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Ontology for Human Talk and Thought (not Robotics)

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1 INTRODUCTION

Hamm, Kamp, and van Lambalgen 2006 (hereafter HKL) propose to relate NL discourse to cognitive representations that also deal with world knowledge, planning, belief revision, etc. Their implementation involves translating NL discourse first into DRT, which explicates the linguistic information, and then into an event calculus, which uses world knowledge and non-monotonic reasoning to arrive at the final cognitive representation.

Surprisingly, to represent human cognition they use an event calculus 'which has found applications in robotics'. They see the following parallel:

> "A typical computation in robotics proceeds as follows. A goal is specified, which can be a certain location … and an action to be performed at that location …. Next a plan is computed, that is, a sequence of actions to get the robot to the required location… Such a computation requires a world model …, a repertoire of activities and of possible observations. On the basis of the world model a plan is computed. While the robot executes the plan, it registers its observations of the world and its actions in the world model...The plan may have to be recomputed in mid-course when the world model must be updated due to new observations… a plan may consist of continuous activities … and… instantaneous actions…
>
> This description should be sufficiently suggestive to enable the reader to see the connection with linguistic processing. The listener starts with an initial discourse model, in which a newly arriving sentence must be integrated computably. Suppose the main verb of the sentence is nonstative. If the sentence is in one of the simple tenses, it is unpacked in an action and its participants, and the discourse model is updated accordingly. This is the analogue of updating the world model with representations of individuals and actions. In more complex cases, such as [*Bill will/is going throw himself off the cliff*], the sentence expresses the existence of a plan directed toward the goal formulated in the VP."

The first paragraph indeed sheds light on the ontology of the event calculus—e.g. *fluents*, a sort unknown in linguistics. It also accounts for the predicates, which by HKL's own testimony 'look somewhat baroque':

(1) *Initially*(f) ('fluent f holds at the beginning of the discourse')
Happens(e, t) ('event type e has a token at t')
Initiates(e, f, t) ('the causal effect of e at t is the fluent f)
Terminates(e, f, t) ('the causal effect of e at t is the negation of f)
Clipped(t, f, t') ('event type terminating f has a token btw t and t')
HoldAt(f, t) ('fluent f is true at t')

But whatever the merits of this event calculus for robotics, I fail to see the connection to human cognition and discourse. Unlike HKL, I very much doubt that the ontology people use to communicate with robots is the same they use to communicate with themselves in their thoughts or with other people in spoken or written discourse. A robot may walk like a human, but not because it has a similar 'anatomy'. It may also make plans and talk like a human but have fundamentally different 'cognitive representations'. So the success of an event calculus in robotics is not an argument for using it to represent human cognition or human discourse.

Assimilating humans to robots severely limits the utility of a theory. In the system of HKL it is exceedingly complex to translate even a simple sentence or mini-discourse of a familiar Indo-European language, as the examples HKL analyze vividly demonstrate. Part of the reason is that the NL ontology and surface NL forms are not transparently related to the robotics-based ontology and 'cognitive translations' in the event calculus. To bridge the gap, HKL must therefore heavily rely on world knowledge and non-monotonic reasoning, which gets very complicated very fast.

An ontology that is more transparently related to NL might simplify the analysis. In Bittner 2003 I proposed a 7-sorted ontology for NL, based on *worlds*, *times*, *places*, *events*, *states*, *animates*, and *inanimates*. All other NL types are defined as partial functions—e.g. *processes*, *habits*, and *kinds* are functions that return as values discourse-transparent parts (*stages* or *instances*). This 7-sorted ontology does not derive from robotics, but from crosslinguistic research on direct interpretation by left-right online update (not top-down, as HKL propose). By now, there are explicitly analyzed discourses in Kalaallisut, Yukatek, Mohawk, and English (Bittner 2003, 2005, and http://www.rci.rutgers.edu/~mbittner). Since these languages are unrelated, the 7-sorted ontology they converge on is presumably universal. The NL-based ontology has fewer basic sorts than the event calculus of HKL. And all of the NL sorts have intuitive content expressed by words that children acquire early.

In what follows I present a sample of Kalaallisut discourse, outline a left-right NL-based theory, and note some problems for the top-down robotics-based theory of HKL. I then suggest that for English, too, the NL-based theory might provide a simpler analysis, because it would shift the burden from world knowledge and non-monotonic reasoning to linguistic knowledge and direct interpretation of surface NL forms.

2 SAMPLE OF KALAALLISUT DISCOURSE

Kalaallisuit is a polysynthetic language with three inflectional classes of words: *nouns*, which inflect for agreement and case; *verbs*, which inflect for mood and agreement; and *particles*, which do not inflect. A ubiquitous grammatical centering system marks third person referents as topical or backgrounded, e.g. *-a* '$3s_{\top}$' vs. *-ni* '$3s_{\perp}$'. The indicated centering status

must hold after the marker is processed—i.e. the antecedent referent either has the required status in the input or its status is updated by the marker.

There are eight nominal cases: absolutive (unmarked) for intransitive subjects and transitive objects, ergative (ERG) for transitive subjects and nominal possessors, locative (LOC) for locations, dative (DAT) for goals, ablative (ABL) for sources, vialis (VIA) for paths, equalis (EQU) for standards of comparison, and modalis (MOD) for all other nominal modifiers.

The mood system distinguishes matrix and dependent verbs. Matrix moods contrast factual reports (IND), non-factual reports (IRR), wishes (OPT), commands (IMP), and questions (QUE). Dependent moods classify associated circumstances. A circumstance may be factual (FCT), non-factual (NON), hypothetical (HYP), habitual (HAB), or elaborating (ELA). It may also concern a topical or backgrounded subject, e.g. *-ga* 'FCT$_{\top}$' vs. *-mm* 'FCT$_{\bot}$'.

There is no (im)perfective dichotomy. Instead, every verbal root and derivational v\v suffix is aspectually typed as a state, event, process or habit:

(2) **state**: *sinig-* 'be asleep', *-u* 'be', *-sima* 'prf', *-nngit* '(be) not', …
event: *itir-* 'wake up', *annit-* 'take out', *-tit* 'cause', *-lir* 'begin', …
process: *pisug-* 'walk', *suliari-* 'process', *-tur* 'use as customary', …
habit: *-tar* 'habit', *-tuar* 'do regularly', *-gajug* 'do often', …

Semantic interpretation also depends on the assignment of the matrix verb and its dependents to topological fields: initial field (*if*), initial boundary (*ib*), middle field (*mf*), final boundary (*fb*), or final field (*ff*). For instance, topical referents are only updated in the initial fields, *if* and *ib*, while the comment minimally includes the matrix verb, in *fb*.

A sample of Kalaallisut discourse is presented in (3a, b, c, d)—four paragraphs of an Eskimo myth from a school reader (Sommer et al. 1972):

(3a) But one day Aataarsuaq noticed that his wife was pregnant. Her belly grew big. And sure enough one day she gave birth to a boy.

Irnir-taa-ni	inu-u-sima-tsiar-tu-q	*if*
son-new-3s$_{\top}$.sg	person-be-prf-briefly-ELA$_{\bot}$.IV-3s$_{\bot}$	
As soon as his$_{\top}$ new son$_{\bot}$ was born, …		
anguta-a-ta	annil-lu-gu	*ib*
father-3s$_{\bot}$.sg-ERG	take.out-ELA$_{\top}$-3s$_{\bot}$	
…the father$_{\top}$ (*lit.* his$_{\bot}$ father$_{\top}$) took him$_{\bot}$ out and		
sissa-mut	arpaliup-pa-a.	*mf fb*
shore-sg.DAT	run.off.with-IND.TV-3s.3s	
…ran off with him$_{\bot}$ [down] to the shore.		
Tasama-ni		*if*
down.there-LOC		
There…		

niaqu-a tasiqqa-mut *ib*
head-3s$_{\perp}$.sg puddle-sg.DAT

sivi-suu-mik mursut-ti-sima-va-a. *mf fb*
duration-long-sg.MOD go.under-cause-prf-IND.TV-3s.3s
…he$_{\top}$ dipped his$_{\perp}$ head in a puddle for a long time.

Taava *if*
Then…

tuavi=innaq illu-min-nut majuup-pa. *mf fb*
hurry=∀ home-3p$_{\top}$.sg-DAT carry.up-IND.TV-3s.3s
…he$_{\top}$ carried him$_{\perp}$ [back] up home, hurrying all the way.

(3b) Taama=iliur-tuar-pa-a. *fb*
thus=do-do.regularly-IND.TV-3s.3s
He$_{\top}$ did that to him$_{\perp}$ on a regular basis.

Ullaa-kkut itir-lu-ni=lu *if*
morning-sg.VIA wake.up-ELA$_{\top}$-3s$_{\top}$=and
Every morning when he$_{\top}$ woke up,

irn-i suli sinit-tu-q *ib*
son-3s$_{\top}$.sg still be.asleep-ELA$_{\perp}$.IV-3s$_{\perp}$
…while his$_{\top}$ son$_{\perp}$ was still asleep,

annit-tar-pa-a, sissa-mu=innaq. *fb ff*
take.out-habit-IND.TV-3s.3s shore-sg.DAT=∀
…he$_{\top}$ took him$_{\perp}$ out, always [down] to the shore.

Kiisa irnir-a pisut-ta-lir-a-mi *if ib*
finally son-3s$_{\perp}$.sg walk-habit-begin-FCT$_{\top}$-3s$_{\top}$
Finally, when his$_{\perp}$ son$_{\top}$ began to walk,

mitir-tut sivi-sutigi-su-mik *mf*
eider-sg.EQU duration-be.as.long.as-iv\cn-sg.MOD

aqqa-uma-sa-lir-pu-q. *fb*
dive-result.state-habit-begin-IND.IV-3s
…he$_{\top}$ began to dive as long as an eider.

(3c) Ila-an-ni *if*
part-3p$_{\perp}$.sg-LOC
Once…

anguta-a qajar-tur-lu-ni *ib*
father-3s$_{\perp}$.sg kayak-use.as.customary-ELA$_{\top}$-3s$_{\top}$
…when his$_{\perp}$ father$_{\top}$ went out kayak-[hunt]ing,

qasigissa-mik pi-sa-qar-pu-q. *mf fb*
spotted.seal-sg.MOD get-tv\rn-have-IND.IV-3s
…he$_{\top}$ caught a spotted seal$_{\perp}$.

Tikik-ka-mi nuli-i uqar-vig-a-a: *if ib fb*
come-FCT$_{\top}$-3s$_{\top}$ wife-3s$_{\top}$.sg say-to-IND.TV-3s.3s
When he$_{\top}$ came back, he$_{\top}$ said to his$_{\top}$ wife$_{\perp}$:

"Ami-a suliari-ssa-va-t, *ib fb*
"skin.of-3s$_{\perp}$.sg process-*x*.expect-IND.TV-2s.3s
"Process its$_{\perp}$ skin$_{\perp}$ [*lit.* you are expected to…],

taliru-i siqqu-i=lu *ff*
hind.flipper-3s$_{\perp}$.pl front.flipper-3s$_{\perp}$.pl=and

ata-til-lu-git!"
attached-cause-ELA$_{\top}$-3p$_{\perp}$
…leaving the hind flippers and the front flippers attached!"

(3d) Nuli-a-ta taama suliar-a-a. *if mf fb*
wife-3s$_{\perp}$.sg-ERG thus process-IND.TV-3s.3s
His$_{\perp}$ wife$_{\top}$ processed it$_{\perp}$ in this way.

Inir-m-at uvi-a-ta … *if ib*
finish-FCT$_{\perp}$-3s$_{\perp}$ husband-3s$_{\perp}$.sg-ERG …
When she$_{\perp}$ finished, her$_{\perp}$ husband$_{\top}$ [stuffed it$_{\perp}$ full …]

This text illustrates some commonly found antecedent-anaphor links: instance-habit and habit-instance in (3b), habit-subperiod in (3c), process-stage in (3c) and (3d), expected process-expected stage in (3c), concept-realization in (3d), and anaphora into and out of quotes in (3c) and (3d).

3 LEFT-RIGHT UPDATE WITH NL ONTOLOGY

These and other common varieties of NL anaphora can be explicated in the theory of left-to-right interpretation by online update developed by Bittner 2003, 2006a. The analysis of the Kalaallisut text (3a–d) is spelled out at http://www.rci.rutgers/~mbittner/kal.html, so I focus here on general issues concerning the relation between NL grammars and theoretical architecture.

First of all, the 7-sorted ontology makes it possible to explicate universal semantic constraints on two universal categories of NL: nouns and verbs. The NL contrast between open versus closed categories (e.g. roots-and-derivational affixes vs. inflections-and-particles) is likewise interpretable, in terms of a distinction between backgrounded and topical referents. Left-to-right update then provides a natural account of semantic generalizations about word order—e.g, in Kalaallisut, that topic update is restricted to the initial fields (*if*, *ib*).

Aspectual part-whole anaphora also falls into place in the 7-sorted NL ontology. This distinguishes *states* and *events* as basic types, and *processes* and *habits* as partial functions whose values are the discourse-transparent parts: *stages* or *instances*. Temporal anaphora, with or without tense, can then be accounted for by a system of aspect-based universals that determine the temporally relevant reality presuppositions, the default topic time (which can be an instant, period, or kind of time), location relative to the input topic time, and the update of the topic time (Bittner 2006b, extrapolating from Kamp and Rohrer 1983, Partee 1984, Moens and Steedman 1988, Webber 1988, Klein 1994, Smith 2005, and Bittner 2005, a.m.o.).

In online update anaphora resolution is primarily based on the current centering rank, restricted to the relevant type of the 7-sorted NL ontology, and only secondarily on world knowledge. This is consistent with the fact that grammatical centering in Kalaallisut renders anaphora unambiguous.

In general, the theory of online update extrapolates from parochial NL grammars to semantic universals of NL. By transparently relating the two, the theory can interpret surface NL forms directly left-to-right, updating the current state of information and attention as each item directs.

4 TOP-DOWN THEORY WITH HKL ONTOLOGY

In contrast, in the theory of HKL the relation between surface NL forms and the robotics-based event calculus is far from transparent.

Translated into this event calculus, nouns become indistinguishable from verbs. The NL distinction between open and closed categories is also ignored—the event calculus does not distinguish the current center of attention from the background. Combined with top-down interpretation, this makes it difficult to capture semantic generalizations about word order.

Aspectual part-whole anaphora is likewise difficult to analyze in the system of HKL. The robotics-based sort, *fluent*, conflates events with processes, amongst other things. Habits are treated as quantificational tests. Thus process-to-stage and habit-to-instance anaphora are both unexplained. And with robotics-based aspectual types (or Vendlerian types, based on parochial facts of English), the above-mentioned aspect-based account of temporal anaphora in NL does not work.

In the system of HKL anaphora seems to be primarily guided by world knowledge and gender presuppositions. It is therefore a mystery how grammatical centering in Kalaallisut—which does not have grammatical gender—renders anaphora unambiguous.

In general, HKL do not use NL grammars to arrive at NL universals. The only linguistic type they consider is Indo-European, which is not enough to distinguish NL universals from parochial facts. Instead, HKL aim for 'cognitive representations' motivated by robotics. But this leads them to ignore ubiquitous NL signs of key updates in the current state of information and attention. And this, in turn, leads to needless complexity,

because world knowledge and non-monotonic reasoning have to pick up the slack. Thus, while all of the anaphoric links in (3a–d) can be analyzed in the NL-based theory of online update, most of these garden varieties of NL anaphora seem too complex for the robotics-based theory of HKL.

5 LEFT-RIGHT UPDATE FOR ENGLISH

While the theory of direct online update is new, its basic ideas are not. Centering-based anaphora has long been informally motivated for English and other languages (Walker et al. 1998 a.m.o.). The implementation by Stone and Hardt 1999 based on mini-discourses naturally extends to the text-based proposal of Bittner 2006b. Likewise, the 7-sorted ontology is supported by English-based and typological work. Moens and Steedman 1988 analyze English aspect in terms of *states*, *events*, and *processes*. They include both telic and atelic processes, in accord with the typological survey by Chung and Timberlake 1985 and the 7-sorted ontology. *Habits* have been proposed as a distinct aspectual type on typological grounds by Comrie 1976, and on the basis of English texts by Smith 2005. Formal semantic theories rarely distinguish *animate* and *inanimate* entities, but NL phenomena are known to do so, e.g. if they refer to an *agent* or *experiencer*. The theory of online update extrapolates from such studies, so it applies to English and Kalaallisut alike (Bittner 2005). For the English examples analyzed by HKL it offers competing analyses.

For instance, HKL attribute the intuition that the pronoun *she* is anaphoric to *a delegate* in (4) but not in (5) (their (21) and (30)) to non-monotonic reasoning: the anaphoric link in (4) is a default, which is defeated in (5) by gender conflict.

(4) A delegate arrived. She registered.

(5) A delegate arrived. His wife arrived somewhat later. She registered (as accompanying person).

But the antecedent shifts even without conflict, as shown by (6). HKL miss the generalization that the pronominal anaphor *she* refers to the most central female referent, and that this cannot be defeated by world knowledge (e.g. that kids are unlikely delegates).

(6) A delegate arrived. Her kid sister arrived somewhat later. She registered {as accompanying person, #with the other delegates}.

Similarly, to account for (7), HKL appeal to ‘world knowledge… that getting a *ticket* terminates, … not initiates *speeding*’:

(7) [1]Jean got a ticket. [2]He was driving too fast.

But (7) is also true if Jean sped past a police camera without stopping. This is predicted by online update that interprets (7^1) as a *process* of getting a ticket, and the start of the driving in (7^2) as one of the *stages*.

6 CONCLUSION

The robotics-based theory of HKL attributes too much to world knowledge and not enough to the ontology, centering, and other universals of NL. It therefore runs into problems already for mini-discourses in Indo-European languages. It is difficult to see how this theory could apply to actual texts and non-Indo-European languages. An NL-based theory, such as direct online update, is more likely to offer a satisfactory crosslinguistic account.

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