DYNAMIC SITUATIONS: ACCOUNTING FOR DOWTY'S INERTIA NOTION USING DYNAMIC SEMANTICS

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In this paper Dowty's notion of inertia is further reduced. This is done by seeing normality as operating within a limited context defined by the current conceptually salient vocabulary. Situations are defined as sets of possibilities indiscernible under the vocabulary. Then, using a partial order of eventiveness, normality is given as a test operator on the set of minimally eventive situations in the information state.

1. The notion of inertia

The notion of inertia was first incorporated into the semantics of the progressive by Dowty 1979, here reproduced in (1). The guiding intuition behind its use is that the progressive commits the speaker to the eventual completion of the ongoing event if and only if nothing out of the ordinary happens. Enforcing this intuition is the semi-formal definition of the inertia set for a world *w* and interval *I*, *Inr(<I,w>)*. This set is said to include an arbitrary world *w'* iff a.(identity) it is exactly like *w* at all times preceding and including *I* and b. (normality) given the past history of *w*, *w'* is a world in which nothing unexpected happens from *I* onwards.

(1) [PROG Φ] is true at $<I,w>$ iff for some interval *I'* such that $I \subset I'$ and *I* is not a final subinterval for *I'*, and for all *w'* such that $w' \in Inr(<I,w>)$, Φ is true at $<I',w'>$.

Yet even with the semi-formal constraints at hand, Dowty's analysis of inertia is incomplete. The semantics still presupposes a notion of normality, of a course of events where nothing unexpected happens. Being unable to provide a formal definition to normality, Dowty 'reluctantly concludes' that inertia as a whole must be accepted as a primitive in the semantics. This paper sets out to extend Dowty's theory 'inwards', so to speak, by providing a formal analysis of normality.[1]

2. Epistemic considerations of normality

Unexpectedness being a crucial ingredient in the notion of normality, it would

[1] The ideas offered in this paper are articulated at length in Ben-Zvi 2005

seem that no formal account of it is likely to succeed. For how can what is unexpected be brought under the rule of logic? To overcome this hurdle the following mental observation is pointed out. When one speculates about the possible developments of a state of affairs, one does not ponder every logically possible continuation. Rather, a limited set of relevant, or conceptually salient, continuations is envisioned. This is also true of other commonsensical reasoning processes. We use the finite conceptual vocabulary that is available to us at the time and envision only the limited set of continuations that are expressible using that vocabulary. Under this observation normality is seen to concern only events that can be described using the available conceptual context. Within this context, there is a body of sentences that we deem true. They form our knowledge, describing what is *expected.* Complementing this set are the salient descriptions that are merely speculative. These describe the *unexpected.* The possible continuations that we ponder differ by the speculative descriptions that are actualized in them. The normal continuations are those in which the actualization of unexpected event descriptions is reduced to a minimum. As one is treading dangerous ground with these investigations, let us continue immediately to the formalization of these ideas. This is done by extending the dynamic semantics of Groenendijk, Stokhof and Veltman 1996 with a formal apparatus of situations.

3. Extending dynamic semantics with situations

The conceptual vocabulary is formalized in (2) as the *linguistic context*. A set of sentences closely related to the discourse through a *growth pattern*. It is assumed that the linguistic context is somehow derived from the actual discourse utterances, and so the context associated with $s[\varphi]$ is formed by applying the growth pattern to the context at s and the sentence φ. The exact contents of the growth pattern function remain unanalyzed in this paper, except for the two characteristics shown in (3): it is monotone, and it always includes the uttered sentence in its range.

(2) Γ, the set of linguistic contexts, is the set: $\Gamma = Pow(FORMULAS)$

(3) Function $f \in \Gamma \times FORMULAS \rightarrow \Gamma$ is a *growth pattern* only if for every $\gamma \in \Gamma$ and $\varphi \in FORMULAS$, $f(\gamma, \varphi) \supseteq \gamma \cup \{\varphi\}$

In dynamic semantics the information state can only be divided into the *logical possibilia* of which it consists (the *possibility* structures). To get conceptually salient ‘continuations’, we need to carve it up more crudely, along the lines set out by the linguistic context sentences. The resulting structures will form *conceptual possibilia,* or *situations.* Each situation is a set of possibility structures (possibilities henceforth) to which the same conceptually salient descriptions apply. Another way of putting it is that each situation is comprised of conceptually indiscernible possibilities. Formally, we start out in (4) by defining the consistency relation between possibilities and sentences, based on the dynamic semantics relations of *possibility extension* and *possibility similarity.* Now (5) defines indiscernibility between possibilities, relative to a linguistic context. Two possibilities are indiscernible when they are consistent with the exact same set of linguistic context sentences.

(4) Let $i \in I$ (the set of possibilities in dynamic semantics); $\varphi \in FORMULAS$.
φ is *consistent* with *i*, *Cons(i,φ)*, iff
$\forall s \in S \ s.t \ i \in s : \exists i^* \in s[\varphi] : i^*$ is similar to an extension i' of *i*.

(5) Let $i, i' \in I$; $\gamma \in \Gamma$. *i* and *i'* are *indiscernible* in γ iff
$\forall \varphi \in \gamma : Cons(i,\varphi) \leftrightarrow Cons(i',\varphi)$.

The definition of situations, in (6), is a little cumbersome due to them containing not only a non empty set of possibilities, but also the linguistic context under which these possibilities are indiscernible. Also, the free variables in the context must be defined in the referent set shared by the possibilities. Lastly, the set must be maximal in the sense that no indiscernible possibility be left out of it.

(6) *M*, the set of situations, is the set

$$\left\{ < J, \gamma > \middle| \begin{array}{l} \gamma \in \Gamma, J \subseteq I, J \neq \emptyset, \\ \forall i, i' \in J: \ i \text{ and } i' \text{ share referent system and are indiscernible in } \gamma, \\ Dom(r) \supseteq FREE\text{-}VARS(\gamma), \\ \text{For every } i \in J \text{ and } i' \in I, \text{ if } i \text{ and } i' \text{ share referent system and world} \\ \text{and are indiscernible in } \gamma \text{ then } i' \in J \end{array} \right\}$$

The partiality of situations is made manifest in (7), with their denotation function. A sentence is true (false) in a situation only inasmuch as the sentence (or its negation) is consistent in all of the underlying possibilities.

(7) Let $\varphi \in FORMULAS$, $m \in M$, $m = <J,\gamma>$. The denotation of φ in situation *m*,
$[\![\varphi]\!]_m$,is defined as follows: $[\![\varphi]\!]_m = \begin{cases} 1 & \textit{if} \quad \forall i \in J : cons(i,\varphi) \\ 0 & \textit{if} \quad \forall i \in J : cons(i,\neg\varphi) \\ \textit{undefined} & \textit{otherwise} \end{cases}$

To wrap up the introduction of situations into the framework, information states are redefined in (8) as sets of situations which share the same linguistic context, under which they are discernible from each other.

(8) *S* ,the set of *information states* (based on situations), is the set

$$\left\{ s \subseteq M \middle| \begin{array}{l} \forall m, m' \in s: \\ m \text{ and } m' \text{ have the same referent system and} \\ \text{linguistic context, and are discernible this context} \end{array} \right\}$$

It turns out that the situations in an information state form a partition on the underlying set of possibilities, based on the indiscernibility relation defined by the linguistic context. In accordance with the new structures, the object language semantics are also renovated by using situations in place of possibilities (but without making any other change), and the update function on information states is redefined as a two stage process. To update state *s* with sentence φ, first the linguistic context is updated by applying the growth pattern to the current context and the sentence φ. This causes a repartitioning of the existing situations, but does not affect the underlying population of possibilities.[2] Only then does the standard semantic interpretation of φ take place (based on situations in place of possibilities). Even though the object language is now redefined based on situations, the updated framework can be shown to be isomorphic to the original framework under the update function, for as long as no new object language operators are introduced. This is stated more formally in (9).

(9) FACT: Let *S* and *T* be the sets of information states in the original and updated dynamic semantics respectively. With $[]_S$ and $[]_T$ their respective update functions.

There exists a function $F : S \xleftrightarrow{1-1} T$ in which the following holds:
If $s \in S$, $s = s_0[\varphi_1]\,[\varphi_2]...\,[\varphi_n]$ where s_0 is an initial state, and where $\{\varphi_i\}_{i=1..n} \subset FORMULAS$, then $\forall \varphi \in FORMULAS : F(s[\varphi]_S) = F(s)[\varphi]_T$

4. Normality again

We now return to normality. Seeing that in this paper events replace intervals, a trace function τ from events to their temporal intervals is used to maintain temporal ordering. Moreover we assume, for simplicity's sake only, a single domain of entities that contains both objects and events. These entities can be quantified over in the object language.

By defining a partial order of *eventiveness* on the situations in the information state and then selecting the minimal elements, we get the 'least unexpected', or normal, situations. One situation is less eventive than another one if for every conceptually expressible eventive fact that holds in the former situation, a similarly described fact also holds in the latter one. Conceptually expressible eventive facts are facts which are described by linguistic context sentences asserting the existence of an event, i.e. sentences such as $\exists x Event(x) \wedge Walk(x) \wedge Ag(Mary, x)$. We may safely ignore the expected/unexpected distinction while ordering, as expected descriptions are uniformly actualized in all situations.

This complex comparison is set out formally in (10). The required event descriptions are sought out by iterating first on the linguistic context sentences and then on the active quantifiers they define.[3] Filtering out quantifiers that don't represent events is done by appending '$\wedge event(q)$' to every sentence.

[2] Note that as the linguistic context monotonically grows, repartitioning after updating the context can only result in a finer grained partition.
[3] The syntactic function *Aq(φ)*, introduced in Groenendijk and Stokhof 1991, gives the active quantifiers of φ. These are the existential quantifiers introduced in φ whose scope is not bound within the sentence.

$$\text{Let } s \in S; m, m' \in s: \ m \text{ is less eventive than } m' \text{ in } s, \text{ iff}$$

(10) $\forall \varphi \in \gamma$ *the linguistic context of situations in s,* $\forall q \in Aq(\varphi)$:

$$[\![\varphi \wedge event(q)]\!]_m = 1 \Rightarrow [\![\varphi \wedge event(q)]\!]_{m'} = 1$$

A new object language operator, *normally*, is now defined as a test in (11). The operator makes use of the minimal elements in the ordering (labeled as *least eventive*) to check if a given sentence (the progressive event's full description as we will see) is indeed valid in every normal situation

(11) $$s[normally(\varphi)] = \begin{cases} s & \text{if } \forall m \in s: LeastEventive(m) \rightarrow [\![\varphi]\!]_m = 1 \\ \varnothing & \text{otherwise} \end{cases}$$

5. The rest of the semantics

Proceeding in brief through the rest of Dowty's semantics, we first take note that the identity requirement in inertia is automatically fulfilled by dynamic semantics. The information state only contains possibilities, and therefore also situations, that are consistent with the knowledge gained thus far. In addition, it is assumed that the reference time interval (denoted by Dowty as *I* but here as *RT*) is at our disposal when we come to analyze the progressive. Finally, for activities the subinterval property must also be postulated.

Given that sentence Φ asserts the existence of an event described by φ, that is – Φ is of the form $\exists e\big(event(e) \wedge \varphi(e)\big)$, the semantics of *PROG(Φ)* is given in (12) as two consecutive updates. The first update asserts what must already be known: that there is an event going on relative to reference time. The second update consists only of the test operator *normally*, that checks if every normal world actualizes the verb description as a fact.

(12) $$s[PROG(\phi)] = s\left[\exists e \begin{pmatrix} event(e) \wedge RT \subset \tau(e) \wedge \\ RT \text{ not a final subinterval of } \tau(e) \end{pmatrix}\right]\left[normally(\varphi)\right]$$

6. Example

Suppose that having started in a state of ignorance, we now see John heading toward the other side of the road. Accordingly we update our information state with (13), the informal notation being used to keep things as simple as possible. Suppose further that the growth pattern is such that along with (13) it extends the linguistic context with the speculative descriptions in (14) during the update.

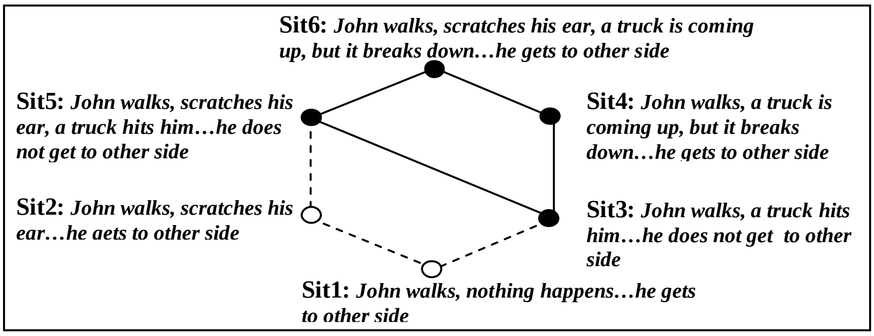
(13) $\exists e_{JohnWalkingDirOtherSideRoad} \wedge \tau(e) \supset RT$

(14) a. $JohnCrossRoad(e)$ c. $\exists e''_{TruckFlyingDownTheRoad} \wedge \tau(e'') > RT$

b. $\exists e'_{JohnScratchHisEar} \wedge \tau(e') > RT$ d. $\exists e'''_{TruckBreakDown} \wedge \tau(e''') > RT$

This information state may even be shared between us as bystanders and John as the agent. Except that, our darker fears materializing, the speeding truck now makes an appearance. Updating our information state (but not John's, he is oblivious to the truck), (14c) now gains the status of an utterance. Graph (15) maps the situations in the two information states according to their eventiveness. The ordering is shown by the connecting arches, with less eventive situations always lower than more eventive ones. John's information state is displayed by the whole graph, while ours is just the solid parts of it.

(15) **John's attempted crossing of the road**



(16) John is crossing the road

(17) John was crossing the road when the truck hit him.

Evaluating the truth of the progressive sentence (16), we see the two information states each provide a different situation as normal. For John it is situation 1, and the sentence true. For us though situation 3 is minimal, and the sentence is false.

To conclude, it is interesting to point out that sentences such as (17) are not accounted for in the suggested framework, for they require simultaneous use of both information states to come out true. Extending dynamic semantics with multiple concurrent information states may provide an answer to such sentences.

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