Dynamic Interval Temporal Logic

James Pustejovsky
Brandeis University

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Lecture 3: Event Structure

- Events as Structured Objects
- Event Types
  - States
  - Transitions
  - Point Verbs
  - Processes
- Events as Labeled Transition Systems
- Dynamic Event Models

Lab on detection of event types properties in corpora

Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative

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(10) . a. The statue stands in the square.
b. The statue is standing in the square.

Structural vs. Phenomenal distinction – Goldsmith and Woisetschlager (1979)

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- Spanish – *ser* vs. *estar*

  (12) a. Soy enfermo (I am a sickly person)
  b. Estoy enfermo (if I have a cold)

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(18) a. John ran for twenty minutes.
b. Sheila ate apples for two days straight.
c. !John ran in twenty minutes.
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Distinguishing Processes from Transitions

- Activities: Atelic i.e. have no natural endpoint or goal (e.g. *I'm running in the park*) Compatible with a durative adverbial (e.g. *for*) that profiles the amount of time the activity takes.

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- Accomplishments: Telic i.e. have a natural endpoint of goal (e.g. *I'm running a mile*) Compatible with a container adverbial (e.g. *in*) that profiles the amount of time taken to reach the desired goal.

Typological Effects

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(21) Jeg reser till Frankrike *på* två månader.
I('m) going to France for two months.

(22) Jeg reste i Frankrike *i* två månader.
I traveled in France for two months.

Achievements and points

Achievements: Events that are conceived of as instantaneous. Often, however, there is an underlying activity that causes a change of state. Their point-like nature tends to require them to be described in the past tense or narrative present.

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(24) a. John shattered the window.
b. ! John shatters/is shattering the window.
c. The canals froze.
d. Mary found her keys.
e. *Mary is finding her keys.
f. John reached the top.

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(27) a. Bill coughed.
b. The light flashed.
c. Bill is coughing.
d. The light is flashing.

(c) and (d) have an iterative interpretation. Compare with the gradual achievements *John is reaching the top* or *The canals are freezing*.

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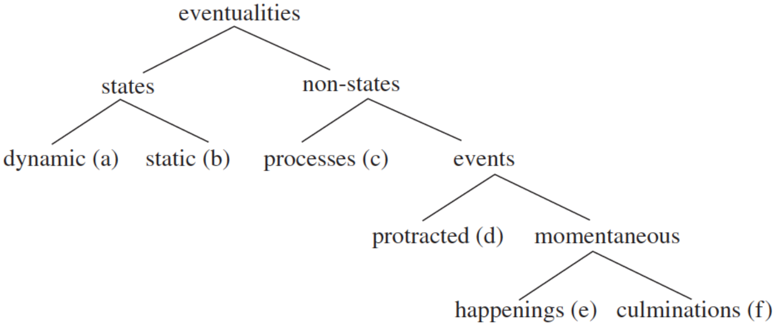
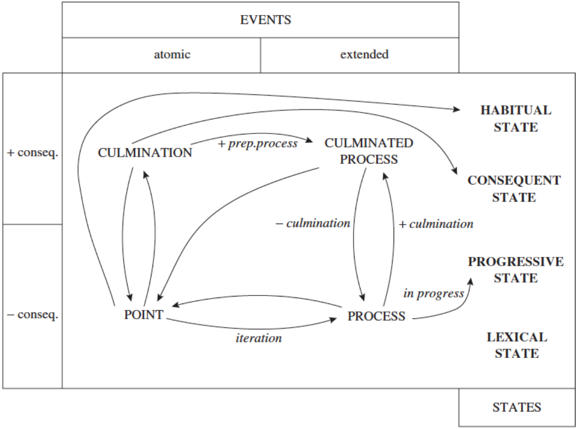
- POINT: John knocked on the door (for 2 minutes).

Bach Eventuality Typology (Bach, 1986)



Event Transition Graph (Moens and Steedman 1988)



Incremental Theme Verbs

- Certain NP's measure out the event. They are direct objects consumed or created in increments over time (cf. *eat an apple* vs. *push a chart*) (Tenny 1994).

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- In *Mary drank a glass of wine* "every part of the glass of wine being drunk corresponds to a part of the drinking event" (Krifka 1992)
- "Incremental themes are arguments that are completely processed only upon termination of the event, i.e., at its end point" (Dowty 1991).

Degree Achievements

- Verbs with variable aspectual behavior: they seems to be change of state verbs like other achievements , but allow durational adverbs (Dowty 1979, Hay, Kennedy and Levin 1999, Rappaport Hovav 2008).

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- For example *cool*, *age*, *lenghten*, *shorten*; *descend*.
- *Let the soup cool for 10 minutes*.
- *I went on working until the soup cooled*.

Points

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- Semelfactives (Smith 1990, Rothstein 2004).
- **arrived/landed for five minutes*, *knocked/tapped for five minutes*.
- Points admit iterative readings under coercive contexts (Moens and Steedman 1988).

Aspectual Composition

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Aspectual Coercion

- "A person *leads* somebody somewhere" (PROCESS) vs. "A road *leads* somewhere" (STATE)

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- "A person *leads* somebody somewhere" (PROCESS) vs. "A road *leads* somewhere" (STATE)
- "An object *falls* to the ground" (TRANSITION) vs. "A case *falls* into a certain category" (STATE)

Subatomic Event Structure

Pustejovsky (1991)

(28) a. EVENT → STATE | PROCESS | TRANSITION

Subatomic Event Structure

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(29) a. EVENT → STATE | PROCESS | TRANSITION
b. STATE: → e

Subatomic Event Structure

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(30) a. EVENT → STATE | PROCESS | TRANSITION

b. STATE: → e

c. PROCESS: → $e_1 \ldots e_n$

Subatomic Event Structure

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(31) a. EVENT → STATE | PROCESS | TRANSITION

b. STATE: → e

c. PROCESS: → $e_1 \ldots e_n$

d. TRANSITION$_{ach}$: → STATE STATE

Subatomic Event Structure

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(32) a. EVENT → STATE | PROCESS | TRANSITION

b. STATE: → e

c. PROCESS: → $e_1 \dots e_n$

d. TRANSITION_{ach}: → STATE STATE

e. TRANSITION_{acc}: → PROCESS STATE

Qualia Structure for Causative

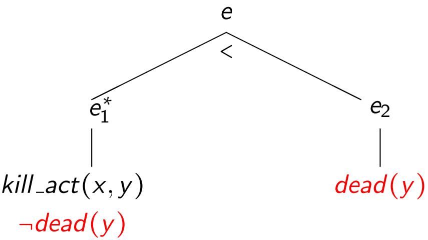
Pustejovsky (1995)

$$\left[\begin{array}{ll} \textbf{kill} & \\ \text{EVENTSTR} = & \left[\begin{array}{l} \text{E}_1 = \textbf{e}_1\textbf{:process} \\ \text{E}_2 = \textbf{e}_2\textbf{:state} \\ \text{RESTR} = <_{\propto} \\ \text{HEAD} = \textbf{e}_1 \end{array}\right] \\ \text{ARGSTR} = & \left[\begin{array}{ll} \text{ARG1} = & \boxed{1}\left[\begin{array}{l}\textbf{ind}\\ \text{FORMAL} = \textbf{physobj}\end{array}\right] \\ \text{ARG2} = & \boxed{2}\left[\begin{array}{l}\textbf{animate\_ind}\\ \text{FORMAL} = \textbf{physobj}\end{array}\right] \end{array}\right] \\ \text{QUALIA} = & \left[\begin{array}{l}\textbf{cause-lcp}\\ \text{FORMAL} = \textbf{dead}(\textbf{e}_2, \boxed{2}) \\ \text{AGENTIVE} = \textbf{kill\_act}(\textbf{e}_1, \boxed{1}, \boxed{2})\end{array}\right] \end{array}\right]$$

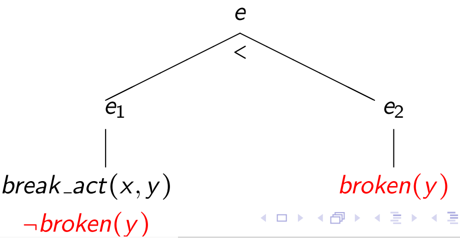
Opposition Structure

Pustejovsky (2000)

(33) kill



(34) break



Qualia Structure with Opposition Structure

$$\begin{bmatrix}
\textbf{kill} & & \\
\text{EVENTSTR} & = & \begin{bmatrix} \text{E}_0 & = & \textbf{e}_0\textbf{:state} \\ \text{E}_1 & = & \textbf{e}_1\textbf{:process} \\ \text{E}_2 & = & \textbf{e}_2\textbf{:state} \\ \text{RESTR} & = & <_{\propto} \\ \text{HEAD} & = & \textbf{e}_1 \end{bmatrix} \\
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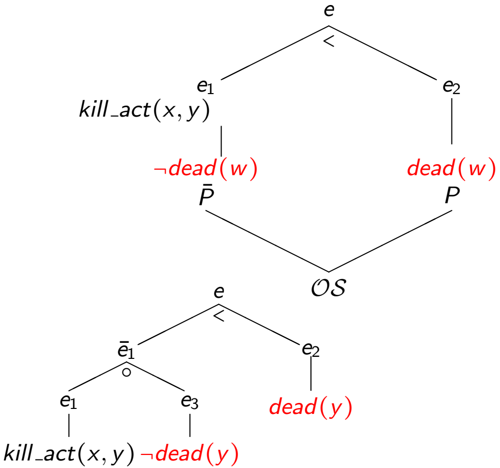
\end{bmatrix}$$

Opposition is Part of Event Structure



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- Tracking change: Models the dynamics of participant attributes

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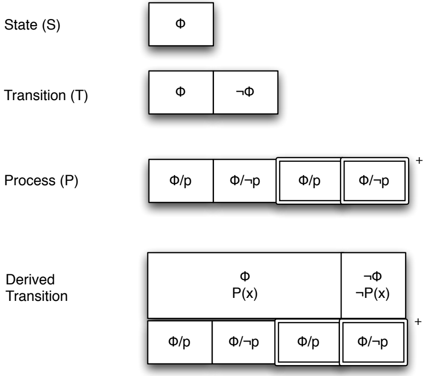
$$\text{Verb}(\text{Arg}_1\text{Arg}_2) \Longrightarrow \lambda y \lambda x \boxed{P_1(x,y)}_A \boxed{P_2(y)}_F$$

Frame-based Event Structure



State (S)

Φ

Transition (T)

Φ ¬Φ

Process (P)

Φ/p Φ/¬p Φ/p Φ/¬p +

Derived
Transition

Φ
P(x)

¬Φ
¬P(x)

Φ/p Φ/¬p Φ/p Φ/¬p +

2nd Conference on CTF, Pustejovsky (2009)

Dynamic Event Structure

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- There may be many changes taking place within one atomic event, when viewed at the subatomic level.

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     $[\alpha]\phi$ (after every execution of α, ϕ is true);
     $\langle\alpha\rangle\phi$ (there is an execution of α, such that ϕ is true);
  5. Formulas can become programs, $\phi?$ (test to see if ϕ is true, and proceed if so).

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(35) a. Mary was sick today.
b. My phone was expensive.
c. Sam lives in Boston.

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We assume that a *state* is defined as a single frame structure (event), containing a proposition, where the frame is temporally indexed, i.e., $e^i \rightarrow \phi$ is interpreted as ϕ holding as true at time i. The frame-based representation from Pustejovsky and Moszkowicz (2011) can be given as follows:

Dynamic Event Structure

(37) $\boxed{\phi}^{i}_{e}$

Dynamic Event Structure

(40) $\boxed{\phi}_{e}^{i}$

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Semantic interpretations for these are:

(51) a. $[\![\boxed{\phi}]\!]_{\mathbf{M},i} = 1$ iff $V_{\mathbf{M},i}(\phi) = 1$.

b. $[\![\boxed{\phi}\boxed{\phi}]\!]_{\mathbf{M},\langle i,j\rangle} = 1$ iff $V_{\mathbf{M},}(\phi) = 1$ and $V_{\mathbf{M},j}(\phi) = 1$, where $i < j$.

Dynamic Event Structure

(52)

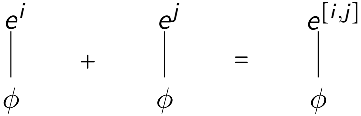
e^i

ϕ

Dynamic Event Structure

(53)

Tree structure for event concatenation:



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(61) $(e_1, \alpha, e_2) \in \rightarrow$

cf. Fernando (2001, 2013)

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As a shorthand for

(64) a. $(e_1, \alpha, e_2) \in \rightarrow$, we will also use:

Labeled Transition System (LTS)

An action, α provides the labeling on an arrow, making it explicit what brings about a state-to-state transition.

As a shorthand for

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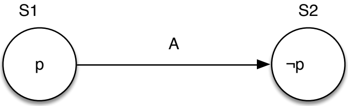

Labeled Transition System (LTS)

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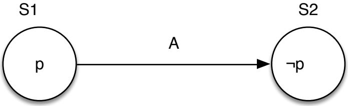

Temporal Labeled Transition System (TLTS)

With temporal indexing from a Linear Temporal Logic, we can define a Temporal Labeled Transition System (TLTS). For a state, e_1, indexed at time i, we say $e_1@i$.
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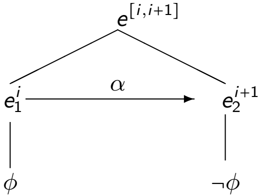
Dynamic Event Structure

(71)



Dynamic Event Structure

(72) Mary awoke from a long sleep.

Dynamic Event Structure

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The state of being asleep has a duration, $[i, j]$, who's valuation is gated by the waking event at the “next state”, $j + 1$.

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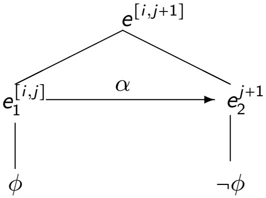

Simple First-order Transition

(78) $x := y$ (ν-transition)
"x assumes the value given to y in the next state."
$\langle \mathcal{M}, (i, i+1), (u, u[x/u(y)]) \rangle \vDash x := y$
iff $\langle \mathcal{M}, i, u \rangle \vDash s_1 \wedge \langle \mathcal{M}, i+1, u[x/u(y)] \rangle \vDash x = y$

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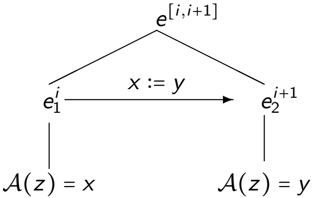
(81)



Processes

With a ν-transition defined, a *process* can be viewed as simply an iteration of basic variable assignments and re-assignments:

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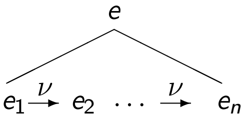

Spatial Relations in Motion Predicates

- Topological Path Expressions
  arrive, leave, exit, land, take off

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- Topo-metric orientation Expressions
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Language Data

- Manner construction languages
  Path information is encoded in directional PPs and other adjuncts, while verb encode manner of motion

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  English, German, Russian, Swedish, Chinese
- Path construction languages
  Path information is encoded in matrix verb, while adjuncts specify manner of motion
  Modern Greek, Spanish, Japanese, Turkish, Hindi

Defining Motion (Talmy 1985)

(84) a. The *event* or situation involved in the change of location ;

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Defining Motion (Talmy 1985)

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c. The region (or *path*) traversed through the motion;
d. A distinguished point or region of the path (the *ground*);

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b. The object (construed as a point or region) that is undergoing movement (the *figure*);
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e. The *manner* in which the change of location is carried out;

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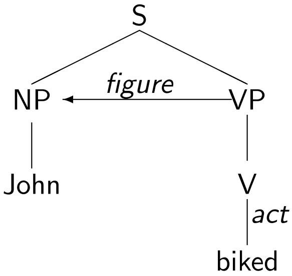
b. The object (construed as a point or region) that is undergoing movement (the *figure*);
c. The region (or *path*) traversed through the motion;
d. A distinguished point or region of the path (the *ground*);
e. The *manner* in which the change of location is carried out;
f. The *medium* through which the motion takes place.

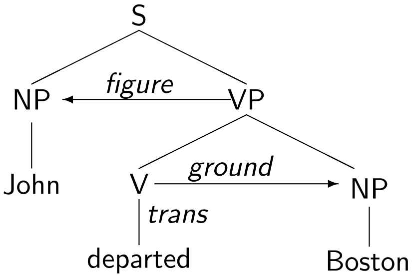
Manner Predicates

(90)



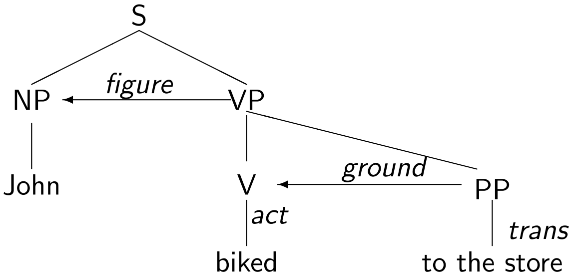
Path Predicates

(91)



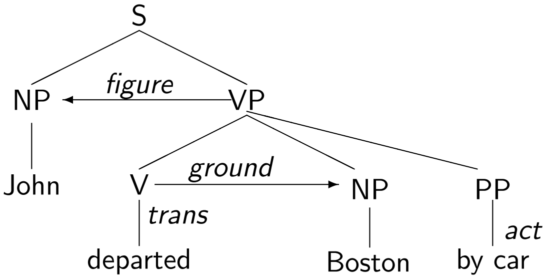
Manner with Path Adjunction

(92)



Path with Manner Adjunction

(93)



Path+manner Predicates (Talmy 2000) 1/2

(94) a. Isabel climbed for 15 minutes.

Path+manner Predicates (Talmy 2000) 1/2

(96) a. Isabel climbed for 15 minutes.
b. Nicholas fell 100 meters.

Path+manner Predicates (Talmy 2000) 1/2

(98) a. Isabel climbed for 15 minutes.
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(99) a. There is an action (e) bringing about an iterated non-distinguished change of location;

Path+manner Predicates (Talmy 2000) 1/2

(100) a. Isabel climbed for 15 minutes.
b. Nicholas fell 100 meters.

(101) a. There is an action (*e*) bringing about an iterated non-distinguished change of location;
b. The figure undergoes this non-distinguished change of location;

Path+manner Predicates (Talmy 2000) 1/2

(102) a. Isabel climbed for 15 minutes.
b. Nicholas fell 100 meters.

(103) a. There is an action (*e*) bringing about an iterated non-distinguished change of location;
b. The figure undergoes this non-distinguished change of location;
c. The figure creates (leaves) a path by virtue of the motion.

Path+manner Predicates (Talmy 2000) 1/2

(104) a. Isabel climbed for 15 minutes.
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b. The figure undergoes this non-distinguished change of location;
c. The figure creates (leaves) a path by virtue of the motion.
d. The action (*e*) is performed in a certain manner.

Path+manner Predicates (Talmy 2000) 1/2

(106) a. Isabel climbed for 15 minutes.
b. Nicholas fell 100 meters.

(107) a. There is an action (*e*) bringing about an iterated non-distinguished change of location;
b. The figure undergoes this non-distinguished change of location;
c. The figure creates (leaves) a path by virtue of the motion.
d. The action (*e*) is performed in a certain manner.
e. The path is oriented in an identified or distinguished way.

Path+manner Predicates (Talmy 2000) 2/2

Unlike pure manner verbs, this class of predicates admits of two compositional constructions with adjuncts.

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(110) **Manner of motion verb with path adjunct;**
John climbed to the summit.

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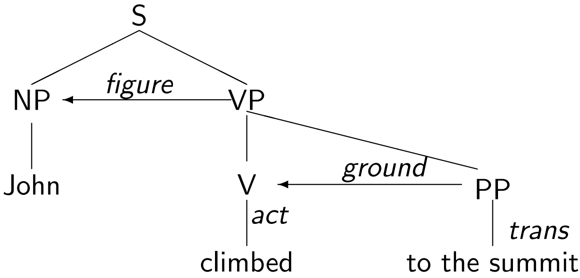
(112) **Manner of motion verb with path adjunct;**
John climbed to the summit.

(113) **Manner of motion verb with path argument;**
John climbed the mountain.

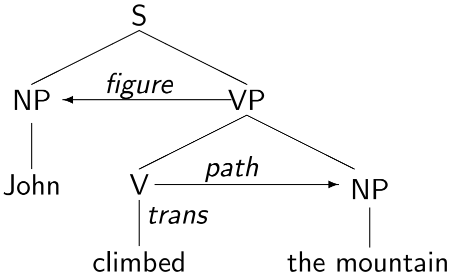
With Path Adjunct

(114)

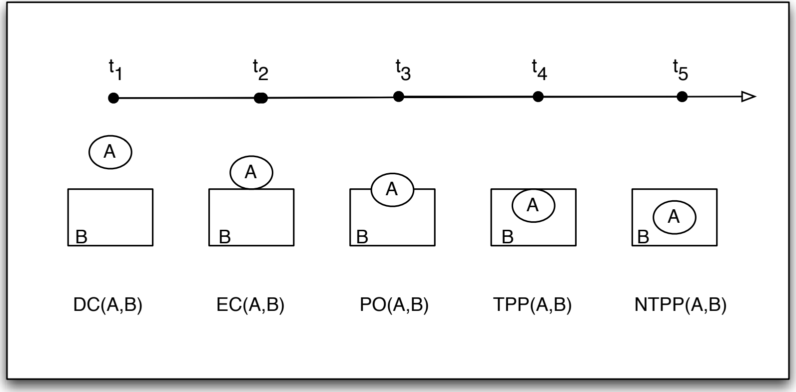


With Path Argument

(115)



Tracking Motion with RCC8: example of enter



Capturing Motion as Change in Spatial Relations

Dynamic Interval Temporal Logic

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- Path verbs designate a distinguished value in the change of location, from one state to another.

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Dynamic Interval Temporal Logic

- Path verbs designate a distinguished value in the change of location, from one state to another.
  The change in value is tested.
- Manner of motion verbs iterate a change in location from state to state.
  The value is assigned and reassigned.

Directed Motion

$$(116)\quad \overset{\overset{x\neq y?}{\curvearrowleft}}{\boxed{loc(z) = x}}_{e_1} \xrightarrow{\nu} \boxed{loc(z) = y}_{e_2}$$

Directed Motion

$$(118)\quad \overset{\overset{x\neq y?}{\curvearrowleft}}{\boxed{loc(z) = x}}_{e_1} \xrightarrow{\nu} \boxed{loc(z) = y}_{e_2}$$

When this test references the ordinal values on a scale, $\mathcal{C}$, this becomes a *directed ν-transition ($\vec{\nu}$)*, e.g., $x \preccurlyeq y$, $x \succcurlyeq y$.

Directed Motion

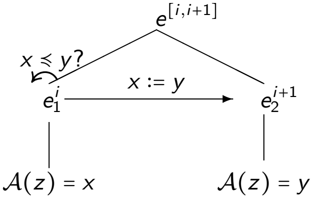
(120) $\overset{\overset{x \neq y?}{\curvearrowleft}}{\boxed{loc(z) = x}}_{e_1} \xrightarrow{\nu} \boxed{loc(z) = y}_{e_2}$

When this test references the ordinal values on a scale, $\mathcal{C}$, this becomes a *directed* ν*-transition* ($\vec{\nu}$), e.g., $x \preccurlyeq y$, $x \succcurlyeq y$.

(121) $\vec{\nu} =_{df} \overset{\overset{\mathcal{C}?}{\curvearrowleft}}{e_i} \xrightarrow{\nu} e_{i+1}$

Directed Motion

(122)



$e^{[i,i+1]}$

$x \preccurlyeq y?$

$x := y$

e_1^i

e_2^{i+1}

$\mathcal{A}(z) = x$

$\mathcal{A}(z) = y$

Change and Directed Motion

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  $loc(x) := y; y := z$
- Directed motion introduces a dimension that is measured against:
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- Path verbs introduce a pair of tests:
  $\neg\phi? \ldots \phi?$

Change and the Trail it Leaves

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- For motion, this trail is the created object of the path p which the mover travels on;
- For creation predicates, this trail is the created object brought about by order-preserving transformations as executed in the directed process above.

Motion Leaving a Trail

(123) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

Motion Leaving a Trail

(124) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

b. Name this value b (this will be the beginning of the movement);

$b := y$

Motion Leaving a Trail

(125) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

b. Name this value b (this will be the beginning of the movement);

$b := y$

c. Initiate a path p that is a list, starting at b;

$p := (b)$

Motion Leaving a Trail

(126) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$$loc(x) := y$$

b. Name this value b (this will be the beginning of the movement);

$$b := y$$

c. Initiate a path p that is a list, starting at b;

$$p := (b)$$

d. Then, reassign the value of y to z, where $y \neq z$

$$y := z, y \neq z$$

Motion Leaving a Trail

(127) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

b. Name this value b (this will be the beginning of the movement);

$b := y$

c. Initiate a path p that is a list, starting at b;

$p := (b)$

d. Then, reassign the value of y to z, where $y \neq z$

$y := z, y \neq z$

e. Add the reassigned value of y to path p;

Motion Leaving a Trail

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$y := z, y \neq z$

e. Add the reassigned value of y to path p;

$p := (p, z)$

f. Kleene iterate steps (d) and (e).

Quantifying the Resulting Trail

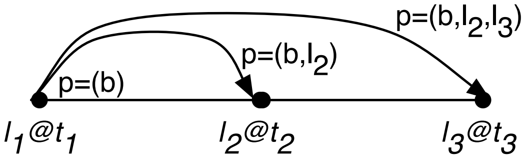

Figure: Directed Motion leaving a Trail

Quantifying the Resulting Trail

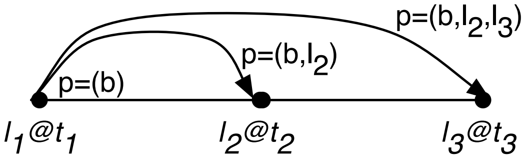

Figure: Directed Motion leaving a Trail

(130) a. The ball rolled 20 feet.

$$\exists p \exists x [[roll(x,p) \wedge ball(x) \wedge length(p) = [20, foot]]$$

Quantifying the Resulting Trail

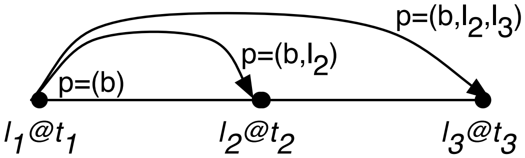

Figure: Directed Motion leaving a Trail

(131) a. The ball rolled 20 feet.

$\exists p \exists x[[roll(x,p) \wedge ball(x) \wedge length(p) = [20, foot]]$

b. John biked for 5 miles.

$\exists p[[bike(j,p) \wedge length(p) = [5, mile]]$

Generalizing the Path Metaphor

- We generalize the Path Metaphor to the analysis of the creation predicates.

Generalizing the Path Metaphor

- We generalize the Path Metaphor to the analysis of the creation predicates.
- We analyze creation predicates as predicates referencing two types of scales.

Type of Creation Verbs

(132) a. John wrote a letter.

Type of Creation Verbs

(134) a. John wrote a letter.
b. Sophie wrote for hours.

Type of Creation Verbs

(136) a. John wrote a letter.
b. Sophie wrote for hours.
c. Sophie wrote for an hour.

(137) a. John built a wooden bookcase.
b. *John built for weeks.

Linguistic View on Scales

- Some verbs expressing change are associated with a scale while others are not (scalar vs. non-scalar change).

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  - EXTENT SCALES: most often found with incremental theme verbs.

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- For example, Rappaport Hovav 2008, Kennedy 2009 claim that "the scale which occurs with incremental theme verbs (extent scale) is not directly encoded in the verb, but rather provided by the referent of the direct object".
- This has lead them to the assumption that when nominal reference plays a role in measuring the change, V is not associated with a scale (denoting a non-scalar change).

Challenge for Scalar Models

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- What is the exact contribution of each member of the linguistic expression to the measurement of the change?
- What is the role of nominal reference in aspectual composition?

How Language Encodes Scalar Information

Pustejovsky and Jezek 2012

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Pustejovsky and Jezek 2012

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- Verbs may reference multiple scales.

Scale Theory: Stevens (1946), Krantz et al (1971)

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Generalizing the Path Metaphor to Creation Predicates

Pustejovsky and Jezek 2012

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- If the program is “change by assignment”, Result refers to the record or trail of the change (e.g., the path of a walking, the stuff written in writing, etc.).

Scale shifting

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- Arguments (selected vs. non-selected, semantic typing, quantification).

Generalizing the Path Metaphor to Creation Predicates

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Accomplishments are Lexically Encoded Tests.

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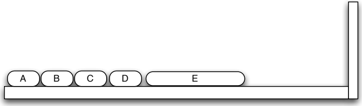
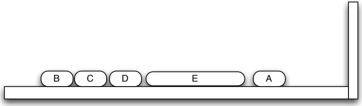
- $\lambda\vec{z}\lambda y\lambda x[build(x, \vec{z}, y)]$
- An ordinal scale drives the incremental creation forward
- A nominal scale acts as a test for completion (telicity)

Incremental Theme and Parallel Scales



- Mary is building a table.
- Change is measured over an **ordinal scale**.
- Trail, τ is null.

Incremental Theme and Parallel Scales



- Mary is building a table.
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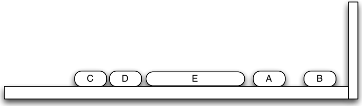
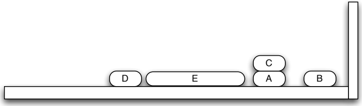
- Trail, $\tau = [A]$.

Incremental Theme and Parallel Scales



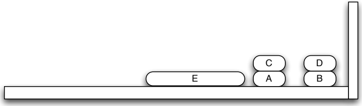
- Mary is building a table.
- Change is measured over an **ordinal scale**.
- Trail, $\tau = [A, B]$

Incremental Theme and Parallel Scales



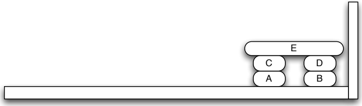
- Mary is building a table.
- Change is measured over an **ordinal scale**.
- Trail, $\tau = [A, B, C]$

Incremental Theme and Parallel Scales



- Mary is building a table.
- Change is measured over an **ordinal scale**.
- Trail, $\tau = [A, B, C, D]$

Incremental Theme and Parallel Scales



- Mary built a table.
- Change is measured over a **nominal scale**.
- Trail, $\tau = [A, B, C, D, E]$; $table(\tau)$.

Accomplishments

(138) a. John built a table.
b. Mary walked to the store.

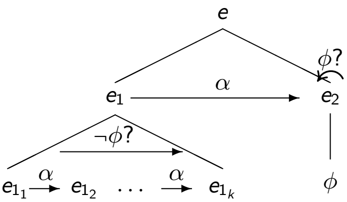
$build(x,z,y)$	$build(x,z,y)^{+}$	$build(x,z,y), y = v$
$\neg table(v)$		$table(v)$

$_{\langle i,j \rangle}$

Table: Accomplishment: parallel tracks of changes

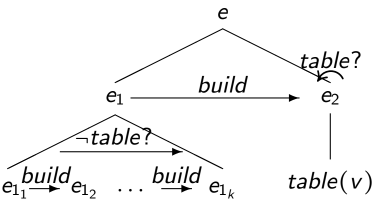
Dynamic Event Structure

(139)



Parallel Scales define an Accomplishment

(140)



Lab on identification of event type properties in corpora

- Choose three target verbs. State your hypothesis regarding the event type associated with the verbs wrt to the extended in time vs instantaneous dimension.
- Count the co-occurrences of the verbs in the raws of the matrix with the expressions in the columns in the BNC using the SkE.
- You can use the context search - setting the window, or refine your search with CQL or Word Sketches.

Lab on detection of event type properties in corpora

- For the "for x time" expressions, you can use the following regular expression:
  $[lemma = "for"][]\{0,1\}[lemma =$
  $"instant|second|minute|hour|day|week|month|year"]$
- Fill the cooccurrence counts in last column of the matrix and rank the verbs accordingly.
- Select 1 concordance for each verb which constitutes an example of event-type shiftings in context.
- Summarize your results.

Lab on detection of event type properties in corpora

Co-occurrence matrixes detecting extended vs. instantaneous events

	suddenly	still	for x time	finishV	total occ
happen					
occur					
breathe					
appear					
die					
sleep					
walk					
run					
laugh					
wake up					
fall					
develop					
watch					
freeze					

Ongoing work E. Jezek, M. Sadrzadeh and E. Ponti (unpublished).