From *Language* to *Time*: A Temporal Expression Anchorer

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Introduction

- Many Natural Language applications need to understand the semantics of *temporal expressions*.
- We developed a constraint-based meaning representation TCNL (Time Calculus for Natural Language).
- We developed system TEA (Temporal Expression Anchorer) for *normalizing* temporal expressions.
- Experiments on emails showed promising results.

Application 1: Emails

```
{thu, 11_day, sep, 1997_year, 0_hour, 14_min, 36_sec} = 19970911T001436
```

Date: **Thu, 11 Sep 1997 00:14:36 -0500**

I have put an outline out in the n10f1 OpReview directory... *(omitted)*

```
+f{thu, night} = (19970911T18????..19970911T23????)
```

We have very little time for this. Please call me **Thursday night** to get clarification. I will need graphs and prose in files **by Saturday Noon.**

```
[f +f{sat, noon}] = min/19970913T12????
```

– Mary

ps. Mark and John , I waited **until AFTER midnight** to send this .

```
[f {>= -p{midnight}}] = min/(19970911..max)
```

Han et al., HLT-NAACL 2006

Application II: QA

Mozart's Activity in Vienna

"Mozart went to Munich to compose the opera **late in 1780**. **The next year**, he was T5 : {1780year} T6 : {-+|1year|} from Munich to Vienna, where the Salzburg court was in residence on the accession of a new emperor. Mozart lived in Vienna for the rest of his life, until he died **in 1791**." T7 : {1791year}

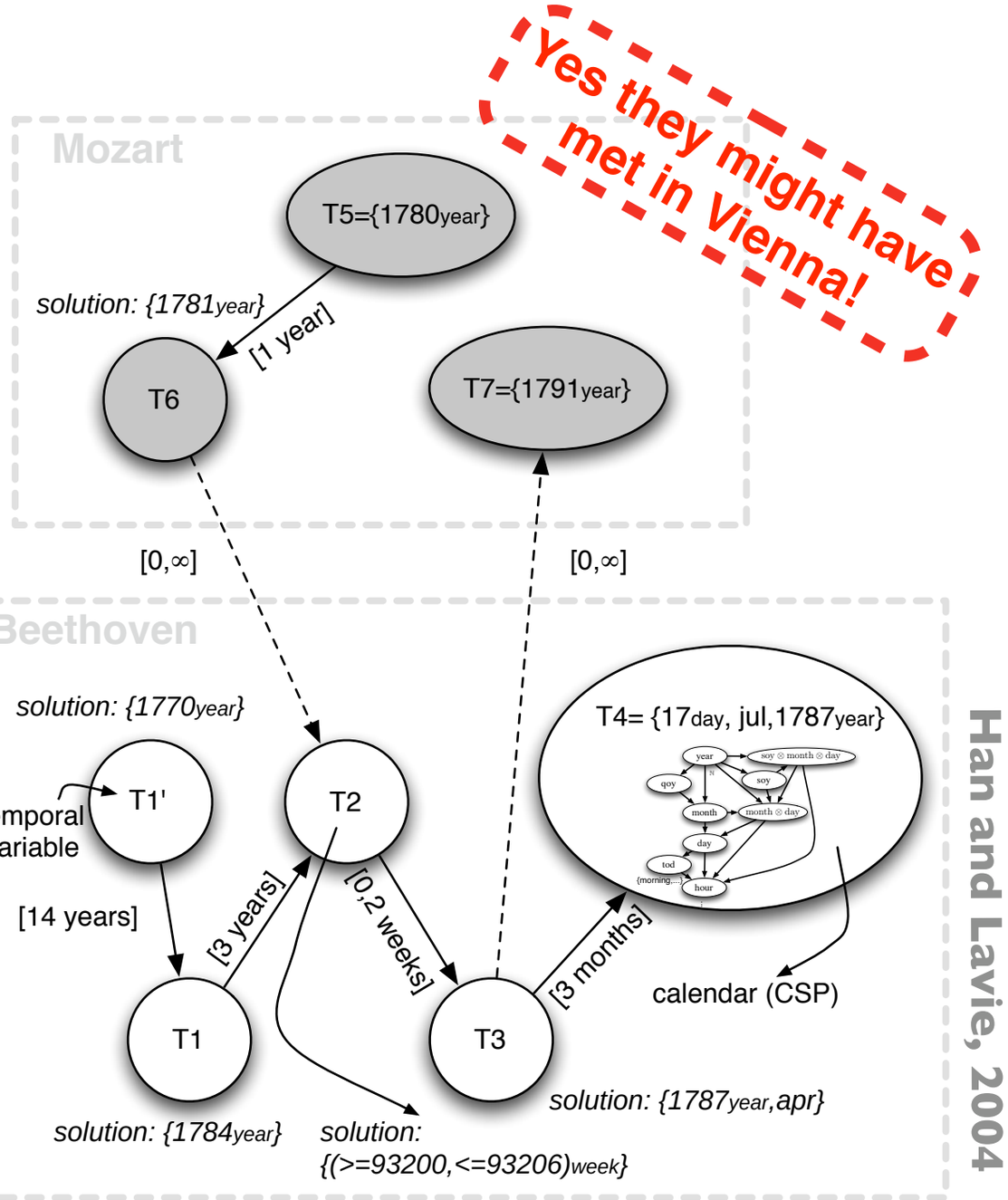
Beethoven's trip to Vienna

T1 : {T1'+|14year|}

"**At 14** Beethoven was able to deputize for his teacher. **Three years later**, recognizi T2 : {-+|3year|} talent, Prince Maximilian Franz sent him to Vienna to further his education. He would soon return **within two weeks** on the news that his mother was dying. She passed away **3 months later on July 17, 1787**.

T3 : {-+|(< 2)week|}

T4 : {-+|3month|, jul, 17day, 1787year}



Temporal Expressions

- 4 types of expressions
  - **Explicit**: Immediately anchorable ("*June 2005*").
  - **Deictic**: Anchorable w.r.t. the *speech time* ("*tomorrow*", "*last year*")
  - **Relative**: Anchorable w.r.t. the *temporal focus* - time central to the discourse ("*on Friday*")
  - **Durational**: Certain length in time ("*two days*", "*less than two hours*")

Temporal Expressions are Complex...

- Many different temporal terms

  summer, *quarter*, ...

- Granularity matters

  tomorrow ≠ *now.day* + 1 (*now* = June 15, 2006 14:00)

- Often under-specified (next slide)

... Especially for Relative Expressions

- Dependency on speech time (tense)
  - "*The company announced on Wednesday...*"
  - "*The company will announce on Wednesday...*"
- Dependency on focus
  - "*Are you free on Wednesday?*"
  - "*Let's meet next week. How about Wednesday?*"
- Hour ambiguity (appears frequently in emails)
  - "*I'll be in school at 9-12.*"

From Language to Time

Date: Thu, 11 Sep 1997 00:14:36

... I will need graphs and prose in files **by Saturday Noon**.

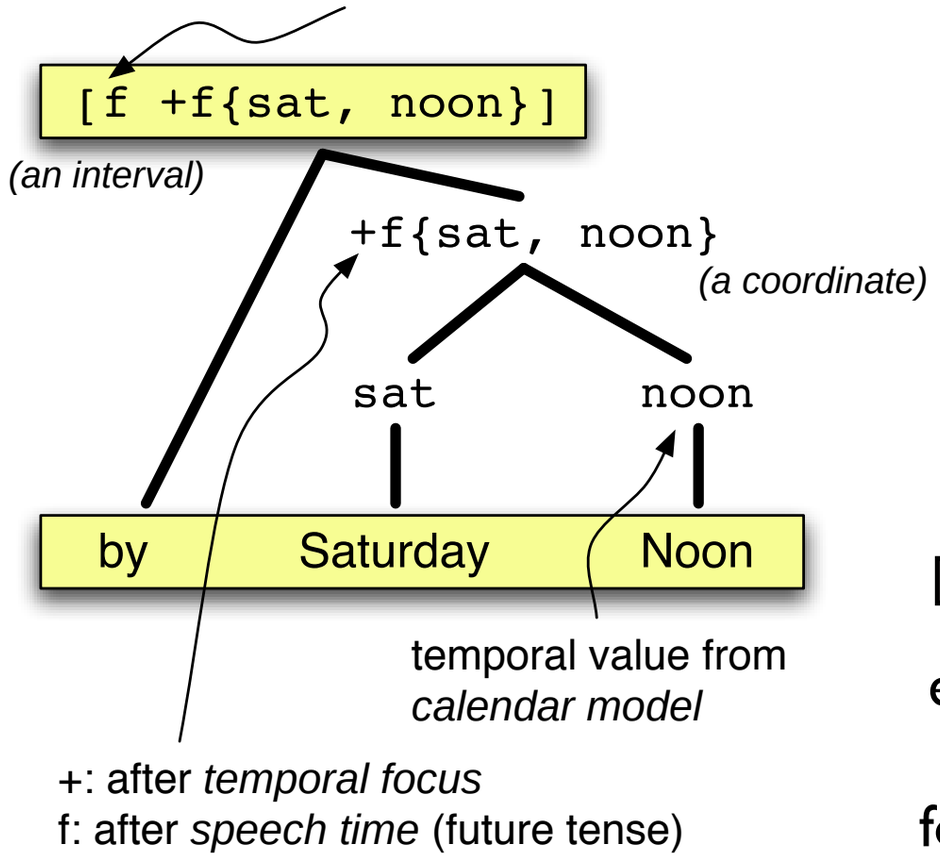
identify verb chunks and tense/aspect

(future tense)

... I **will need** graphs and prose in files **by Saturday Noon**.

build TCNL representation

f: relation *finishes* (Allen 1984)



evaluate TCNL formulae

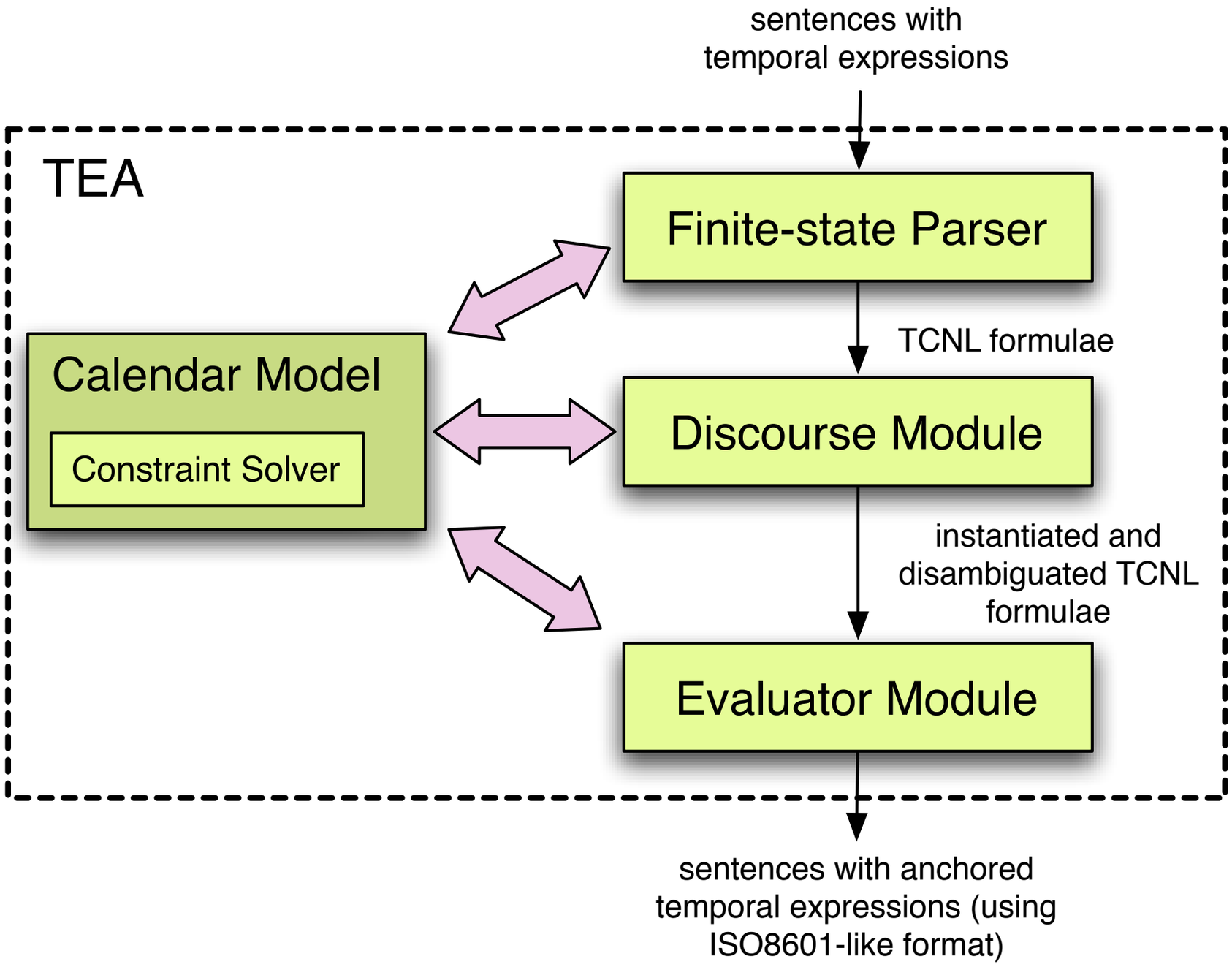
Date: Thu, 11 Sep 1997 00:14:36

... I will need graphs and prose in files **by Saturday Noon**.

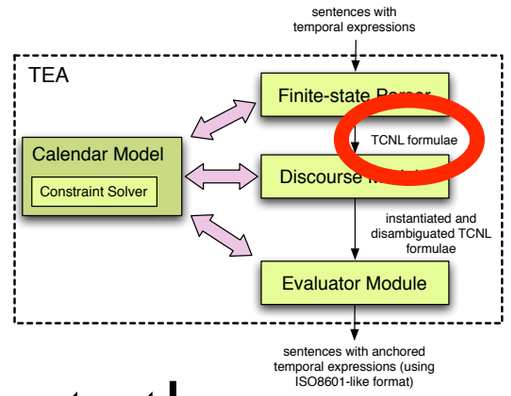
`min/19970913T12????`

(possible temporal focus)

Temporal Expression Anchorer



Time Calculus for Natural Language



- TCNL has two components
  - A (typed) representational language.
  - A constraint-based calendar model that supports the representational language.
- Features
  - Calendar-agnostic: new temporal units can be added.
  - Captures the *intensional* meaning of temporal expressions.
  - Exposes contextual dependency by using variables.
  - Type system and operators make granularity conversion and re-interpretation a transparent process.

Han and Kohlhase, 2003

TCNL: Types

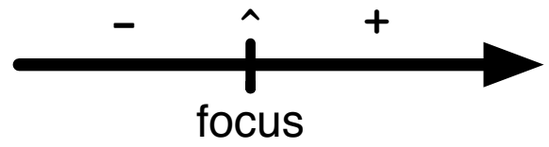
- Three types in TCNL:
  - **Coordinates**: Loosely a time point
    "*September 2005*": `{sep, 2005_year}`
    value unit
  - **Quantities**: Loosely a duration
    "2 *days*": 12_day1
  - **Enumerations**: Sets of coordinates
    "*Wednesday and Friday*": `[{wed}, {fri}]`
    "*from Wednesday to Friday*": `[{wed}:{fri}]`

More Complex Stuff

- Variables
  - Speech time (now): "*tomorrow*": {now+|1_day|}
  - Temporal focus (_): can move in a discourse
    "*Friday the next week*": {fri, _+|1_week|}
- Operators: +/–, @, etc.
  "*the 2nd Sunday in May*": {|2_{sun}|@{may}}
- Relations: <, >, f, d, de, etc [Allen 1984]
  "a *Friday before yesterday*": {fri, < {_-|1_day|}}

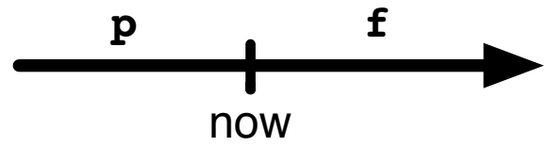
Coordinate Prefixes

- **Focus** prefixes: +/–/^



  - Specifies the relation with focus for *non-generics*.
    "*on Friday*" = `+{fri}` is evaluated as
    `{|1_{fri}|@{>= _}}`
  - ^ is the *saliency* prefix: try + and – and returns the interpretation *closest* to the focus.

- **Tense** prefixes: `f`/`p`



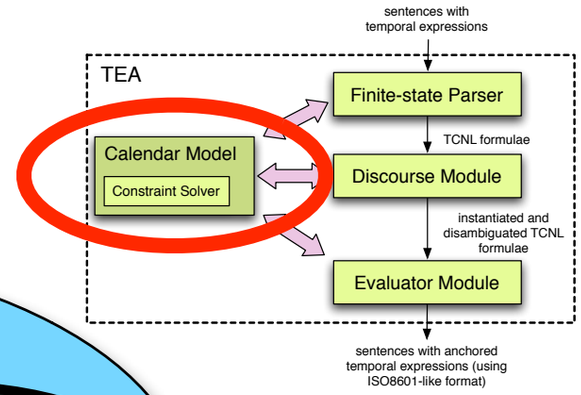
  - Specifies the relation with the speech time.
    "*Friday*" (future) = `f{fri}` is evaluated as `{fri,>=now}`

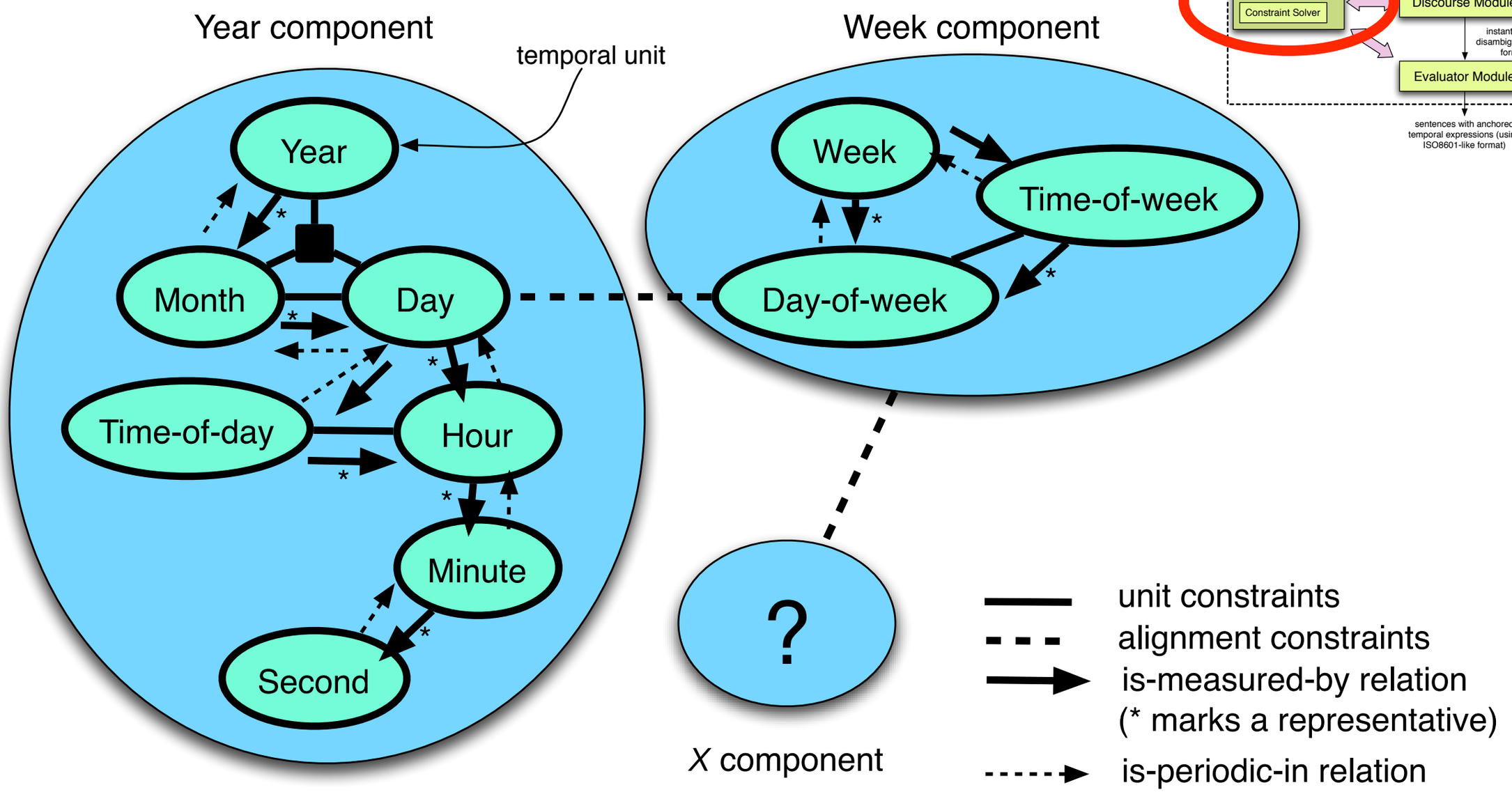
- "*on Friday*" (future) = `+f{fri}` =
  `{|1_{fri}|@{>= _, >= now}}`

Re-interpretation and Granularity Conversion

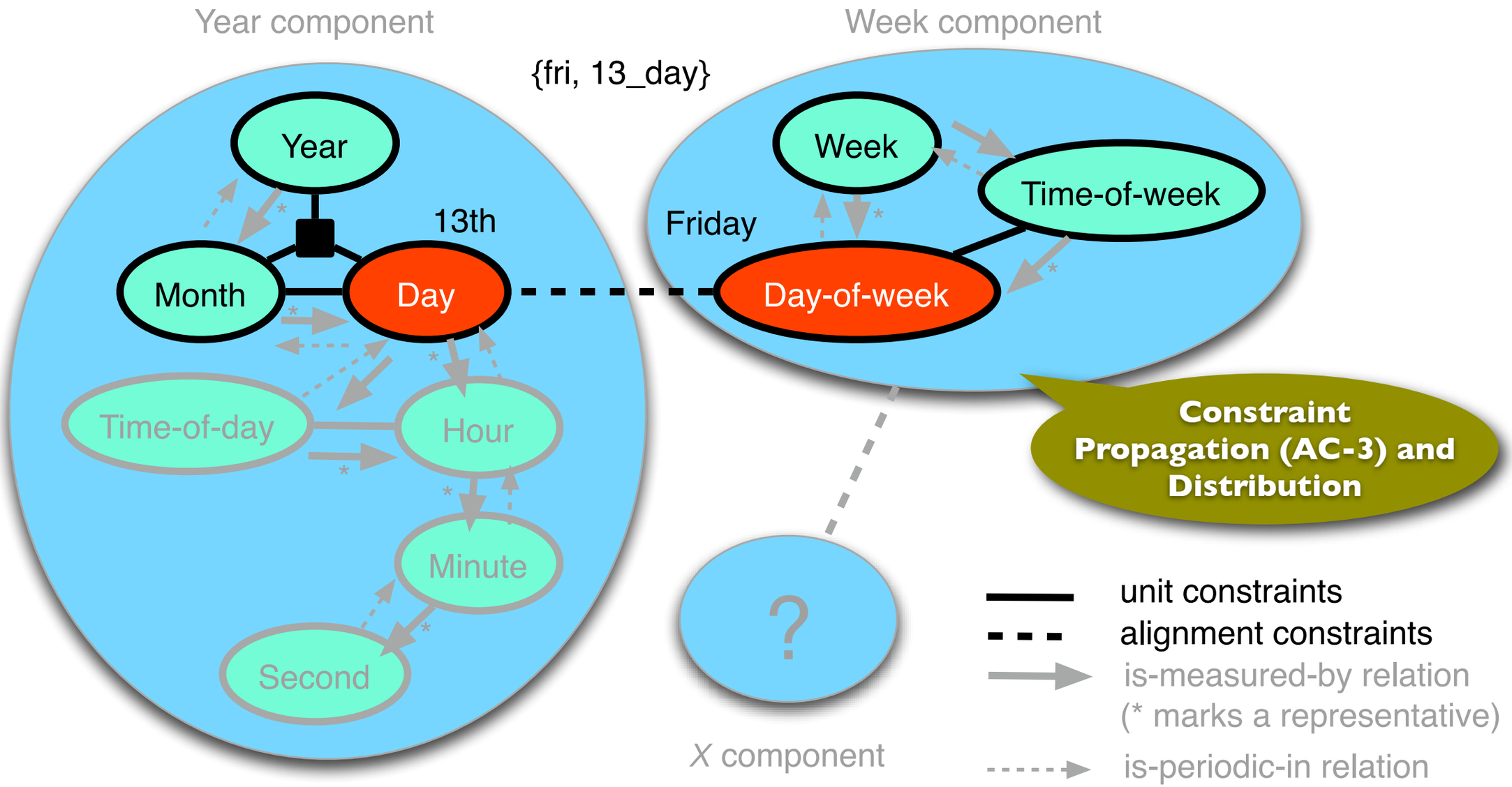
- "*the first week of May, 2006*"
  = `{|1_week|@{may, 2006_year}}`
  - Type requirement of `@` (*ordinal* operator) is $Q \times E \rightarrow C$; granularity requirement is $g(\text{RHS}) \leftarrow g(\text{LHS})$
  - Re-interpret *coordinate* `{may, 2006_year}` of granularity `month` as an *enumeration* in `week`: `[{104633_week}:{104637_week}]`
  - Choose the first element: `{104633_week}`

Calendar Model



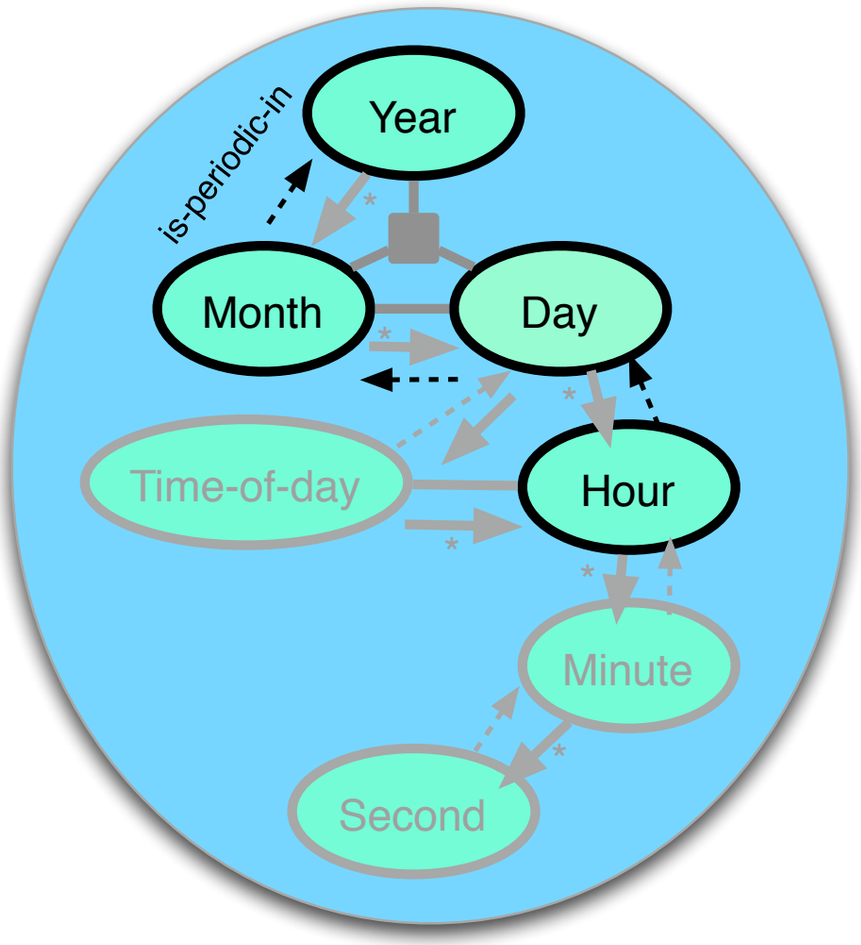


"Friday the 13th"

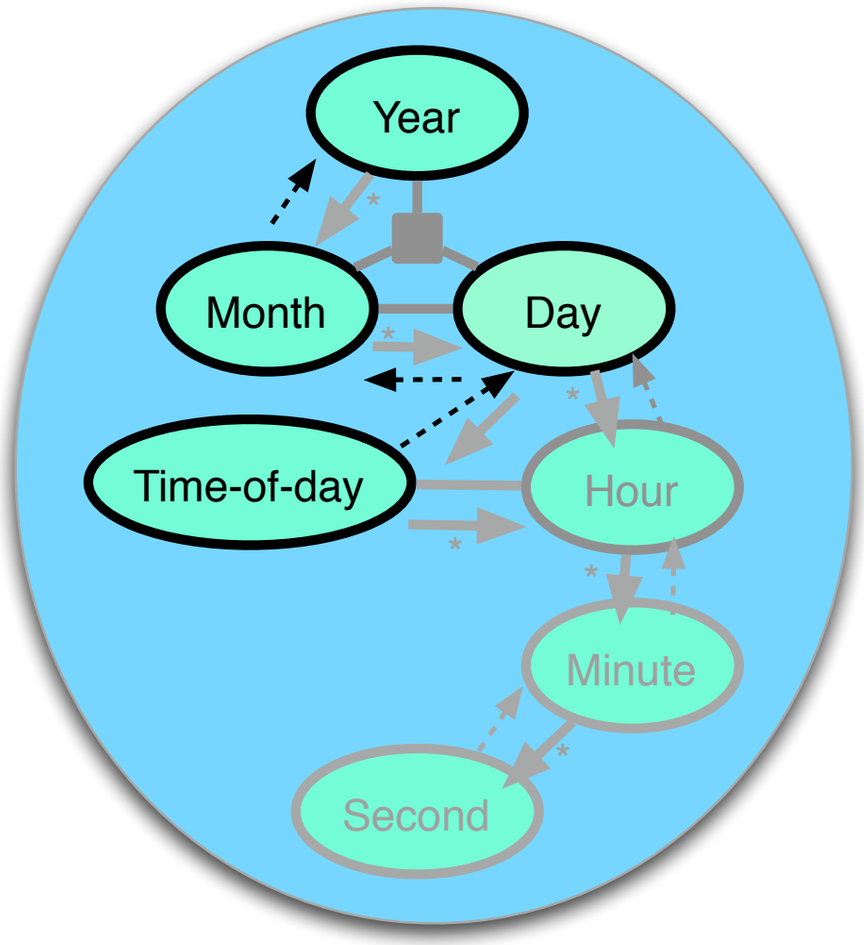


Comparing Times

Anchor path of `hour` =
`<year, month, day, hour>`



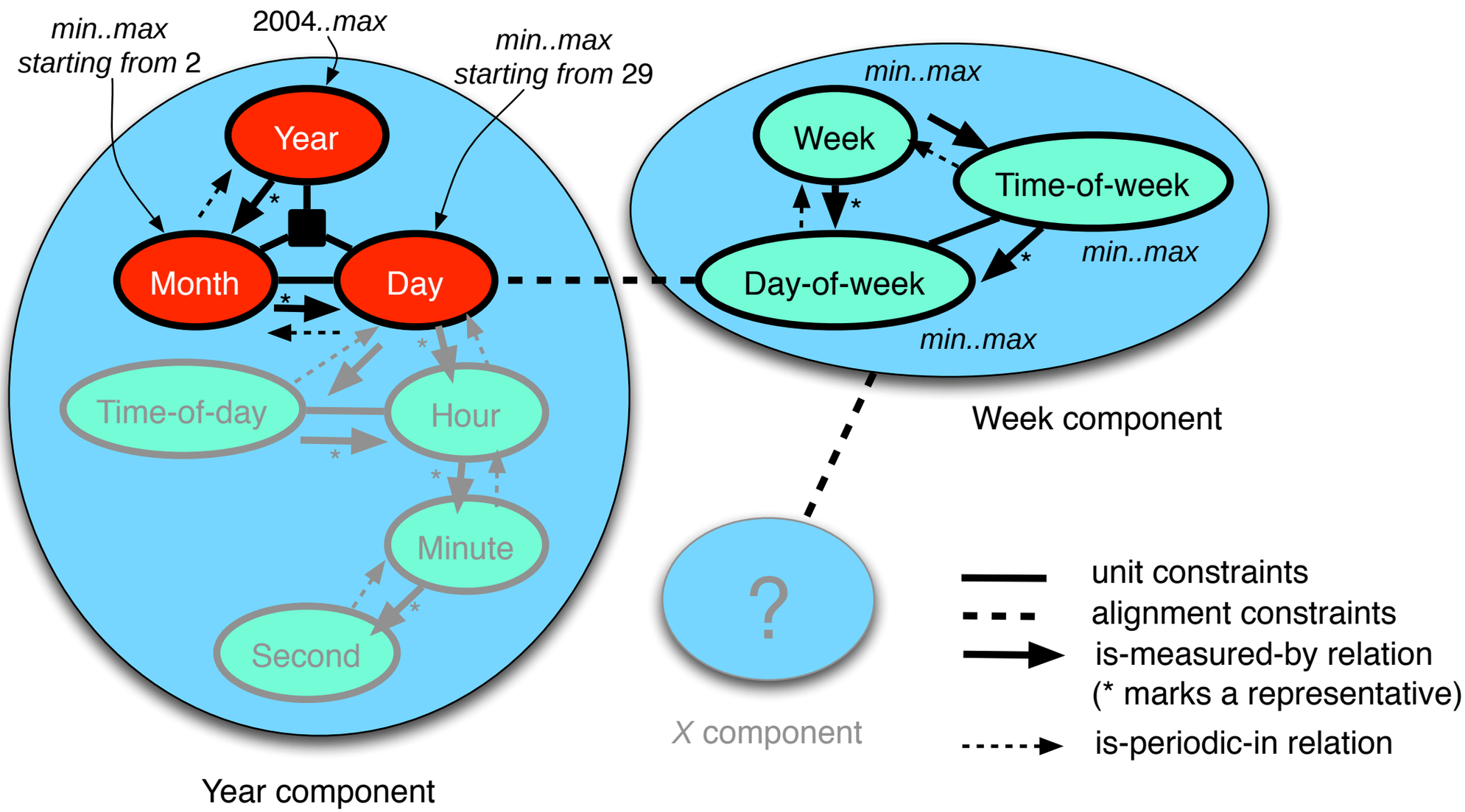
Anchor path of `time-of-day` =
`<year, month, day, time-of-day>`



"*7am, February 29, 2004*" is earlier than "*afternoon on February 29, 2004*"

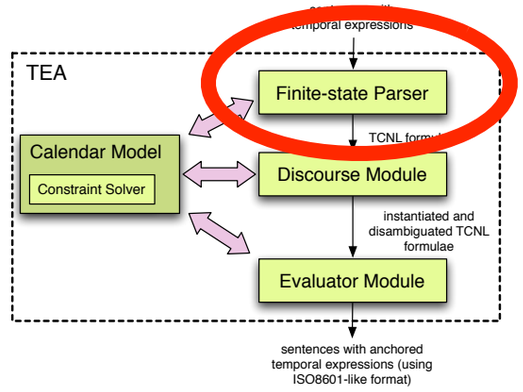
Add = Iterate-and-test

Add *x* days to "*Feb 29, 2004*"



Finite-State Parsing

- Identify the nearest verb chunk and its tense/aspect.
- Partial semantics (granularity) is available to the parser.



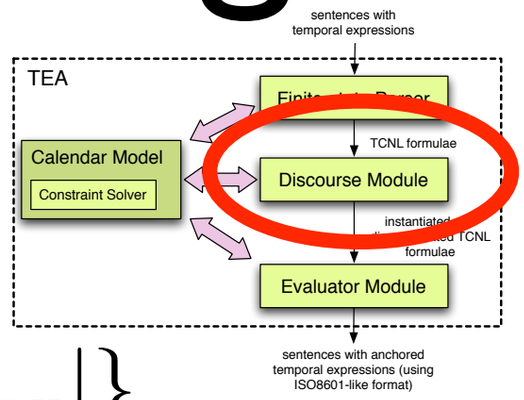
"*Tuesday before Christmas*"
$= \{\texttt{tue}, < \{|25_{\texttt{day}}|@\{\texttt{dec}\}\}\}$ ... 1

"*Tuesday before 6pm*"
$= \{< \{\texttt{tue}, 18_{\texttt{hour}}\}, \textbf{de}\ \{\texttt{tue}\}\}$ ... 2

Pattern "*X before Y*":

- If granularity of X is coarser than Y, choose 2.
- Otherwise choose 1.

Discourse Processing



- Instantiate `now` and _ (focus).

  $\{\_+|2_{\mathtt{day}}|\} = \{\{2006_{\mathtt{year}}, \mathtt{jun}, 5_{\mathtt{day}}\}+|2_{\mathtt{day}}|\}$

- Disambiguation
  - Coordinate: pick the closest to the focus

    $\{3_{\mathtt{hour}}\}|\{15_{\mathtt{hour}}\} \rightarrow \{15_{\mathtt{hour}}\}$ (focus: 1pm)

  - Enumeration: pick the shortest one that begins closest to the focus

    $[(\{3_{\mathtt{hour}}\}|\{15_{\mathtt{hour}}\}) : (\{5_{\mathtt{hour}}\}|\{17_{\mathtt{hour}}\})] \rightarrow$
    $[\{15_{\mathtt{hour}}\} : \{17_{\mathtt{hour}}\}]$ (focus: 1pm)

Focus Tracking

- Heuristic 1: Use the most recently mentioned time as the focus.
- Heuristic 2: Do not use noun-modifying time as the focus.

Date: Sep 19, 1997 10:33:15

*IT basically analyses the breakdown on labor costs and compares our **1998** labor costs with their demands for **1999-2000**.*

...

*I will check mail **on Sunday** and see any feedback.*

Demo: TimeShell

(interactive front-end of TEA)

Experiments: Emails

- Data collected from MBA students @ CMU during a 14-week course running simulated companies [Kraut et al., 2004].
- Hand-picked 1,196/15,000+ emails, and divided them into 5 sets: **email1-email5**.
- All datasets were tagged using MinorThird* rules and manually corrected.
- Evaluated by two of the authors.

* http://minorthird.sourceforge.net

Basic Statistics

	# of emails	# of tempex	explicit	deictic	relative	durational
email1	253	300	3 (1%)	139 (46.33%)	158 (52.67%)	N/A
email2	253	344	19 (5.5%)	112 (32.6%)	187 (54.4%)	27 (7.8%)
email4 (part.)	149	279	71 (25.4%)	77 (27.6%)	108 (38.7%)	22 (7.9%)
email5	126	213	14 (6.6%)	105 (49.3%)	92 (43.2%)	3 (1.4%)

- Explicit expressions account for 9%.
- Estimated baseline = Explicit % + Deictic %.
- Real baseline using **email1** (didn't use tense/ aspect, no focus tracking): 50%.
- Developed on **email2** and **email5**, and tested on **email4**.

Emails are Hard (vs. Newswire)

- Newswire has more *explicit* expressions
  - [Mani et al., 2003] reported **25%** in the North American News Corpus. We have **9%**.

- Other quirks of emails
  - Reply/forwarding.
  - Addressing to multiple recipients.
  - Creative formatting/spelling.
  - Human errors.

Examples

Creative formatting

So here is the summary of the today's meeting... *(snipped)*

Presenter	Time (min)	Items
Takeshi	**12**	Company's Past Performance, and Our Goal
George	**8**	The Overall Strategy, and the ...
...		

Addressing to multiple people

Mike,

I will show you the table **on Wednesday** ... (snipped)

Emily,

If you are able to finish your sections **Monday night...** *(snipped)*

Human errors

Date: **Mon**, 15 Sep 1997 00:20:11

As for the labor proposal, we should have it first thing **tomorrow (Monday) morning...** *(snipped)*

Results

	Accuracy	Parsing errors	Human errors	Anchoring errors
email2 (dev)	78.2%	10.47%	1.7%	9.63%
email5 (dev)	85.45%	5.16%	1%	8.39%
email4 (testing)	76.34%	17.92%	$< 1\%$	5.74%

- Accuracy = $\frac{\text{\# of correctly anchored expressions in dataset } X}{\text{total \# of expressions in dataset } X}$
- Parsing errors: Finite-state Parser failed transducing a temporal expression into its TCNL representation.
- Anchoring errors: incorrect focus, anchoring generics, etc.

Related Work

- Representation/annotation: Zeitgram [Stede and Hass 1998], TOP [Androutsopoulos 1999], Timex3/ TimeML [Saurí et al., 2006].
- Normalizing temporal expressions on *newswire*: [Mani and Wilson 2000], [Schilder and Habel 2001], [Filatova and Hovy 2001], [Mani et al. 2003].
- Normalizing temporal expressions on *transcribed phone conversations*: [Wiebe et al., 1998]
  - Reported average accuracy 80.9% on CMU corpus and 68.9% on NMSU corpus.

Conclusion

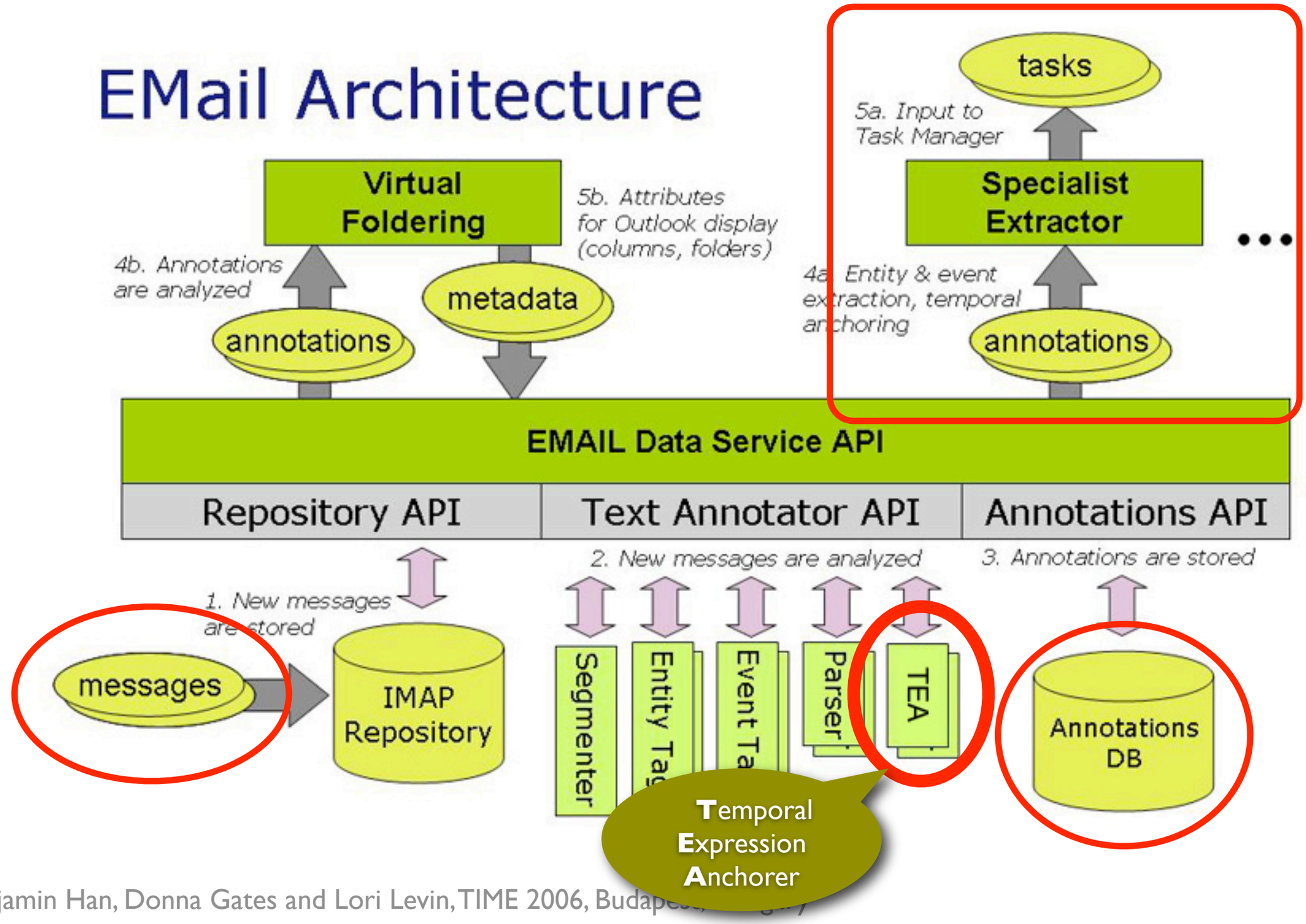
- Developed TCNL and its underlying constraint-based reasoning mechanism for temporal expressions.
- Connected natural language with the representation through the development of TEA.
- Experiments on a novel and challenging genre: emails.
- TEA showed promising performance, but much room for improvement.

Future Work

- Expand representation/parsing coverage: recurrence expressions ("3-5 every Tuesday and Thursday", "every 4 years").
- A better focus tracking method using various syntactic/semantic cues.
- Detect generics/non-generics.
- Testing on other genres (newswire ongoing).

Questions?

RADAR Architecture



TCNL: Operators

operator	Type requirement	Granularity requirement	Semantics	Example
$+$ and $-$	$C \times Q \rightarrow C$	$g(LHS) \leftarrow g(RHS)$	fuzzy forward/backward shifting	$\{\texttt{now}+\lvert 1_{\texttt{day}}\rvert\}$ (“*tomorrow*”)
$++$ and $--$	$C \times Q \rightarrow C$	$g(LHS) \leftarrow \min(g(LHS) \cup g(RHS))$	exact forward/backward shifting	$\{\texttt{now}++\lvert 2_{\texttt{hour}}\rvert\}$ (“*2 hours from now*”)
@	$Q \times E \rightarrow C$	$g(RHS) \leftarrow g(LHS)$	ordinal	$\{\lvert 2_{\{\texttt{sun}\}}\rvert @\{\texttt{may}\}\}$ (“*the 2nd Sunday in May*”)
&	$C \times C \rightarrow C$ $C \times E \rightarrow E$ $E \times C \rightarrow E$ $E \times E \rightarrow E$	$g(LHS) \leftarrow \min(g(LHS) \cup g(RHS))$	distribution	$\{\texttt{now}\ \&\{\texttt{now}+\lvert 1_{\texttt{year}}\rvert\}\}$ (“*this time next year*”) $[\{15_{\texttt{hour}}\}\&[\{\texttt{wed}\}:\{\texttt{fri}\}]]$ (“*3pm from Wednesday to Friday*”)

TCNL: Relations

Relations	**Type requirement**	**Semantics**
$<, <=, >=, >$	Q $\times$ Q	shorter-than, shorter-than or equal-to, longer-than or equal-to, and longer-than
$<, <=, >=, >$	C $\times$ C	before, before or equal-to, after or equal-to, and after
b, **s**, **d**, **de**, **f**, **di**	C $\times$ E	LHS is before/starting/during/during-equal/finishing/after RHS; **de** is defined as (**s** or **d** or **f**).
b, **s**, **f**, **bi**	E $\times$ C	LHS is a maximal interval that is before/starting at/finishing at/after RHS.
b, **m**, **o**, **s**, **d**, **f**, **=**, **fi**, **di**, **si**, **oi**, **mi**, **bi**	E $\times$ E	See [1].

TCNL vs. Timex3/TimeML

- Different goals
  - Timex3/TimeML is designed mainly for annotation, and it includes event annotations too.
  - TCNL is designed to be a *computable* representation.
- TCNL is calendar-agnostic: new temporal units/values can be added
  - fiscal quarters, semesters, etc.
- TCNL delegates focus tracking to an external mechanism

TCNL vs. Timex3/TimeML

- Example: "*two weeks from next Tuesday*"

Timex3/TimeML (Saurí et al., 2006):

```
<TIMEX3 tid="t1" type="TIME" value="2002-08-06"
 temporalFunction="true" anchorTimeID="t0">
two weeks from next Tuesday</TIMEX3>
```

TCNL:

$\{\{_{-}+|1_{\{\texttt{tue}\}}|\}++|2_{\texttt{week}}|\}$ (what _ denotes is decided separately)

Results

- Accuracy on each expression type

	explicit	deictic	relative	durational
email2 (dev)	89.47%	94.64%	67.38%	77.78%
email5 (dev)	100.00%	94.29%	73.91%	66.67%
email4 (testing)	95.77%	83.12%	74.07%	0.00%
weighted avg	94.26%	90.71%	71.28%	48.99%

Creative formatting (numbers in table)

Easiest (emails vs. news = 9% vs. 25%)

$$\% = 100\% - \frac{\#\text{ or errors on expression type } X \text{ in dataset } Y}{\text{total } \#\text{ of expression type } X \text{ in dataset } Y}$$

Results

- Percentages of errors made on each expression type

	explicit	deictic	relative	durational
email2 (dev)	2.67%	8.00%	81.33%	8.00%
email5 (dev)	0.00%	19.35%	77.42%	3.23%
email4 (testing)	4.55%	19.70%	42.42%	33.33%
weighted avg	2.91%	14.53%	65.70%	16.86%

$$\% = \frac{\text{\# or errors on expression type } X \text{ in dataset } Y}{\text{total \# of errors in dataset } Y}$$

Error Cases

Speech time can change too

Date: **Wed, 10 Sep 1997 12:02:27**
Subject: Fwd: Yes we have class

Please start the meeting at **6:00PM** without me first. *(snipped)*

--- Forwarded message begins here ---
Date: **Tue, 9 Sep 1997 20:11:41**

... I just wanted to remind you that we will have class **tomorrow night** in Mellon auditorium. *(snipped)*

Richer calendar model is needed

Date: **Mon, 25 Aug 1997 09:24:37**

So **the first day of our school year** has begun. *(snipped)*

Tense can hurt (or lexical semantics matters too)

Date: **Mon, 25 Aug 1997 09:24:37**

... Well , I reserved 318 room **from 4pm to 7pm.** *(snipped)*

Focus tracking is hard

Date: **Fri, 19 Sep 1997 02:34:19**

... The next move is **Tuesday next week.** Let's get together **Monday 3:30PM.** *(snipped)*

Forward referencing focus

Date: **Sun, 07 Sep 1997 09:32:15**

... We have got a **9am** scheduled for **Tues** and I'd like to leave it at that. *(snipped)*

Generics

The deadline for the announcement is **the morning** of the game move prior to the game move in which your firm wants to buy or sell your own stock.

(snipped)

If you wish to buy or sell stock on **wednesday,** the s-1 should be posted **on Sunday morning.**