TweeTime:

A Minimally Supervised Method for Recognizing and Normalizing Time Expressions in Twitter

Jeniya Tabassum
Alan Ritter
Wei Xu

THE OHIO STATE UNIVERSITY

TweeTime:

A Minimally Supervised Method for Recognizing and Normalizing Time Expressions in Twitter

Jeniya Tabassum

Alan Ritter

Wei Xu

THE OHIO STATE UNIVERSITY

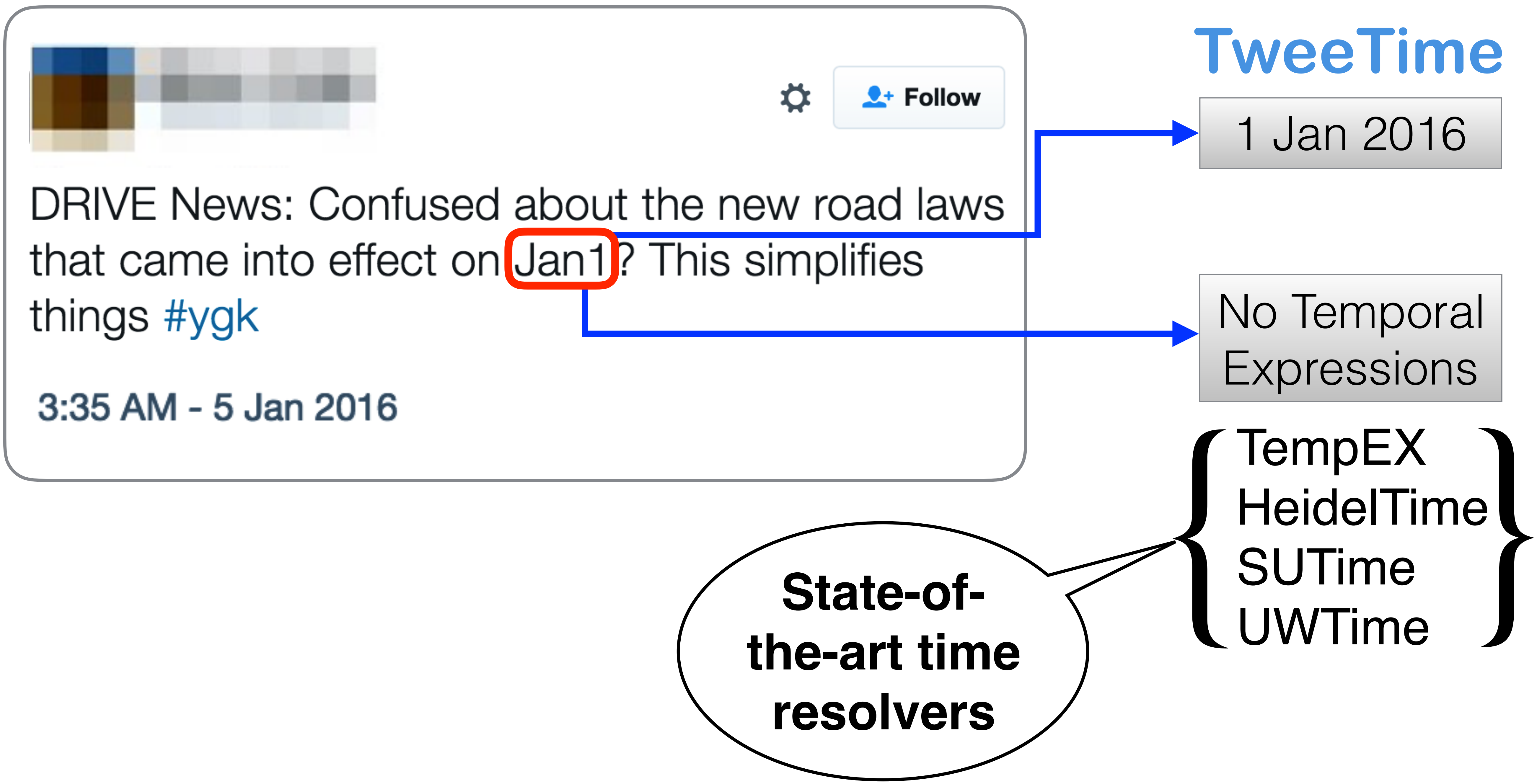
Time Resolution from Tweets

Follow

DRIVE News: Confused about the new road laws that came into effect on Jan1? This simplifies things #ygk

3:35 AM - 5 Jan 2016

Time Resolution from Tweets



Challenge: Diversity

Tomorrow

2m 2ma 2mar 2mara 2maro 2marrow 2mor 2mora 2moro 2morow 2morr 2morro 2morrow 2moz 2mr 2mro 2mrrw 2mrw 2mw tmmrw tmo tmoro tmorrow tmoz tmr tmro tmrow tmrrow tmrrw tmrw tmrww tmw tomaro tomarow tomarro tomarrow tomm tommarow tommarrow tommoro tommorow tommorrow tommorw tommrow tomo tomolo tomoro tomorow tomorro tomorrw tomoz tomrw tomz

Rule-Based

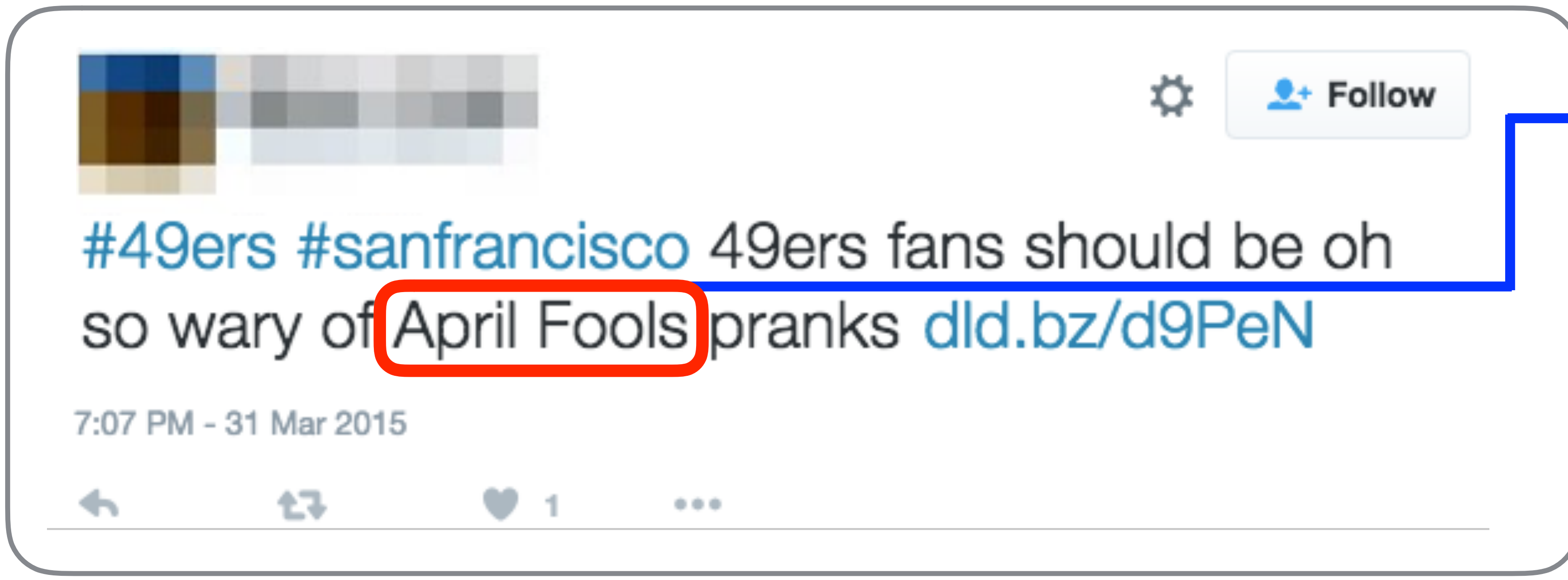
- HeidelTime [Strötgen & Gertz, 2013]
- SUTime [Chang & Manning, 2012]
- TempEX [Mani & Wilson, 2000]

Previous **rule based systems** do not handle noisy text.

Previous **supervised systems** perform poorly due to domain mismatch.

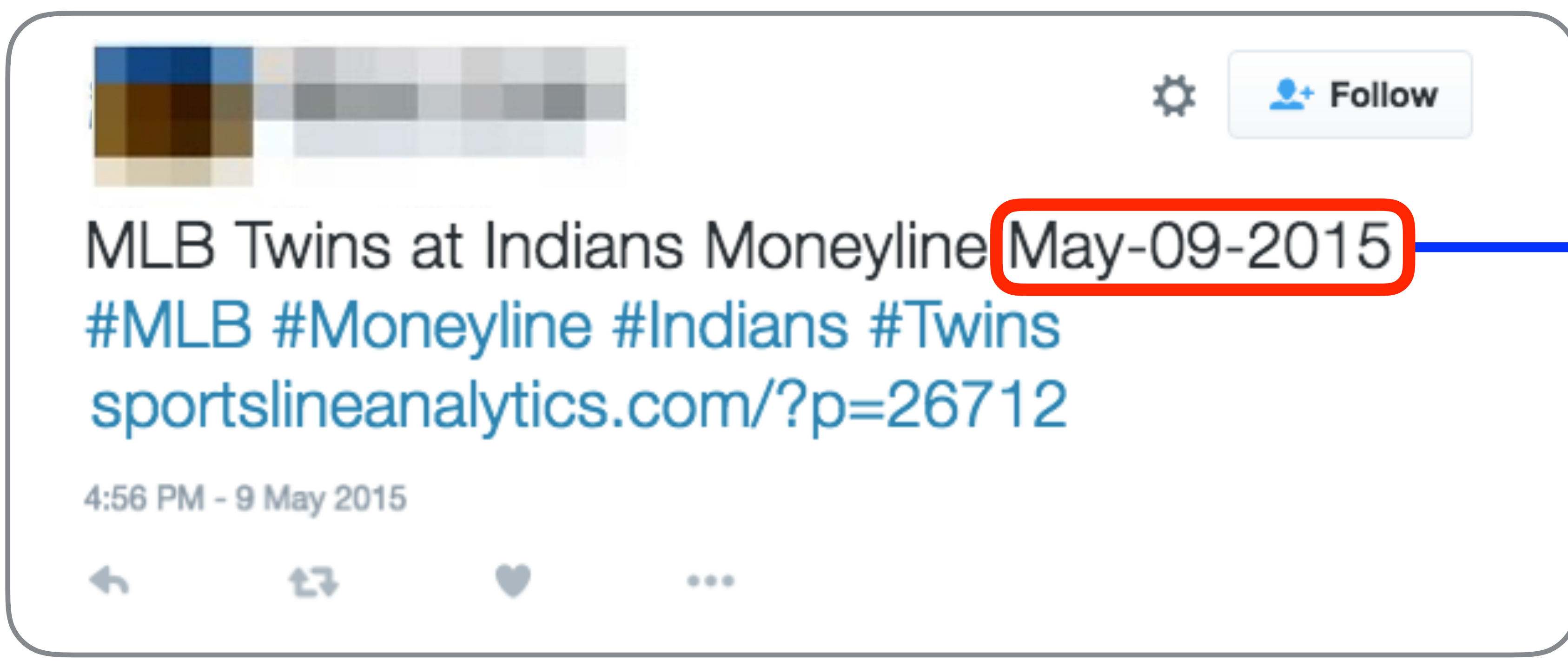
Supervised	UWTime [Lee et al., 2014]
Requires Human Labels	ParsingTime [Angeli et al., 2012/2013]

Social Media is Hard



No Temporal Expressions

Missing Rule



No Temporal Expressions

Tokenization

Social Media is Hard

Date Resolution in Social Media

Event Extraction

Disease Outbreaks

[Kanhabua et al., 2012]

Cyber Security

Victim	Date
spamhaus	2013/03/18
soca	2011/06/20
etrade	2012/01/05
interpol	2012/02/29
ustream	2012/05/09

[Ritter et al., 2015]

[Chang et al., 2016]

Date Resolution in Social Media

Event Extraction

Disease Outbreaks

[Kanhabua et al., 2012]

Cyber Security

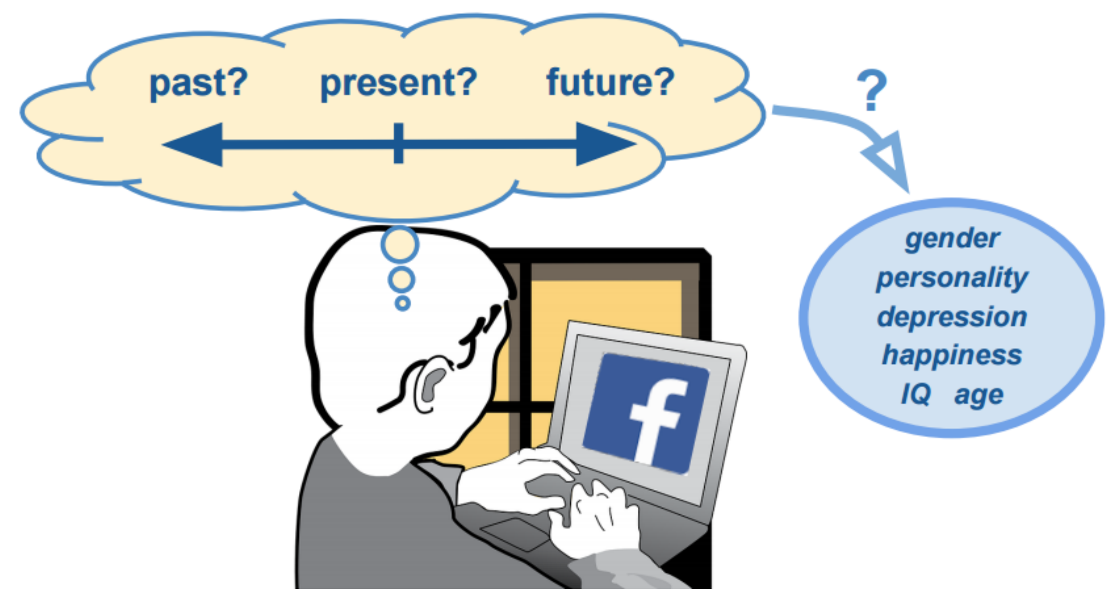
Victim	Date
spamhaus	2013/03/18
soca	2011/06/20
etrade	2012/01/05
interpol	2012/02/29
ustream	2012/05/09

[Ritter et al., 2015]

[Chang et al., 2016]

Social Science

Temporal Orientation



[Schwartz et al., 2015]

No existing temporal resolver for social media

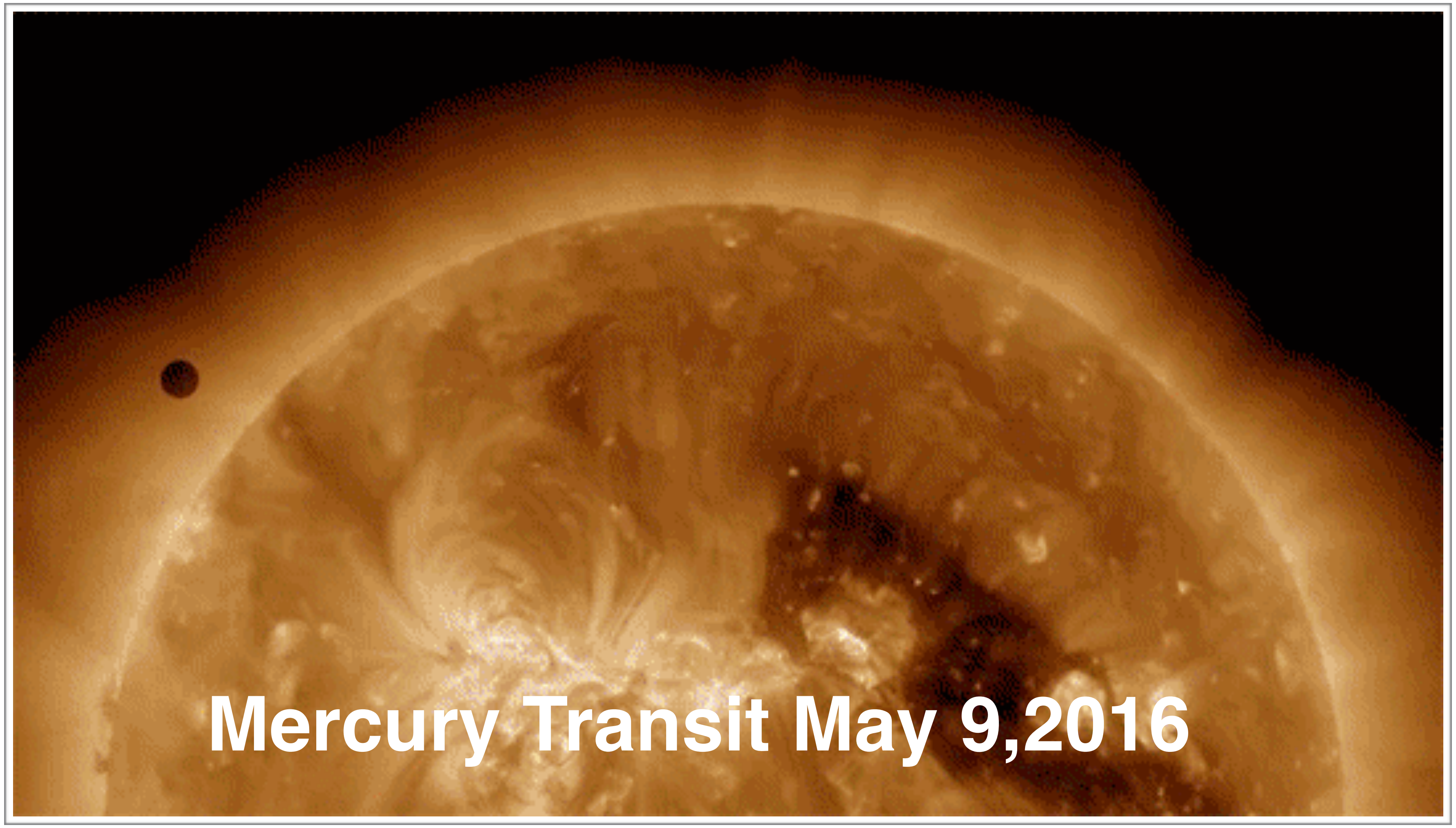
TweeTime

can handle noisy Twitter Text

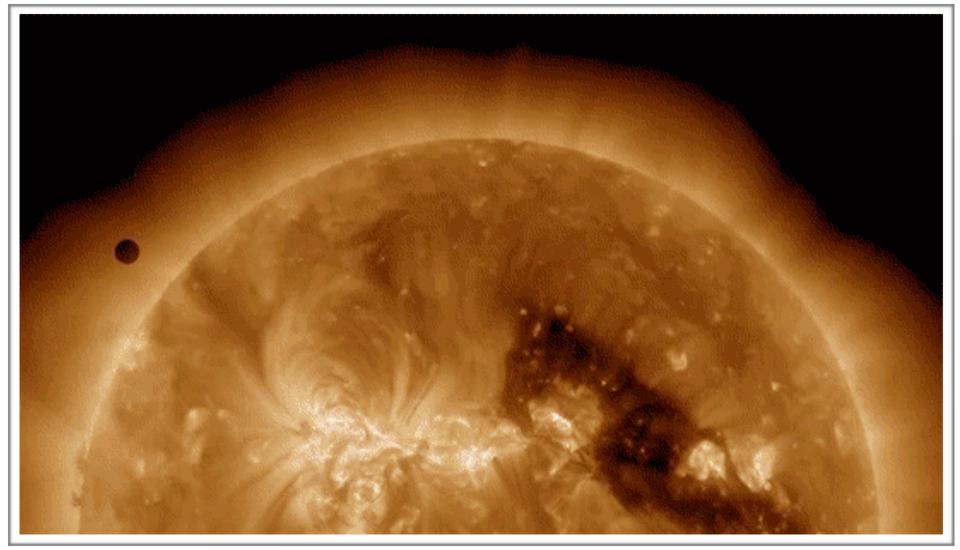
Distant Supervision

(no human labels needed!)

Distant Supervision Assumption



Distant Supervision Assumption



8 May | 9 May | 10 May

8 May

Mercury will make a rare transit across the sun tmrw morning (Mon). If you're able to catch it, don't miss out -- and use a solar filter!

Mercury Transit 2morrow starting at 6:00 AM Mercury will pass in front of Sun @14News @14FirstAlert #mercurytransit

7:30 PM - 8 May 2016

⋮

9 May

Paul from Creators Hand Photography captured a shot of today's Mercury transit, along with a larger sunspot that... fb.me/7jaxf4rfC

i didn't get to see mercury transit today because of this horrible weather 😤

3:54 PM - 9 May 2016

⋮

10 May

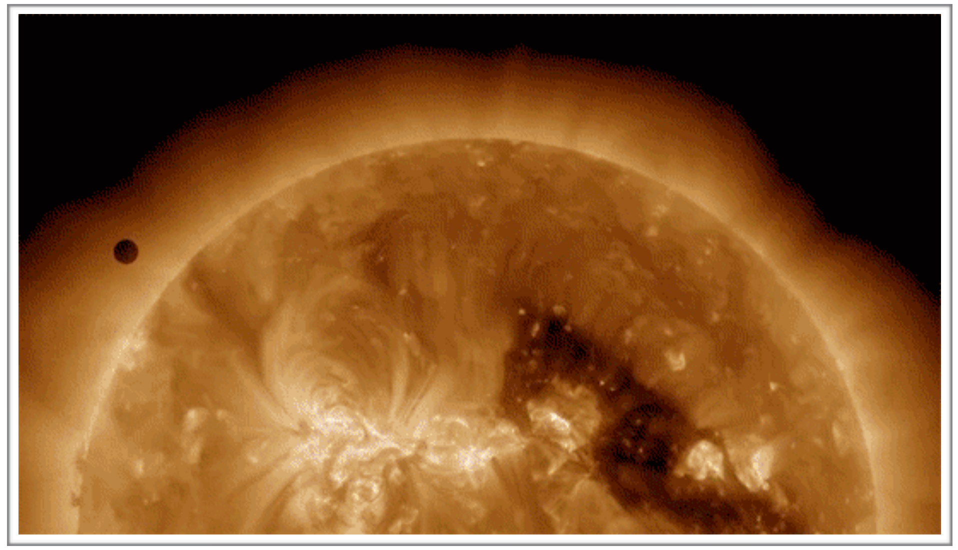
I watched this event yesterday by a small telescope with all the precautions, but this transit of Mercury is great!

Mercury passes between Earth and the sun only about 13 times a century.
It was yesterday! May 9th #lagalaxiaensmira

3:17 PM - 9 May 2016

⋮

Distant Supervision Assumption



8 May

Mercury will make a rare transit across the sun tmrw morning (Mon). If you're able to catch it, don't miss out -- and use a solar filter!

10:28 PM - 8 May 2016

Mercury Transit 2morrow starting at 6:00 AM Mercury will pass in front of Sun @14News @14FirstAlert #mercurytransit

7:30 PM - 8 May 2016

9 May

Paul from Creators Hand Photography captured a shot of today's Mercury transit, along with a larger sunspot that... fb.me/7jaxf4rfC

i didn't get to see mercury transit today because of this horrible weather 😤

3:54 PM - 9 May 2016

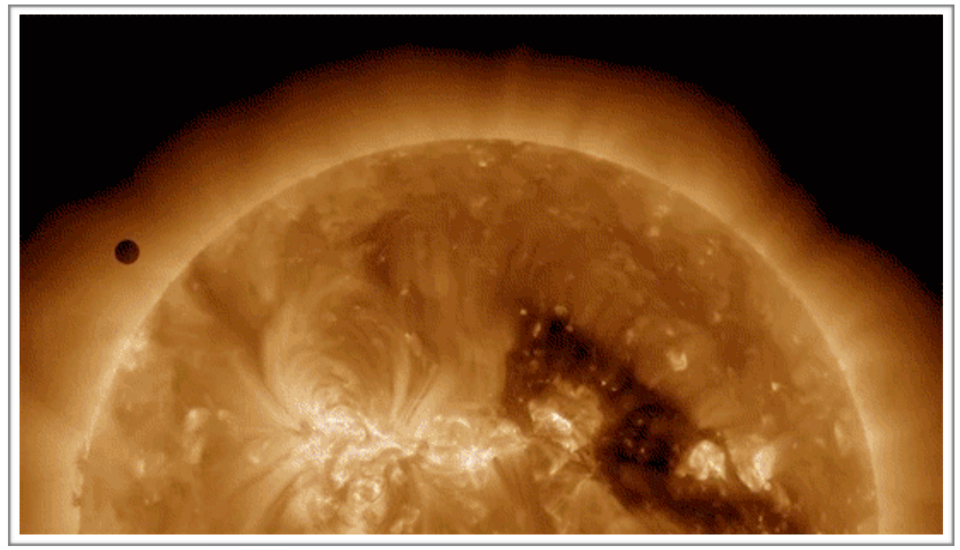
10 May

I watched this event yesterday by a small telescope with all the precautions, but this transit of Mercury is great!

Mercury passes between Earth and the sun only about 13 times a century.
It was yesterday May 9th #lagalaxiaensmira

3:17 PM - 9 May 2016

Distant Supervision Assumption



Distant Supervision Assumption

Tweets posted near an event that mention a key entity are likely to **contain time expressions** referring to the event's date.

Contribution

- First distant Supervision approach for date resolution
  - Most prior work on relation extraction

    [Mintz et al., 2009b; Riedel et al., 2010; Hoffmann et al., 2011]

- Novel **multiple-instance-learning tagging model**
  - Learns word-level tags using only sentence labels

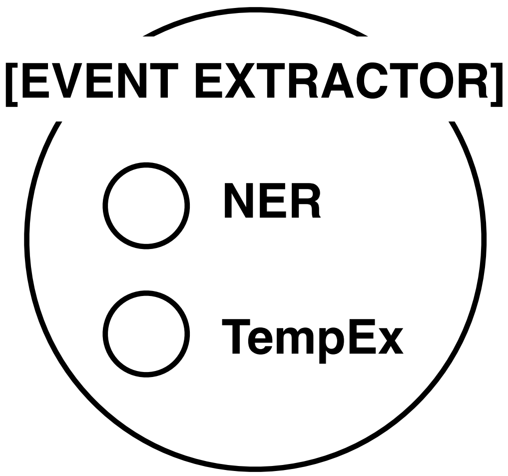
- State of the art results on social media domain
  - 17% increase in F-score over SUTime

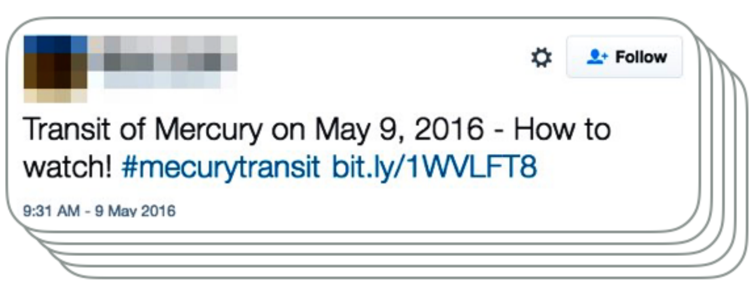
System Overview

[10,000 events]

[EVENT DATABASE]

ENTITY	DATE
Mercury	5/9/2016
…	…
…	…

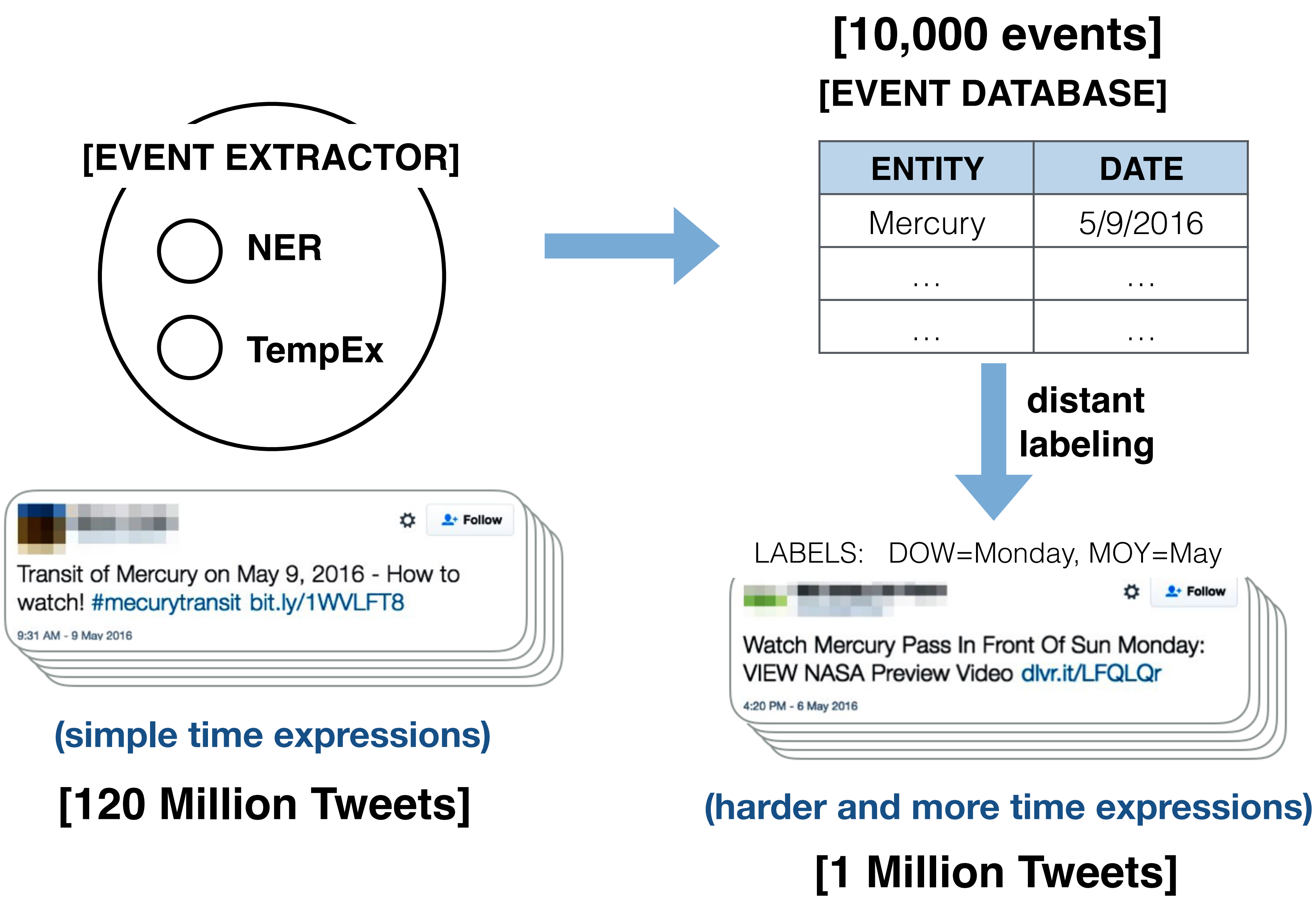




(simple time expressions)

[120 Million Tweets]

System Overview



System Overview

[EVENT EXTRACTOR]

- NER
- TempEx

Transit of Mercury on May 9, 2016 - How to watch! #mecurytransit bit.ly/1WVLFT8

9:31 AM - 9 May 2016

(simple time expressions)

[120 Million Tweets]

[10,000 events]

[EVENT DATABASE]

ENTITY	DATE
Mercury	5/9/2016
...	...
...	...

distant labeling

LABELS: DOW=Monday, MOY=May

Watch Mercury Pass In Front Of Sun Monday: VIEW NASA Preview Video dlvr.it/LFQLQr

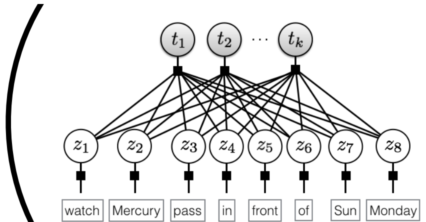
4:20 PM - 6 May 2016

(harder and more time expressions)

[1 Million Tweets]

model training

[RECOGNIZER]



[NORMALIZER]

$$P(d_i|t_j,d_c) \propto e^{\theta \cdot \phi_{ij}(t_j,d_c,tags_j)}$$

Temporal Recognizer

[Event Database]

ENTITY	DATE
Mercury	5/9/2016
...	...

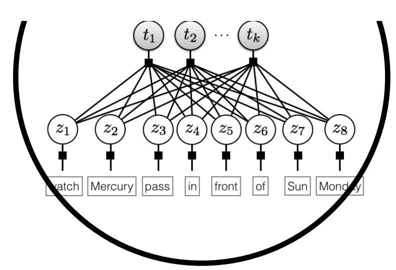
LABELS: Day of Week, Day of Month, Month, Timeline

< Monday, 9, May, Future >

[1 Million Tweets]

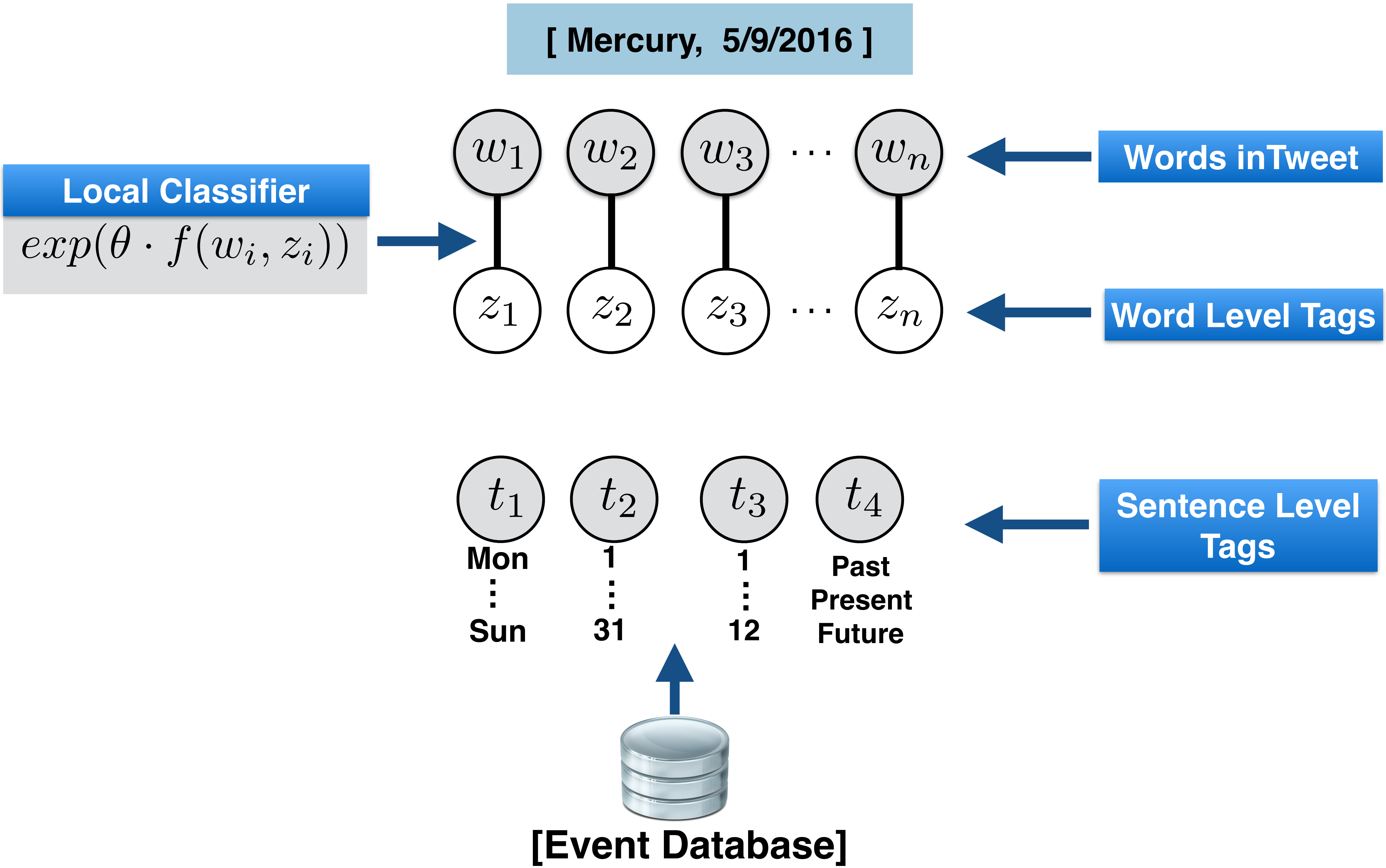
[automatically labeled]

[RECOGNIZER]

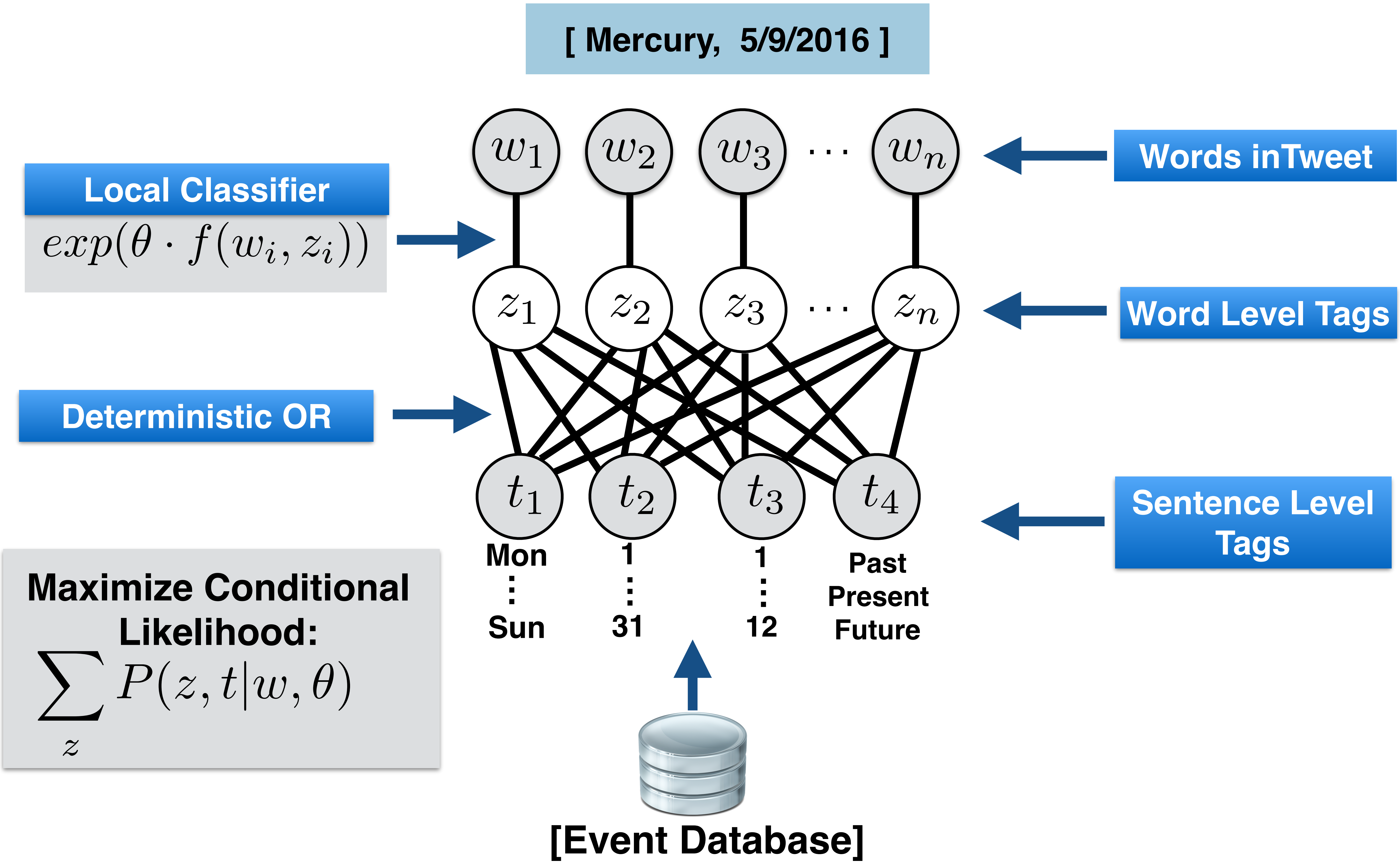


Word	Happy	Friday!	#Fri	yey	#TGIF
Tag	NA	FRI	FRI	NA	FRI

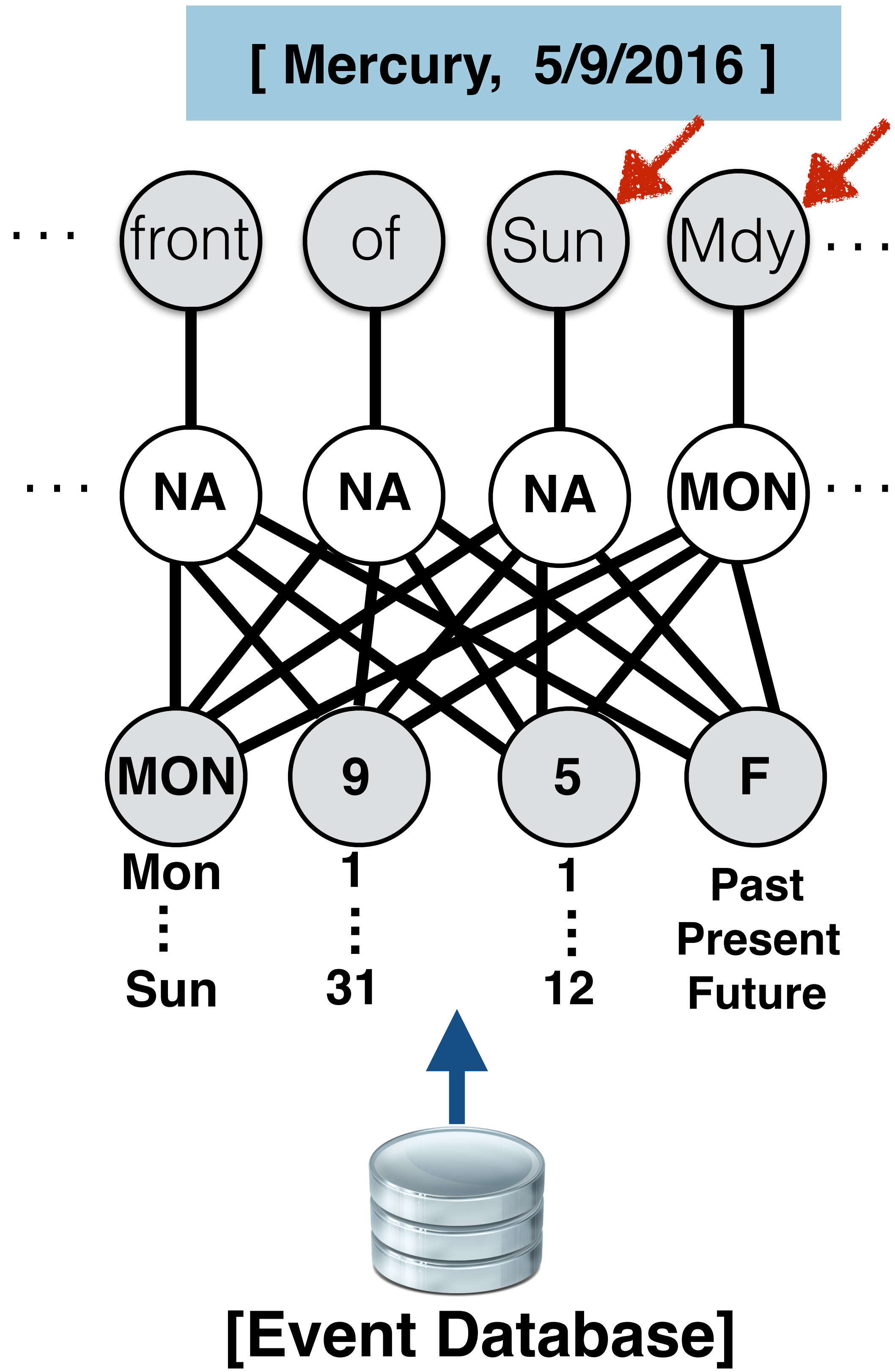
MultiT Tagger



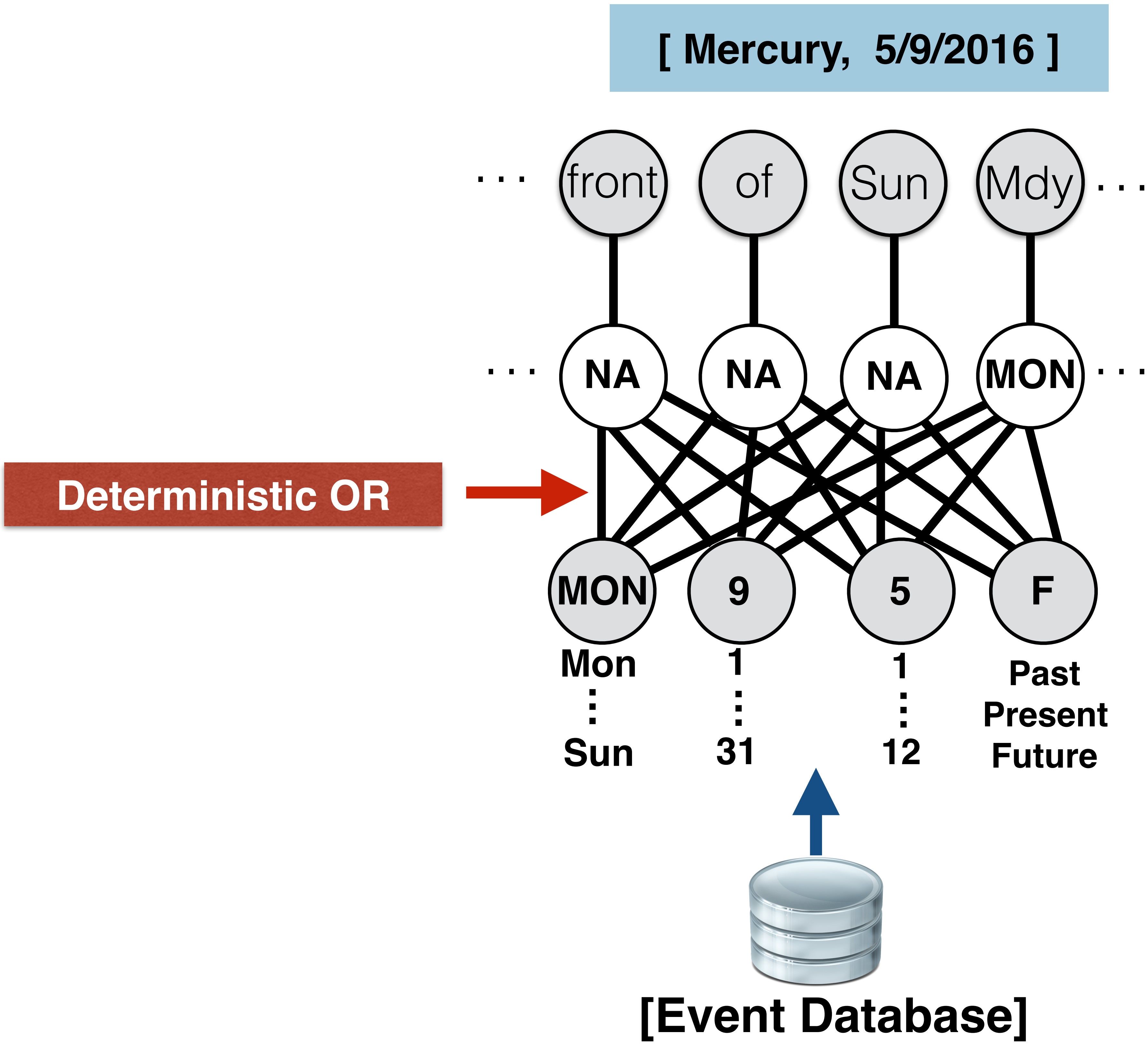
MultiT Tagger



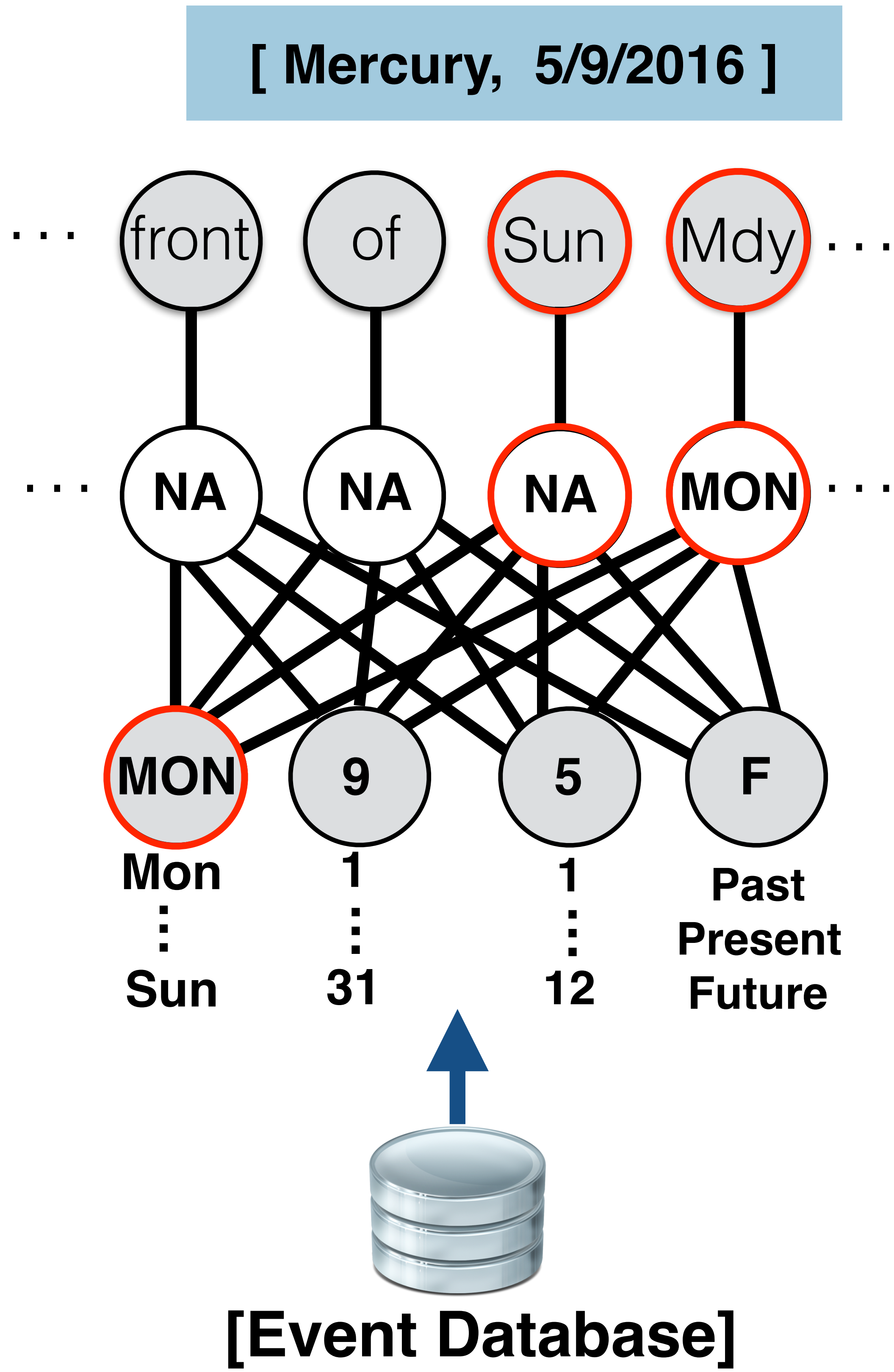
MultiT Tagger



MultiT Tagger



MultiT Tagger



MultiT : Learning

Latent-Variable Perceptron (MAP-based learning)

Gradient of Conditional Log-Likelihood:

$$\nabla P(t|w) = \sum_{z} P(z|w,t;\theta) \cdot f(z,w) \; - \; \sum_{t,z} P(t,z|w;\theta) \cdot f(z,w)$$

MultiT : Learning

Latent-Variable Perceptron (MAP-based learning)

Gradient of Conditional Log-Likelihood:

$$\nabla P(t|w) = \sum_{z} P(z|w,t;\theta) \cdot f(z,w) \;-\; \sum_{t,z} P(t,z|w;\theta) \cdot f(z,w)$$

$$\nabla P(t|w) = \max_{P(z|w,t;\theta)} f(z,w) \;-\; \max_{P(t,z|w;\theta)} f(z,w)$$

Weighted Edge Cover Problem

MultiT : Learning

Latent-Variable Perceptron (MAP-based learning)

Gradient of Conditional Log-Likelihood:

$$\nabla P(t|w) = \sum_{z} P(z|w,t;\theta) \cdot f(z,w) \; - \; \sum_{t,z} P(t,z|w;\theta) \cdot f(z,w)$$

$$\nabla P(t|w) = \max_{P(z|w,t;\theta)} f(z,w) \; - \; \max_{P(t,z|w;\theta)} f(z,w)$$

Assumptions: MultiT Tagger

$$Sentence\ Level\ Tags \in Word\ Level\ Tags$$

Assumptions: MultiT Tagger

Sentence Level Tags:

TL = Future
MOY= May
DOM=9
DOW= Mon

$$Sentence\ Level\ Tags \in Word\ Level\ Tags$$

Assumptions: MultiT Tagger

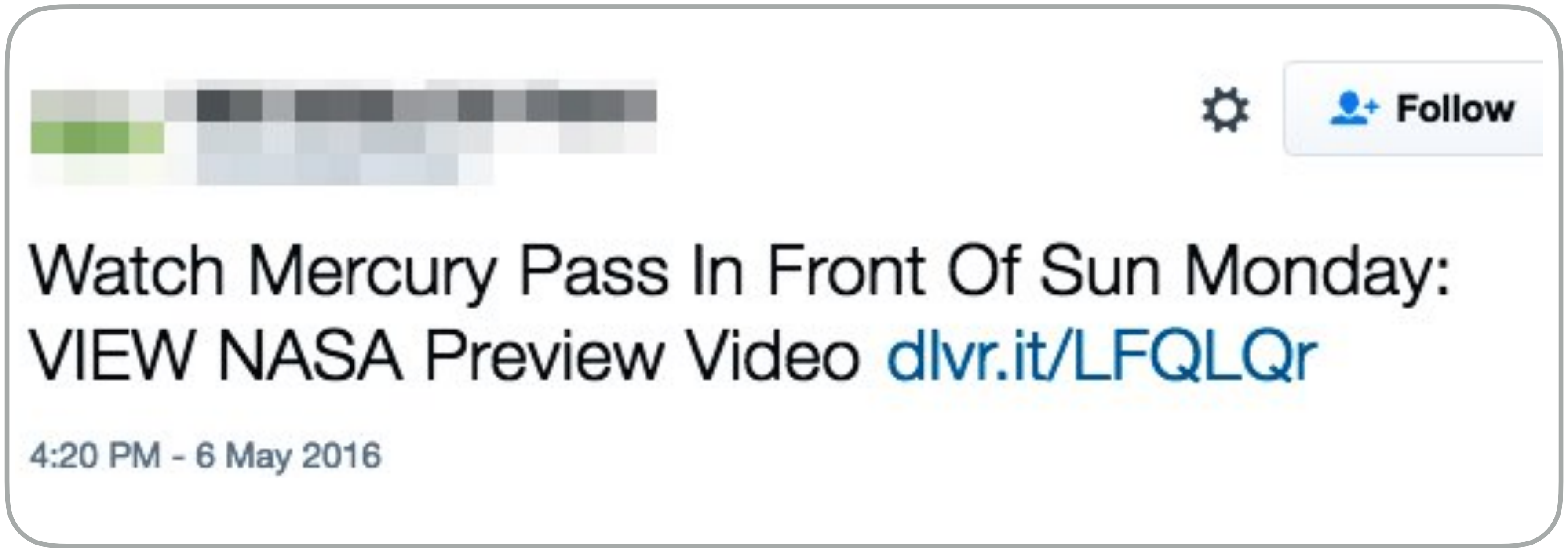
Sentence Level Tags:

TL = Future
MOY= May
DOM=9
DOW= Mon

$$Sentence\ Level\ Tags \in Word\ Level\ Tags$$

$$Word\ Level\ Tags \in Sentence\ Level\ Tags$$

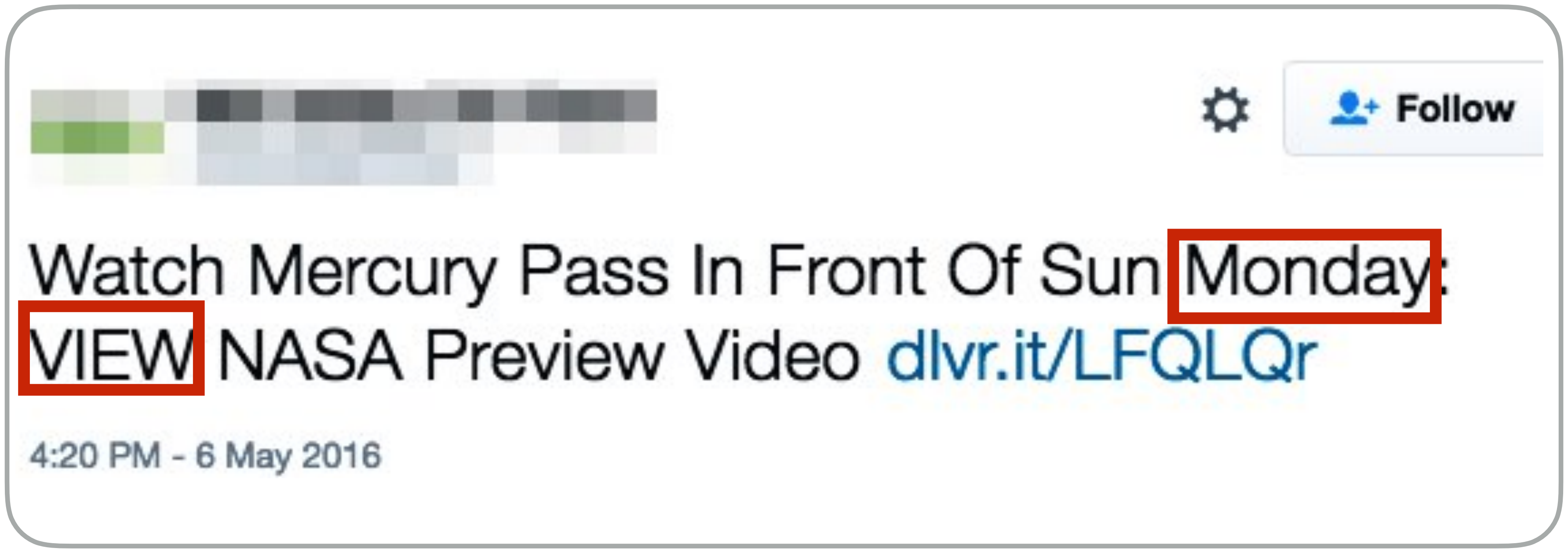
Missing Data Problem



Sentence Level Tags:

TL = Future
MOY= May
DOM=9
DOW= Mon

Missing Data Problem



Sentence Level Tags:

- ✓ TL = Future
- ✗ MOY= May
- ✗ DOM=9
- ✓ DOW= Mon

Missing Data Problem

Sentence Level Tags:

- ✔ TL = Future
- ✘ MOY= May
- ✘ DOM=9
- ✔ DOW= Mon

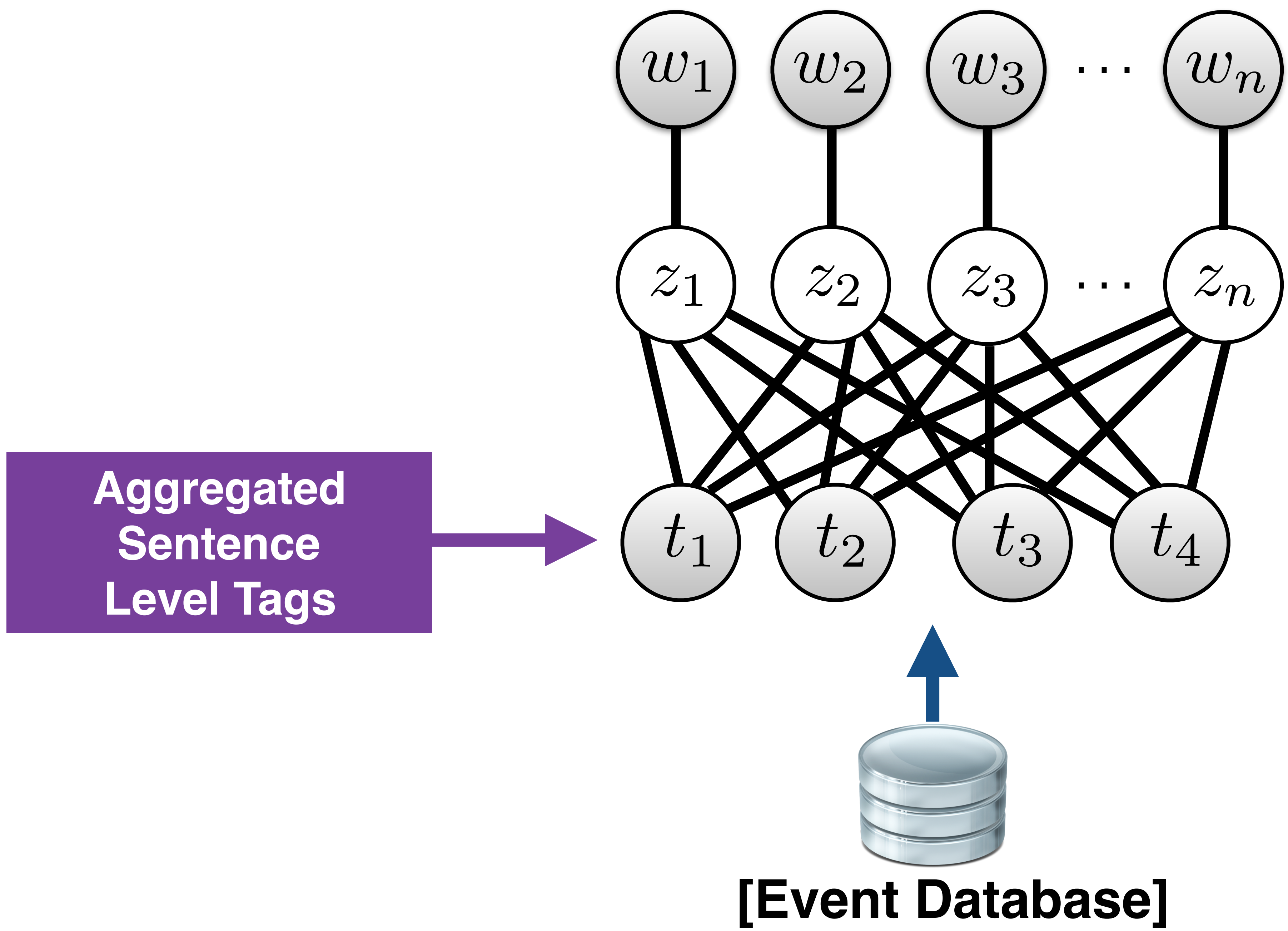
$$Sentence\ Level\ Tag \notin Word\ Level\ Tag$$

$$Word\ Level\ Tag \notin Sentence\ Level\ Tag$$

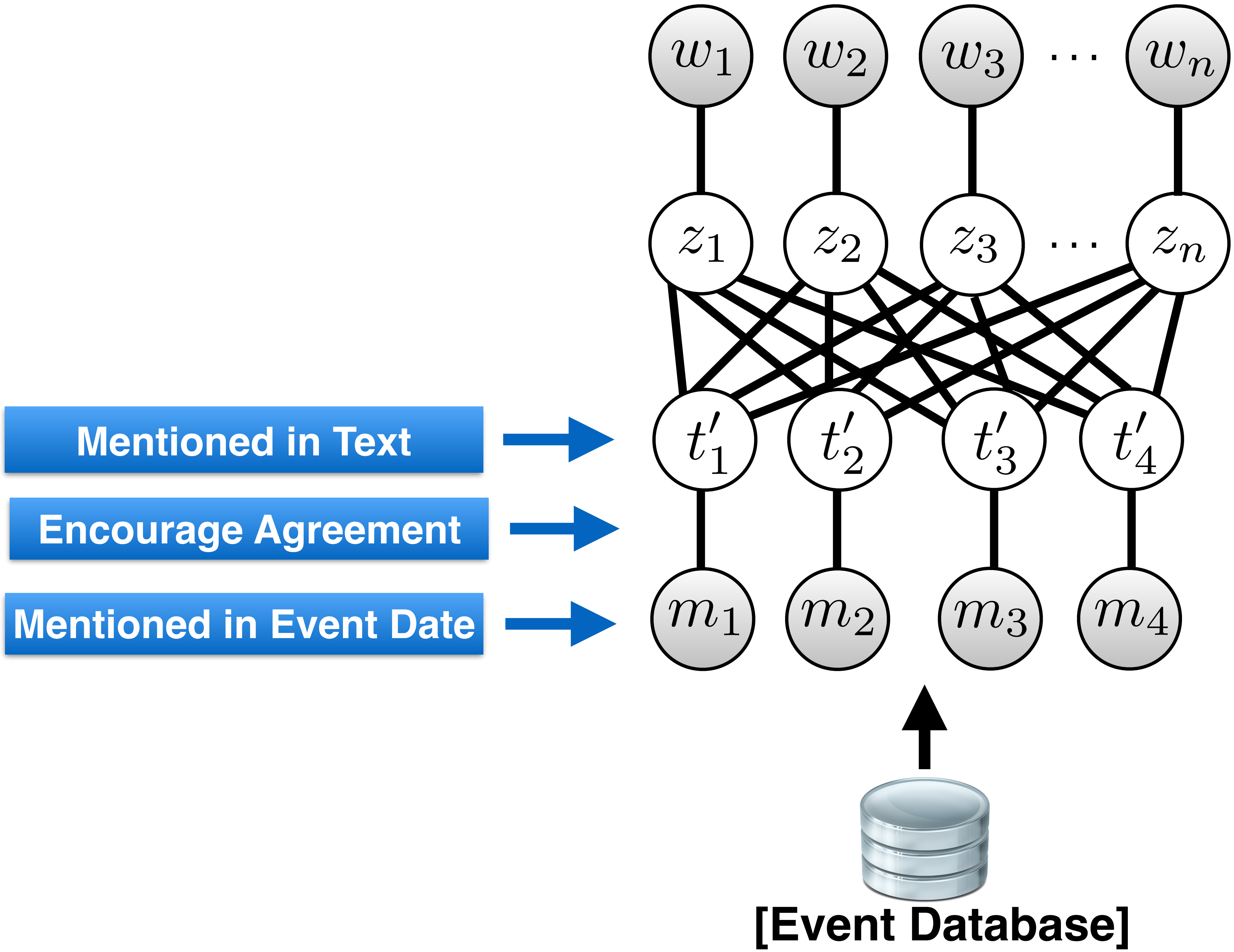
Solution:

Multiple Instance Learning Missing Data Model

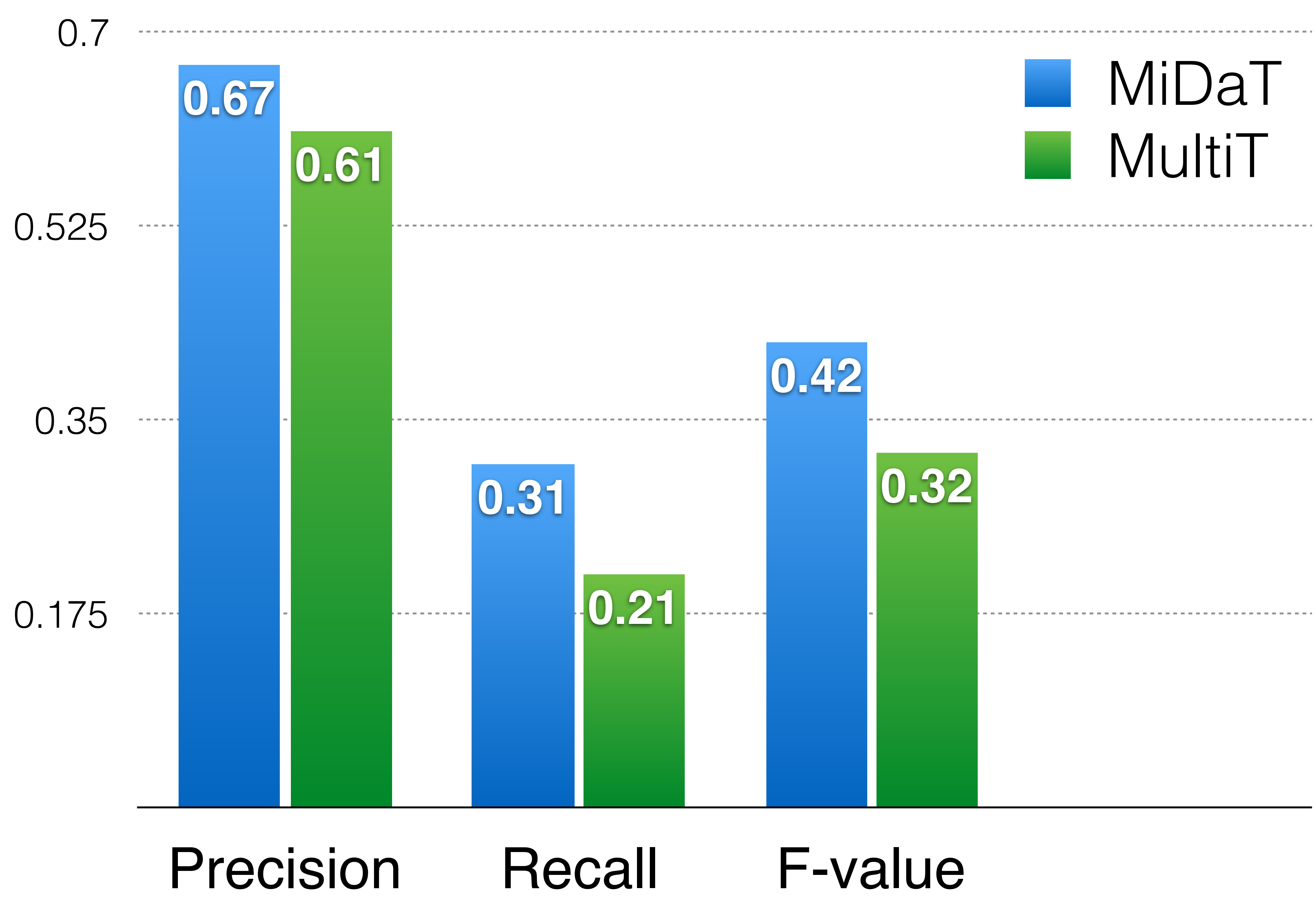
Missing Data Extension



MiDaT Tagger [Extension of MultiT]



MultiT Vs MiDaT [Intrinsic evaluation]



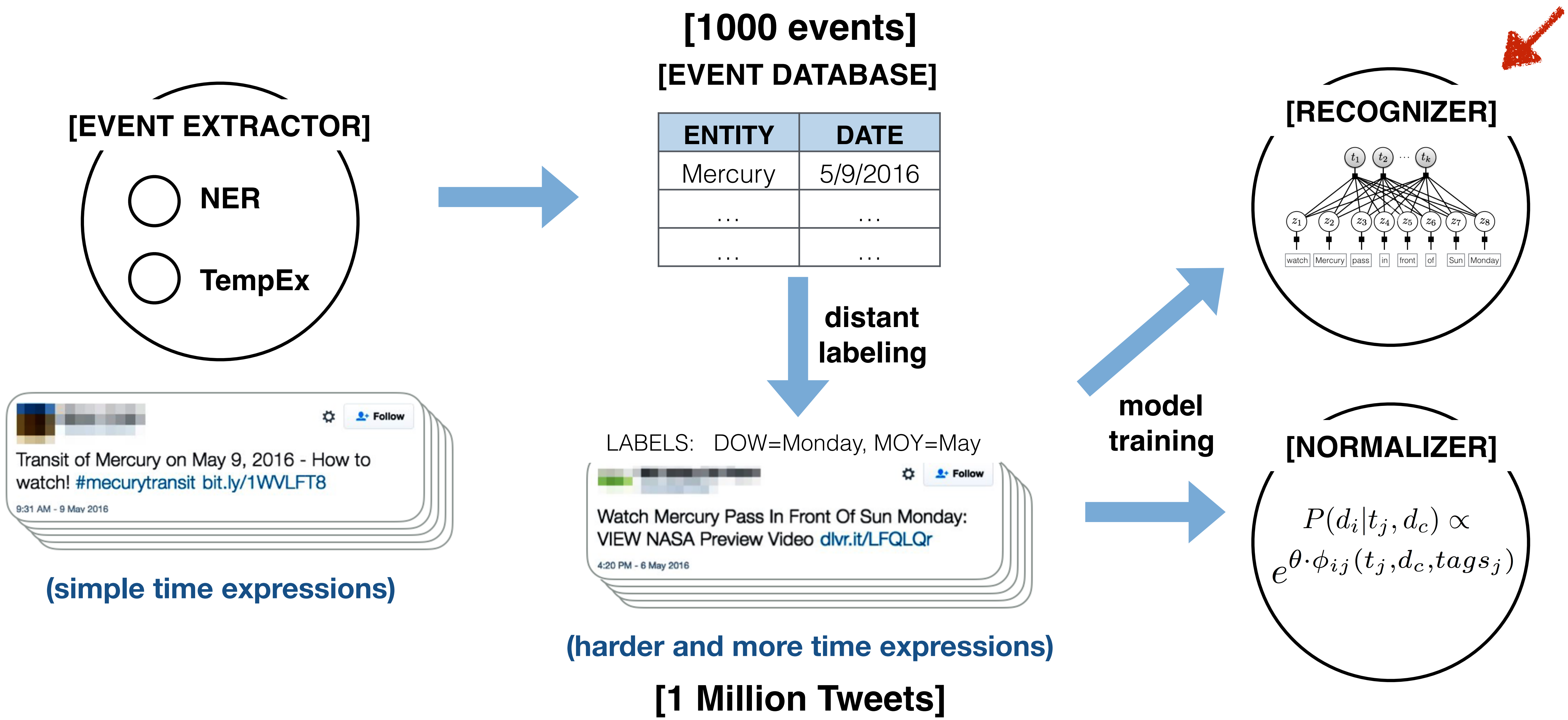
Example Tags

Word	Im	Hella	excited	for	tomorrow
Tag	NA	NA	Future	NA	Future

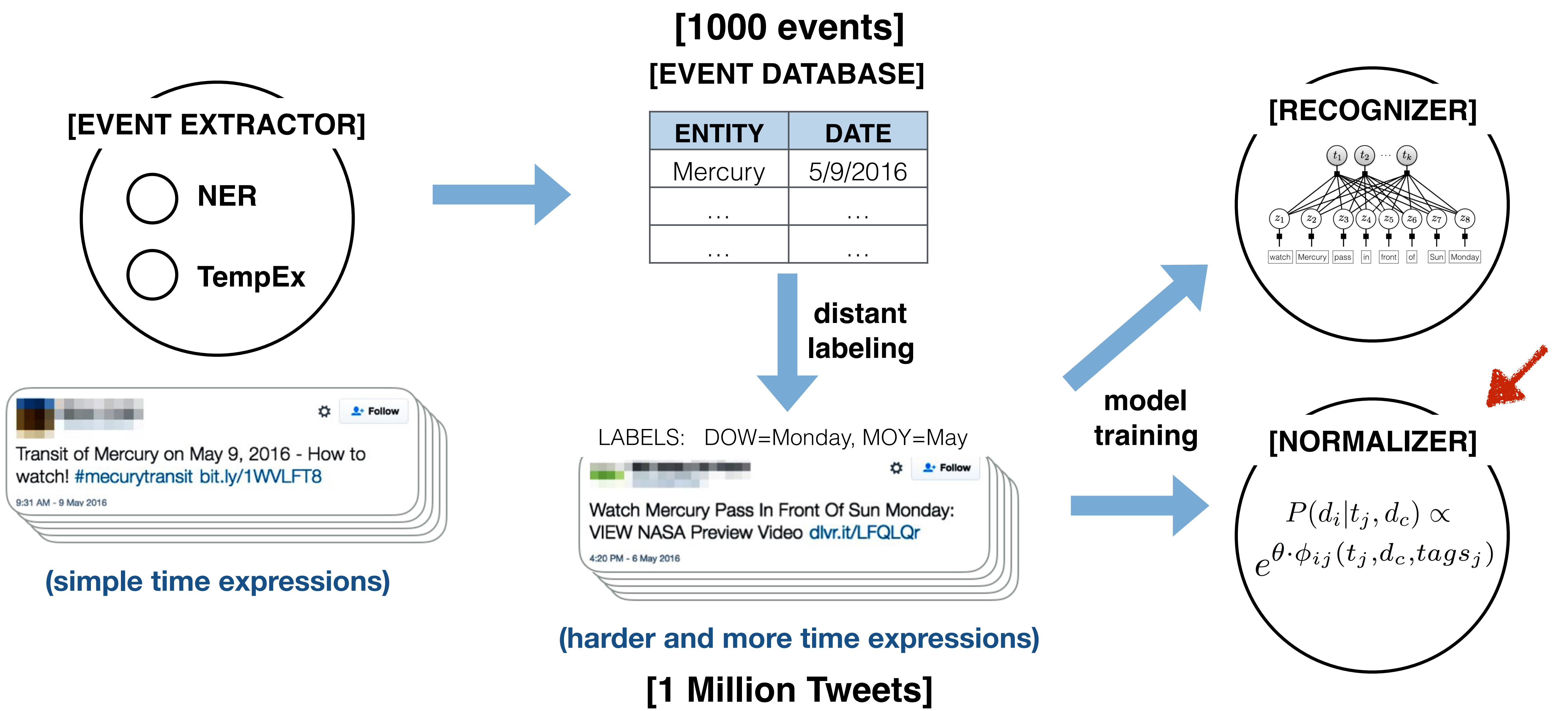
Word	Thnks	for	a	Christmas	party	on	fri
Tag	NA	NA	NA	Dec	NA	NA	FRI

[Not always matches human intuition]

System Overview



System Overview



Temporal Normalizer

[Event Database]

LABEL: May 9 2016

[$\frac{1}{2}$ Million Tweets]

[NORMALIZER]

$$P(d_i|t_j, d_c) \propto e^{\theta \cdot \phi_{ij}(t_j, d_c, tags_j)}$$

Temporal Normalizer

[Event Database]

LABEL: May 9 2016

[$\frac{1}{2}$ Million Tweets]

[NORMALIZER]

$$P(d_i|t_j, d_c) \propto e^{\theta \cdot \phi_{ij}(t_j, d_c, tags_j)}$$

$$P(d_i|t_j, d_c) \propto e^{\theta \cdot \phi_{ij}(t_j, d_c, tags_j)}$$

Temporal Normalizer

[Event Database]

LABEL: May 9 2016

[$\frac{1}{2}$ Million Tweets]

Creation Date: 11/1

EMNLP starts 4m tmrw!

[NORMALIZER]

$$P(d_i | t_j, d_c) \propto e^{\theta \cdot \phi_{ij}(t_j, d_c, tags_j)}$$

D_{-10}	...	D_{-1}	D_0	$\boxed{D_{+1}}$	...	D_{+10}	$None$
10/22		10/31	11/1	11/2		11/11	NA

Temporal Normalizer: Features

$P($ **Candidate Date:** 5/9/2016 $| \cdots) \propto f \Bigg($

Word Tags predicted by recognizer:

TL = Future

DOW= Mon

⋮

Creation Date: 5/6/2016

Candidate Date: 5/9/2016

$\Bigg) \cdot \theta$

Lexical Features

Tag Features

Time Difference Features

Temporal Normalizer: Features

$P($ **Candidate Date:** 5/9/2016 $|\cdots) \propto f\Bigg($

Follow

Watch Mercury Pass In Front Of Sun Monday: VIEW NASA Preview Video dlvr.it/LFQLQr

4:20 PM - 6 May 2016

Word Tags predicted by recognizer:

TL = Future

DOW= Mon

⋮

Creation Date: 5/6/2016

Candidate Date: 5/9/2016

$\Bigg) \cdot \theta$

Lexical Features

$w =$ "Monday" $\wedge$ candidate date $\in Monday$

Temporal Normalizer: Features

$P($ **Candidate Date:** 5/9/2016 $| \cdots) \propto f$

Word Tags predicted by recognizer:
TL = Future
DOW= Mon
⋮

Creation Date: 5/6/2016

Candidate Date: 5/9/2016

$\cdot\,\theta$

Tag Features

$$t = \textsc{Future} \wedge \text{candidate date} \in \mathit{future}$$

Temporal Normalizer: Features

$P($ **Candidate Date:** 5/9/2016 $| \cdots) \propto f$

Follow

Watch Mercury Pass In Front Of Sun Monday: VIEW NASA Preview Video dlvr.it/LFQLQr

4:20 PM - 6 May 2016

Word Tags predicted by recognizer:

TL = Future

DOW= Mon

⋮

Creation Date: 5/6/2016

Candidate Date: 5/9/2016

$\cdot \theta$

Time Difference Features

$$DIFF_{days} = +3$$

$$DIFF_{weeks} = +1$$

Evaluation

250 Tweet [2014-2015]

dev : 50
test : 200

Manually
Annotated

Temporal Resolver

[TweeTime, HeidelTime, UWTime, SUTime, TempEX]

Evaluation

250 Tweet [2014-2015]

dev : 50
test : 200

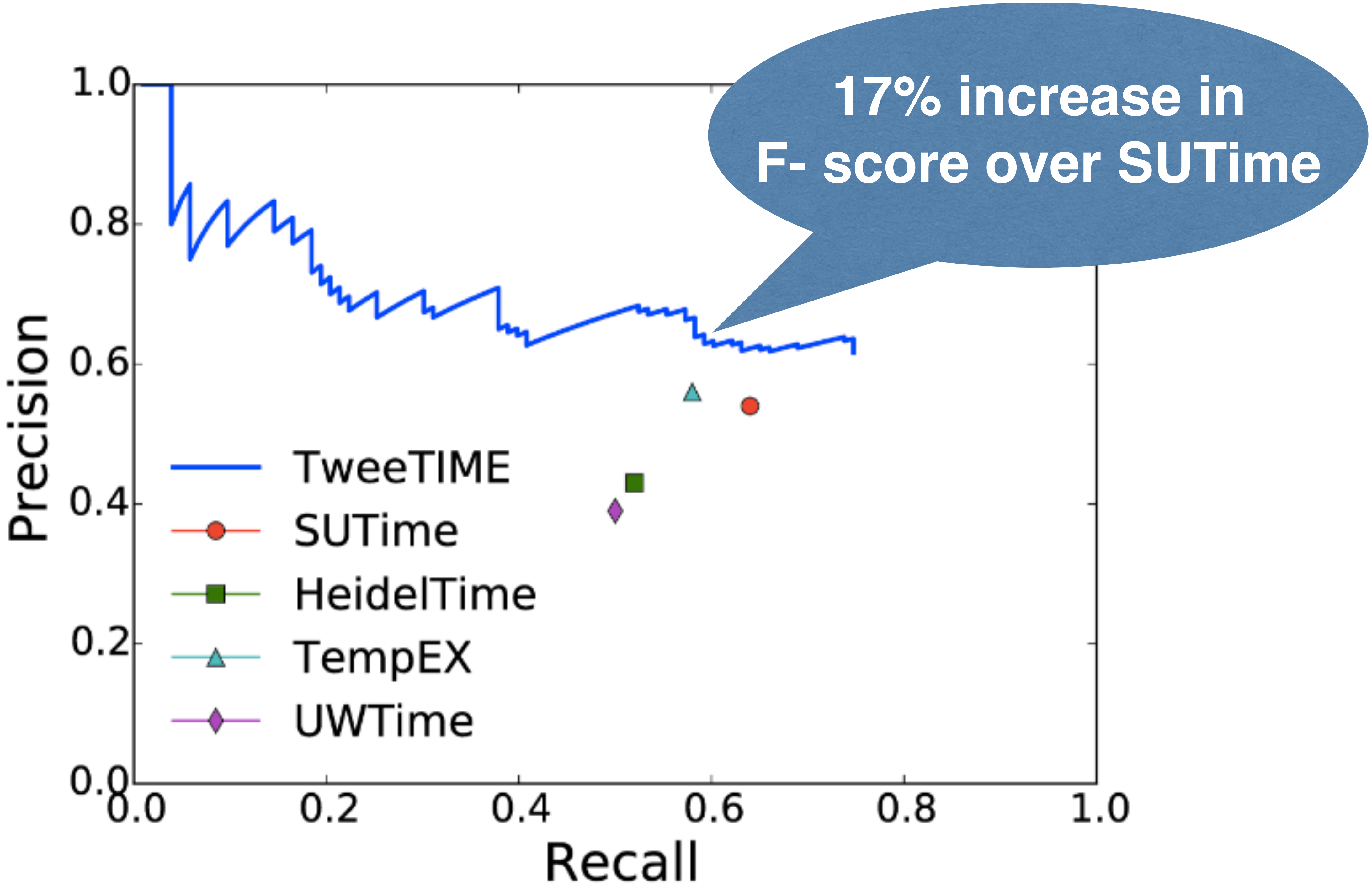
Manually
Annotated

Temporal Resolver

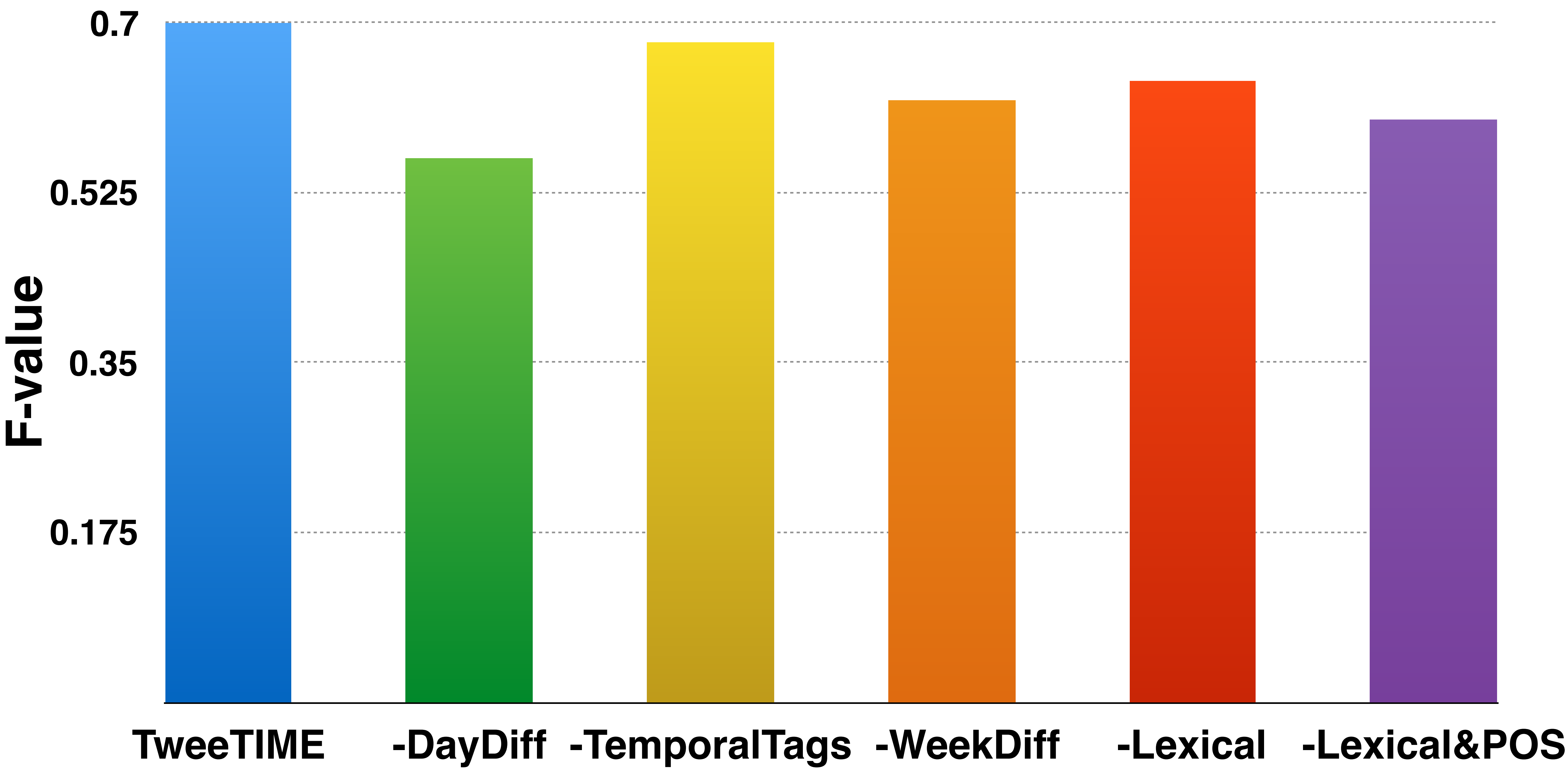
[**TweeTime**, HeidelTime, UWTime, SUTime, TempEX]

Train Set [2011-2012]

System Performance



Feature Ablation



Takeaways

- 1st and best date resolver for Twitter
- 1st use of distant supervision for time expressions (**no human labels needed**)
- Code will be available: [***https://github.com/jeniyat/TweeTime***](https://github.com/jeniyat/TweeTime)

Takeaways

- 1st and best date resolver for Twitter
- 1st using distant supervision for time expressions (**no human labels needed**)
- Code will be available: ***https://github.com/jeniyat/TweeTime***

Jeniya Tabassum