Intervals & events with & without points

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JAMES ALLEN: intervals as primitive

> *There seems to be a strong intuition that, given an event, we can always "turn up the magnification" and look at its structure. . . . Since the only times we consider will be times of events, it appears that we can always decompose times into subparts. Thus the formal notion of a time point, which would not be decomposable, is not useful.*

DAVID DOWTY: decomposable statives plus . . .

> *the different aspectual properties of the various kinds of verbs can be explained by postulating a single homogeneous class of predicates* — stative predicates — *plus three or four sentential operators or connectives.*

Strings & homogeneous subparts

a overlap a' as: $\boxed{}\boxed{a}\boxed{a, a'}\boxed{a'}\boxed{}$

A-reduct $\rho_A(s)$ sees only what's in A

$$\rho_{\{a\}}(\boxed{}\boxed{a}\boxed{a, a'}\boxed{a'}\boxed{}) = \boxed{}\boxed{a}\boxed{a}\boxed{}\boxed{}$$

$$\rightsquigarrow \boxed{}\boxed{a}\boxed{}$$

$$\alpha_1 \cdots \alpha_n \;\approx\; \alpha_1^+ \cdots \alpha_n^+ \quad \text{as homogeneity}$$

(1) It rained from 8am to midnight.

(2a) It rained from 8am to noon.

(2b) It rained from 10am to midnight.

Compression two ways & projection

$$s\alpha\alpha s' \rightsquigarrow s\alpha s'$$

$\alpha_1 \cdots \alpha_n$ is *stutterless* if $\alpha_i \neq \alpha_{i+1}$ for $1 \leq i < n$

$$bc^{-1}\alpha_1 \cdots \alpha_n \;=\; \alpha_1^+ \cdots \alpha_n^+ \quad \text{for stutterless } \alpha_1 \cdots \alpha_n$$

$$s\Box s' \rightsquigarrow ss'$$

$\alpha_1 \cdots \alpha_n$ is *depadded* if $\alpha_i \neq \Box$ for $1 \leq i \leq n$

$$d_\Box^{-1}\alpha_1 \cdots \alpha_n \;=\; \Box^*\alpha_1\Box^* \cdots \Box^*\alpha_n\Box^* \quad \text{for depadded } \alpha_1 \cdots \alpha_n$$

s *projects to* s' if $d_\Box(\rho_{voc(s')}(s)) = s'$, where

$$voc(\alpha_1 \cdots \alpha_n) \;:=\; \alpha_1 \cup \cdots \cup \alpha_n$$

Points & intervals via a transduction

a is an *s-point* if s projects to $\boxed{a}$ — i.e., $d_\Box(\rho_{\{a\}}(s)) = \boxed{a}$

$$s \models (\exists x)(\forall y)(P_a(y) \equiv x = y)$$

a is an *s-interval* if $b(s)$ projects to $\boxed{l(a)}\boxed{r(a)}$

$$s \models (\exists x)(\exists y)(x < y \wedge (\forall z)(P_a(z) \equiv x < z \wedge z \leq y))$$

$b : (2^A)^* \to (2^{A_\bullet})^*,\ \alpha_1 \cdots \alpha_n \mapsto \beta_1 \cdots \beta_n$

$$A_\bullet \;:=\; \{l(a) \mid a \in A\} \cup \{r(a) \mid a \in A\}$$
$$\beta_n \;:=\; \{r(a) \mid a \in \alpha_n\}$$
$$\beta_i \;:=\; \{l(a) \mid a \in \alpha_{i+1} - \alpha_i\} \cup \{r(a) \mid a \in \alpha_i - \alpha_{i+1}\} \quad \text{for } i < n$$

Outline

§1 Allen interval relations
- 13 strings
- composition via superposition (constrained)

§2 Events under inertia & force

§3 MSO variations

Allen relations projected

$$s \models aRa' \iff b(s) \text{ projects to } \mathfrak{s}_R(a,a')$$

R	aRa'	$\mathfrak{s}_R(a,a')$	R^{-1}	$\mathfrak{s}_{R^{-1}}(a,a')$
$<$	a before a'	$\boxed{l(a)}\boxed{r(a)}\boxed{l(a')}\boxed{r(a')}$	$>$	$\boxed{l(a')}\boxed{r(a')}\boxed{l(a)}\boxed{r(a)}$
m	a meets a'	$\boxed{l(a)}\boxed{r(a), l(a')}\boxed{r(a')}$	mi	$\boxed{l(a')}\boxed{r(a'), l(a)}\boxed{r(a)}$
o	a overlaps a'	$\boxed{l(a)}\boxed{l(a')}\boxed{r(a)}\boxed{r(a')}$	oi	$\boxed{l(a')}\boxed{l(a)}\boxed{r(a')}\boxed{r(a)}$
s	a starts a'	$\boxed{l(a), l(a')}\boxed{r(a)}\boxed{r(a')}$	si	$\boxed{l(a), l(a')}\boxed{r(a')}\boxed{r(a)}$
d	a during a'	$\boxed{l(a')}\boxed{l(a)}\boxed{r(a)}\boxed{r(a')}$	di	$\boxed{l(a)}\boxed{l(a')}\boxed{r(a')}\boxed{r(a)}$
f	a finishes a'	$\boxed{l(a')}\boxed{l(a)}\boxed{r(a), r(a')}$	fi	$\boxed{l(a)}\boxed{l(a')}\boxed{r(a), r(a')}$
$=$	a equal a'	$\boxed{l(a), l(a')}\boxed{r(a), r(a')}$	$=$	

Each $\mathfrak{s}_R(a,a')$ projects to $\boxed{l(a)}\boxed{r(a)}$ and $\boxed{l(a')}\boxed{r(a')}$

From 2 intervals to 3

$$\frac{a < a' \qquad a' < a''}{a < a''} \qquad\qquad \frac{a \text{ o } a' \qquad a' \text{ d } a''}{a \ \{\text{d,o,s}\}\ a''}$$

	$<$	o	d	$\cdots$
$<$	$<$	$<$	$<$ d m o s	$\cdots$
o	$<$	$<$ m o	d o s	$\cdots$
d	$<$	$<$ d m o s	d	$\cdots$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\cdots$

$$\mathfrak{s}_<(a,a')\ \&\ \mathfrak{s}_<(a',a'') = \boxed{l(a)}\boxed{r(a)}\boxed{l(a')}\boxed{r(a')}\boxed{l(a'')}\boxed{r(a'')}$$

$$\begin{aligned}\mathfrak{s}_{\text{o}}(a,a')\ \&\ \mathfrak{s}_{\text{d}}(a',a'') &= \boxed{l(a'')}\boxed{l(a)}\boxed{l(a')}\boxed{r(a)}\boxed{r(a')}\boxed{r(a'')} && a \text{ d } a'' \\ &+ \boxed{l(a)}\boxed{l(a'')}\boxed{l(a')}\boxed{r(a)}\boxed{r(a')}\boxed{r(a'')} && a \text{ o } a'' \\ &+ \boxed{l(a), l(a'')}\boxed{l(a')}\boxed{r(a)}\boxed{r(a')}\boxed{r(a'')} && a \text{ s } a''\end{aligned}$$

Superposition

$$\&(\boxed{l(a)}\boxed{r(a)}, \boxed{l(a')}\boxed{r(a')}, s) \iff s = \mathfrak{s}_R(a,a') \text{ for some } R$$

$$\frac{}{\&(\epsilon,\epsilon,\epsilon)} \qquad \frac{\&(s,s',s'')}{\&(\alpha s, \alpha' s, (\alpha \cup \alpha')s'')} \qquad \frac{\&(s,s',s'')}{\&(\alpha s, s', \alpha s'')} \qquad \frac{\&(s,s',s'')}{\&(s, \alpha' s', \alpha' s'')}$$

Constrain through Σ, Σ'

$$\frac{\&_{\Sigma,\Sigma'}(s,s',s'') \qquad \alpha \cap \Sigma' \subseteq \alpha' \qquad \alpha' \cap \Sigma \subseteq \alpha}{\&_{\Sigma,\Sigma'}(\alpha s, \alpha' s, (\alpha \cup \alpha')s'')}$$

$$\frac{\&_{\Sigma,\Sigma'}(s,s',s'') \qquad \alpha \cap \Sigma' = \emptyset}{\&_{\Sigma,\Sigma'}(\alpha s, s', \alpha s'')} \qquad\qquad \frac{\&_{\Sigma,\Sigma'}(s,s',s'') \qquad \alpha' \cap \Sigma = \emptyset}{\&_{\Sigma,\Sigma'}(s, \alpha' s', \alpha' s'')}$$

$$\&_{voc(s),voc(s')}(s,s',s'') \iff \&(s,s',s'') \text{ and } s'' \text{ projects to } s \text{ and } s'$$

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- inverting Dowty aspect hypothesis
- forces beyond borders

§3 MSO variations

Borders & consequences

$$P_{l(a)}(x) \equiv \neg P_a(x) \wedge (\exists y)(xSy \wedge P_a(y))$$
$$P_{r(a)}(x) \equiv P_a(x) \wedge \neg(\exists y)(xSy \wedge P_a(y))$$

so that s projects to a string from

$$(\boxed{l(a)}\boxed{r(a)})^* + \boxed{r(a)}(\boxed{l(a)}\boxed{r(a)})^*$$

Conversely,

$$P_a(x) \equiv (\exists X)(X(x) \wedge \underbrace{a\text{-path}(X)}_{\forall x(X(x) \supset P_{r(a)}(x) \vee \exists y(xSy \wedge X(y))) \ \wedge\ \neg\exists x(X(x) \wedge P_{l(a)}(x))})$$

Forces & inertia: $l(a), r(a) \rightsquigarrow \mathrm{f}a, \mathrm{f}\overline{a}$

$$\neg P_a(x) \wedge (\exists y)(xSy \wedge P_a(y)) \supset P_{\mathrm{f}a}(x)$$
$$P_a(x) \wedge (\exists y)(xSy \wedge \neg P_a(y)) \supset P_{\mathrm{f}\overline{a}}(x)$$

No change without force (INERTIA)

Moens & Steedman 1988

	atomic	extended
+conseq	culmination	culminated process
	$\boxed{\overline{\varphi}}\boxed{\varphi}$	$\boxed{\overline{\varphi},\mathrm{ap}(f)}\boxed{\overline{\varphi},\mathrm{ap}(f),\mathrm{ef}(f)}\boxed{\mathrm{ef}(f),\varphi}$
−conseq	point	process
	$\boxed{\mathrm{ap}(f)}\boxed{\mathrm{ef}(f)}$	$\boxed{\mathrm{ap}(f)}\boxed{\mathrm{ap}(f),\mathrm{ef}(f)}\boxed{\mathrm{ef}(f)}$

Effects of forces?

Competition & incrementality

$$P_{\mathrm{f}a}(x) \wedge xSy \wedge \neg P_a(x) \supset P_a(y)$$

may fail because

- fa may co-occur with an opposing force
- f's incremental effect falls short.

Analyze P_a as attribute-value pair (A, v) with $0 \leq v \leq 1$

so that at $v \notin \{0, 1\}$,
a force may raise the A-value
and/or
a force may lower the A-value
— i.e., forces may compete, with effects $\notin \{0, 1\}$.

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- variable ontology (many-sorted)
- reducts & truthmakers (institutions)

Leibniz's law: identity of indiscernibles

$$x \neq y \;\supset\; (\exists P)\neg(P(x) \equiv P(y)) \qquad \text{(LL)}$$

- take P from a finite set A

$$x \not\equiv_A y \;:=\; \bigvee_{a \in A} \neg(P_a(x) \equiv P_a(y)) \qquad bc$$

$$\equiv \bigvee_{a \in A} (\neg P_a(x) \wedge P_a(y)) \vee (P_a(x) \wedge \neg P_a(y))$$

$$P_{l(a)}(x) \qquad\qquad P_{r(a)}(x) \qquad d\square$$

- replace $\neq$ by adjacency S "time steps$_S$ only with change$_A$"

$$xSy \;\supset\; x \not\equiv_A y \qquad (\mathrm{LL}_{A,S})$$

Reducts & institutions

$$s \models \varphi \iff \rho_{voc(\varphi)}(s) \models \varphi \qquad (\varphi \in \mathsf{MSO}_A)$$

$$s \text{ projects to } s' \iff d_\square(\rho_{voc(s')}(s)) = s'$$

$$s \models_\Sigma \sigma[\varphi] \iff s_\sigma \models_{\Sigma'} \varphi$$

$$\Sigma' \overset{\sigma}{\to} \Sigma \quad \begin{cases} \sigma[\cdot] : \mathsf{Sen}(\Sigma') \to \mathsf{Sen}(\Sigma) \\ \cdot_\sigma : \mathsf{Mod}(\Sigma) \to \mathsf{Mod}(\Sigma') \end{cases}$$

Satisfaction condition (Barwise, Goguen & Burstall)

e.g. φ as: $= s'$

$\sigma[\varphi]$ as: $(\rho_{voc(s')}; d_\square)^{-1} s'$ (in MSO by Büchi Elgot Trakh)

Events as truthmakers (Davidson)

strings to the left & right of $\models$

particular $s \models$ universal φ

(7) Amundsen flew to the North Pole in May 1926.
$\exists x$ (Amundsen-flew-to-the-North-Pole(x) $\wedge$ In(May1926,x))

"if (7) is true, then there is an event that makes it true" (D 67)

$$s \models \varphi \;\rightsquigarrow\; s \in \mathcal{L}(\varphi) \;\rightsquigarrow\; s_\sigma \in \mathcal{L}_\sigma(\varphi)$$

$x \rightsquigarrow$ substring of $\alpha_1 \cdots \alpha_n$

ρ_A reduces α_i to $\alpha_i \cap A$ "thin"

$d_\square$ may drop an entire α_i "thick"