Temporal Reasoning in Language

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Motivation: Question-Answering

Q&A systems need to resolve temporal expressions in questions and answers

When is Ramadan this year?

What is the largest U.S. military operation since Vietnam?

How many Canadians have died of SARS since February?

What is the current unemployment rate?

How many Iraqi civilian casualties were there in the first week of the U.S. invasion of Iraq?

- Q: When did the Berlin Wall fall?
- A: Thursday

  East German border workers began dismantling the Berlin Wall at the historic Brandenburg gate on Thursday night to make a new crossing.

Motivation: Coherent and Faithful Summaries

- Single-document sentence extraction summarizers (e.g., BioGen) are plagued by dangling references
  - especially temporal ones

- Multi-Document summarizers can be misled by the weakness of vocabulary overlap methods
  - leads to inappropriate merging of distinct events

..worked *in recent summers..*

..was the source of the virus *last week..*

…where Morris was a computer science undergraduate *until June..*

…..whose virus program *three years ago* disrupted…

14 Oct 2000 07:27:13 -0400 (EDT)
GULU: **on 13 Oct 2000**, it was reported that at least 30 people in this northern Uganda town **have died in recent weeks** of a hemorrhagic fever that authorities fear may be caused by the Ebola or Marburg virus.
14 Oct 2000 23:25:01 -0400
So far 10 people have died in hospital, including 3 nurses treating the
16 Oct 2000 11:42:34 GMT
KAMPALA: The dreaded Ebola virus that struck over 300 people in Kikwit, in the Democratic Republic of Congo in 1995, has killed 31 people in northern Uganda.
17 Oct 2000 09:33:41 -0400
NAIROBI - Fears of the deadly Ebola fever gripped Kenya **on Monday as 2 children died** of a mystery disease and several others were admitted to hospital. The disease is reported to have killed 37 people in northern Uganda at the weekend.
17 Oct 2000 21:37:42 -0200
NAIROBI: **By Tue 17 Oct 2000**, Radio Uganda was reporting 73 known cases, of whom 37 had **died**.
18 Oct 2000 13:26:08 GMT

A Strawman and its Problems

1. Ignore relative times!
   - More than 66% of time expressions are relative[1]
2. Interpret relative dates in questions with respect to current date!
   - Will address only a small subset of question types
3. Interpret relative dates in documents with respect to Document Creation Time (DCT)!
   - Only 15% of time expressions refer directly to DCT[2]
   - At least 42% of uses of today are non-specific[3]
   - Ignoring direction of offset will lead to errors, e.g., last February, February
   - Requires calendar arithmetic anyway
4. Don't bother to link events to times!
   - Will miss event-dependent temporal expressions

[1]study of 728 time expressions
[2]study of 1916 clauses
[3]study of 191 *today* sentences

Embedded tenses in English

Three interpretations of embedded tenses:

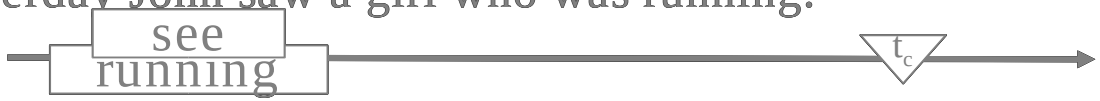
Absolute: embedded tense is independent of main clause tense

Yesterday John saw a girl who was running this morning.

This morning John saw a girl who was running yesterday.

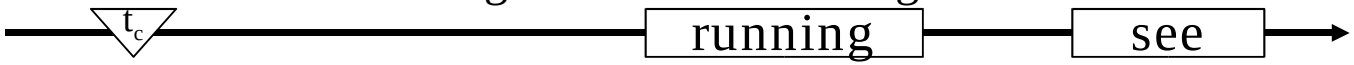
Anaphoric: embedded tense is anaphoric on the main clause tense

Yesterday John saw a girl who was running.



Relative: embedded tense is interpreted with respect to the main clause tense

Tomorrow John will see a girl who was running earlier.



Constraints on interpretation

- Tense interpretation displays both structural restrictions and lexical preferences

Relative clause interpretation:

At the party John danced with the woman (previously/later) he ate dinner with.

At the party John met the woman he married

Complement clause interpretation

At the party John said that he (previously/??later) ate dinner with a certain woman.

Crosslinguistic variation

Variation in relative clause interpretation

- Japanese

  Mariko-wa naiteiru otokonoko-ni hanasikaketa

  Mariko-TOP cry-teiru-PRES boy-to talk-PAST

  “Mariko talked to the boy who is/was crying”

- Russian

  Ma?sa videla ?celoveka, kotoryj placet.

  Masha see-PAST-IMP man who cry-PRES

  “Masha saw a/the man who is crying”

Crosslinguistic variation

Variation in complement clauses interpretation

- Japanese

  Bernhard-wa Junko-ga byookida to it-ta

  B.-TOP J.-NOM sick-PRES comp say-PAST

  “Bernhard said that Junko was sick”

- Russian

  Ma?sa skazala, cto Vova spit.

  Masha say-PAST-PERF that Voval sleep-PRES

  “Masha said that Vova was sleeping”

Embedded tenses cross-linguistically

	Relative	Complement
Eng./Ish.	absolute state +	relative + weight on-
Japanese	absolute	relative
Kiswahili	absolute	relative

Via cross-linguistic investigation a picture of embedded tenses emerges:

- Absolute tense is limited to relative clauses
- Relative tense is predominant in complement clauses

The Conceptual and Linguistic Basis

- TimeML presupposes the following temporal entities and relations.
- Events are taken to be situations that occur or happen, punctual or lasting for a period of time. They are generally expressed by means of tensed or untensed verbs, nominalisations, adjectives, predicative clauses, or prepositional phrases.
- Times may be either points, intervals, or durations. They may be referred to by fully specified or underspecified temporal expressions, or intensionally specified expressions.
- Relations can hold between events and events and times. They can be temporal, subordinate, or aspectual relations.

Events and Relations

Event expressions;

- **tensed verbs;** has left, was captured, will resign;
- **stative adjectives;** sunken, stalled, on board;
- **event nominals;** merger, Military Operation, Gulf War;

Dependencies between events and times:

- **Anchoring;** John left on Monday.
- **Orderings;** The party happened after midnight.
- **Embedding;** John said Mary left.

Relating Events and Times

Anchoring:

- *John taught on Monday*

∃e1[teaching(e1,john) & on(e1,Monday) & PAST(e1)]

Relations:

- *John said he taught*

∃e1 ∃e2[saying(e1,john) & teaching(e2,john) & PAST(e1)] & PAST(e2) & e1>e2]

Temporal Expressions

- Fully Specified Temporal Expressions
  - **June 11, 1989**
  - **Summer, 2002**
- Underspecified Temporal Expressions
  - **Monday**
  - **Next month**
  - **Last year**
  - **Two days ago**
- Durations
  - **Three months**
  - **Two years**

ISO 8601 Standard

- **1994-11-05T08:15:30-05:00**
  - corresponds to November 5, 1994, 8:15:30 am, US Eastern Standard Time.
- **1994-11-05T13:15:30Z**
  - corresponds to the same instant.

Year:

YYYY (eg 1997)

Year and month:

YYYY-MM (eg 1997-07)

Complete date:

YYYY-MM-DD (eg 1997-07-16)

Complete date plus hours and minutes:

YYYY-MM-DDThh:mmTZD (eg 1997-07-16T19:20+01:00)

Complete date plus hours, minutes and seconds:

YYYY-MM-DDThh:mm:ssTZD (eg 1997-07-16T19:20:30+01:00)

Complete date plus hours, minutes, seconds and a decimal fraction of a second

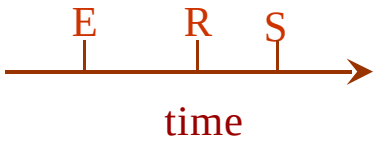
YYYY-MM-DDThh:mm:ss.sTZD (eg 1997-07-16T19:20:30.45+01:00)

Tense as Anaphor: Reichenbach

- Tensed utterances introduce <u>references</u> to 3 'time points'
  - Speech Time: S
  - Event Time: E
  - Reference Time: R

$_S$I had [mailed the letter]$_E$ [when John came & told me the news]$_R$

$E < R < S$



- The concept of 'time point' is an abstraction –- it can map to an interval
- Three temporal relations are defined on these time points
  - at, before, after
- 13 different relations are possible

Reichenbachian Tense Analysis

Relation			
E<R<S	Anterior past	Past perfect	I had slept
E=R<S	Simple past	Simple past	I slept
E<S= R	Anterior present	Present perfect	I have slept
S= R= E	Simple present	Simple present	I sleep
S= R<E	Posterior present	Simple future	I will sleep *Je vais dormir*
S<R=E	Simple future	Simple future	I will sleep *Je dormirai*
S<R<E	Posterior future		I shall be going to sleep

E>R<S

E<R>S

- <u>Tense</u> is determined by relation between R and S
  - R=S, R<S, R>S
- <u>Aspect</u> is determined by relation between E and R
  - E=R, E < R, E> R
- Relation of E relative to S not crucial
  - Represent R<S=E as E>R<S
- Only 7 out of 13 relations are realized in English
  - 6 different forms, simple future being ambiguous
  - Progressive no different from simple tenses
    - But I was eating a peach ≠> I ate a peach

Tense as Operator: Prior

Relation				
E<R<S	Anterior past	PP?	Παστ περφεχτ	I ηαδ σλεπτ
E=P<Σ	Σιμπλε παστ	Π?	Σιμπλε παστ	I σλεπτ
E<Σ= P	Αντεριορ πρεσεντ	Π?	Πρεσεντ περφεχτ	I ηαϖε σλεπτ
Σ= P= E	Σιμπλε πρεσεντ	?	Σιμπλε πρεσεντ	I σλεεπ
Σ= P<E	Ποστεριορ πρεσεντ	Φ?	Σιμπλε φυτυρε	I ωιλλ σλεεπ ϑε ϖαισ δορμιρ
Σ<P=E	Σιμπλε φυτυρε	Φ?	Σιμπλε φυτυρε	I ωιλλ σλεεπ ϑε δορμιραι
Σ<P<E	Ποστεριορ φυτυρε	ΦΦ?		I σηαλλ βε γοινγ το σλεεπ

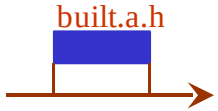
- Free iteration captures many more tenses,
  - *I would have slept* $PFP\phi$
- But also expresses many non-NL tenses
  - PPPPϕ [*It was the case*]^4 *John had slept*

Aspect

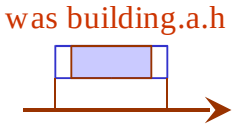
- Two Varieties
  - Grammatical Aspect
    - Distinguishes viewpoint on event
  - Lexical Aspect
    - Distinguishes types of events (situations) (eventualities)
    - Also called Aktionsarten

Grammatical Aspect

- Perfective – focus on situation <u>as a whole</u>
  - John built a house



- Imperfective – focus on <u>internal phases</u> of situation
  - John was building a house



Aktionsarten

- STATIVES *know, sit, be clever, be happy, killing, accident*
  - can refer to state itself (ingressive) *John knows* , or to entry into a state (inceptive) *John realizes*
  - **John is knowing Bill, *Know the answer, *What John did was know the answer*
- ACTIVITIES *walk, run, talk, march, paint*
  - if it occurs in period t, a part of it (also an activity) must occur for every/most sub-periods of t
  - X is Ving entails that X has Ved
  - *John ran for an hour, *John ran in an hour*

	Telic	Dynamic	Durative	E.g.
Stative	-	-	+	know, have
Activity	-	+	+	walk, paint
Accomplishment	+	+	+	destroy, build
Achievement	+	+	-	notice, win

- ACCOMPLISHMENTS *build, cook, destroy*
  - culminate (telic)
  - x Vs for an hour does not entail x Vs for all times in that hour
  - X is Ving does not entail that X has Ved.
  - *John booked a flight in an hour, John stopped building a house*
- ACHIEVEMENTS *notice, win, blink, find, reach*
  - instantaneous accomplishments
  - **John dies for an hour, *John wins for an hour, *John stopped reaching New York*

Allen (1984)
Temporal Logic

- **Time primitives are temporal intervals.**

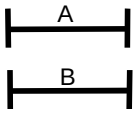
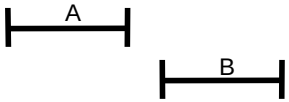
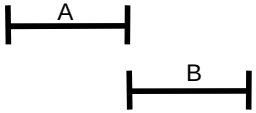
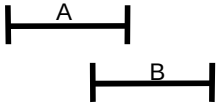
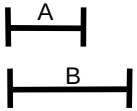
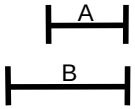
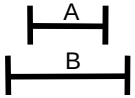
- **No branching into the future or the past**

- **13 basic (binary) interval relations**
  - **[b,a,eq,o,oi,s,si,f,fi,d,di,m,mi],**
    (six are inverses of the other six)

- **Supported by a transitivity table that defines the conjunction of any two relations.**

- **All 13 relations can be expressed using *meet*:**
  - **Before (X, Y) $\Rightarrow$ $\exists$Z , (meets(X, Z) $\wedge$ (meets (Z, Y))**

Allen's 13 Temporal Relations

	A is EQUAL to B B is EQUAL to A
	A is BEFORE B B is AFTER A
	A MEETS B B is MET by A
	A OVERLAPS B B is OVERLAPPED by A
	A STARTS B B is STARTED by A
	A FINISHES B B is FINISHED by A
	A DURING B B CONTAINS A

Allen's Temporal Ontology

- ***Properties*** **hold over every subinterval of an interval**

  —> Holds(*p*, *T*) e.g., "John was sick for a day."

- ***Events*** **hold only over an interval and not over any subinterval of it.**

  —> Occurs(*e*, *T*) e.g., "Mary wrote a letter this afternoon."

- ***Processes*** **hold over *some* subintervals of the interval they occur in.**

  —> Occuring(*p*, *T*) e.g., "Mary is writing a letter today."

Situation Type: Formal Constraints

- Homogeneity
  - All subevents of P are also of P (downward entailment)
    - though only down to a minimal size
  - The sum of all subevents of P are also of P (upward entailment)
- Subinterval Property
  - Activity: x Ps for t => x P's for all subintervals of t. excluding those below a minimal size and excluding certain gaps
    - *For* is downward entailing, but the maximal interval is more felicitous
  - Accomplishment: x Ps in t => there is a subinterval t' of t in which Become(x, P) is true
    - *In* is upward entailing, but the minimal interval is more felicitous
    - In-adverbials apply to quantized event predicates
      - A predicate is quantized iff whenever it applies to e it doesn't apply to subparts of e

Event Structure

- Quantification over events as individuals: I.e., events as first-order objects.
- Finer-grain representation than Prior's tense logic.
- Allows representation of word-based causality.
- Simplifies reasoning with identity and overlap relations.

Theories of Event Structure

Davidson (1967): Proposes individuation over events.

Kamp (1968): Formal Model for tensed events, extending Prior's Tense Logic to predicates.

Moens and Steedman (1988): Finite-state model of event phases.

Pustejovsky (1991): Phrase structure model for subevent semantics for word meaning.

McCarthy and Hayes (1969)
The Situation Calculus

- Represents actions and their effects on the world
- The world is represented as a set of **states.**
- **Fluents** are time-varying properties of individuals.
- **Actions** are functions that map states to states.
- Used for multiple tasks, especially planning
- Major problems:
  - Concurrent actions cannot be represented
  - No duration of actions or delayed effects

Hayes 1985
Histories in Naïve Physics

- A **history** is an entity that incorporates time and space
- An **object** *O* in a **situation** *s* is the intersection of the situation with the object's history
- Permanent locations are bound spatially, but are restricted temporally
- Situations are unbound spatially, but are limited temporally by surrounding events
- Most objects are between these two extremes
- **Events** are instantaneous
- **Episodes** have a duration

- The history of an object is described over time

Kowalski & Sergot (1986)
Event Calculus

- ***Developed for updating databases and for narrative understanding***
- ***Based on the notion of an event and its descriptions (relationships)***
- ***Relationships are ultimately over time points***

  after(e) = the period of time started by event e

- ***Udates can only add; deletions add new information about the end of the period of time over which the old relationship holds***
- ***Uses nonmonotonic, default reasoning since relations change as new***

  information arrives (a new event can signal the end of an old one)

- ***Allows partial description of events, using semantic cases***
- ***Defined and interpreted as Horn clauses in Prolog***

Properties of Events

Events have parts:

The rock broke the window.

$\exists e1 \exists e2[action(e1,rock,window)\ \&$
$broken(e2,window)\ \&$
$e1<e2]$

Actions have consequences:

Mary arrived in Boston.

$\exists e1 \exists e2[action(e1,mary,boston)\ \&$
$in(e2,mary,boston)\ \&$
$e1<e2]$

Introduction to TimeML

- A Proposed Metadata Standard for Markup of events, their temporal anchoring, and how they are related to each other in News articles.

- Product of TERQAS Workshop 2002.

TimeML 1.0

- Adopts the core of Setzer's annotation framework (Sheffield Temporal Annotation Guidelines, STAG)
- Remains compliant (as much as possible) with TIDES TIMEX2 annotation.
- Introduces a TLINK tag: an object that links events/times to events/times.
- Introduces an ALINK tag: an object that associates aspectual phases to events.
- Introduces an SLINK tag: an object that subordinates events within modality, negation, or another event.
- Enrich temporal relations: adds i-after, i-before, and aspectual relations.
- Introduces event identity.
- Introduces Temporal functions for doing temporal math without evaluation.
- Introduces STATE as a possible event class.

TIDES TIMEX2 Examples

The Foreign Minister told Thailand's Nation Newspaper <TIMEX2 VAL="1998-01-04">Sunday</TIMEX2> Pol Pot had left Cambodia but was not in Thailand, ending credence to a claim <TIMEX2 VAL="1997-W52">last week</TIMEX2> the aged and ailing former Khmer Rouge leader had fled to China.

……. …

But in <TIMEX2 NON_SPECIFIC="YES">today</TIMEX2>'s Japan, the impossible has become possible, and in <TIMEX2 VAL="1998-12">December</TIMEX2>, seven years shy of his retirement, Akimoto "quit" and joined the 2.91 million other Japanese who are officially looking for a job.

TIMEX2 Annotation Scheme

Time Points <TIMEX2 VAL="2000-W42">the third week of October</TIMEX2>

Durations <TIMEX2 VAL="PT30M">half an hour long</TIMEX2>

Indexicality <TIMEX2 VAL="2000-10-04">tomorrow</TIMEX2>

Sets <TIMEX2 VAL="XXXX-WXX-2" SET="YES" PERIODICITY="F1W" GRANULARITY="G1D">every Tuesday</TIMEX2>

Fuzziness <TIMEX2 VAL="1990-SU">Summer of 1990 </TIMEX2>

TIMEX2 Tag Attributes

Attribute	Function	Example
VAL	Contains a normalized form of the date/time.	VAL="1964-10-16"
MOD	Captures temporal modifiers.	MOD="APPROX"
SET	Identifies expressions denoting sets of times.	SET="YES"
PERIODICITY	Captures the period between regularly recurring times.	PERIODICITY="P1M"
GRANULARITY	Captures the unit of time denoted by each set member in a set of times.	GRANULARITY="G3D"
ANCHOR_VAL	Contains a normalized form of an anchoring date/time.	ANCHOR_VAL="1964-10-16"
ANCHOR_DIR	Captures the relative direction between VAL and ANCHOR_VAL.	ANCHOR_DIR="BEFORE"
NON_SPECIFIC	Identifies non-specific expressions.	NON_SPECIFIC="YES"

How TimeML Differs from Previous Markups

- Extends TIMEX2 annotation;
  - **Temporal Functions:** three years ago
  - **Anchors to events and other temporal expressions:** three years after the Gulf War
- Identifies signals determining interpretation of temporal expressions;
  - **Temporal Prepositions:** for, during, on, at;
  - **Temporal Connectives:** before, after, while.
- Identifies event expressions;
  - **tensed verbs;** has left, was captured, will resign;
  - **stative adjectives;** sunken, stalled, on board;
  - **event nominals;** merger, Military Operation, Gulf War;
- Creates dependencies between events and times:
  - **Anchoring;** John left on Monday.
  - **Orderings;** The party happened after midnight.
  - **Embedding;** John said Mary left.

<TIMEX3>

- Fully Specified Temporal Expressions
  - **June 11, 1989**
  - **Summer, 2002**
- Underspecified Temporal Expressions
  - **Monday**
  - **Next month**
  - **Last year**
  - **Two days ago**
- Durations
  - **Three months**
  - **Two years**

functionInDocument allows for relative anchoring of temporal expression values

TIMEX3 Corpus 1

- **TIDES (100,000 words)**

  23,337 tides-nytimes

  35,628 tides-bbc

  36,539 tides-africa

  95.5 K words

- **Number of Timexes** (Timex tokens): 31,659
- **Unique Timexes**: 1,134

- **Normalization**:

  digit --> X

  a,an,the --> [Det]

- **Format**:

  <frequency> <timex>

TIMEX3 Corpus 2

3498	XXXX
2388	now
1742	X Dec XXXX
1547	XX Nov XXXX
683	today
649	yesterday
635	XX Dec XXXX
561	current
540	this year
513	once
506	last year
466	[Det] past
451	XX September
434	Wednesday
407	future
401	X Jan XXXX
389	Friday
380	Now
376	Thursday
351	Tuesday
341	Monday
335	[Det] future
307	XXXXs
296	last week
285	Sunday
280	this week
272	next year
269	Saturday
253	Christmas
242	Sept. XX
242	November
214	Daily
204	September
193	XX November
193	last month

……

TIMEX3 Corpus 3

26	[Det] month ago
26	fourth quarter
25	three years ago
25	Tuesday XX
25	Tuesday XX November
25	last Saturday
25	yesterday morning
25	Wednesday XX
25	XX Nov.
25	XX January
25	Dec. X
25	Nov.
25	July XXXX
24	Monday morning
24	early October
23	two weeks ago
23	This week
23	last weekend
22	Thanksgiving
22	Nov. XX
22	XX September XXXX
22	long ago
22	last Friday
21	early this year
21	Tuesday afternoon
21	Wednesday XX November
21	[Det] week ago
20	[Det] XXst century
……	
1	November of this year
1	January X XXXX
1	August next year
1	July , XXXX
1	last December X
1	June XX every year
1	two thousand years ago
1	Ten years
1	late this afternoon
1	[Det] year ago today
1	last week Friday
1	[Det] morning of Oct. X
1	[Det] next quarter
1	Friday , December XX

TIDES TIMEX2 Examples

The Foreign Minister told Thailand's Nation Newspaper <TIMEX2 VAL="1998-01-04">Sunday</TIMEX2> Pol Pot had left Cambodia but was not in Thailand, ending credence to a claim <TIMEX2 VAL="1997-W52">last week</TIMEX2> the aged and ailing former Khmer Rouge leader had fled to China.

……. …

But in <TIMEX2 NON_SPECIFIC="YES">today</TIMEX2>'s Japan, the impossible has become possible, and in <TIMEX2 VAL="1998-12">December</TIMEX2>, seven years shy of his retirement, Akimoto "quit" and joined the 2.91 million other Japanese who are officially looking for a job.

TIMEX2 Annotation Scheme

Time Points <TIMEX2 VAL="2000-W42">the third week of October</TIMEX2>

Durations <TIMEX2 VAL="PT30M">half an hour long</TIMEX2>

Indexicality <TIMEX2 VAL="2000-10-04">tomorrow</TIMEX2>

Sets <TIMEX2 VAL="XXXX-WXX-2" SET="YES" PERIODICITY="F1W" GRANULARITY="G1D">every Tuesday</TIMEX2>

Fuzziness <TIMEX2 VAL="1990-SU">Summer of 1990 </TIMEX2>

<TIMEX2 VAL="1999-07-15TMO">This morning</TIMEX2>

Non-specificity <TIMEX2 VAL="XXXX-04" NON_SPECIFIC="YES">April</TIMEX2> is usually wet.

TIMEX3

- Fully Specified Temporal Expressions
  - **June 11, 1989**
  - **Summer, 2002**
- Underspecified Temporal Expressions
  - **Monday**
  - **Next month**
  - **Last year**
  - **Two days ago**
- Durations
  - **Three months**
  - **Two years**

Unannotated Article 1

AP-NR-08-15-90 1337EDT

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In another mediation effort, the Soviet Union said today it had sent an envoy to the Middle East on a series of stops to include Baghdad. Soviet officials also said Soviet women, children and invalids would be allowed to leave Iraq.

Unannotated Article 2

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The U.S. military buildup in Saudi Arabia continued at fever pace, with Syrian troops now part of a multinational force camped out in the desert to guard the Saudi kingdom from any new thrust by Iraq.

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TimeML Event Classes

- Occurrence:
  - die, crash, build, merge, sell, take advantage of, ..
- State:
  - Be on board, kidnapped, recovering, love, ..
- Reporting:
  - Say, report, announce,
- I-Action:
  - Attempt, try,promise, offer
- I-State:
  - Believe, intend, want, …
- Aspectual:
  - begin, start, finish, stop, continue.
- Perception:
  - See, hear, watch, feel.

Event Expressions 1

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SLINK

SLINK or Subordination Link is used for contexts introducing relations between two events, or an event and a signal, of the following sort:

Factive: Certain verbs introduce an entailment (or presupposition) of the argument's veracity. They include **forget** in the tensed complement, **regret**, **manage**:

John forgot that he was in Boston last year.

Mary regrets that she didn't marry John.

Counterfactive: The event introduces a presupposition about the non-veracity of its argument: **forget (to), unable to** (in past tense), **prevent, cancel, avoid, decline**, etc.

John forgot to buy some wine.

John prevented the divorce.

Evidential: Evidential relations are introduced by REPORTING or PERCEPTION:

John said he bought some wine.

Mary saw John carrying only beer.

Negative evidential: Introduced by REPORTING (and PERCEPTION?) events conveying negative polarity:

John denied he bought only beer.

Conditional: Introduced when a conditional is present:

If Mary leaves today, John will leave tomorrow.

Subordinated Links 1

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Subordinated Links 2

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ALINK

ALINK or Aspectual Link represent the relationship between an aspectual event and its argument event. Examples of the possible aspectual relations we will encode are:

1. **Initiation**:

   John started to read.

2. **Culmination**:

   John finished assembling the table.

3. **Termination**:

   John stopped talking.

4. **Continuation**:

   John kept talking.

Aspectual Links 1

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Aspectual Links 2

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TLINK

Also today, King Hussein of Jordan arrived in Washington.

```
<TIMEX3 tid="t1" type=”DATE" value=”1990-08-15">
today
</TIMEX3>
King Hussein of Jordan
<EVENT eid="e1" class="OCCURRENCE">
arrived
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense=”PAST”
aspect=”NONE” negation=”false”/>
In Washington
<TLINK timeID=”t1” relatedToEvent=”ei1”
relType=”IS_INCLUDED”/>
```

SLINK

… by promising to withdraw …

by
<EVENT eid="e1" class="I_ACTION”>
promising
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1” tense= “nil” aspect = “PROG”/>
<SLINK eventInstanceID="ei1" signalID="s1" subordinatedEvent="ei2” relType="MODAL"/>
<SIGNAL sid="s1"> to </SIGNAL>
<EVENT eid="e2" class="OCCURRENCE" >
withdraw
</EVENT>
<MAKEINSTANCE eiid="ei2" eventID="e2” tense=“nil” aspect=“NONE”/>

ALINK

He will begin withdrawing troops from Iranian territory …

```
He
will
<EVENT eid="e1" class=”ASPECTUAL">
begin
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense=”PAST” aspect=”NONE”
negation=”false”/>
<EVENT eid="e1" class=”OCCURRENCE">
withdrawing
</EVENT>
<MAKEINSTANCE eiid="ei2" eventID="e2" tense=”nil” aspect=”PROG”
negation=”false”/>

<ALINK eventInstanceID="ei1" signalID="s1" relatedToEvent="ei2” relType="INITIATE"/>
```

Motivating TimeML

- **MakeInstance**: Instances of event descriptions
- **Negation**: An attribute of MakeInstance
- **Modality**: An attribute of MakeInstance
- **TLINK**:
  - Anchoring events to times
  - Ordering events relative to each other
  - Ordering times relative to each other
- **ALINK**: phases of events
- **SLINK**: Events subordinating another event

MAKEINSTANCE 1.2

(1) “must not teach twice”

must not

<EVENT eid=“e1” class=”OCCURRENCE”>

teach

</EVENT>

<SIGNAL sid=”s1”>

twice

</SIGNAL>

<MAKEINSTANCE eiid=”ei1” eventID=”e1” tense=”PRESENT”
aspect=”NONE” nf_morph=“NONE” negation=”true”
modality=”MUST” signalID=”s1” cardinality=”2”/>

MAKEINSTANCE 1.2

(2) “taught on Tuesday but not on Friday”

```
<EVENT eid=”e1” class=”OCCURRENCE”> taught </EVENT>
<SIGNAL sid=”s1”> on </SIGNAL>
<TIMEX3 tid=”t1” type=”DATE” value=”XXXX-WXX-2”> Tuesday </TIMEX3>
but not
<SIGNAL sid=”s2”> on </SIGNAL>
<TIMEX3 tid=”t2” type=”DATE” value=”XXXX-WXX-5”> Friday </TIMEX3>
<MAKEINSTANCE eiid=”ei1” eventID=”e1” tense=”PAST” aspect=”NONE”
    nf_morph=“NONE” negation=”false”/>
<MAKEINSTANCE eiid=”ei2” eventID=”e1” tense=”PAST” aspect=”NONE”
    nf_morph=“NONE” negation=”true”/>
<TLINK eventInstanceID="ei1" signalID="s1"relatedToTime="t1"
    relType="IS_INCLUDED"/>
<TLINK eventInstanceID="ei2" signalID="s2" relatedToTime="t2"
    relType="IS_INCLUDED"/>
```

TIMEX3 1.2 -- Sets

- New TIMEX3 type: SET
- New attributes
  - quant: quantification over the set
  - freq: frequency within the set

(3) “every month”

<TIMEX3 tid=”t1” type=”SET” value=”P1M” quant=”EVERY”>
every month
</TIMEX3>

TIMEX3 1.2 -- SET Examples

(4) “twice a month”

<TIMEX3 tid=”t1” type=”SET” value=”P1M” freq=”P2X”>

twice a month

</TIMEX3>

(5) “daily”

<TIMEX3 tid=”t1” type=”SET” value=”P1D” quant=”EVERY”>

daily

</TIMEX3>

TIMEX3 1.2 -- Anchored Durations

- Usage 1: Explicit duration with specified begin point or end point within the text
  - Result: Non-consuming TIMEX3 for unspecified begin or end point
- Usage 2: Implicit duration with specified begin point and end point within the text
  - Result: Non-consuming TIMEX3 for unspecified duration

TIMEX3 1.2 -- Durations Examples

- Usage 1 -- Explicit Duration

(6) “two weeks from June 7, 2003”

```
<TIMEX3 tid="t6" type="DURATION" value="P2W"
    beginPoint=”t61” endPoint=”t62”>
two weeks
</TIMEX3>
<SIGNAL sid=”s1”>
from
</SIGNAL>
<TIMEX3 tid=”t61” type=”DATE” value=”2003-06-07”>
June 7, 2003
</TIMEX3>
<TIMEX3 tid=”t62” type=”DATE” value=”2003-06-21”
    temporalFunction=”true” anchorTimeID=”t6”/>
```

TIMEX3 1.2 -- Durations Examples

- Usage 2 -- Implicit Duration

(7) “1992 through 1995”

```
<TIMEX3 tid=”t71” type=”DATE” value=”1992”>
1992
</TIMEX3
<SIGNAL sid=”s1”>
through
</SIGNAL>
<TIMEX3 tid=”t72” type=”DATE” value=”1995”>
1995
</TIMEX3>
<TIMEX3 tid=”t7” type=”DURATION” value=”P4Y” beginPoint=”t71”
    endPoint=”t72” temporalFunction=”true”/>
```

TimeML Example 1

The young industry's rapid growth also is attracting regulators eager to police its many facets.

```
The young industry's rapid
<EVENT eid="e1" class="OCCURRENCE">
growth
</EVENT>
also is
<EVENT eid="e2" class="OCCURRENCE">
attracting
</EVENT>
regulators
<EVENT eid="e4" class="I_STATE">
eager
</EVENT>
to
<EVENT eid="e5" class="OCCURRENCE">
police
</EVENT>
its many facets.
```

TimeML Example 2

Israel will ask the United States to delay a military strike against Iraq until the Jewish state is fully prepared for a possible Iraqi attack.

```
Israel will
<EVENT eid="e1" class="I_ACTION">
ask
</EVENT>
the United States to
<EVENT eid="e2" class="I_ACTION">
delay
</EVENT>
a military
<EVENT eid="e3" class="OCCURRENCE">
strike
</EVENT>
against Iraq until the Jewish state is fully
<EVENT eid="e4" class="I_STATE">
prepared
</EVENT>
for a possible Iraqi
<EVENT eid="e5" class="OCCURRENCE">
attack
</EVENT>
```

TLINK

TLINK or Temporal Link represents the temporal relationship holding between events or between an event and a time, and establishes a link between the involved entities, making explicit if they are:

Simultaneous (happening at the same time)

Identical: (referring to the same event)

John drove to Boston. During his drive he ate a donut.

One **before** the other:

The police looked into the slayings of 14 women.

In six of the cases suspects have already been arrested.

One **after** the other:

One **immediately before** the other:

All passengers died when the plane crashed into the mountain.

One **immediately after** than the other:

One **including** the other:

John arrived in Boston last Thursday.

One **being included** in the other:

One **exhaustively during** the duration of the other:

John taught for 20 minutes.

One being the **beginning** of the other:

John was in the gym between 6:00 p.m. and 7:00 p.m.

One being **begun by** the other:

One being the **ending** of the other:

John was in the gym between 6:00 p.m. and 7:00 p.m.

One being **ended by** the other:

TLINK: Example 1

(4) John left on Monday.

```
John
<EVENT eid="e1" class="OCCURRENCE">
left
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense=”PAST”
aspect=”NONE” negation=”false”/>
<SIGNAL sid=“s1”>
on
</SIGNAL>
<TIMEX3 tid="t1" type="DURATION" value=”XXXX-WXX-1">
Monday
</TIMEX3>
<TLINK eventInstanceID=”ei11” relatedToTime=”t2” signalID=“s1”
relType=”IS_INCLUDED”/>
```

TLINK: Example 2

(8) John taught twice on Monday but only once on Tuesday.

```
John
<EVENT eid="e1" class="OCCURRENCE">
taught
</EVENT>
<SIGNAL sid="s1"> twice </SIGNAL>
<SIGNAL sid="s2"> on </SIGNAL>
<TIMEX3 tid="t1" type="DATE" value="xxxx-wxx-1">
Monday
</TIMEX3>
but only
<SIGNAL sid="s3">
once
</SIGNAL>
<SIGNAL sid="s4">
on
</SIGNAL>
<TIMEX3 tid="t2" type="DATE" value="xxxx-wxx-2">
Tuesday
</TIMEX3>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense="PAST" aspect="NONE" negation="false"
signalID="s1" cardinality="2"/>
<MAKEINSTANCE eiid="ei2" eventID="e1" tense="PAST" aspect="NONE" negation="false"
signalID="s3" cardinality="1"/>
<TLINK eventInstanceID="ei1" signalID="s2" relatedToTime="t1"
relType="IS_INCLUDED"/>
<TLINK eventInstanceID="ei2" signalID="s4" relatedToTime="t2"
```

ALINK: Example

(17) The boat began to sink.

The boat
<EVENT eid="e1" class="ASPECTUAL" >
began
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1” tense=”PAST” aspect=”NONE” negation=”false” />
<SIGNAL sid="s1">
to
</SIGNAL>
<EVENT eid="e2" class="OCCURRENCE" >
sink
</EVENT>
<MAKEINSTANCE eiid="ei2" eventID="e2” tense=nil aspect=”NONE” negation=”false” />

<ALINK eventInstanceID="ei1" signalID="s1" relatedToEvent="ei2” relType="INITIATES"/>

SLINK: Example 1

Bill wants to teach on Monday.

```
Bill
<EVENT eid="e1" class="I_STATE”>
wants
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1” tense= “PRESENT” aspect = “NONE”/>
<SLINK eventInstanceID="ei1" signalID="s1" subordinatedEvent="ei2”
relType="MODAL"/>
<SIGNAL sid="s1"> to </SIGNAL>
<EVENT eid="e2" class="OCCURRENCE" >
teach
</EVENT>
<MAKEINSTANCE eiid="ei2" eventID="e2” tense=“nil” aspect=“NONE”/>
<SIGNAL sid="s2">
on
</SIGNAL>
<TIMEX3 tid="t1" type="DATE" temporalFunction="true" value="XXXX-WXX-1">
Monday
</TIMEX3>
<TLINK eventInstanceID="ei2" relatedToTime="t1" relType="IS_INCLUDED"/>
```

Syntax of Event

```
<Event>
attributes ::= eid class

eid ::= ID
{eid ::= EventID
EventID ::= e<integer>}
class ::=    'OCCURRENCE' | 'PERCEPTION' |
'REPORTING'                'ASPECTUAL' | 'STATE' |
'I_STATE' |                'I_ACTION'
```

Syntax of MakeInstance

```
<MakeInstance>
attributes ::= eiid eventID tense aspect negation [modality]
[signalID] [cardinality]
eiid ::= ID
{eiid ::= EventInstanceID
EventInstanceID ::= ei<integer>}
eventID ::= IDREF
{eventID ::= EventID}
tense ::= 'PAST' | 'PRESENT' | 'FUTURE' | 'NONE'
aspect ::= 'PROGRESSIVE' | 'PERFECTIVE' | 'PERFECTIVE_PROGRESSIVE'
| 'NONE'
negation ::= 'true' | 'false'
{negation ::= boolean}
modality ::= CDATA
signalID ::= IDREF
{signalID ::= SignalID}
cardinality ::= CDATA
```

MakeInstance: Examples 1

```
(1) should have bought

should have
<EVENT eid="e1" class="OCCURRENCE">
bought
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense="PAST" aspect="PERFECTIVE"
negation="false" modality="SHOULD"/>

(2) did not teach

did not
<EVENT eid="e1" class="OCCURRENCE">
teach
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense="PRESENT" aspect="NONE"
negation="true"/>
```

MakeInstance: Examples 2

(3) must not teach twice

```
must not
<EVENT eid="e1" class="OCCURRENCE">
teach
</EVENT>
<SIGNAL sid="s1">
twice
</SIGNAL>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense="PRESENT"
aspect="NONE" negation="true" modality="MUST" signalID="s1"
cardinality="2"/>
```

Syntax of Timex3

```
<Timex3>
attributes ::= tid type [functionInDocument] [beginPoint] [endPoint] [quant] [freq] [temporalFunction] (value |
valueFromFunction) [mod] [anchorTimeID]

tid ::= ID
{tid ::= TimeID
TimeID ::= t<integer>}
type ::= 'DATE' | 'TIME' | 'DURATION' | 'SET'
beginPoint ::= IDREF
{beginPoint ::= TimeID}
endPoint ::= IDREF
{endPoint ::= TimeID}
quant ::= CDATA
freq ::= CDATA
{value ::= duration}
functionInDocument ::= 'CREATION_TIME' | 'EXPIRATION_TIME' | 'MODIFICATION_TIME' | 'PUBLICATION_TIME' |
                         'RELEASE_TIME'| 'RECEPTION_TIME' | 'NONE' {default, if absent, is 'NONE'}
temporalFunction ::= 'true' | 'false' {default, if absent, is 'false'}
{temporalFunction ::= boolean}
value ::= CDATA
{value ::= duration | dateTime | time | date | gYearMonth | gYear | gMonthDay | gDay | gMonth}
valueFromFunction ::= IDREF
{valueFromFunction ::= TemporalFunctionID
TemporalFunctionID ::= tf<integer>}
mod ::= 'BEFORE' | 'AFTER' | 'ON_OR_BEFORE' | 'ON_OR_AFTER' |'LESS_THAN' | 'MORE_THAN' |
                         'EQUAL_OR_LESS' | 'EQUAL_OR_MORE' | 'START' | 'MID' | 'END' | 'APPROX'
anchorTimeID ::= IDREF
{anchorTimeID ::= TimeID}
```

Timex3 Examples

(4) no more than 60 days

```
<TIMEX3 tid="t1" type="DURATION" value="P60D"
mod="EQUAL_OR_LESS">
no more than 60 days
</TIMEX3>
```

(5) the dawn of 2000

```
<TIMEX3 tid="t2" type="DATE" value="2000"
mod="START">
the dawn of 2000
</TIMEX3>
```

Temporal Functions in TimeML

(15) John taught last week.

```
John
<EVENT eid="e1" class="OCCURRENCE">
taught
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1" tense=”PAST” aspect=”NONE”
negation=”false”/>
<TIMEX3 tid="t1" type="DATE" value="XXXX-WXX" temporalFunction="true"
anchorTimeID="t2">
last week
</TIMEX3>
<TIMEX3 tid="t2" type="DATE" value="1996-03-27"
functionInDocument="CREATION_TIME">
03-27-96
</TIMEX3>
<TLINK eventInstanceID="ei1" relatedToTime="t1" relType="IS_INCLUDED"/>
```

Syntax of Signal

```
<Signal>
attributes ::= sid

sid ::= ID
{sid ::= SignalID
SignalID ::= s<integer>}
```

Syntax of TLINK

```
<TLINK>
attributes ::= [lid] [origin] (eventInstanceID | timeID) [signalID]
(relatedToEventInstance | relatedToTime) relType
lid ::= ID
{lid ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventInstanceID ::= IDREF
{eventInstanceID ::= EventInstanceID}
timeID ::= IDREF
{timeID ::= TimeID}
signalID ::= IDREF
{signalID ::= SignalID}
relatedToEventInstance ::= IDREF
{relatedToEventInstance ::= EventInstanceID}
relatedToTime ::= IDREF
{relatedToTime ::= TimeID}
relType ::= 'BEFORE' | 'AFTER' | 'INCLUDES' | 'IS_INCLUDED' | 'DURING'
                 'SIMULTANEOUS' | 'IAFTER' | 'IBEFORE' | 'IDENTITY' |
                 'BEGINS' | 'ENDS' | 'BEGUN_BY' | 'ENDED_BY'
```

Syntax of SLINK

```
<SLINK>
attributes ::= [lid] [origin] [eventInstanceID]
[signalID] subordinatedEventInstance relType

lid ::= ID
{lid ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventInstanceID ::= IDREF
{eventInstanceID ::= EventInstanceID}
subordinatedEventInstance ::= IDREF
{subordinatedEventInstance ::= EventInstanceID}
signalID ::= IDREF
{signalID ::= SignalID}
relType ::= 'MODAL' | 'EVIDENTIAL' | 'NEG_EVIDENTIAL'
          | 'FACTIVE' | 'COUNTER_FACTIVE'
```

Events introducing Slinks

The following EVENT classes interact with SLINK:

1. `REPORTING`
2. `I_STATE`
3. `I_ACTION`

Verbs that introduce `I_STATE` EVENTs that induce SLINK:

1. want, desire, crave, lust
2. believe, doubt, suspect
3. hope, aspire
4. intend
5. fear, hate
6. love
7. enjoy
8. like
9. know

Verbs that introduce `I_ACTION` EVENTs that induce SLINK:

1. attempt, try
2. persuade
3. promise
4. name
5. swear, vow

Syntax of ALINK

```
<ALINK>
attributes ::= [lid] [origin] eventInstanceID [signalID]
relatedToEventInstance relType

lid ::= ID
{lid ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventInstanceID ::= ID
{eventInstanceID ::= EventInstanceID}
signalID ::= IDREF
{signalID ::= SignalID}
relatedToEventInstance ::= IDREF
{relatedToEventInstance ::= EventInstanceID}
relType ::= 'INITIATES' | 'CULMINATES' | 'TERMINATES' |
            'CONTINUES' | 'REINITIATES'
```

Semantics of TimeML

- Annotations can be viewed as a set of conditions on variables
  - An Example:

```
John
<EVENT eid="e1“>
taught
</EVENT>
<SIGNAL sid="s1">
on
</SIGNAL>
<TIMEX3 tid="t2" type="DATE" value="XXXX-WXX-1">
Monday
</TIMEX3>
<MAKEINSTANCE eventID="e1" eventInstanceID="ei1" class="OCCURRENCE" tense="PAST"
    aspect="NONE">
<TLINK eventInstanceID="ei1" signalID="s1" relatedToTime="t2" relType="IS_INCLUDED"/>
```

  - The TimeML says: this is true if there is an event of John teaching that is located on a Monday

Semantics of TimeML

We will interpret TimeML texts with respect to a class of model structures

$\langle E, I, <, \subseteq, \tau, V \rangle$ where

E is the set of events

I the set of times

$<$ is the ordering relation on time intervals

$\subseteq$ is the inclusion relation on time intervals

τ is the run-time function from E to I

V is the valuation function.

These models must satisfy a number of axioms, for example:

$\forall x,y,z \in I.\ \ x<y \ \&\ y<z \rightarrow x<z$

$\forall x,y,z \in I..\ \ x\subseteq y \ \&\ y\subseteq z \rightarrow x\subseteq z$

$\forall w,x,y,z \in I..\ x<y \ \&\ z\subseteq x \ \&\ w\subseteq y \rightarrow z<w$

$\forall w,x,y,z.\ x<y \ \&\ y<z \ \&\ x \subseteq w \ \&\ z\subseteq w \rightarrow y\subseteq w$

Semantics of TimeML: Attribute values

TimeML defines a large number of attributes for tags.
The intended models for TimeML are models in which Val assigns appropriate denotations to these terms.

For all attributes α,

If α is an ISO-8601 term that doesn't start with P then
Val(α) = the interval determined by the ISO notation

If α is an ISO-8601 term that start with P then
Val(α) = the set of all intervals determined by the ISO notation

If α is an an event predicate then Val(α) = the set of all events of the appropriate type
…

Semantics of TimeML Text

Let T be a TimeML Text,

$Dom_e(T)$ = the set of event ids in T

$Dom_t(T)$ = the set of time ids in T

$Dom_{ei}(T)$ = the set of event instance ids in T

Tag(T) = the set of all tags in T

A text T is satisfied by a model M iff there are functions (that assign denotations to identifier variables)

f_e: Dom_e (T) -> Pow(E), and

f_{ei}: Dom_{ei} (T) -> E

f_t: Dom_t (T) -> I , such that

for all tags $t \in$ Tag(T), t is satisfied by f_e f_{ei} and f_t in M.

Semantics of TimeML Text Embedding

We define satisfaction of a tag by a set of functions in a model by enumeration.

A tag t is satisfied by f_e,f_t, and f_{ei} in M iff if t has the form

- "<EVENT eid = α class = β pred= δ >"
  then $f_e(\alpha) = Val(\delta)$
- "<TIMEX3 tid = α type = DATE value= δ >"
  then $f_t(\alpha) = Val(\delta)$
- "<TIMEX3 tid = α type = DURATION value= δ >"
  then $f_t(\alpha) \in Val(\delta)$
- "<MAKEINSTANCE eiid = α eid = β negation='FALSE' modal = ''>"
  then $f_{ei}(\alpha) \in f_e(\beta)$
- "<MAKEINSTANCE eiid = α eid = β negation='TRUE' modal = ''>"
  then $f_{ei}(\alpha) \notin f_e(\beta)$

Semantics of TimeML Text Embedding

Cont'd

- "<TLINK eventInstanceID = α relatedtoTime = β relType= 'IS_INCLUDED'>"
  then $\tau(f_{ei}(\alpha)) \subseteq f_t(\beta)$

- "<TLINK eventInstanceID = α relatedtoEventInstance = β relType= 'BEFORE' >"
  then $\tau(f_{ei}(\alpha)) < \tau(f_{ei}(\beta))$

- "<TLINK eventInstanceID = α relatedtoTime = β relType= 'DURING>"
  then $\tau(f_{ei}(\alpha)) = f_t(\beta)$

Semantics: Example

```
John
<EVENT eid="e1"   class="OCCURRENCE"  pred="TEACH">
taught
</EVENT>
<TIMEX3 tid="t1" type="DURATION" value="P20M">
20 minutes
</TIMEX3>
<SIGNAL sid="s1">
on
</SIGNAL>
<TIMEX3 tid="t2" type="DATE" value="XXXX-WXX-1">
Monday
</TIMEX3>
<MAKEINSTANCE eventID="e1" eventInstanceID="ei1" " negation="FALSE">
<TLINK eventInstanceID="ei1" signalID="s1" relatedToTime="t2" relType="IS_INCLUDED"/>
<TLINK eventInstanceID="ei1" relatedToTime="t1" relType="DURING"/>
```

Dom_e = {e1} Dom_{ei} = {ei1} Dom_t = {t1,t2}

This annotation is satisfied in M if we can find f_e,f_t, and f_{ei} such that:

f_e(e1) is set of teaching events,

f_t(t2) is a Monday,

f_t(t1) is a twenty minute interval and

$f_{ei}(ei1) \in (f_e(e1))$, $\tau(f_{ei}(ei1)) \subseteq f_t(t2)$ and $\tau(f_{ei}(ei1)) = f_t(t1)$

Semantics: Negation Example

```
John didn't
<EVENT eid="e1"   class="OCCURRENCE"  pred="TEACH">
teach
</EVENT>
<SIGNAL sid="s1">
on
</SIGNAL>
<TIMEX3 tid="t2" type="DATE" value="XXXX-WXX-1">
Monday
</TIMEX3>
<MAKEINSTANCE eventID="e1" eventInstanceID="ei1" " negation="TRUE">
<TLINK eventInstanceID="ei1" signalID="s1" relatedToTime="t2" relType="IS-INCLUDED"/>
```

Dom_e = {e1} Dom_{ei} = {ei1} Dom_t = {t2}

This annotation is satisfied in M if we can find f_e,f_t, and f_{ei} such that:

f_e(e1) is set of teaching events,

f_t(t2) is a Monday,

and

$f_{ei}(ei1) \notin f_e(e1)$, $\tau(f_{ei}(ei1)) \subseteq f_t(t2)$

Semantics: Problem

"John didn't teach on Monday"

$Dom_e = \{e1\}$ $Dom_{ei} = \{ei1\}$ $Dom_t = \{t2\}$
This annotation is satisfied in M if we can find f_e,f_t, and f_{ei} such that:

$f_e(e1)$ is set of teaching events,
$f_t(t2)$ is a Monday,
and
$f_{ei}(ei1) \notin f_e(e1)$, $\tau(f_{ei}(ei1)) \subseteq f_t(t2)$

(This says that there was an event of something other than teaching that was on Monday)

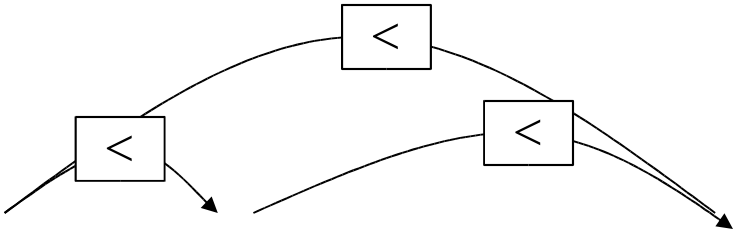
Unfortunately such a model might actually have an event of teaching included somewhere on a Monday

Problem: We do not have scope!
Possible Solutions: Introduce event types into the TLINK.
…

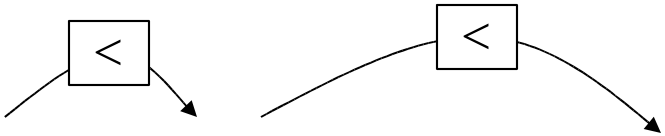
Issues for Semantic Annotation

Evaluating the Annotation

- Annotations need do be compared semantically, not ‘syntactically’



Before she arrived John met the girl who won the race.

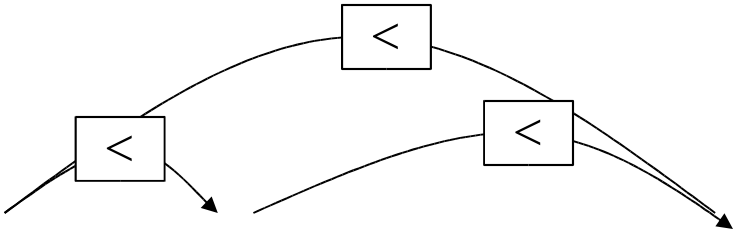


Before she arrived John met the girl who won the race.

These are equivalent

Issues for Semantic Annotation

But these are not:



Before she arrived John met the girl who won the race.

Before she arrived John met the girl who won the race.

Comparing Annotations

We can define in model-theoretic terms four relations that hold between TimeML texts A and B:

- A and B are **equivalent** if all models satisfying A satisfy B, and vice-verse.
- A **subsumes** annotation B iff all models satisfying B satisfy A.
- A and B are **consistent** iff there are models satisfying both A and B.
- A and B are **inconsistent** if there are no models satisfying both A and B

The Need for Closure

Closure in TERQAS

- Goals
  - Annotation Completeness

    The number of temporal relations is quadratic to the number of objects that are being linked temporally. A complete manual annotation is not feasible, automatic inferences are needed.
  - Annotation Consistency

    Axiom application reveals inconsistencies in annotation.
  - Encourage Inter-annotator agreement

    While agreement on entities like TIMEXes and Events is high (.85 F), annotators only annotate about 3-5% of all possible links. Agreement figures here (with AWB) hover around 15%.
- Lesson Learned
  - Discovery mechanism

    Closure generated links that came as a surprise to the annotator, they were not immediately obvious from the interfaces that were used in TERQAS.

TANGO: Event Graph Closure

- Implemented a more compact algorithm than the one used for the TERQAS project.

  Algorithm is EVENT/TIMEX3 based rather than TLINK based.

- Algorithm is based on the Warshall algorithm for graph closure.

  For all event and timex3 nodes Y:

  if RelA(X,Y) and RelB(Y,Z)

  and there is an axiom RelA & RelB RelC

  then add RelC(X,Z)

Complete Axiom Set

The TERQAS axiom set is incomplete. It uses TimeML relations as primitives without having a complete theory about the semantics of those relations. As a result, inconsistencies were not ruled out.

A complete axiom set is derived using the underlying semantics of TimeML relations. This ensures that the axiom set is complete.

Each Event and Timex3 is represented as an interval with a begin point and an end point. Each TimeML relation is translated into a set of precedence and/or equality statements between points-in-time.

```
X                ==>   x1 - x2
Y                ==>   y1 - y2
before(X,Y)      ==>   x2 < y1
includes(X,Y)    ==>   x1 < y1  &  y2 < x2
```

Complete Axiom Set

Using precedence and equality relations over points in time allows us to use the properties of a partial order to *automatically* derive all possible axioms:

1. Compile out all possible relations using = and < on the begin and end points.
2. Create the Cartesian product of this set.
3. For each pair, compute transitive closure, using transitivity of equality (=) and precedence (<) relations.
4. Check whether derived relations between points can be translated back into a new relation between intervals.

Complete Axiom Set

Two TimeML relations

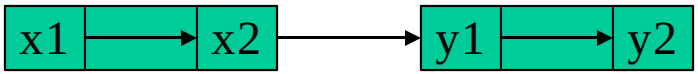
X before Y

Y before Z

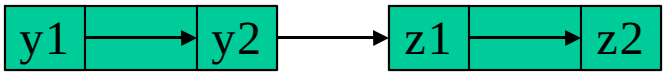
Complete Axiom Set

Translate into precedence relations on points

X before Y



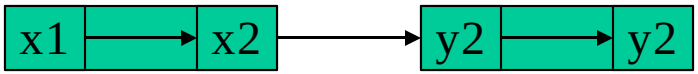
Y before Z



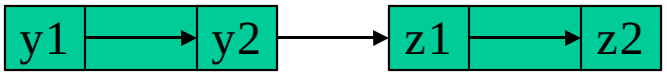
Complete Axiom Set

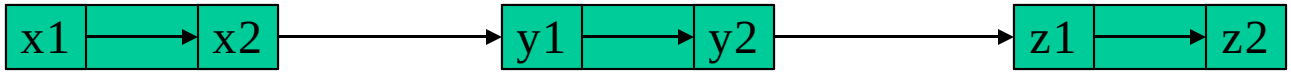
Collapse identical events

X before Y



Y before Z

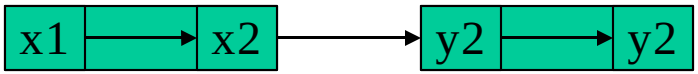




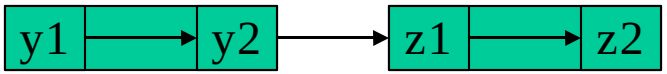
Complete Axiom Set

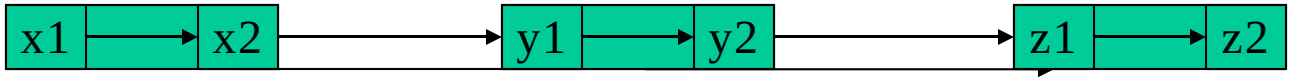
Applying transitivity of precedence relation

X before Y



Y before Z

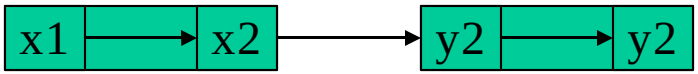




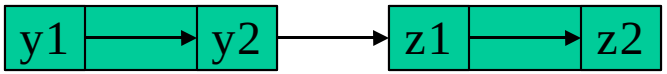
Complete Axiom Set

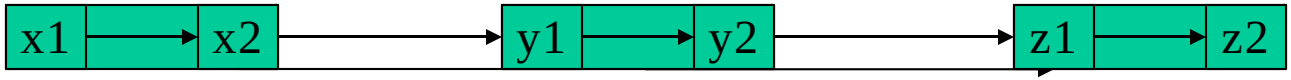
Pull out new information

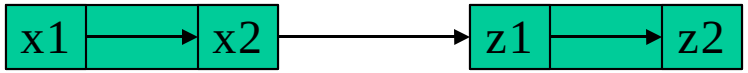
X before Y



Y before Z



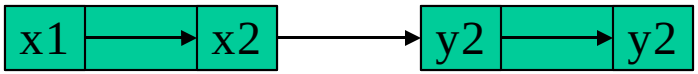




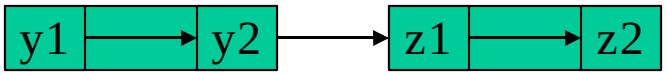
Complete Axiom Set

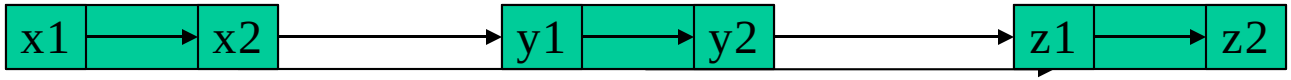
Translate point relations back to TimeML

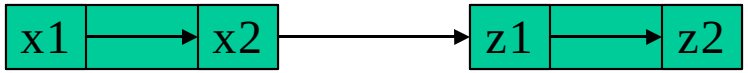
X before Y



Y before Z







X before Z

Complete Axiom Set

Using precedence and equality relations over points in time allows us to use the properties of a partial order to *automatically* derive all possible axioms:

1. Compile out all possible relations using = and < on the begin and end points.
2. Create the Cartesian product of this set.
3. For each pair, compute transitive closure, using transitivity of equality (=) and precedence (<) relations.
4. Check whether derived relations between points can be translated back into a new relation between intervals.

Axioms for Closure

AXIOM 0.0

[[x1 < y1] [x1 < y2]]

[[y1 < z1] [y1 < z2] [y2 < z2] [z1 < y2]]

==> [x1 < z1] [x1 < z2]

IN	**before ended_by ibefore includes overlap_before**
OUT	**overlap_before**
NEW	**before ended_by ibefore includes overlap_before**

AXIOM 0.1

[[x1 < y1] [x1 < y2]]

[[y1 = z1] [y1 < z2] [z1 = y1] [z1 < y2] [z2 < y2]]

==> [x1 < z1] [x1 < z2]

IN	**before ended_by ibefore includes overlap_before**
OUT	**begun_by**
NEW	**before ended_by ibefore includes overlap_before**

AXIOM 0.3

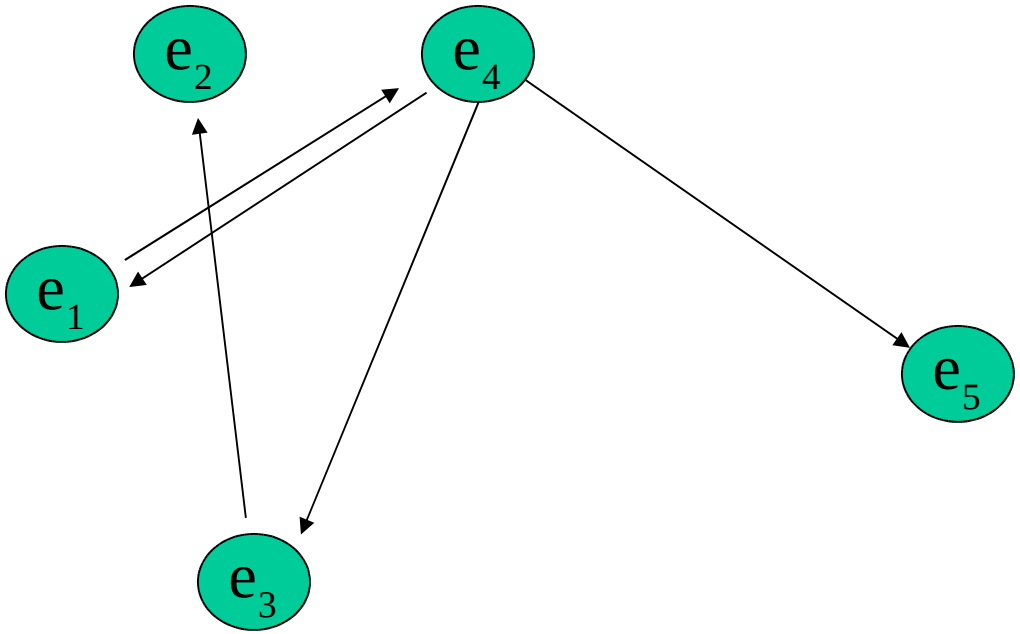
[[x1 < y1] [x1 < y2]]

[[y1 < z1] [y1 < z2] [y2 < z2]]

==> [x1 < z1] [x1 < z2]

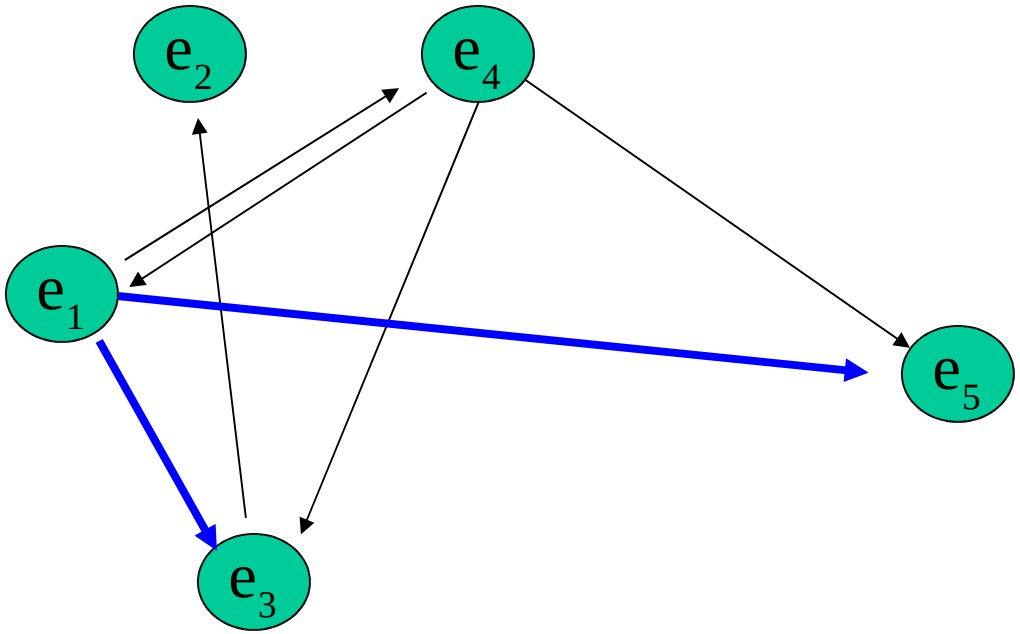
IN	**before ended_by ibefore includes overlap_before**
OUT	**before ibefore overlap_before**
NEW	**before ended_by ibefore includes overlap_before**

Warshall-Based Event Closure Algorithm



The nodes are processed one by one. When node i is processed, new edges are added in order ensure that for every path a -> i -> b (in the current graph, not the original graph) there be an edge a -> b.

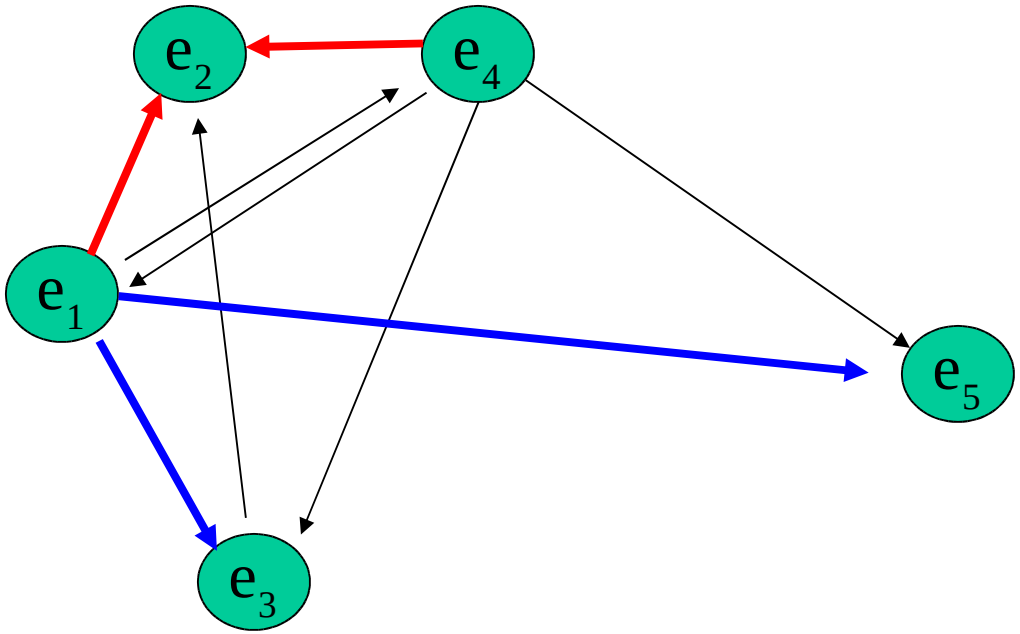
Closure Algorithm 2



Start anywhere in the graph. Ex: event 4.

When event 4 is processed, new edges are added from event 1 to events 3 and 5.

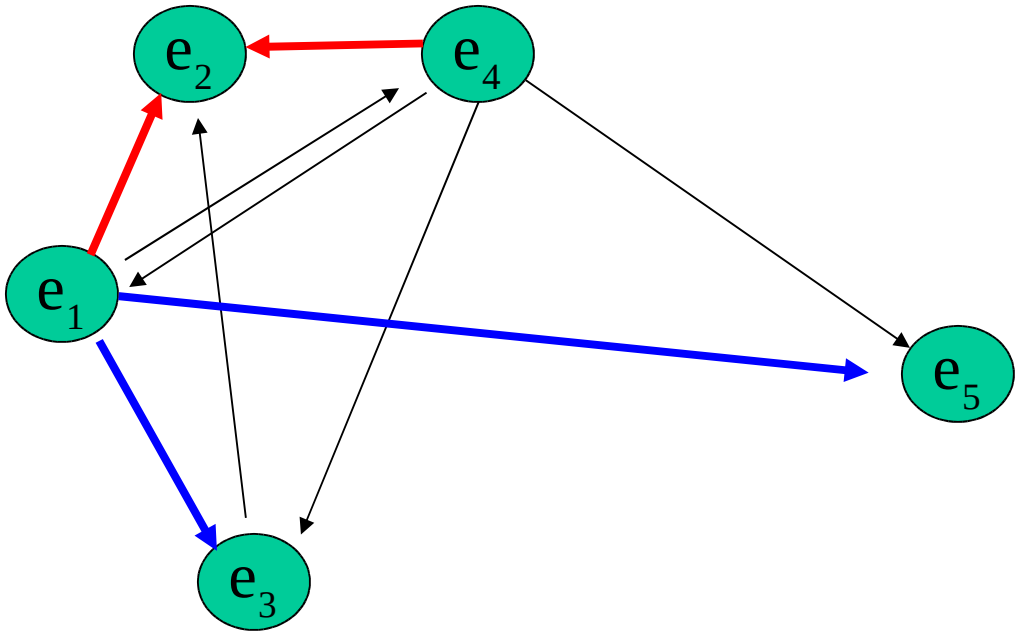
Closure Algorithm 3



When event 5 is processed, nothing happens. When node 3

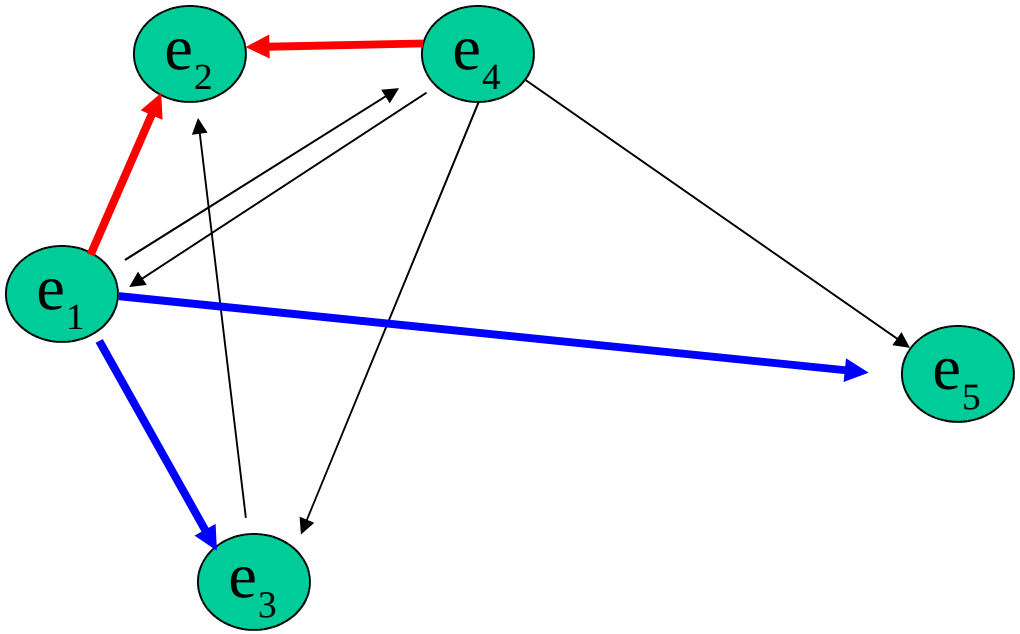
is processed, arcs must be added from 4 and 1 to 2.

Closure Algorithm 4



When events 1 and 2 are processed, nothing happens.

Closure Algorithm 5



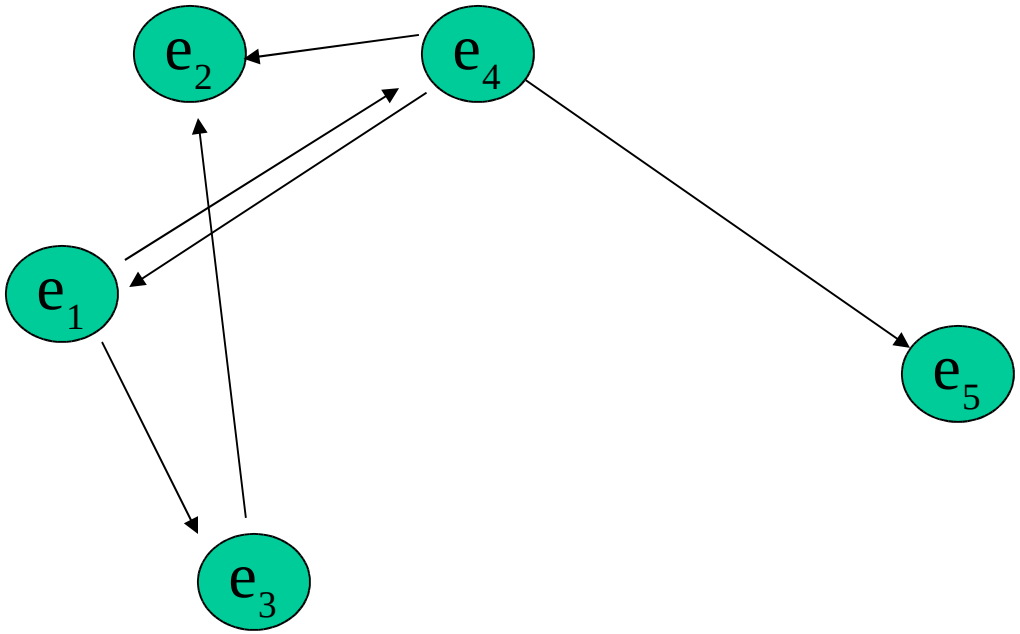
When events 1 and 2 are processed, nothing happens.

The graph is now closed.

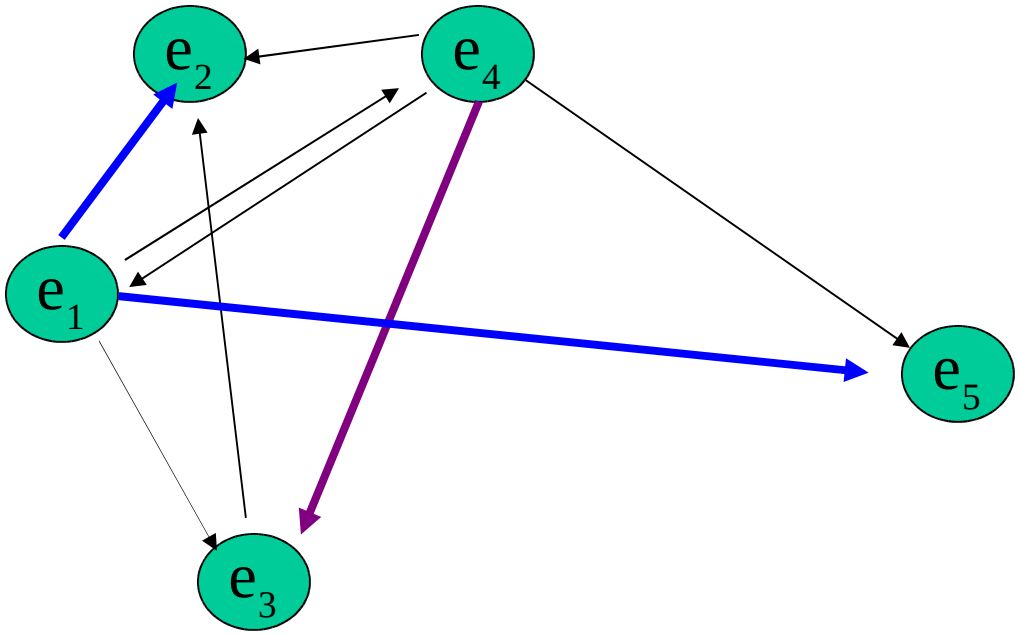
Different Annotation of Events

- Distinct set of links for an article
- Equivalent after closure

Annotation 2

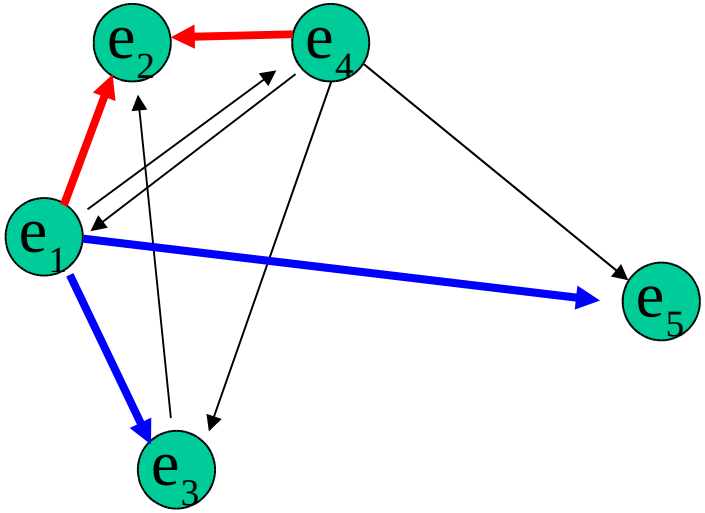


Annotation 2 Closure

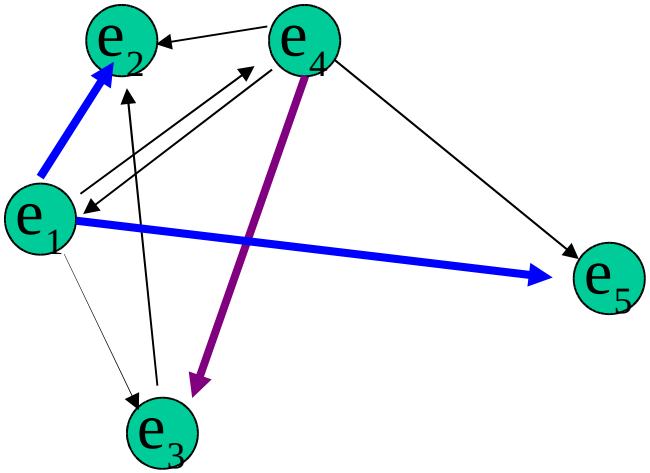


Annotation Comparison

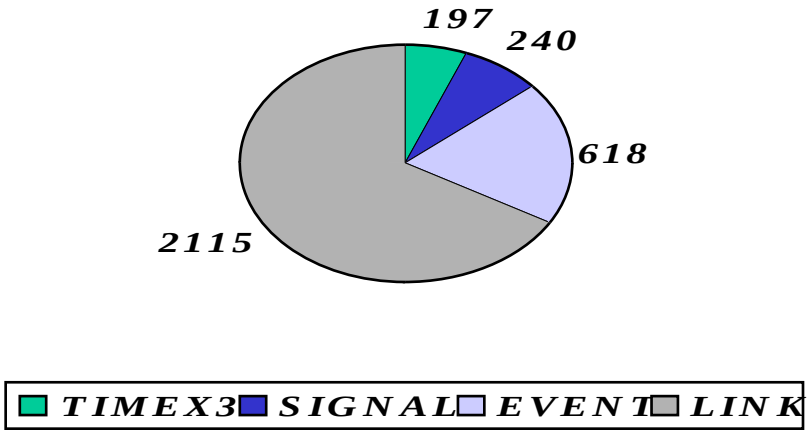
- Annotator 1



- Annotator 2



TimeML Density Information



TimeML tag frequencies in

56.6K bytes (raw) dataset

TANGO Participants

- James Pustejovsky — Brandeis University (Co-Team Lead)
- Inderjeet Mani — MITRE Virginia (Co-Team Lead)
- Branimir Boguraev — IBM, Yorktown Heights
- Linda Van Guilder — MITRE
- Marc Verhagen — Brandeis University
- Andrew See — Brandeis University
- David Day — MITRE
- Bob Knippen — Brandeis University
- Jessica Littman — Brandeis University
- Luc Bélanger — University of Montreal
- Svetlana Symonenko — University of Syracuse
- Anna Rumshisky — Brandeis University

Supported by ARDA

The Corpus: Text Sources

The 300 texts in the TIMEBANK corpus were chosen to cover a wide variety of media sources from the news domain:

- DUC (TIPSTER) texts from the Document Understanding Conference corpus cover areas like biography, single and multiple events (for example dealing with news about earthquakes and Iraq). This covers 12% of the corpus;
- Texts from the Automatic Content Extraction (ACE) program come from transcribed broadcast news (ABC, CNN, PRI, VOA) and newswire (AP, NYT). These comprise 17% and 16% of the corpus, respectively.
- Propbank (Treebank2) texts are Wall Street Journal newswire texts, making up 55% of the corpus.

The Annotation Effort

- The annotation of each document involves:
  - an automatic pre-processing step in which some of the events and temporal, modal and negative signals are tagged;
  - a human annotation step which
    - checks the output of the pre-processing step;
    - introduces other signals and events, time expressions, and the appropriate links among them.
- The average time to annotate a document of 500 words by a trained annotator is 1 hour.
- The annotators came from a variety of backgrounds.
  - 70% of the corpus annotated by TimeML developers;
  - 30% annotated by students from Brandeis University.

The Annotation Tool (1)

- To help the annotators with the annotation effort, a modified version of the Alembic Workbench (Vilain and Day 1996) was developed.
- When a text is loaded into the tool:
  - the text is shown in one window with the results of the pre-processing shown via coloured tags. These tags can be edited or deleted, and new tags can be introduced.
  - links are shown in a second window

    These links can be created by selecting tags in the text window and inserting these into the link window.

TANGO Demo

- Performing link analysis on a text

Domains and Data Sets

- Document Collection (300):
  - ACE
  - DUC
  - PropBank (WSJ)

- Query Corpus Collection:
  - Excite query logs
  - MITRE Corpus
  - TREC8/9/10
  - Queries from TIMEBANK

Corpus Statistics (1)

- The statistics collected so far give:
  - the proportion of tagged text in the corpus
  - the distribution of:
    - event classes
    - TIMEX3 types
    - LINK types
- Information like this gives a useful starting point when analysing the mechanisms used to convey temporal information.
- For example, 62% of links were TLINKs, indicating the importance of this link type.
- Further analysis of the TLINK will reveal the proportion of explicitly expressed temporal relations (i.e. a signal is used) to implicitly expressed temporal relations (no signal is used).

Corpus Statistics (2)

- For example, here is the distribution of tag types:

	Count	Proportion
Tokens	68555	100%
Tags (all 3 kinds)	11206	16.3%
Events	7571	11.0%
TIMEX3	1423	2.1%
Signals	2212	3.2%

The Question Corpus

- TimeML aims to contribute to Question Answering (QA) – temporal question answering in particular.
- Temporal questions can be broadly classified into two categories:
  - Questions that ask for a temporal expression as an answer, like

    When was Clinton president of the United States?

    When was Lord of the Rings: The Two Towers released?

    We call this type explicit.
  - Questions that either use temporal expression to ask for a non-temporal answer or that ask about the relations holding between events.

    Who was president of the United States in 1990?

    Did world steel output increase during the 1990s?

    We call this type of temporal question implicit.

The Question Corpus (2)

- To evaluate the usefulness of TimeML for (temporal) QA, a question corpus of 50 questions has been created.
- This corpus was annotated according to a specially developed annotation scheme. This scheme allows features such as:
  - the type of the expected answer
  - the volatility of the answer (i.e. how often it changes)

  to be annotated.
- The questions contained in the corpus cover both types mentioned above. Examples of questions in the corpus are:

  When did the war between Iran and Iraq end?

  When did John Sununu travel to a fundraiser for John Ashcroft?

  How many Tutsis were killed by Hutus in Rwanda in 1994?

  Who was Secretary of Defense during the Gulf War?

Tempex

- Wilson and Mani (2002) MITRE
- Timex2 parsing
- Direct Interpretation to ISO value

What is TempEx?

- Perl module that implements the TIDES Temporal Annotation Guidelines
- Handles many formats
  - *Feb. 10*, *Feb. 10th*, *February Tenth*
- Some parts of standard not fully implemented
  - Embedded Expressions: *Two weeks ago tomorrow*
  - Unknown Components: *June 10* (VAL = XXXX0610)
- Some very small extensions
  - *Easter* gets an ALT_VAL

Sample Output

POS Tags removed

I got up
<TIMEX2 TYPE="DATE" VAL="20010216TMO" MOD="EARLY">early this morning</TIMEX2>.

I ate lunch <TIMEX2 TYPE="TIME" VAL="20010216T1207">an hour and a half ago</TIMEX2>.

In <TIMEX2 TYPE="DATE" VAL="FUTURE_REF">the future</TIMEX2> I will know better.

I went to Hong Kong <TIMEX2 TYPE="DATE" VAL="2000W40">the wee of October third</TIMEX2>.
I went to Hong Kong <TIMEX2 TYPE="DATE" VAL="2000W42">the third week of October</TIMEX2>.

Reference Date: 02/16/2001 13:37:00

Performance

Interannotator agreement

	TIMEX	VAL	MOD
Human x Human	0.789	0.889	0.871
TempEx x Human	0.624	0.705	0.301

Speed - 0.5Megabyte/Minute

Demo: **Tempex**

TIMEX3 Parser Objects (T3PO)

Automatic TimeML Markup

- Extends TIDES TIMEX2 annotation:
  - Broader Coverage of temporal expressions
  - Larger lexicon of temporal triggers
- Delays Computation of Temporal Math:
  - Annotation with Temporal Functions
  - Import Hobbs' Semantic Web Temporal System
- Distinct Cascaded Processes:
  - TIMEX3 and signal recognizer;
  - Event Predicate recognizer
  - LINK creation transducer.

T3PO Overview

Preprocessing:

POS, Shallow Parsing

Three Finite State modules:

- Temporal Expressions
- Events
- Signals
- Links

Discourse Information

Temporal Expressions

Extension to Timex2

- Coverage
- Absolute ISO Values
- Signals

Functional Representation:

- Anchor Resolution
- Suite of Temporal Functions

Event Recognition

In Verbal uses VG chunks:

- Encodes Tense and Aspect information

Nominal Events using:

- Morphological information
- POS ambiguity
- Signals
- Semantic Information

Link Recognition

Event -Timex Links

Use of heuristics.

Extra-sentential (Event-DCT Links)

Event-Event Links:

- Intrasentential
  - SLINKS (evidential)
  - SLINKS (infinitivals)
- Extrasentential

Preliminary Tests Estimation

(6 documents with human annotated version)

Precision	Recall	TASK
90%	77%	TIMEX RECOGNITION
81%	69%	TIMEX VALUE RECOGNITION
48%	55%	SIGNAL RECOGNITION
85%	89 %	EVENT RECOGNITION.
48%	54%	EVENT CLASS RECOGNITION
	50%	TIMEX-EVENT LINK RECOGNITION

Mani et al. (2003)

- A variety of theories have been proposed as to the roles of semantic and pragmatic knowledge in event ordering
- Very little prior work on corpus-based methods for event ordering
- They carried out a pilot experiment with 8 subjects who provided event-ordering judgments for 280 clause pairs. Results revealed that:
  - A. Narrative convention applied only 47% of the time in ordering events in 131 pairs of successive past-tense clauses
  - B. ~75% of clauses lack explicit time expressions
    - Suggests that anchoring events only to *explicit* times wouldn't be sufficient

Motivation

- Question Answering from News
  - When do particular events occur
    - *When did the war between Iran and Iraq end?*
  - Which events occur in a temporal relation to a given event
    - *What is the largest U.S. military operation since Vietnam?*
- Multi-Document News Summarization
  - Event chronologies (e.g., timelines) are used widely in everyday news
  - Need to know when events occur, to avoid inappropriate merging of distinct events

were admitted to hospital. The disease is reported to have killed 37 people in northern Uganda at the weekend.
17 Oct 2000 21:37:42 -0200
NAIROBI: **By Tue 17 Oct 2000**, Radio Uganda was reporting 73 known cases, of whom 37 had **died**,

Problem Characteristics

- In news, events aren't usually described in the (narrative) order in which they occur
  - Temporal structure dictated by perceived news value
    - Latest news usually presented first
  - News sometimes expresses multiple viewpoints, with commentaries, eyewitness recapitulations, etc.,
- Temporal ordering appears to involve a variety of knowledge sources
  - Tense & aspect
    - Max *entered* the room. Mary stood up/*was seated* on the desk.
  - Temporal adverbials
    - Simpson made the call *at 3*. *Later*, he was spotted driving towards Westwood.
  - Rhetorical relations and World Knowledge
    - Narration Max stood up. John greeted him.
    - Cause/Explanation Max fell. John pushed him.
    - Background Boutros-Ghali Sunday opened a meeting in Nairobi of ....He arrived in Nairobi from South Africa.

Event Ordering and Reference Time

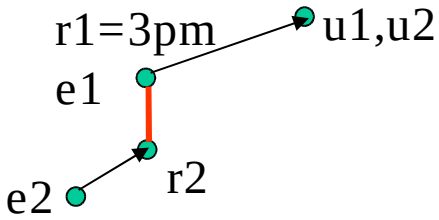
- Reference Time (Reichenbach 47) – provides temporal anchoring for events

  $_{u}$I *had*$_{r}$ *mailed*$_{e}$ the letter (when John came and told me the news).

  Past Perfect: e < r < u *Past: e =r < u*

- Movement of Reference Time depends on tense, aspect, rhetorical relations, world knowledge, etc.

  $_{u1}$*John picked*$_{r1,e1}$ *up the phone (at 3 pm)*
  $_{u2}$*He had*$_{r2}$ *told*$_{e2}$ *Mary he would call her*
  Assuming r2 = e1 (stative), e2 < e1
  (Hwang & Schubert 92)



Two Clause Interpretation

Past2Past

- Max stood up. John greeted him
  - AFTER relation
- Max fell. John pushed him.
  - BEFORE relation
- Max entered the room. Mary was seated behind the desk.
  - Equal (SIMULTANEOUS or INCLUDE) relation

Past2PastPerfect

- Max entered the room. He had drunk a lot of wine
  - BEFORE relation

PastPerfect2Past

- Max had been in Boston. He arrived late.
  - AFTER relation

Factors That Determine Relation

- Aspect:
  - Progressive or not
- Order:
  - The iconic order in text
- Tempex:
  - The existence of a temporal expression
- Tense:
  - Past vs. Past Perfect
- Meaning:
  - Lexical or constructional semantics of the sentence.

Automatic Link Identification in Text

- *Mani, Schiffman, and Zhang (2003)*

Time Expression and Clause Processing

TIDES TIMEX2 Annotation Scheme

The Foreign Minister told Thailand's Nation Newspaper <TIMEX2 VAL="1998-01-04">Sunday</TIMEX2> Pol Pot had left Cambodia but was not in Thailand, ending credence to a claim <TIMEX2 VAL="1997-SU">last summer</TIMEX2> the aged and ailing former Khmer Rouge leader had fled to China.

Clause Tagging

<S><C>The United States unleashed <RC>what appeared<CO>to be its fiercest daylight strike on Afghanistan on <TIMEX2 VAL="1991-01-21">Monday but</CO></RC></C> <C>the administration faced concern from Saudi Arabia and Pakistan over the bombardment <CO>to force Taliban leaders</CO> <CO>to hand over Saudi militant Osama bin Laden</CO>. </C></S>

TIMEX2 Accuracy

5 annotators	F-measure	
193 TDT2 docs	Extent	Value
Human Agreement	.79	.86
TempEx 1.03	.76	.82

CLAUSE-IT Tagger

- special-purpose finite-state grammars used with CASS to identify NPs, PPs, and VPs, and links between verbs and their subjects.
- proposed clause boundaries confirmed or adjusted using verb subcategorization information from Penn Treebank
  - e.g., a PP can be attached to a VP containing an object NP if the verb has been followed in the PTB by a NP and a PP headed by the current prep.

Computing Reference Times

Explicit reference time

Implicit reference time encoded in clause tval feature

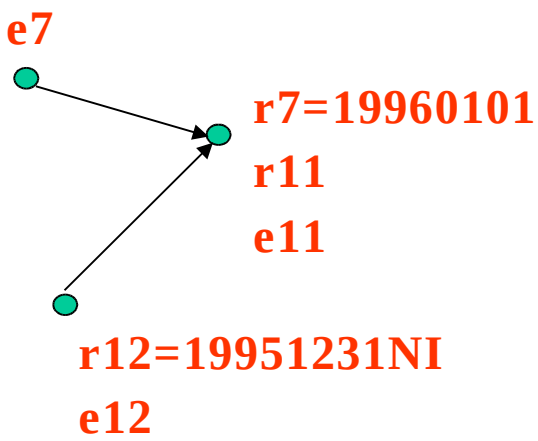
<doc>
<refdate id=t1>19960101</refdate>ï¿½ï¿½ï¿½ï¿½ï¿½
<s>
<c val=ï¿4ï¿>“
At the start of 199512 tval=t4 December, the 10 main projects of the Airport Core Programme were 46 percent complete. <[redacted]/s>
<s>
<c val=ï¿1ï¿>“
Billy Lam, director of the New Airport Projects Co-ordination Office, said </c[redacted]
<c val=ï¿1ï¿>“
the project, <r val=ï¿½ï¿½>
which will replace congested Kai Tak airport perched on the edge of Hong Kong harbour,
[redacted]
was both on schedule and within budget. </[redacted]s>

```
history_list := {doc_date}
for each finite clause c do
        rtime = timex2(c)
        if rtime then
                tval(c) = rtime
                unless type(c, rel_clause)
                        push(rtime, history_list)
        elsif reporting_verb(c)  then
                tval(c) = doc_date
        elsif ∃j s.t. inside_quote(c, j) then
                tval(c) = tval(j)
        else tval(c) = last (history_list)
```

A Naïve Algorithm For Computing tval (59% accurate)

Partially Ordering Links

- Machine-learnt rules used to generate anchor tuples
  - <temporal_reln, event-index, tval>
- Timex2 sorting used to generate tval tuples
  - <temporal_reln, tval, tval>



<c index=7 tval=19960101 anchor-C5.0=BEF >
Some 280,000 federal workers have been *furloughed* …</c>

<c index=11 tval=19960101 anchor-C5.0=AT>After breakfast with weekend participants, Clinton *went* to play 18 holes of golf with several friends despite fog and rain.</c>

<c index=12 tval=19951231NI anchor-C5.0=AT>The president and his family *celebrated* New Year's Eve at a dinner party sponsored by the Renaissance Weekend.</c>

Event Ordering		
Link Recall	**Link Precision**	**F-measure**
.777 (562/723)	.737 (563/764)	.757

7 docs, 194 clauses, 723 human links

Mani et al. Results

- Introduces a corpus-based approach for anchoring and ordering events
  - Approach is motivated by a pilot experiment investigating human event ordering capabilities
- Uses clause tagging and shallow semantic tagging of tense, aspect, time expressions
- Achieves .84 accuracy in anchoring events and .75 F-measure in partially ordering them

Features in TimeML 2.0

- Argument binding into Events
- Pred feature in EVENT
  - General types with like entailments
- Vendler classification:
- Scope of Negation and Modality:
  - Represented on TLINK

Argument Binding into Events

Syntax of Entity

```
<ENTITY>
attributes ::= aid type agreement det
aid ::= ID
{aid ::= argumentID
argumentID ::= a<integer>}
type ::= <named entity type>
agreement ::= ???
det ::= ‘a’|’the’|’possessive’|’quant’
```

Syntax of Arglink

```
<ARGLINK>
attributes ::= [lid] [origin] eventInstanceID
(relatedEventInstanceID | relatedArgumentID) preposition

lid ::= ID
{lid ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventInstanceID ::= IDREF
{eventInstanceID ::= EventInstanceID}
relatedEventInstanceID ::= IDREF
{eventInstanceID ::= EventInstanceID}
relatedArgumentID ::= IDREF
{argumentID ::= argumentID}
preposition ::= CDATA
```

Example of Arguments 1

John left on Saturday.

<ENTITY aid=”a1”> John </ENTITY>

<EVENT eid=”e1” class=”OCCURRENCE”>

left

</EVENT>

<MAKEINSTANCE eiid=”ei1” eid=”e1” tense=”past” aspect=”none”/>

<SIGNAL sid=“s1”> on </SIGNAL>

<TIMEX3 tid=“t1” value=20011014T112713> Saturday </TIMEX>

<ARGLINK eventInstanceID=”ei1” relatedEntityID=”a1” />

<TLINK eventInstanceId=“ei1” relatedToTime=“t1” RelType = IS_INCLUDED/>

Example of Arguments

Police arrested the suspect in the airport on Tuesday.

<ENTITY aid=”a1”> Police </ENTITY>

<EVENT eid=”e1” class=”OCCURRENCE”>

arrested

</EVENT>

<MAKEINSTANCE eiid=”ei1” eid=”e1” tense=”past” aspect=”none”/>

<ENTITY aid=”a2” det=”the”> the suspect </ENTITY>

in

<ENTITY aid=”a3” det=”the”> the airport </ENTITY>

<SIGNAL> on </SIGNAL>

<TIMEX3 tid=“t1” value=20011014T112713> Saturday </TIMEX>

<ARGLINK eventInstanceID=”ei1” relatedEntityID=”a1” />

<ARGLINK eventInstanceID=”ei1” relatedEntityID=”a2” />

<ARGLINK eventInstanceID=”ei1” relatedEntityID=”a3” prepostion=”in”/>

<TLINK eventInstanceId=“ei1” relatedToTime=“t1” RelType = IS_INCLUDED/>

Negation over Events: Currently

Survivors

were

not

<EVENT eid="e1" class="OCCURRENCE" pred="TEACH">

found

</EVENT>

<SIGNAL sid="s1">

on

</SIGNAL>

<TIMEX3 tid="t2" type="DATE" value="XXXX-WXX-1">

Monday

</TIMEX3>

<MAKEINSTANCE eventID="e1" eventInstanceID="ei1" " negation="TRUE">

<TLINK eventInstanceID="ei1" signalID="s1" relatedToTime="t2" relType="IS_INCLUDED"/>

No survivors were found.

<MAKEINSTANCE eventID="e1" eventInstanceID="ei1" " negation="FASLE">

<TLINK eventInstanceID="ei1" signalID="s1" relatedToTime="t2" relType="IS_INCLUDED"/>

Quantifiers and Negation: 1

Survivors were not found on Monday.

<ENTITY aid=”a1”> Survivors </ENTITY>

Were

<SIGNAL > not </SIGNAL>

<EVENT eid=”e1” class=”OCCURRENCE” pred=“find” tense=”past” aspect=”none”>

found

</EVENT>

<SIGNAL sid= “s1”> on </SIGNAL>

<TIMEX3 tid=“t1” value=20011014T112713> Monday </TIMEX>

<ARGLINK eventID=”ei1” relatedEntityID=”a1” />

<TLINK eventId=“ei1” relatedToTime=“t1” Polarity= “NEG” RelType = IS_INCLUDED/>

Quantifiers and Negation: 2

No survivors were found on Monday.

<ENTITY aid=”a1” quant=“NO”> No survivors </ENTITY>

were

<EVENT eid=”e1” class=”OCCURRENCE” pred=“find” tense=”past” aspect=”none”>

found

</EVENT>

<SIGNAL sid= “s1”> on </SIGNAL>

<TIMEX3 tid=“t1” value=20011014T112713> Monday </TIMEX>

INTENDED INTERPRETATION

<ARGLINK eventID=”ei1” relatedEntityID=”a1” />

<TLINK eventId=“ei1” relatedToTime=“t1” Polarity= “FALSE” RelType = IS_INCLUDED/>

Reference to the Argument (“no survivors”) provides a resource to the interpretation function for determining the polarity of the TLINK.

TimeML German Fragment

(Due to Frank Schilder, ms. 2003)

TimeML in German

- Corpus study in German focussing on the preposition *in*.
  - Ca. 100 occurrences of the preposition *in* extracted from taz articles
  - Marked with simplified TimeML:
    - Only TLINKS
    - Different Aspect specification
  - Marked with additional features (see below)
- Goal: definition of a semantics for the proposition *in* considering:
  - Aspectual classes
  - Granularity
  - Reference time

Schilder (2003)

German temporal and event expressions

- Different tense and aspect system:
  - Usage of tenses:
    - Present tense is ambiguous wrt. Present/future tense.
    - No progressive form
    - (Past perfect preferred tense in spoken language for expressing past events)
  - Aspectual information not morphologically encoded in a consistent way
    - Different Aktionsarten:
      - Ingressive: *verlieben* (to fall in love)
      - Exgressive: *verblühen* (to wither)
      - Semelfactive: *husten* (to cough)
      - Iterative: *hüsteln* (coughing)
      - …
    - No imperfective/perfective aspect

Schilder (2003)

German temporal and event expressions

- Different syntactical structure:
  - Prefix-verbs: *ausschließen (exclude) / schließen (close): Die Bedingungen schließen einen Verkauf aus*
  - Reflexive verbs: *sich entwickeln (come out) / entwickeln (develop)*
  - Complex verb constructions: *sich in der Lage sehen etwas zu tun (feel capable of doing something)*

  Sah sich die Polizei schon bisher nicht in der Lage …

  , dass die die Polizei sich schon bisher nicht in der Lage sah …
  - Normally, Verbs are at position 2, but
    - Participle verbs come at the end of a clause and
    - Subordinate clauses and relative clauses: end of clause

Schilder (2003)

“Schröder hatte bereits am Wochenende signalisiert, dass er eine dritte Amtszeit anstrebt.”

<ENTITY aid=”a1”> Schröder </ENTITY>

hatte

bereits

<SIGNAL> am </SIGNAL>

<TIMEX3 tid=“t1” type = “date” value=YYYY-XX-WE> Wochenende </TIMEX>

<EVENT eid=”e1” class=”OCCURRENCE”> signalisiert </EVENT>

<MAKEINSTANCE eiid=”ei1” eid=”e1” tense=”past” aspect=”none”/>

<SLINK eventInstanceID="ei1" subordinatedEvent="ei2 relType="MODAL"/>

<TLINK eventInstanceId=“ei1” relatedToTime=“t1” RelType = IS_INCLUDED/>

dass

<ENTITY aid=”a2” > er </ENTITY>

<ENTITY aid=”a3” det=”eine”> eine dritte Amtszeit </ENTITY>

<EVENT eid=”e1” class=”OCCURRENCE”> anstrebt </EVENT>

<MAKEINSTANCE eiid=”ei2” eid=”e2” tense=”present” aspect=”none”/>

<ARGLINK eventInstanceID=”ei1” relatedEntityID=”a1” />

<ARGLINK eventInstanceID=”ei1” relatedEventID=”ei2” />

<ARGLINK eventInstanceID=”ei2” relatedEntityID=”a2” />

<ARGLINK eventInstanceID=”ei2” relatedEntityID=”a3” />

Outstanding Problems

Semantics of TimeML

A text T is satisfied by a model M iff there are functions

f_e: Dom_e -> Pow(E), and

f_{ei}: Dom_{ei} -> E

f_t: Dom_t -> I , such that

for all tags $t \in Tag(T)$, t is satisfied by f_e f_{ei} and f_t in M.

A tag t is satisfied by f_e,f_t, and f_{ei} in M iff if t has the form

- "<EVENT eid = α class = β pred= δ >"
  then $f_e(\alpha) = Val(\delta)$

- "<TIMEX3 tid = α type = DATE value= δ >"
  then $f_t(\alpha) = Val(\delta)$

- "<TLINK eventInstanceID = α relatedtoTime = β relType= 'IS_INCLUDED'>"
  then $\tau(f_{ei}(\alpha)) \subseteq f_t(\beta)$

Problems for Interpretation

- Negation
  - John didn't teach on Tuesday
    <EVENT eid = "ei1"…pred="TEACH">
    <MAKEINSTANCE eiid ="eii1"…negation="true">
    <TIMEX3 tid="t1" val="XXXX-WXX-2">
    <TLINK relatedToTime ="t1" eventInstance="eii1" relation="IS_INCLUDED">
  - -> SCOPE for negation
- Multiple Events
  - John taught twice on Tuesday
    <EVENT eid = "ei1"…pred="TEACH">
    <MAKEINSTANCE eiid ="eii1" … event="e1" cardinality=2>
    <TIMEX3 tid="t1" val="XXXX-WXX-2">
    <TLINK relatedToTime ="t1" eventInstance="eii1" relation="IS_INCLUDED">

    - "<MAKEINSTANCE eiid = α eid = β negation='FALSE' modal = '' cardinality=γ>"
      then $f_{ei}(\alpha) \in f_e(\beta)$
      <MAKEINSTANCE eiid ="eii1" … event="e1" >
      <MAKEINSTANCE eiid ="eii2" … event="e1" >

    - Condition on Embedding Functions

Problems for TimeML

- Set-valued Times
  - John taught
    <TIMEX3 tid=”t4” type=”SET” value=”P1M” quant=”EVERY” freq=”3D”> three days every month</TIMEX3>
  - PROBLEM: the temporal identifier can’t be interpreted as denoting a particular interval of time, it must be a set of intervals (or even a set of sets of intervals!)
- Disjunction
  - John taught on Monday or on Wednesday

Some Solutions

Negation:

Use TLINK as a scope domain, eliminate MAKEINSTANCE

- John didn't teach on Tuesday

  <EVENT eid = "ei1"…pred="TEACH">
  <TIMEX3 tid="t1" val="XXXX-WXX-2">
  <TLINK relatedToTime ="t1" eventID="ei1" relation="IS_INCLUDED"
  Polarity="false">

New TLINK Rules

"<TLINK eventID = α relatedtoTime = β relType= "IS_INCLUDED" Polarity="true">"

there is an $e \in E$ such that $e \in f_e(\alpha)$ and $\tau(e) \subseteq f_t(\beta)$

"<TLINK eventID = α relatedtoTime = β relType= "IS_INCLUDED" Polarity="false">"

there is no $e \in E$ such that $e \in f_e(\alpha)$ and $\tau(e) \subseteq f_t(\beta)$

Some Solutions

Multiple events

Add cardinality element to the TLINK

- John taught twice on Tuesday

  <EVENT eid = “ei1”…pred=“TEACH”>

  <TIMEX3 tid=“t1” val=“XXXX-WXX-2”>

  <TLINK relatedToTime =“t1” eventID=“ei1” relation=“IS_INCLUDED” Polarity=“true” cardinality=“2”>

“<TLINK eventID = α relatedtoTime = β relType= “IS_INCLUDED” Polarity=“true” cardinality=γ>” is satisfied iff

there are Val(γ) distinct $e \in E$ such that $e \in f_e(\alpha)$ and $\tau(e) \subseteq f_t(\beta)$

Harder Problems

- **Vagueness**
  - When he left, **shortly after** 5 am Tuesday, he discovered someone had smashed a window.
  - Appavu has been involved with healthcare standards development for about a decade, an interest he developed **shortly after** he began working with information systems at Cook County.
  - Domino's Pizza of Washington reported that they delivered "In excess" of 100 large pizzas to the White House **late this afternoon**.
  - It was then,**early in December** of 1977, that he went to the NORML conference.

Vagueness

- **Current Treatment:**
  - <TIMEX3 tid="t1" val="20030829TAFT" mod="END">
    late this afternoon </TIMEX3>
  - <TIMEX3 tid="t1" val="197712" mod="START">
    early in December of 1977 </TIMEX3>
- **Problem:**
  - No semantics for mod attributes means no possibility for doing reasoning.
    - It was then,early in December of 1977, that he went to the NORML conference. Two weeks later he was a convert.
      - **Before or after Christmas?**

We might fake a solution by being overly general:

- Interpret START to mean "the first half of"

Current Treatment

No general solution for mod values:

- Shortly after 5am -> minutes
- Shortly after he began working -> weeks or months

Semantic Weakness

Simple annotation of temporal relations is too week:

- President John F. Kennedy's gravesite at Arlington National Cemetery has been restored to its original condition, **after** someone tried unsuccessfully to dig up some of its granite paving stones.
- South Africa, **after** losing the toss, were bowled out for 107 against England.

- How long after?
  - Days or weeks
  - An hour or two.

This is not generally encoded overtly.

Context Dependent Vagueness

If we did code this, lots of world-knowledge based information could be encoded by annotators:

- They ate lunch early on Monday.
- They ate dinner early on Monday.
- They ate breakfast early on Monday.

Probably

before noon

in the early evening

in the very early morning

Questions

- How to talk about a “likely distribution” in time?
- How to compare such annotations?

TimeML-enabled Applications

Web-based Temporal Reasoning

- Web Negotiation Agents (Brokers)
- Scheduling Programs

Semantic Web

Delivery within five business days.

```
<EVENT  eid="e1" class="OCCURRENCE" tense="NONE"  aspect="NONE">
order
</EVENT>
<MAKEINSTANCE eiid="ei1" eventID="e1"/>

<EVENT  eid="e2" class="OCCURRENCE" tense=nil  aspect="PERFECTIVE">
delivery
</EVENT>
<MAKEINSTANCE eiid="ei2" eventID="e2"/>
<SIGNAL sid="s1">
within
</SIGNAL>
<TIMEX3 tid="t1" type="DURATION" value=nil temporalFunction="true">
 five business days
</TIMEX3>
<TLINK  eventInstanceID="ei2" signalID="s1"  relatedToEvent="ei1” relType="AFTER" />

<TLINK  eventInstanceID="ei2" signalID="s1"  relatedToTime="t1” relType="IS_INCLUDED" />

 <TLINK  eventInstanceID="ei1" signalID="s1"  relatedToTime="t1” relType=" BEGINS" />
```

www.TimeML.org