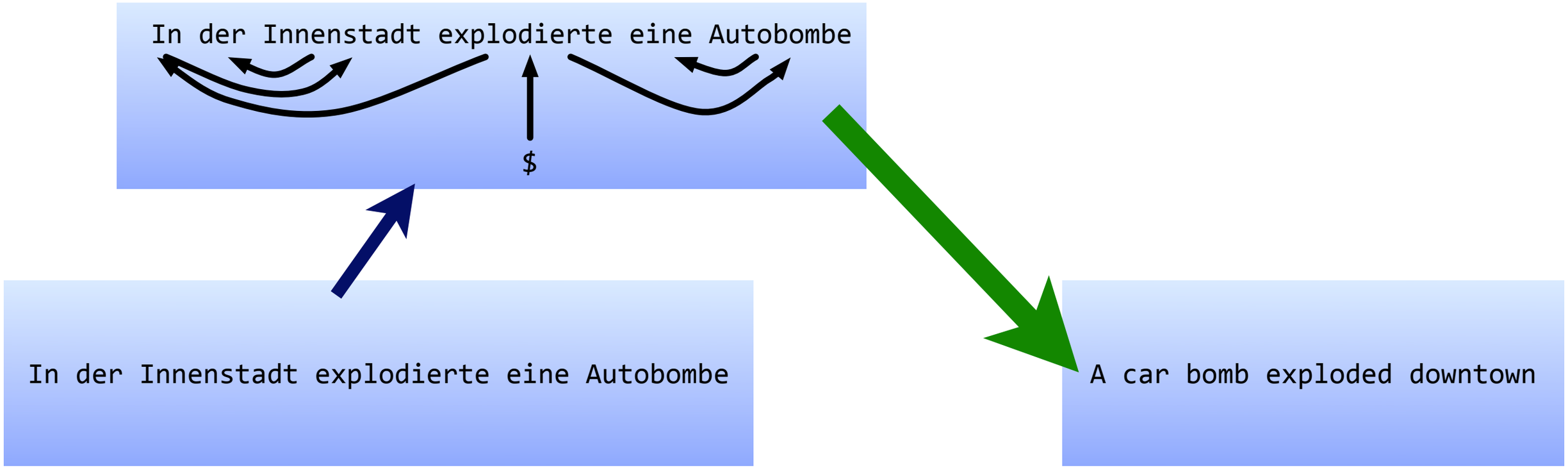
Egyptian

Greek



In der Innenstadt explodierte eine Autobombe

A car bomb exploded downtown


In der Innenstadt explodierte eine Autobombe
$
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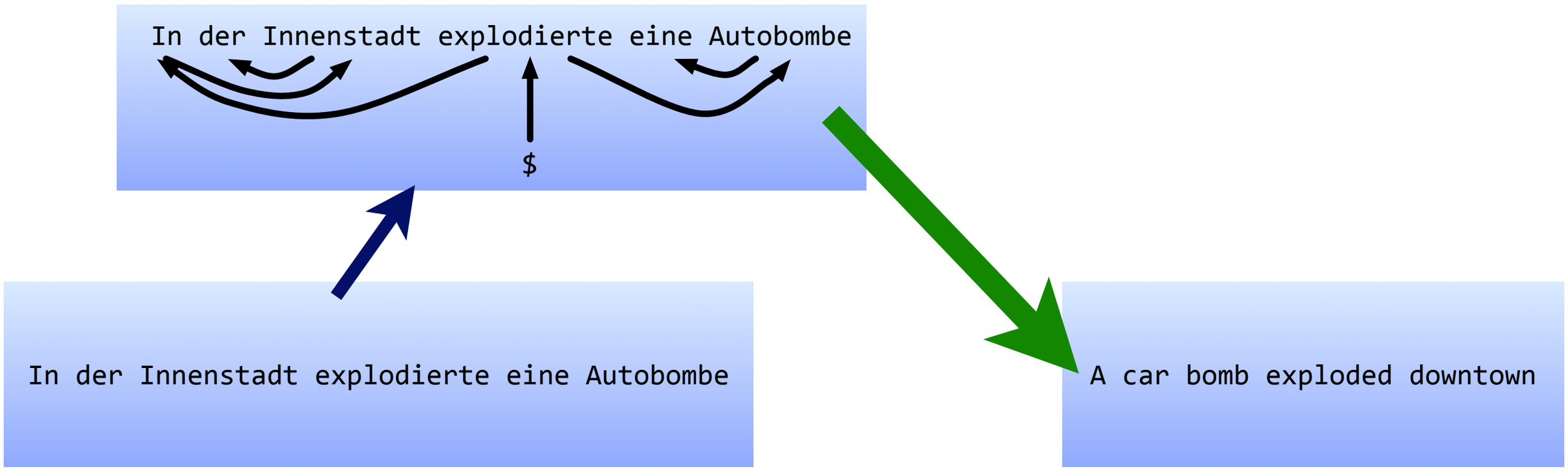
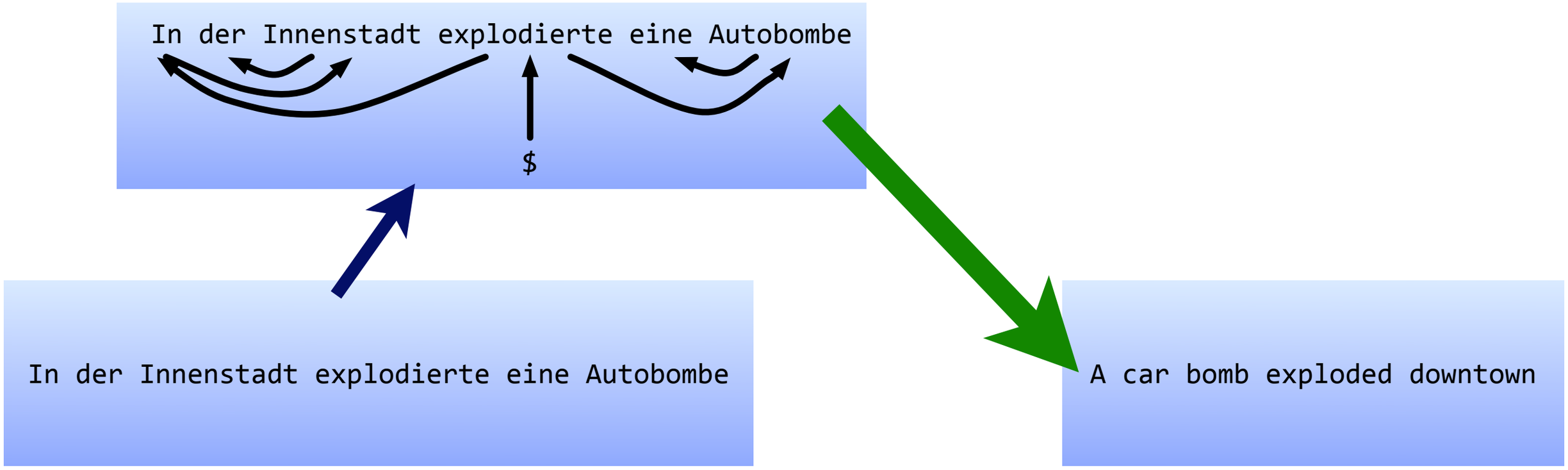
- **Tree-to-string translation**
  - Syntactic *analysis* of source (parse)
  - *Transfer* from tree to string
  - Source trees have some benefits
    - Proxy for semantic relationships
    - Syntax is a natural source of reordering constraints

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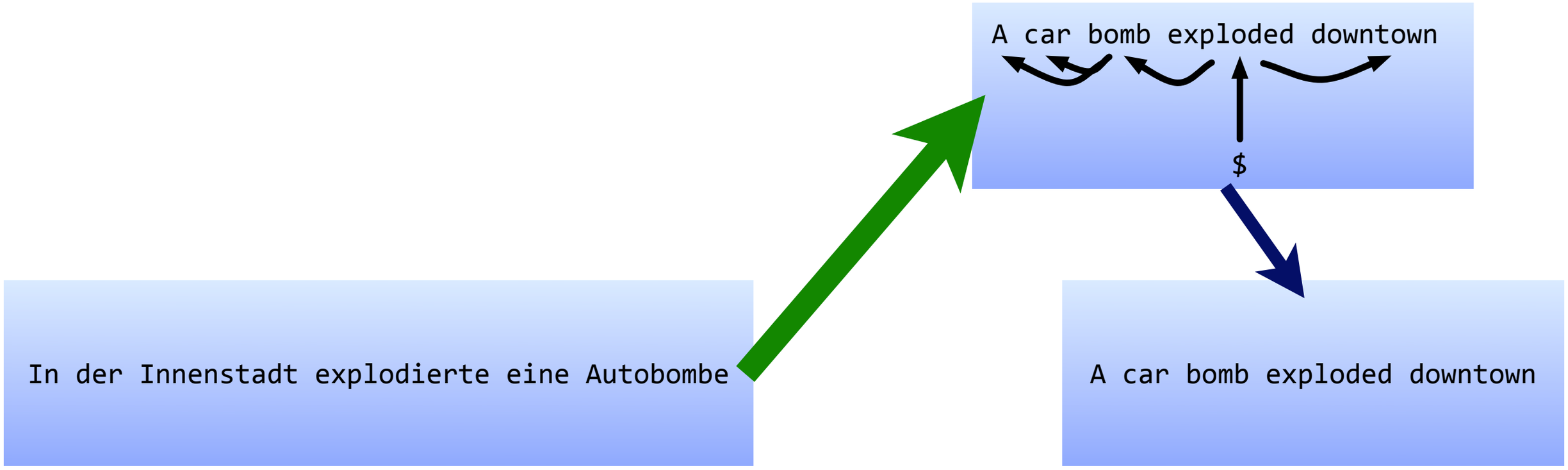
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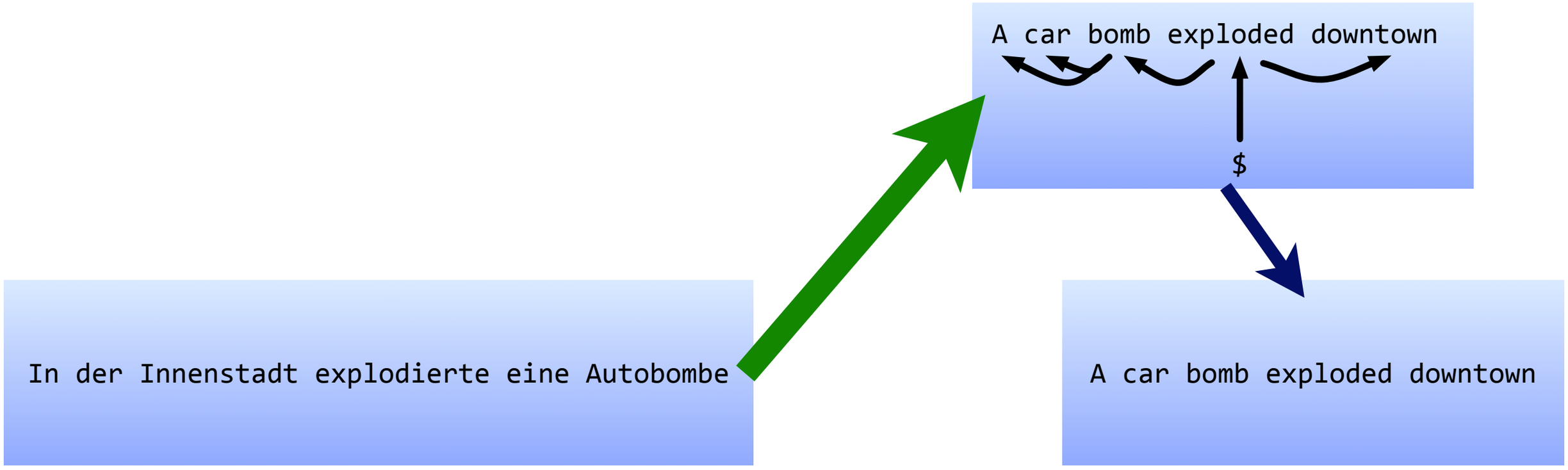
- **String-to-tree translation**
  - Transfer from source tree to target string
  - Formally a generalization of **monolingual parsing**
  - Intuition: it is more important to know the language you are translating into well than the source language



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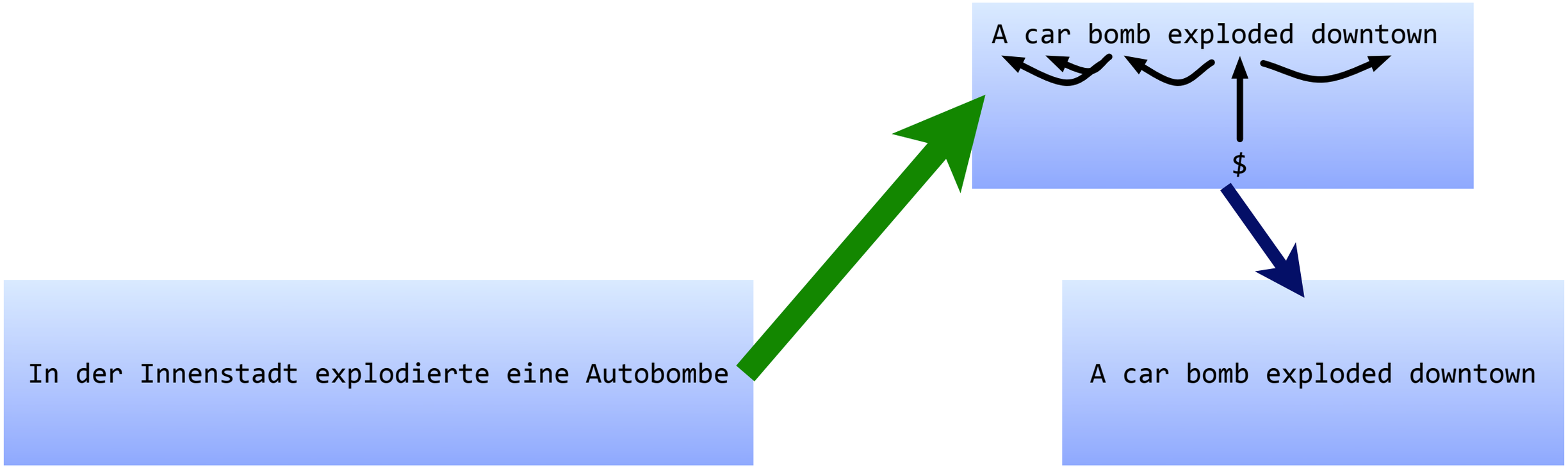
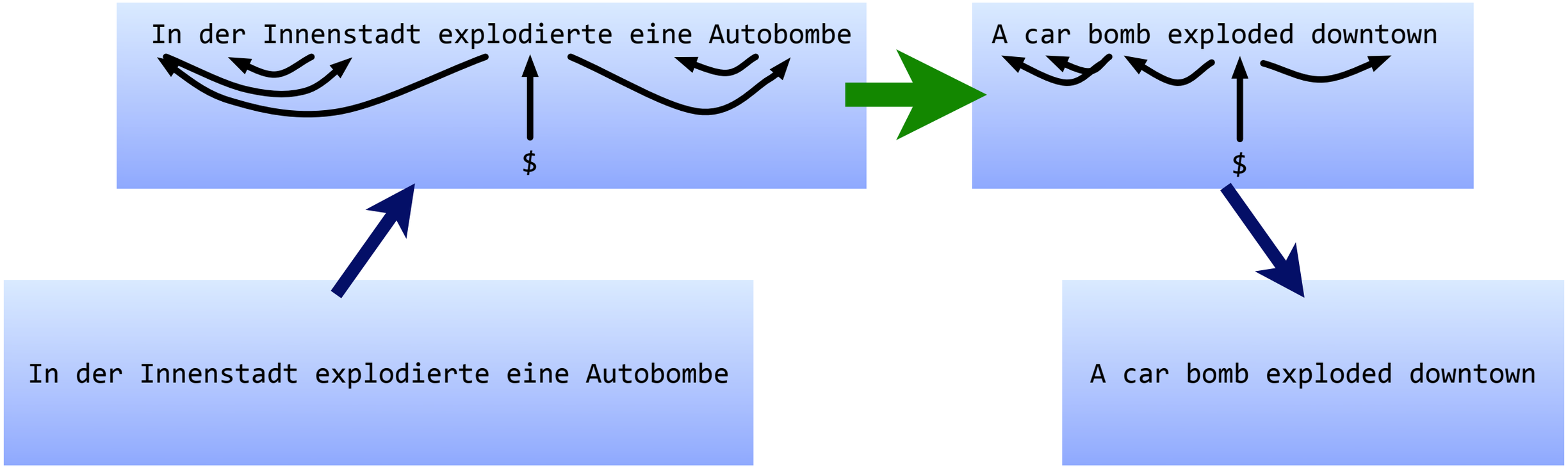
The best Chinese-English systems are string-to-tree

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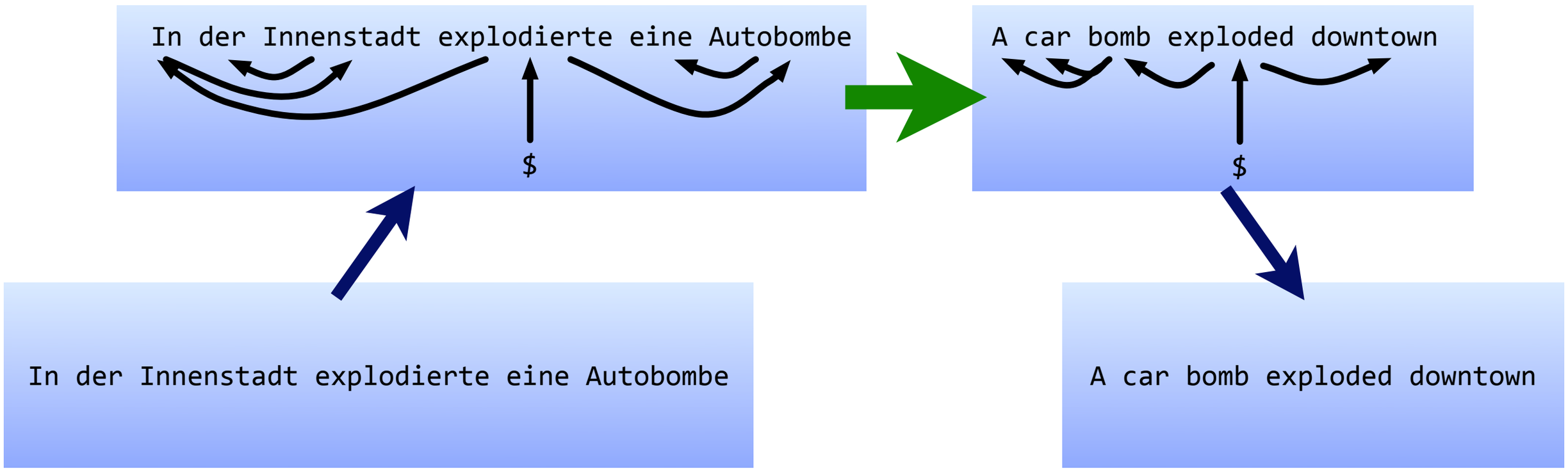
- **Tree to tree translation**
  - Use syntax to predict syntax
  - Benefits
    - As parsers improve, MT will improve (we hope)
    - Rich information for modeling in source and target
  - Downside: where does the syntax come from?

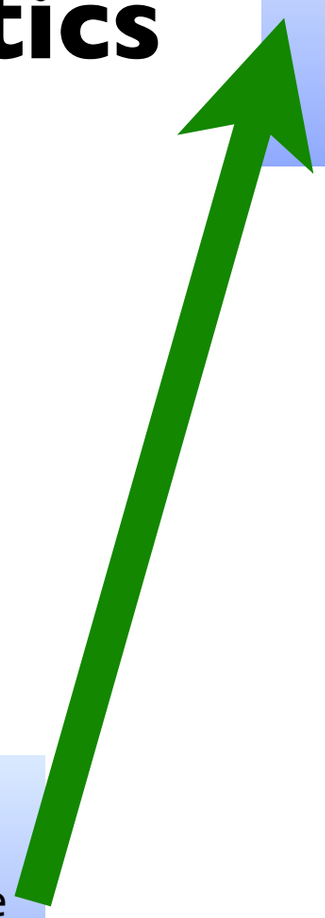


In der Innenstadt explodierte eine Autobombe

Semantics

"logical form"

```
detonate
     :arg0 bomb
     :arg1 car
     :loc downtown
     :time past
```



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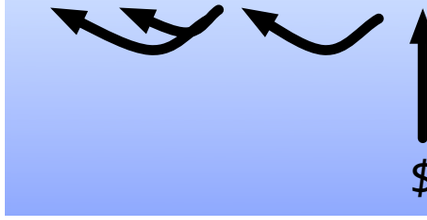

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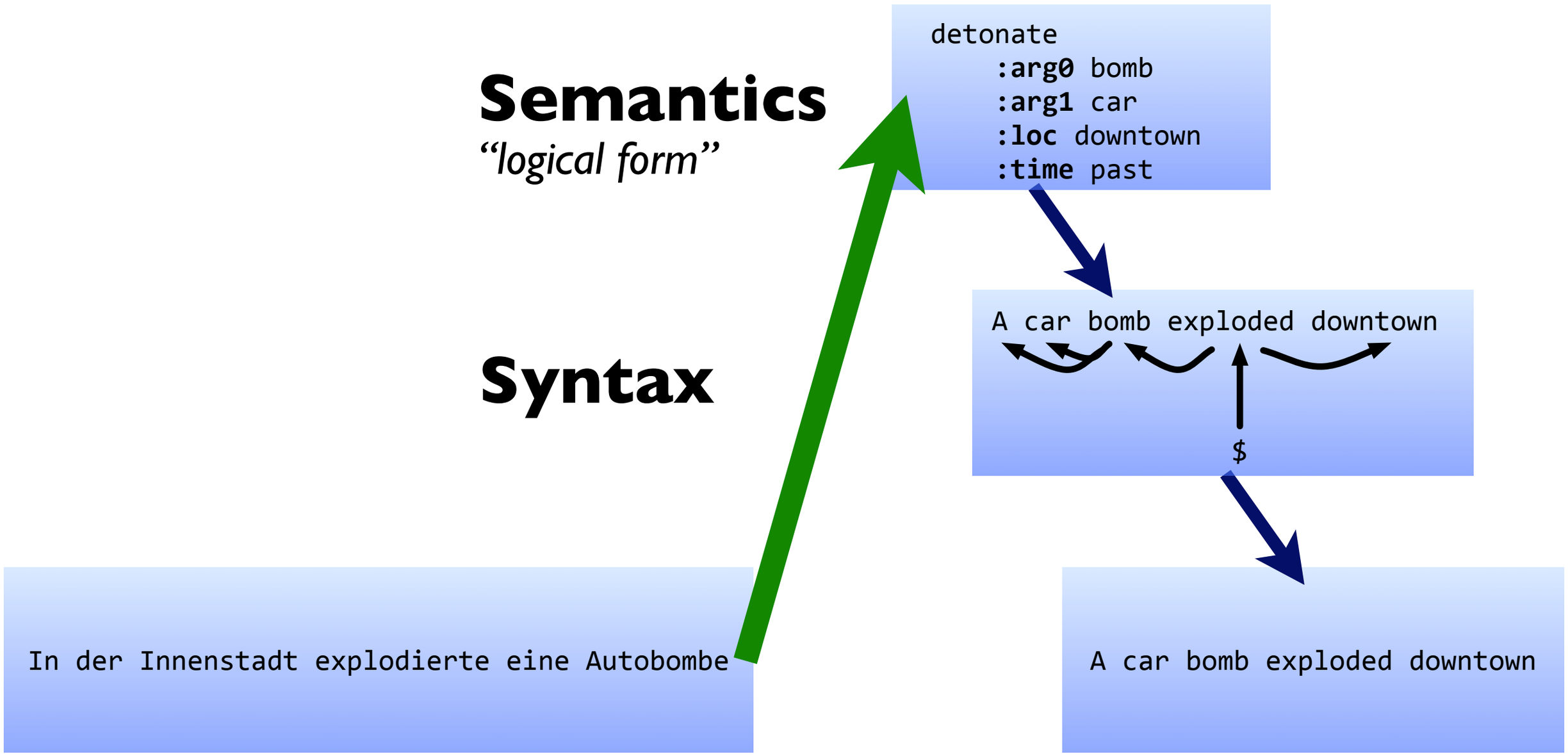

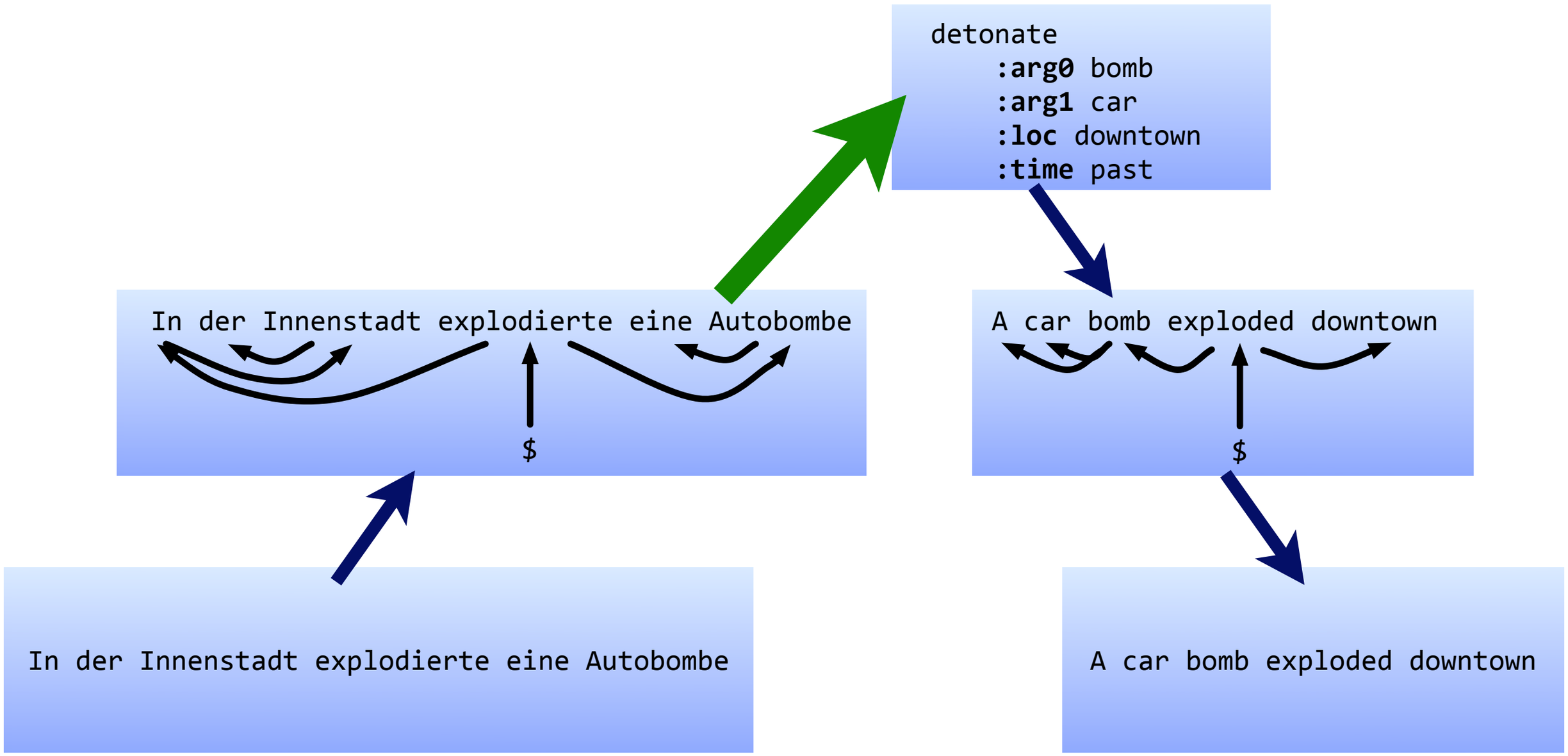
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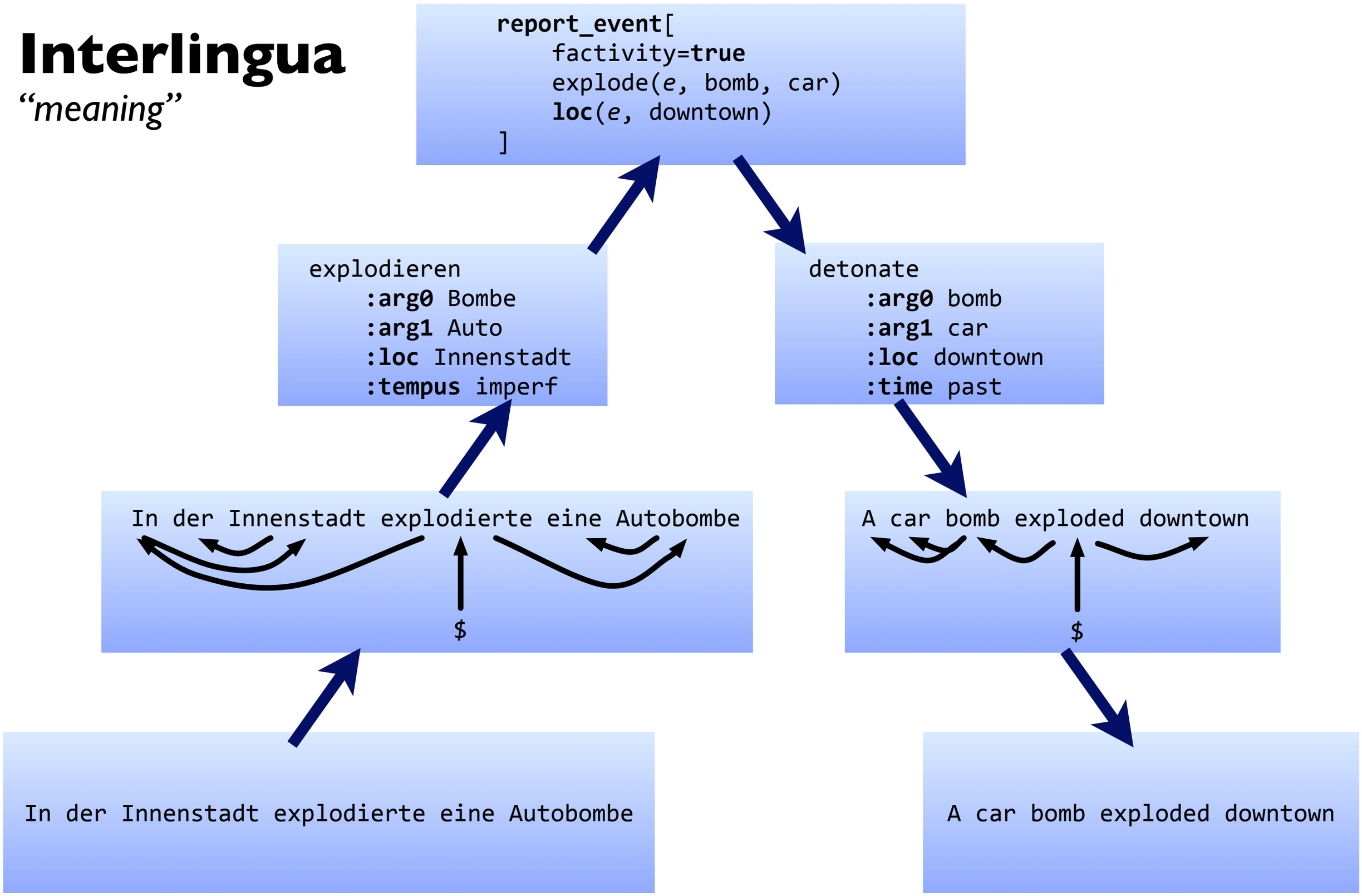
Interlingua

"meaning"



More Abstract Models

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  - How do we support more abstraction without sacrificing accuracy on frequent elements?

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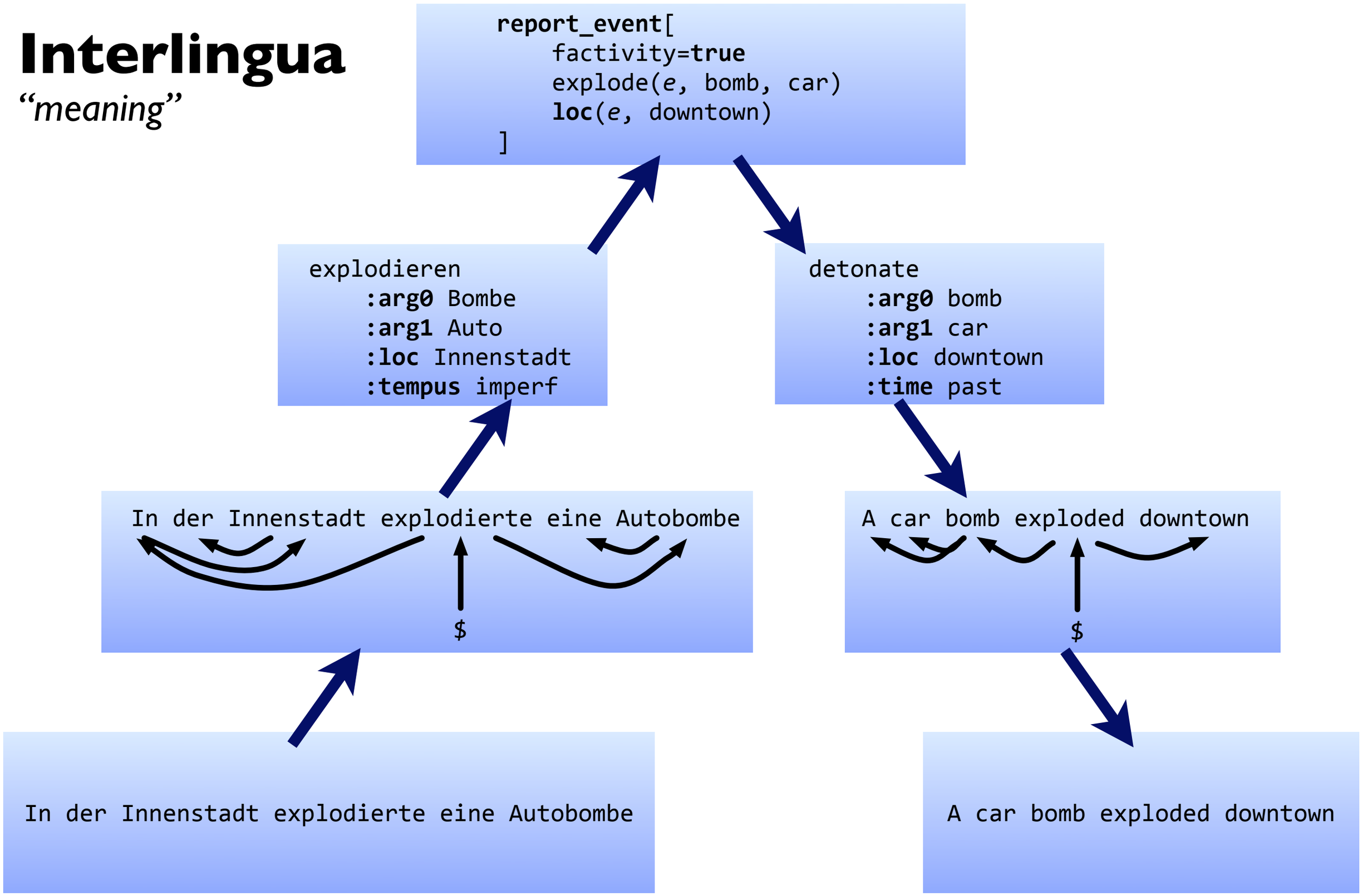
- **Computational challenges**
  - Large search spaces
  - Error propagation in pipelines
- **Learning challenges**
  - Nonconvexity
  - Where does the data come from?

Interlingua

"meaning"



Interlingua

"meaning"

```
report_event[
    factivity=true
    explode(e, bomb, car)
    loc(e, downtown)
]
```

```
explodieren
    arg0 Bombe
    loc Innenstadt
    tempus imperf
```

```
detonate
    :arg0 bomb
    :arg car
    :loc downtown
    :time past
```

Hidden

```
In der Innenstadt explodierte eine Autobombe
                $
```

```
A car bomb exploded downtown
            $
```

In der Innenstadt explodierte eine Autobombe

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Other Challenges

European parliament language (training):

I declare resumed the session of the European Parliament adjourned on Friday 17 December 1999, and I would like once again to wish you a happy new year in the hope that you enjoyed a pleasant festive period.

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Its Me Edith :) @Lovelyyedi 40m

Birthday is on sunday & im pribably not doin anythin cause mom planned that other thing for sat nd sunday idk tf ima do -.-

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spelling error

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nonstandard contractions

Questions?