Language Technology 2:
Natural Language(-based) Interaction

www.coli.uni-saarland.de/courses/late2-08

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dialogue modelling

(slides based on Ivana Kruijff-Korbayova's)

outline

- dialogue management
- dialogue models
  - state machines
  - frames
  - more flexibility?...
  - in grounding and verification
    - inititative and cooperation...
      - → information state update
- current challenges

dialogue management

dialogue flow control

dialogue modeling → dialogue context, dialogue moves

error handling

initiative and cooperation

adaptivity

…

dialogue flow control

when to say something,

when to stop

$\Rightarrow$ turn taking

turn taking

dialogue participants take turns (like in a game): A, B, A, B

dialogue turn: a continuous “contribution” to the dialogue by one speaker

turn passing at TRPs

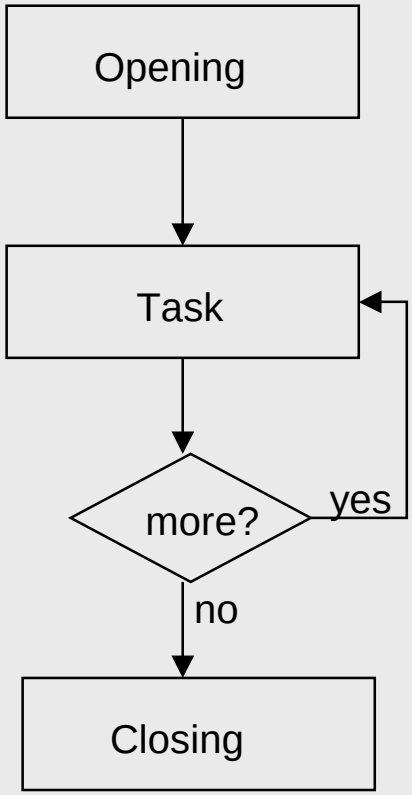
turn taking in human-machine dialogue

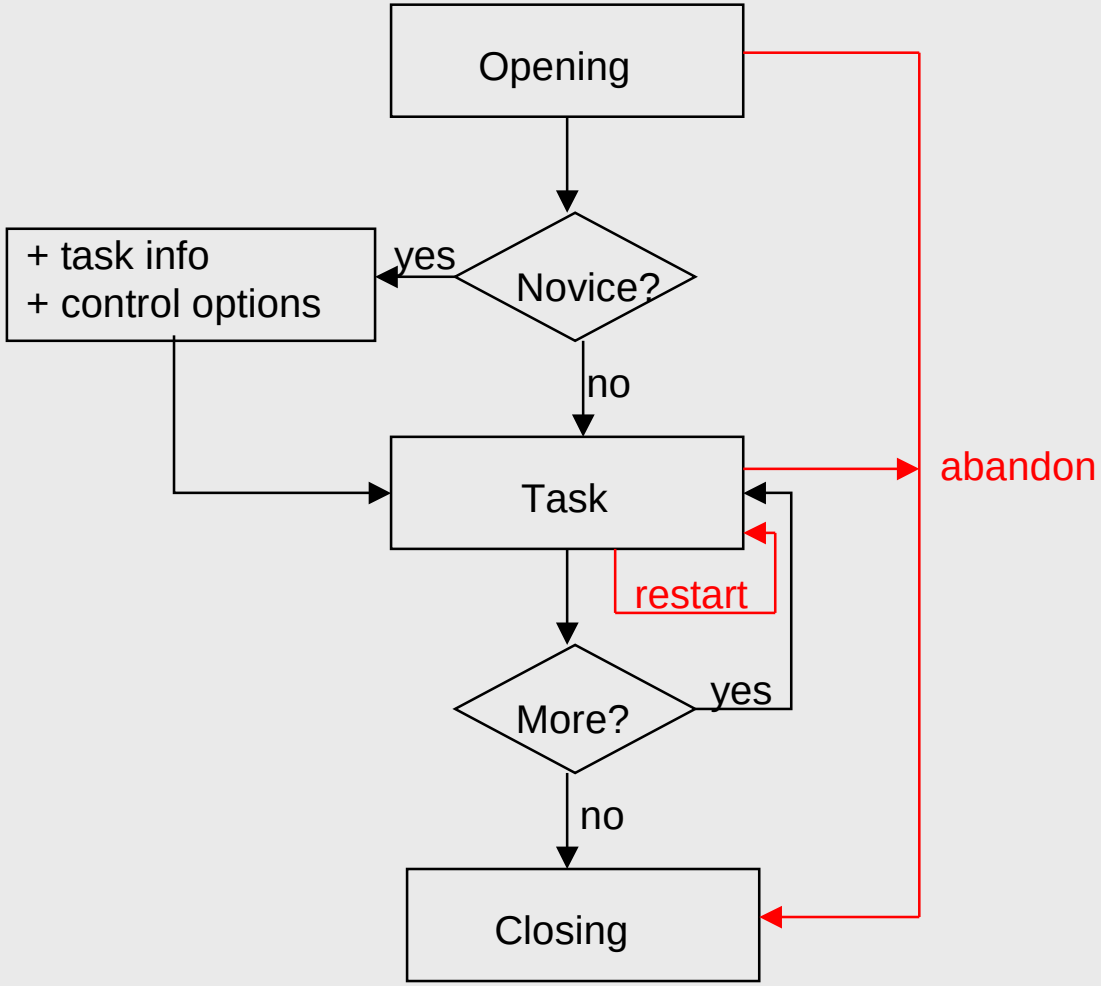
- rigid: strict separation of system/user turns
  - how to determine the end of user's turn? (Is s/he finished?)
  - how long to wait for user's turn? (Is the user still engaged? Did s/he hear?)
  - avoid user's speaking too early by explicit turn-taking signals
- flexible, with barge-in
  - user barge-in: system stops speaking when it detects input
    - Open-mic: system listening all-the-time
      - Problems: talk vs. noise; system's own talk is also "noise"
    - Push-to-talk: user pushes a button to open the mic (take a turn)
      - Problem: What has actually been conveyed to the user? What is the resulting common ground between the system and the user?
        E.g., list with several options, complex info --> reference resolution
  - system barge-in: When appropriate at all? When is a TRP?

dialogue modeling

where we are
&
what to say next

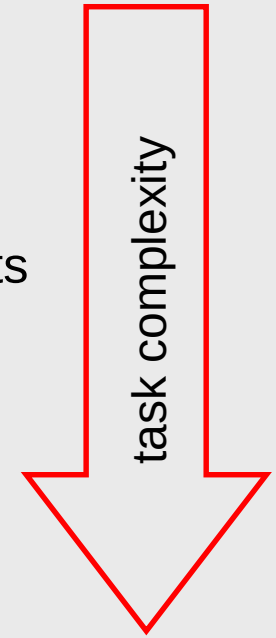
global structure





dialogue models

- script-based: finite automata
  - sequence of pre-defined steps (dialogue script)
- frame-based (also: form-filling)
  - set of slots to be filled (task template) and corresponding prompts
- Information-State Update
  - declarative rules for updating dialogue context



script-based models: state machines

finite automata

- automaton describes all possible dialogues
- set of states and transitions
  - state determines system utterance
  - user utterance determines transition to next state (deterministic)
- no recursion (= no nested subdialogues)
- fixed dialogue script
- system-driven interaction

finite automata

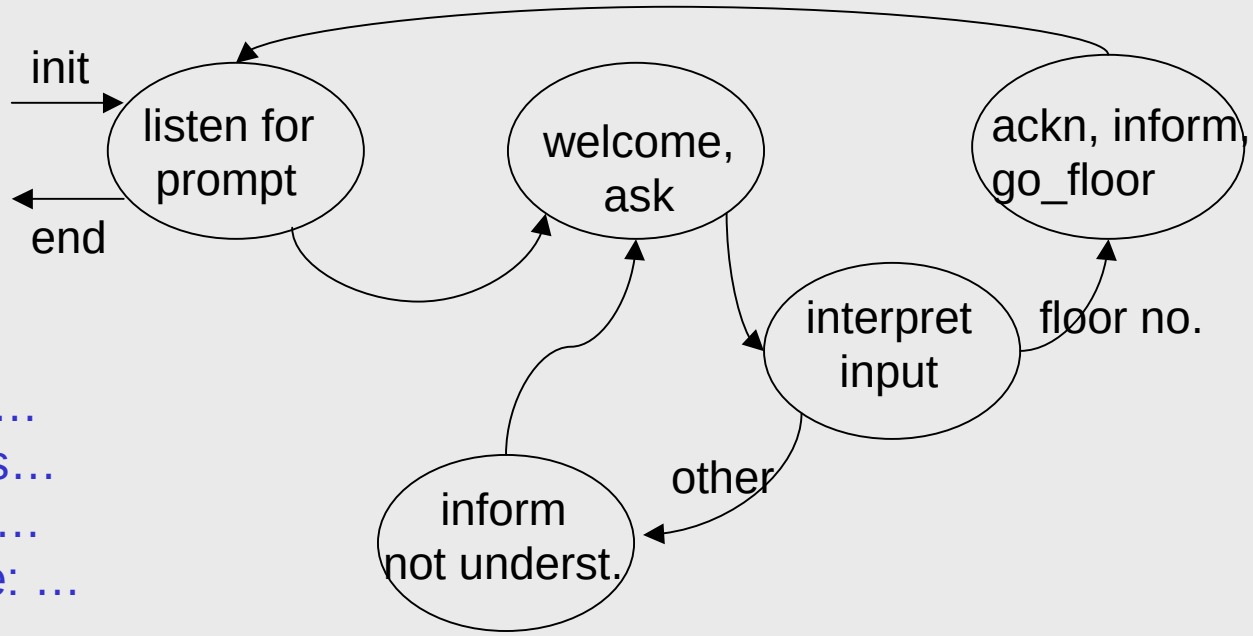
$<Q_{\text{states}}, \Sigma_{\text{alphabet}}, \delta_{\text{transitions (mapping: Q x } (\Sigma \cup \varepsilon) \rightarrow P(Q))}, Q_{i\text{initial states}}, Q_{f\text{final states}}>$

variants: machines with

- actions associated with states or transitions (Moore and Mealy machines; transducers)
- transitions conditioned on no input symbol (a null)
- more than one transition for a given symbol and state (nondeterministic FSM)
- states designated as accepting states (recognizer)
- etc.

finite automata

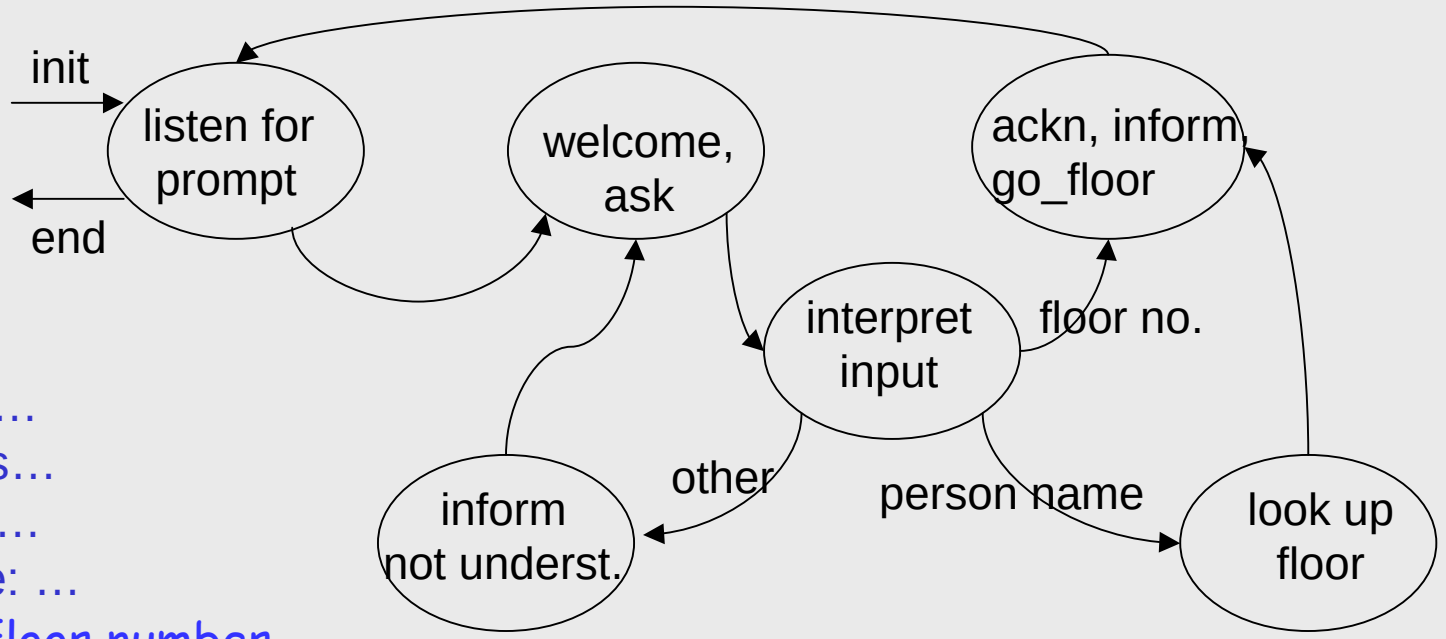
U: Elevator.
S: Hello. Which floor would you like to go to?
U: Third floor.
S: OK, I am taking you to the third floor.



States: …
Alphabet: …
Transitions…
Init-State: …
Final-State: …

finite automata

U: Elevator
S: Hello. Where would you like to go to?
U: Prof. Barry.
S: Prof. Barry is on the fourth floor.
I am taking you to the fourth floor.



States: …
Alphabet: …
Transitions…
Init-State: …
Final-State: …
variable: floor number

finite automata: summary

- advantages
  - fixed prompts can be pre-recorded
  - speech recognition and input interpretation can be tuned for each state
- disadvantages
  - rigid dialogue flow
  - inhibiting user initiative
  - only suitable for simple tasks
  - in principle, more flexible possible, but it quickly gets very complex
- however: modular solutions are possible → e.g. DialogOS

frame-based models: form filling

frame-based models

frame (form): what info should be supplied by user

departure_city	?
departure_date	?
destination_city	?
return_date	?
…	

dialogue states: which slots are filled

general routines for what system should do next (given which slots are filled)

frame-based models

S: What can I do for you?
U: I want to fly to Paris

departure_city	?
departure_date	?
destination_city	**Paris**
return_date	?
…	

S: Where will you fly from?
U: From Berlin on August 1st.

overanswering

departure_city	Berlin
departure_date	01/08/07
destination_city	Paris
return_date	?
…	

frame-based models

- deciding what to do next:
  - next unfilled slot
  - slot-combination weighting
  - ontology-based coherence
- database lookup:
  - delayed (typically; after certain slots filled)
  - immediate (can be “expensive”: takes time, but faciliates more helpful system behavior)

frame-based models: delayed vs. immediate information retrieval

S: What can I do for you?
U: I want to fly from Berlin to Paris.
S: When would you like to fly?
U: April 1st.
S: At what time would like to fly?
U: In the morning.
S: Sorry. There is no flight from Berlin to Paris on April 1st in the morning.
When would you like to fly?
U: Afternoon.
S: There is one flight. It leaves Berlin at 3 PM and arrives to Paris at 5 PM.

S: What would you like to hear?
U: Play Yesterday.
S: There are 5 songs called Yesterday. Which artist would you like?
U: The Beatles.
S: Sorry, I do not have Yesterday by the Beatles. Would you like another artist?
U: …

frame-based models: VoiceXML

web-based markup language for representing spoken dialogs

main elements of a VoiceXML document:

- form: basic unit of functionality
- field: prompts for and accepts user input
- prompt: sequence of audio elements or TTS messages
- audio: audio file or TTS message to play
- filled: processes input, can pass control to other forms

form interpretation algorithm

- defines how fields in a form are filled in and how the fill ordering can be modified

global event handlers (e.g., error handling, help)

- define behavior for predefined global conditions occur

control transfer conditions and subroutine constructs

(= special-purpose programming language)

- http://www.palowireless.com/voicexml/tutorials.asp
- http://www.vocomosoft.com/voicexml_tutorial.htm
- http://cafe.bevocal.com/docs/tutorial/index.html

(btw: new, more expresive standard: State Chart XML)

frame-based models: summary

- advantages
  - more flexible dialogue
  - enables some user initiative
- disadvantages
  - speech recognition more difficult, because user input less restricted
  - not every task can be modeled by a frame

grounding

establishing common ground

grounding

mis-communication or non-communication may arise are due to (among others):

- lack of perception or recognition
- ambiguity
- misunderstanding

decision: accept/reject/verify/clarify/repair/ignore …
clarification and repair strategies, e.g., ask for repetition, rephrase, clarify

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

assumption: collaboration

humans collaborate in conversation to establish common ground

discourse is modelled in terms of **contributions:**

contribution : presentation + acceptance

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

levels of joint action in conversation → Clark's joint action ladder

Level	Speaker S's actions	Hearers's actions
4	S is **proposing** a joint project w to H	H is **considering** S's proposal of w
3	S is **signalling** that P for H	H is **recognizing** that P from S
2	S is **presenting** signal s to H	H is **identifying signal** s from S
1	S is **executing** behaviour b for H	H is **attending to behaviour** b from S

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

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coordinate the Hearer's attention with Speaker's communicative actions (e.g. S must make sure H is listening)

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once a speech act successfully executed and attended to, Hearer must try to identify the presented signals (verbal and non-verbal)

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coordinate the Hearer's attention with Speaker's communicative actions (e.g. S must make sure H is listening)
once a speech act successfully executed and attended to, Hearer must try to identify the presented signals (verbal and non-verbal)
Hearer must understand what Speaker means
once understood, decide whether to comply to the proposed project or action

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

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e.g. Can you pass the salt?
H must succeed (jointly with S) in construing the meaning of the utterance (Level 3) before H can consider S's *request* to pass the salt (Level 4).

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

levels of joint action in conversation → Clark's joint action ladder

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H can be in one of the following states:

H did not notice that S's uttered U
H noticed, but did not hear it correctly
H heared it correctly, but did not understand it
H understood

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

grounding theories

- Clark & Schaefer's discourse contributions
- Traum's conversational acts

the grounding criterion

> S and H mutually believe that H understood what S said to a criterion sufficient for the current purposes

grounding (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

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grounding acts (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

computational model of grounding in conversation

conversational acts (extension of speech acts theory)

- turn-taking
- grounding
- core speech acts
- argumentational acts

grounding acts (Clark and Schaefer 1989, Clark 1996, Traum 1994, 1998)

computational model of grounding in conversation

conversational acts (extension of speech acts theory)

- turn-taking
- **grounding: Initiate, Continue, Cancel, ReqAck, Ack, ReqRepair, Repair**
- core speech acts
- argumentational acts

grounding acts (Clark and Schaefer 1989, Clark (1996), Traum 1998)

Discourse Unit (DU): unit of content to be grounded

goal: grounded state (mutually believed common ground)

what is the function of utterance U?

e.g. is H signalling how S's last utterance was interpreted?

does U initiate, continue, complete a discourse unit DU?

grounding acts (Clark and Schaefer 1989, Clark (1996), Traum 1998)

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Label	Description
initiate	Begin new DU, content separate from previous uncompleted DUs
continue	same agent adds related content to open DU
acknowledge	Demonstrate or claim understanding of previous material by other agent
repair	Correct (potential) misunderstanding of DU content
Request Repair	Signal lack of understanding
Request Ack	Signal for other to acknowledge
cancel	Stop work on DU, leaving it ungrounded and ungroundable

grounding acts (Clark and Schaefer 1989, Clark (1996), Traum 1998)

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does U initiate, continue, complete a discourse unit DU?

S: start DU
F: final (DU grounded)
D: DU abandoned
I: initiator, R: responder

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Next Act	In State						
	S	1	2	3	4	F	D
initiate^I	1						
continue^I		1			4		
continue^R			2	3			
repair^I		1	1	1	4	1	
repair^R		3	2	3	3	3	
ReqRepair^I			4	4	4	4	
ReqRepair^R		2	2	2	2	2	
ack^I				F	1	F	
ack^R		F	F			F	
ReqAck^I		1				1	
ReqAck^R				3		3	
cancel^I		D	D	D	D	D	
cancel^R			1	1		D	

grounding acts: example

(1)	A:	Move the boxcar to Corning	initiate DU1
	A:	and load it with pineapples	continue
	B:	OK	ack
	A:	I mean, oranges.	Repair
	B:	OK.	ack
	A:	and now take the pinapples...	initiate DU2

(2)	A:	Move the boxcar to Corning	initiate DU1
	A:	and load it with pineapples	continue
	B:	OK.	ack
	B:	Pineapples?	ReqRepair
	A:	I mean, oranges.	Repair
	B:	OK.	ack

grounding strategies in dialogue systems

- pessimistic strategy
  - immediate explicit verification (terribly inefficient)
- optimistic strategy
  - delayed accumulated verification (difficult to recover from errors; error-chaining)
- carefully optimistic strategy
  - „implicit” verification by incorporating info to be grounded in next system turn

grounding strategies in dialogue systems: examples

immediate explicit feedback (and verification request)

S: Where do you want to go?

U: Hamburg.

S: Traveling to Hamburg. (OK?)

U: Yes.

S: When do you want to go?

delayed explicit feedback by summarizing at task end

…

S: So. Traveling from Saarbrücken to Hamburg on Monday June 6 …

immediate “implicit” feedback by incorporating material to be grounded in the next system turn (see if user accepts or protests)

S: Where do you want to go?

U: Hamburg.

S: And when do you want to go to Hamburg?

grounding strategy in dialogue systems: factors

ASR confidence below/above threshold

pragmatic plausibility (Gabsdil & Lemon 2004)

- combining ASR confidence with task interpretation confidence (plausible actions in context)

context-adaptive strategies

- dialogue progress so far

- $\rightarrow$ reinforcement learning: learn optimal strategies from data based on rewards for „good” dialogue and user satisfaction (Lemon et al. 2006)

initiative
&
cooperation

initiative

who is in control of the dialogue progression?

- being the one who's talking does not necessarily mean being in control, e.g., just answering a question

dialogue initiative vs. task initiative

two models:

- **fixed initiative** model → one participant in control
  - *system-initiative* (typical for script-based and form-based DM)
  - *user initiative*
- **mixed initiative** model → either participant can assume initiative, depending on knowledge, skills, situation, etc.
  - typical in human-human conversation
  - but: how to decide whether to take initiative?

cooperation

conversation (and communication in general) is a joint activity

- has a purpose (agreed on by the participants)
- involves collaboration/cooperation in achieving goals

being cooperative: helping each other to accomplish goals by, e.g.,

- cooperative interpretation beyond literal meaning (inference), (indirect) dialogue act recognition
- cooperative answering:
  - complying with requests or directives when possible
  - correcting false presuppositions or misconceptions
  - intensional answers and generalizations
- taking initiative when this helps to accomplish the joint activity:
  - providing more information than requested (when it is relevant or useful),
  - e.g., helpful responses (suggestions), when user's input uninterpretable,
  - when it has to be rejected (e.g., no database results)
  - or when too many database results

flexible dialogue modelling: Information State Update

information state

representation of the current state of dialogue

used by the system to:

- (contextually) interpret user's turn
- decide which external actions to take
- decide what to say
- store information (dialogue context representation)

utterances update the information state

(approaches to IS-base modelling differ in how IS is represented, what role it plays, what it contains)

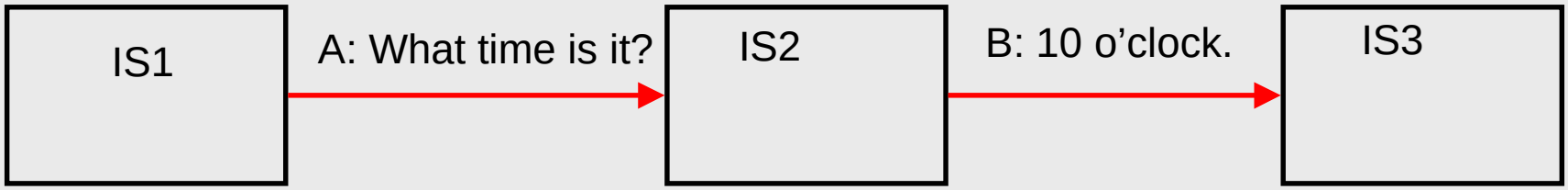
information state based theories of dialogue modelling: components

- a description of the informational components of the IS
  - (aspects of common context, participants, common ground, linguistic and intensional structure, commitments, beliefs, intentions, user model...)
- their formal representation
  - (e.g. lists, sets, typed feature structures, DRSs, propositions, modal operators, etc.)
- set of dialogue moves (DMs) triggering the update of the IS
- set of update rules governing the IS updates given various conditions of current IS and performed DMs
  - (e.g. set of selection rules that licence choosing a particular DM to perform given IS)
- a control strategy to decide which update rule(s) to select at a given point in the dialogue
  - (e.g. „pick first that applies”, game theory, statistical methods)

information state: update rules

describe possible transitions from one information state to the next

```
if <conditions-on-IS-values>
then <changes-to-IS-values>
```



conditions: when rule applicable

effects: how IS changes

information state: state machine model as IS update

IS: current-state + input

update rules:

```
if [state] & [input]
then [output]; [next-state]
```

information state: frame-based model as IS update

IS: task-frame + user's move + system move

update rules:

e.g.,

```
if [user move = slot X value V] then [fill X with V]
if <conditions-on-frame-values> then <ask-slot-value Y>
```

(decision about next system move is also a rule!...)

information state: place of the task model

task- vs. dialogue structure

task → dialogue

but, dialogue does not have to follow task (execution) structure

„planning” dialogue → agenda

task model fills agenda with task-related goals

dialogue manager can add more goals, e.g., for grounding

update model:

Question Under Discussion (QUD-based): Godis

obligations-based: Edis

agent-based (collaborative problem solving): TALK

QUD-based information state update

information state in Godis:

```
[ PRIVATE : [ AGENDA : stack(Action)
              PLAN : stack(Action)
              BEL : set(Prop)      ]
  SHARED  : [ COMMITMENTS : set(Prop)
              QUD : stack(Question)
              LU: [ SPEAKER: Speaker
                    MOVES: assocSet(Move) ] ] ]
```

+ module interface variables

```
INPUT : String
LATEST-MOVES: Set(Move)
LATEST-SPEAKER: Speaker
NEXT-MOVES: Set(Move)
OUTPUT: String
```

QUD-based information state update: example rules

U: ”how much does a flight cost?”

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, then add P=Q[A] to SHARED.COM

if P in SHARED.COM and Q topmost on QUD and P **resolves** Q, then pop QUD

if P in SHARED.COM and P **fulfils goal** of findout(Q) and findout(Q) on PLAN, then pop PLAN

QUD-based information state update: example plan

```
findout(?x.transport(x))
findout(?x.dest-city(x))
findout(?x.depart-city(x))
findout(?x.dept-month(x))
findout(?x.dept-day(x))
findout({?class(economy), ?class(business)}
consultDB(?x.price(x))
respond(?x.price(x))
```

$\Rightarrow$ system's agenda

QUD-based information state update: answer integration

IS update rule for answer integration

```
integrateAnswer
        pre: in($SHARED.LU.MOVES, answer(A))
             fst($SHARED.QUD, Q)
             $DOMAIN:about(A, Q)

        eff: DOMAIN: combine(Q, A, P)
             add(SHARED.COM, P)
```

(before answer can be integrated, it must be matched to a question on QUD!...)

QUD-based information state update: answer integration example

…

S: ”what class did you have in mind?”

U: ”cheap”

if consultDB(Q) on PLAN, consult database for answer to Q and store result in PRIVATE.BEL

if Q on QUD and P in PRIVATE.BEL s.t. P resolves Q, answer(P)

S: ”The price is £123”

QUD-based information state update

IS update rules take care of multiple issues, e.g.:

if user asks Q, push Q on QUD and load plan for dealing with Q

if users asks Q' while system is dealing with Q, **throw out plan for Q,** but Q remains on QUD

when Q' resolved, Q topmost on QUD will trigger reloading plan for dealing with Q

- general rule: if SHARED.COM contains info resolving Q, don't ask Q
- so any resolved questions in plan will be thrown out

QUD-based information state update: QUD updates

U: I want price information [raise ?x.price(x)]

S: Where do you want to go?

U: London

S: When do you want to travel?
   QUD=<?x.dept-month(x), ?x.price(x)>

U: Do I need a Visa? [raise ?visa]
   QUD=<?visa, ?x.dept-month(x), ?x.price(x)>

S: Where are you travelling from?

U: Gothenburg

S: No, you don't need a Visa.
   QUD=<?x.dept-month(x), ?x.price(x)>
   PLAN empty;

QUD-based information state update: QUD and plan

(1)
U: OK.

QUD=<?x.dept-month(x), ?x.price(x)>
PLAN empty, so reload plan for dealing with ?x.price(x)
throw out all already resolved questions; raise the first unresolved question on plan

S: When do you want to travel? [= re-raise question]
U: I want to leave in April
S: What day do you want to leave?

(2)
U: OK, I want to leave in April [answers dept-month(april)]

QUD=<?x.price(x)>
PLAN empty, so reload plan for dealing with ?x.price(x)
throw out all already resolved questions; raise the first unresolved question on plan

S: What day do you want to leave?
…

information state update based systems

projects: Trindi, Siridus, D’Homme, BEETLE, WITAS, TALK, …

software tools:

TrindiKit (Gothenburg U.) http://www.ling.gu.se/trindi/trindikit/

Dipper (U. of Edinburgh) http://www.ltg.ed.ac.uk/dipper/

MIDIKI (MITRE Corp.) http://midiki.sourgeforge.net/

information state update based systems: summary

- advantages:
  - generic approach to dialogue modeling
  - handling various dialogue phenomena
    - accommodation (“overanswering”)
    - reraising of issues
    - task switching, sharing information across tasks
  - various dialogue genres (e.g., negotiation, tutoring…)
- disadvantages
  - static dialogue plans, not much work done on those
    - → integrate with ideas in agent architectured where focus on task planning (current research)

Current Challenges

- adaptivity
  - systems need to be dynamically adaptive in a number of different ways:
  - to the environments in which they are used (modality), to their user's preferences
  - and needs (personalisation), and to changes in task and context
- ability to learn
  - systems need to be able to learn from interactions with users in order to provide an optimally usable interface that matches the current environment and user
- standardisation
  - there is a need for a common set of standards to support re-usability for developers and to support usability for the users of spoken dialogue systems
- pervasive systems
  - systems need to handle distributed dialogues (shifts to different dialogue situations / managers), concurrent dialogues (issues of co-ordination, synchronisation, redundancy);
  - interaction model needs to be predominantly event-based (external events, opportunistic)