Inertia in Temporal Modification

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Distinguishing states from events is basic to many accounts of temporal semantics (e.g. DRT), inviting the question: what underlies the state-event distinction? The present paper bases that distinction on laws of *inertia* implicated in the notorious *frame problem* of McCarthy and Hayes 1969, explaining

(c1) why states tend to persist (and overlap) in a way that events do *not*

(c2) how to base temporal *for* and *in* modification on conjunctive modification (as with simple Davidsonian cases of event modification)

(c3) how inertia bears on the imperfective paradox afflicting the progressive

(c4) how a Reichenbachian analysis of the perfect yields continuative/universal, existential and resultative readings

(c5) why certain uses of *before* are non-veridical

(c6) how to devise more refined eventuality types.

References to inertia in linguistic semantics appear in Dowty 1979,1986 and more recently in Steedman 2000 and Hamm and van Lambalgen 2003. What is distinctive about the present approach is the formulation of inertial laws over strings $\in \mathit{Power}(\Phi)^*$ where each symbol is a subset of some finite set Φ of formulae. A string $\mathsf{s} = \alpha_1\alpha_2\cdots\alpha_n \in \mathit{Power}(\Phi)^*$ records a sequence of observations, at the ith point of which, each formula in α_i is observed (making s essentially a comic strip/movie that begins with the still picture/snapshot α_1, followed by α_2 and ending with α_n). Very roughly, a formula φ is inertial if in the absence of any force acting on φ, we have $\varphi \in \alpha_i$ iff $\varphi \in \alpha_{i+1}$. More precisely, let us fix a subset $\mathit{Inr} \subseteq \Phi$ of *inertial* formulae, and assume that we can associate with each $\varphi \in \mathit{Inr}$ a non-inertial formula $\mathsf{F}(\varphi) \in \Phi - \mathit{Inr}$ saying: some force is acting on φ. Let us draw $\Box$ for $\emptyset$-as-symbol, using in general boxes instead of braces for sets-as-symbols (as opposed say, to sets-as-languages). To illustrate with a $\varphi \in \mathit{Inr}$, inertia turns the string $\Box\boxed{\varphi}\Box$ to $\boxed{\varphi}\boxed{\varphi}\boxed{\varphi}$, and $\boxed{\mathsf{F}(\varphi)}\boxed{\varphi}\Box$ to $\boxed{\mathsf{F}(\varphi)}\boxed{\varphi}\boxed{\varphi}$, but for $\psi \neq \varphi$, $\boxed{\mathsf{F}(\psi)}\boxed{\varphi}\Box$ to $\boxed{\mathsf{F}(\psi),\varphi}\boxed{\varphi}\boxed{\varphi}$. More generally, we have the inertial laws

$$\frac{\mathsf{s}\alpha\alpha'\mathsf{s}'}{\mathsf{s}\alpha(\alpha'\cup\boxed{\varphi})\mathsf{s}'}\ \varphi \in \alpha \cap \mathit{Inr} \text{ and } \mathsf{F}(\varphi) \notin \alpha \qquad \frac{\mathsf{s}\alpha\alpha'\mathsf{s}'}{\mathsf{s}(\alpha\cup\boxed{\varphi})\alpha'\mathsf{s}'}\ \varphi \in \alpha' \cap \mathit{Inr} \text{ and } \mathsf{F}(\varphi) \notin \alpha$$

which together induce a map i sending a language $L \subseteq \mathit{Power}(\Phi)^*$ to the language

$$\begin{aligned} \mathsf{i}(L) \;=\; & \{\mathsf{s}\alpha(\alpha'\cup\boxed{\varphi})\mathsf{s}' \mid \varphi \in \alpha\cap\mathit{Inr} \text{ and } \mathsf{F}(\varphi)\notin\alpha \text{ for some } \mathsf{s}\alpha\alpha'\mathsf{s}' \in L\} \cup \\ & \{\mathsf{s}(\alpha\cup\boxed{\varphi})\alpha'\mathsf{s}' \mid \varphi \in \alpha'\cap\mathit{Inr} \text{ and } \mathsf{F}(\varphi)\notin\alpha \text{ for some } \mathsf{s}\alpha\alpha'\mathsf{s}' \in L\}\ . \end{aligned}$$

A string s is *inertially grounded* (i.g.) if $\mathsf{i}(\{\mathsf{s}\}) \subseteq \{\mathsf{s}\}$ (allowing $\mathsf{i}(\{\mathsf{s}\}) = \emptyset$ in case every occurrence in s of an inertial formula φ is accompanied by $\mathsf{F}(\varphi)$). The *inertial completion* $ic(L)$ *of* L is

$$ic(L) \;=\; \{\mathsf{s} \in \bigcup_{n\geq 0} \mathsf{i}_n(L) \mid \mathsf{s} \text{ is i.g.}\}$$

where $\mathsf{i}_0(L) = L$ and $\mathsf{i}_{n+1}(L) = \mathsf{i}(\mathsf{i}_n(L))$. (For example, $ic(\Box^*\boxed{\varphi}\Box^*) = \boxed{\varphi}^+$ for $\varphi \in Inr$.) L is *inertially complete* if $ic(L) = L$. Now the relevance of inertia to claims (c1)-(c6) above rests on the application of inertially complete languages to semantically interpret phrases. (This contrasts to the appeal in Dowty 1986 to inertia for *multi*-sentential discourse, applied *defeasibly*.) For example, an inertially complete L can be said to persist in the way referred to in (c1) if $ic(\Box^* L \Box^*) \subseteq L$. (Putting $\Box^*$ on either side of L provides a test bed for persistence.) Thus, the stative description $L = \boxed{\varphi}^+$ persists, but *not* the eventive description $L = \boxed{\varphi, \mathsf{F}(\varphi), \mathsf{F}(\psi)}\boxed{\psi}$ of a transition with pre-condition φ and post-condition ψ (nor for that matter, any non-empty L, all strings in which begin with a symbol containing some $\mathsf{F}(\varphi)$). As for (c2), the conjunction mentioned there is the binary function & on languages L, L' that returns the language

$$L\&L' \;=\; \bigcup_{n\geq 1}\{(\alpha_1 \cup \alpha_1')\cdots(\alpha_n \cup \alpha_n') \mid \alpha_1\cdots\alpha_n \in L \text{ and } \alpha_1'\cdots\alpha_n' \in L'\}$$

superimposing strings from L and L' of equal length. A phrase such as "rain for two hours" can then be interpreted as the inertial completion of

$$\Box^*\boxed{\mathsf{rain}}\Box^* \quad \& \quad \boxed{0(\tau)}\Box^+\boxed{\text{2hours}(\tau)}$$

where $\mathsf{rain} \in Inr$, but $0(\tau)$, $\text{2hours}(\tau) \in \Phi - Inr$ (with $0(\tau)$ for the clock τ ticking 0, and $\text{2hours}(\tau)$ for τ marking 2 hours). Temporal "in"-modification involves a similar inertial completion, with an additional twist $L\&(\Box^*\boxed{R})$ for telicity that adjoins a non-inertial formula R to the end of L. R is used here as a realis marker, stating that the part of L up to R has been realized. This intuition can be substantiated model-theoretically, and is re-used in formulating a Reichenbachian approach to aspect via reference time R, with the progressive of an inertially complete language L given by L & $(\Box^+\boxed{R}\Box^+)$ (marking an intermediate point in L), and the perfect of L by the inertial completion of $L\Box^*\boxed{R}$ (marking some point after L). Whether or not the perfect is existential depends on whether or not for every $\mathsf{s}\alpha \in L$, and every inertial $\varphi \in \alpha$, $\mathsf{F}(\varphi) \in \alpha$. If so, then $L\Box^*\boxed{R}$ is already inertially complete, and we get an existential perfect. As for (c5), a sentence such as "Pat stopped the car before it slammed into the tree" can be shown to be non-veridical (in that NOT slam(car,tree)) insofar as the post-condition of Pat-stop-car clashes with the pre-condition for car-slam-into-tree. Finally, as for (c6), I claim that if L is a regular language, then so is $ic(L)$. Given this result, the causal realm Steedman 2000 asserts to be central to temporality may, in no small measure, be conceived as consisting of finite-state machines.