
НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

# Morphological disambiguation

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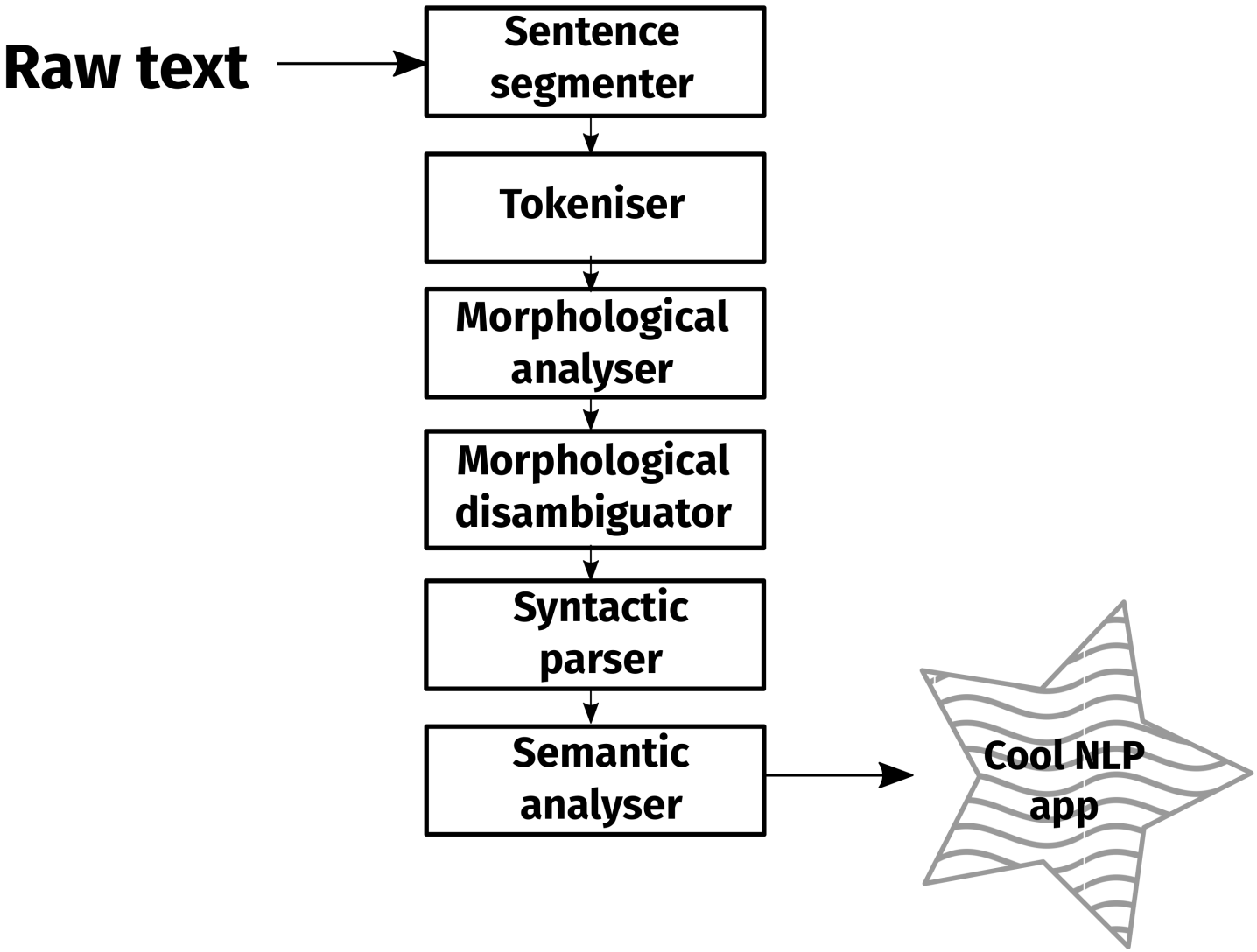
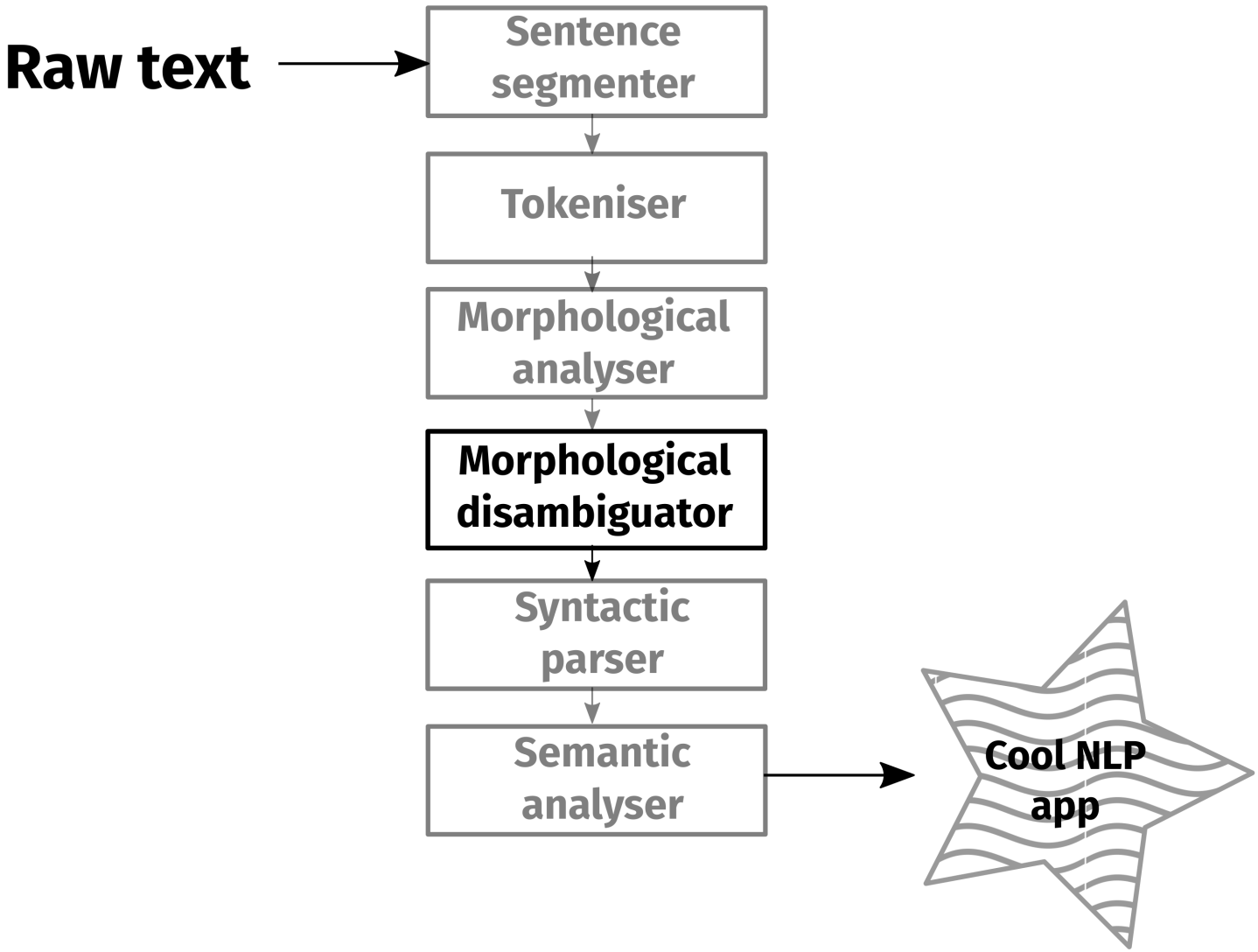
# Introduction

- Introduction, tagsets
- Approaches
  - Rule-based
  - HMM-based
  - Averaged perceptron
- Discussion

# Pipeline


Raw text
Sentence segmenter
Tokeniser
Morphological analyser
Morphological disambiguator
Syntactic parser
Semantic analyser
Cool NLP app

# Pipeline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# Motivating example

**при**

# Motivating example

**при:**

- *при* pr
- *пря* n f nn sg gen
- *пря* n f nn pl nom
- *пря* n f nn pl acc
- *переть* vblex impf tv imp p2 sg
- *переть* vblex impf iv imp p2 sg

# Motivating example

Это я знал еще с 46-го года, когда начал писать, а может быть и раньше, – и факт этот не раз поражал меня и ставил меня в недоумение о полезности искусства **при** таком видимом его бессилии.

**при:**

- *при* pr
- *пря* n f nn sg gen
- *пря* n f nn pl nom
- *пря* n f nn pl acc
- *переть* vblex impf tv imp p2 sg
- *переть* vblex impf iv imp p2 sg

# Applications

Aside from being a stage in the pipeline, what can use POS tagging directly ?

- **Speech synthesis**: How to pronounce a word in context, e.g. *conduct*
  - NOUN: /'kondukt/, VERB /kon'dukt/
- **Disambiguation of meaning**:
  - lie NOUN vs. lie VERB
- **Corpus linguistics**:
  - Find sequences of lexical categories
  - Limit searches for a wordform to a particular category

# Terminology

**Part-of-speech tagging:**

- Traditional term, based on approach(es) for English, finite-set of tags for all combinations of lexical category and morphology.

| | | | | |
|---|---|---|---|---|
| **In:** | This | is | a | test |
| | This/PRON | is/VERB | a/DET | test/NOUN |

**Morphological disambiguation:**

- More cross-linguistically applicable, conception is of disambiguating after morphological analysis.

| | | | | |
|---|---|---|---|---|
| **In:** | This/DET/PRON | is/VERB | a/DET | test/VERB/NOUN |
| | This/PRON | is/VERB | a/DET | test/NOUN |


I DON'T MEAN TO GO ALL LANGUAGE NERD ON YOU, BUT I JUST LEGIT ADVERBED "LEGIT," VERBED "ADVERB," AND ADJECTIVED "LANGUAGE NERD."

# What is a tagset?

- Lemmas generalise over sets of inflectional forms
- Part-of-speech tags generalise over sets of lexemes/lemmas that have similar syntactic distribution

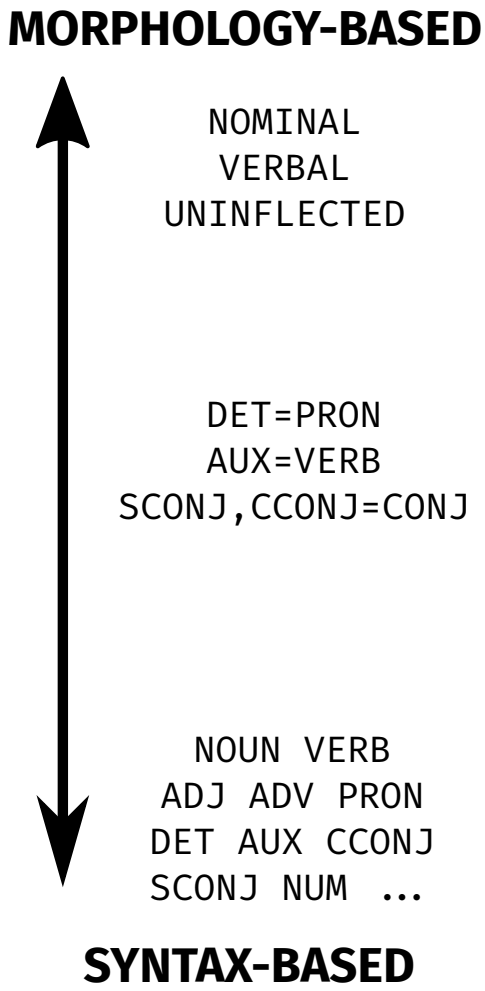
# Tagset design

**Examples:**

- Splitting: Participles from adjectives
- Merging: One class for all nominals

**Questions:**

- Can the ambiguity be resolved?
- Does the distinction help downstream applications?



# Example tagsets

**Penn Treebank**

```
This/DT
tagset/NNS
contains/VBZ
48/CD
unique/JJ
tags/NNP
./.
```

- 48 tags
- Tags are atomic
- Principles have been applied to other languages (Chinese, Bengali, …)
- Extensible ?

# Example tagsets

**Table 2**
The Penn Treebank POS tagset.

| | | | |
|---|---|---|---|
| 1. CC | Coordinating conjunction | 25. TO | *to* |
| 2. CD | Cardinal number | 26. UH | Interjection |
| 3. DT | Determiner | 27. VB | Verb, base form |
| 4. EX | Existential *there* | 28. VBD | Verb, past tense |
| 5. FW | Foreign word | 29. VBG | Verb, gerund/present participle |
| 6. IN | Preposition/subordinating conjunction | 30. VBN | Verb, past participle |
| 7. JJ | Adjective | 31. VBP | Verb, non-3rd ps. sing. present |
| 8. JJR | Adjective, comparative | 32. VBZ | Verb, 3rd ps. sing. present |
| 9. JJS | Adjective, superlative | 33. WDT | *wh*-determiner |
| 10. LS | List item marker | 34. WP | *wh*-pronoun |
| 11. MD | Modal | 35. WP$ | Possessive *wh*-pronoun |
| 12. NN | Noun, singular or mass | 36. WRB | *wh*-adverb |
| 13. NNS | Noun, plural | 37. # | Pound sign |
| 14. NNP | Proper noun, singular | 38. $ | Dollar sign |
| 15. NNPS | Proper noun, plural | 39. . | Sentence-final punctuation |
| 16. PDT | Predeterminer | 40. , | Comma |
| 17. POS | Possessive ending | 41. : | Colon, semi-colon |
| 18. PRP | Personal pronoun | 42. ( | Left bracket character |
| 19. PP$ | Possessive pronoun | 43. ) | Right bracket character |
| 20. RB | Adverb | 44. " | Straight double quote |
| 21. RBR | Adverb, comparative | 45. ‘ | Left open single quote |
| 22. RBS | Adverb, superlative | 46. “ | Left open double quote |
| 23. RP | Particle | 47. ’ | Right close single quote |
| 24. SYM | Symbol (mathematical or scientific) | 48. ” | Right close double quote |

# Example tagsets

## Positional tags

```
<s id="Osl.1.2.3.4">
  <w lemma="Winston" ana="Npmsn">Winston</w>
  <w lemma="se" ana="Px------y">se</w>
  <w lemma="biti" ana="Vcip3s--n">je</w>
  <w lemma="napotiti" ana="Vmps-sma">napotil</w>
  <w lemma="proti" ana="Spsd">proti</w>
  <w lemma="stopnica" ana="Ncfpd">stopnicam</w>
  <c>.</c>
</s>
```

+ Compact
- Hard to read
- No support for derivational morphology

# Example tagsets

## Mnemonic tags

```
Sápmelaččas [sápmelaš] N Sg Loc
leai [leat] V IV Ind Prt Sg3
dakkár [dakkár] Pron Dem Attr
luondu [luondu] N Sg Nom
, [,] CLB
ahte [ahte] CS
son [son] Pron Pers Sg3 Nom
háliidišgođii [háliidit] V TV Der/goahti Ind Prt Sg3
gottiid [goddi] N Pl Acc
. [.] CLB
```

+ Easily handle derivations
+ Implicit morphological structure
- Number of tags can explode
- Modelling derivation is less language-independent

# Example tagsets

## Feature/value pairs

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Польша | _ | PROPN | _ | Animacy=Inan\|Case=Nom\|Gender=Fem\|Number=Sing | _ |
| 2 | является | _ | VERB | _ | Aspect=Imp\|Number=Sing\|Person=3\|Tense=Pres | _ |
| 3 | безъядерной | _ | ADJ | _ | Animacy=Inan\|Case=Ins\|Gender=Fem\|Number=Sing | _ |
| 4 | страной | _ | NOUN | _ | Animacy=Inan\|Case=Ins\|Gender=Fem\|Number=Sing | _ |
| 5 | . | _ | PUNCT | _ | _ | _ |

+ Easy to read
- No support for derivational morphology
- No implicit morphological structure
- Takes up a lot of space

# Limitations

ӷорагыркиплыткогъат

- ӷора-гырки-плыткогъат
- reindeer-catch-finish-3PL
- *They finished catching reindeer.*

- Does `VERB` really capture what this is ?
- We can represent morphology easily, maybe even derivation
- But what about the incorporation ?

# Scale of the problem

- UD corpora
- Percentage of tokens and types that receive more than one analysis
- Underestimation, e.g. Turkish *için*:
  - \+ for.POST
  - \+ inside.GEN
  - \- inside.2SG.NOM
  - \- drink.IMP.2PL

| Language | Tokens | /type | /token |
|---|---|---|---|
| Turkish | 58k | 4.29 | 17.44 |
| Finnish | 201k | 3.46 | 18.09 |
| Kurmanji | 10k | 9.35 | 36.72 |
| Basque | 121k | 11.47 | 38.47 |
| Russian | 1.1M | 13.50 | 40.94 |
| Erzya | 2k | 9.73 | 41.37 |
| Norwegian | 301k | 8.28 | 43.78 |
| Czech | 1.5M | 18.09 | 47.17 |
| English | 254k | 14.20 | 52.34 |
| German | 292k | 20.17 | 56.52 |
| Portuguese | 227k | 13.19 | 64.51 |
| Catalan | 531k | 8.31 | 66.49 |
| Hebrew | 161k | 15.56 | 71.62 |
| Hindi | 351k | 36.28 | 86.84 |

# Types of ambiguity

| Type | all tokens | ambig. tokens |
|---|---|---|
| Intraparadigm. | 59.0% | 90.9% |
| Incongruent | 27.7% | 42.7% |
| Congruent | 1.2% | 1.8% |

- Intraparadigmatic:
  - ’тела (SG.GEN) vs. тел’а (PL.NOM)
- Morphosyntactically incongruent:
  - до’рога (NOUN) vs. дорог’а (ADJ)
- Morphosyntactically congruent:
  - ’замок (SG.NOM) vs. зам’ок (SG.NOM)

# Approaches

- **Rule-based**
- **HMM-based**
- **Averaged perceptron**

# Rule-based

# Constraint Grammar

- Developed by Fred Karlsson[1] in the late 1980s
- Does not aim at producing a full "parse tree"
- Describes what is *ungrammatical*, not what is grammatical
- Linguists formalise "constraints" which describe language impossibilities
  - e.g. "No noun can be in prepositional case without a preposition which governs the prepositional case."
- No "encapsulation", all parts of the analysis (surface form $\rightarrow$ semantics) are always available
- Input is all possible analyses, output is only possible analyses

[1] The same Fred Karlsson that wrote "Finsk grammatik".

# Formalism

**Input:**

```
«Польша>”
    ”Польша”np top f sg nom
«является>”
    ”являться”v impf iv pres p3 sg
«безъядерной>”
    ”безъядерный”adj f an sg gen
    ”безъядерный”adj f an sg dat
    ”безъядерный”adj f an sg prp
    ”безъядерный”adj f an sg ins
«страной>”
    ”страна”n f nn sg ins
«.>”
    ”.”sent
```

**Operators:**

- select: Discard all readings except the reading matching a condition
- remove: Discard a single reading matching a condition

**Context conditions:**

- (-1 pres) $\rightarrow$ previous token has the tag PRES
- (1C ins) $\rightarrow$ following token *only* has the tag INS
- (NOT -1* pr) $\rightarrow$ no token to the left has the tag PR

# Basic example

## Input:

```
«Польша>”
    ”Польша”np top f sg nom
«является>”
    ”являться”v impf iv pres p3 sg
«безъядерной>”
    ”безъядерный”adj f an sg gen
    ”безъядерный”adj f an sg dat
    ”безъядерный”adj f an sg prp
    ”безъядерный”adj f an sg ins
«страной>”
    ”страна”n f nn sg ins
«.>”
    ”.”sent
```

# Basic example

**Input:**

```
«Польша>”
    ”Польша”np top f sg nom
«является>”
    ”являться”v impf iv pres p3 sg
«безъядерной>”
    ”безъядерный”adj f an sg gen
    ”безъядерный”adj f an sg dat
    ”безъядерный”adj f an sg prp
    ”безъядерный”adj f an sg ins
«страной>”
    ”страна”n f nn sg ins
«.>”
    ”.”sent
```

1 REMOVE prp IF (not -1* pr)

# Basic example

**Input:**

```
«Польша>”
    ”Польша”np top f sg nom
«является>”
    ”являться”v impf iv pres p3 sg
«безъядерной>”
    ”безъядерный”adj f an sg gen
    ”безъядерный”adj f an sg dat
    ”безъядерный”adj f an sg prp
    ”безъядерный”adj f an sg ins
«страной>”
    ”страна”n f nn sg ins
«.>”
    ”.”sent
```

1. REMOVE prp IF (not -1* pr)
2. REMOVE gen IF (-1 pres) (0C adj) (not 1 gen)

# Basic example

**Input:**

```
«Польша>”
    ”Польша”np top f sg nom
«является>”
    ”являться”v impf iv pres p3 sg
«безъядерной>”
    ”безъядерный”adj f an sg gen
    ”безъядерный”adj f an sg dat
    ”безъядерный”adj f an sg prp
    ”безъядерный”adj f an sg ins
«страной>”
    ”страна”n f nn sg ins
«.>”
    ”.”sent
```

1. REMOVE prp IF (not -1* pr)
2. REMOVE gen IF (-1 pres) (0C adj) (not 1 gen)

Exercise: Can we safely remove the dative reading?

# Less basic example

« Для соседних с Руандой государств руандийские события апреля – июля 1994 года вылились в огромное число прибывших беженцев . »

# Standard trigram taggers

| | |
|---|---|
| Для | PR |
| соседних | A=pl,gen,plen |
| с | PR |
| Руандой | S,f,inan=sg,ins |
| государств | S,n,inan=pl,gen |
| руандийские | A=pl,acc,inan,plen |
| события | S,n,inan=pl,acc |
| апреля | S,m,inan=sg,gen |
| – | – |
| июля | S,m,inan=sg,gen |
| 1994 | NUM=ciph |
| года | S,m,inan=sg,gen |
| вылились | V,pf,intr,med=pl,praet,indic |
| в | PR |
| огромное | A=n,sg,acc,inan,plen |
| число | S,n,inan=sg,acc |
| прибывших | V,pf,intr,act=partcp,pl,gen,praet,plen |
| беженцев | S,m,anim=pl,gen |
| . | . |

# Standard trigram taggers

| | |
|---|---|
| Для | PR |
| соседних | A=pl,gen,plen |
| с | PR |
| Руандой | S,f,inan=sg,ins |
| государств | S,n,inan=pl,gen |
| руандийские | **A=pl,acc,inan,plen** |
| события | **S,n,inan=pl,acc** |
| апреля | S,m,inan=sg,gen |
| – | – |
| июля | S,m,inan=sg,gen |
| 1994 | NUM=ciph |
| года | S,m,inan=sg,gen |
| вылились | V,pf,intr,med=pl,praet,indic |
| в | PR |
| огромное | A=n,sg,acc,inan,plen |
| число | S,n,inan=sg,acc |
| прибывших | V,pf,intr,act=partcp,pl,gen,praet,plen |
| беженцев | S,m,anim=pl,gen |
| . | . |

2 / 19 = 89.5% accuracy

# Input: Morphological analysis

```
«Для>”
   ”для”pr
«соседних>”
   ”соседний”adj mfn an pl gen
   ”соседний”adj mfn an pl prp
   ”соседний”adj mfn aa pl acc
«с>”
   ”с”pr
«Руандой>”
   ”Руанда”np top f sg ins
«государств>”
   ”государство”n nt nn pl gen
«руандийские>”
   ”руандийский”adj mfn an pl nom
   ”руандийский”adj mfn nn pl acc
«события>”
   ”событие”n nt nn sg gen
   ”событие”n nt nn pl nom
   ”событие”n nt nn pl acc
«апреля>”
   ”апрель”n m nn sg gen
«–>”
   ”–”guio
«июля>”
   ”июль”n m nn sg gen
```

rule: –

```
«1994>”
   ”1994”num
«года>”
   ”год”n m nn sg gen
«вылились>”
   ”вылиться”v perf iv past mfn pl
«в>”
   ”в”pr
«огромное>”
   ”огромный”adj nt an sg nom
   ”огромный”adj nt an sg acc
«число>”
   ”число”n nt nn sg acc
   ”число”n nt nn sg nom
«прибывших>”
   ”прибыть”v perf iv pp actv mfn an pl acc
   ”прибыть”v perf iv pp actv mfn an pl prp
   ”прибыть”v perf iv pp actv mfn aa pl gen
«беженцев>”
   ”беженец”n m aa pl gen
   ”беженец”n m aa pl acc
«.>”
   ”.”sent
```

# Input: Morphological analysis

```
«Для>”
   ”для”pr
«соседних>”
   ”соседний”adj mfn an pl gen
   ”соседний”adj mfn an pl prp
   ”соседний”adj mfn aa pl acc
«с>”
   ”с”pr
«Руандой>”
   ”Руанда”np top f sg ins
«государств>”
   ”государство”n nt nn pl gen
«руандийские>”
   ”руандийский”adj mfn an pl nom
   ”руандийский”adj mfn nn pl acc
«события>”
   ”событие”n nt nn sg gen
   ”событие”n nt nn pl nom
   ”событие”n nt nn pl acc
«апреля>”
   ”апрель”n m nn sg gen
«–>”
   ”–”guio
«июля>”
   ”июль”n m nn sg gen
```

rule: 1

```
«1994>”
   ”1994”num
«года>”
   ”год”n m nn sg gen
«вылились>”
   ”вылиться”v perf iv past mfn pl
«в>”
   ”в”pr
«огромное>”
   ”огромный”adj nt an sg nom
   ”огромный”adj nt an sg acc
«число>”
   ”число”n nt nn sg acc
   ”число”n nt nn sg nom
«прибывших>”
   ”прибыть”v perf iv pp actv mfn an pl acc
   ”прибыть”v perf iv pp actv mfn an pl prp
   ”прибыть”v perf iv pp actv mfn aa pl gen
«беженцев>”
   ”беженец”n m aa pl gen
   ”беженец”n m aa pl acc
«.>”
   ”.”sent
```

# Input: Morphological analysis

```
«Для>"
    "для"pr
«соседних>"
    "соседний"adj mfn an pl gen
    "соседний"adj mfn an pl prp
    "соседний"adj mfn aa pl acc
«с>"
    "с"pr
«Руандой>"
    "Руанда"np top f sg ins
«государств>"
    "государство"n nt nn pl gen
«руандийские>"
    "руандийский"adj mfn an pl nom
    "руандийский"adj mfn nn pl acc
«события>"
    "событие"n nt nn sg gen
    "событие"n nt nn pl nom
    "событие"n nt nn pl acc
«апреля>"
    "апрель"n m nn sg gen
«->"
    "-"guio
«июля>"
    "июль"n m nn sg gen
```

rule: 2

```
«1994>"
    "1994"num
«года>"
    "год"n m nn sg gen
«вылились>"
    "вылиться"v perf iv past mfn pl
«в>"
    "в"pr
«огромное>"
    "огромный"adj nt an sg nom
    "огромный"adj nt an sg acc
«число>"
    "число"n nt nn sg acc
    "число"n nt nn sg nom
«прибывших>"
    "прибыть"v perf iv pp actv mfn an pl acc
    "прибыть"v perf iv pp actv mfn an pl prp
    "прибыть"v perf iv pp actv mfn aa pl gen
«беженцев>"
    "беженец"n m aa pl gen
    "беженец"n m aa pl acc
«.>"
    "."sent
```

# Input: Morphological analysis

```
«Для>”
   ”для”pr
«соседних>”
   ”соседний”adj mfn an pl gen
   ”соседний”adj mfn an pl prp
   ”соседний”adj mfn aa pl acc
«с>”
   ”с”pr
«Руандой>”
   ”Руанда”np top f sg ins
«государств>”
   ”государство”n nt nn pl gen
«руандийские>”
   ”руандийский”adj mfn an pl nom
   ”руандийский”adj mfn nn pl acc
«события>”
   ”событие”n nt nn sg gen
   ”событие”n nt nn pl nom
   ”событие”n nt nn pl acc
«апреля>”
   ”апрель”n m nn sg gen
«->”
   ”–”guio
«июля>”
   ”июль”n m nn sg gen
```

rule: 3

```
«1994>”
   ”1994”num
«года>”
   ”год”n m nn sg gen
«вылились>”
   ”вылиться”v perf iv past mfn pl
«в>”
   ”в”pr
«огромное>”
   ”огромный”adj nt an sg nom
   ”огромный”adj nt an sg acc
«число>”
   ”число”n nt nn sg acc
   ”число”n nt nn sg nom
«прибывших>”
   ”прибыть”v perf iv pp actv mfn an pl acc
   ”прибыть”v perf iv pp actv mfn an pl prp
   ”прибыть”v perf iv pp actv mfn aa pl gen
«беженцев>”
   ”беженец”n m aa pl gen
   ”беженец”n m aa pl acc
«.>”
   ”.”sent
```

# Input: Morphological analysis

```
«Для>”
   ”для”pr
«соседних>”
   ”соседний”adj mfn an pl gen
   ”соседний”adj mfn an pl prp
   ”соседний”adj mfn aa pl acc
«с>”
   ”с”pr
«Руандой>”
   ”Руанда”np top f sg ins
«государств>”
   ”государство”n nt nn pl gen
«руандийские>”
   ”руандийский”adj mfn an pl nom
   ”руандийский”adj mfn nn pl acc
«события>”
   ”событие”n nt nn sg gen
   ”событие”n nt nn pl nom
   ”событие”n nt nn pl acc
«апреля>”
   ”апрель”n m nn sg gen
«->”
   ”-”guio
«июля>”
   ”июль”n m nn sg gen
```

rule: 4

```
«1994>”
   ”1994”num
«года>”
   ”год”n m nn sg gen
«вылились>”
   ”вылиться”v perf iv past mfn pl
«в>”
   ”в”pr
«огромное>”
   ”огромный”adj nt an sg nom
   ”огромный”adj nt an sg acc
«число>”
   ”число”n nt nn sg acc
   ”число”n nt nn sg nom
«прибывших>”
   ”прибыть”v perf iv pp actv mfn an pl acc
   ”прибыть”v perf iv pp actv mfn an pl prp
   ”прибыть”v perf iv pp actv mfn aa pl gen
«беженцев>”
   ”беженец”n m aa pl gen
   ”беженец”n m aa pl acc
«.>”
   ”.”sent
```

# Input: Morphological analysis

```
«Для>"
    "для"pr
«соседних>"
    "соседний"adj mfn an pl gen
    "соседний"adj mfn an pl prp
    "соседний"adj mfn aa pl acc
«с>"
    "с"pr
«Руандой>"
    "Руанда"np top f sg ins
«государств>"
    "государство"n nt nn pl gen
«руандийские>"
    "руандийский"adj mfn an pl nom
    "руандийский"adj mfn nn pl acc
«события>"
    "событие"n nt nn sg gen
    "событие"n nt nn pl nom
    "событие"n nt nn pl acc
«апреля>"
    "апрель"n m nn sg gen
«->"
    "-"guio
«июля>"
    "июль"n m nn sg gen
```

rule: 5

```
«1994>"
    "1994"num
«года>"
    "год"n m nn sg gen
«вылились>"
    "вылиться"v perf iv past mfn pl
«в>"
    "в"pr
«огромное>"
    "огромный"adj nt an sg nom
    "огромный"adj nt an sg acc
«число>"
    "число"n nt nn sg acc
    "число"n nt nn sg nom
«прибывших>"
    "прибыть"v perf iv pp actv mfn an pl acc
    "прибыть"v perf iv pp actv mfn an pl prp
    "прибыть"v perf iv pp actv mfn aa pl gen
«беженцев>"
    "беженец"n m aa pl gen
    "беженец"n m aa pl acc
«.>"
    "."sent
```

# Input: Morphological analysis

```
«Для>"
    "для"pr
«соседних>"
    "соседний"adj mfn an pl gen
    "соседний"adj mfn an pl prp
    "соседний"adj mfn aa pl acc
«с>"
    "с"pr
«Руандой>"
    "Руанда"np top f sg ins
«государств>"
    "государство"n nt nn pl gen
«руандийские>"
    "руандийский"adj mfn an pl nom
    "руандийский"adj mfn nn pl acc
«события>"
    "событие"n nt nn sg gen
    "событие"n nt nn pl nom
    "событие"n nt nn pl acc
«апреля>"
    "апрель"n m nn sg gen
«->"
    "-"guio
«июля>"
    "июль"n m nn sg gen
```

rule: 5

```
«1994>"
    "1994"num
«года>"
    "год"n m nn sg gen
«вылились>"
    "вылиться"v perf iv past mfn pl
«в>"
    "в"pr
«огромное>"
    "огромный"adj nt an sg nom
    "огромный"adj nt an sg acc
«число>"
    "число"n nt nn sg acc
    "число"n nt nn sg nom
«прибывших>"
    "прибыть"v perf iv pp actv mfn an pl acc
    "прибыть"v perf iv pp actv mfn an pl prp
    "прибыть"v perf iv pp actv mfn aa pl gen
«беженцев>"
    "беженец"n m aa pl gen
    "беженец"n m aa pl acc
«.>"
    "."sent
```

# Proposed rule (I)

1. Immediately after “для” remove any reading which is in a case other than genitive.

**Exceptions:**

- None ?

**Formalised:**

```
LIST Gen = gen ;
SET NGDAIP = nom OR gen OR dat OR acc OR ins OR prp ;
REMOVE NGDAIP - Gen IF (-1C (”для”)) ;
```

# Proposed rule (II)

2 After “в” remove any reading which is in nominative

**Exceptions:**

- Joining an organisation ?

**Formalised:**

```
LIST Nom = nom ;
REMOVE Nom IF (-1C (”в”)) ;
```

# Proposed rule (III)

3 In a sentence with a single intransitive finite verb, remove any reading in accusative which is not immediately governed by a preposition

**Exceptions:**

- There is a trans. part. form having an acc. arg.
- Some adverbial forms... *Мы проехали километр.*

**Formalised:**

```
LIST IV = iv ;
LIST TV = tv ;
LIST Acc = acc ;
LIST Pr = pr ;
REMOVE Acc IF (0 Acc LINK NOT -1* Pr) ((-1* IV) OR (1*
IV)) (0 Acc LINK NOT 1* TV) (0 Acc LINK NOT -1* TV) ;
```

# Proposed rule (IV)

4 Select nominative if there is an intransitive verb which agrees with a nominative noun in the sentence for number (and/or gender)
   - and is preceeded by an adj. that can only be nom.
   - and there is no other nom. head in the sentence.

**Exceptions:**

- Appositions, titles, parentheticals ? Non-canonical agreement ?

**Formalised:**

```
LIST Head = np n prn ;
SET NUM = (sg) OR (pl) ;
SELECT Nom + $$NUM IF (-1C A + Nom) (NOT -1* Head + Nom)
(NOT 1* Head + Nom) ((-1* V + $$NUM) OR (1* V + $$NUM));
```

# Proposed rule (V)

5 If there is a prepositional case reading, remove it if you see a noun which is only in a case other than prepositional without any preceeding transitive participle form

**Exceptions:**

- ...

**Formalised:**

```
LIST Prp = prp ;
LIST N = n ;
REMOVE Prp IF (-1* N + NGDAIP - Prp) ;
```

# Output: Morphologically-disambiguated text

```
«Для>"
    "для"pr
«соседних>"
    "соседний"adj mfn an pl gen
    "соседний"adj mfn an pl prp
    "соседний"adj mfn aa pl acc
«с>"
    "с"pr
«Руандой>"
    "Руанда"np top f sg ins
«государств>"
    "государство"n nt nn pl gen
«руандийские>"
    "руандийский"adj mfn an pl nom
    "руандийский"adj mfn nn pl acc

«события>"
    "событие"n nt nn sg gen
    "событие"n nt nn pl nom
    "событие"n nt nn pl acc

«апреля>"
    "апрель"n m nn sg gen
«->"
    "-"guio
«июля>"
    "июль"n m nn sg gen

«1994>"
    "1994"num
«года>"
    "год"n m nn sg gen
«вылились>"
    "вылиться"v perf iv past mfn pl
«в>"
    "в"pr
«огромное>"
    "огромный"adj nt an sg nom
    "огромный"adj nt an sg acc
«число>"
    "число"n nt nn sg acc
    "число"n nt nn sg nom

«прибывших>"
    "прибыть"v perf iv pp actv mfn an pl acc
    "прибыть"v perf iv pp actv mfn an pl prp
    "прибыть"v perf iv pp actv mfn aa pl gen
«беженцев>"
    "беженец"n m aa pl gen
    "беженец"n m aa pl acc

«.>"
    "."sent
```

# Examples

Languages with constraint grammars:

- Finnish
- North Sámi, Lule Sámi, South Sámi
- Norwegian (Nynorsk, Bokmål)
- Faroese
- Udmurt
- Breton

# HMM-based

Predict hidden states from observed events

- hidden states = sequence of part of speech tags
- observed events = ambiguity classes or surface forms

$$M = (A, B, \pi)$$

- $A$ = transition probabilities
- $B$ = emission probabilities
- $\pi$ = initial probabilities

# Visible events

The visible events can be either:

- **Surface forms:** In many traditional HMM-based taggers, the visible events are surface forms
- **Ambiguity classes:** Generalisation over types of ambiguity e.g. NOUN/VERB, DET/PRON

Example:

| | | | | | |
|---|---|---|---|---|---|
| Surface forms: | This | is | a | test | . |
| Ambig. classes: | PRON/DET | VERB/AUX | DET | VERB/NOUN | PUNCT |

# A tagged corpus

**Analysed:**

Vino/NOUN/VERB a/ADP la/DET/PRON playa/NOUN ./PUNCT
Voy/VERB a/ADP la/DET/PRON casa/NOUN/VERB ./PUNCT
Bebe/VERB vino/NOUN/VERB en/ADP casa/NOUN/VERB ./PUNCT
La/DET/PRON casa/NOUN/VERB es/VERB grande/ADJ ./PUNCT
Es/VERB una/DET/PRON/VERB ciudad/NOUN grande/ADJ ./PUNCT

**Tagged:**

Vino/VERB a/ADP la/DET playa/NOUN ./PUNCT
Voy/VERB a/ADP la/DET casa/NOUN ./PUNCT
Bebe/VERB vino/NOUN en/ADP casa/NOUN ./PUNCT
La/DET casa/NOUN es/VERB grande/ADJ ./PUNCT
Es/VERB una/DET ciudad/NOUN grande/ADJ ./PUNCT

# Transition probabilities

We calculate the transition probabilities, *A* from a matrix of transition counts:

| | Second tag | | | | | | |
|---|---|---|---|---|---|---|---|
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
| VERB | 0 | 1 | 1 | 0 | 2 | 1 | 0 |
| NOUN | 1 | 0 | 0 | 0 | 1 | 1 | 3 |
| DET | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| PRON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| PUNCT | 3 | 0 | 1 | 0 | 0 | 0 | 0 |

# Transition probabilities

We calculate the transition probabilities, *A* from a matrix of transition counts:

| | Second tag | | | | | | |
|---|---|---|---|---|---|---|---|
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
| VERB | 0 | 1 | 1 | 0 | 2 | 1 | 0 |
| NOUN | 1 | 0 | 0 | 0 | 1 | 1 | 3 |
| DET | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| PRON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| PUNCT | 3 | 0 | 1 | 0 | 0 | 0 | 0 |

# Transition probabilities

We calculate the transition probabilities, *A* from a matrix of transition counts:

| | Second tag | | | | | | |
|---|---|---|---|---|---|---|---|
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
| VERB | **0** | **1** | **1** | **0** | **2** | **1** | **0** |
| NOUN | 1 | 0 | 0 | 0 | 1 | 1 | 3 |
| DET | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| PRON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| PUNCT | 3 | 0 | 1 | 0 | 0 | 0 | 0 |

# Transition probabilities

We calculate the transition probabilities, $A$ from a matrix of transition counts:

| | Second tag | | | | | | |
|---|---|---|---|---|---|---|---|
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
| VERB | 0 | 0.2 | 0.2 | 0 | 0.4 | 0.2 | 0 |
| NOUN | 0.16 | 0 | 0 | 0 | 0.16 | 0.16 | 0.5 |
| DET | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| PRON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 0.3 | 0.6 | 0 | 0 | 0 | 0 |
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| PUNCT† | 0.75 | 0 | 0.25 | 0 | 0 | 0 | 0 |

† This row represents the initial probabilities, $\pi$ of the model.

# Transition probabilities

We calculate the transition probabilities, $A$ from a matrix of transition counts:

| | Second tag | | | | | | |
|---|---|---|---|---|---|---|---|
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
| VERB | 0 | 0.2 | 0.2 | 0 | 0.4 | 0.2 | 0 |
| NOUN | 0.16 | 0 | 0 | 0 | 0.16 | 0.16 | 0.5 |
| DET | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| PRON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 0.3 | 0.6 | 0 | 0 | 0 | 0 |
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **PUNCT**† | 0.75 | 0 | 0.25 | 0 | 0 | 0 | 0 |

† This row represents the initial probabilities, $\pi$ of the model.

# A tagged corpus

**Analysed:**

Vino/NOUN/VERB a/ADP la/DET/PRON playa/NOUN ./PUNCT
Voy/VERB a/ADP la/DET/PRON casa/NOUN/VERB ./PUNCT
Bebe/VERB vino/NOUN/VERB en/ADP casa/NOUN/VERB ./PUNCT
La/DET/PRON casa/NOUN/VERB es/VERB grande/ADJ ./PUNCT
Es/VERB una/DET/PRON/VERB ciudad/NOUN grande/ADJ ./PUNCT

**Tagged:**

Vino/VERB a/ADP la/DET playa/NOUN ./PUNCT
Voy/VERB a/ADP la/DET casa/NOUN ./PUNCT
Bebe/VERB vino/NOUN en/ADP casa/NOUN ./PUNCT
La/DET casa/NOUN es/VERB grande/ADJ ./PUNCT
Es/VERB una/DET ciudad/NOUN grande/ADJ ./PUNCT

# Emission probabilities

The probability of seeing an ambiguity class given a tag, *B*.

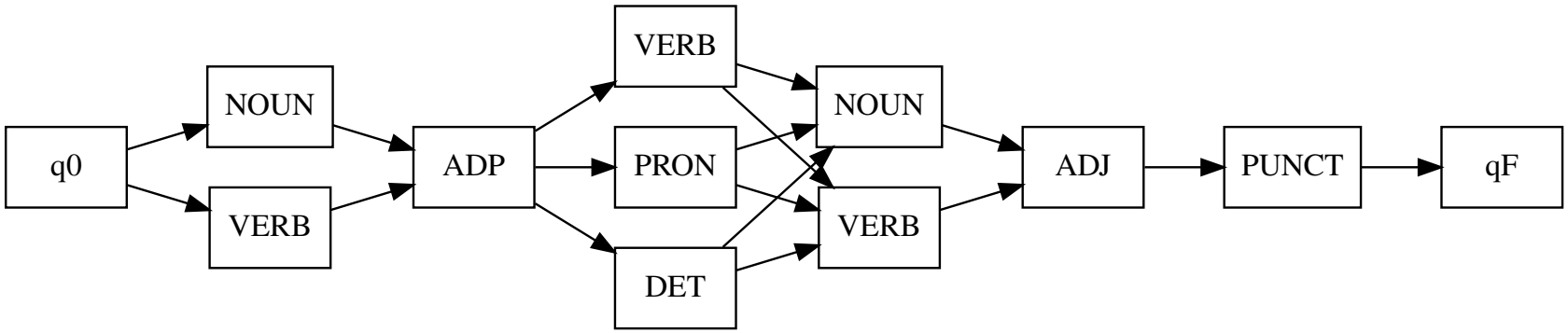
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
|---|---|---|---|---|---|---|---|
| ADJ | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| DET/PRON | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| DET/PRON/VERB | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| NOUN | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| NOUN/VERB | 1 | 4 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| PUNCT | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| VERB | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total: | 5 | 6 | 4 | 0 | 3 | 2 | 5 |

# Emission probabilities

The probability of seeing an ambiguity class given a tag, *B*.

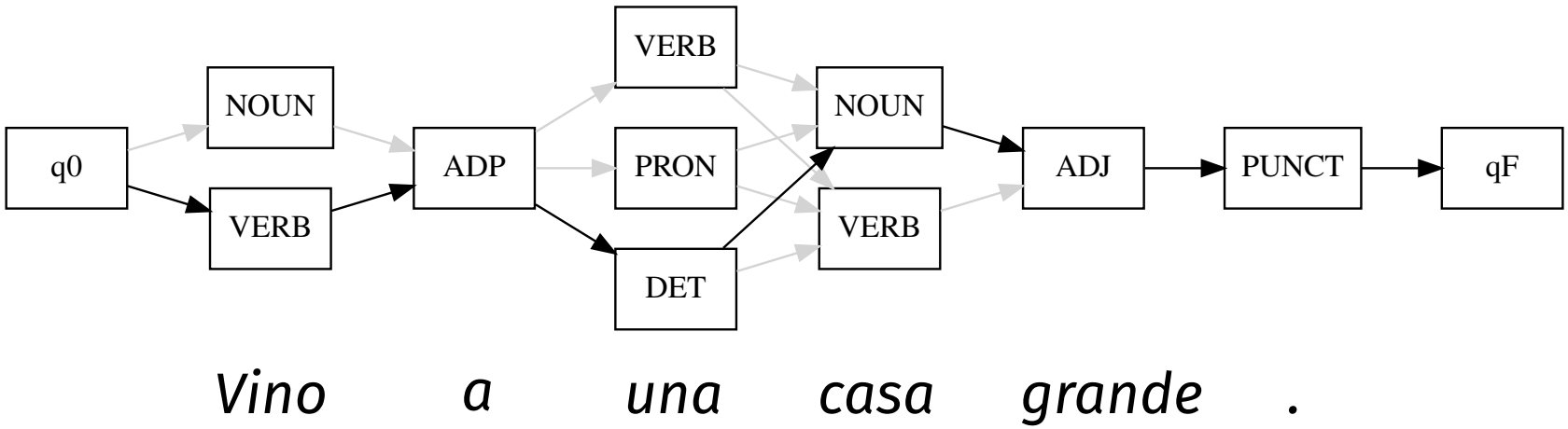
| | VERB | NOUN | DET | PRON | ADP | ADJ | PUNCT |
|---|---|---|---|---|---|---|---|
| ADJ | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 |
| DET/PRON | 0 | 0 | 0.75 | 0 | 0 | 0 | 0 |
| DET/PRON/VERB | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 |
| NOUN | 0 | 0.33 | 0 | 0 | 0 | 0 | 0 |
| NOUN/VERB | 0.2 | 0.67 | 0 | 0 | 0 | 0 | 0 |
| ADP | 0 | 0 | 0 | 0 | 1.0 | 0 | 0 |
| PUNCT | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 |
| VERB | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |

# Viterbi




- Dynamic programming algorithm
- Find the most likely sequence of hidden states given observed sequence
- e.g. Find POS tag sequence given words or ambiguity classes

# Viterbi




- Dynamic programming algorithm
- Find the most likely sequence of hidden states given observed sequence
- e.g. Find POS tag sequence given words or ambiguity classes

# Decoding

*Vino a una casa grande.*

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | | | | | | | |
| NOUN | | | | | | | |
| DET | | | | | | | |
| PRON | | | | | | | |
| ADP | | | | | | | |
| ADJ | | | | | | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | | | | | |
| NOUN | 0.0, $q_0$ | | | | | | |
| DET | | | | | | | |
| PRON | | | | | | | |
| ADP | | | | | | | |
| ADJ | | | | | | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(VERB,PUNCT) * P(VERB, VERB/NOUN) = 0.75 * 0.2 = 0.15
- = P(NOUN,PUNCT) * P(NOUN, VERB/NOUN) = 0.0 * 0.67 = 0.0

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | | | | | |
| NOUN | 0.0, $q_0$ | | | | | | |
| DET | | | | | | | |
| PRON | | | | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(ADP,VERB) * P(ADP, ADP) * P(PATH) = 0.4 * 1.0 * 0.15 = 0.06
- = P(ADP,NOUN) * P(ADP, ADP) * P(PATH) = 0.16 * 1.0 * 0.0 = 0

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | | | | |
| NOUN | 0.0, $q_0$ | | | | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(DET,ADP) * P(DET, DET/PRON/VERB) * P(PATH) = 0.6 * 0.25 * 0.06 = 0.009
- = P(PRON,ADP) * P(PRON, DET/PRON/VERB) * P(PATH) = 0.0 * 0.0 * 0.06 = 0.0
- = P(VERB,ADP) * P(VERB, DET/PRON/VERB) * P(PATH) = 0.0 * 0.0 * 0.06 = 0.0

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(NOUN,VERB) * P(NOUN, NOUN/VERB) * P(PATH) = 0.2 * 0.67 * 0.009 = 0.001
- = P(VERB,VERB) * P(VERB, NOUN/VERB) * P(PATH) = 0.0 * 0.2 * 0.009 = 0.0
- = P(NOUN,DET) * P(NOUN, NOUN/VERB) * P(PATH) = 1.0 * 0.67 * 0.009 = 0.006
- = P(VERB,DET) * P(VERB, NOUN/VERB) * P(PATH) = 0.0 * 0.2 * 0.009 = 0.0
- = P(NOUN,PRON) * P(NOUN, NOUN/VERB) * P(PATH) = 0.0 * 0.67 * 0.009 = 0.0
- = P(VERB,PRON) * P(VERB, NOUN/VERB) * P(PATH) = 0.0 * 0.67 * 0.009 = 0.0

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(ADJ,NOUN) * P(ADJ, ADJ) * P(PATH) = 0.16 * 1.0 * 0.006 = 0.00096
- = P(ADJ,VERB) * P(ADJ, ADJ) * P(PATH) = 0.2 * 1.0 * 0.0 = 0.0

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

- = P(PUNCT,ADJ) * P(PUNCT, PUNCT) * P(PATH) = 1.0 * 1.0 * 0.001 = 0.001

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, **ADJ** | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

ADJ PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, **NOUN** | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

NOUN ADJ PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, **DET** | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

DET NOUN ADJ PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, **ADP** | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

ADP DET NOUN ADJ PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, **VERB** | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

VERB ADP DET NOUN ADJ PUNCT

# Decoding

$\rightarrow$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $q_F$ | | | | | | | |
| VERB | 0.15, $q_0$ | | 0.0, ADP | 0.0, DET* | | | |
| NOUN | 0.0, $q_0$ | | | 0.006, DET | | | |
| DET | | | 0.009, ADP | | | | |
| PRON | | | 0.0, ADP | | | | |
| ADP | | 0.06, VERB | | | | | |
| ADJ | | | | | 0.001, NOUN | | |
| PUNCT | | | | | | 0.001, ADJ | |
| | VERB/NOUN | ADP | DET/PRON/VERB | NOUN/VERB | ADJ | PUNCT | |
| | *Vino* | *a* | *una* | *casa* | *grande* | . | |

VERB ADP DET NOUN ADJ PUNCT

# Implementation

https://paste2.org/HMgn7amd

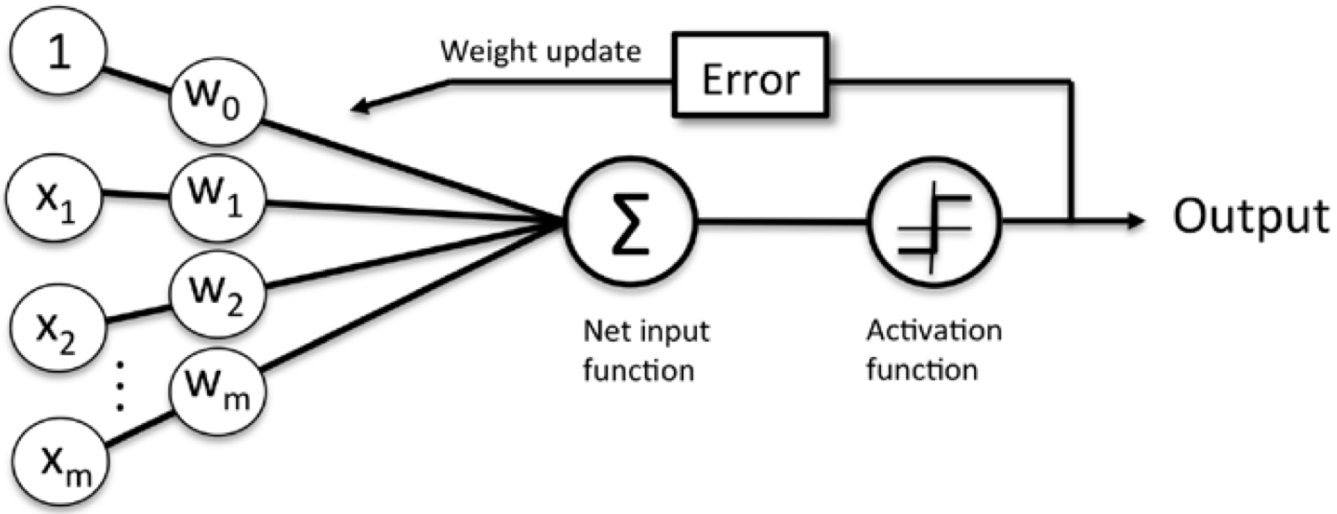
```
1.  def viterbi(obs, states, start_p, trans_p, emit_p):
2.     V = [{}] # Path probability matrix
3.     for state in states: # Initialisation step,
4.        V[0][state] = {"prob": start_p[state] * emit_p[state][obs[0]], "prev": None}
5.     for t in range(1, len(obs)): # Recursion step, run Viterbi while t > 0
6.        V.append({})
7.        for state in states:
8.           max_tr_prob = max(V[t-1][prev_state]["prob"] * trans_p[prev_state][state] for prev_state in states)
9.           for prev_state in states:
10.             if V[t-1][prev_state]["prob"] * trans_p[prev_state][state] == max_tr_prob:
11.                max_prob = max_tr_prob * emit_p[state][obs[t]]
12.                V[t][state] = {"prob": max_prob, "prev": prev_state}
13.                break
14.    dptable(V);
15.    best_path = []
16.    # Get the highest probability from the final state
17.    max_prob = max(value["prob"] for value in V[-1].values())
18.    previous = None
19.    # Get most probable state and its backtrack
20.    for st, data in V[-1].items():
21.       if data["prob"] == max_prob:
22.          best_path.append(st)
23.          previous = st
24.          break
25.    # Follow the backtrack till the first observation
26.    for t in range(len(V) - 2, -1, -1):
27.       best_path.insert(0, V[t + 1][previous]["prev"])
28.       previous = V[t + 1][previous]["prev"]
29.    print('--\nBest path: %.8f\t%s' % (max_prob, ' '.join(best_path)));
```

# Extensions

- Trigrams
  - Instead of conditioning on previous tag, condition on previous two
- Unknown words
  - Incorporate suffixes into the tags
- Backoff
  - If the bi-/tri-gram hasn't been seen, backoff to lower order model
- Capitalisation
  - Use capitalisation features

# Averaged perceptron

## A binary perceptron:




- Discriminative model ... find the category, not the distribution
- Beautifully simple

`github.com/ftyers/conllu-perceptron-tagger`

# Training

```
1.  def train(self, nr_iter, examples):
2.      ''' Update the feature weights according to guesses '''
3.      for i in range(nr_iter):
4.          for features, true_tag in examples:
5.              guess = self.predict(features)
6.              if guess != true_tag:
7.                  for f in features:
8.                      self.weights[f][true_tag] += 1
9.                      self.weights[f][guess] -= 1
10.         random.shuffle(examples)
11.
```

- We iterate through the whole training data *n* times
- For each tag we try and predict the value
  - If we get it wrong, we increase the weight of the features for the correct class

# Features

| Vino | a | una | casa | grande | . |
|---|---|---|---|---|---|
| $i-2$ | $i-1$ | $i$ | $i+1$ | $i+2$ | $i+3$ |

- Specify whatever features you want,
- Easy to add new ones!

| | | |
|---|---|---|
| $i$ | Trigram suffix | una |
| $i$ | Unigram prefix | u |
| $i-1$ | Tag | ADP |
| $i-2$ | Tag | VERB |
| $i$ | Word | una |
| $i-1, i$ | Tag, Word | ADP + una |
| $i-1$ | Word | a |
| $i-1$ | Trigram suffix | a |
| $i-2$ | Word | Vino |
| $i+1$ | Word | casa |
| $i+1$ | Trigram suffix | asa |
| $i+2$ | Word | grande |

# Averaging

**Problem:**

- In later iterations it changes the weights a lot for the last few samples it is getting wrong
- …overfitting

**Solution:**

- Average the weights over the iterations

# Dictionary

Given the amount of unambiguous words:

- Make a dictionary
- When you see the word, output it
- But have a frequency threshold, e.g. 20

# Prediction

```
1.  def predict(self, features):
2.      '''Dot-product the features and current weights and return the best class.'''
3.      scores = defaultdict(float)
4.      for feat in features:
5.          if feat not in self.weights:
6.              continue
7.          weights = self.weights[feat]
8.          for clas, weight in weights.items():
9.              scores[clas] += weight
10.     # Do a secondary alphabetic sort, for stability
11.     return max(self.classes, key=lambda clas: (scores[clas], clas))
12.
```

- For each class (POS), add the weights of the features we've seen
- Take the class with the maximum weight

# Discussion

# Comparison of approaches

| | + | - |
|---|---|---|
| **CG** | Start from scratch | Tagset not learnt |
| **HMM** | Model distribution | Hard to incorporate feats |
| **Perceptron** | Easy to incorporate feats | No *n*-best |

All techniques can reach 97% token accuracy.

- Great ... but 57% full-sentence accuracy.

# Comparison of approaches

**Table 4.** Frequency of different POS tagging error types.

| Class | Frequency |
|---|---|
| 1. Lexicon gap | 4.5% |
| 2. Unknown word | 4.5% |
| 3. Could plausibly get right | 16.0% |
| 4. Difficult linguistics | 19.5% |
| 5. Underspecified/unclear | 12.0% |
| 6. Inconsistent/no standard | 28.0% |
| 7. Gold standard wrong | 15.5% |

Chris Manning (2011) “Part-of-Speech Tagging from 97% to 100%: Is It Time for Some Linguistics?”

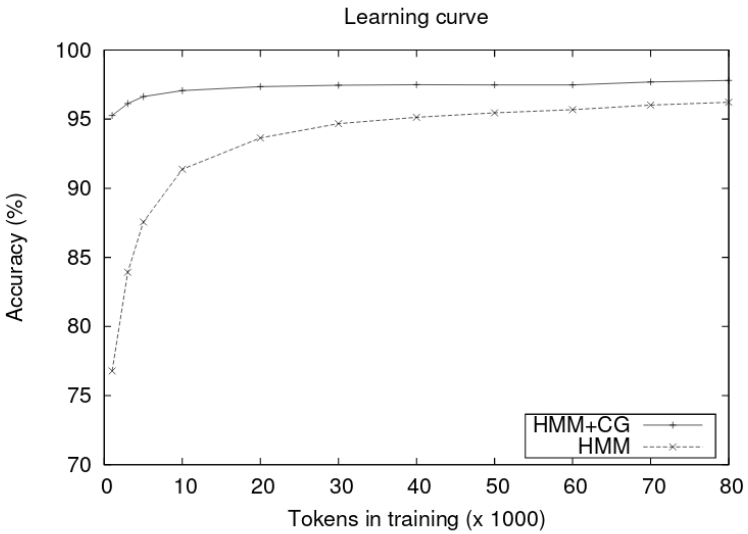
# How much time and effort ?

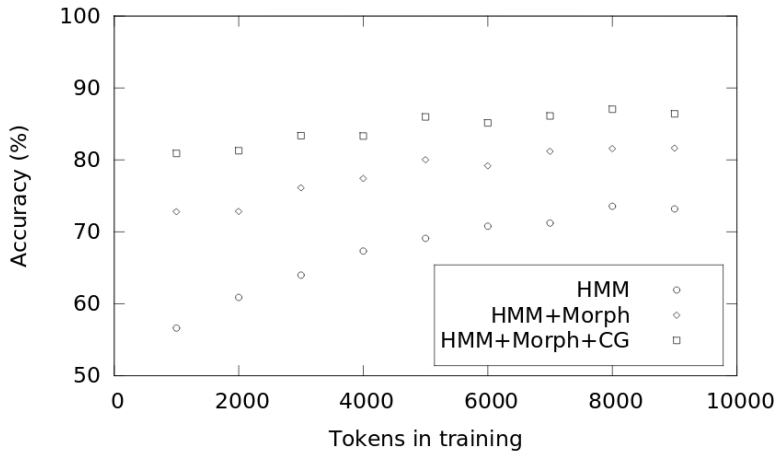
Annotation time vs. rule-writing time

- Hand annotation: 8000–10000 tokens/month
  - 50–100k tokens = 6–12 months
- Rule-based:
  - Morphological analyser: 3–6 months
  - Constraint grammar: 3–6 months

Approaching a new language, depends on what you like doing more.

# Tagger combination




- Voting systems
- Combine systems that make complementary errors

# Some taggers

**Russian:**

- `pymorphy2`
- `mystem3`

**Trainable:**

- HunPos (HMM, OCaml)
- UDPipe/MorphoDiTa (Av. Perceptron, C++)
- MarMot (CRF, Java)
- NLTK (various, Python)

# Practicals

https://ftyers.github.io/2017-КЛ_МКЛ/practicals/disambiguation.html

- **Tagger comparison**:
  - Compare three taggers on a language/domain of your choice
- **Constraint grammar**:
  - Select a small text (one paragraph) in a language of your choice
  - Analyse it with a morphological analyser
  - Resolve as much of the ambiguity as you can
- **Perceptron tagger**:
  - Download https://github.com/ftyers/conllu-perceptron-tagger
  - Run it on a language from Universal Dependencies
  - Improve it so that you get better performance
    - Add support for morphological features
    - Try tweaking other features