Multilingual Temporal Parsing

Gabor Angeli  
angeli@stanford.edu  

Jakob Uszkoreit  
uszkoreit@google.com
Example

Let’s meet for a few hours next week, say August 12?
Example

Let’s meet for a few hours next week, say August 12?

Detection Finding temporal phrases in a sentence.
Example

Let’s meet for a few hours next week, say August 12?

Detection Finding temporal phrases in a sentence.

Interpretation Finding the grounded meaning of a phrase
Example

Let’s meet for a few hours next week, say August 12?

~1H  WXX  08/12

Detection  Finding temporal *phrases* in a sentence.

Interpretation  Finding the grounded *meaning* of a phrase

But, often incomplete information
Example

Let’s meet for a few hours next week, say August 12?

Detection Finding temporal phrases in a sentence.

Interpretation Finding the grounded meaning of a phrase
But, often incomplete information
Incorporate a reference time
News

[The falcon] was found injured **last Thursday** in . . .

. . . she died **early Saturday morning**

Benjamin Franklin Federal Savings and Loan Association said it plans to restructure in the wake of a **third-quarter loss**
News

[The falcon] was found injured last Thursday in . . .

. . . she died early Saturday morning

Benjamin Franklin Federal Savings and Loan Association said it plans to restructure in the wake of a third-quarter loss

Communication

Actually I am on vacation the last three weeks of November

I have some time available at the end of next week
System

Input \((w, t)\) (Last 2 days phrase, 2013-08-05 reference)

Latent parse

\[ R \]

RangetakeLeft(2 \times \text{DAY})

\[ f : \ldots \times \text{DAY} \]

Number 2

two

Duration \text{DAY}

days

Output \(\tau^*\) normalized time 2013-08-03−2013-08-05

Angeli et al. 2012
Input \((w,t)\)  \((\text{Last 2 days, 2013-08-05})\)
System

Input \((w,t)\) (Last 2 days, 2013-08-05)

Output \(\tau^*\) normalized time

Angeli et al. 2012
System

Input \((w,t)\)  \((\text{Last 2 days}, 2013-08-05)\)

Output \(\tau^*\)  \(2013-08-03 \rightarrow 2013-08-05\)

Angeli et al. 2012
System

Input \((w,t)\) (Last 2 days, 2013-08-05)

Latent\n
parse\n
\(R\)

Latent\n
parse\n
\(R\)

Output \(\tau^*\) 2013-08-03 — 2013-08-05

Angeli et al. 2012
System

Input \((w,t)\) \(\left( \text{Last 2 days}, 2013-08-05 \right)\)

Latent parse \(R\)

\[
\text{takeLeft}(2 \times 2 \text{ DAY})
\]

Output \(\tau^*\) \(2013-08-03 - 2013-08-05\)

Angeli et al. 2012
Elements of Latent Parse

- **Range**: the week of August 5, 2013
- **Sequence**: week
- **Duration**: a week
- **Nil**: this
- **Functions**: last \[ \text{takeLeft}(-) \]
Prior Work

Hand coded rules

Rigid

Syntax: last Friday the 12th

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Prior Work

Hand coded rules

Rigid

Syntax: last Friday the 13th

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Prior Work

Hand coded rules

Rigid

Syntax: *last Friday the 13th*

Domain pragmatics: *A year ago*

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Prior Work

**Hand coded rules**

- **Rigid**
  
  Syntax: *last Friday the 13\textsuperscript{th}*
  
  Domain pragmatics: *Sales are down from a year ago*

---

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Prior Work

Hand coded rules

Rigid

Syntax: *last Friday the 13th*

Domain pragmatics: *Remember? We got married a year ago*

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Prior Work

Hand coded rules

Rigid

Syntax: last Friday the 13th

Domain pragmatics: Remember? We got married a year ago

Rule engineering challenge

Always more rules: 2 days prior, the previous 2 days

/last Friday the 13th

/Remember? We got married a year ago

/2 days prior, the previous 2 days

Mani & Wilson (2000); Strögen and Gertz (2010); Chang and Manning (2012)
Prior Work

Hand coded rules

Rigid

Syntax: last Friday the 13th

Domain pragmatics: Remember? We got married a year ago

Rule engineering challenge

Always more rules: 2 days prior, the previous 2 days

New set of rules for each language

Mani & Wilson (2000); Strötgen and Gertz (2010); Chang and Manning (2012)
Motivation

Language independent

Arbitrary training data: Last Sunday / domingo pasado
Motivation

Language independent

Arbitrary training data: **Last Sunday / domingo pasado**

Hard:

- *pasado* → `last(-)`
- *domingo* → `SUN` ($DOW$) /pasado/

($DOW$) /pasado/
Motivation

Language independent

Arbitrary training data: Last Sunday / domingo pasado

Easier: annotate training data for domingo pasado
Motivation

Language independent
Arbitrary training data: Last Sunday / domingo pasado
Easier: annotate training data for domingo pasado
∼ 100 grammar rules total
Same learning algorithm, hyperparameters
Motivation

Language independent

Arbitrary training data: Last Sunday / domingo pasado

Easier: annotate training data for domingo pasado

~ 100 grammar rules total

Same learning algorithm, hyperparameters

HeidelTime

English: ~ 2000 rules (185 combination rules)
Motivation

Language independent

Arbitrary training data: Last Sunday / domingo pasado
Easier: annotate training data for domingo pasado
~ 100 grammar rules total
Same learning algorithm, hyperparameters

HeidelTime

English: ~ 2000 rules (185 combination rules)
Spanish: ~ 1200 rules (167 combination rules)
Italian: ~ 1600 rules (156 combination rules)
...
Motivation

Language independent
Arbitrary training data: Last Sunday / domingo pasado
Easier: annotate training data for domingo pasado
~ 100 grammar rules total
Same learning algorithm, hyperparameters

HeidelTime
English: ~ 2000 rules (185 combination rules)
Spanish: ~ 1200 rules (167 combination rules)
Italian: ~ 1600 rules (156 combination rules)
...

SUTime
English: ~ 900 rules
Language Independent

Latent semantic representation

_last 2 days_

\[ \text{takeLeft}(2 \times \text{DAY}) \]

\[ \begin{align*}
\text{takeLeft}(\text{last}) & \quad 2 \times \text{DAY} \\
\text{last} & \quad 2 \\
\text{two} & \quad \text{days} \\
\end{align*} \]

\[ [2013-08-05] \rightarrow 2013-08-03 - 2013-08-05 \]
Language Independent

Latent semantic representation
Many languages share representation
últimos dos días

takeLeft( 2 × \( \overline{\text{DAY}} \) )

takeLeft(−) 2 × \( \overline{\text{DAY}} \)

últimos 2 dos días

[ 2013-08-05 ] \( \rightarrow \) 2013-08-03 − 2013-08-05
Latent semantic representation
Many languages share representation

$ultimi$ $due$ $giorni$

$\text{takeLeft}(2 \times \# \text{DAY})$

$\text{takeLeft}(-) \quad 2 \times \# \text{DAY}$

$ultimi \quad 2 \quad \# \text{DAY}$

due \quad giorni

$[2013-08-05] \rightarrow 2013-08-03 - 2013-08-05$
Language Independent

Latent semantic representation
Many languages share representation

előző két nap

takeLeft( 2 × DAY )

<table>
<thead>
<tr>
<th>takeLeft(−)</th>
<th>2 × DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>előző</td>
<td>2</td>
</tr>
<tr>
<td>két</td>
<td>nap</td>
</tr>
</tbody>
</table>

[ 2013-08-05 ] → 2013-08-03 — 2013-08-05
Language Independent

Latent semantic representation
Many languages share representation

最後兩天

takeLeft( 2 × \text{DAY} )

2 × \text{DAY}

[ 2013-08-05 ] → 2013-08-03 − 2013-08-05
Language Independent

Latent semantic representation
Many languages share representation

\[ \text{takeLeft}(2 \times \text{DAY}) \]

\[ \text{takeLeft}(\cdot) \quad 2 \times \text{DAY} \]

最後

2

兩

天

[2013-08-05] \rightarrow 2013-08-03 - 2013-08-05
Parsing temporal phrases

Explained in, but not specific to English

\[
\text{takeLeft}(2 \times \text{DAY})
\]

\[
\text{takeLeft}(-)
\]

\[
\text{last}
\]

\[
2 	imes \text{DAY}
\]

\[
2
\]

\[
two
\]

\[
days
\]
Parsing

Parsing temporal phrases

Explained in, but not specific to English
Naïvely, domain of nonterminals is large

\[ \text{takeLeft}(3 \times \text{DAY}) \]

\[ \text{last} \]

\[ 3 \times \text{DAY} \]

\[ \text{three} \]

\[ \text{days} \]
Parsing

Parsing temporal phrases
Explained in, but not specific to English
Naïvely, domain of nonterminals is large

\[ \text{takeLeft}(4 \times \text{DAY}) \]

\[ \text{takeLeft}(-) \]
\[ 4 \times \text{DAY} \]
\[ \text{last} \]
\[ 4 \]
\[ \text{four} \]
\[ \text{days} \]
Domain of nonterminals is large

Consider: last 7 days, last 3 months, etc.

**Generative Grammar:** Group nonterminals based on types

\[ f : \text{Duration} \rightarrow \text{Range} \]
Domain of nonterminals is large
Consider: *last 7 days*, *last 3 months*, etc.

**Generative Grammar:** Group nonterminals based on *types*

\[ f : \text{Duration} \rightarrow \text{Range} \]
\[ \text{Range} \]
\[ \text{Duration} \]
\[ \text{Number} \]
\[ 3 \]
\[ \text{months} \]
Domain of nonterminals is large

Consider: *last 7 days*, *last 3 months*, etc.

**Generative Grammar:** Group nonterminals based on types
Parsing

Domain of nonterminals is large
Consider: last 7 days, last 3 months, etc.

Generative Grammar: Group nonterminals based on types

Discriminative model
Coarse-grained features over types: Range
Fine grained features over values: 2013

Adapt semantic parser (e.g., Liang et al. 2011)
Features

Friday of this week
Features

FRI ∩ EveryWeek
FRI
Friday
EveryWeek
Nil
of this
EveryWeek
week
lex < FRI, Friday >
Parallel generative grammar

Friday
of this week
lex < FRI, Friday >

Parallel generative grammar
Features

FRI ∩ EveryWeek
FRI
Friday
EveryWeek
Nil
of this
EveryWeek
week
lex < Nil , of this >
Parallel generative grammar

lex < NIL , of this >

Friday Nil of this week
Features

\[ FRI \cap \text{EveryWeek} \]

\[ FRI \]

\[ \text{Friday} \]

\[ \text{EveryWeek} \]

\[ \text{Nil} \]

\[ \text{of this} \]

\[ \text{EveryWeek} \]

\[ \text{week} \]

\[ \text{lex} < \text{Nil}, \text{of this} > \]

\[ \text{lex} < \text{Nil}, \text{of} > \]

\[ \text{lex} < \text{Nil}, \text{this} > \]
Features

\begin{align*}
\text{FRI} & \quad \text{Friday} \\
\cap & \quad \text{Nil} \\
\text{EveryWeek} & \quad \text{of this} \\
\text{EveryWeek} & \quad \text{week}
\end{align*}

\text{lex} < \text{EveryWeek}, \text{week} >
Features

\[
\begin{align*}
\text{FRI} & \quad \text{EveryWeek} \\
\downarrow & \quad \downarrow \\
\text{Friday} & \quad \text{Nil} \\
& \quad \downarrow \\
& \quad \text{of this} \\
& \quad \downarrow \\
& \quad \text{week}
\end{align*}
\]

\begin{align*}
\text{bracket} & \quad < \text{Nil} , \text{Sequence} > \\
Parallel \text{ generative grammar}
\end{align*}
Features

FRI ∩ EveryWeek
FRI
Friday
EveryWeek
Nil
of this
EveryWeek
week
bracket < Nil , Sequence >
bracket < Nil , EveryWeek >

bracket < Nil , Sequence >
bracket < Nil , EveryWeek >
Features

\[ FRI \cap \text{EveryWeek} \]

\[ \text{Friday} \]

\[ \text{Nil of this} \]

\[ \text{week} \]

\[ \text{bracket } < \text{Nil}, \text{Sequence} > \]
\[ \text{bracket } < \text{Nil}, \text{EveryWeek} > \]
\[ \text{lex } < \text{Nil of this}, \text{Sequence} > \]
\[ \text{lex } < \text{Nil of}, \text{Sequence} > \]
\[ \text{lex } < \text{Nil this}, \text{Sequence} > \]
Features

\( FRI \cap \text{EveryWeek} \)

\( FRI \)

\( \text{EveryWeek} \)

\( \text{Friday} \)

\( \text{Nil} \)

\( \text{EveryWeek} \)

\( \text{of this} \)

\( \text{week} \)

bracket \( \langle \text{SEQUENCE}, \text{SEQUENCE} \rangle \)

bracket \( \langle \text{INTERSECT}, FRI, \text{EveryWeek} \rangle \)
Features

\[ \text{FRI} \cap \text{EveryWeek} \]

- \text{FRI}
- \text{EveryWeek}
- \text{Friday}
- \text{Nil}
- \text{EveryWeek}

- \text{of this}
- \text{week}

\text{bracket} < \text{SEQUENCE}, \text{SEQUENCE} >

\text{bracket} < \text{INTERSECT}, \text{FRI}, \text{EveryWeek} >

\text{valid} < \text{is_valid} >

(e.g., filter February 30th)
Training Setup

Given \( \{(x, y)\} \)
Training Setup

*Given* \{ ( ( Phrase, Reference ), Time ) \}
Training Setup

**Given** \{ \(( Phrase , Reference ), Time )\}  

- Not given latent parse  
- Not given lexical or language cues
Training Setup

**Given** \{ ( ( Phrase, Reference ), Time ) \}

Not given latent parse
Not given lexical or language cues

**Therefore, in general, multiple parses ground to same time**
Training Setup

**Given** \{((Phrase, Reference), Time)\}

Not given latent parse
Not given lexical or language cues

Therefore, in general, multiple parses ground to same time

\(((w_1 w_2, 2013-08-05), 2013-08-12)\)
Training Setup

Given \{ ((\textit{Phrase}, \textit{Reference}), \textit{Time}) \}

Not given latent parse
Not given lexical or language cues

Therefore, in general, multiple parses ground to same time

\(( (w_1 \ w_2, 2013-08-05), 2013-08-12)\)

e.g., \(w_1 = \text{next}, w_2 = \text{Monday}\)
Training Setup

Given \( \{ ( ( Phrase, Reference ), Time ) \} \)

- Not given latent parse
- Not given lexical or language cues

Therefore, in general, multiple parses ground to same time

\[
( ( w_1, w_2, 2013-08-05 ), 2013-08-12 )
\]

- moveRight\( ( x, \underline{\text{WEEK}} ) \)
- moveRight\( ( x, \_\_\_ ) \)

\( w_1 \)
\( w_2 \)

- e.g., \( w_1 = \text{next}, w_2 = \text{Monday} \)
- e.g., \( w_1 = \text{next}, w_2 = \text{week} \)
Training Setup

Given \{ ((\text{Phrase}, \text{Reference}), \text{Time}) \} 

Not given latent parse 
Not given lexical or language cues 

Therefore, in general, multiple parses ground to same time 
\(( (w_1, w_2, 2013-08-05), 2013-08-12)\) 

\begin{align*}
\text{MON} & \quad \text{Nil} \\
\downarrow & \quad \downarrow \\
w_1 & \quad w_2
\end{align*}

e.g., \(w_1 = \text{next}, w_2 = \text{Monday}\) 
e.g., \(w_1 = \text{next}, w_2 = \text{week}\) 
e.g., \(w_1 = \text{the}, w_2 = \text{Monday}\)
Training

For each example:

Get $k$-best parses for phrase
Training

For each example:

Get $k$-best parses for phrase

((next Monday, 2013-08-05), 2013-08-12)
Training

For each example:
Get $k$-best parses for phrase

$$((\text{next Monday}, 2013-08-05), 2013-08-12)$$
Training

For each example:
Get $k$-best parses for phrase

\[
( ( \text{next Monday}, 2013-08-05 ), 2013-08-12 )
\]

\[
\begin{align*}
\phi_1 \cdot w & \quad \phi_2 \cdot w \\
\phi_3 \cdot w & \quad \phi_4 \cdot w \\
\phi_5 \cdot w & \quad \phi_6 \cdot w \\
\phi_7 \cdot w & \quad \phi_8 \cdot w
\end{align*}
\]
Training

For each example:
Get $k$-best parses for phrase
Re-weight correct parses as distribution

$((\text{next Monday, 2013-08-05}), 2013-08-12)$

$\phi_1 \cdot w$
$\phi_2 \cdot w$
$\phi_3 \cdot w$
$\phi_4 \cdot w$

$\phi_5 \cdot w$
$\phi_6 \cdot w$
$\phi_7 \cdot w$
$\phi_8 \cdot w$
Training

For each example:
Get $k$-best parses for phrase
Re-weight correct parses as distribution

$(\text{next Monday}, 2013-08-05), 2013-08-12)$

\begin{align*}
\text{moveRight1}(\text{MON}) & \quad \phi_1 \cdot w \\
\text{moveRight1}(\text{FRI}) & \quad \phi_5 \cdot w \\
\text{moveRight}(x, \text{WEEK}) & \quad \phi_2 \cdot w \\
\text{takeLeft}(\text{WEEK}) & \quad \phi_6 \cdot w \\
\text{moveLeft1}(\text{TUE}) & \quad \phi_3 \cdot w \\
\text{takeRight}(\text{MONTH}) & \quad \phi_7 \cdot w \\
\text{moveLeft1}(\text{TUE}) & \quad \phi_4 \cdot w \\
\text{moveRight}(x, \text{MONTH}) & \quad \phi_8 \cdot w
\end{align*}
Training

For each example:
Get $k$-best parses for phrase
Re-weight correct parses as distribution

( (next Monday, 2013-08-05), 2013-08-12 )

moveRight1(MON)
movRight1(−) MON
next Monday

0.57

moveRight( $x$, WEEK )
movRight( $x$,−) WEEK
next Monday

0.36

moveLeft1(TUE)
movLeft1(−) TUE
next Monday

0.00

moveLeft1(FRI)
movLeft1(−) FRI
next Monday

0.00

moveRight1(MON)
movRight1(−) MON
next Monday

0.07

moveLeft1(FRI)
movLeft1(−) FRI
next Monday

0.00

moveRight( $x$, MONTH )
movRight( $x$,−) MONTH
next Monday

0.00

moveRight( $x$,−) MONTH
next Monday

0.00

moveLeft( WEEK )
takLeft(−) WEEK
next Monday

0.00

moveRight( WEEK )
takRight(−) MONTH
next Monday

0.00

moveLeft(−) WEEK
next Monday

0.00

moveLeft(−) MONTH
next Monday

0.00
Training

For each example:
Get $k$-best parses for phrase
Re-weight correct parses as distribution
Gradient update on multiclass hinge loss

For each example:
Get $k$-best parses for phrase
Re-weight correct parses as distribution
Gradient update on multiclass hinge loss
Dataset

TempEval2

Newswire annotated for temporal expressions
TempEval2

Newswire annotated for temporal expressions

6 languages: English, Spanish, Italian, Chinese, Korean, French
Dataset

TempEval2

Newswire annotated for temporal expressions
6 languages: **English**, **Spanish**, Italian, Chinese, Korean, French
Various sizes: **1052**, **1092**, 523, 659, 247, 206 examples
Dataset

**TempEval2**
Newswire annotated for temporal expressions
6 languages: **English, Spanish**, Italian, Chinese, Korean, French
Various sizes: **1052, 1092, 523, 659, 247, 206** examples

**Evaluation**

*Type*: Accuracy over result’s temporal type

August 5, 2013 = August 12, 2013
TempEval2

Newswire annotated for temporal expressions
6 languages: English, Spanish, Italian, Chinese, Korean, French
Various sizes: 1052, 1092, 523, 659, 247, 206 examples

Evaluation

Type: Accuracy over result’s temporal type

August 5, 2013 = August 12, 2013

Value: Accuracy over result’s value, if types match

August 5, 2013 \ne August 12, 2013
Dataset

TempEval2
Newswire annotated for temporal expressions
6 languages: English, Spanish, Italian, Chinese, Korean, French
Various sizes: 1052, 1092, 523, 659, 247, 206 examples

Evaluation
Type: Accuracy over result’s temporal type
August 5, 2013 = August 12, 2013

Value: Accuracy over result’s value, if types match
August 5, 2013 ≠ August 12, 2013
Constrained to guess on each example; no contextual cues
Results

English (all expressions; gold detection)

GUTime (Mani and Wilson, 2000)
SUTime (Chang and Manning, 2012)
HeidelTime (Strötgen and Gertz, 2010)
ParsingTime (Angeli et al., 2012)
Results

English (all expressions; gold detection)

GUTime (Mani and Wilson, 2000)
SUTime (Chang and Manning, 2012)
HeidelTime (Strötgen and Gertz, 2010)
ParsingTime (Angeli et al., 2012)

Spanish

UC3M (Vincente-Díez et al. 2010)
## Results

**English (all expressions; gold detection)**

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUTime</td>
<td>0.80</td>
<td>0.42</td>
</tr>
<tr>
<td>SUTime</td>
<td>0.94</td>
<td>0.71</td>
</tr>
<tr>
<td>HeidelTime</td>
<td>0.85</td>
<td>0.71</td>
</tr>
<tr>
<td>ParsingTime</td>
<td>0.88</td>
<td>0.72</td>
</tr>
</tbody>
</table>
## Results

### English (all expressions; gold detection)

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUTime</td>
<td>0.80</td>
<td>0.42</td>
</tr>
<tr>
<td>SUTime</td>
<td>0.94</td>
<td>0.71</td>
</tr>
<tr>
<td>HeidelTime</td>
<td>0.85</td>
<td>0.71</td>
</tr>
<tr>
<td>ParsingTime</td>
<td>0.88</td>
<td>0.72</td>
</tr>
<tr>
<td>This Work</td>
<td>0.91</td>
<td><strong>0.76</strong></td>
</tr>
</tbody>
</table>
## Results

### English (all expressions; gold detection)

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUTime</td>
<td>0.80</td>
<td>0.42</td>
</tr>
<tr>
<td>SUTime</td>
<td>0.94</td>
<td>0.71</td>
</tr>
<tr>
<td>HeidelTime</td>
<td>0.85</td>
<td>0.71</td>
</tr>
<tr>
<td>ParsingTime</td>
<td>0.88</td>
<td>0.72</td>
</tr>
<tr>
<td>This Work</td>
<td>0.91</td>
<td>0.76</td>
</tr>
</tbody>
</table>

### Spanish

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC3M</td>
<td>0.79</td>
<td>0.72</td>
</tr>
<tr>
<td>This Work</td>
<td>0.92</td>
<td>0.76</td>
</tr>
</tbody>
</table>
## Results

### All Languages (value accuracy)

<table>
<thead>
<tr>
<th>Language</th>
<th># Examples</th>
<th>Train</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>1052</td>
<td>0.81</td>
<td>0.76</td>
</tr>
<tr>
<td>Spanish</td>
<td>1092</td>
<td>0.84</td>
<td>0.76</td>
</tr>
</tbody>
</table>
# Results

## All Languages (value accuracy)

<table>
<thead>
<tr>
<th>Language</th>
<th># Examples</th>
<th>Train</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>1052</td>
<td>0.81</td>
<td>0.76</td>
</tr>
<tr>
<td>Spanish</td>
<td>1092</td>
<td>0.84</td>
<td>0.76</td>
</tr>
<tr>
<td>Italian</td>
<td>523</td>
<td>0.85</td>
<td>0.38</td>
</tr>
<tr>
<td>Chinese</td>
<td>659</td>
<td>0.73</td>
<td>0.60</td>
</tr>
<tr>
<td>Korean</td>
<td>247</td>
<td>0.67</td>
<td>0.42</td>
</tr>
<tr>
<td>French</td>
<td>206</td>
<td>0.76</td>
<td>0.35</td>
</tr>
</tbody>
</table>

First results on remaining 4 languages
## All Languages (value accuracy)

<table>
<thead>
<tr>
<th>Language</th>
<th># Examples</th>
<th>Train</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>1052</td>
<td>0.81</td>
<td>0.76</td>
</tr>
<tr>
<td>Spanish</td>
<td>1092</td>
<td>0.84</td>
<td>0.76</td>
</tr>
<tr>
<td>Italian</td>
<td>523</td>
<td>0.85</td>
<td>0.38</td>
</tr>
<tr>
<td>Chinese</td>
<td>659</td>
<td>0.73</td>
<td>0.60</td>
</tr>
<tr>
<td>Korean</td>
<td>247</td>
<td>0.67</td>
<td>0.42</td>
</tr>
<tr>
<td>French</td>
<td>206</td>
<td>0.76</td>
<td>0.35</td>
</tr>
</tbody>
</table>

First results on remaining 4 languages
Test accuracy correlates with training size
Analysis

What are we still missing?
Analysis

29%  Pragmatics

_Next Saturday?_ → 2013-08-10 or 2013-08-17
29%  **Pragmatics**

*Next Saturday? → 2013-08-10 or 2013-08-17*

*Last year? → a day? a quarter? a year?*
29%  **Pragmatics**

*Next Saturday?* → 2013-08-10 or 2013-08-17

*Last year?* → a day? a quarter? a year?

Hard even for humans
Analysis

29% Pragmatics
16% Type error

Just given *day*

*The past 5 days*
Analysis

29%  Pragmatics
16%  Type error
10%  Incorrect number

Drop the number

Spelled out names: *seventeen seventy-six* → 17 76
29% Pragmatics
16% Type error
10% Incorrect number
7% Absolute versus relative ambiguity

moveLeft1(\text{EveryMonth})

moveLeft1(−) \text{EveryMonth}

\downarrow \quad \downarrow
\text{July} \quad 2013
Analysis

29% Pragmatics
16% Type error
10% Incorrect number
7% Absolute versus relative ambiguity
19% Other parse errors
Analysis

29%  Pragmatics
16%  Type error
10%  Incorrect number
7%   Absolute versus relative ambiguity
19%  Other parse errors
19%  Out of scope
Analysis

29% Pragmatics
16% Type error
10% Incorrect number
7% Absolute versus relative ambiguity
19% Other parse errors
19% Out of scope
16% Missing context

That time
From time to time
Analysis

29%  Pragmatics
16%  Type error
10%  Incorrect number
7%   Absolute versus relative ambiguity
19%  Other parse errors
19%  Out of scope
16%  Missing context

*That time*

*From time to time*

3%   Bad reference time

Annotation error
Reference time is not publication time
Conclusion

Multilingual temporal parsing
  Compositional grammar of time
  Results competitive with state-of-the-art
Conclusion

Multilingual temporal parsing
  Compositional grammar of time
  Results competitive with state-of-the-art

Takeaway points
  Multilingual, with no language-specific tuning
  Rich features over *types* and *values*
  Learns pragmatics of training domain
Thank You!

(Time for questions)