

Empirical Validation of Reichenbach's Tense Framework

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The Role of Time

Why is time important in language processing?

- World state changes constantly
- Every empirical assertion has temporal bounds
- “*The sky is blue*”, but it was not always
- Without it, naïve knowledge extraction will fail (given an Almanac of Presidents, who is President?)

Temporal relations critical



Representations

Attempts to reify time in discourse

- (ISO-)TimeML: XML-like standard
- TimeBank: about 180 documents of newswire

Automatic temporal IE immediately useful for:

- Fact-bounding (TAC KBP)
- Clinical: summarisation, event ordering
- NLG: Carsim, Babytalk
- Machine translation

Relations

Temporal relations difficult to extract
What do they look like?

- A BEFORE B
- A INCLUDES B

TempEval 2 results suggest event-event are hardest ⁰

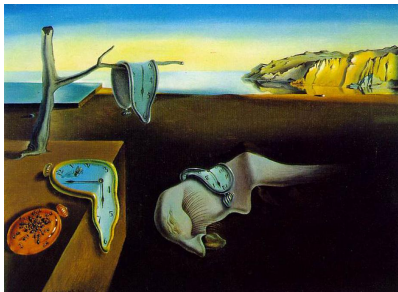
0. Verhagen, M. et al. 2010. "SemEval-2010 task 13: TempEval-2" in *Proc. Int'l Workshop on Semantic Evaluation*



The problem seems “ML-resistant”

TE2 best performance: 0.65 accurate; MCC baseline: 0.59
accurate

Sophisticated features: 1.5% improvement



We need more insight

Many event-event relations are between tensed verbs



Formal framework

Tripartite perception of time ¹

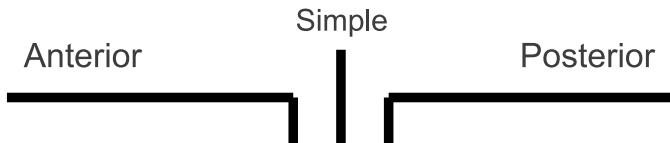


What about the perfect?

1. McTaggart, J.M.E. 1908 "The Unreality of Time" *Mind: A Quarterly Review of Psychology and Philosophy*, 17

Formal framework

Another similar partitioning, for “perspective”



“By 9p.m., I will have left”

Reichenbach

Let's introduce a framework of tense and aspect ²

- Each verb happens at event time, E
- The verb is uttered at speech time, S
- Past tense: $E < S$ *John ran.*
- Present tense: $E = S$ *I'm free!*

Reflects basic tripartite model

2. Reichenbach, H. 1947 "The Tense of Verbs" in *Elements of Symbolic Logic*,
Macmillan



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Reference time

What differentiates simple past from past perfect?

Add reference time - three points S , E , R

- *John ran.* is not the same as *John had run.*
- Introduce abstract reference time, R
- *John had run.* $E < R < S$

R acts as abstract focus

Corresponds to centre of advanced tripartite



Reichenbachian tenses

What tenses can we have?

<i>Relation</i>	<i>Reichenbach's Tense Name</i>	<i>English Tense Name</i>	<i>Example</i>
$E < R < S$	Anterior past	Past perfect	<i>I had slept</i>
$E = R < S$	Simple past	Simple past	<i>I slept</i>
$R < E < S$	Posterior past		<i>I expected that I would sleep</i>
$R < S = E$			
$R < S < E$			
$E < S = R$	Anterior present	Present perfect	<i>I have slept</i>
$S = R = E$	Simple present	Simple present	<i>I sleep</i>
$S = R < E$	Posterior present	Simple future	<i>I will sleep (Je vais dormir)</i>
$S < E < R$	Anterior future	Future perfect	<i>I will have slept</i>
$S = E < R$			
$E < S < R$			
$S < R = E$	Simple future	Simple future	<i>I will sleep (Je dormirai)</i>
$S < R < E$	Posterior future		<i>I shall be going to sleep</i>

Table : Reichenbach's tenses

Total 19 combinations: the above are useful for English



Permanence of the reference point

How can we use this for temporal relations?

Principle of permanence

“although the events referred to in the clauses may occupy different time points, the reference point should be the same for all clauses”

Shared R

Applies when verb events are in the same context: “sequence of tenses”

More on this later!



Time to validate

With permanence, we can reason about event order
This seems great, but first:

Is Reichenbach's framework correct?

Let's look at the data

- 7935 EVENTs
- 6418 TLINKs

We'll have to connect Reichenbach's framework with TimeML semantics first



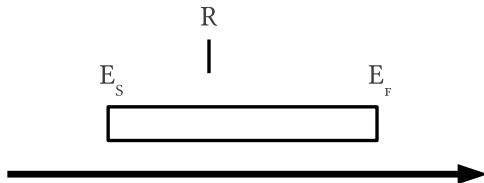
TimeML tense and aspect

TimeML tense	TimeML aspect
past	none
present	perfect
future	progressive
	both

Progressive? This isn't in the framework

Progressive

As TimeML assumes events are intervals, let's do the same:



Decompose progressives into incipitive and concluding instants

$E \rightarrow E_s, E_f$

Event is viewed at a point where it is ongoing

Place R between E_s and E_f

Connect the two

Now we can describe tensed TimeML events in Reichenbachian terms:

TimeML Tense	TimeML Aspect	Reichenbach structure
PAST	NONE	$E = R < S$
PAST	PROGRESSIVE	$E_s < R < S, R < E_f$
PAST	PERFECTIVE	$E_f < R < S$
PRESENT	NONE	$E = R = S$
PRESENT	PROGRESSIVE	$E_s < R = S < E_f$
PRESENT	PERFECTIVE	$E_f < R = S$
FUTURE	NONE	$S < R = E$
FUTURE	PROGRESSIVE	$S < R < E_f, E_s < R$
FUTURE	PERFECTIVE	$S < E_s < E_f < R$

Table : TimeML tense/aspect combinations, in terms of the Reichenbach framework.



Relation ambiguity

The target for validation: temporal relations

Follow Allen's relation set of 14 ³

Our Reichenbach triples underspecific for the precise interval relation. E.g.:

- If E_1 is simple past and E_2 simple future
- Tense suggests that E_1 starts before E_2
- There are many Allen interval relation types for this - before, during, includes

3. Allen, J. 1983 "Maintaining Knowledge about Temporal Intervals" *Comm. ACM* **26** (11)



TimeML relation disjunctions

Solution: use disjunctions

Use Reichenbach to just *constrain* the relation type

- Tense suggests that E_1 starts before E_2
- The available Allen relation types for E_1 / E_2 are:
- BEFORE, IBEFORE, DURING, ENDED_BY and INCLUDES.

Any one of these relation types is a valid response.



Freksa's Semi-Intervals

Surprise Observation Slide!

Build set of Allen disjunctions from all possible combs. of R'bach triples that come from TimeML tenses

Identical to groups in Freska's semi-interval algebra ⁴



– which was designed for annotating natural language

(are Freksa relations more appropriate than Allen's, for this task?)

4. Freksa, C. 1992 "Temporal reasoning based on semi-intervals" *AI* **54** (1)



Recap

So: now we can

- Map TimeML verb events into Reichenbach triples
- Temporally relate Reichenbach verb events
- Map Reichenbach event relations back to TimeML

Which pairs of verbs, e.g. which temporally related events to choose?

Temporal context

TLINK requirements:

- Event-Event;
- PoS = verb;
- same temporal context

Reichenbach unclear – “sequence of tenses”

Possible for expert annotator to label

We prefer an automatic method!



Context modelling

Need to *model* context

Perhaps proximity in text can hint at relatedness?

- same sentence
- same or adjacent sent

Same *S R* order

- *R* should be in same place
- *S* shouldn't move



Results

For TLINKs with event verb arguments in the same context
What proportion have relation types within constraints of R'bach's framework?

Context model	TLINKs	Consistent
None (all pairs)	1 167	81.5%
Same sentence, same <i>SR</i>	300	88.0%
Same sentence	600	71.2%
Same / adjacent sentence, same <i>SR</i>	566	91.9%
Same / adjacent sentence	913	78.3%

Table : Consistency of relation types suggested by Reichenbach's framework with ground-truth.

Relation type IAA: 0.77



Super-stringent results

Sometimes no constraint is possible

e.g. “Jack went to school, Jill went to the circus”

What if we exclude these?

Context model	Non- “all” TLINKs	Consistent
None (all pairs)	481	55.1%
Same sentence, same <i>SR</i>	95	62.1%
Same sentence	346	50.0%
Same / adjacent sentence, same <i>SR</i>	143	67.8%
Same / adjacent sentence	422	53.1%

Table : Consistency of relation types suggested by Reichenbach's framework with ground-truth.

Relation type IAA: 0.77



Summary

What have we done?

- Extended Reichenbach's framework to account for progressive
- Described a mapping between R'bach and TimeML
- Applied this to event-event relations

Finding: Reichenbach's framework appropriately constrains
TimeML relation type

The model is not contradicted by data, but in fact supported



Comments

Temporal annotation is hard for humans, which gives machines problems

New problem: temporal context

Are the Allen full-interval relations over-specific for linguistic annotation?

Annotation of Reichenbach in TimeML ⁵

5. Derczynski, Gaizauskas. 2011 “An Annotation Scheme for Reichenbach’s Verbal Tense Structure” in *Proc. ISA-6*



Thank you

Thank you!
Are there any questions?



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Events and Times

How else can we use the model?

Positional use

- Sets R to equal a timex (*At 10p.m. I had showered*)
- Select event-time relations using dependency parses
- Only consider cases where the event and time are linguistically connected
- Add a feature hinting at the ordering
- We reach 75% accuracy from a 66% baseline

Also used for timex standard transduction ⁶

6. Derczynski et al. 2012 “Massively increasing TIMEX3 resources: a transduction approach” in *Proc. LREC*

