# Extended HVS parser

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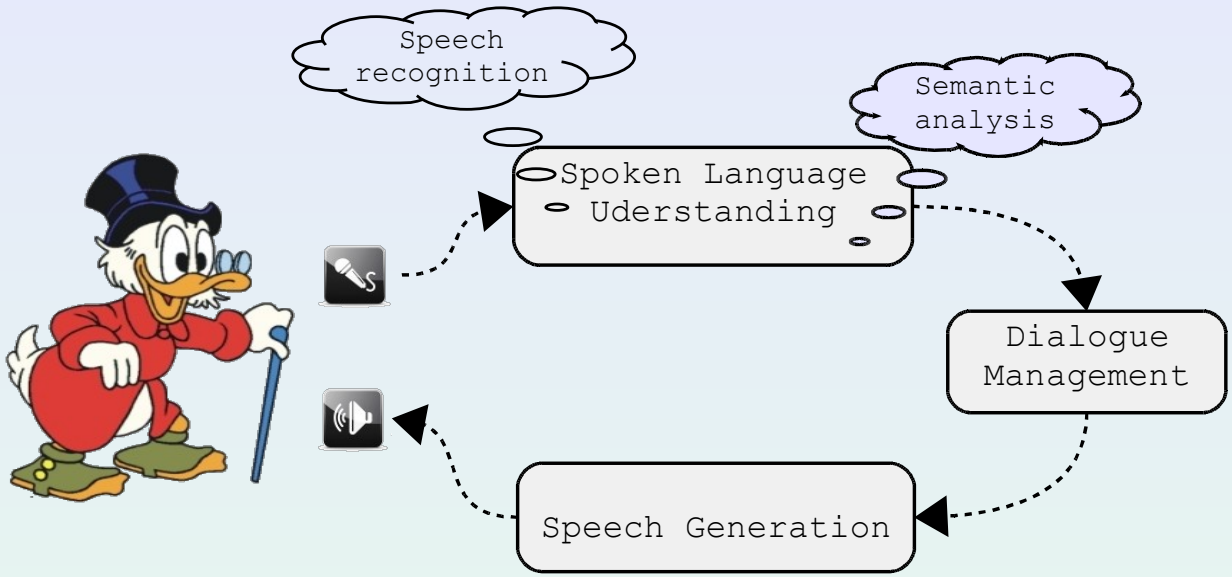
# Outline

# Dialogue systems




## Spoken language understanding

- continuous spontaneous spoken speech
- spoken speech is often ungrammatical, includes disfluences
- the transformation into text form contains errors

# Systems using ATIS data

## Based on context free grammars

- TINA from Massachusetts Institute of Technology
- PHOENIX from Carnegie Mellon University
- GEMINI from SRI International

## Based on statistical models

- CHRONUS (Markov models) from AT&T
- Hidden Understanding Model (HUM) from BBN Technologies
- Hidden Vector State (HVS) parser from The University of Cambridge

# Concept sequence decoding

## Concept sequence decoding

$$S^* = \underset{S}{\operatorname{argmax}}\, P(W|S)P(S)$$

- $P(S)$ is the semantic model
- $P(W|S)$ is the lexical model

# Flat-concept parser

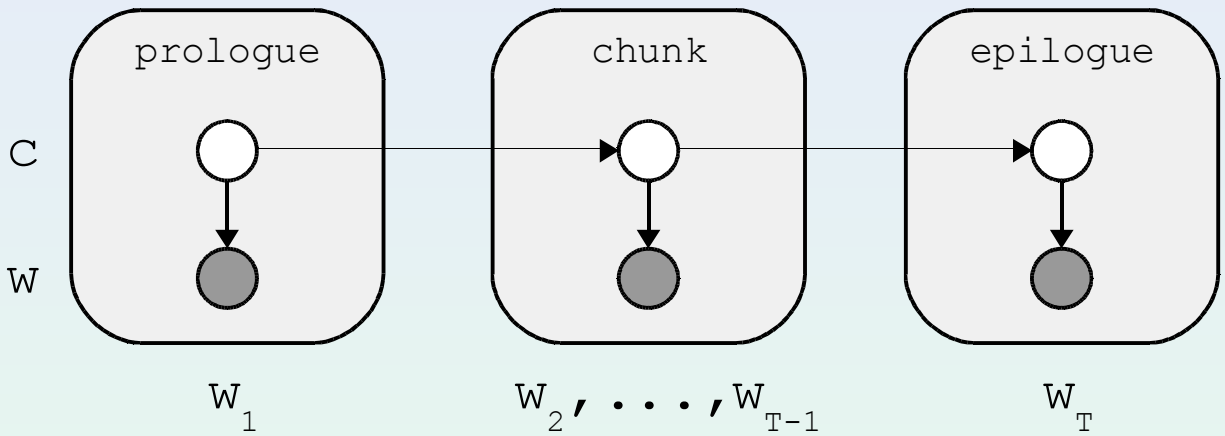



Figure: The graphical model of the FC model.

# Flat-concept parser

## Implementation

The semantic model is

$$P(S) = \prod_{t=1}^{T} P(c_t|c_{t-1})$$

The lexical model is

$$P(W|S) = \prod_{t=1}^{T} P(w_t|c_t)$$

# The Hidden Vector State parser

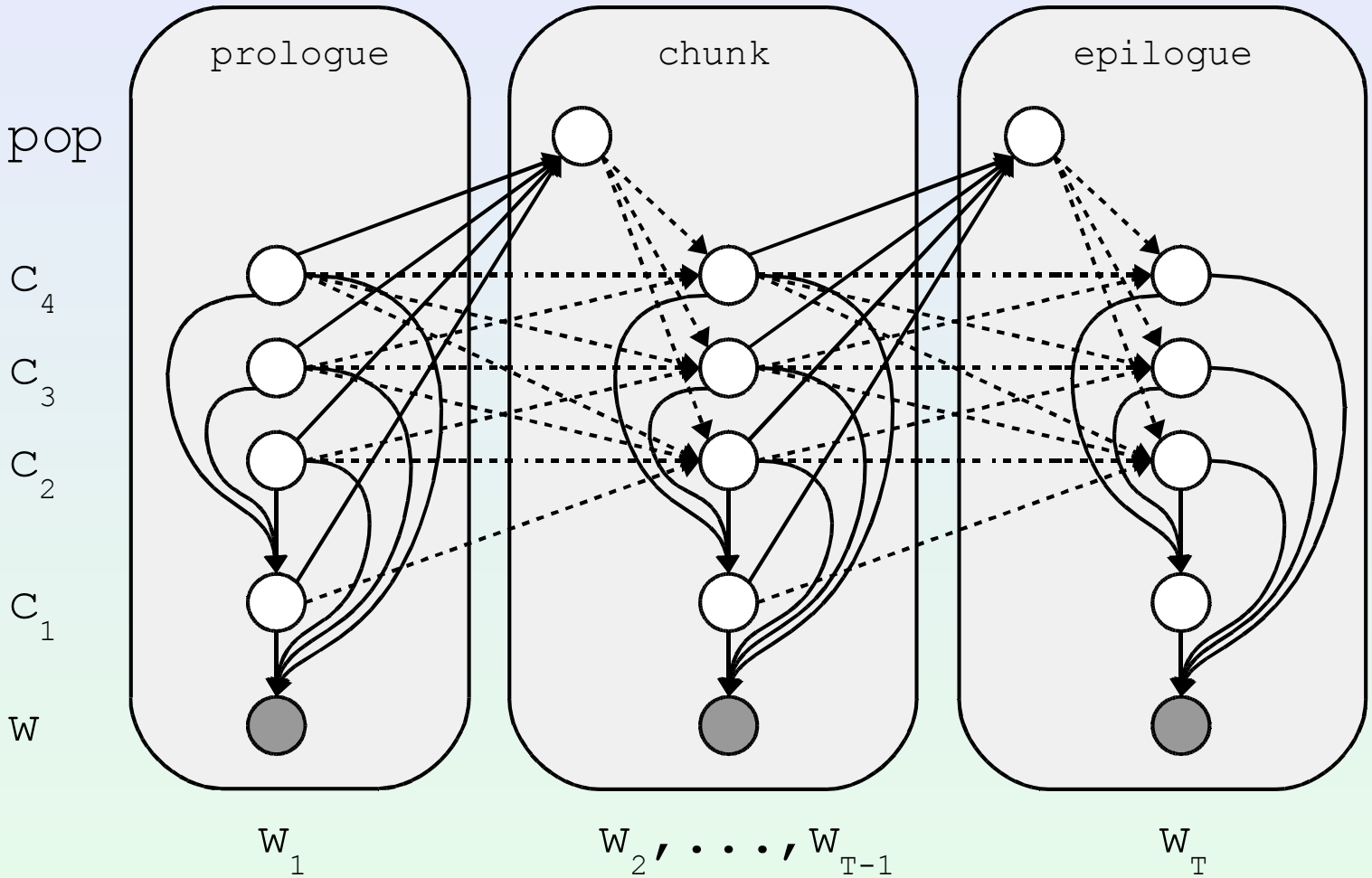



Figure: The graphical model of the HVS parser.

# The Hidden Vector State parser

## Implementation

The semantic model is

$$P(S) = \prod_{t=1}^{T} P(pop_t | c_{t-1}[1,4]) P(c_t[1] | c_t[2,4])$$

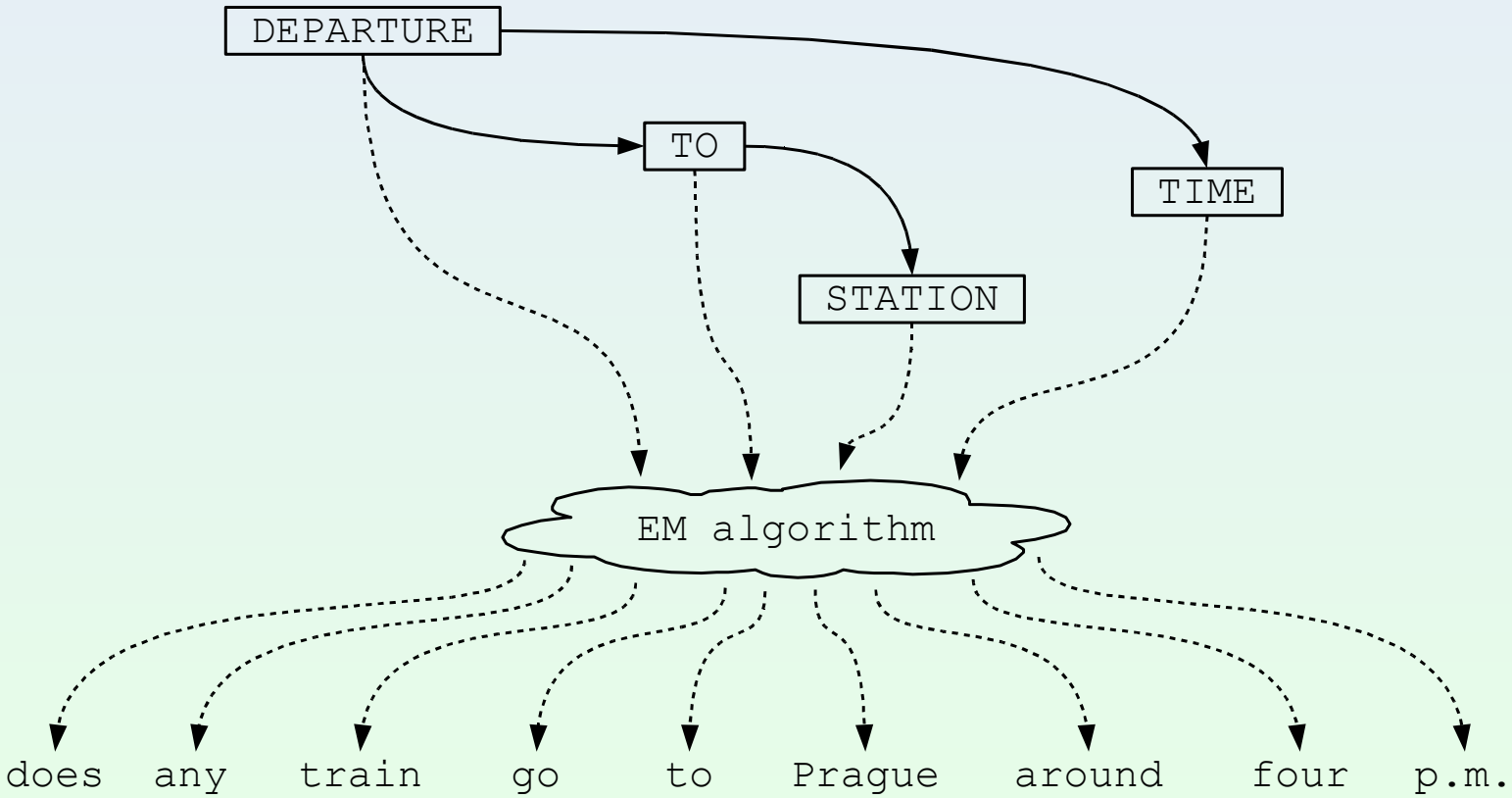
The lexical model is

$$P(W|S) = \prod_{t=1}^{T} P(w_t | c_t[1,4])$$

# HVS parser - training data

## Training data

*does any train go to Prague around four p.m.*
DEPARTURE( TO( STATION), TIME)



# HVS parser - output of decoding

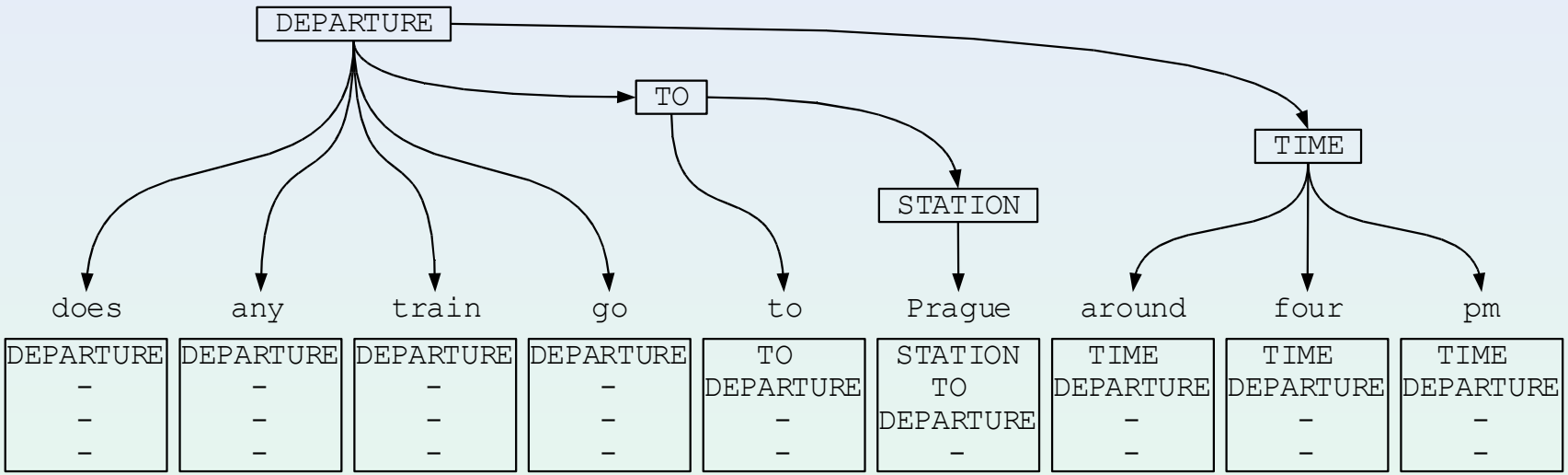



Figure: A full semantic parse tree with the corresponding stack sequence.

# Outline

# Semantic example dialogue - UWB

| Semantics | Utterance (Literal English translation) |
|---|---|
| GREETING | the information please |
| GREETING | hello |
| DEPARTURE(TIME,<br>TRAIN_TYPE,<br>TO(STATION)) | I have a question how can I go today<br>by regional train<br>to Starýho Plzence |
| OTHER_INFO | well we do not have many connections here |
| TIME,<br>TIME | now one goes at eight sixteen if you<br>catch it after that only at eleven ten |
| TIME | at eleven ten |
| ACCEPT(TIME,<br>FROM(STATION)) | it is not so bad at eleven ten<br>from Hlavního yeah |
| TRAIN_TYPE | is it possible to take a stroller with me |
| ACCEPT | of course madam be sure that you can |
| TRAIN_TYPE | so there are the new cars |

# Size, cardinality and reliability

## Size of the corpus

- 1,109 dialogues
- 17,900 utterances
- 2,872 unique words

## Cardinality

- 35 semantic concepts (DEPARTURE, FROM, TO, STATION, ...)

## Reliability of semantics

- stability (intra-annotator's agreement): about 0.90
- reproducibility (inter-annotator's agreement): about 0.81

# Difference between CU-ATIS and UWB semantic data

| | CU-ATIS data | UWB data |
|---|---|---|
| **order of semantic concepts** | **not defined** | **defined** |
| lexical classes | defined | not defined |
| performance evaluation based on | extracted slot values | semantics |

## Order of semantic concepts

it is not so bad at eleven ten from Hlavního yeah

S1: ACCEPT(TIME, FROM(STATION))
S2: ACCEPT(FROM(STATION), TIME)

# Difference between CU-ATIS and UWB semantic data

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## Lexical classes

it is not so bad at eleven ten from Hlavního yeah

$\Longrightarrow$

it is not so bad at eleven ten from station_name yeah

# Difference between CU-ATIS and UWB semantic data

| | CU-ATIS data | UWB data |
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| lexical classes | defined | not defined |
| **performance evaluation based on** | **extracted slot values** | **semantics** |

## Evaluation

Frame: FLIGHT

Slots:

- FROMLOC.CITY = Boston
- TOLOC.CITY = NewYork

×

HYP: ACCEPT(TIME, FROM(STATION))

# Error criteria

## Semantic Accuracy - SAcc

The reference and the hypothesis annotations are considered equal only if they exactly match each other.

## Example

REF: ARRIVAL(TIME, FROM(STATION))

HYP1: ARRIVAL(TIME, TO(STATION))
HYP2: DEPARTURE(TRAIN_TYPE)

# Error criteria

## Semantic Accuracy - SAcc

The reference and the hypothesis annotations are considered equal only if they exactly match each other.

## Example

REF: ARRIVAL(TIME, FROM(STATION))

HYP1: ARRIVAL(TIME, TO(STATION))
HYP2: DEPARTURE(TRAIN_TYPE)

# Error criteria

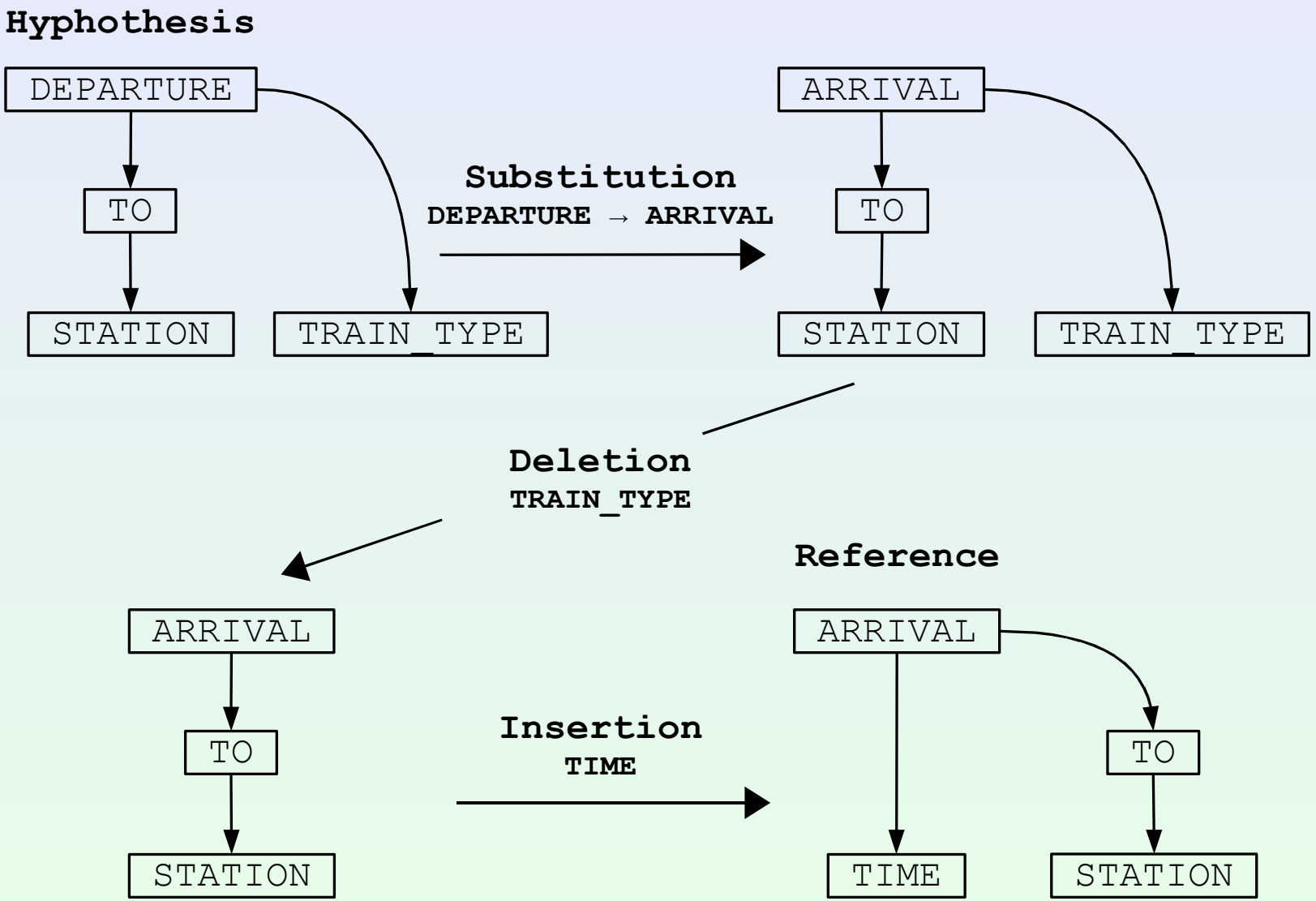
## Concept Accuracy - CAcc

Measures the minimum number of:

- substitutions
- deletions
- insertions

required to transform one tree into another.

# The tree edit distance



# Performance

| | Test data | | Development data | |
|---|---|---|---|---|
| | SAcc | CAcc | SAcc | CAcc |
| **the lower-bound baseline** | **17.3** | **26.0** | - | - |
| the tuned HVS parser | 47.9 | 63.2 | 50.7 | 64.3 |
| **the upper-bound ceiling** | **85.0** | **91.0** | - | - |

## Tunned system

- insertion penalty
- scaling factor - $P(S)$
- pruning of vocabulary
- number of EM iterations

# Performance

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## Tunned system

- insertion penalty
- scaling factor - $P(S)$
- pruning of vocabulary
- number of EM iterations

# Outline

# Positive examples

## The corpus

| | |
|---|---|
| does any train go to Prague around four p.m. | DEPARTURE(TO(STATION) TIME) |
| what is the price of a ticket to Cambridge around six a.m. | PRICE(TO( STATION), TIME) |
| if you want a direct train than it departures around nine p.m. | DEPARTURE(TRAIN_TYPE, TIME) |

## Positive example not labeled in the corpus (word level)

| Word (words) | Concept (Semantics) |
|---|---|
| Prague | STATION |
| around four p.m. | TIME |
| Cambridge | STATION |
| around six a.m. | TIME |
| direct | TRAIN_TYPE |
| around nine p.m. | TIME |
| ... | ... |

# Positive examples

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| Cambridge | STATION |
| around six a.m. | TIME |
| direct | TRAIN_TYPE |
| around nine p.m. | TIME |
| ... | ... |

# Negative examples

## The corpus

| | |
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| does any train go to Prague around four p.m. | DEPARTURE(TO(STATION) TIME) |
| what is the price of a ticket to Cambridge around six a.m. | PRICE(TO( STATION), TIME) |
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## Negative examples not labeled in the corpus (word level)

| Word (words) | Concept (Semantics) |
|---|---|
| a | STATION |
| around | STATION |
| train | STATION |
| p.m. | STATION |
| ... | ... |

# Negative examples

## The corpus

| | |
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| does any train go to Prague around four p.m. | DEPARTURE(TO(STATION) TIME) |
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| Word (words) | Concept (Semantics) |
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| a | STATION |
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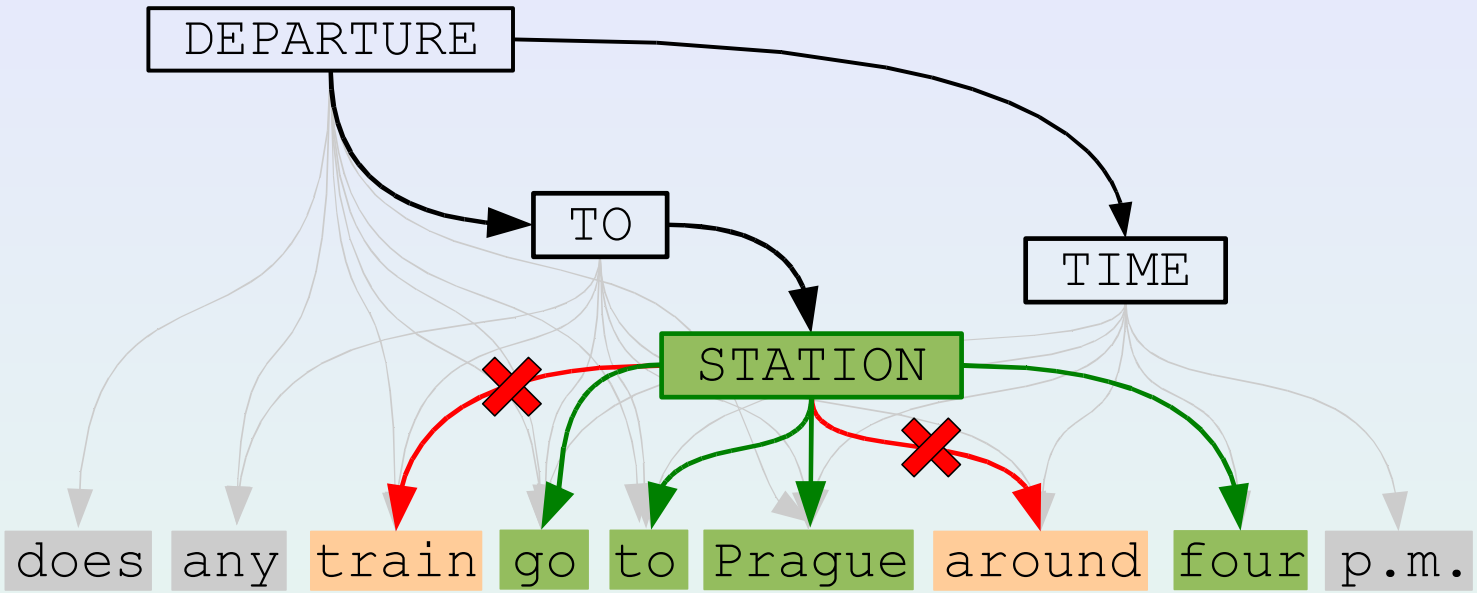
| train | STATION |
| p.m. | STATION |
| ... | ... |

# Negative examples




## Negative examples not labeled in the corpus (word level)

| Word (words) | Concept (Semantics) |
|---|---|
| a | STATION |
| around | STATION |
| train | STATION |
| p.m. | STATION |
| ... | ... |

# Extraction of negative examples

## Used concepts

AMOUNT, LENGTH, NUMBER, TIME, STATION and TRAIN_TYPE

## Potential problems

- the lexical realization of the concepts AMOUNT, LENGTH, NUMBER, TIME is similar
- incorrectly annotated utterance

| Utterance | Semantics |
|---|---|
| does any train go to Prague around four p.m. | DEPARTURE(TRAIN_TYPE, TIME) |

- too general concept in the annotation

| Word (words) | Concept (Semantics) |
|---|---|
| weather is pleasant today in Prague | OTHER_INFO |
| ... | ... |

# Extraction of negative examples

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| Utterance | Semantics |
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- too general concept in the annotation

| Word (words) | Concept (Semantics) |
|---|---|
| weather is pleasant today in Prague | OTHER_INFO |
| ... | ... |

# Selection of proper utterances

## Only utterances containing concepts

ACCEPT, ARRIVAL, DELAY, DEPARTURE, DISTANCE, DURATION, PLATFORM, PRICE, and REJECT

## Example

| Utterance | Semantics |
|---|---|
| what is the price of a ticket to Cambridge | PRICE(TO(STATION)) |
| it will arrive at the second platform | ARRIVAL(PLATFORM(NUMBER)) |
| ... | ... |

# Application of negative examples

## Modification of the lexical model

$$x(w, c[1,4]) = \begin{cases} \epsilon & \text{if } (w, c[1]) \text{ is a negative example,} \\ 1/|V| & \text{otherwise} \end{cases}$$

$$P(w|c[1,4]) = \frac{x(w, c[1,4])}{\sum_{\overline{w} \in V} x(\overline{w}, c[1,4])} \quad \forall c[1,4] \quad \forall w \in V$$

where $\epsilon$ is reasonably small positive value and $V$ is a word lexicon.

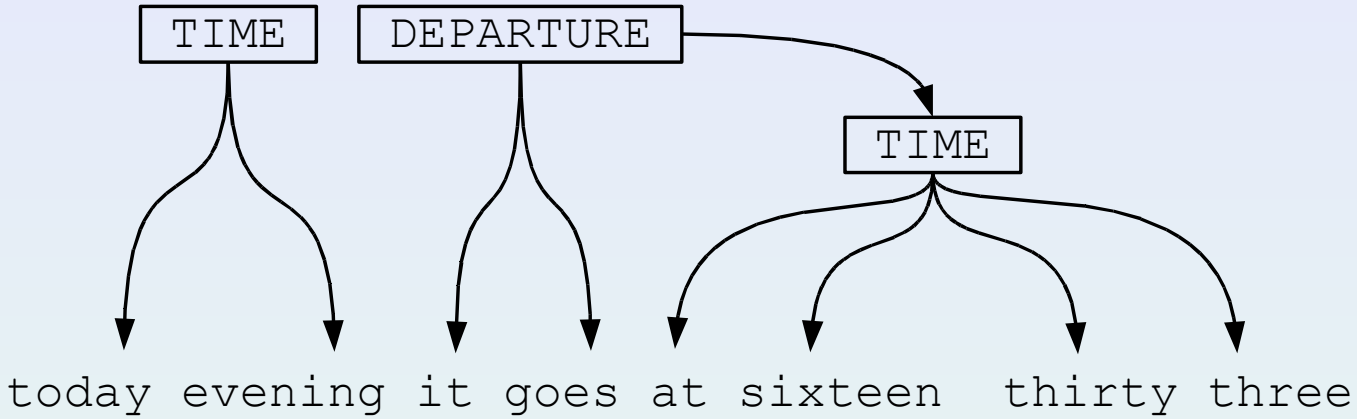
# Performance

| | Test data | | | Development data | | |
|---|---|---|---|---|---|---|
| | SAcc | CAcc | $p$-value | SAcc | CAcc | $p$-value |
| baseline | 47.9 | 63.2 | | 50.7 | 64.3 | |
| **neg. examples** | **50.4** | **64.9** | $< 0.01$ | **52.8** | **67.0** | $< 0.01$ |

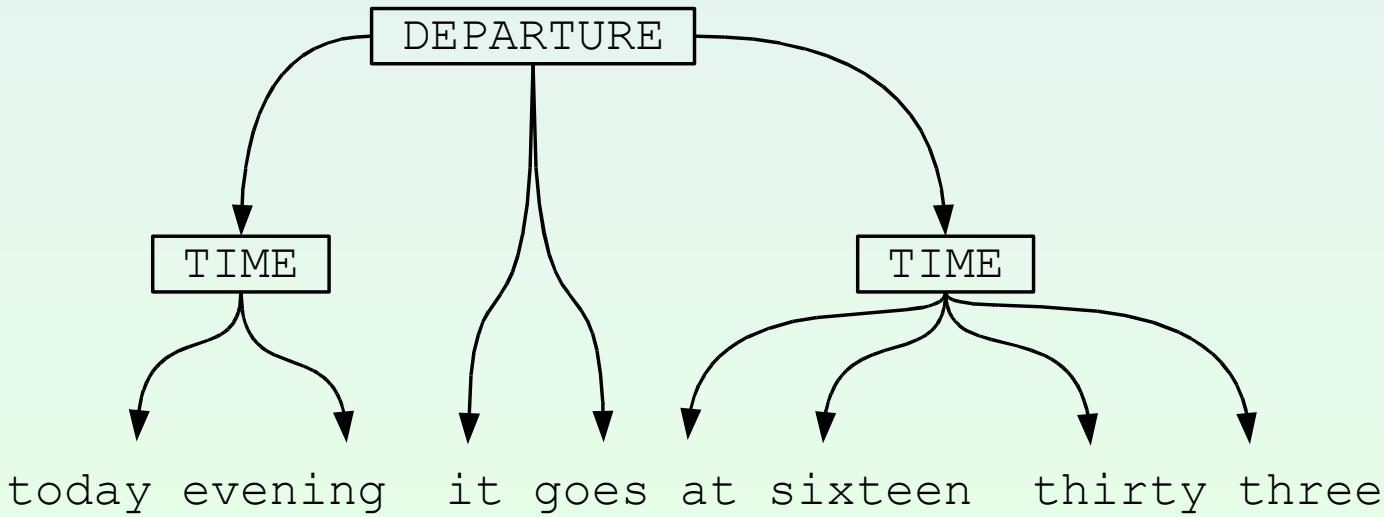
# Outline

# The incorrect parse tree

The incorrect parse tree from a right-branching parser




The correct parse tree from a left-right-branching parser



# Recapitulation - The Hidden Vector State parser

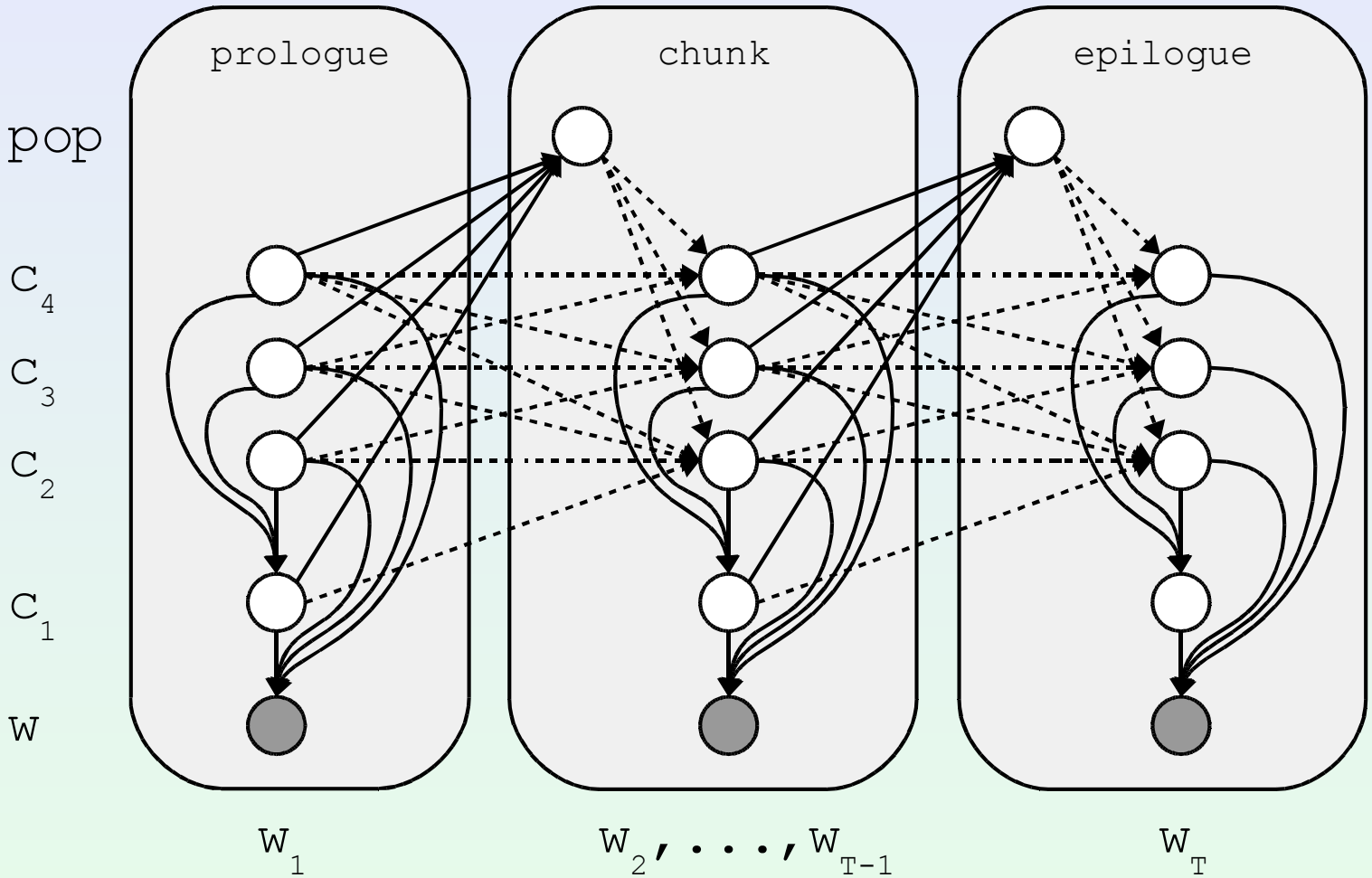



Figure: The graphical model of the HVS parser.

# The HVS parser with probabilistic pushing

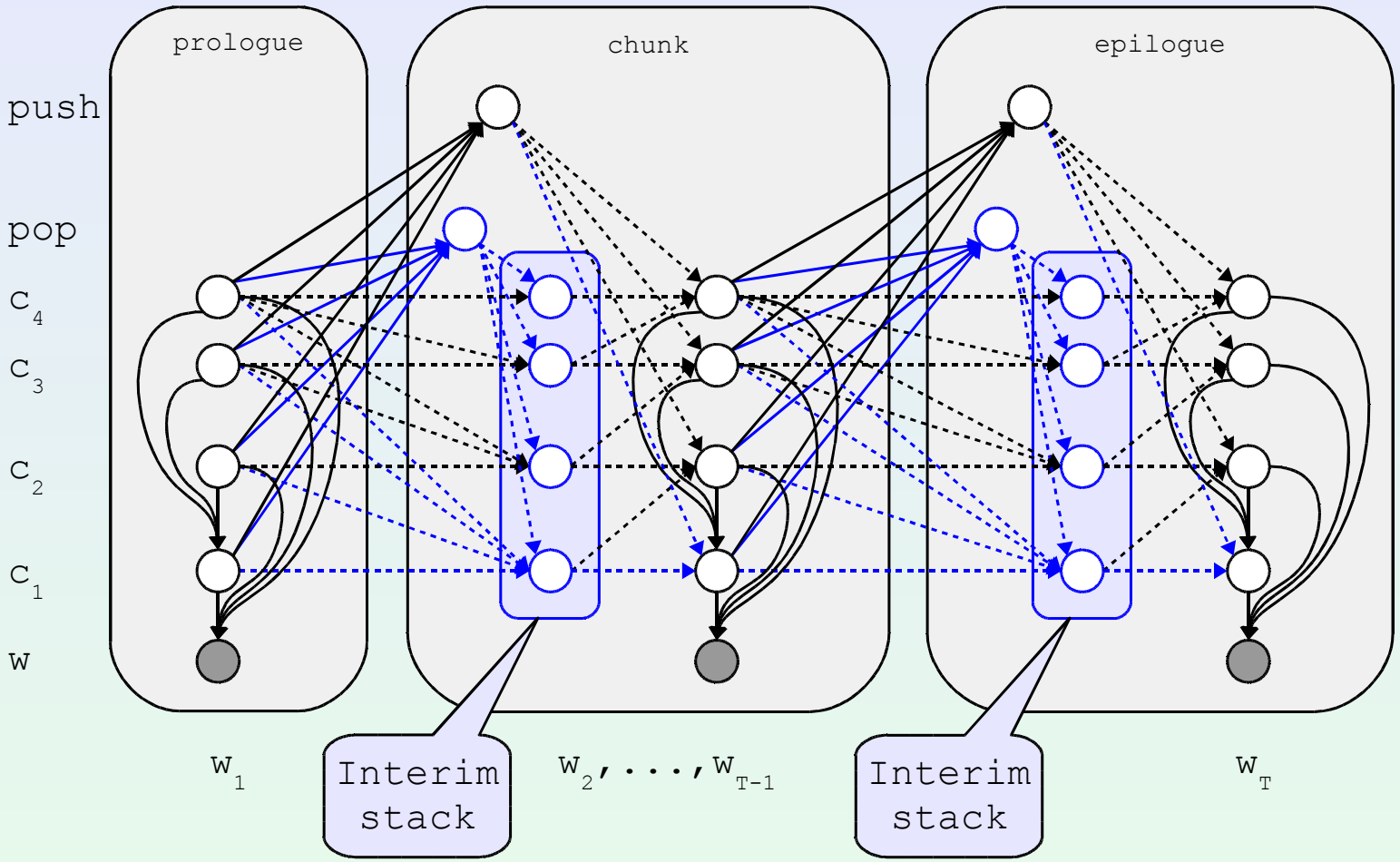



Figure: The graphical model of the HVS parser with probabilistic pushing (HVS-PP).

# The left-right-branching HVS

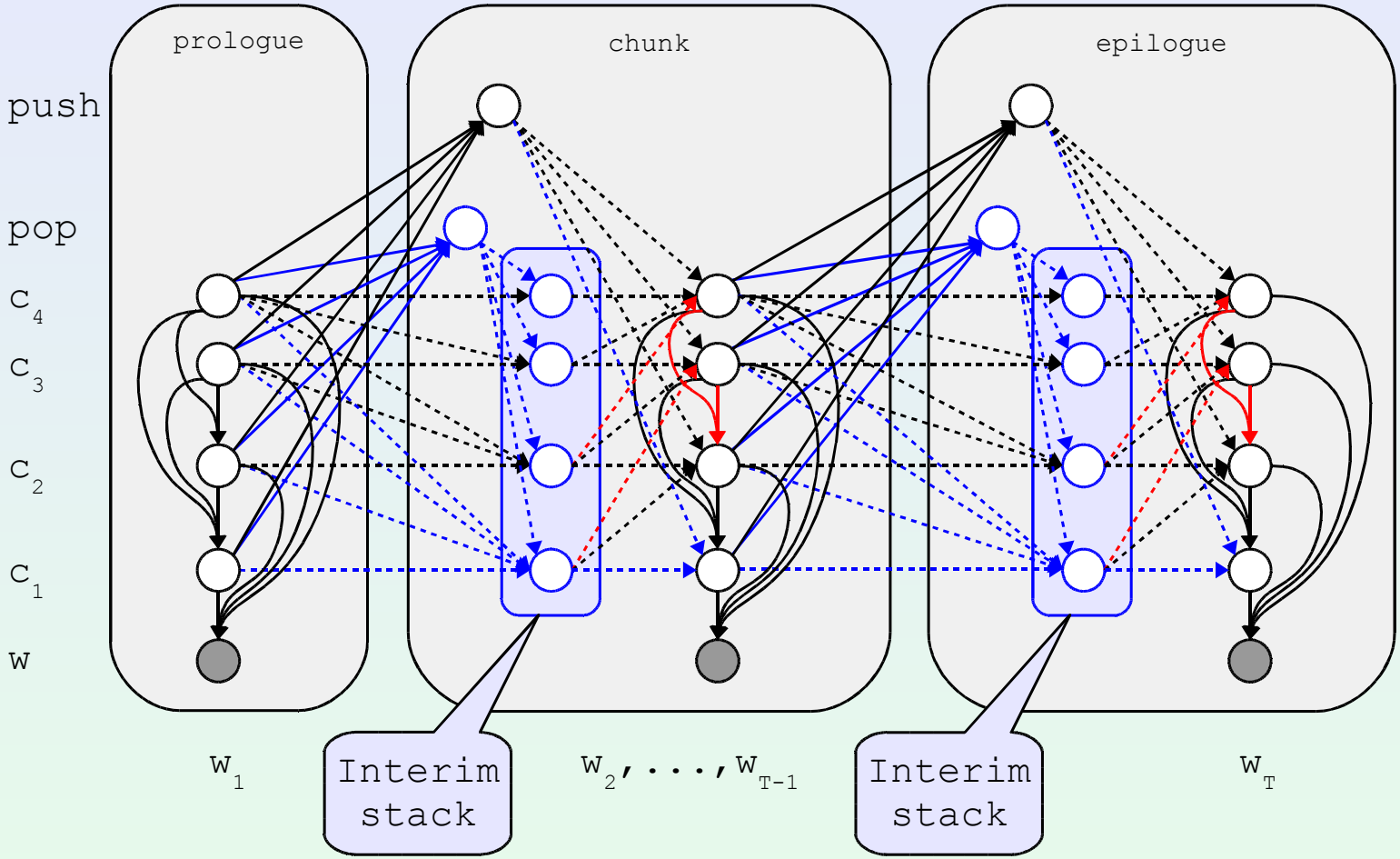



Figure: The graphical model of the right-branching HVS parser limited to insert at most two new concepts (LRB-HVS).

# Mathematical representation

## The HVS parser with probabilistic pushing

$$P(S) = \prod_{t=1}^{T} P(pop_t|c_{t-1}[1,4])P(push_t|c_{t-1}[1,4])$$

$$\cdot \begin{cases} 1 & \text{if } push_t = 0 \\ P(c_t[1]|c_t[2,4]) & \text{if } push_t = 1 \end{cases}$$

## The left-right-branching HVS

$$P(S) = \prod_{t=1}^{T} P(pop_t|c_{t-1}[1,4])P(push_t|c_{t-1}[1,4])\cdot$$

$$\cdot \begin{cases} 1 & \text{if } push_t = 0 \\ P(c_t[1]|c_t[2,4]) & \text{if } push_t = 1 \\ P(c_t[1]|c_t[2,4])P(c_t[2]|c_t[3,4]) & \text{if } push_t = 2 \end{cases}$$

# Performance

The baseline is the parser using negative examples.

| | Test data | | | Development data | | |
|---|---|---|---|---|---|---|
| | SAcc | CAcc | $p$-value | SAcc | CAcc | $p$-value |
| baseline | 50.4 | 64.9 | | 52.8 | 67.0 | |
| HVS-PP | 54.1 | 67.2 | $< 0.01$ | 56.6 | 68.4 | $< 0.01$ |
| **LRB-HVS** | **58.3** | **69.3** | $< 0.01$ | **60.1** | 70.6 | $<$ **0.01** |

# Outline

# Input feature vector

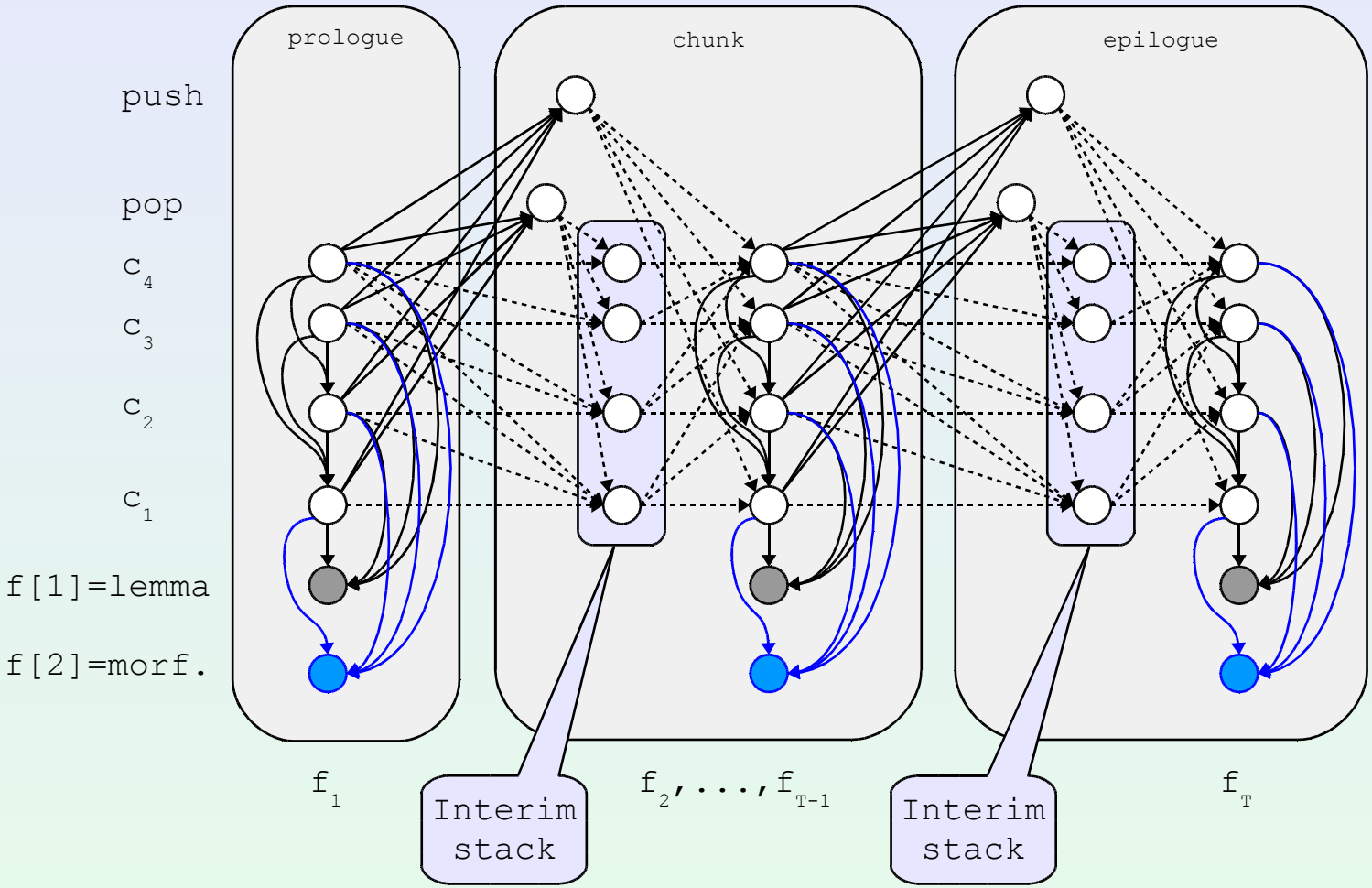



Figure: The graphical model of the HVS parser with the input feature vector composed of a lemma and a morphological tag (HVS-IFV).

# Mathematical representation

## Input feature vector

$$P(F|S) = \prod_{t=1}^{T} P(f_t \mid c_t)$$
$$= \prod_{t=1}^{T} P(f_t[1], f_t[2], \ldots f_t[N] \mid c_t)$$
$$\approx \prod_{t=1}^{T} \prod_{i=1}^{N} P(f_t[i] \mid c_t)$$

## Scaling of the semantic model

$$S^* = \arg\max_S P(F|S)P^{\lambda}(S)$$

# Performance

The baseline is the LRB-HVS parser.

| | Test data | | | Development data | | |
|---|---|---|---|---|---|---|
| input feature vector | SAcc | CAcc | $p$-value | SAcc | CAcc | $p$-value |
| baseline (Words) | 58.3 | 69.3 | | 60.1 | 70.6 | |
| Lemmas | 58.4 | 69.8 | | 60.5 | 71.3 | |
| **Lemmas+Morphological tags** | **63.1** | **73.8** | $< 0.01$ | **65.4** | **75.7** | $< 0.01$ |

# Benefits

## Example

| | |
|---|---|
| from the corpus: Words | ehm from Břeclavi to Mikulova then |
| from the corpus: Lemmas | ehm from Břeclav to Mikulov then |
| from the corpus: Morf. tags | J R N R N D |
| | |
| parser's input: Words | ehm from _unseen_ to _unseen_ then |
| parser's input: Lemmas | ehm from _unseen_ to _unseen_ then |
| parser's input: Morf. tags | J R N R N D |
| | |
| LRB-HVS Output Semantics | OTHER_INFO |
| HVS-IFV Output Semantics | FROM(STATION),TO(STATION) |

Extra

# Outline

# GMTK

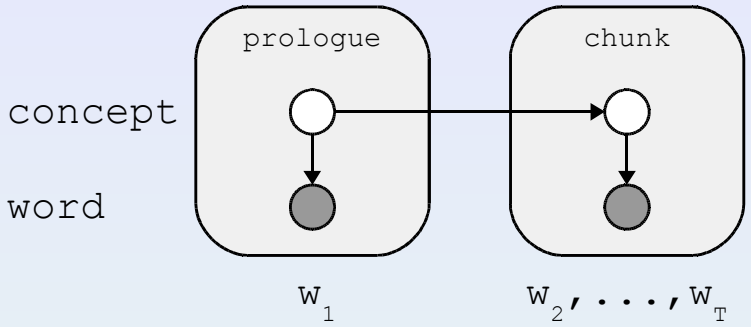
## The Graphical Models Toolkit (GMTK)

- Jeff Bilmes, University of Washington, Dept. of EE
- Geoffrey Zweig, Microsoft, Speech Research Group
- `http://ssli.ee.washington.edu/~bilmes/gmtk/`
- `http://ssli.ee.washington.edu/~bilmes/gmtk/doc.pdf`

## Main tools used from GMTK

- Preparing input files: gmtkTriangulate, gmtkDTindex
- Training: gmtkEMtrain(New)
- Decoding: gmtkViterbi(New)

# HMM Tagger (flat-concept parser) in GMTK



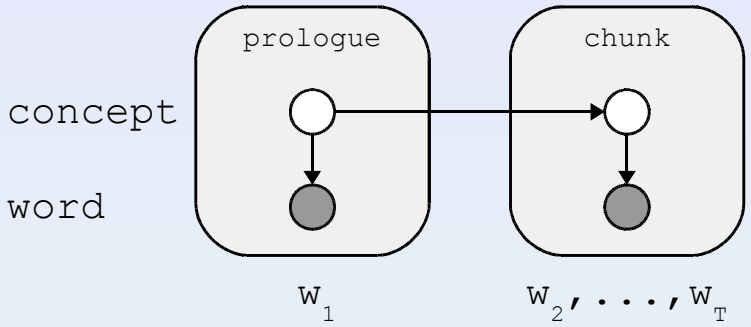

```
#include "commonParams"

frame : 0 {
  variable : concept {
    type: discrete hidden cardinality CONCEPT_CARD;
    switchingparents : nil;
    conditionalparents: nil using DeterministicCPT("conceptZero");
  }

  variable : word  {
    type: discrete observed 0:0 cardinality WORD_CARD;
    switchingparents : nil;
    conditionalparents: concept(0) using DenseCPT("wordGivenC1");
  }
}

...
```

# HMM Tagger (flat-concept parser) in GMTK

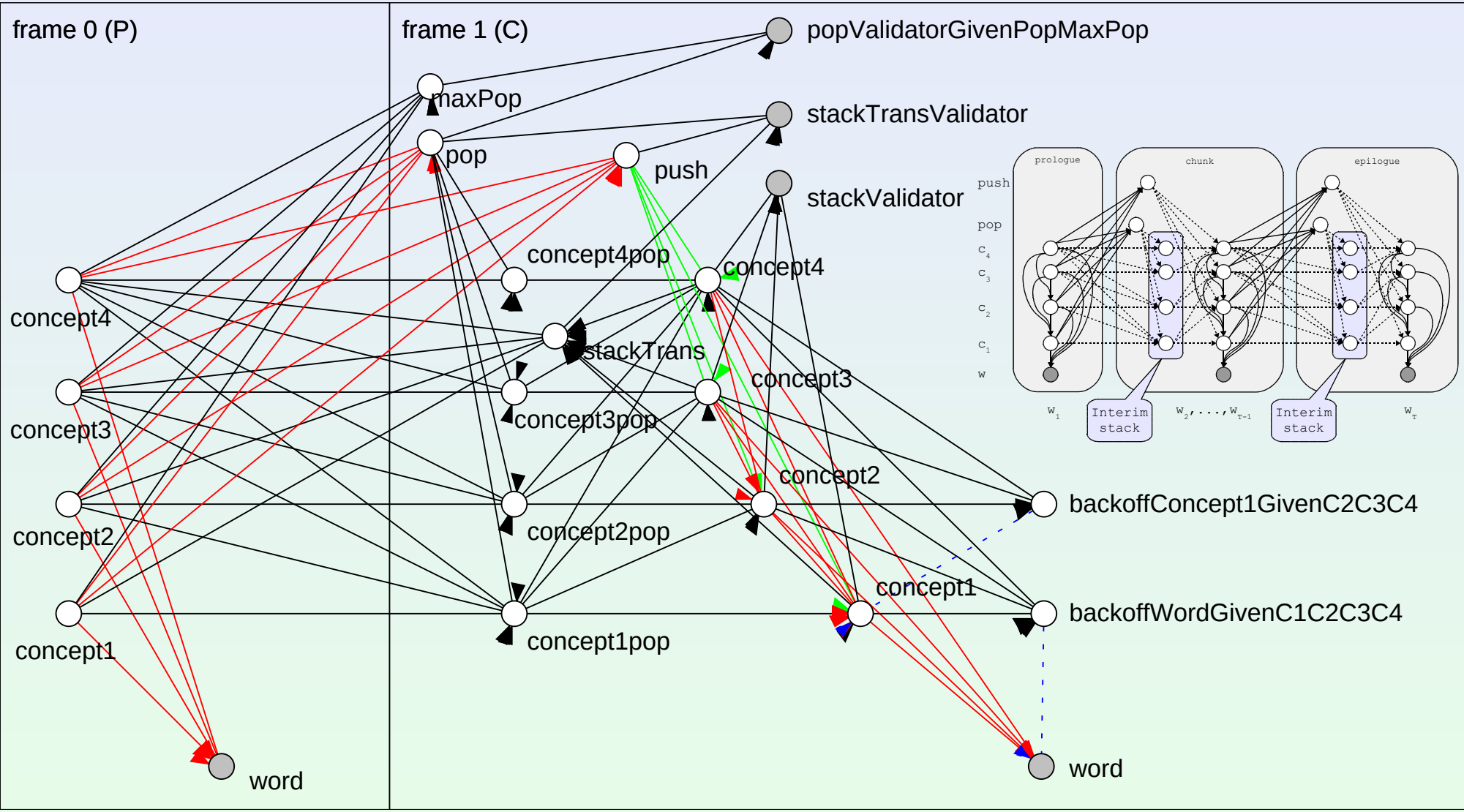



```
frame : 1 {
  variable : concept {
    type: discrete hidden cardinality CONCEPT_CARD;
    switchingparents : nil;
    conditionalparents: concept(-1) using DenseCPT("conceptGivenC_1");
  }

  variable : word  {
    type: discrete observed 0:0 cardinality WORD_CARD;
    switchingparents : nil;
    conditionalparents: concept(0) using DenseCPT("wordGivenC1");
  }
}

chunk 1:1
```

# Graphical model from implementation



# Stack transition validator

## Motivation - Duplicit paths with the same stack sequence

$(pop_t = 1, push_t = 1, concept1_{t-1} = concept1_t)$ equals to $(pop_t = 0, push_t = 0)$

```
variable : stackTrans {
    type: discrete hidden cardinality STACK_TRANS_CARD;
    switchingparents: nil;
    conditionalparents: concept1(0),concept1(-1),concept2(0),concept2(-1),c
      using DeterministicCPT("stackTransGivenC1C1_1C2C2_1C3C3_1C4C4_1");
}

% make sure that in case no change on the stack, it will use pop==push==0
variable : stackTransValidator {
    type: discrete observed value 1 cardinality 2;
    switchingparents: nil;
    conditionalparents: stackTrans(0), pop(0), push(0)
      using DeterministicCPT("stackTransValidatorGivenStPopPush");
}
```

# Stack transition validator - decision trees

```
1 % a DT that evaluates to one when there is "transition"
stackTransGivenC1C1_1C2C2_1C3C3_1C4C4_1
8 % number of parents
-1  {(!((p0==p1) && (p2==p3) && (p4==p5) && (p6==p7)))}

2 % a DT that validate pop, push, and stack transition
%   if there is no transition, the pop and push RV should be equal to 0
stackTransValidatorGivenStPopPush
3 % number of parents
0 2 0 default
  -1  {(p1==0)&&(p2==0)}  % the pop and push should be equal to 0
  -1  {p1||p2}    % the pop or push should be different to 0
```

# Outline

# Performance overview

| | Test data | | | Development data | | |
|---|---|---|---|---|---|---|
| | SAcc | CAcc | $p$-value | SAcc | CAcc | $p$-value |
| the lower-bound baseline | 17.3 | 26.0 | | | | |
| original HVS parser | 47.9 | 63.2 | | 50.7 | 64.3 | |
| negative examples | 50.4 | 64.9 | $< 0.01$ | 52.8 | 367.0 | $< 0.01$ |
| LRB-HVS | 58.3 | 69.3 | $< 0.01$ | 60.1 | 70.6 | $< 0.01$ |
| **HVS-IFV** | **63.1** | **73.8** | $< 0.01$ | **65.4** | **75.7** | $< 0.01$ |
| the upper-bound ceiling | 85.0 | 91.0 | | | | |

# Questions?

Thank you!

## And also

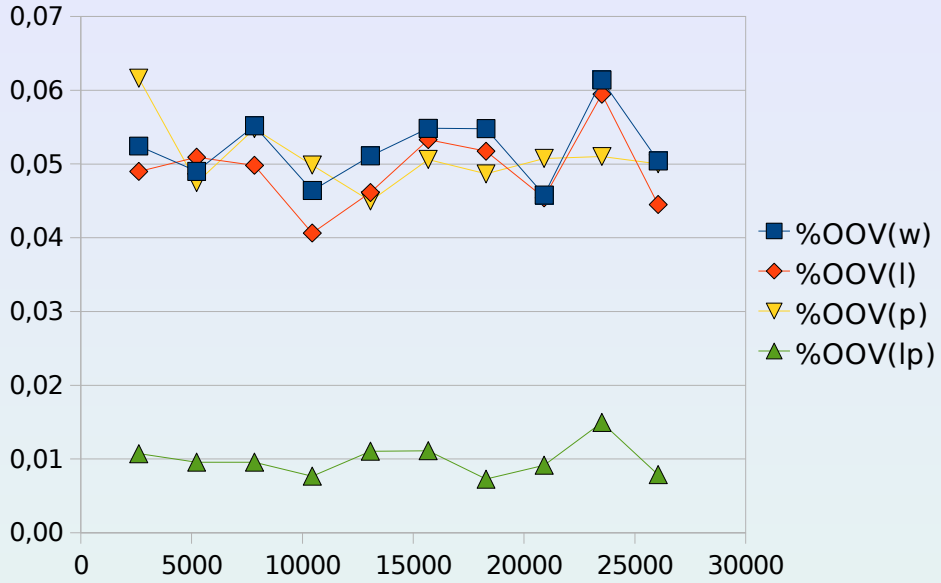
Many thanks to my colleague Jan Švec from UWB for his work on the IFV part of the parser.

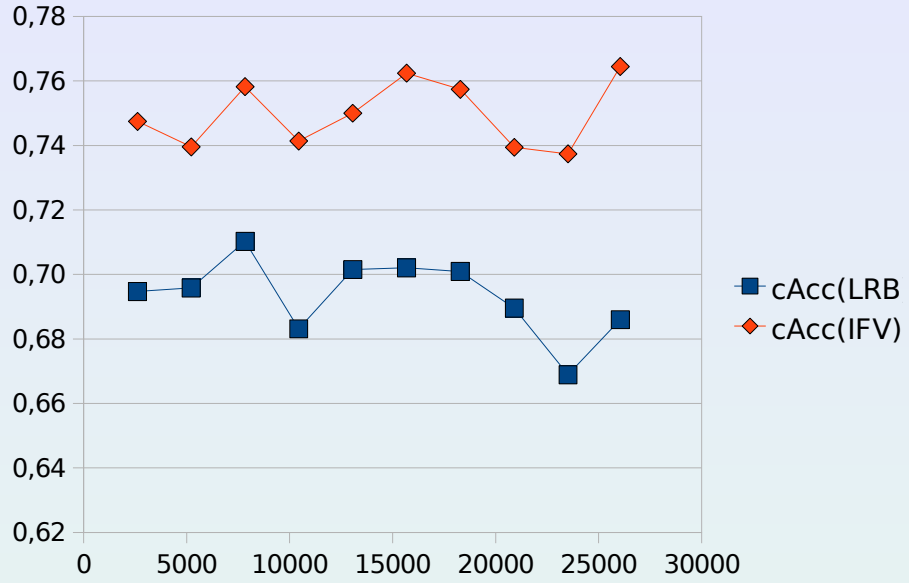
## The parser is available at

`http://code.google.com/p/extended-hidden-vector-state-parser/`

`http://code.google.com/p/dialogue-act-editor/`

## Original results




## Sorted results according cAcc(IFV) - cAcc(LRB)