Modelling and Managing Dialogue

Approaches and Challenges

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Introduction

- **A dialogue models / systems**:
- RUDI, implementation of theory of dialogue semantics / pragmatics (SDRT)
  [joint work with Alex Lascarides (Edinburgh), Ann Copestake (Stanford / Cambridge)]
- PotBot, a tourism information system
  [joint work with Manfred Stede (Potsdam)]

Introduction

- Information State Update: a common framework for formalising and implementing dialogue models.
  - Very general, so can be used for models of widely differing complexity (from FSM to BDI).
  - Good for *comparing* models.
  - Good for *testing* variations.
  - Good for re-using or sharing components.

Overview of talk

- Phenomena / Analysis ("Challenges"):
  - Context sensitive interpretation
  - Interaction Management
- Models ("Approaches"):
  - structured dialogue approaches
  - plan-based approaches
  - information state update-based approaches
- Summary

Part I - Phenomena

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

Phenomena - Context Sensitivity

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Dialogue means more than the sum of its parts.

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A: Let's meet next week.
B: I'm busy after the 24th.

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October 2003

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5	6	7	8	9	10	11
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-> utterances must be interpreted in context!

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Dialogue means more than the sum of its parts.

A: Is this interesting?
B: Yes, very.

A: Is this boring?
B: Yes, very.

-> utterances must be interpreted in context!

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Dialogue means more than the sum of its parts.

A: Did Peter come?
B: He was there, briefly.

A: Is this Peter's car?
B: Hm. The doors look weird.

-> utterances must be interpreted in context!

Phenomena - Anaphora

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Anaphora as one device for achieving *cohesion*:

A: Did Peter come?
B: He was there, briefly.

A: Is this Peter's car?
B: Hm. The doors look weird.

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Anaphora as one device for achieving *cohesion*:

Bridging relations (Clark 1977)

A: Is this Peter's car?
B: Hm. The doors look weird.

Phenomena - Anaphora

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Anaphora as one device for achieving *cohesion*:

Bridging relations (Clark 1977)

A: Let's meet next week.
B: I'm busy after the 15th.

(RUDI resolves such relations in dialogues from this domain.)

Phenomena - Fragments

- *Spontaneous spoken* languag
  - syntax of utterances
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Fragments: utt. that are intentionally non-sentential, but convey *messages.*

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

(RUDI resolves such fragments in dialogues from that domain.)

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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)*.

(RUDI resolves such fragments in dialogues from appointment domain.)

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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!

Phenomena - Dialogue Acts

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Dialogue Acts: what is the function of the utt.?

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Dialogue Acts: what is the function of the utt.?

- depends on context.

A: Let's meet next week.
B: I'm busy after the 24th.
(Plan correction or plan elaboration?)

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Dialogue Acts: what is the function of the utt.?

- not just one function; several "layers"

answer

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

Phenomena - Dialogue Acts

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Dialogue Acts: what is the function of the utt.?

- not just one function; several "layers"

answer

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

understood

Phenomena - Interact. Manag.

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Autonomous agents have to coordinate their actions to reach common goal (to have a dialogue).

Phenomena - Grounding

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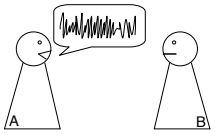
Grounding: ensuring that all participants mutually believe they have understood *what was said*. (Clark and Schaefer 1987; Clark 1996)

Grounding



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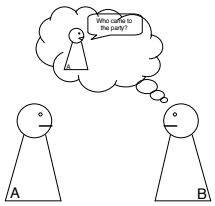

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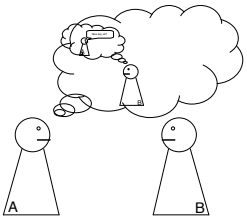

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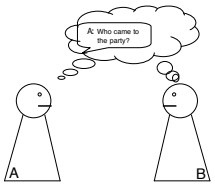

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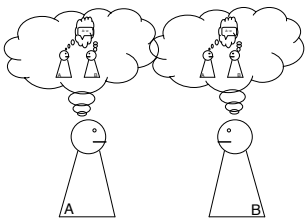

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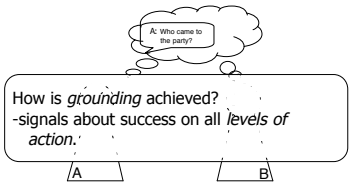
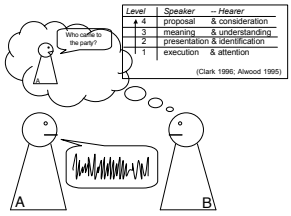


Grounding - Levels of action



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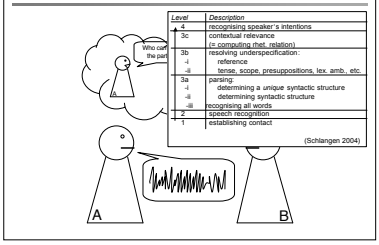

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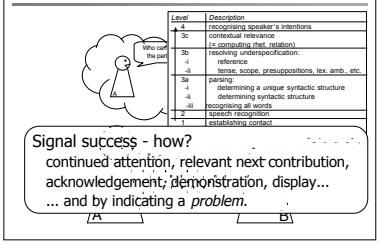
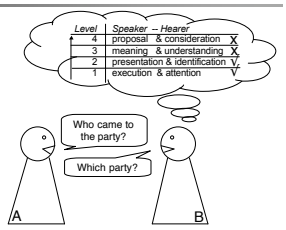


Grounding - Clarification Requests

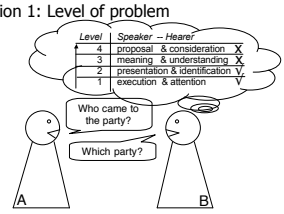


Grounding - Clarification Requests

- frequent: around 5% of utterances in task-oriented dialogues
  (Purver et al. 2001, Rodríguez & Schlangen 2004)
- multi-dimensional classification of problems leading to CRs, from (Schlangen 2004):
  - Level of problem
  - Extent
  - Severity

Clarification Requests

Dimension 1: Level of problem



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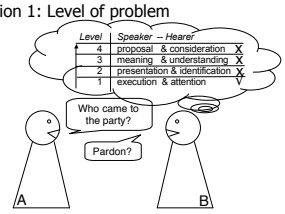

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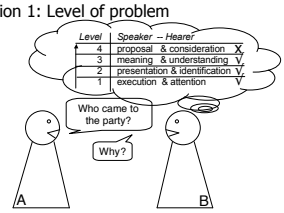
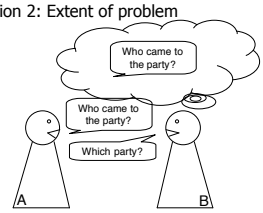


Clarification Requests

Dimension 2: Extent of problem



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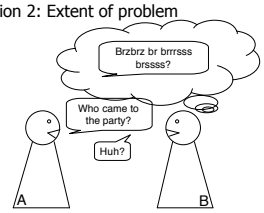
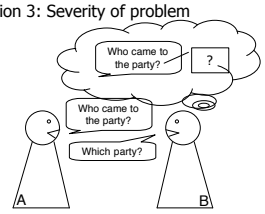


Clarification Requests

Dimension 3: Severity of problem



Clarification Requests

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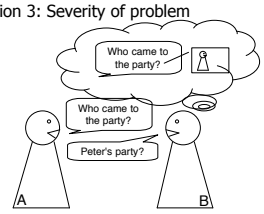


CR analysis: Dimension "Level"

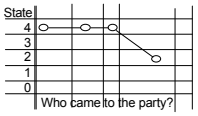
- Clark's model, + theory-specific additions:

Level	Description
4	recognising speaker's intentions
3c	contextual relevance (+ computing rhet. relation)
3b -i -ii	resolving underspecification: reference tense, scope, presuppositions, lex. amb., etc.
3a -i -ii -iii	parsing: determining a *unique* syntactic structure determining syntactic structure recognising all words
2	speech recognition
1	establishing contact

(Schlangen 2004)

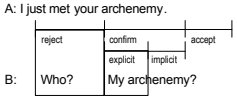
CR analysis: Dimension "Extent"

- e.g. "which party?" vs. "huh?"
- (Clark & Schaefer 1987):



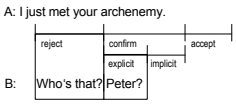
CR analysis: Dimension "Severity"

- is hypothesis maintained or not?
  ("Peter?" vs. "Who?")
- *quality* of hypothesis / confidence in it
- … old news to people working on SDS: confidence score of speech recognition



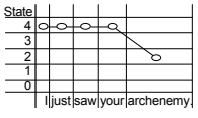
CR analysis: Dimension "Severity"

- *quality* of hypothesis / confidence in it needed at *all* levels of processing!
  E.g. reference resolution:



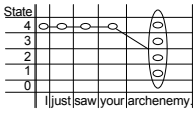
CR analysis: Interdependencies

- not always in discrete state..



Interdependencies

- snowballing: wrong hypothesis at one level will lead to dubious hyps. at higher levels.



Grounding - Summary

- DPs must reach mutual understanding about what was said / meant (to a degree sufficient for current purposes).
- This means they are obliged to indicate problems (& obliged to help to repair them)
- 3 Aspects:
  - Level of understanding at which problem occured
  - Extent of the problem
  - Severity of the problem

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Part II - Models

- Phenomena ("Challenges"):
  - Context sensitive interpretation
  - Interaction Management
- Models ("Approaches"):
  - structured dialogue approaches
  - plan-based approaches
  - information state update-based approaches
- Summary

Part II - Models

- Criteria for comparison;
  - How well do models handle phenomena?
  - How do they decide what to say next?
- Models ("Approaches"):
  - structured dialogue approaches
  - plan-based approaches
  - information state update-based approaches
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Structured dialogue approaches

- Example: booking a flight

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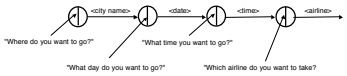

pro:
- good for ASR: no surprises
- easy to build (initially)

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cons:
- very inflexible, order is fixed, no overansw.

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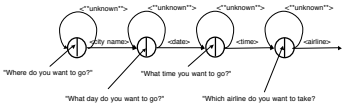
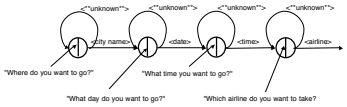


pro:
- good for ASR: no surprises
- easy to build (initially)

cons:
- very inflexible, order is fixed, no overansw.
- everything must be explicit (turn-taking, grounding, context sens., etc.)

Structured dialogue approaches

- Example: booking a flight



pro:
- good for ASR: no surprises
- easy to build (initially)

cons:
- very inflexible, order is fixed, no overansw.
- everything must be explicit (turn-taking, grounding, context sens., etc.)
- can become huge (banking sys: 1,500 states)

Structured dialogue approaches

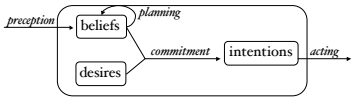
- various ways to make them more flexible:
  - forms, agendas, dialogue games...
  - .. topic structures (Stede & Schlangen 2004).
- but difficult to integrate principled accounts of dialogue management;
- difficult to separate domain knowledge from discourse knowledge;
- designer must have detailed advanced knowledge about the dialogue that is to be expected, and hence...
- ... suitable only for dialogues of limited complexity;
- unappealing as model of human dialogue behaviour.

Part II - Models

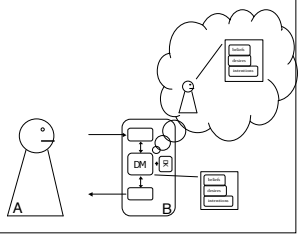
- Phenomena ("Challenges"):
  - Context sensitive interpretation
  - Interaction Management
- Models ("Approaches"):
  - structured dialogue approaches
  - plan-based approaches
  - information state update-based approaches
- Summary

Plan-based approaches

- History: developed out of AI theories of speech acts that integrated speech acts into reasoning about plans. (Cohen, Perreault, Allen 1980s)
- Take notion of *agent* seriously: model interpretation and deliberation with logics of *Beliefs, Desires, Intentions* (BDI)

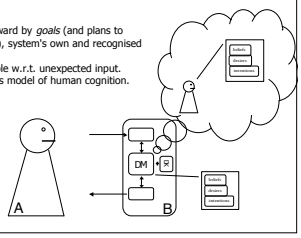


Plan-based approaches



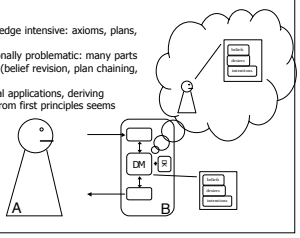
Plan-based approaches

Properties:
- Driven forward by *goals* (and plans to reach them), system's own and recognised from user
- More flexible w.r.t. unexpected input.
- Plausible as model of human cognition.



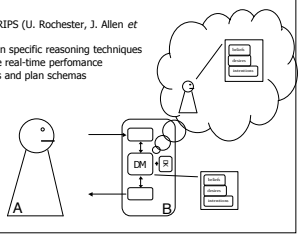
Plan-based approaches

Problems:
- Very knowledge intensive: axioms, plans, schemas
- Computationally problematic: many parts intracktable (belief revision, plan chaining, ...)
- For practical applications, deriving everything from first principles seems overkill.



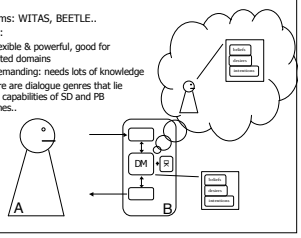
Plan-based approaches

TRAINS / TRIPS (U. Rochester, J. Allen *et al.*):
- use domain specific reasoning techniques to achieve real-time perfomance
- use scripts and plan schemas



Plan-based approaches, summary

Other systems: WITAS, BEETLE..
Conclusions:
- Very flexible & powerful, good for complicated domains
- Very demanding: needs lots of knowledge
- ... There are dialogue genres that lie between capabilities of SD and PB approaches..



Part II - Models

- Phenomena ("Challenges"):
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- Summary

Information State Update, intro

- 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

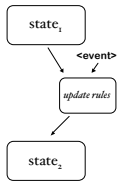
- Starting observation:
  All dialogue models have
  - a notion of the state the dialogue is in at a given point (that can include the dialogue history, the states of the DPs, etc.);
  - a notion of how the dialogue progresses from one state to the next (e.g., which events drive it forward, what are the conditions for which changes, etc.).

Information State Update, intro

- More formally, an ISU-theory consists of:
  - A formal representation of the ***Information State****;* i.e. a specification of its components (BDI, or common ground, or QUD..);
  - A set of ***Dialogue Moves*** that trigger updates (on any level of abstraction: surface moves, logical forms, speech acts);
  - A set of ***Update Rules*** that determine how observed moves change IS, or how changes in IS license moves to make. Rules inspect (parts of the) IS.

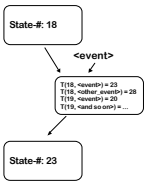
Information State Update, intro

- Schematic view of update process:



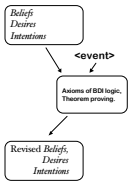
Information State Update, intro

- Is general enough to encode SD-style approaches:



Information State Update, intro

- ... or BDI approach:
- IS is not finite, unlike state in SD approaches!



Information State Update, GODIS

- Example system: GODIS (Larsson 2002), travel booking system
- IS:

PRIVATE : AGENDA : OpenQueue(Action)
PLAN : stack(Action)
BEL : set(Prop)

SHARED : COM : set(Prop)
QUD : stack(Question)
LU: SPEAKER: Speaker
MOVES: OQueue(Move)

(based on Ginzburg's (1998) *Questions Under Discussion* approach)

Information State Update, GODIS

- Example dialogue plan in GODIS:
  - **findout(?x.transport(x))**
  - **findout(?x.dest-city(x))**
  - **findout(?x.depart-city(x))**
  - ....
  - **consultDB(?x.price(x))**
- update rules match these elementary actions to dialogue moves

Information State Update, GODIS

- Example update rule:
  - IntegrateAnswer
    "if the latest move was an assertion from the user that can be understood as a relevant answer to a question under discussion, then combine question and answer to a proposition, which is added to the common ground."

pre: { in($/SHARED/LU/MOVES, answer(A))
fst($/SHARED/QUD, Q)
$DOMAIN:relevant(A, Q)

eff: { ! DOMAIN: combine(Q, A, P)
add(/SHARED/COM, P)

- update rules use simple functions and relations that work on IS fields

Information State Update, GODIS

- Example mini-dialogue:

U: "price information please"
raises price issue:
- if user asks Q, push respond(Q) on AGENDA
- if respond(Q) on AGENDA and PLAN empty, find plan for Q and load to PLAN
- if findout(Q) first on PLAN, ask Q

S: "where do you want to go?"

U: "Paris"
- if LM=answer(A) and A **about** Q, add P=Q[A] to SHARED.COM
- if P in SHARED.COM and Q topmost on QUD and P **resolves** Q, pop QUD
- if P in SHARED.COM and P **fulfils goal** of findout(Q) and findout(Q) on PLAN, pop PLAN

Information State Update, GODIS

- So far, nothing that form-filling couldn't handle...
- ... but note clear separation of domain knowledge (plans) and conversational knowledge (update rules).
- GODIS adds principled way of dealing with grounding. (On dimension 1, level of action.)

GODIS vs. RUDI

- GODIS:
  - practical dialogue system (connected to ASR & synthesis)
  - shallow processing (keyword spotting), simplified semantics
  - (fairly) robust
  - grounding: only level of action
- RUDI:
  - not practical system, "testbed" for theory of dialogue semantics and pragmatics
  - deep processing: "real" grammar, "real" LFs, "real" inference
  - detailed model of grounding
  - not very robust...

RUDI, intro

- not a (full) dial sys!
  overhearer that tracks conversation and
  - resolves bridging relations on temporal expressions... (Schlangen, Lascarides and Copestake 2001)
    A: Let's meet next week.
    B: How about Monday? RUDI: Monday of next week.
  - ... and fragments (Schlangen and Lascarides 2002)
    A: On what day shall we meet?
    B: On Monday. RUDI: *We shall meet* on Monday.
  - and asks for clarification, if necessary (Schlangen 2004)
    A: Let's meet this weekend.
    B: How about 4 pm? RUDI: 4pm on Sat or Sun?

RUDI, intro

- works in domain of scheduling dialogues:
  - corpus available (VerbMobil)
  - grammar available (Stanford ERG, large scale HPSG)
  - 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.

RUDI, SDRT

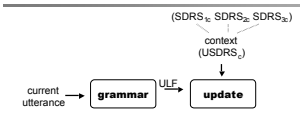
- is a (partial) implementation of SDRT (Asher 1993, Asher & Lascarides 2003)
  - dynamic semantics + (AI-style) pragmatics
  - DRT + *rhetorical relations* (Hobbs 1985, Mann & Thompson 1987)
  - computes *pragmatically preferred interpretation of discourse*
  - central notion: *coherence*

RUDI, SDRT

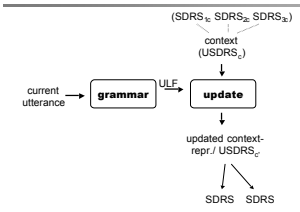
- Main principles:
  - separate *logic of content* from *logic of information packaging.* (diff. to Hobbs abduction)
  - when computing coherence of discourse, always use "cheapest" information available: from syntax, lexical semx, semx, to WK & cognitive states.

Logics of Conversation

Logics of Conversation



Logics of Conversation



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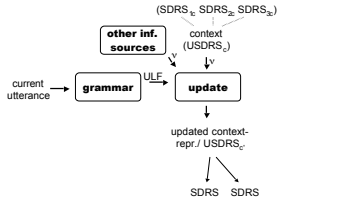

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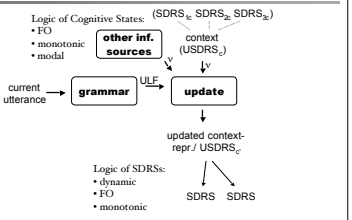

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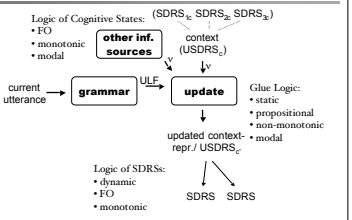

RUDI, SDRT

- Main principles:
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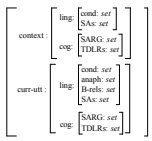
  - when computing coherence of discourse, always use "cheapest" information available: from syntax, lexical semx, semx, to WK & cognitive states.

RUDI, SDRT

- RUDI: *resolving underspecification using discourse information*
- Main hypothesis: resolving underspecification is a by-product of establishing *discourse coherence* (= computing rhetorical relations)

RUDI, information state

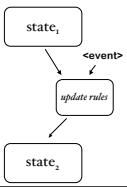
- RUDI's information state:



- dialogue moves: surface speech acts (proposition, question, request), Logical Forms (underspecified).

RUDI, overview

- RUDI computes *update* in several stages:



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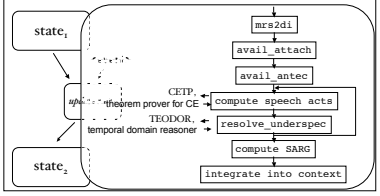
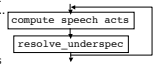


RUDI, 2 ways of resolving US

- RUDI resolves underspecification by...
  - first trying to infer rhetorical relation, and using semantic constraints on the relation to resolve underspecification...
  - ... if that fails, RUDI "guesses" resolution (i.e., compute specification of ULF), then infers relation using this additional information.



→ Information can flow in both directions..

2 ways of resolving underspec.

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

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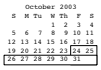
Inferring DS ⇒ Resolving US

2 ways of resolving underspec.

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



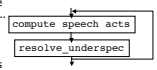
2 ways of resolving underspec.

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

We need to know how interval "24th -- 3rd" relates to "next week" before deciding for Plan-Elab or Plan-Corr...
---> Resolving US ⇒ Inferring DS

RUDI, 2 ways of resolving US

- RUDI resolves underspecification by...
  - first trying to infer rhetorical relation, and using semantic constraints on the relation to resolve underspecification...
  - ... if that fails, RUDI "guesses" resolution (i.e., compute specification of ULF), then infers relation using this additional information.



→ Information can flow in both directions..

Speech acts / Rhet. Rels in RUDI

4 main relations / dialogue acts, from SDRT:

- *Q-Elab*(α,β)
  - β is a question; any possible answer elaborates a plan for achieving a SARG of α
- *IQAP*(α,β)
  - α is a question; questioner can infer direct answer from β
- *Plan-Correction*(α,β)
  - β is proposition; speaker of β rejects a SARG of α
- *Plan-Elaboration*(α,β)
  - β is proposition; elaborates plan to achieve SARG of α

Speech acts / Rhet. Rels in RUDI

Semantics & inf. rules parametrised for domain:

- *Q-Elab*(α,β)
  - Infer Q-Elab: $?(\alpha,\beta) \wedge \beta{:}? > Q\text{-}Elab(\alpha,\beta)$
  - Sem. Conseq.: all answers elaborate plan for achieving SARG of α: $Q\text{-}Elab(\alpha,\beta) \rightarrow temp\_include(SARG_\alpha, t_\beta)$
- *Plan-Correction*(α,β)
  - Sem. Conseq.: β is proposition; speaker of β rejects a SARG of α
  - Infer Q-Elab: $?(\alpha,\beta) \wedge \beta{:}! \wedge temp\_include(t_\beta, SARG_\alpha) > P\text{-}Corr(\alpha,\beta)$

RUDI, summary bridging relations

- 2 ways to resolve bridging rels:
  - either you can infer SA directly, and then use semx. of SA to infer BRs [the cheap way], or...
  - ... you need to "guess" BRs and then infer SAs [the less cheap way]
- ... next: fragments.

RUDI, fragments

- Two kinds of fragments:
  - *resolution via identity*: syntactic parallelism
    A: On *what day* shall we meet?
    B: On *Monday* (shall we meet).
  - *resolution via inference:* no parallelism
    A: Let's meet next week.
    B: OK. Friday? (= How about Friday next week?)

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

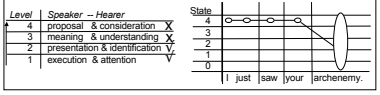
- resolve *res-via-id.* fragments via additional constraints on the rules for SAs;
- resolve res-via-inf. in domain specific way.

RUDI, summary

- Contextual aspects of interpretation:
  - bridging relations, resolving temporal expressions...
  - fragments.
- Next: when RUDI has problems...

Clarification Requests revisited

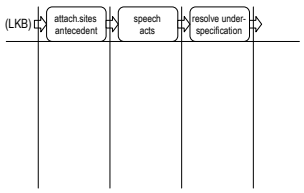
Dimension 1: Level of problem
Dimension 2: Extent of problem
Dimension 3: Severity of problem



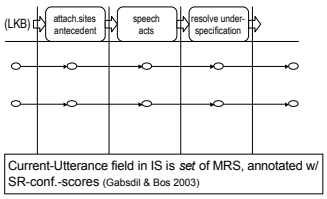
Interdependencies

- SR confidence + NLU features:
  (Duff, Gates & LuperFoy 1996), (Walker, Wright & Langkilde 2000), (Gabsdil 2004)
- generalised to other levels:
  (Paek & Horvitz 1999)
- these approaches: probabilistic. RUDI is symbolic; combines w/ principled semantics.

RUDI$_{clar}$

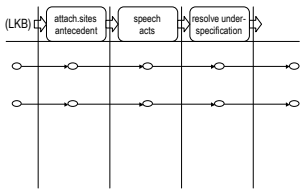


RUDI$_{clar}$



Current-Utterance field in IS is *set* of MRS, annotated w/ SR-conf.-scores (Gabsdil & Bos 2003)

RUDI$_{clar}$



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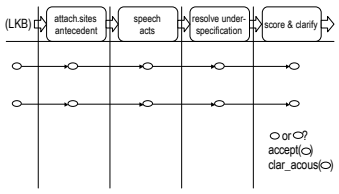

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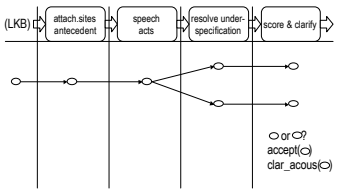
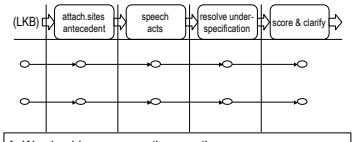
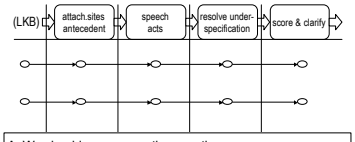


RUDI$_{clar}$



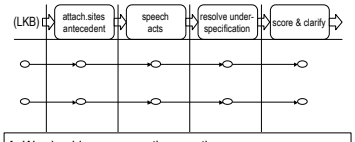
A: We should arrange another meeting.
B: I am free on {Monday | Sunday} the 15th.

RUDI$_{clar}$



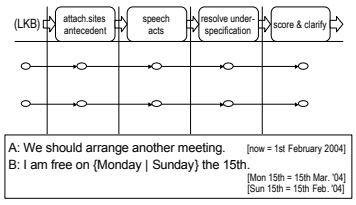
A: We should arrange another meeting. [now = 1st March 2004]
B: I am free on {Monday | Sunday} the 15th.
[Mon 15th = 15th Mar. '04]
[Sun 15th = 15th Aug. '04]

RUDI$_{clar}$

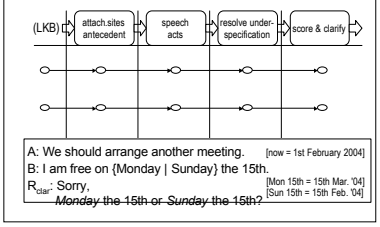


A: We should arrange another meeting. [now = 1st March 2004]
B: I am free on {Monday | Sunday} the 15th.
R_{clar}: Monday the 15th?
[Mon 15th = 15th Mar. '04]
[Sun 15th = 15th Aug. '04]

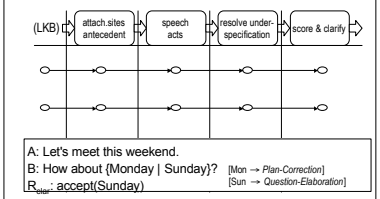
RUDI$_{clar}$



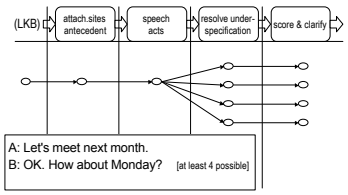
RUDI$_{clar}$



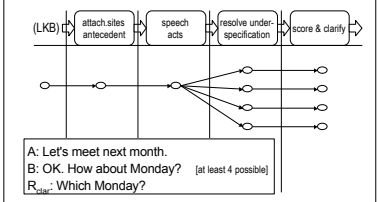
RUDI$_{clar}$



RUDI$_{clar}$



RUDI$_{clar}$



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, summary

- RUDI:
  - not practical system, "testbed" for theory of dialogue semantics and pragmatics
    - test theory
    - improve practical systems?
  - deep processing: "real" grammar, "real" LFs, "real" inference
  - use different logics: "simple" logic to compute discourse structure, "heavy" logic to represent content.
  - detailed model of grounding
  - not very robust...

ISU, summary

- Information State Update framework is flexible enough to allow many different approaches to be encoded...
- ... and compared.
- Allows degrees of flexibility between SD and PB.

Summary

- Phenomena ("Challenges"):
  - Context sensitive interpretation
  - Interaction Management
- Models ("Approaches"):
  - structured dialogue approaches
  - plan-based approaches
  - information state update-based approaches
- Summary

The end

Thank you!

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