Modelling and Managing Dialogue

Approaches and Challenges

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Introduction

- A dialogue model (SDRT), and its implementation in a dialogue system (RUDI).
  [joint work with Alex Lascarides (Edinburgh), Ann Copestake (Stanford / Cambridge)]
- RUDI:
  - not practical dialogue system --- "testbed" for theory of dialogue semantics and pragmatics.
  - deep processing: "real" grammar, "real" LFs, "real" inferences.
  - not full DS: *overhearer* which tracks conversation and
    - computes certain context sensitive aspects of its meaning,
    - and asks for clarification, if it has problems understanding what it tracks.

Preview

- Context sensitivity of interpretation: "dialogue means more than sum of parts"
  - hypothesis: *discourse structure* determines additional content.
  - implementation: leave "holes" in LF produced by grammar, fill them using discourse information.
- Interaction management: "DPs work together to repair understanding problems"
  - hypothesis: understanding problems occur on many levels, & are of different severity.
  - implementation: evaluate quality of interpretation hypothesis at all stages to decide whether repair is needed.

Overview of talk

- SDRT
- RUDI
  - RUDI-01: Bridging Relations
    - Phenomenon
    - Implementation
  - RUDI-02: Fragments
    - Phenomenon
    - Implementation

  } context sensitivity of interpretation

  - RUDI-04: Clarification Requests
    - Phenomenon
    - Implementation

  } interaction management
- Information-State Update Framework
- Summary

Intro to SDRT

- SDRT (Asher 1993, Asher & Lascarides 2003)
  - explanandum: discourse means more than sum of its parts.

(1) John arrived in Edinburgh.
Peter met him at the platform.

- models "pragmatic competence":
  more than what grammar outputs, less than full belief revision

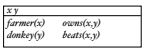
Intro to SDRT

- SDRT (Asher 1993, Asher & Lascarides 2003)
  - dynamic semantics + (AI-style) pragmatics
  - DRT + rhetorical relations
    (Hobbs 1985, Mann & Thompson 1987)

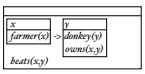
SDRT = DRT + ...

- DRT (Kamp & Reyle 1993): semantics of *discourses*. Meaning as *context change potential*.

(2) A farmer owns a donkey.
He beats it.



(3) Every farmer owns a donkey.
??He beats it.



- *Accessibility* constraint

SDRT = DRT + rhetorical relations

Narration

(5) Max fell. John helped him up.
e_α e_β $e_\alpha < e_\beta$

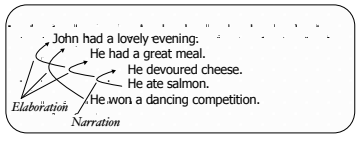
Explanation

(6) Max fell. John pushed him.
e_α e_β $e_\beta < e_\alpha$

- Temporal order is determined by rhetorical structure.
- --> *Disc. means more than sum of parts.*

SDRT in a nutshell

- *SDRSs*: Extend DRT with rhetorical relations, which encapsulate additional content.
- Central notion: *coherence*. Utterances must be connected to context via rhetorical relations.



SDRT in a nutshell

- *SDRSs*: Extend DRT with rhetorical relations, which encapsulate additional content.
- Central notion: *coherence*. Utterances must be connected to context via rhetorical relations.

John had a lovely evening.
He had a great meal.
He devoured cheese.
?
He ate salmon.
John's sister has black hair.

SDRT in a nutshell

- *SDRSs*: Extend DRT with rhetorical relations, which encapsulate additional content.
- Central notion: *coherence*. Utterances must be connected to context via rhetorical relations.
- Separate logic of content from logic in which discourse structure (i.e., which rhetorical relations hold) is computed, keeping the latter simpler.

Representation of Content: FOL, *undecidable*.
Computation of Disc. Structure: Prop. Logic, *decidable*.

SDRT in a nutshell

- *SDRSs*: Extend DRT with rhetorical relations, which encapsulate additional content.
- Central notion: *coherence*. Utterances must be connected to context via rhetorical relations.
- Separate logic of content from logic in which discourse structure (i.e., which rhetorical relations hold) is computed, keeping the latter simpler.
- Technical ingredients:
  - underspecified logical forms
  - default logics

Ingredient: Underspecification

sentence (e.g. "Every man loves a woman.")

"There is a woman which every man loves."
∃(y, woman(y), ∀(x, man(x), loves(x,y))
LF
LF
∀(x, man(x), ∃(y, woman(y), loves(x,y))
"For every man there is a woman who he loves."

Ingredient: Underspecification

sentence
is generated by grammar
ULF
"describes" commonalities
∃(y, woman(y), ∀(x, man(x), loves(x,y))
LF
LF
∀(x, man(x), ∃(y, woman(y), loves(x,y))

"The formula contains two quantifiers, the relative scope of which however I don't know."

Ingredient: Underspecification

Max arrived in E'burgh. John met him at the platform.
platform(x) & B(y, x) & B=? & y=?

is generated by grammar
ULF
"describes" commonalities
...
LF
LF
...

"The formula refers to a platform, which is somehow bridged to an entity in the context, but I don't know how, and to which.

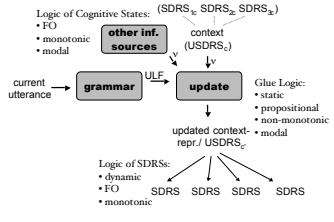
Ingredient: Underspecification

ULFs: partial descriptions of LFs, representing what's common between them, leaving out what differs.

ULFs: LFs with "holes" for discourse component to fill in.

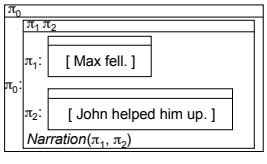
ULF → LF
∀(x, man(x), ∃(y, woman(y), loves(x,y))

Logics of Conversation



SDRT: Logic of Content

(5) Max fell.
John helped him up.



Some Meaning Postulates

content-level relations:

- Axiom on Narration:

$\phi_{Narration(\alpha,\beta)} \Rightarrow$ (a) $e_\alpha < e_\beta$ and
(b) things don't move location between the end of e_α and start of e_β

Max fell. John helped him up.

Some Meaning Postulates

content-level relations:

Max fell. John pushed him.

- Axiom on Explanation:

$\phi_{Explanation(\alpha,\beta)} \Rightarrow \neg(e_\alpha < e_\beta)$

$\phi_{Explanation(\alpha,\beta)} \Rightarrow (\text{event}(e_\alpha) \Rightarrow e_\beta < e_\alpha)$

Another Meaning Postulate

cognitive-level relations:

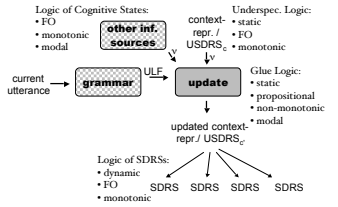
- Semantics of IQAP (indirect question-answer pair)

(a) $IQAP(\alpha,\beta) \Rightarrow K_\beta$

(b) K_β contains sufficient content such that when it is added to S(α)'s beliefs, he can nonmonotonically compute a direct answer to his question.

A: Can we meet next week?
B: I'm on holidays.

Logics of Conversation



SDRT: Construction

- which info is needed to infer rhet. rel.?
  - sometimes it's explicitly signalled:
    (11) Max fell.
    And then Peter kicked him.
  - most of the times it isn't, and we need WK, knowledge about cognitive states, goals etc.:
    (12) Max fell.
    Peter pushed him.

SDRT: Construction

- note: these are *default* guesses.

(16) Max took an aspirin.
He was sick.

(17) Max took an aspirin overdose.
He was sick.

Logic must be able to handle conflicting information.

SDRT: Construction

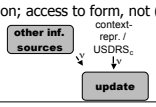
- another desideratum: logic must be decidable.

⇒ use *Common-sense Entailment* (Asher 1997; Morreau 1994), a non-monotonic propositional logic.

$A > B$ (If A, then normally B.)
"Birds normally fly."
"Tweety is a bird."
"Tweety is a penguin."

Glue logic: how is info accessed?

- Axiom schema for inferring rhet. rels:
  $(?(\alpha,\beta) \wedge [\textit{some info}..]) > R(\alpha,\beta)$
- Logic of content is a FOPL, glue logic is propositional. How does info get from content to glue logic?
  ⇒ transfer function; access to form, not (all) entailments.



Glue Logic: Some Axioms

- IQAP $?(\alpha,\beta) \wedge \alpha{:}? > \text{IQAP}(\alpha,\beta)$
- Q-Elab $?(\alpha,\beta) \wedge \beta :? > \text{Q-Elab}(\alpha,\beta)$
- QAP $?(\alpha,\beta) \wedge \alpha{:}? \wedge \textit{qap-sat}(\alpha,\beta) > \text{QAP}(\alpha,\beta)$
- Elab $?(\alpha,\beta) \wedge \textit{subtype}_D(\beta,\alpha) > \text{Elab}(\alpha,\beta)$
- Expl $?(\alpha,\beta) \wedge \textit{cause}_D(\beta,\alpha) > \text{Expl}(\alpha,\beta)$

Glue Logic: Some Axioms

- IQAP $?(\alpha,\beta) \wedge \alpha{:}? > \mathrm{IQAP}(\alpha,\beta)$

  Semantics of IQAP (indirect question-answer pair)

  (a) $IQAP(\alpha,\beta) \Rightarrow K_\beta$

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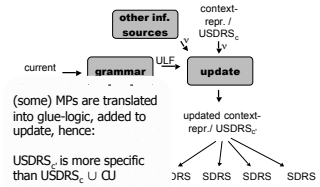
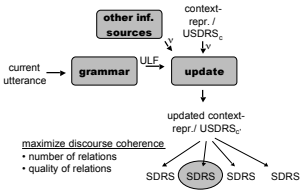


(some) MPs are translated into glue-logic, added to update, hence:

USDRS$_{c'}$ is more specific than USDRS$_c$ ∪ CU

Maximize discourse coherence



Resolving Underspec., Inf. Flow

$\mathrm{USDRS}_c + \mathrm{USDRS}_u = \mathrm{USDRS}_{c'}$

glue-logic

speech act → add. info that resolves underspec.

e.g. infer IQAP on basis of sentence moods; add consequences to SDRS.

Resolving Underspec., Inf. Flow

$\mathrm{USDRS}_c + \mathrm{USDRS}_u = \mathrm{USDRS}_{c'}$

… SDRS SDRS SDRS SDRS ...

glue-logic

speech act → add. info that resolves underspec.

maximize discourse coherence

resolution → allows inf. to speech act, making this SDRS preferred.

SDRT, summary

- *rhetorical relations* are essential to capture semantics of discourse;
- *update:* function from (ULF of) current utterance + context representation to updated (more specific) context representation.
- update is computed in *glue logic,* propositional default logic;
- two ways to resolve underspec (plug holes):
  - either added semantic consequences of rhetorical relation resolve underspec, or
  - certain resolution is preferred, because it maximises discourse coherence.

SDRT, summary

- all very nice, but will this ever work on real data?
- what kind of information is needed exactly?

Overview of talk

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    - Implementation
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  } context sensitivity of interpretation

  - RUDI-04: Clarification Requests
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What does RUDI do?

A: We should meet next week. ⌐ *Q-Elab*

B: How about Friday? ⌙ (= Friday next week)

- computes Bridging Inferences...
- ...via computing Discourse Structure

(RUDI = *R*esolving *U*nderspecification using *D*iscourse *I*nformation)

What does RUDI do?

A: We should meet next week. ┐ *Q-Elab*
B: How about Friday? ┘ (= Friday next week)

- computes Bridging Inferences…
- …via computing Discourse Structure
- is a proof-of-concept implementation of SDRT

Why scheduling dialogues?

- corpus available: VerbMobil
- grammar available: ERG
- nicely restricted domain:
  - simple goal: agree on a time
  - simple plan: zoom in on time
  - utterances are either about good or about bad times.
  - finite number of bridging relations, conventionalised.

Resolving underspecification

A: We should meet next week.
B: How about Friday?
day_of_week(x, Fri) ∧B(x,y) ∧ y=? ∧ B=?

`inferring Q-Elab` ?(α,β) ∧ β :? > Q-Elab(α,β)

`semantics of Q-Elab` β is a question s.t. all answers elaborate on plan to reach goal of α
⇒ temp_inc(t_α , t_β)

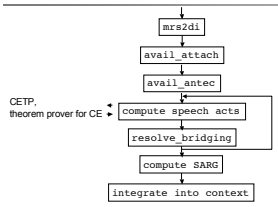
Inferring DS ⇒ Resolving US

Resolving underspecification

A: We should meet next week.
B: I'm busy from the 24th until the 3rd.
- rejection or elaboration?

Resolving US ⇒ Inferring DS

RUDI: Overview of Algorithm



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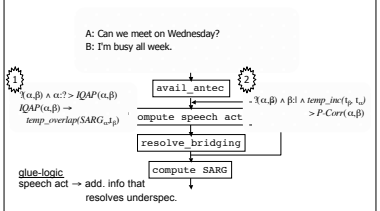

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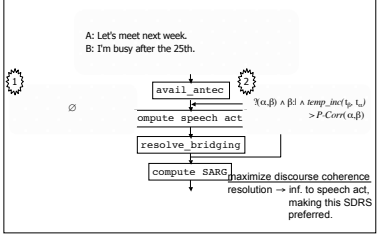

Discussion

RUDI:
- Clear way from syntax / compositional semantics to discourse structure.
- Discourse structure is used to resolve underspec.
- Framework for testing axioms.

"Evaluation":
- Used in semi-automatic annotation system: on VM-corpus, 44% of all decisions (for SAs) were correct.

But will this scale up?
- mechanism for resolving underspec. should transfer to other domains, but
- interface to reasoning about plans must be more complicated for almost all other domains.

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Phenomena - Fragments

- *Spontaneous spoken* language
  - syntax of utterances
  - disfluencies
- Context sensitive interpretation
  - anaphora;
  - fragments;
  - dialogue acts;
  - gestures;
- Interaction Management
  - turn taking;
  - initiative;
  - grounding

Fragments: utt. that are intentionally non-sentential, but convey *messages.*

A: Who came to the party?
B: Peter.

Phenomena - Fragments

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Fragments: utt. that are intentionally non-sentential, but convey *messages.*

A: Who came to the party?
B: Peter *(came to the party).*

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Fragments:

- frequent: around 10% in typical dialogue (Fernández & Ginzburg 2002, Schlangen 2003)
- not just answers, occur in all sorts of contexts

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Fragments, two kinds:

- *resolution via identity*:

A: On what day shall we meet?
B: On Monday (shall we meet).

- *resolution via inference:*

A: Peter has left already.
B: Exams.
(= Peter has left because he *has to take / supervise / mark / etc.* exams)

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Fragments, two kinds:

- *resolution via identity*:

A: Wem hat er geschmeichelt?
B: Dem Jungen. / *Den Jungen.

A: Wen hat er gelobt?
B: Den Jungen. / *Dem Jungen.

-> syntactic parallelism!

RUDI, fragments

- extended grammar with rules for fragments:
  phrases -> sentence w/ underspec. predicate
  ("Monday" -> $unknown(Monday)$)
- transfer some syntactic information to information state (so that syn.par. can be enforced)

RUDI, fragments

- *resolution via identity*:

A: On *what day* shall we meet?
B: On *Monday.*

`IQAP`	$?(\alpha,\beta) \wedge \alpha? > IQAP(\alpha,\beta)$
`Frag IQAP->QAP`	$IQAP(\alpha,\beta) \wedge frg(\beta) \rightarrow QAP(\alpha,\beta)$
`Frag-QAP-c->rvi`	$QAP(\alpha,\beta) \wedge aq(\alpha) \rightarrow res\text{-}v\text{-}id(\alpha,\beta)$

res-v-id/2 does lambda-abstraction & application of question to answer; also checks syn-par.

RUDI, fragments

- *resolution via inference:*

A: Let's meet next week.
B: OK. Friday? (= How about Friday next week?)

No changes needed! Temporal expression can be accessed in ULF (" $unknown(Friday)$ ").

All relevant semantic consequences follow from computing *Q-Elab in this domain.*

RUDI, fragments: summary

- resolve *res-via-id.* fragments via additional constraints on the rules for SAs;
- resolve res-via-inf. in domain specific way.

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Introduction

- RUDI:
  - "testbed" for theory of dialogue semantics and pragmatics, not practical system;
  - deep processing: "real" grammar, "real" LFs, "real" inference;
  - not a (full) dial sys!

  overhearer that tracks conversation and
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  - and asks for clarification, if it has problems understanding what it tracks.

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- Context sensitivity of interpretation: "dialogue means more than sum of parts"
  - hypothesis: *discourse structure* determines additional content.
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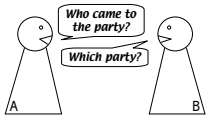
  - hypothesis: understanding problems occur on many levels, & are of different severity.
  - implementation: evaluate quality of interpretation hypothesis at all stages to decide whether repair is needed.

RUDI - Clarification Requests

RUDI - Clarification Requests

- indicate *understanding problem.*
- RUDI distinguishes two dimensions:
  - source of the problem
  - severity of the problem.



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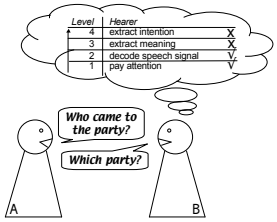

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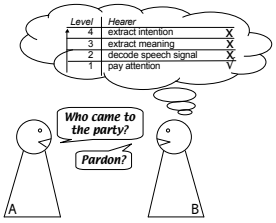

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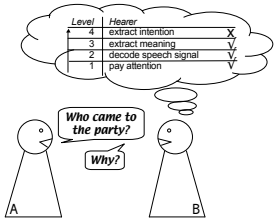
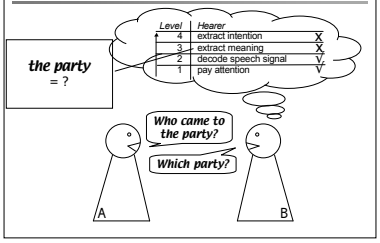


CR: severity



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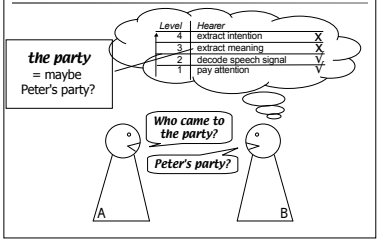
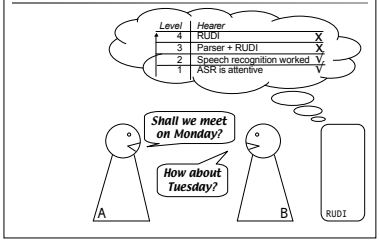
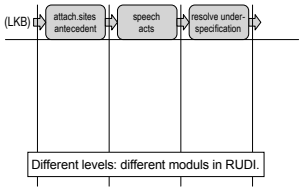


CR: severity, modelled in $RUDI_{clar}$



$RUDI_{clar}$



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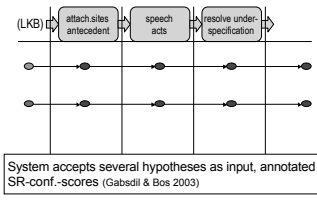

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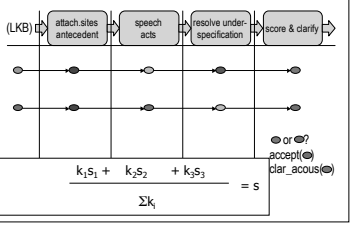
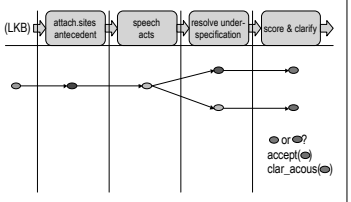


$RUDI_{clar}$



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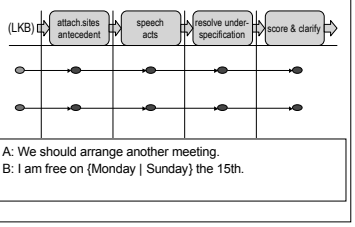

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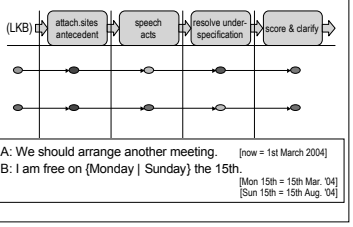

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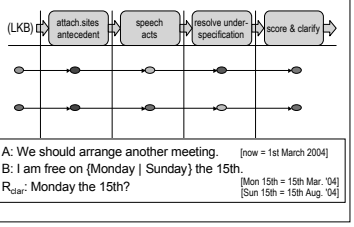

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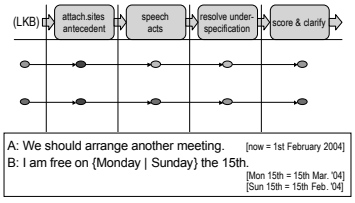

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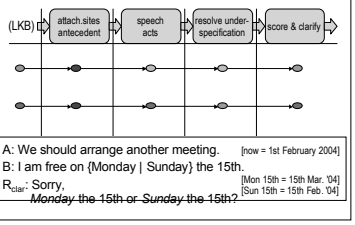

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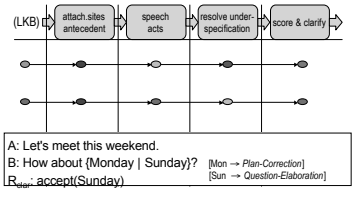

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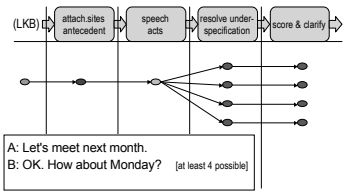

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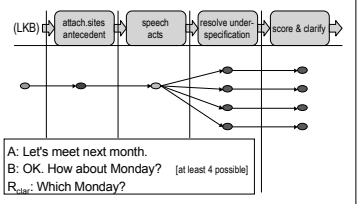

RUDI, clarification: summary

- Confidence scores on all levels.
- Distinguish:
  - domain-specific scoring rules ("prefer dates closer to now", "prefer times between 8am and 8pm", etc.)
  - discourse general sc. rules ("prefer direct SAs")
- Combine these scores to one overall value that determines CR behaviour.

RUDI, clarification: summary

- Further work:
  - learn weights for combination of scores?
  - test whether "disc. general" rules are indeed disc. general.

Overview of talk

- RUDI
  - RUDI-01: Bridging Relations
    - Phenomenon
    - SDRT
    - Implementation
  - RUDI-02: Fragments
    - Phenomenon
    - Implementation

  } context sensitivity of interpretation

  - RUDI-04: Clarification Requests
    - Phenomenon
    - Implementation

  } interaction management

- Information-State Update Framework
- Summary

RUDI, summary

- RUDI:
  - not practical system, "testbed" for theory.
    - tested model of context sens. interpretation;
    - tested model of clarification
  - deep processing: "real" grammar, "real" LFs, "real" inference
  - future work:
    - other context sens. phenomena, eg. presupp.
    - misunderstandings
    - make more robust, combine w/ stochastic model

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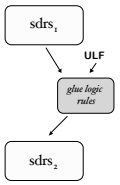
Information State Update, intro

- Schematic view of update process in RUDI:



Information State Update, intro

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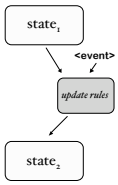
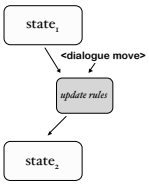


- Developed within the EU-project "Trindi" (Larsson 2003; Traum and Larsson 2004), integrating ideas from many previous projects.
- Not an approach *per se:* more an abstraction that allows different approaches to be compared, a *framework*.

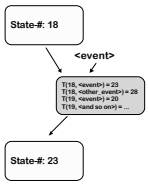
Information State Update, intro

- More formally, an ISU-theory consists of:
  - A formal representation of the ***Information State.***
  - A set of ***Dialogue Moves*** that trigger updates.
  - A set of ***Update Rules*** that determine how observed moves change IS, or how changes in IS license moves to make.



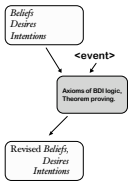
Information State Update, intro

- Is general enough to encode SD-style approaches:



Information State Update, intro

- ... or BDI approach:



Information State Update, intro

Why formulate your theory in this framework?

Best practice: allows

- models to be compared (common terminology);
- modules to be shared.

Information State Update, other

- systems that have been implemented in this framework:
  - GODIS (Larsson 2002). Uses QUD-stack to structure dialogue.
  - MIDAS (Bos 2000). Uses DRTs as part of IS. Theorem provers for updates.
  - EDIS (Mattheson, Poesio, Traum 2000). Focus on grounding and obligations.
  - RUDI (not actually in TRINDI-kit, but similar in spirit)

Summary

- SDRT
  - *Coherence:* information in discourse must be connected via rhetorical relations. Explains how discourse means more than indiv. utterances.
  - Computing DS can be done in simpler logic than needed for representing content.
- RUDI: implementation of SDRT for small domain. Also model of Clarification.
- ISU: common terminology for Dialogue Models.

The end

Thank you!

`http://www.ling.uni-potsdam.de/~das`

Speech acts / Rhet. Rels in RUDI

- *Q-Elab*(α,β)
  - β is a question; any possible answer elaborates a plan for achieving a SARG of α

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- *IQAP*(α,β)
  - ?(α,β) ∧ α:? > *IQAP*(α,β)
  - questioner can infer direct answer to α from β: *IQAP*(α,β) → *temp_overlap*($SARG_\alpha$,t_β)

Speech acts / Rhet. Rels in RUDI

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A: We should meet next week.
B: I'm busy from the 24th until the 3rd.

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A: We should meet next week.
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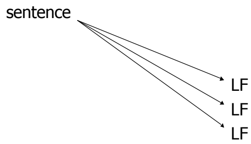
Related Work - Hobbs et al.

- Hobbs et al. (1993)
  "Interpretation as Abduction"
  disc. interpr. as search for (cheapest) proof,
  - also coherence-driven,
  - but non-modular:
    - logic for interpreting content is same as that for composing LF of discourse
    - always uses common-sense reasoning, even for anaphora etc. (⇒ not informed by dyn. sem.)
  - weights are extra-logical machinery

Detour: Underspecification



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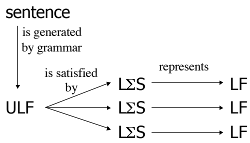

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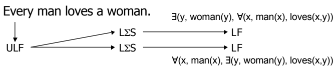

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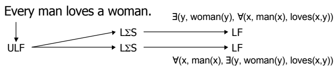

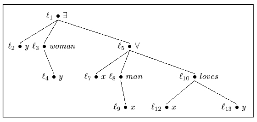

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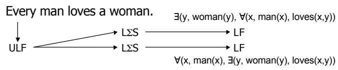

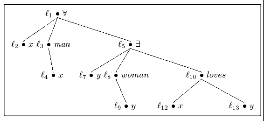

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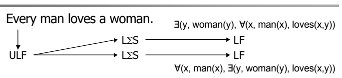

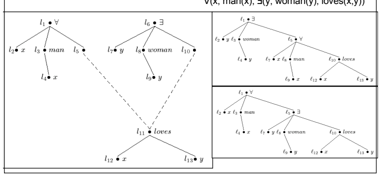

CE: Inference Patterns

A > B means "If A then normally B"

<u>Closure on the right</u>:

A > B, B → C ⊢ A > C

Lions normally walk.
Things that walk have legs.
___
Lions normally have legs.

CE: Inference Patterns

<u>Defeasible Modus Ponens</u>:

A > B, A |~ B

If Tweety is a bird, then normally Tweety flies
Tweety is a bird
___
Tweety flies

A, A>B, ¬B |≁ B

If Tweety is a bird, then normally Tweety flies
Tweety is a bird
Tweety does not fly
___
*Tweety flies

CE: Inference Patterns

Knowledge Conflict:

Penguin Principle:

C→A,
A>B,
C>¬B, C⊢¬B

If Tweety is a penguin, then Tweety is a bird.
If Tweety is a bird, then normally Tweety flies.
If Tweety is a penguin, then normally Tweety doesn't fly
Tweety is a penguin.
Tweety doesn't fly.

Nixon Diamond:

A>B, C>¬B, A, C⊬B (or ¬B)

If Nixon is a Quaker, then normally he's a pacifist.
If Nixon is a Republican, then normally he's non-pacifist.
Nixon is a Quaker.
Nixon is a Republican.
?

Glue logic: how is info accessed?

- Axiom schema for inferring rhet. rels:
  $(?(\alpha,\beta,\lambda) \wedge [\textit{some info}..]) > R(\alpha,\beta,\lambda)$
- Logic of content is a FOPL, glue logic is propositional. How does info get from content to glue logic?
  ⇒ transfer function; access to form, not (all) entailments.

Glue Logic: Transfer Function

π_1: Max fell.
π_2: John pushed him.

$[\textit{fall}(e, m)](\pi_1)$
$[\textit{push}(e_2, j, m)](\pi_2)$

Glue Logic: Transfer Function

π_1: Max fell.
π_2: John pushed him.

$[\textit{fall}(e, m)](\pi_1)$
$[\textit{push}(e_2, j, m)](\pi_2)$

$[\textit{fall}(e_\alpha, y)](\alpha) \wedge [\textit{push}(e_\beta, x)](\beta) \rightarrow \textit{cause}_D(\beta, \alpha)$
$(?(\alpha, \beta) \wedge \textit{cause}_D(\beta, \alpha)) > \textit{Explanation}(\alpha, \beta)$