Time and Tense in Language

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.

Tense

• Grammatical expression of the time of the situation described, relative to some other time (e.g., moment of speech)

Reichenbach

• Tensed utterances introduce references to 3 ‘time points’
  - Speech Time: S
  - Event Time: E
  - Reference Time: R

\[ \text{I had [mailed the letter] when John came & told me the news} \]

\[ E < R < S \]

• 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

George admires Adolf.
George admired Jesus.
Tense as Anaphor: Reichenbach

- Tensed utterances introduce references to 3 ‘time points’
  - Speech Time: S
  - Event Time: E
  - Reference Time: R

\[ \text{I had [mailed the letter] [when John came & told me the news]} \]  \[ E < R < S \]

- 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

<table>
<thead>
<tr>
<th>Relation</th>
<th>Reichenbach’s Tense Name</th>
<th>English Tense Name</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>E=R=S</td>
<td>Anterior past</td>
<td>Past perfect</td>
<td>I had slept</td>
</tr>
<tr>
<td>E=R=S</td>
<td>Simple past</td>
<td>Simple past</td>
<td>I slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Anterior past</td>
<td>Present perfect</td>
<td>I have slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Simple present</td>
<td>Simple present</td>
<td>I will sleep</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Anterior future</td>
<td>Future perfect</td>
<td>I will have slept</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Simple future</td>
<td>Simple future</td>
<td>Je dormirai</td>
</tr>
<tr>
<td>S&gt;R=E</td>
<td>Anterior future</td>
<td>Future perfect</td>
<td>I shall be going to sleep</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relation</th>
<th>Reichenbach’s Tense Name</th>
<th>English Tense Name</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>E=R=S</td>
<td>Anterior past</td>
<td>Past perfect</td>
<td>I had slept</td>
</tr>
<tr>
<td>E=R=S</td>
<td>Simple past</td>
<td>Simple past</td>
<td>I slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Anterior past</td>
<td>Present perfect</td>
<td>I have slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Simple present</td>
<td>Simple present</td>
<td>I will sleep</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Anterior future</td>
<td>Future perfect</td>
<td>I will have slept</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Simple future</td>
<td>Simple future</td>
<td>Je dormirai</td>
</tr>
<tr>
<td>S&gt;R=E</td>
<td>Anterior future</td>
<td>Future perfect</td>
<td>I shall be going to sleep</td>
</tr>
</tbody>
</table>

Tense as Operator: Prior

- Free iteration captures many more tenses,
  - I would have slept
  - But also expresses many non-NL tenses
    - [It was the case] John had slept

<table>
<thead>
<tr>
<th>Relation</th>
<th>Reichenbach’s Tense Name</th>
<th>PRIOR</th>
<th>English Tense Name</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>E=R=S</td>
<td>Anterior past</td>
<td>PP?</td>
<td>Past perfect</td>
<td>I had slept</td>
</tr>
<tr>
<td>E=R=S</td>
<td>Simple past</td>
<td>??</td>
<td>Simple past</td>
<td>I slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Anterior past</td>
<td>F?</td>
<td>Present perfect</td>
<td>I have slept</td>
</tr>
<tr>
<td>R=S&lt;E</td>
<td>Simple present</td>
<td>??</td>
<td>Simple present</td>
<td>I will sleep</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Anterior future</td>
<td>F?</td>
<td>Future perfect</td>
<td>I will have slept</td>
</tr>
<tr>
<td>S=E&lt;R</td>
<td>Simple future</td>
<td>??</td>
<td>Simple future</td>
<td>Je dormirai</td>
</tr>
<tr>
<td>S&gt;R=E</td>
<td>Anterior future</td>
<td>FF?</td>
<td>Future perfect</td>
<td>I shall be going to sleep</td>
</tr>
</tbody>
</table>

Aspect

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

Reichenbachian Tense Analysis

- Tense is determined by relation between R and S
  - R=S, R<S, R>S
- Aspect 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
Grammatical Aspect

• Perfective – focus on situation as a whole
  – John built a house

• Imperfective – focus on internal phases of situation
  – John was building a house

Different types of tense systems across languages

• Using verbal inflection:
  – Languages with a two-way contrast:
  - English: Past (before the moment of speaking) vs. Nonpast
    past -ed: She worked hard.
    nonpast (unmarked): We admire her. I will leave tomorrow.
  - Dyirbal (Australian language): Future vs. nonfuture:
    future -ñu:  ‘will come’
    nofuture -ñ: bani-ñu ‘can be, is coming’
  – Languages with a three-way distinction:
    - Catalan, Lithuanian: Past vs. Present vs. Future
      (Cat.) past: treball-à.  (Lit.) Dirb-au.  ‘I worked’
      present: treball-a.  Dirb-ú.  ‘I work’
      future: treball-arà.  Dirb-stic.  ‘I will work’
    - ChiBemba (Bantu language):

Different types of tense systems across languages

• A much richer distinction:
  – ChiBemba (Bantu language):

  For past:
  - Remote past (before yesterday) Ba-ði-bomba ‘they worked’
  - Removed past (yesterday) Ba-ði-bomba ‘they worked’
  - Near past (earlier today) Ba-ðë-bomba ‘they worked’
  - Immediate past (just happened) Ba-ðë-bomba ‘they worked’

  For future:
  - Immediate future (very soon) Ba-ðið-bomba ‘they’ll work’
  - Near future (later today) Ba-ðë-bomba ‘they’ll work’
  - Removed future (tomorrow) Ba-ðë-bomba ‘they’ll work’
  - Remote future (after tomorrow) Ba-ðë-bomba ‘they’ll work’

Aktionsarten

• STATIVES know, sit, be clever, be happy,
  – 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 X has Ved
  - John booked a flight in an hour, John stopped building a house

• ACHIEVEMENTS notice, win, blink, find, reach
  – instantaneous accomplishments

<table>
<thead>
<tr>
<th></th>
<th>Telic</th>
<th>Dynamic</th>
<th>Durative</th>
<th>E.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>know, have</td>
</tr>
<tr>
<td>Activity</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>walk, paint</td>
</tr>
<tr>
<td>Accomplishment</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>destroy, build</td>
</tr>
<tr>
<td>Achievement</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>notice, win</td>
</tr>
</tbody>
</table>

Note: Tense systems are not explicitly marked in every language, but they are present in the examples given.
Aspect

- Internal temporal organization of the situation described by an event.
- Most common:
  - **Perfective**: Situation viewed as a bounded whole.
  - **Imperfective**: Looking inside the temporal boundaries of the situation.
    - Habitual
    - Progressive
- Other related aspectual distinctions:
  - **Iterative**: The action is repeated.
  - **Inceptive**: The action is began.
  - **Inchoative**: Entering into a state.

Different types of aspect systems across languages

- Some languages use auxiliaries and particles associated with the verb:
- **English**:
  - **Perfective**: have + Past Participle  
    - *I have eaten.*
  - **Progressive**: be + Present Participle  
    - *I am eating.*
  - **Habitual**: use to + Base form  
    - *I used to sing.*
- **Catalan**:
  - **Habitual**: soler + Infinitive
    - *Sol parlar. ‘She generally talks.’
    - *Solia cantar. ‘She used to talk’
- **Iterative**: anar (past) (‘to go’) + Present Part
  - *Va tornant ‘She keeps coming back’

Different types of aspect systems across languages

- **Russian**: by means of a system of verbal prefixes
  - **Imperfective**: simple verbs *ja ˇcitálu ‘I was reading’
  - **Perfective**: prefixed verbs *ja proˇcitálu ‘I (did) read’
- **Finnish**: by means of the case of the object
  - **Perfective**: Hän luki kirjan (acc.) ‘He read the book’
  - **Imperfective**: Hän luki kirjaa (part.) ‘He was reading the book’.

  Basic meaning: only part of the object being referred to is affected by the situation.

Tense and Aspect

- **Aspect and Tense generally cross-classify**:
  - **Russian**:
    - Present:
      - Only imperfective: ‘citáju ‘I read’
    - Past:
      - Imperfective: ja ‘citálu ‘I was reading’
      - Perfective: ja proˇcitáju ‘I (did) read’
    - Future:
      - Imperfective: ??
      - Perfective: ja proˇcitáju ‘I shall read’
Tense and Aspect

- Basque:
  - Present:
    - Imperfect (Gerund + Present tense auxiliary) ekartzen du ‘he is bringing it’
    - Perfect (Past Participle + Present tense aux.) ekarri du ‘he has brought it’
  - Past:
    - Imperfect (Gerund + Past tense aux.) ekartzen zuen ‘he brought, used to bring’
    - Perfect (Past Participle + Past tense aux.) ekarri zuen ‘he brought, had brought’
  - Future:
    - Simple (Future Participle + Pres. tense aux.) ekarriko du ‘he will bring it’
    - Past Future (Future Participle + Past tense aux.) ekarriko zuen ‘he would bring’

An interesting case

- Tense and Aspect in 2 different creoles, evolved independently from each other:

<table>
<thead>
<tr>
<th>Structure</th>
<th>Hawaiian Creole</th>
<th>Haitian Creole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Form</td>
<td>He walk</td>
<td>Li maché</td>
</tr>
<tr>
<td>Progressive</td>
<td>He stay walk</td>
<td>L’ap maché (Li ap maché)</td>
</tr>
<tr>
<td>Perfect</td>
<td>He bin walk</td>
<td>Li té maché</td>
</tr>
<tr>
<td>Perfective Progressive</td>
<td>He bin stay walk</td>
<td>Li l’ap maché (Li té ap maché)</td>
</tr>
<tr>
<td>Irreal</td>
<td>He go walk</td>
<td>L’ao maché</td>
</tr>
<tr>
<td>Irreal Progressive</td>
<td>He go stay walk</td>
<td>L’ao ap maché (Li té ao maché)</td>
</tr>
<tr>
<td>Irreal Perfective</td>
<td>He bin go walk</td>
<td>Li t’a o maché (Li té ao maché)</td>
</tr>
<tr>
<td>Irreal Perfective Progressive</td>
<td>He bin go stay walk</td>
<td>Li t’a o ap maché (Li té ao maché)</td>
</tr>
</tbody>
</table>

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 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**
  
  Maˇsa videla ˇceloveka, 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**
  
  Maˇsa skazala, cto Vova spit.
  Masha say-PAST-PERF that Voval sleep-PRES
  “Masha said that Vova was sleeping”

Embedded tenses cross-linguistically

<table>
<thead>
<tr>
<th>Language</th>
<th>Relative Clause</th>
<th>Complement Clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>absolute relative anaphoric</td>
<td>relative anaphoric</td>
</tr>
<tr>
<td>Japanese</td>
<td>absolute relative</td>
<td>relative</td>
</tr>
<tr>
<td>Russian</td>
<td>absolute anaphoric</td>
<td>relative</td>
</tr>
</tbody>
</table>

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.

- 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) \# $Z , (meets(X, Z) \% (meets(Z, Y))$

Allen’s Temporal Relations

<table>
<thead>
<tr>
<th>Relation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A # B</td>
<td>A is BEFORE B, B is AFTER A</td>
</tr>
<tr>
<td>A % B</td>
<td>A MEETS B, B is MET by A</td>
</tr>
<tr>
<td>A * B</td>
<td>A OVERLAPS B, B is OVERLAPPED by A</td>
</tr>
<tr>
<td>A * B</td>
<td>A STARTS B, B is STARTED by A</td>
</tr>
<tr>
<td>A * B</td>
<td>A FINISHES B, B is FINISHED by A</td>
</tr>
<tr>
<td>A * B</td>
<td>A DURING B, B CONTAINS A</td>
</tr>
</tbody>
</table>

Allen’s Temporal Ontology

- Properties hold over every subinterval of an interval
  - $\text{Holds}(p, T)$ e.g., “John was sick for a day.”
- Events hold only over an interval and not over any subinterval of it.
  - $\text{Occurs}(e, T)$ e.g., “Mary wrote a letter this afternoon.”
- Processes hold over some subintervals of the interval they occur in.
  - $\text{Occuring}(p, T)$ e.g., “Mary is writing a letter today.”

Situation Type: Formal Constraints

- Homogeneity
  - All subevents of P are also of P (downward entailment)
  - 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.

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
  \[ \text{after}(e) = \text{the period of time started by event } e \]
- Updates 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.
  \[ \exists e_1 \exists e_2 [\text{action}(e_1, \text{rock}, \text{window}) \land \text{broken}(e_2, \text{window}) \land e_1 < e_2] \]

Actions have consequences:
- Mary arrived in Boston.
  \[ \exists e_1 \exists e_2 [\text{action}(e_1, \text{mary}, \text{boston}) \land \text{in}(e_2, \text{mary}, \text{boston}) \land e_1 < e_2] \]