A Simple Domain-Independent Approach to Generation

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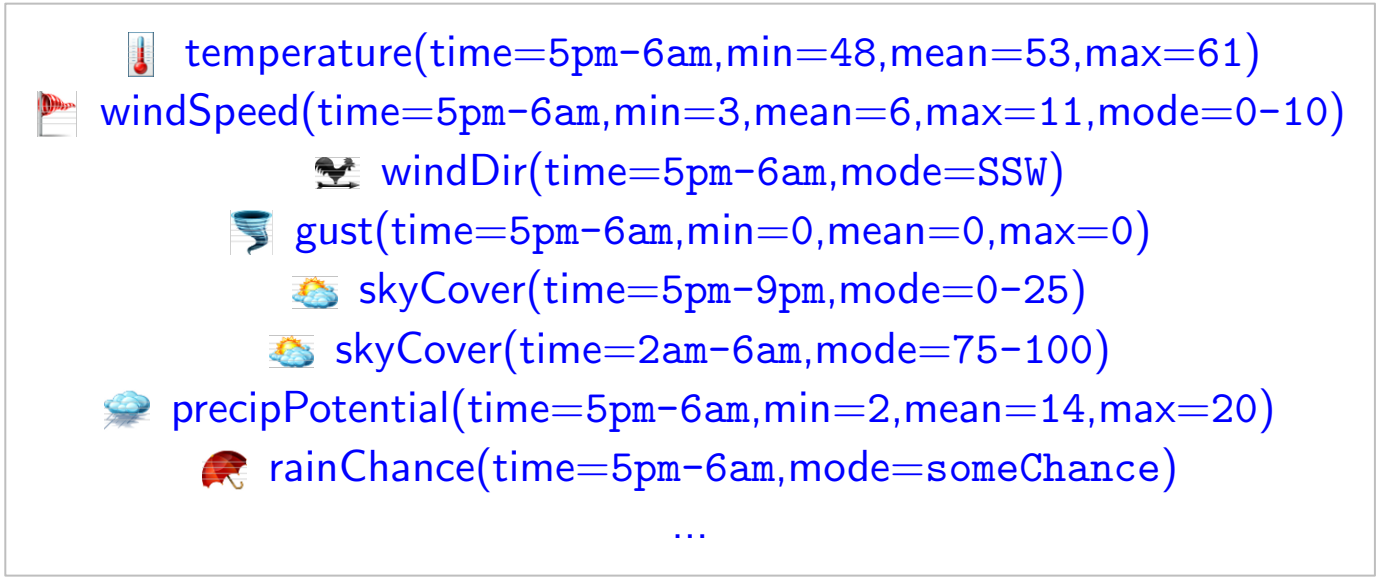
Introduction

Task: Generate text from database records

s:



w: *A 20 percent chance of showers after midnight. Increasing clouds, with a low around 48. southwest wind between 5 and 10 mph.*

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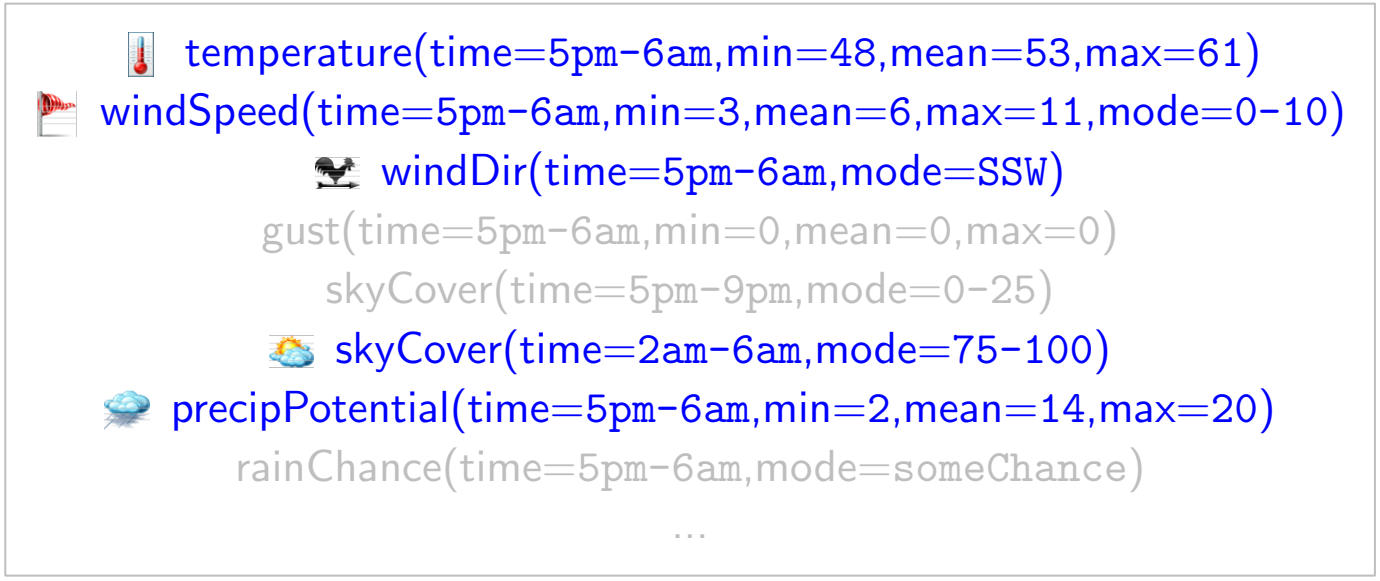

Requires both **content selection**

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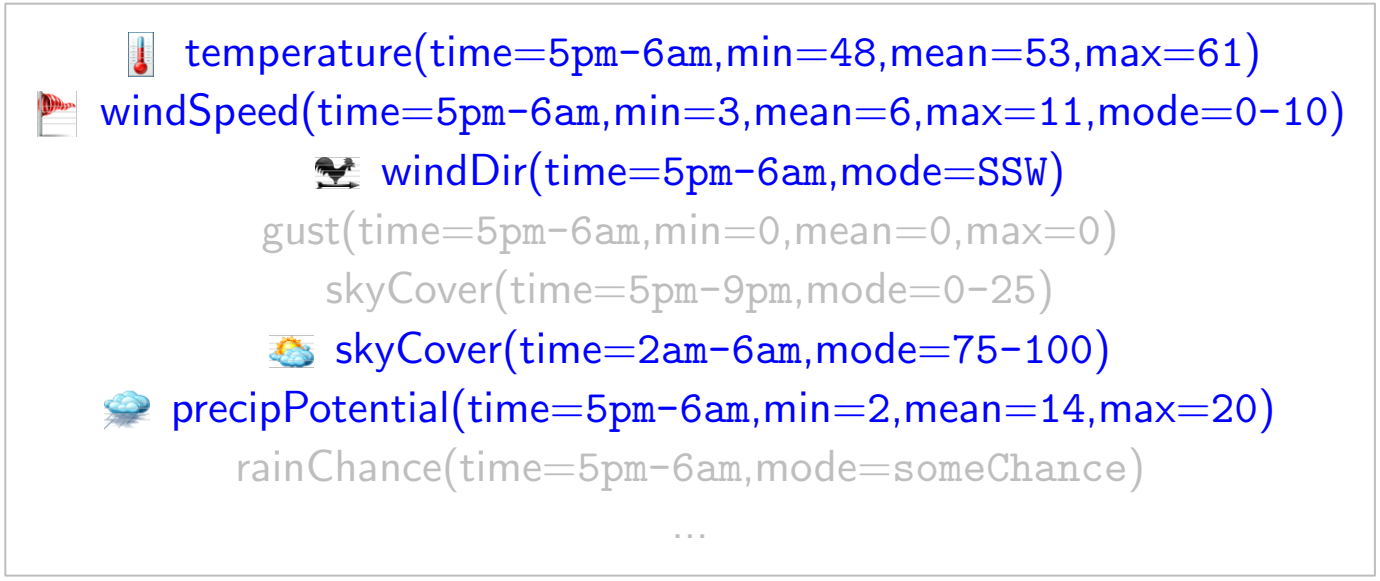

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Requires both **content selection** and **surface realization**

Main Ideas

Complete Pipeline:

Do content selection and surface realization in a unified framework

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Domain Independent Approach:

Applicable to multiple domains with minimal tweaking

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- Applicable to multiple domains with minimal tweaking
- Contrast with domain-tuned systems,
  - e.g. Chen and Mooney (2008), Belz (2008)

Domain Independent

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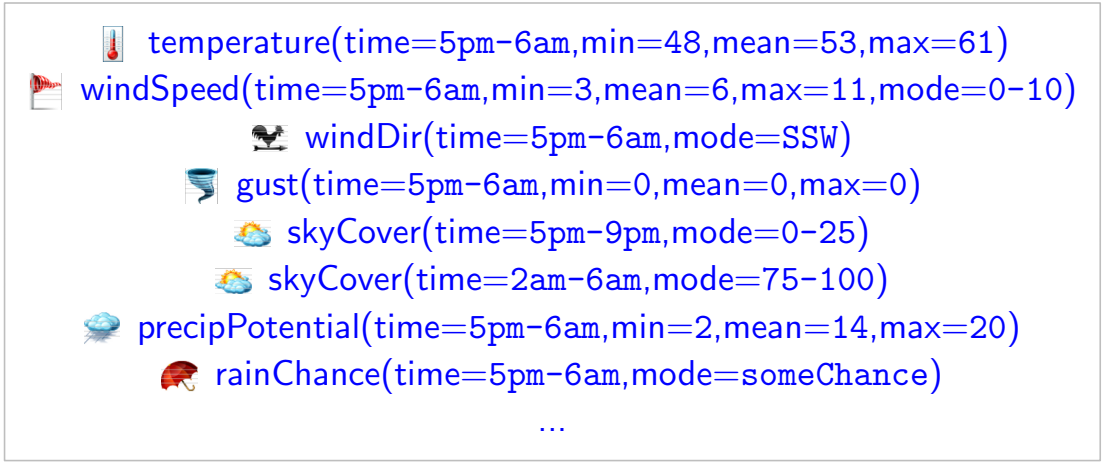

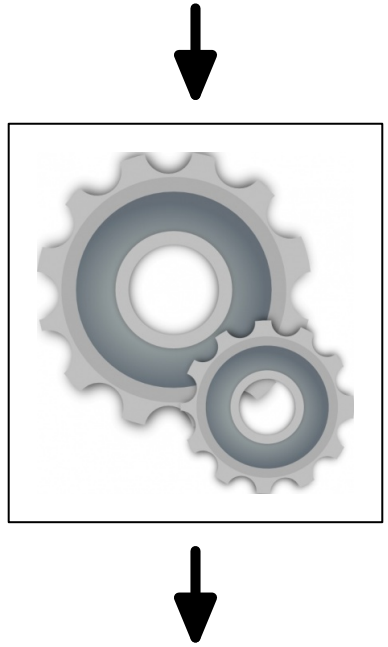

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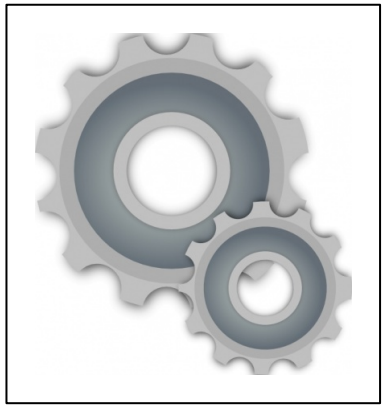
Domain Independent

s:

kick(arg1=purple3)
badPass(arg1=purple3, arg2=pink9)
turnover(arg1=purple3, arg2=pink9)

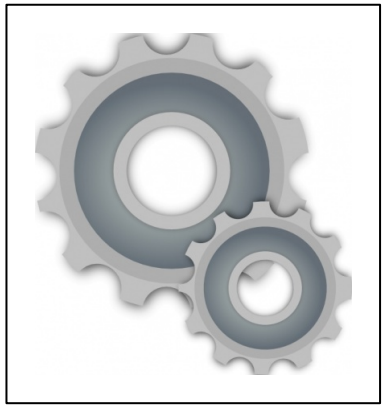


w: *Purple3 made a bad pass that was picked off by pink9.*

Domain Independent

s:

wind10m(time=6am,dir=SW,min=16,max=20,gust min=0,gust max=0)
wind10m(time=9pm,dir=SSW,min=28,max=32,gust min=40,gust max=0)
wind10m(time=12am,dir=-,min=24,max=28,gust min=36,gust max=0)



w: *sw 16 - 20 backing ssw 28 - 32 gusts 40 by mid evening easing 24 - 28 gusts 36 late evening*

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Do content selection and surface realization in a unified framework

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Surface Realization: e.g. Soricut and Marcu (2006), White, et al. (2007)

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Contrast with domain-tuned systems,

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Data Driven:

Learned from annotated training data

Learning Based

Learning Based

Train

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temperature(time=5pm-6am,min=48,mean=53,max=61)
windSpeed(time=5pm-6am,min=3,mean=6,max=11,mode=0-10)
windDir(time=5pm-6am,mode=SSW)
gust(time=5pm-6am,min=0,mean=0,max=0)
skyCover(time=5pm-9pm,mode=0-25)
skyCover(time=2am-6am,mode=75-100)
precipPotential(time=5pm-6am,min=2,mean=14,max=20)
rainChance(time=5pm-6am,mode=someChance)
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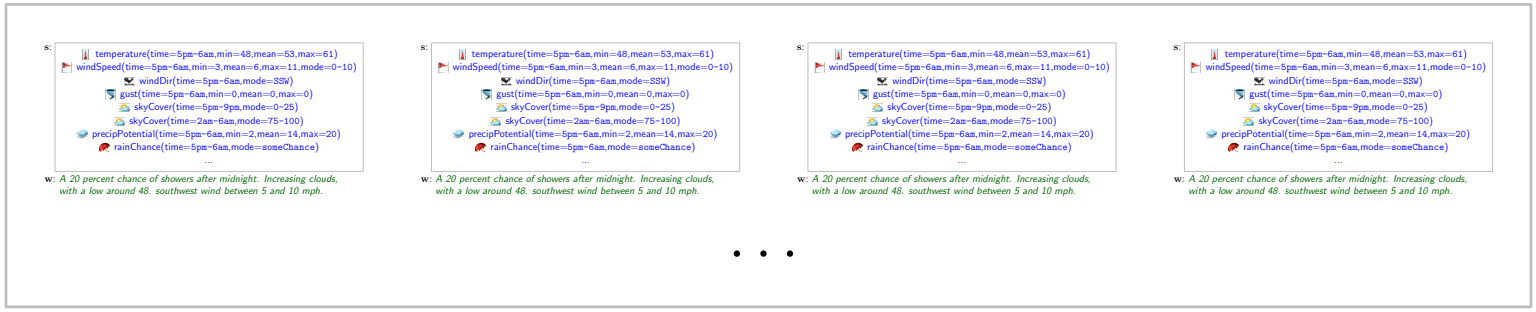

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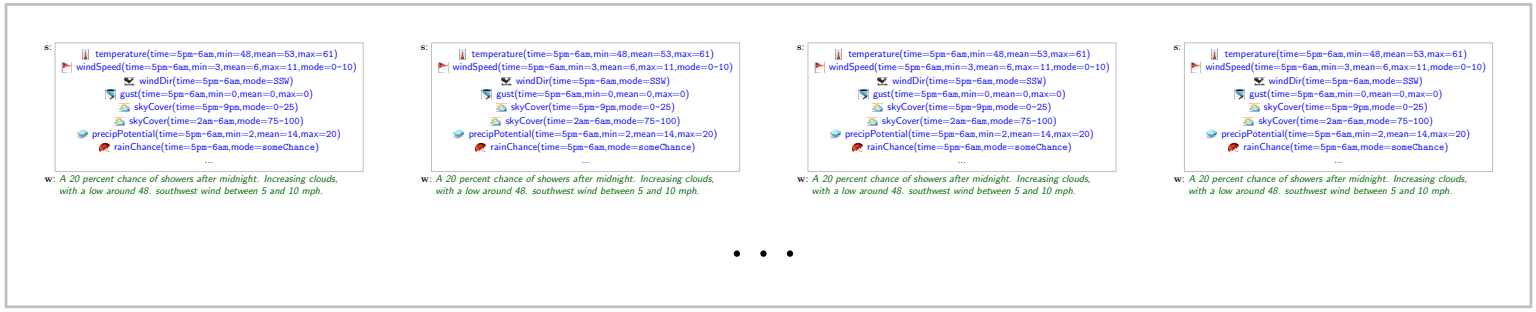

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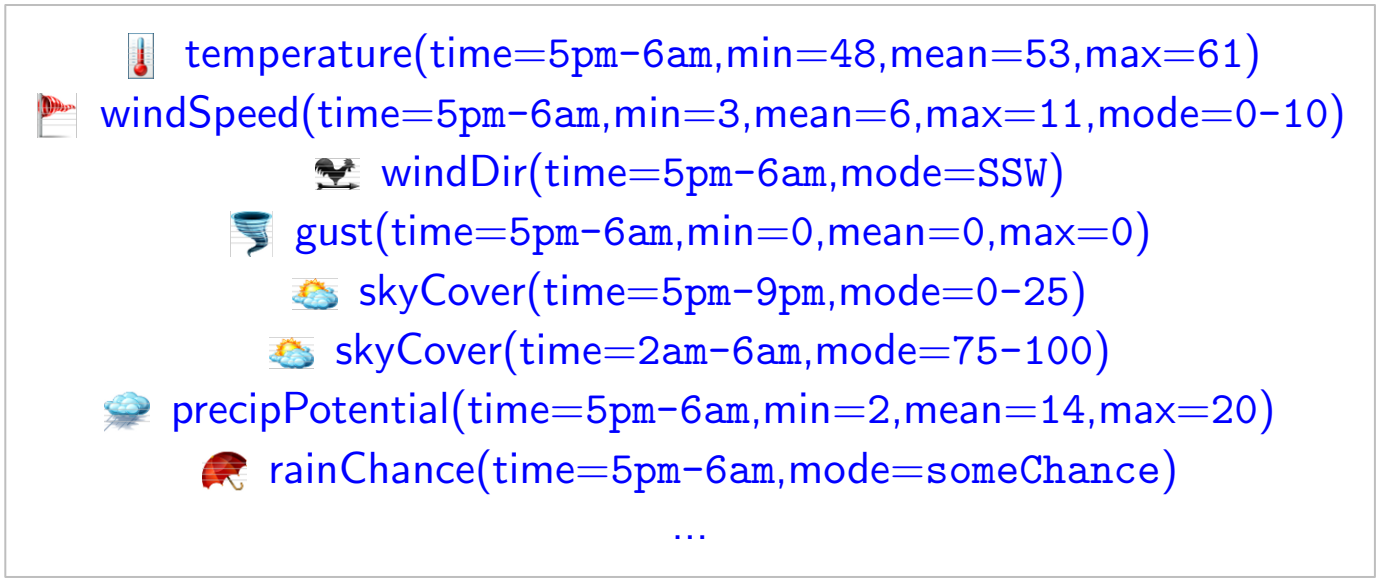

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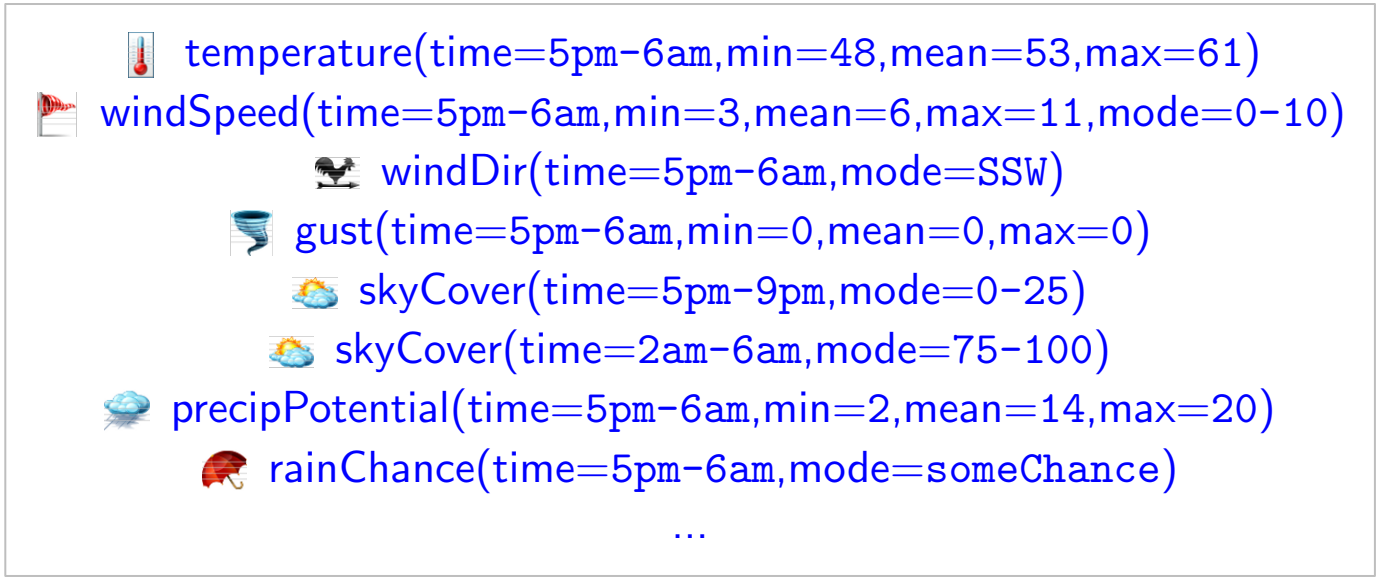

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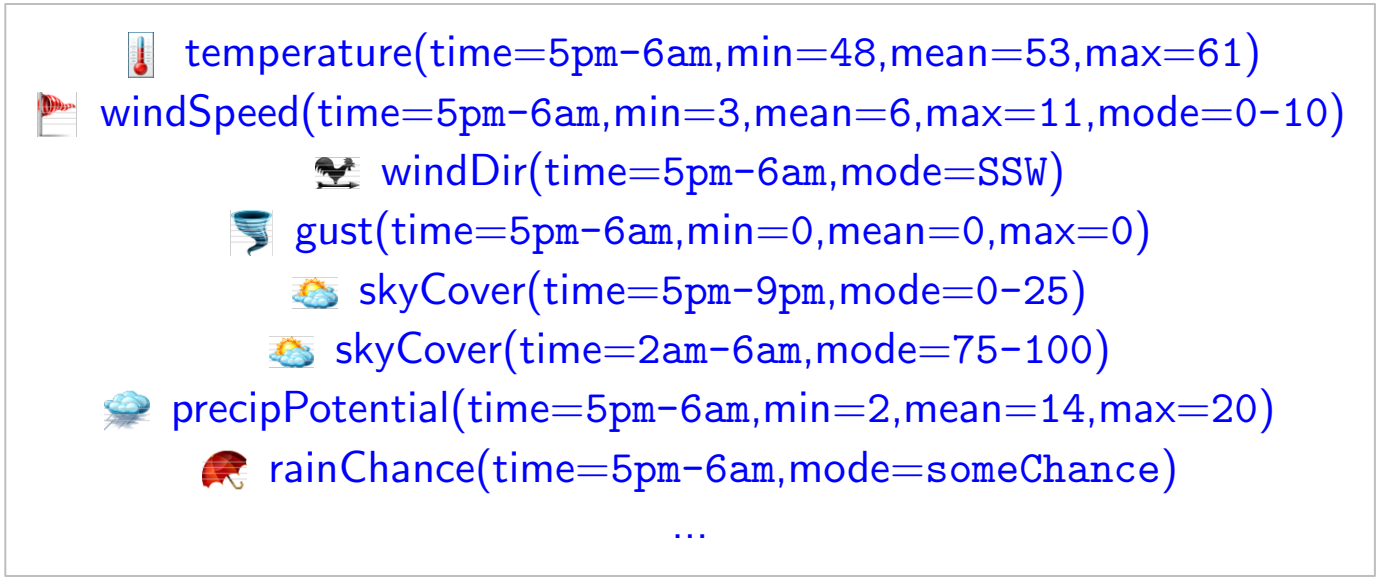

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- Language independent

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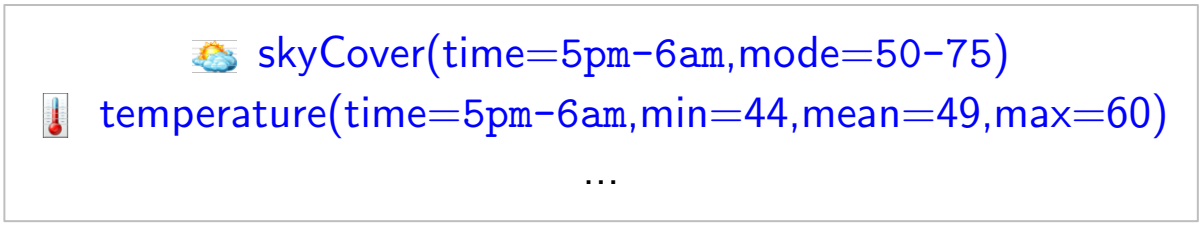
Templates extracted automatically from the training data (stay tuned)

Generation as Decisions

s:



Generation as Decisions

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skyCover(time=5pm-6am,mode=50-75)
temperature(time=5pm-6am,min=44,mean=49,max=60)
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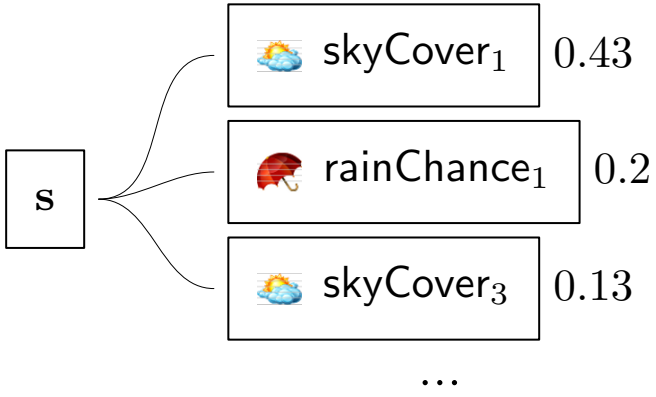
Record

Field set

Template



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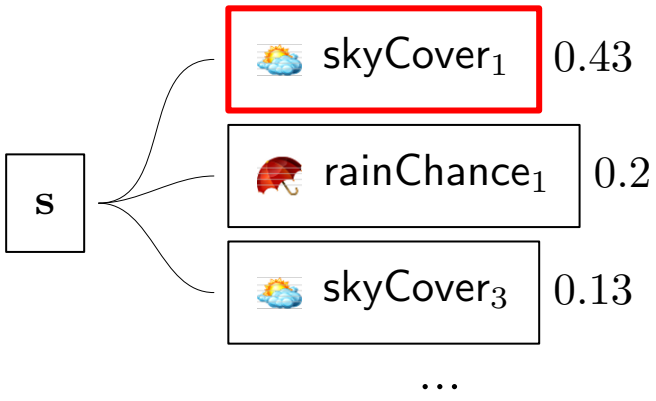

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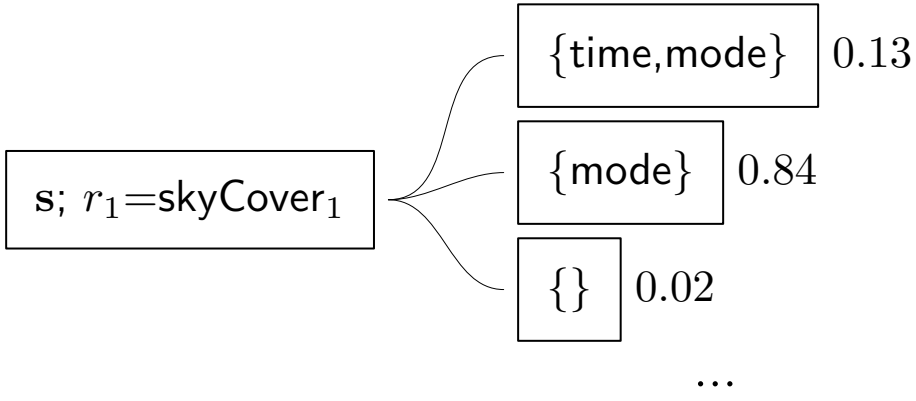
Record r_1 = skyCover$_1$

Field set

Template



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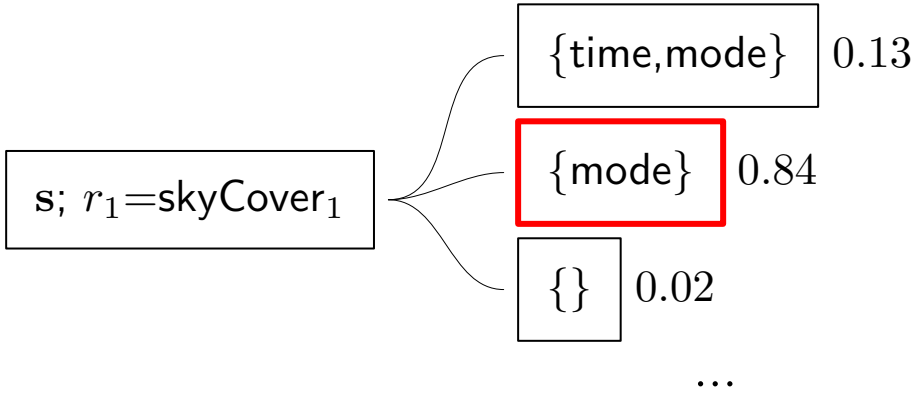

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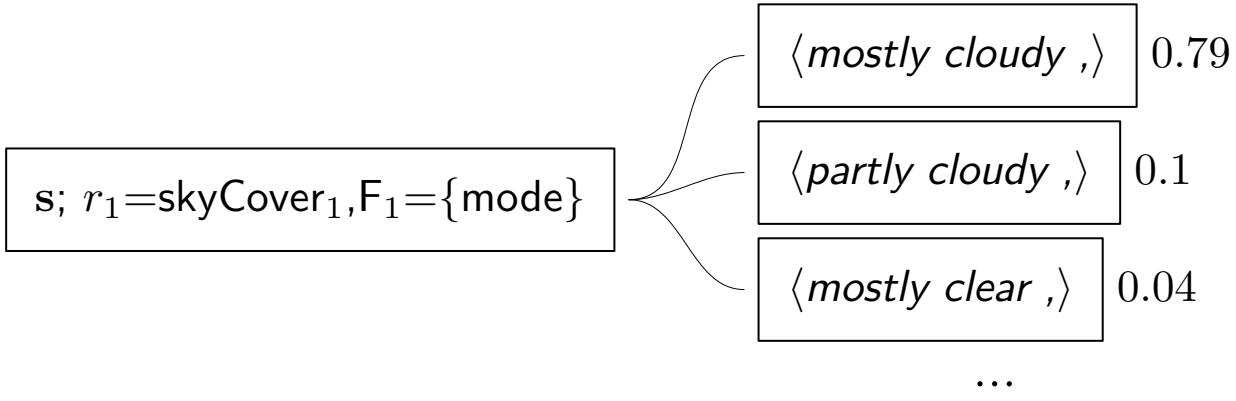
Template



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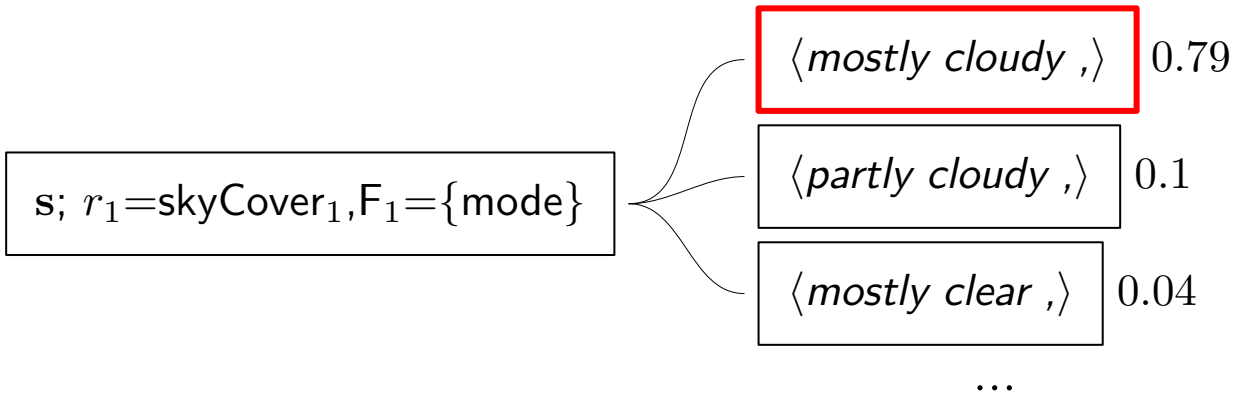

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Field set $F_1 = \{\text{mode}\}$

Template $W_1 = \langle \textit{mostly cloudy} , \rangle$

s; r_1=skyCover$_1$,F$_1$={mode},T$_1$=$\langle$*mostly cloudy* ,$\rangle$

- rainChance$_1$ 0.02
- thunderChance$_3$ 0.01
- temperature$_1$ 0.95
- ...

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Field set $F_1 = \{\text{mode}\}$

Template $W_1 = \langle \textit{mostly cloudy} , \rangle$

s; ...,F_1={mode},T_1=$\langle$*mostly cloudy* ,$\rangle$,r_2=temperature

- {mean,min,max} 0.12
- {time,min} 0.6
- {min} 0.13
- ...

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s; ...,T_1=⟨*mostly cloudy* ,⟩,r_2=temperature,F_2={time,min}

- ⟨*with a low around* [min .⟩ 0.83
- ⟨*with a high around* [max] .⟩ 0.01
- ⟨*with a high near* [max] .⟩ 0.05

...

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Template	$W_1 = \langle \textit{mostly cloudy} , \rangle$	$W_2 = \langle \textit{with a low around } [\min] \ . \rangle$

s; ...,r$_2$=temperature,F$_2$={time,min},T$_2$=⟨*with a low around* min .⟩

- windDir$_1$ 0.37
- temperature$_1$ 0.03
- STOP 0.43
- ...

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temperature(time=5pm-6am,min=44,mean=49,max=60)
...

Record	$r_1 =$ skyCover$_1$	$r_2 =$ temperature$_1$	$r_3 = \text{STOP}$
Field set	$F_1 = \{\text{mode}\}$	$F_2 = \{\text{time}, \text{min}\}$	
Template	$W_1 = \langle$*mostly cloudy ,*$\rangle$	$W_2 = \langle$*with a low around* $[\text{min}]$.$\rangle$	

mostly cloudy , with a low around 44 .

Generation as Decisions

s:

skyCover(time=5pm-6am,mode=50-75)
temperature(time=5pm-6am,min=44,mean=49,max=60)
...

Record	$r_1 =$ skyCover$_1$	$r_2 =$ temperature$_1$	$r_3 = \text{STOP}$
Field set	$F_1 = \{\text{mode}\}$	$F_2 = \{\text{time}, \text{min}\}$	
Template	$W_1 = \langle$*mostly cloudy ,*$\rangle$	$W_2 = \langle$*with a low around* $[\text{min}]$.$\rangle$	

mostly cloudy , with a low around 44 .

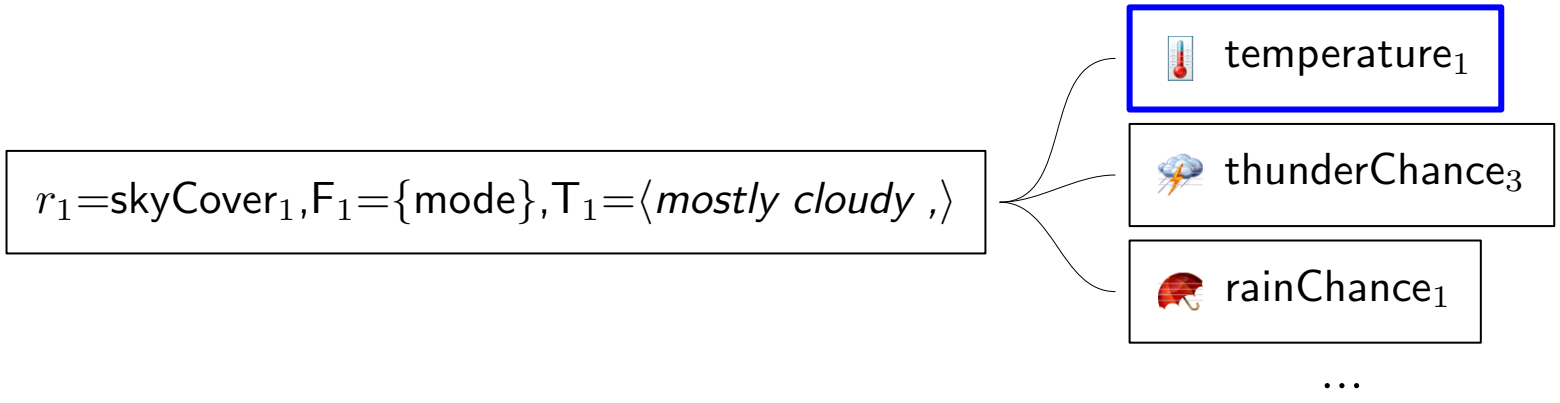
Features: Record

Record	$r_1 =$ skyCover$_1$	$r_2 =$ temperature$_1$
Field set	$F_1 = \{\text{mode}\}$	
Template	$W_1 = \langle \textit{mostly cloudy} , \rangle$	

Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$



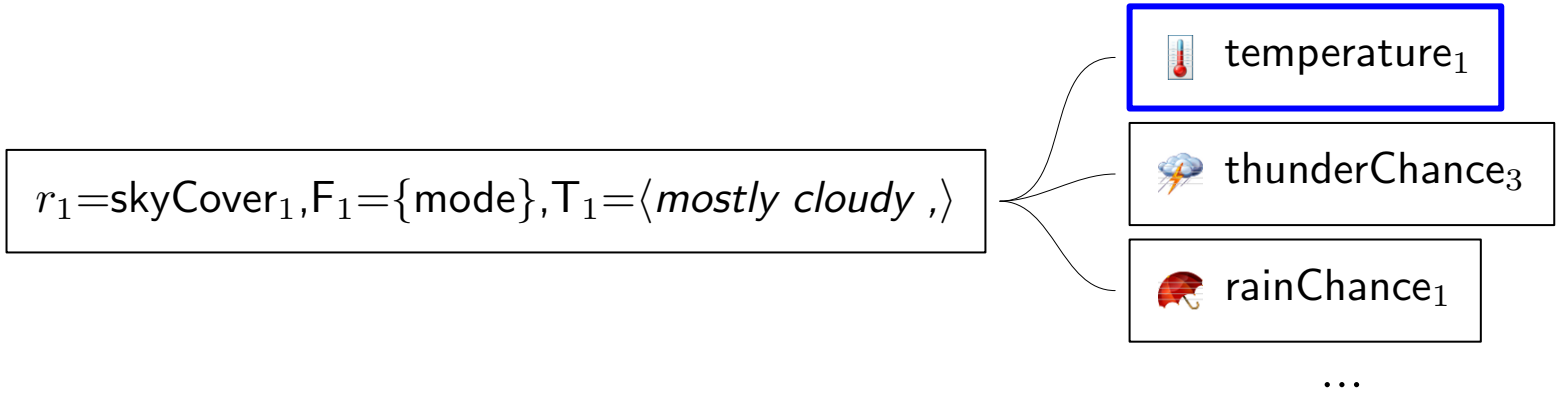
Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{temperature and } \{r_1.t\} = \{\text{skyCover}\}]\!]$



Features: Record

(R1) **List of last two record types**

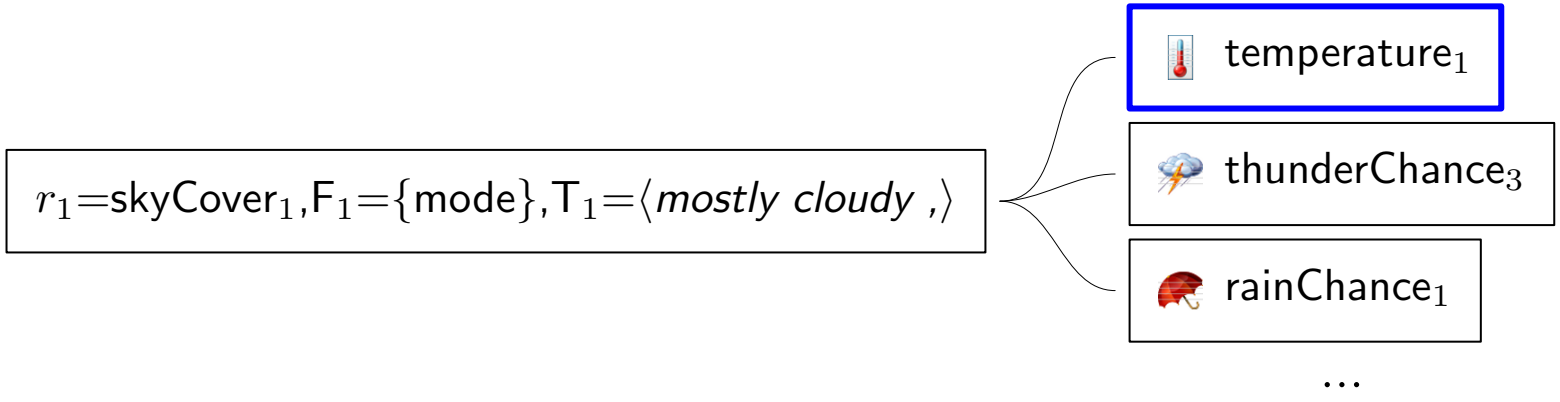
$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{temperature and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

(R3) **Record type already generated**

$[\![r_2.t = \text{temperature and } r_j.t \neq \text{temperature } \forall j < 2]\!]$



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

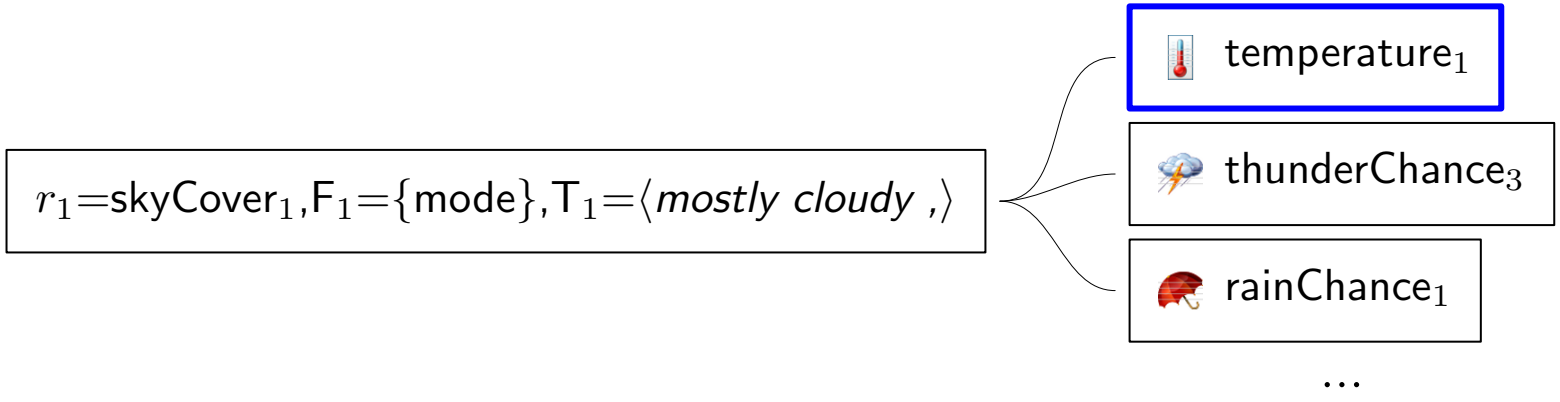
$[\![r_2.t = \text{temperature and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

(R3) **Record type already generated**

$[\![r_2.t = \text{temperature and } r_j.t \neq \text{temperature } \forall j < 2]\!]$

(R4) **Field values**

$[\![r_2.t = \text{temperature and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

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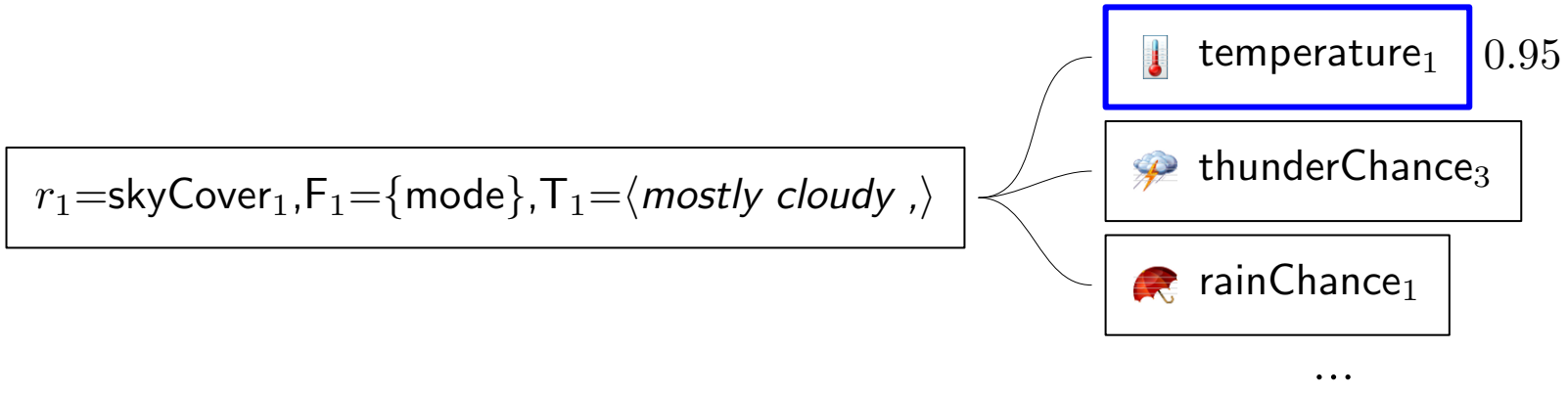
(R4) **Field values**

$[\![r_2.t = \text{temperature and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$

(R5) **Stop under language model**



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{thunderChance and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{thunderChance and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

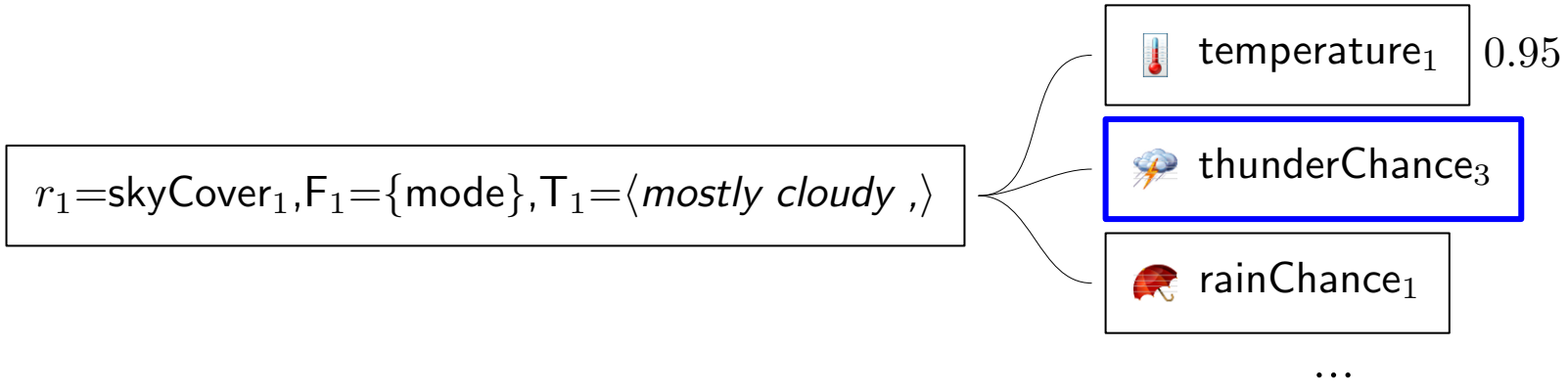
(R3) **Record type already generated**

$[\![r_2.t = \text{thunderChance and } r_j.t \neq \text{thunderChance } \forall j < 2]\!]$

(R4) **Field values**

$[\![r_2.t = \text{thunderChance and } r_2.v[\text{time}] = \texttt{2am-6am}]\!]$

(R5) **Stop under language model**



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{thunderChance and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{thunderChance and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

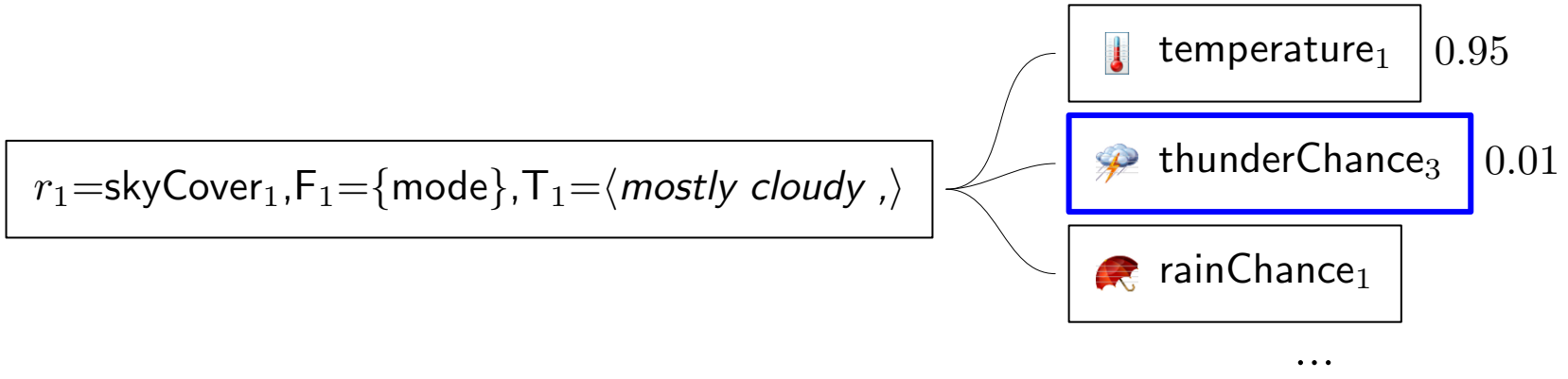
(R3) **Record type already generated**

$[\![r_2.t = \text{thunderChance and } r_j.t \neq \text{thunderChance } \forall j < 2]\!]$

(R4) **Field values**

$[\![r_2.t = \text{thunderChance and } r_2.v[\text{time}] = \texttt{2am-6am}]\!]$

(R5) **Stop under language model**



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{rainChance and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{rainChance and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

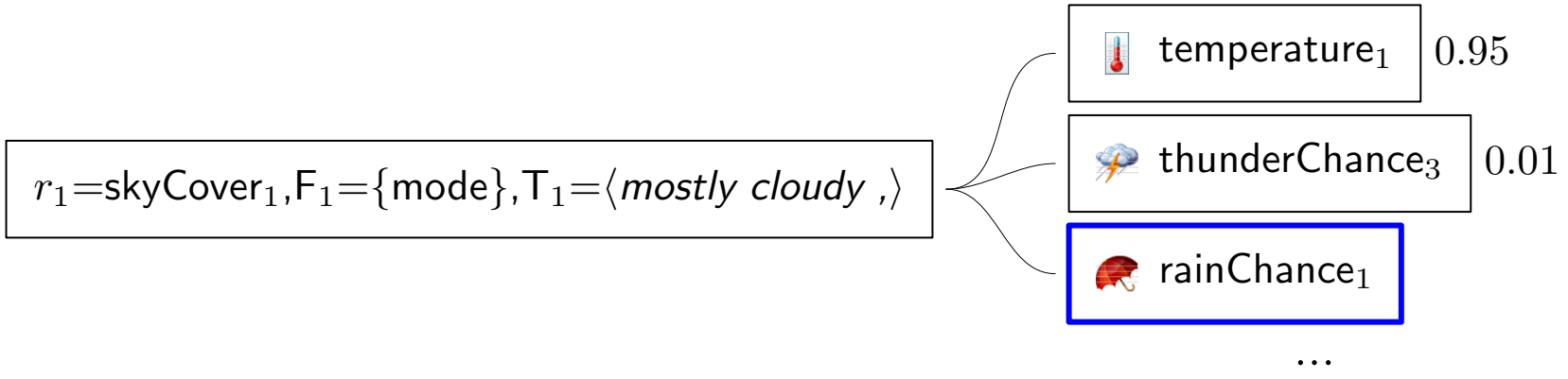
(R3) **Record type already generated**

$[\![r_2.t = \text{rainChance and } r_j.t \neq \text{rainChance } \forall j < 2]\!]$

(R4) **Field values**

$[\![r_2.t = \text{rainChance and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$

(R5) **Stop under language model**



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{rainChance and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

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$[\![r_2.t = \text{rainChance and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

(R3) **Record type already generated**

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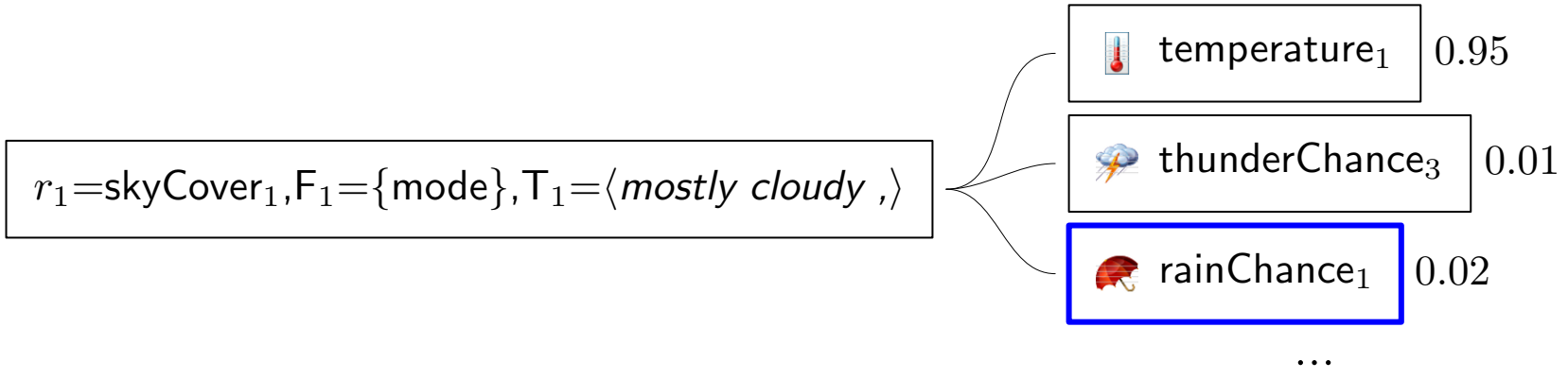
(R4) **Field values**

$[\![r_2.t = \text{rainChance and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$

(R5) **Stop under language model**



Features: Record

(R1) **List of last two record types**

$[\![r_2.t = \text{temperature and } (r_1.t, r_0.t) = (\text{skyCover}, \text{START})]\!]$

(R2) **Set of previous record types**

$[\![r_2.t = \text{temperature and } \{r_1.t\} = \{\text{skyCover}\}]\!]$

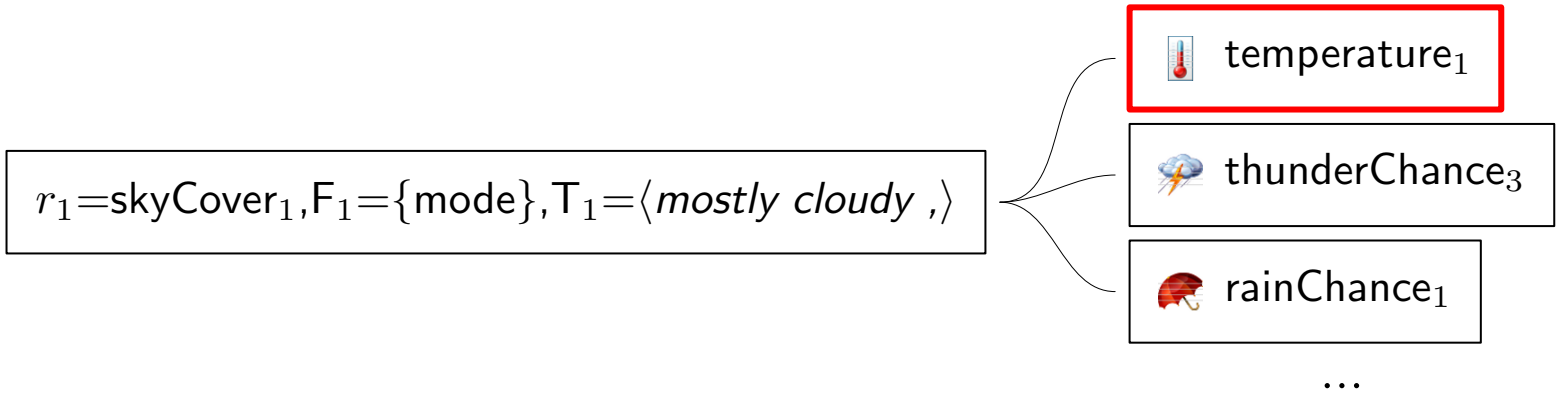
(R3) **Record type already generated**

$[\![r_2.t = \text{temperature and } r_j.t \neq \text{temperature } \forall j < 2]\!]$

(R4) **Field values**

$[\![r_2.t = \text{temperature and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$

(R5) **Stop under language model**



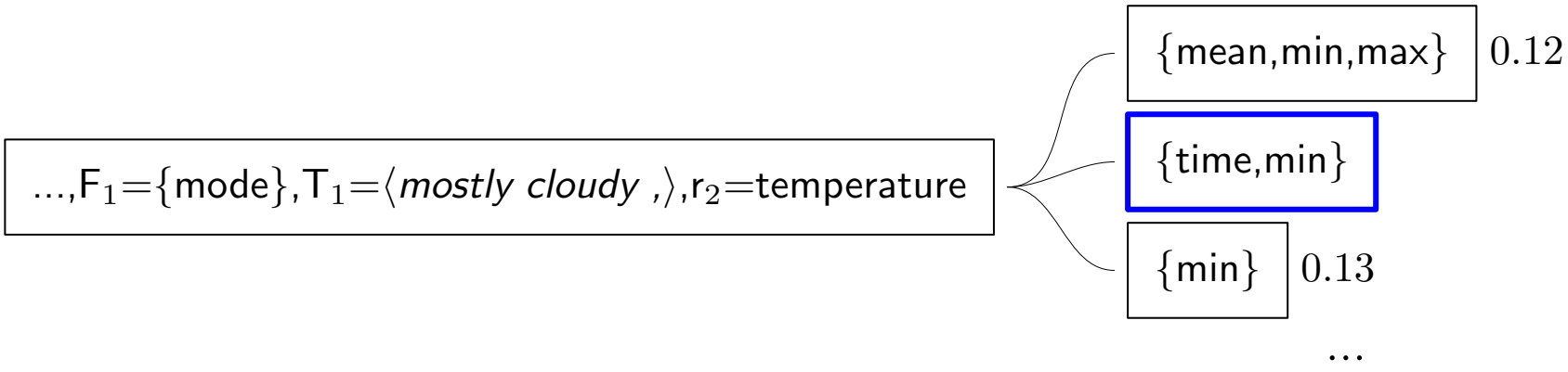
Features: Field Set

Record	$r_1 =$ 🌥️ skyCover$_1$	$r_2 =$ 🌡️ temperature$_1$
Field set	$F_1 = \{\text{mode}\}$	$F_2 = \{\text{time}, \text{min}\}$
Template	$W_1 = \langle \textit{mostly cloudy} , \rangle$	

Features: Field Set

(R1) **Field Set**

$[\![F_2 = \{\text{time}, \text{min}\}]\!]$



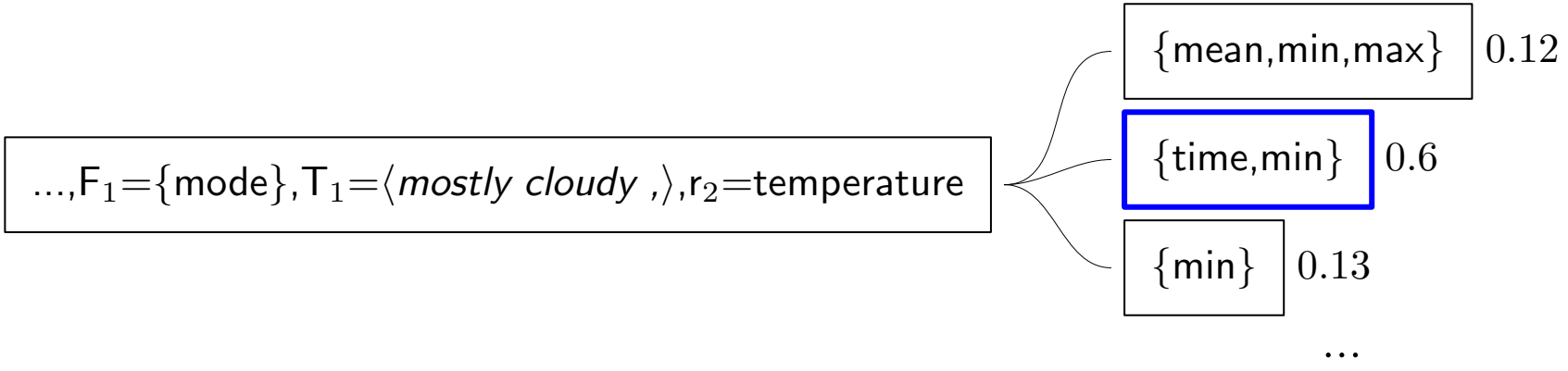
Features: Field Set

(R1) **Field Set**

$[\![F_2 = \{\text{time}, \text{min}\}]\!]$

(R2) **Field Set Values**

$[\![F_2 = \{\text{time}, \text{min}\} \text{ and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$



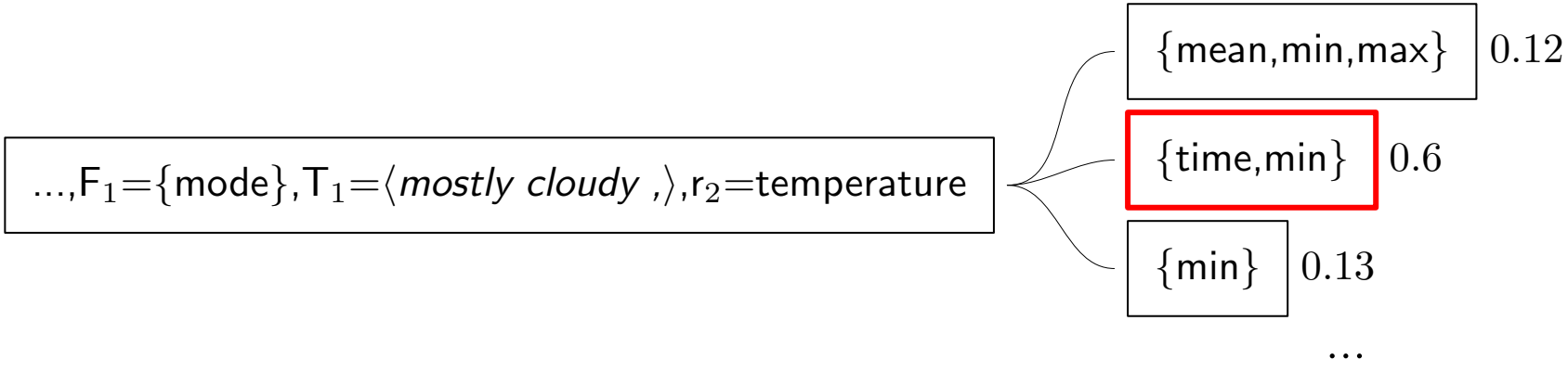
Features: Field Set

(R1) **Field Set**

$[\![F_2 = \{\text{time}, \text{min}\}]\!]$

(R2) **Field Set Values**

$[\![F_2 = \{\text{time}, \text{min}\} \text{ and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$

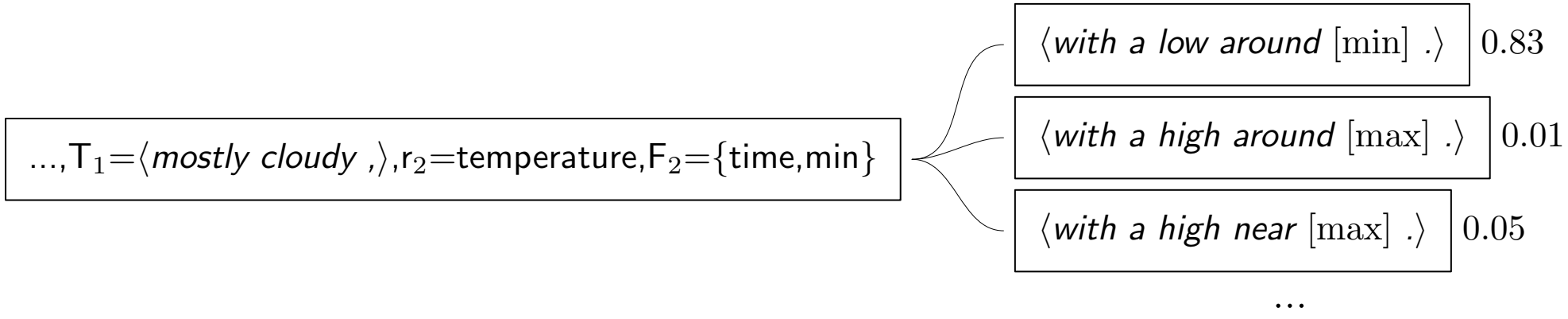


Features: Template

Record	$r_1 =$ skyCover$_1$	$r_2 =$ temperature$_1$
Field set	$F_1 = \{\text{mode}\}$	$F_2 = \{\text{time}, \text{min}\}$
Template	$W_1 = \langle \textit{mostly cloudy} \ , \rangle$	$W_2 = \langle \textit{with a low around} \ [\text{min}] \ . \rangle$

Features: Template

Record	$r_1 =$ skyCover$_1$	$r_2 =$ temperature$_1$
Field set	$F_1 = \{\text{mode}\}$	$F_2 = \{\text{time}, \text{min}\}$
Template	$W_1 = \langle \textit{mostly cloudy} , \rangle$	$W_2 = \langle \textit{with a low around } [\text{min}] \ . \rangle$



Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)

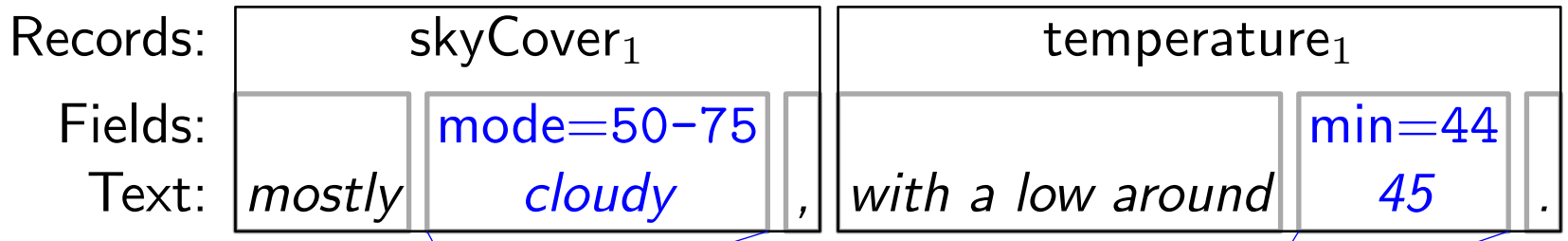
Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)

Records:	skyCover$_1$			temperature$_1$		
Fields:		mode=50-75			min=44	
Text:	*mostly*	*cloudy*	,	*with a low around*	*45*	.

Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)



$<$ *mostly* [mode] , $>$ $<$ *with a low around* [min] . $>$

Ideal: Extract alignments directly from the alignment

Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)

Records:	skyCover$_1$	temperature$_1$			
Fields:	mode=50-75		time=17-30	min=44	mean=49
Text:	*mostly cloudy ,*	*with a*	*low around*	*45*	*.*

Ideal: Extract alignments directly from the alignment

Challenge: Alignments are often noisy

Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)

Records:	skyCover$_1$	temperature$_1$			
Fields:	mode=50-75		time=17-30	min=44	mean=49
Text:	*mostly cloudy ,*	*with a*	*low around*	*45*	*.*

$\textsc{Coarse}$ $<$ [mode] $>$ $<$ *with a* [time] [min] [mean] $>$

$\textsc{Base}$ $<$ *mostly cloudy ,* $>$ $<$ *with a low around* [min] *.* $>$

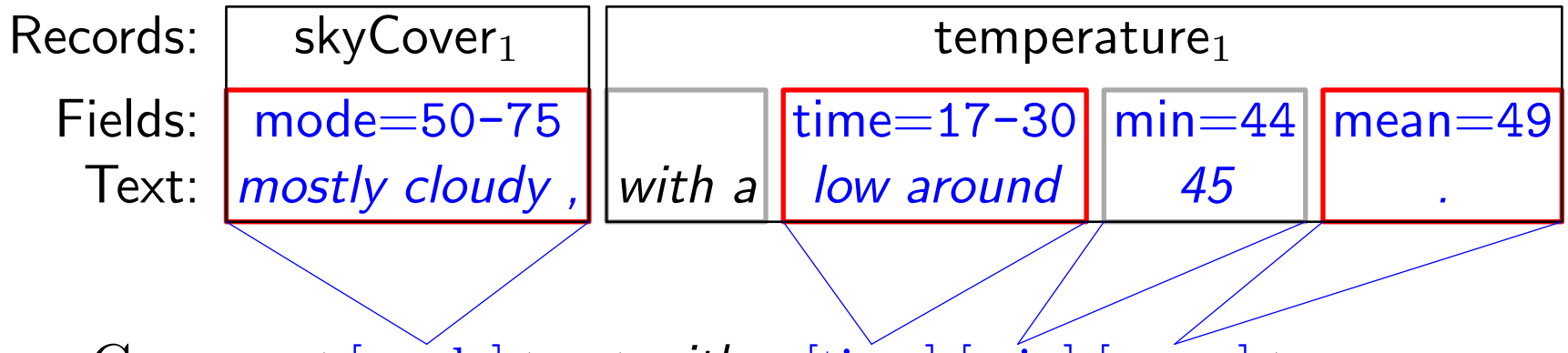
Ideal: Extract alignments directly from the alignment

Challenge: Alignments are often noisy

Approach: Extract templates of different granularities:

Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)



COARSE< [mode] > < *with a* [time] [min] [mean] >

BASE < *mostly cloudy ,* > < *with a low around* [min] *.* >

Ideal: Extract alignments directly from the alignment

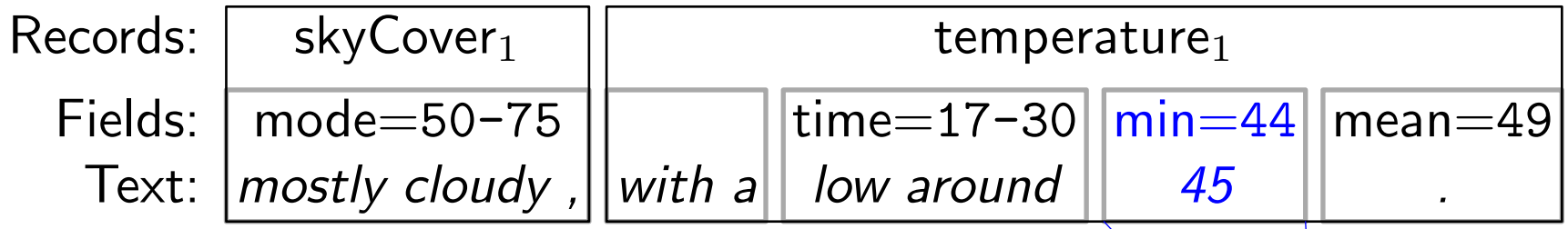
Challenge: Alignments are often noisy

Approach: Extract templates of different granularities:

COARSE: taken verbatim from the [noisy] alignment

Template Extraction

Templates extracted from induced alignments of Liang, et. al (2009)



COARSE< [mode] > < *with a* [time] [min] [mean] >

BASE < *mostly cloudy ,* > < *with a low around* [min] *.* >

Ideal: Extract alignments directly from the alignment

Challenge: Alignments are often noisy

Approach: Extract templates of different granularities:

COARSE: taken verbatim from the [noisy] alignment

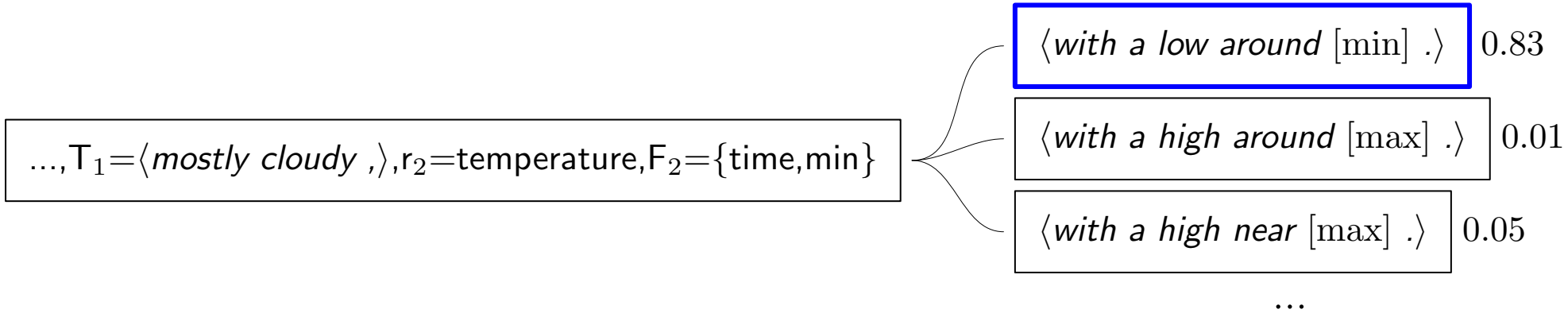
BASE: created by abstracting field matching regexp (e.g. *[0-9]+*)

Features: Template

Note: Features defined over both template granularities

(R1) **Template**

$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle]\!]$



Features: Template

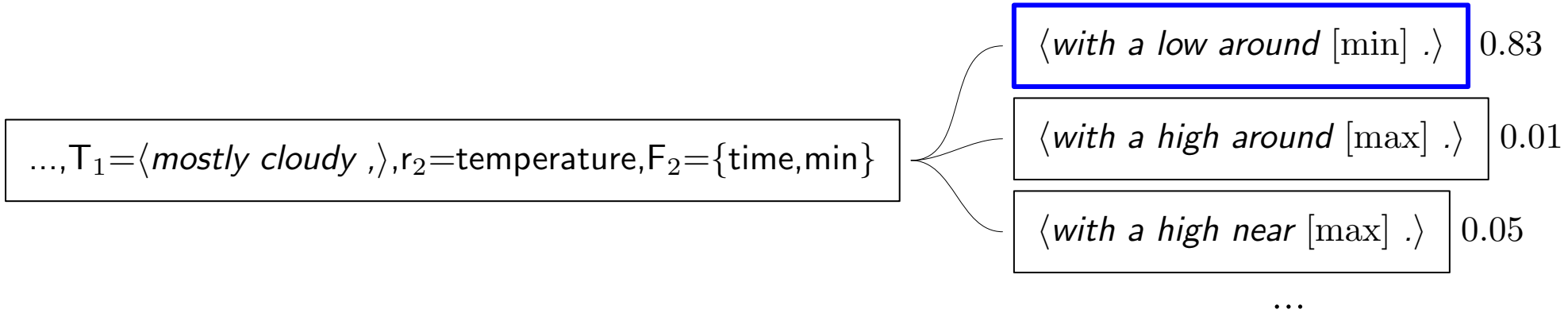
Note: Features defined over both template granularities

(R1) **Template**

$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle]\!]$

(R2) **Field Values**

$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle \text{ and } r_2.v[\text{time}] = \texttt{5pm-6am}]\!]$



Features: Template

Note: Features defined over both template granularities

(R1) **Template**

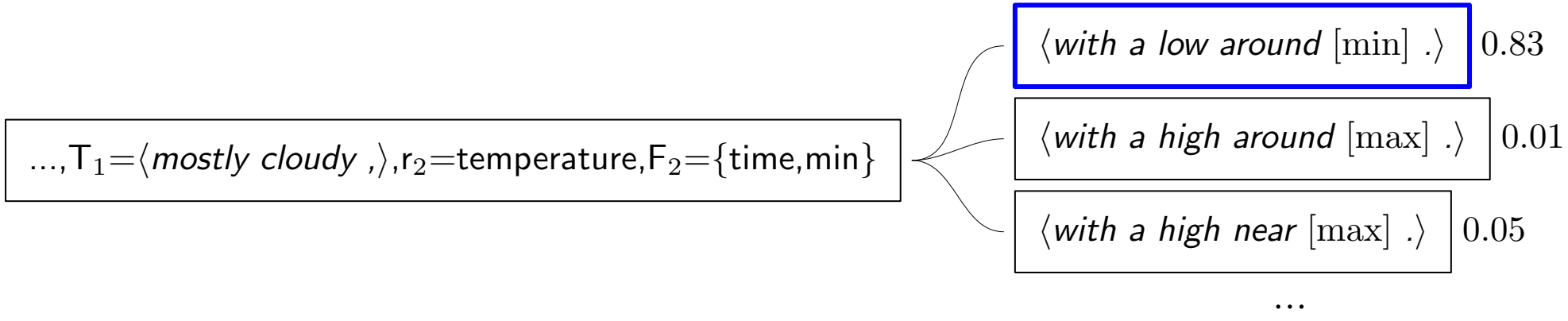
$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle]\!]$

(R2) **Field Values**

$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle \text{ and } r_2.v[\texttt{time}] = \texttt{5pm-6am}]\!]$

(R3) **First word in template under LM**

$\log p_{\text{LM}}(\textit{with} \mid \textit{cloudy ,})$



Features: Template

Note: Features defined over both template granularities

(R1) **Template**

$[\![\textsc{Base}(T_2) = \langle \textit{with a low around } [\min]\rangle]\!]$

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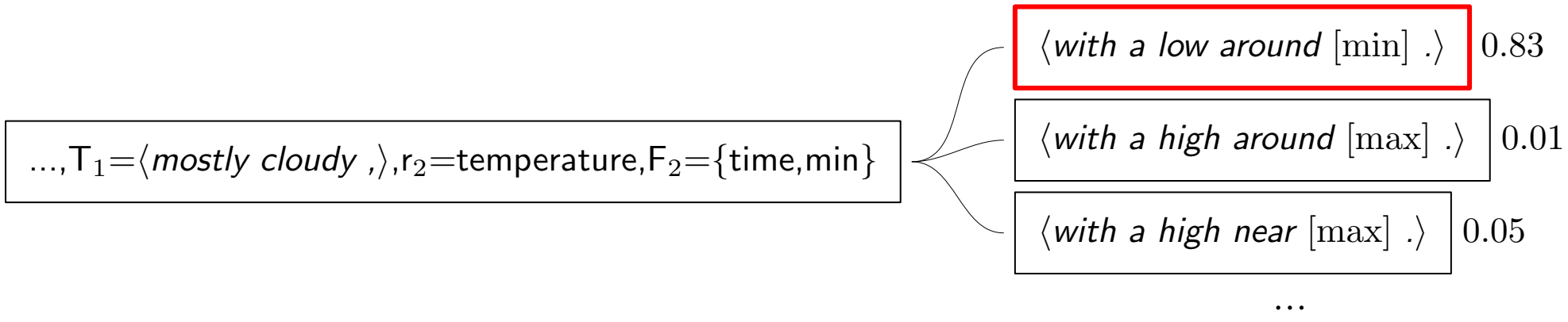
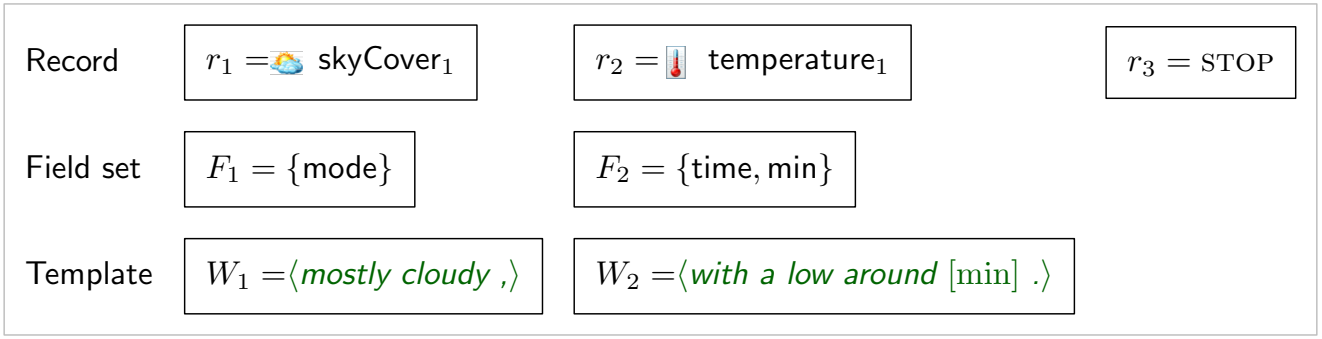


Training: Log-Linear Model

Generation treated as a sequence of local decisions

Similar in spirit to Ratnaparkhi (1996)



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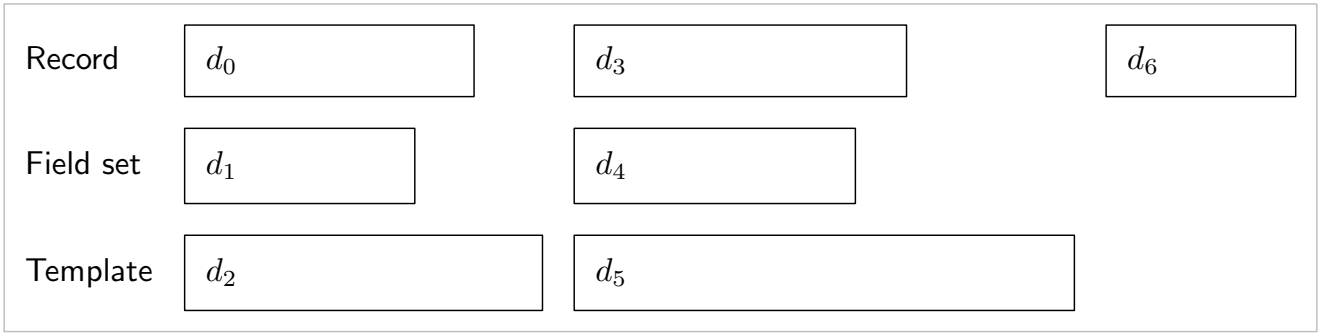

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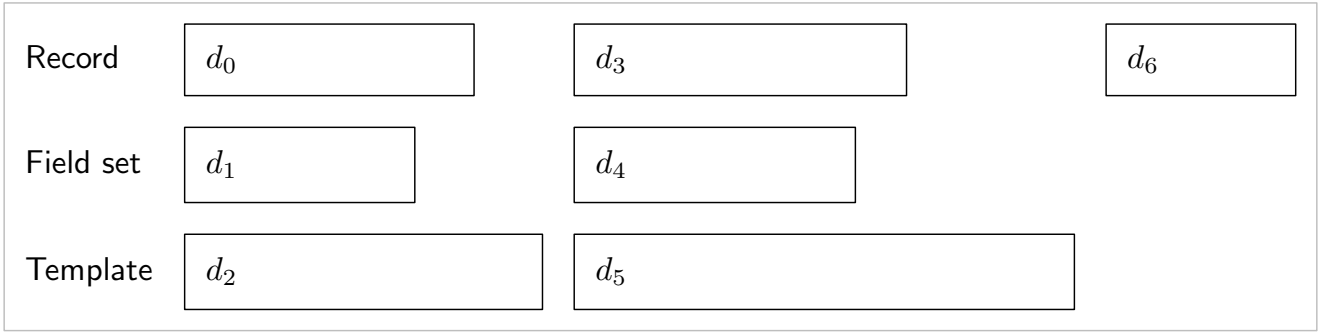

Log-linear model: Each decision trained using a log-linear model

$$p(d_j \mid d_{j-1}, d_{j-2}, \ldots, \mathbf{s}; \theta) \propto \exp\{\phi_j(d_j, d_{j-1}, d_{j-2}, \ldots, \mathbf{s})^\top \theta\}$$

Training: Log-Linear Model

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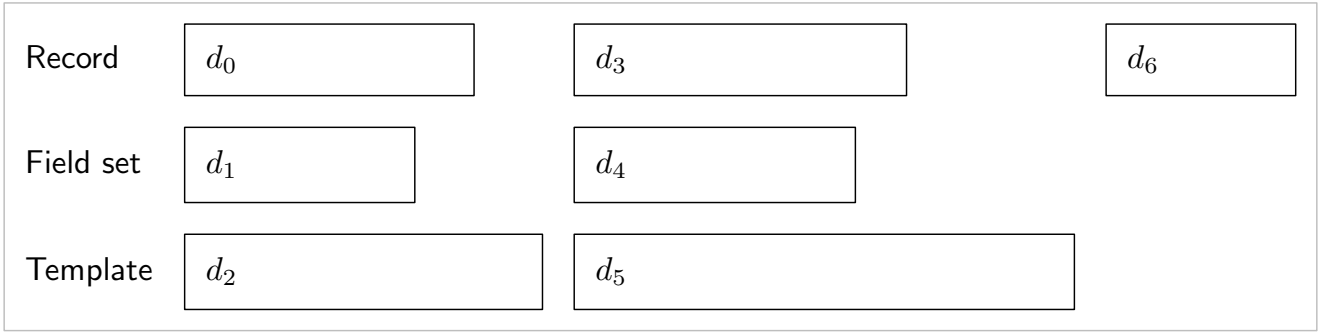

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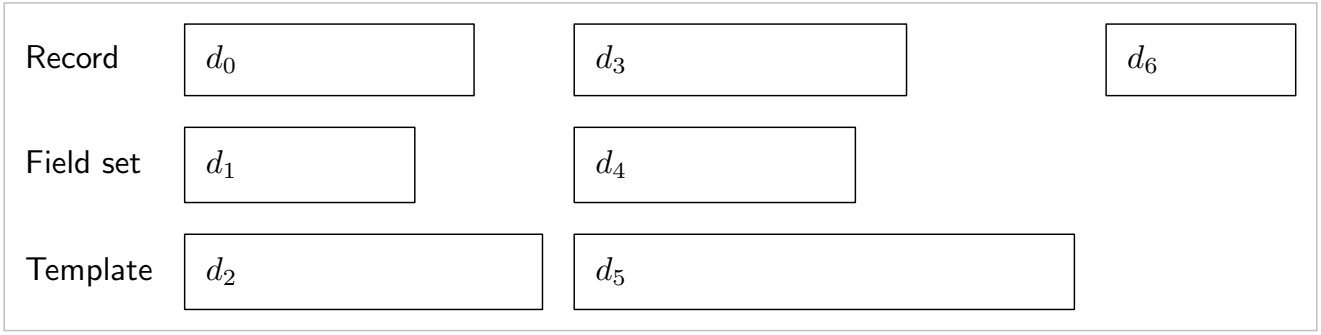
Log-likelihood maximized using L-BFGS

Training: Log-Linear Model

Generation treated as a sequence of local decisions

Similar in spirit to Ratnaparkhi (1996)



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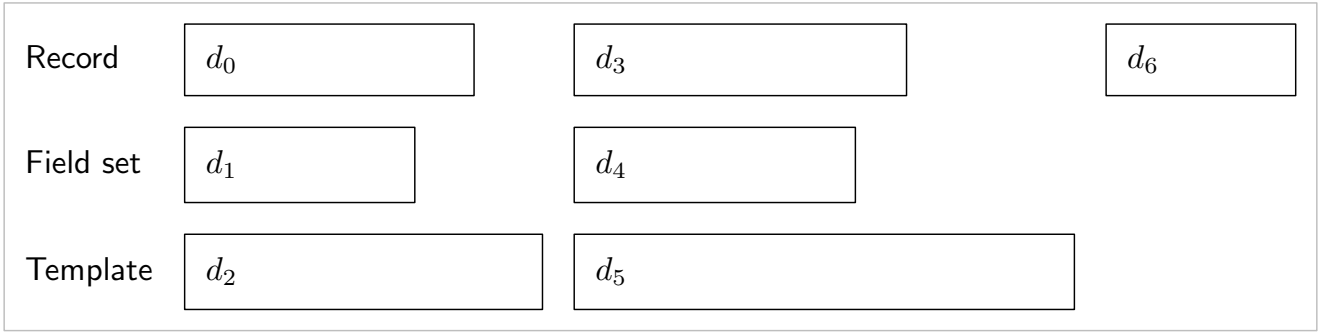
Log-likelihood maximized using L-BFGS

No dynamic program since decisions have long-range dependencies

Training: Log-Linear Model

Generation treated as a sequence of local decisions

Similar in spirit to Ratnaparkhi (1996)



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Log-likelihood maximized using L-BFGS

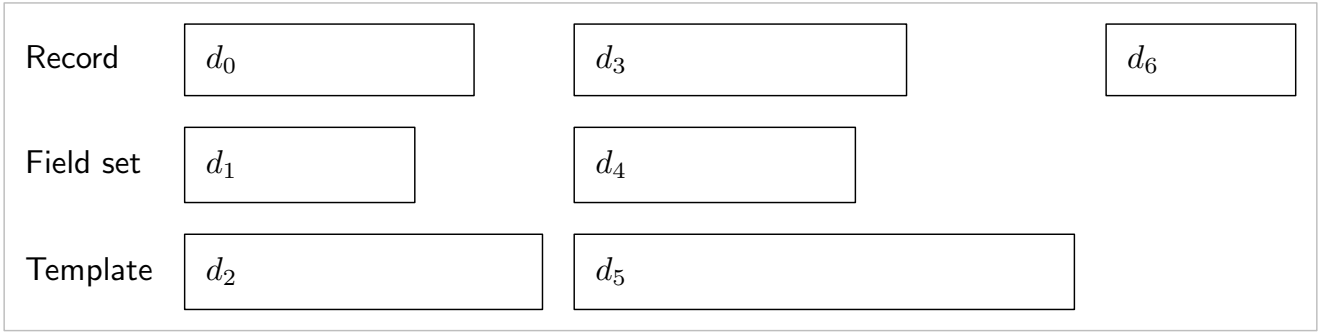
No dynamic program since decisions have long-range dependencies

Training problem is fully supervised

Training: Log-Linear Model

Generation treated as a sequence of local decisions

Similar in spirit to Ratnaparkhi (1996)



Log-linear model: Each decision trained using a log-linear model

$$p(d_j \mid d_{j-1}, d_{j-2}, \ldots, \mathbf{s}; \theta) \propto \exp\{\phi_j(d_j, d_{j-1}, d_{j-2}, \ldots, \mathbf{s})^\top \theta\}$$

Log-likelihood maximized using L-BFGS

No dynamic program since decisions have long-range dependencies

Training problem is fully supervised

Generating a new text is done using greedy search

Evaluation: Domains

ROBOCUP: RoboCup sportscasting data

Evaluation: Domains

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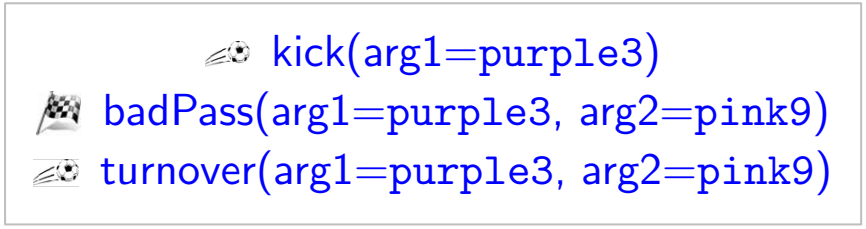
Content Selection: Chose one record

s:



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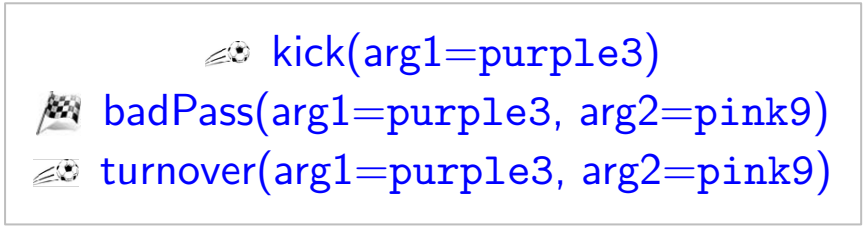

Surface Realization:

w: *Purple3 made a bad pass that was picked off by pink9.*

Evaluation: Domains

ROBOCUP: RoboCup sportscasting data

SUMTIME: Weather forecasts for oil rigs

Evaluation: Domains

ROBOCUP: RoboCup sportscasting data

SUMTIME: Weather forecasts for oil rigs

Content Selection: No content selection

s:

wind10m(time=6am,dir=SW,min=16,max=20,gust min=0,gust max=0)
wind10m(time=9pm,dir=SSW,min=28,max=32,gust min=40,gust max=0)
wind10m(time=12am,dir=-,min=24,max=28,gust min=36,gust max=0)

Evaluation: Domains

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Surface Realization:

w: *sw 16 - 20 backing ssw 28 - 32 gusts 40 by mid evening easing 24 - 28 gusts 36 late evening*

Evaluation: Domains

ROBOCUP: RoboCup sportscasting data

SUMTIME: Weather forecasts for oil rigs

WEATHERGOV: Weather forecasts from `weather.gov`

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Content Selection: Complex; chose a few out of around 35 records

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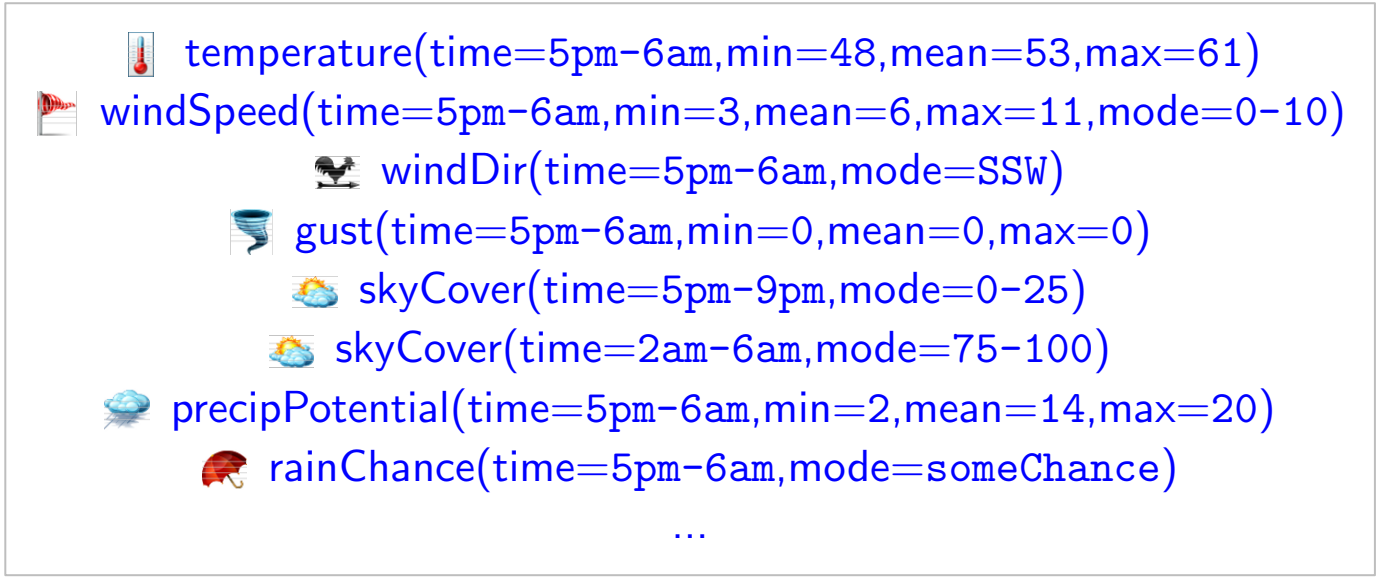

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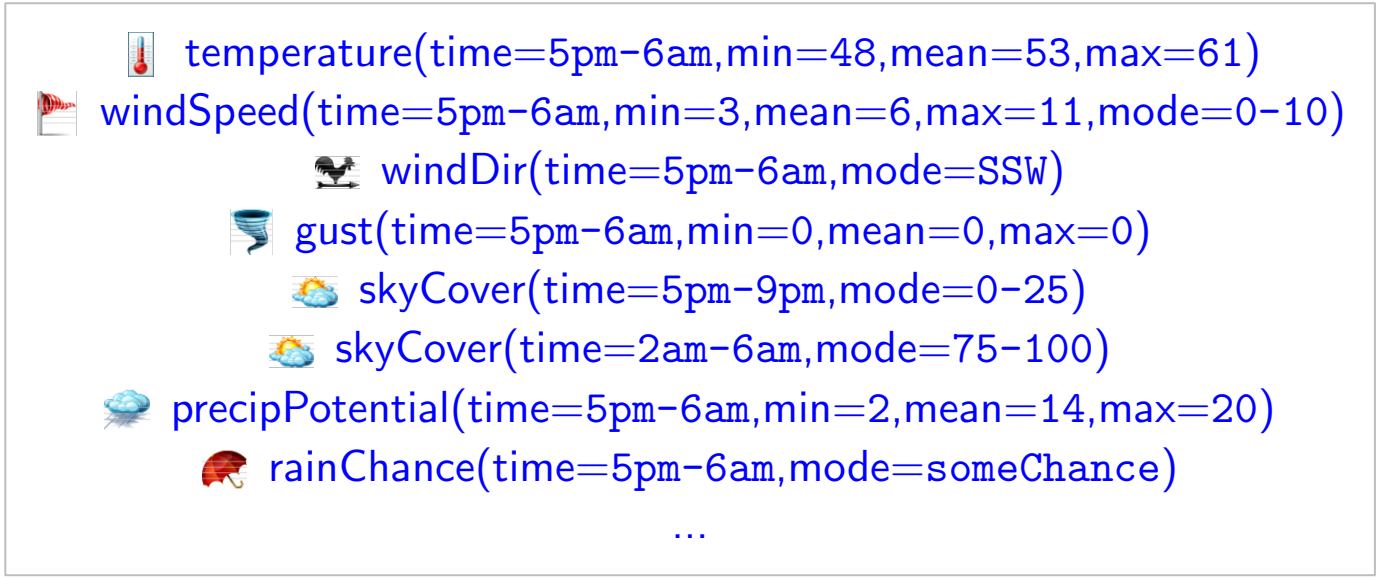

Surface Realization:

w: *A 20 percent chance of showers after midnight. Increasing clouds, with a low around 48. southwest wind between 5 and 10 mph.*

Evaluation: Metrics

Automatic metrics:

Content selection: F_1 score (record precision and recall)

Surface realization: BLEU score (system output versus human annotated)

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Rank *english fluency* and *semantic correctness* on 1-5 scale

Score	**English Fluency**	**Semantic Correctness**
5	Flawless	Perfect
4	Good	Near Perfect
3	Non-native	Minor Errors
2	Disfluent	Major Errors
1	Gibberish	Completely Wrong

Evaluation: Metrics

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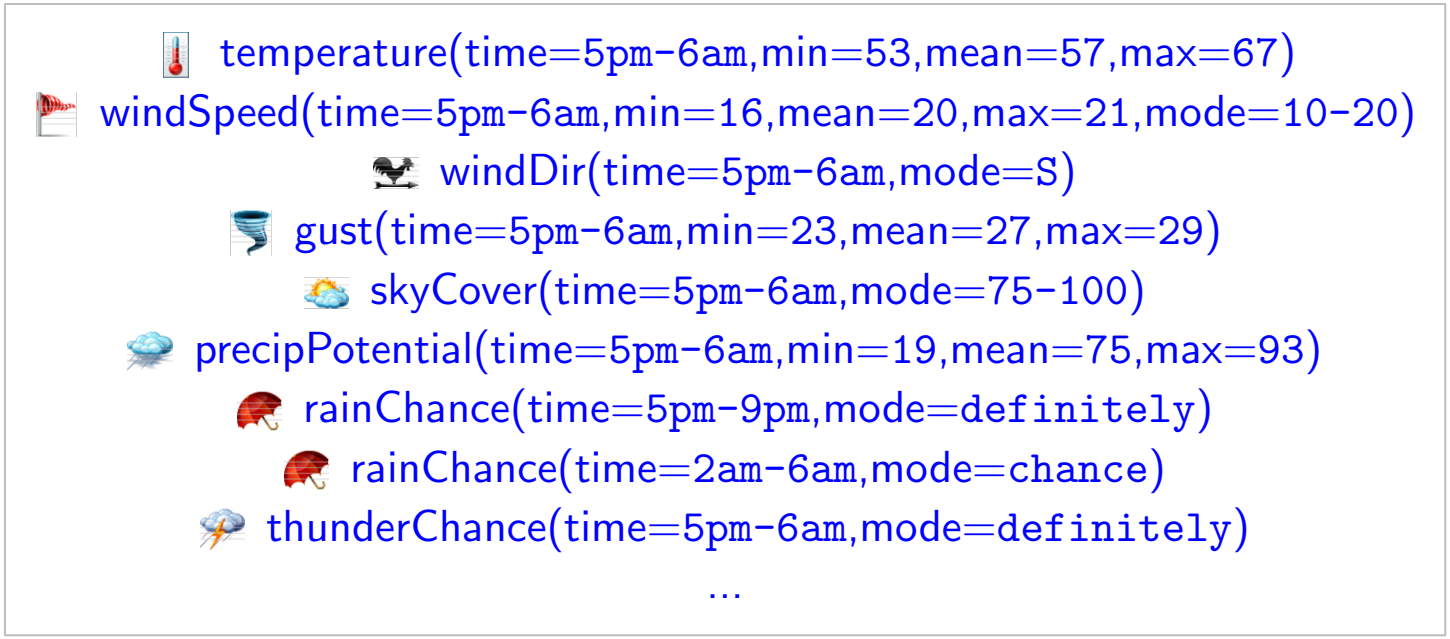

w: *Rain. Some of the storms could be severe and 53. South wind between 16 and 21 mph chance of precipitation is 95%.*

English Fluency: 3.45 Semantic Correctness: 4.00

Evaluation: Systems

Baseline

Subset of features

R1	List of last record type
R5	Stop under language model
F1	Field set
T1	Template
T3	First word of template under LM

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Evaluation: Systems

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OurSystem: All features

OurSystem-Custom: 8 domain-dependent features for SumTime

Evaluation: Systems

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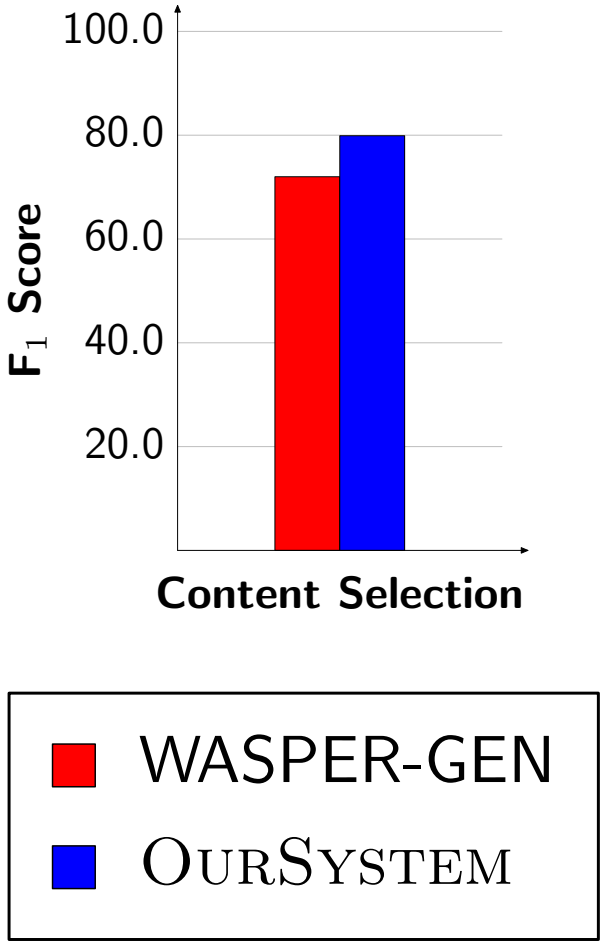
Evaluation: ROBOCUP Results



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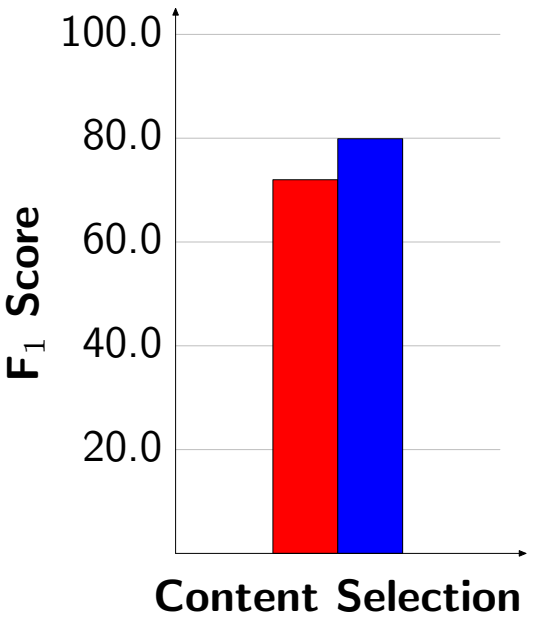

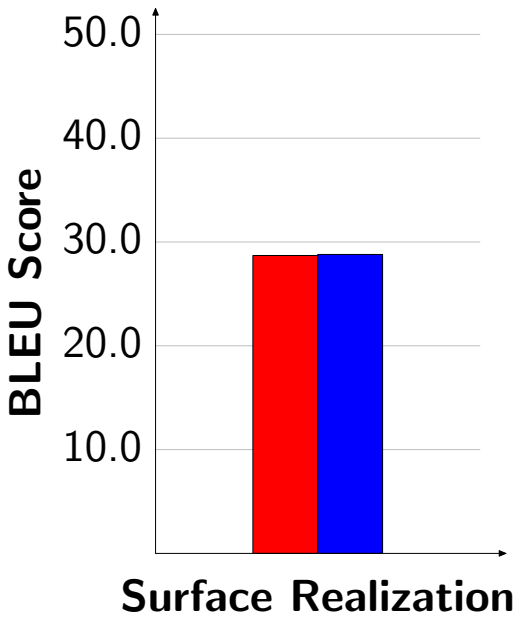

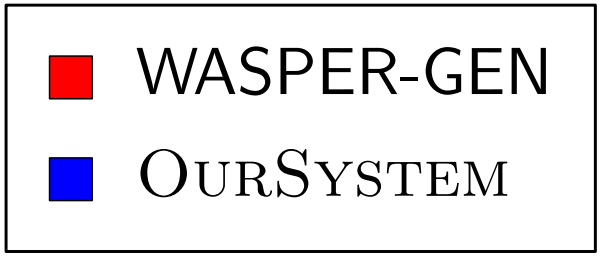

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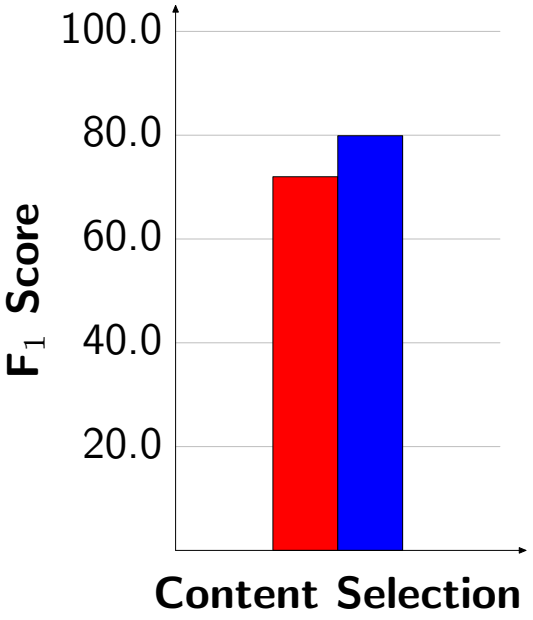
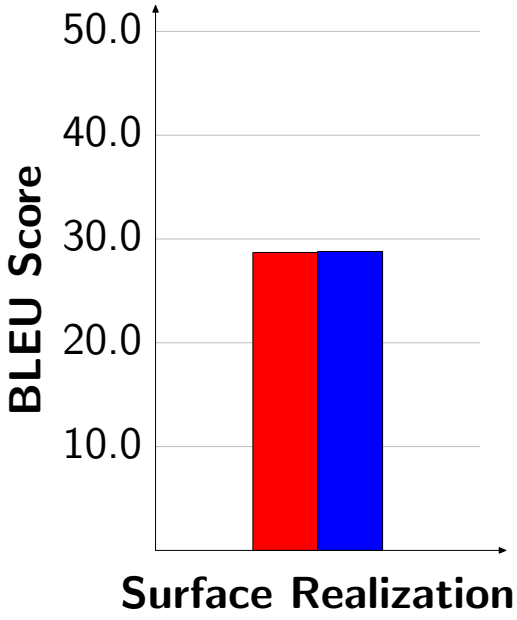
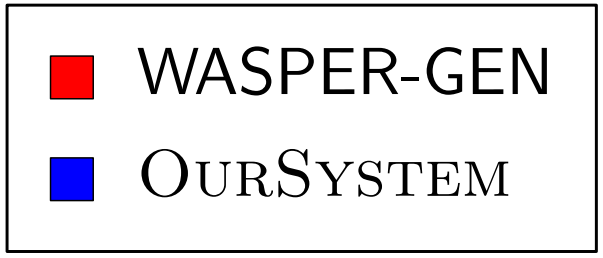
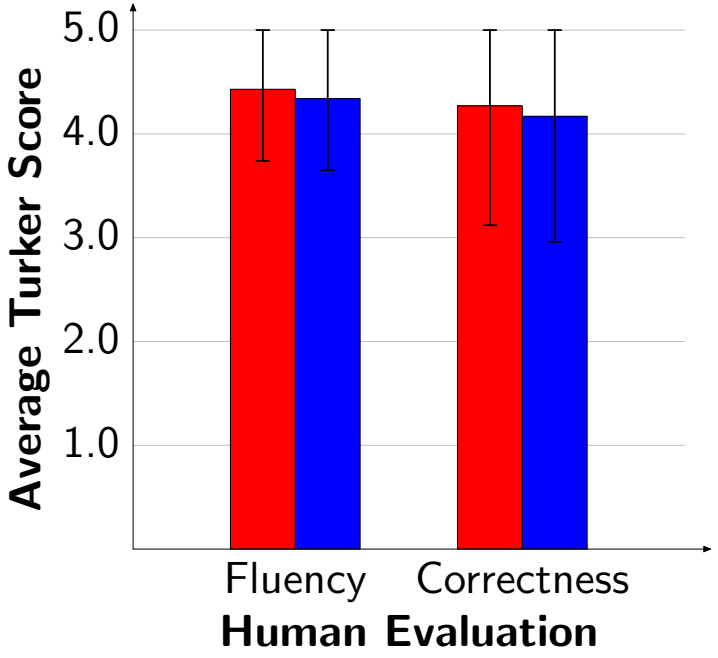
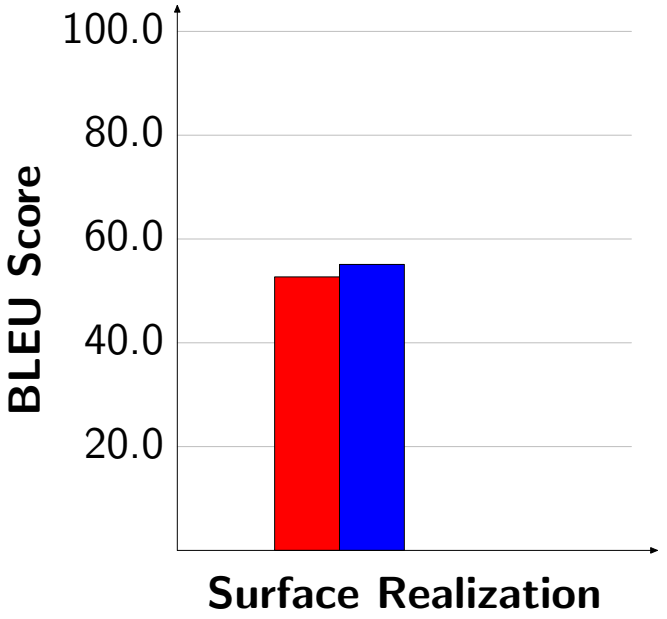








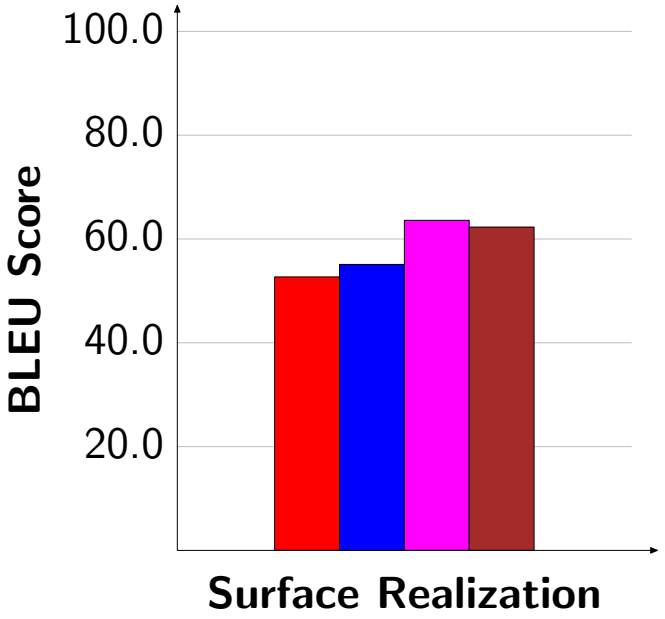
Evaluation: SumTime Results



SumTime-Hybrid

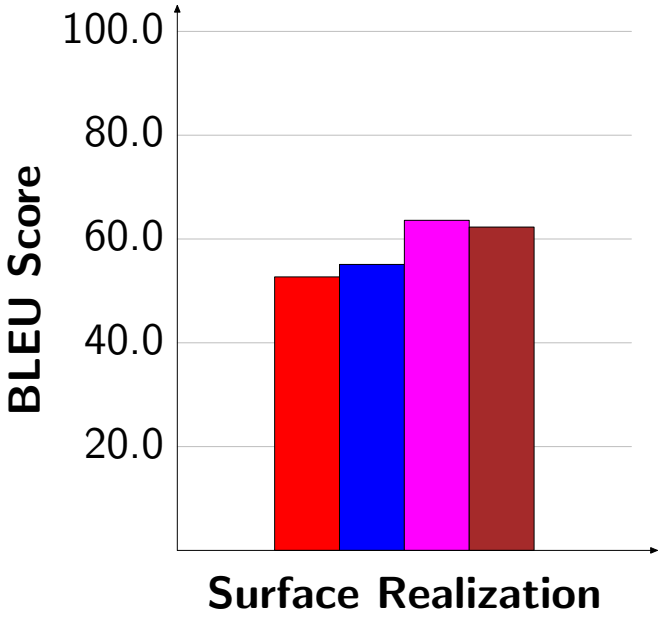
OurSystem

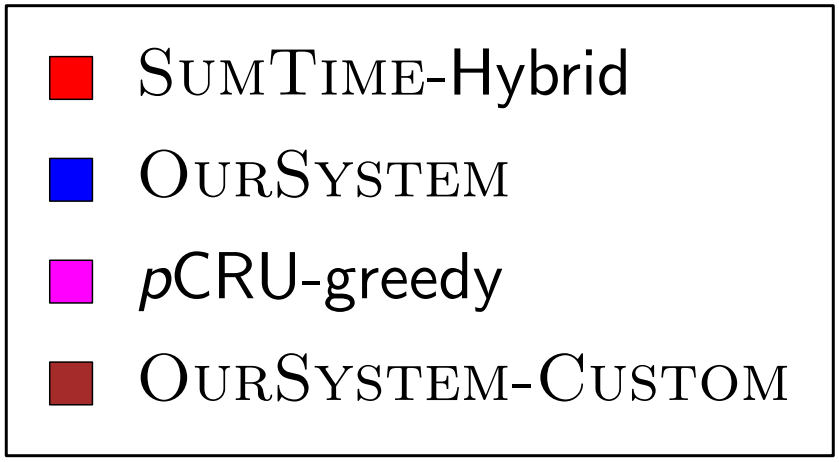
Evaluation: SumTime Results

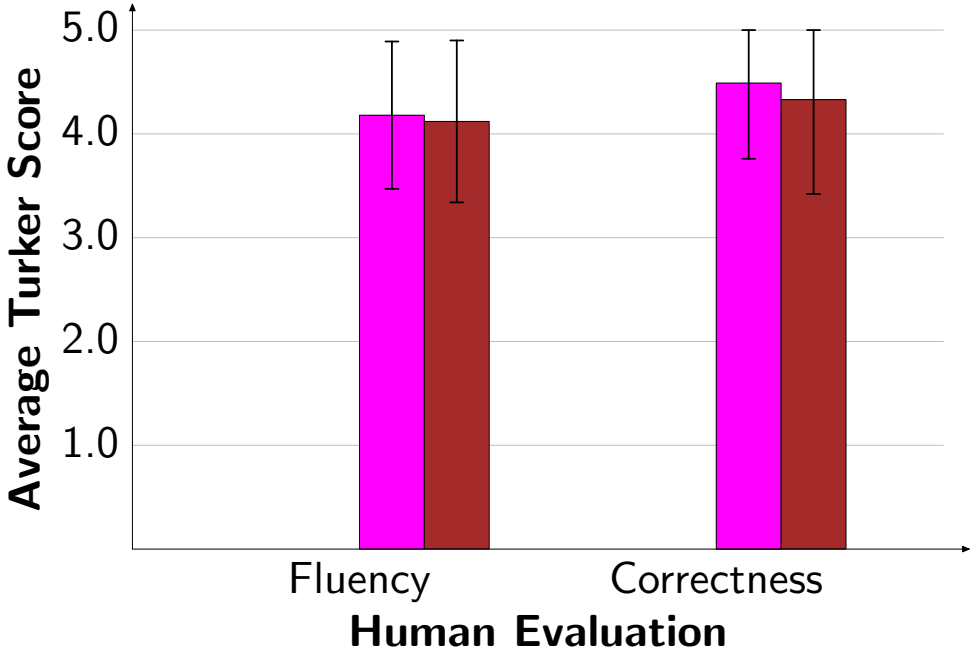


- SumTime-Hybrid
- OurSystem
- *p*CRU-greedy
- OurSystem-Custom

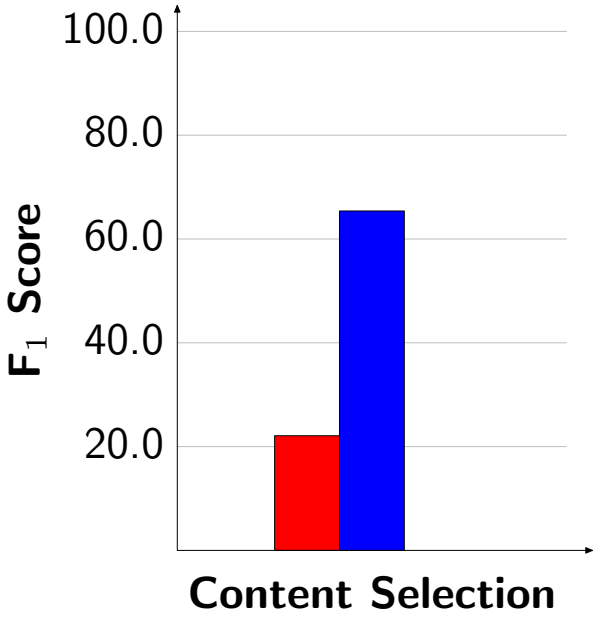
Evaluation: SumTime Results

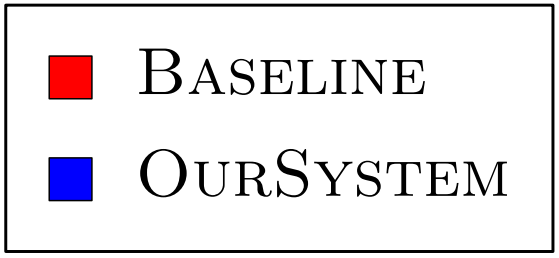






Evaluation: WeatherGov Results





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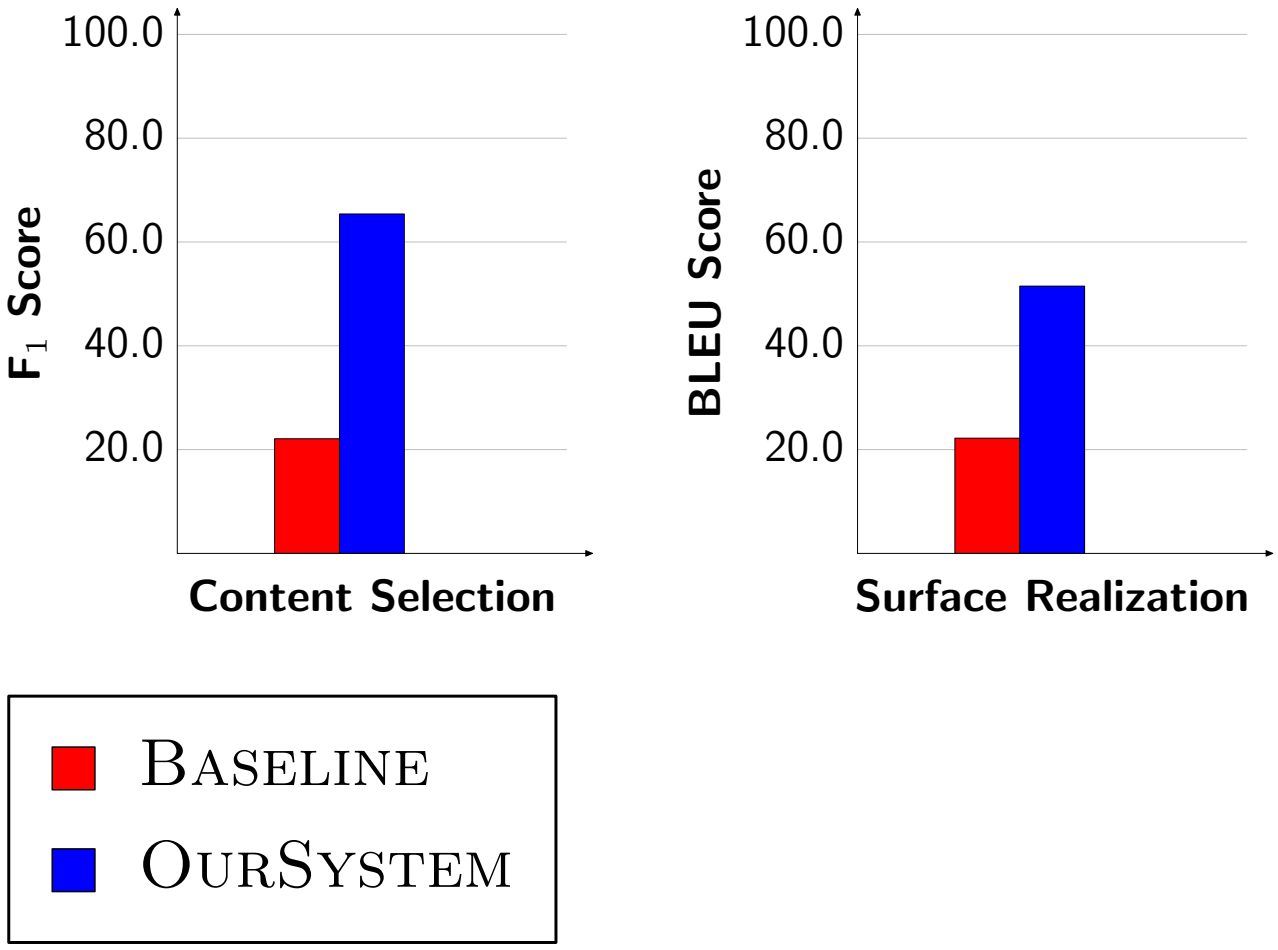

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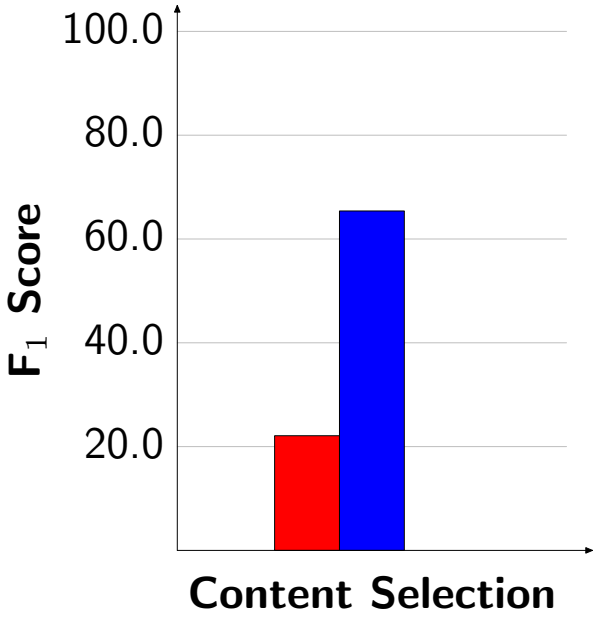

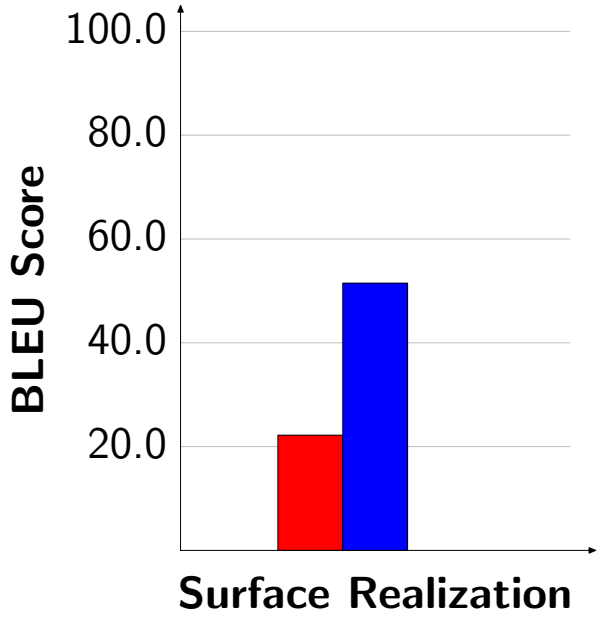

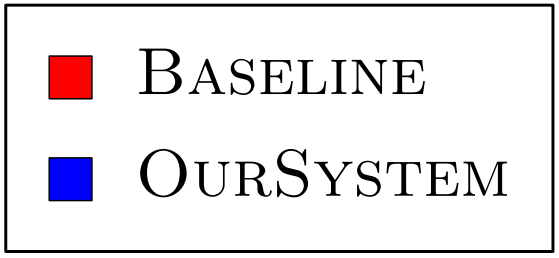

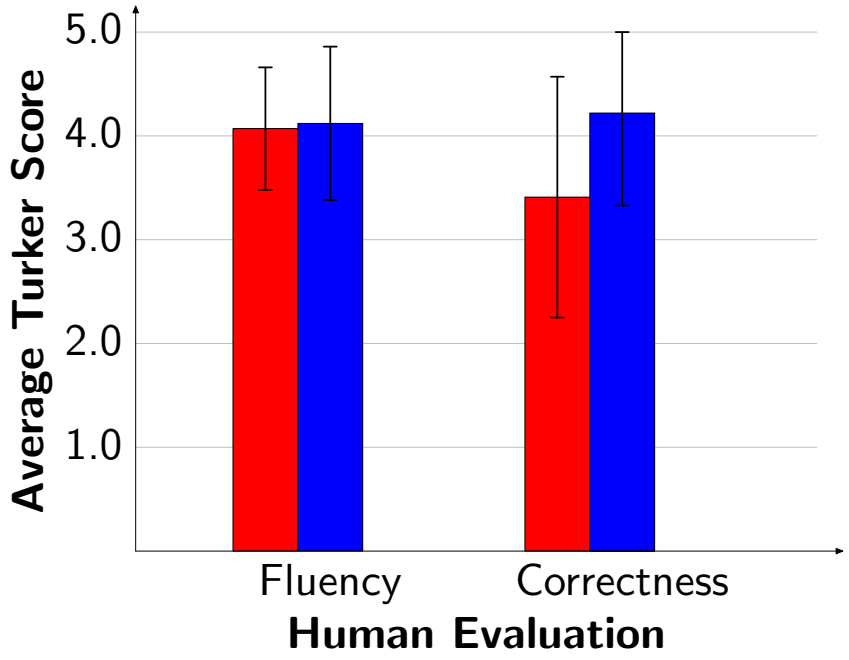

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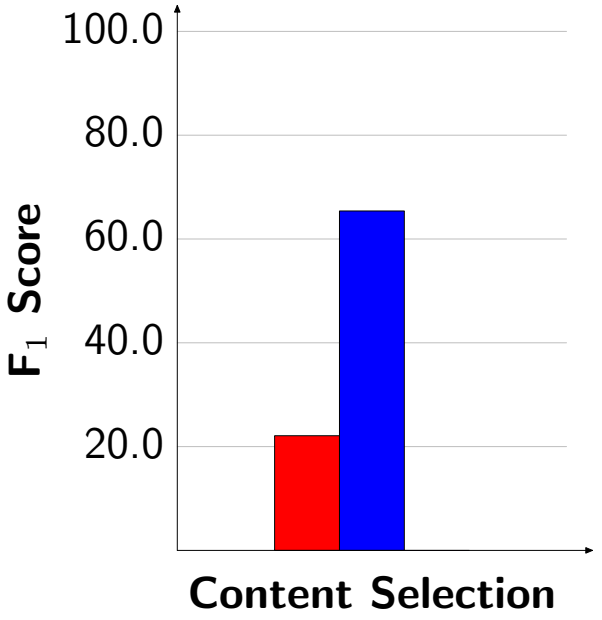

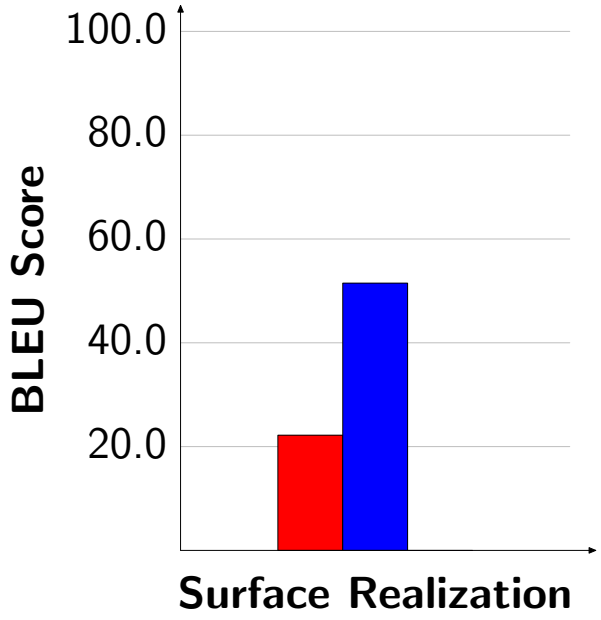

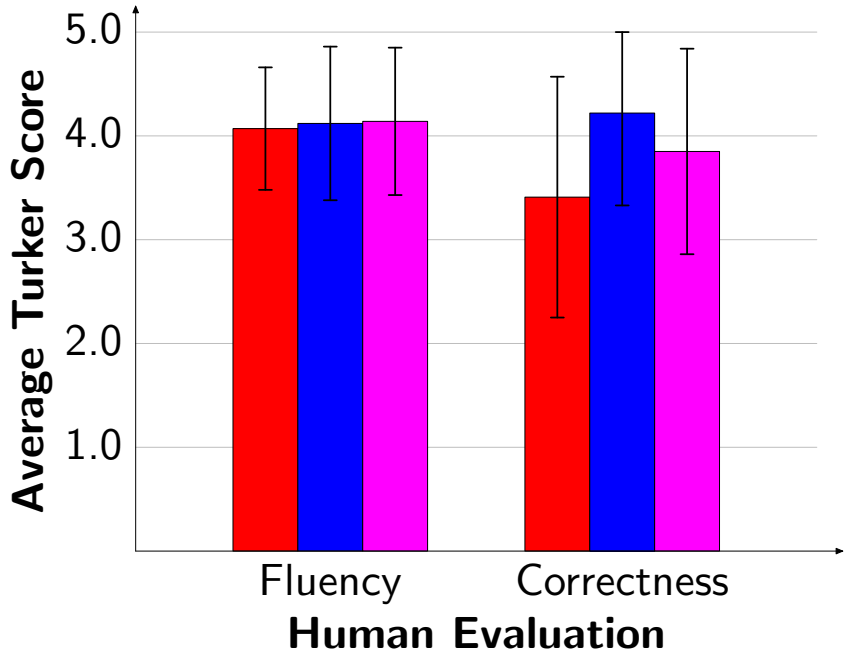

Summary

Complete pipeline

Same framework for content selection and surface realization

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Domain independent Approach

Minimal tweaking between domains

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Comparable results

Results comparable to state of the art

Thank You!