Type Theory with Records for Natural Language Semantics: Lecture 4

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Grounding

- Grounding (Herb Clark and collaborators): A's dialogue move m_1 before it enters the common ground must be *grounded* by B. Grounding requires that *B understands m_1 relative to her own purposes.*
- Alwood: 'Contributions in the form of "acknowledging feedback" are not needed to constitute speech acts but rather to inform the interlocutor of the extent to which his communicative objectives are met.'
- Traum 1994: computationally explicit account; fused into Conversational Discourse Representation Theory in collaboration with Massimo Poesio (PTT).
- PTT integrates grounding into the general semantic interpretation process, uses DRT to account for anaphoric uses to previous utterances; very detailed picture of the common ground subsequent to an utterance.

Failing to ground

- How to construe the grounding criterion?
- Not so crucial to formalize *B understands* m_1 *relative to her own purposes.* if one concentrates on successful cases (for discussion of challenges to formalization see e.g. Traum 1999).
- More crucial if one wishes to study *What are the consequences of grounding failure?*

When grounding fails: *CRification*

(1) Tim: Could I have one of those (unclear)? Dorothy: Can you have what? Tim: Have one of those things. Dorothy: What things? Tim: Those pink things that af after we had our lunch. Dorothy: Pink things? Tim: Yeah. Er those things in that bottle. Dorothy: Oh **I know what you mean.** For your throat?

When grounding fails: *CRification*

- Clarification Requests (CRs)—one of the most explicit pieces of evidence we have of the distribution of sources of *trouble* in interaction.
- Occur approx 5% of the time (BNC: 'eh': 1943, pardon: 768)
- More *difficult* cognitively: kids start producing only from approx. 30 months; no evidence of non-human CRs.
- Crucial tool of linguistic stability: evidence from simulations (see Macura and Ginzburg, 2008, Macura 2007 PhD thesis)

Purver et al taxonomy

- There are a wide range of forms of CRs that can follow a given utterance—their characterization is an adequacy requirement for any theory of dialogue context:
- See Purver et al 2001, Purver, 2004, for the taxonomy of CRs used here.
- This is based on a random sampling of the 10 million word dialogue subcorpus of the BNC consisting of c. 150,000 words. 4% of sentences were found to be clarification requests.

CRs: form classification

(2) a. A: Did Bo leave?

b. *Wot* B: Eh? / What? / Pardon?

c. *Explicit* B: What did you say? / Did you say ‘Bo’ ?

d. *Literal reprise* B: Did BO leave? / Did Bo LEAVE?

e. *Wh-substituted Reprise* B: Did WHO leave? / Did Bo WHAT?

f. *Reprise sluice* B: Who? / What?

g. *Reprise fragment* (CE) B: Bo? / Leave?

h. *Gap* B: Did Bo . . . ?

i. **Filler**: A: Did Bo . . . B: Win? (Table I from Purver, 2006)

CRs: content classification

- Four classes of contents were identified: they can be exemplified in the form of Explicit CRs:

(3)
a. **Repetition**: What did you say? Did you say 'Bo'?
b. **Clausal confirmation**: Are you asking if Bo left? You're asking if who left?
c. **Intended Content**: What do you mean ()? Who is 'Bo'?
d. **Correction**: Did you mean to say 'Bro'?

CRs: content classification

- Many CR utterances are multiply ambiguous. The most extreme case is RF, which seems able to exhibit all four readings, main two being clausal and intended-content:

(4) a. Marsha: yeah that's it, this, she's got three rottweilers now and
Sarah: three?
Marsha: yeah, one died so only got three now
Are you saying she's got THREE rottweilers now?

(5) Tim: Could I have one of those (unclear)? Dorothy: Can you have what? Tim: Have one of those things. Dorothy: What things? Tim: Those pink things that af after we had our lunch. Dorothy: Pink things? Tim: Yeah. Er those things in that bottle. Dorothy: Oh **I know what you mean.** For your throat?

CR form and type as percentage of CRs – demographic portion

	expl	lit	sub	slu	rf	gap	fil	wot	oth	Total
cla	4.1	4.7	1.0	11.3	24.8	0	0	0	0.5	46.5
int	6.2	0	0	0	1.8	0	0	5.7	0	13.6
rep	0.8	0	2.6	2.3	0.3	0.5	3.1	26.3	0	35.9
cor	1.0	0.5	0	0	1.0	0	0	0	0	2.6
oth	0	0	0	0	0.8	0	0	0.5	0	1.3
Total	12.1	5.2	3.6	13.6	28.6	0.5	3.1	32.5	0.5	100.0

CR form and type as percentage of CRs – demographic portion

- CRs were found to make up just under 4% of sentences when calculated over the demographic portion, or just under 3% when calculated over all domains.
- Forms: Commonest: *wot* and *reprise fragment* forms, with each making up over 25% of CRs. Explicit CRs and reprise sluices also common, each contributing over 10% of CRs. Other forms are all around 5% or less.
- Readings: nearly 50% of CRs— clausal-conf with the repetition (about 35%) and int-content (about 15%) non-trivial.

CE: parallelism conditions

- The clausal-conf and intended-content readings involve distinct syntactic and phonological parallelism conditions.
- Clausal readings do not require phonological identity between target and source:

(6) a. A: Did Bo leave? B: My cousin?
    b. A: Did she annoy Bo? B: Sue?

- syntactic parallelism: an XP used to clarify an antecedent sub-utterance u_1 must match u_1 categorially:

(7) a. A: I phoned him. B: him? / #he?
    b. A: Did he phone you? B: he? / #him?
    c. A: Did he adore the book. B: adore? / #adored?
    d. A: Were you cycling yesterday? B: Cycling?/biking?/#biked?

CE: parallelism conditions

- Int-cont readings of CE do seem to involve (segmental) phonological identity with their source.

  (8) (i) A: Did Bo leave? B: Max? (cannot mean: int-cont reading: **who are you referring to?**)

Non-existent CRs

- Two of the most highly researched areas in formal and computational grammar are syntactic ambiguity (e.g. prepositional attachment) and scopal ambiguity.
- **not a single CR concerned with syntactic or scopal ambiguity has been found**, suggesting that either these are not domains that involve much uncertainty for interlocuters in human conversation, or that there is some factor that prevents their production.
- See Ginzburg, 2012 for discussion of constructed scope disambiguation CRs such as:

(9)

A(1): The boys kept a cat.
B(2): A cat? One cat for all the boys or different ones?
A(3): They each kept a cat.

Empirical Conclusions

- Schegloff's claim: (applied to CRs, not self-repair) 'Because anything in talk can be a source of trouble, everything in conversation is, in principle, "repairable".' use
- Evidence from three corpus studies Purver *et al.* (2001); Rodriguez and Schlangen (2004); Rieser and Moore (2005) (two concern English conversations, one German; two involve task oriented conversations, the most comprehensive involves a wide range of primarily free unrestricted conversation types.)

Empirical Conclusions

- **Restricted range of contents**: the function of CRs seems, to a very large extent, to consist of either (a) confirming or querying intended content or (b) requesting repetition of a misheard (sub)-utterance. use
- **Syntactic and phonological parallelism**: CRs frequently exhibit (segmental) phonological parallelism with their source, indeed for certain form/content combinations this is a grammatical requirement; this requirement is weakened to syntactic parallelisms for other constructions.

GRCR conditions

- The ability to characterize for any utterance type the update that emerges in the aftermath of successful mutual understanding (*grounding*), and the full range of possible clarification requests (Clarification interaction = CRification) otherwise.

What entity delivers GRCR conditions?

- Need entity which (a) both CPs have interest in preserving,
- from which range of CRs is derivable,
- and which allows original speaker (Ariadne) to interpret and recognize the coherence of a class of possible clarification queries that original addressee (Barabas) might make.
- allows utterance presuppositions to be derived.

What entity delivers GRCR conditions?

- Content: pro: in Ariadne's DGB post-utterancely; con: not necessarily in Barabas'; too coarse grained.
- Meanings (Montague/Kaplan sense): pro: range of contextual parameters offers a possible characterization of the contextually variable and hence potentially problematic constituents of utterance content.
- if we conceive of meanings as entities which characterize potential sources of misunderstanding, then at a minimum all open class words will also need to be assumed to project parameters which requiring instantiation in context.

What entity delivers GRCR conditions?

- Con 1: coarse grained

(10) a. Ariadne: Jo is a lawyer. Barabas: A lawyer?/What do you mean a lawyer?/#What do you mean an advocate?/#What do you mean an attorney?

b. Ariadne: Jo is an advocate. Barabas: #What do you mean a lawyer?/An advocate?/What do you mean an advocate?/#What do you mean an attorney?

Con 2: need syn/phon data to ensure potential for syntactic and phonological parallelism (e.g. for CE).

Sub-utterance potential for CRs

- *a priori* ANY sub-utterance is clarifiable (but significant caveats qualitatively and quantitatively):

  (11) a. Who rearranged the plug behind the table?
  b. Who? / rearranged?/ the plug? / behind? / the table?
  c. A: Is that the shark? B: The? B: Well OK, *A*. (based on an example in the film *Jaws*.)

- The consequences this has for utterance representation is that we need to ensure that for a given utterance each *sub*-utterance is accessible as an antecedent.

An utterance type

$$\begin{bmatrix} \text{PHON} : \texttt{is georges here} \\ \text{CAT} = \mathsf{V[+fin]} : \mathsf{syncat} \\ \mathsf{constits} = \left\{ \mathsf{is,\ georges,\ here,\ is\ georges\ here} \right\} : \mathsf{set(sign)} \\ \text{C-PARAMS} : \begin{bmatrix} \mathsf{spkr} : \mathsf{IND} \\ \mathsf{addr} : \mathsf{IND} \\ \mathsf{c1} : \mathsf{address(s,a)} \\ \mathsf{s0} : \mathsf{SIT} \\ \mathsf{l} : \mathsf{LOC} \\ \mathsf{g} : \mathsf{IND} \\ \mathsf{c3} : \mathsf{Named(g,`georges')} \end{bmatrix} \\ \mathsf{cont} = \mathsf{Ask(spkr,addr,}\ ?\begin{bmatrix} \mathsf{sit} = \mathsf{s0} \\ \mathsf{sit\text{-}type} = \mathsf{In(l,g)} \end{bmatrix}) : \mathsf{IllocProp} \end{bmatrix}$$

What entity delivers GRCR conditions?

- The locutionary proposition defined by u, T_u is a grammatical type that classifies u is the proposition $\begin{bmatrix} \text{sit} = \text{u} \\ \text{sit-type} = \text{T}_u \end{bmatrix}$. This will deliver GRCR conditions.
- Why the grammatical type:
  - Finer grain than content, meaning
  - syn/phon parallelism with source utterance
- Why the utterance token:
  - Need instantiated content, not merely meaning
  - Reference to sub-utterances tokens figure in CRs (‘Bo?’ = Who referring to in that utterance of ‘Bo’.)

A locutionary proposition

(12)
$$\left[\begin{array}{l}
\text{sit} = \left[\begin{array}{l}
\text{phon} = \texttt{dijoliv} \\
\text{cat} = \text{V[+fin,+root]} \\
\text{constits} = \left\{\text{di,jow,liv}\right\} \\
\text{dgb-params} = \left[\begin{array}{l}
\text{s0} = \text{sit0} \\
\text{t0} = \text{time0} \\
\text{j} = \text{j0} \\
\text{c3} = \text{c30}
\end{array}\right] \\
\text{cont} = ([])\left[\begin{array}{l}
\text{sit} = \text{s0} \\
\text{sit-type} = \text{Leave(j,t0)}
\end{array}\right]
\end{array}\right] \\
\text{sit-type} = \left[\begin{array}{l}
\textsc{phon} : \texttt{did jo leave} \\
\textsc{cat} = \text{V[+fin,+root]} : \text{syncat} \\
\text{constits} = \left\{\text{did, jo, leave}\right\} : \text{set(sign)} \\
\textsc{dgb-params} : \left[\begin{array}{l}
\text{s0:} \ \text{SIT} \\
\text{t0:} \ \text{TIME} \\
\text{j:} \ \text{IND} \\
\text{c3:} \ \text{Named(j,jo)}
\end{array}\right] \\
\text{cont} = ([])\left[\begin{array}{l}
\text{sit} = \text{s0} \\
\text{sit-type} = \text{Leave(j,t0)}
\end{array}\right] : \text{Questn}
\end{array}\right]
\end{array}\right]$$

Incorporating metacommunicative interaction

- Add resource: Pending—incompletely processed utterances.
- In light of need for fine grainedness and non-semantic parallelism:
  Change type of resource Moves, Pending keep track of $\langle$ utt. token, utt. type $\rangle$ pair (*locutionary propositions*)
- New defn of DGBType:

$$\begin{bmatrix} \text{spkr: Ind} \\ \text{addr: Ind} \\ \text{utt-time: Time} \\ \text{c-utt : addressing(spkr,addr,utt-time)} \\ \text{Facts : Set(Prop)} \\ \textbf{Pending : list(LocProp)} \\ \text{Moves : list(LocProp)} \\ \text{QUD : poset(Question)} \end{bmatrix}$$

Incorporating metacommunicative interaction

- Grounding: utterance type fully classifies utterance token
- CRification: utterance type calculated is weak (e.g. incomplete word recognition); need further information to spell out token (e.g. incomplete contextual resolution).

Pending: composition

- Utterances are kept track of in a contextual attribute PENDING in the immediate aftermath of the speech event.
- Given a presupposition that u is the most recent speech event and that T_u is a grammatical type that classifies u, a record of the form $\begin{bmatrix} \text{sit} = \text{u} \\ \text{sit-type} = \text{T}_u \end{bmatrix}$ (of type LocProp (*locutionary proposition*)), gets added to PENDING.

Contextual extension

- Contextual instantiation will of course occur as soon as an utterance has taken place, but it can also take place subsequently, as when more information is provided as a consequence of CRification

(13) **Contextual extension**
given the MaxPending locutionary proposition p = $\begin{bmatrix} \text{sit} = \text{u} \\ \text{sit-type} = \text{T}_u \end{bmatrix}$ and a record w that (a) contextually extends u and such that (b) $w.c - params$ is a subrecord of the c-param anchoring intended by u's speaker, integrate w into p.

CRification

- Failure to fully instantiate contextual parameters or recognize phonological types triggers CRification.
- This involves accommodation of questions into context by means of a particular class of conversational rules—Clarification Context Update Rules (CCURs).
- We can do this given the highly restricted nature of potential CRs, given our corpus results.

CRification

- Each CCUR specifies an accommodated MaxQUD built up from sub-utterance u1 of the target utterance *MaxPending*.
- Common to all CCURs is a license to follow up *MaxPending* with an utterance which is *co-propositional* with MaxQud
- We can define *CoPropositionality* as follows:
  - Two utterances u_0 and u_1 are *co-propositional* iff the questions q_0 and q_1 they contribute to QUD are co-propositional.
  - q_0 and q_1 are co-propositional if there exists a record r such that $q_0(r) = q_1(r)$.
- In practice: *co-propositional* here: either a CR which differs from MaxQud at most in terms of its domain, or a correction—a proposition that instantiates MaxQud.
- Example: ‘Whether Bo left’, ‘Who left’, and ‘Which student left’ (assuming Bo is a student.)

CRification

- Parameter identification:

$$\left[\begin{array}{ll} \text{pre} : & \left[\begin{array}{l} \text{Spkr} : \text{Ind} \\ \text{MaxPending} : \text{LocProp} \\ \text{u0} \in \text{MaxPending.sit.constits} \end{array}\right] \\ \text{effects:} & \left[\begin{array}{l} \text{MaxQUD} = \lambda x(\mathit{Mean}(\mathit{pre.spkr}, u0, x) : \text{Question} \\ \text{LatestMove} : \text{LocProp} \\ \text{c1:} \ \text{CoProp(LatestMove.cont,MaxQUD)} \end{array}\right] \end{array}\right]$$

Parameter Identification

- Underpins CRs such as:

(14) A: Is Bo here?
  a. Who do you mean 'Bo'?
  b. WHO?
  c. Bo? (= Who is 'Bo'?)

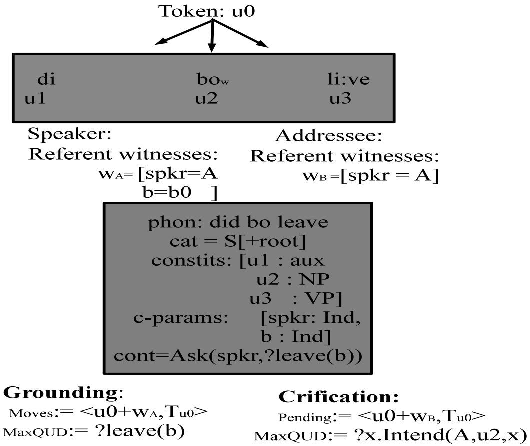
- Example shortly; NSU cases tomorrow.
- We can also deal with corrections, as in (15). B's corrective utterance is co-propositional with λxMean(A,u2,x), and hence allowed in by the specification.

(15) a. A: Is Bo here?
  b. B: You mean Jo.

Incorporating metacommunicative interaction

- Single (public) input leads to distinct outputs on 'public level'.

The Turn Taking Puzzle



An example

(16) A(1): Is Georges here?
B(2): WHO do you mean?
A(3): George Sand.
B:(4) Ah,(5) no.

Example

$$
\begin{bmatrix}
\mathrm{T}_u = \mathrm{IGH} \\
\mathrm{u} = \mathrm{u0} \\
\mathrm{dgb0} = \begin{bmatrix}
\mathrm{spkr} = \mathrm{A} \\
\mathrm{addr} = \mathrm{B} \\
\mathrm{Pending} = \langle\rangle \\
\mathrm{Moves} = \langle\rangle \\
\mathrm{qud} = \left\langle\right\rangle \\
\mathrm{facts} = \left\{\begin{array}{l}
\ldots \mathrm{In}(\mathrm{I}, \left\{\mathrm{A},\mathrm{B}\right\}), \\
\mathrm{MostRecentSpeechEvent}(\mathrm{u0}), \\
\mathrm{Classify}(\mathrm{IGH},\mathrm{u0}),\ \ldots
\end{array}\right\}
\end{bmatrix}
\end{bmatrix}
$$

Example

$$
\text{dgb2'} = \begin{bmatrix}
\text{spkr} = \text{A} \\
\text{addr} = \text{B} \\
\text{pending} = \left\langle \begin{bmatrix}
\text{sit} = \text{w0'} \\
\begin{bmatrix}
\text{phon} = \text{izjorjhiya} \\
\text{cat} = \text{V[+fin,+root]} \\
\text{constits} = \left\{ \begin{array}{l} \text{v1(iz),v2(jorj),} \\ \text{v3(hiya),v4(izjorjhiya)} \end{array} \right\} \\
\text{dgb-params} = \begin{bmatrix}
\text{spkr} = \text{A} \\
\text{addr} = \text{B} \\
\text{time} = \text{t0} \\
\text{s0} = \text{sit1} \\
\text{l} = \text{l0} \\
\text{c3} = \text{pr1}
\end{bmatrix} \\
\text{cont} = \text{Ask(spkr,addr, ?}\begin{bmatrix} \text{sit} = \text{s0} \\ \text{sit-type} = \text{In(l,g)} \end{bmatrix}\text{)}
\end{bmatrix} \\
\text{sit-type} = \text{IGH}
\end{bmatrix} \right\rangle \\
\text{qud} = \text{dgb0.qud}
\end{bmatrix}
$$

Example

$$\begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{T}_u = \text{WDYM} \\ \text{u} = \text{u1} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w0'} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \\ \text{c3} = \text{pr3} \\ \text{q1} = \lambda x \ \text{Mean(pre.spkr,pre.v2,x)} : \text{Questn} \\ \text{qud} = \left\langle \text{q1} \right\rangle \\ \text{facts} = \text{facts1'} = \text{dgb0.facts} \cup \left\{ \text{MostRecentSpeechEvent(u1)} \right\} \\ \text{moves} = \left\langle \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{WDYM} \end{bmatrix} \right\rangle \end{bmatrix}$$

Example

$$\begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w0'} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \\ \text{qud} = \left\langle \lambda x \text{Mean(A,v2,x)} \right\rangle \\ \text{facts} = \text{facts1'} \\ \text{moves} = \left\langle \text{Ask(B,A,}\lambda x\text{Mean(A,v2,x))} \right\rangle \end{bmatrix}$$

An example

(17) a. $$\text{A.dgb7} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{WDYM} \end{bmatrix} \right\rangle \\ \text{qud} = \left\langle \text{p1?} \right\rangle \\ \text{facts} = \left\{ \begin{array}{l} \text{In(l,}\left\{\text{A,B}\right\}\text{)} \\ \text{Named('Georges',g),} \\ \text{2ndMostRecentSpeechEvent(u0),} \\ \text{Classify(IGH,u0)} \\ \text{MostRecentSpeechEvent(u1),} \\ \text{Classify(WDYM,u1)} \end{array} \right\} \\ \text{moves} = \left\langle \begin{bmatrix} \text{sit} = \text{w0} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \end{bmatrix}$$

An example

(18)

$$\text{B.dgb7'} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w0'} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \\ \text{qud} = \left\langle \lambda x \text{Ask(A,B,?In(l,x))} \right\rangle \\ \text{facts} = \left\{ \begin{array}{l} \text{In(l,} \left\{ \text{A,B} \right\} \text{)} \\ \text{Named('Georges',g),} \\ \text{2ndMostRecentSpeechEvent(u0),} \\ \text{Classify(IGH,u0)} \\ \text{MostRecentSpeechEvent(u1),} \\ \text{Classify(WDYM,u1)} \end{array} \right\} \\ \text{moves} = \left\langle \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{WDYM} \end{bmatrix} \right\rangle \end{bmatrix}$$

The TTP revisited

- A has the question of *whether Georges is here* as the sole member of QUD, whereas the utterance 'WHO do you mean?' remains pending;
- remains pending because no applicable LatestMoveUR.

The TTP revisited

- In contrast, B's QUD consists of the question *who do you mean*, whereas the utterance 'Is Georges here' is pending.

The TTP revisited

- However, TTP-type mismatches are exhibited intrinsically on the level of production, but need not arise at the level of comprehension.
- That is, in the current example—and more generally—it is rarely the case that the author of an utterance u fails to understand CRs relating to u, let alone to recognize their coherence.

  (19) A: Who does Bo admire? b: Bo?
- In order to enable this possibility, we offer a rule that *inter alia* allows the integration of CRs concerning u by the author of u.

CR Accommodation

- CCUR.qud(u1)—question accommodated by applying a CCUR to u1.
- *CR accom rule*: if the speaker of LatestMove is the current addressee, *p* is pending, and u1 is a constituent of LatestMove, one can update moves with *p* and QUD with CCUR.qud(u1), so long as *p* is co-propositional with CCUR.qud(u1).

An example

$$\text{A.dgb8} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \langle\rangle \\ \text{qud} = \left\langle \lambda x \text{Ask(A,B,), p1?} \right\rangle \\ \text{facts} = \text{dgb7.facts} \\ \text{moves} = \left\langle \begin{matrix} \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{WDYM} \end{bmatrix}, \\ \begin{bmatrix} \text{sit} = \text{w0} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

An example

(20) a. A(3): (I'm asking about) George Sand. B:(4) Ah,(5) no.

An example

$$\text{B.dgb8'} = \begin{bmatrix} \text{spkr} = \text{A} \\ \text{addr} = \text{B} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w0'} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \\ \text{qud} = \left\langle \text{?Mean(A,v2,gs)¡,}\lambda x\text{Ask(A,B,}\lambda x\text{Mean(A,v2,x))} \right\rangle \\ \text{facts} = \text{dgb7'.facts} \\ \text{moves} = \left\langle \begin{matrix} \begin{bmatrix} \text{sit} = \text{w3} \\ \text{sit-type} = \text{GS} \end{bmatrix}\text{'} \\ \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{IWH} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

An example

$$\text{B.dgb9'} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \left\langle \begin{bmatrix} \text{sit} = \text{w0'} \\ \text{sit-type} = \text{IGH} \end{bmatrix} \right\rangle \\ \text{qud} = \langle\rangle \\ \text{facts} = \left\{ \text{Ask(A,B,Mean(A,v2,gs))} \right\} \\ \cup \text{ dgb7'.facts} \\ \text{moves} = \left\langle \begin{matrix} \begin{bmatrix} \text{sit} = \text{w4} \\ \text{sit-type} = \text{Ah} \end{bmatrix}, \\ \begin{bmatrix} \text{sit} = \text{w3} \\ \text{sit-type} = \text{GS} \end{bmatrix}, \\ \begin{bmatrix} \text{sit} = \text{w1} \\ \text{sit-type} = \text{IWH} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

An example

$$
\text{B.dgb10'} =
\begin{bmatrix}
\text{spkr} = \text{B} \\
\text{addr} = \text{A} \\
\text{pending} = \left\langle
\begin{bmatrix}
\text{sit} = \text{w0} = \begin{bmatrix}
\text{dgb-params} = \begin{bmatrix}
\text{spkr} = \text{A} \\
\text{addr} = \text{B} \\
\text{time} = \text{t0} \\
\text{s0} = \text{sit1} \\
\text{l} = \text{l0} \\
\text{g} = \text{gs} \\
\text{c3} = \text{pr1}
\end{bmatrix} \\
\text{cont} = \text{Ask}(\text{spkr},\text{addr}, ?\begin{bmatrix}
\text{sit} = \text{s0} \\
\text{sit-type} = \text{In}(\text{l},\text{g})
\end{bmatrix})
\end{bmatrix} \\
\text{sit-type} = \text{IGH}
\end{bmatrix}
\right\rangle \\
\text{qud} = \text{dgb9'.qud} \\
\text{facts} = \text{dgb9'.facts} \\
\text{moves} = \text{dgb9'.moves}
\end{bmatrix}
$$

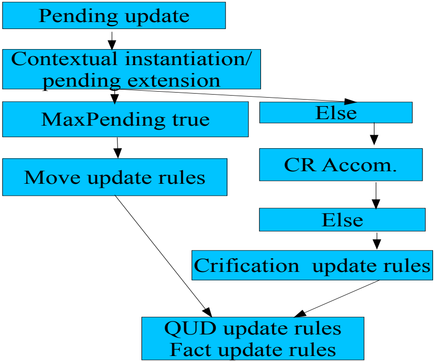
An example

$$\text{B.dgb11'} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \langle\rangle \\ \text{qud} = \text{dgb9'.qud} \\ \text{facts} = \text{dgb9'.facts} \\ \text{moves} = \left\langle \begin{bmatrix} \text{sit} = \text{w0} \\ \text{sit-type} = \text{IGH} \end{bmatrix}, \text{dgb10'.moves} \right\rangle \end{bmatrix}$$

An example

$$\text{B.dgb12'} = \begin{bmatrix} \text{spkr} = \text{B} \\ \text{addr} = \text{A} \\ \text{pending} = \langle\rangle \\ \text{qud} = \left\langle \text{?In(lo,gs)} \right\rangle \\ \text{facts} = \text{dgb9'.facts} \\ \text{moves} = \text{dgb11'.moves} \end{bmatrix}$$

Summary


Pending update
Contextual instantiation/
pending extension
MaxPending true
Else
Move update rules
CR Accom.
Else
Crification update rules
QUD update rules
Fact update rules

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