Approaches to Dialogue Systems and Dialogue Management

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Outline for Course

- Monday: Introduction, Architecture of Dialogue Systems, Example Systems
- Yesterday: Simple structures: S-R, IR, finite State
- Today: Frame-based and Information State
- Tomorrow: Plan-based and Logic Based
- Friday: Advanced Topics

Possible Topics for Friday

- Dialogue System Evaluation
- Grounding
- Multiparty dialogue
- Non-cooperative dialogue agents
- Enculturated Dialogue Agents

Outline for Today

- Transaction Dialogues
  - Examples, approaches
- Issues
  - Initiative
  - Grounding & Repair
- Frame-based approach
  - Example systems: MIT
- Frame+agenda
  - CMU Communicator
- Information-state approach
  - Approach
  - Trindikit & other kits
  - Example information-based theories & systems
  - EDIS

Transaction Dialogues

- User has a request
- System needs info from user to process request
- Dialogue proceeds as:
  - User specifies request
  - System gathers necessary info
    - Q&A
    - Spontaneous assertion from user
  - System looks up information & provides response

Example Transaction Dialogue

S Welcome to the flight confirmation system.
S What is your flight number?
U United 123
S What is your departure city?
S Los Angeles
S What is the day of departure?
S August 8th
S Flight United 123 confirmed to depart Los Angeles for London at 2pm on August 8th.

Finite State Transaction Dialogues

- Good if
  - there is a defined sequence of questions
  - questions are independent
- Not so good for
  - Arbitrary order
  - Non-state-based Constraints on applicability
  - Mixed-initiative

Non-mixed initiative Transaction Dialogue

S Welcome to the flight confirmation system.

S What is your flight number?

U United 123 on August 8th from Los Angeles

S What is your departure city?

S I told you, Los Angeles, on August 8th

S I'm sorry, I didn't understand. What is your departure city?

S Los Angeles leaving august 8th.

S What is the day of departure?

S You don't listen you bloody machine August 8th

S Please say the day of departure?

S August 8th

S Flight United 123 confirmed to depart Los Angeles for London at 2pm on August 8th.

Mixed-initiative Transaction Dialogue

S Welcome to the flight confirmation system.

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Initiative Issues

- What is initiative?
- What are consequences of having initiative?
- What is Mixed-initiative?
  - How does one shift initiative?
  - When should one shift initiative?
  - Should systems reason about initiative?

Views on initiative (control)

- Any Contribution
  - MI Planning
  - Turn (Donaldson, Hagen)
- Type of Dialogue move
  - Initiative/Response (Dahlback et al, Carletta et al, Ishizaki)
  - Patterns: command, question, assertion, prompt
    - (Whittaker, Stenton &Walker, Smith and Hipp)
  - Amount/type of information
- Goal Interactions
  - Whose goals are being addressed
  - Game Playing: Sente or Tempo - forcing moves of other
  - Obligations vs. Goal (Traum & Allen)
- Multi-level concepts:
  - Choice of speaker, task, outcome (Novick & Sutton)
  - Discourse vs Task (Chu-Carroll & Brown), Local vs. Global (Rich and Sidner)
  - Hierarchical (Whittaker&Walker)

Example: Chu-Carroll & Brown

1. Customer:
   - I need some money. How Much do I have in my 6-month CD?
2. T alternatives:
   A. T: no initiative
      - You Have $5000 in that CD.
   B. T: Dialogue initiative
      - You Have $5000 in that CD, but that CD will not mature for another 3 months.
   C. T: both dialogue and task initiative
      - You Have $5000 in that CD, but that CD will not mature for another 3 months. However you have $3000 in another CD that will mature next week.

Consequences of initiative

- Type of move generated
  - Prompt, query, proposal, evaluation,…
- Amount of information to express
- Amount & Type of reasoning
  - query, plan checking, intention recognition, plan generation
- Source of generation-reasoning
  - own vs other goals

Views on Mixed-initiative

- Contributions by multiple parties
- Changing initiative-holder mid-interaction
  - Fixed phases, or variable shift
- User providing more input than asked for
  - Middle level between system and user
- Ability to handle set of complex behaviors
  - Answer, ignore, over-answer, barge-in (Hagen)

Example: Narayanan et al

- System Initiative (SI)
  - System: “VPQ. Please say the name of the person.”
  - Acceptable Response from User: “Larry Rabiner.”
- Mixed Initiative (MI)
  - System: “VPQ. Please say the name of the person.”
  - Acceptable Response from User: “Larry Rabiner’s fax number, please.”
- User Initiative (UI)
  - System: “VPQ. What can I do for you?”
  - Acceptable Response from User: “I’d like the fax number for Larry Rabiner.”

How does one shift initiative?

- Types of Dialogue moves
  - prompts, repetitions, interruptions
- When dialogue phase changes
- Extra contributions
- Type of reasoning
- Discourse cues (e.g., silence)

When should one shift initiative?

- Expertise (Guinn)
  - Knows better what to say
  - Detects problems
- When user (sufficiently) understands task and interaction abilities
- e.g., tutorial domain
- When user gets stuck

Should Systems Reason about initiative?

- Pro:
  - finer control of interaction,
  - tuning to user preferences,
  - efficiency
- Con:
  - one more thing to reason about
  - Epiphenomenal aspects

Factors affecting initiative

- Individual or joint goals?
- Collaborative or competitive task?
- Distribution of knowledge/expertise
- Complexity of task
- Task-based roles
- Social roles
- Social projection (face)

Initiative in Group Tasks

- Much less studied
- Ishizaki & Kato 98
  - Equal #s of turns/characters
  - Unequal initiative patterns
- Choice of speaker more important aspect, even for responses.
- Computer mediated conferencing systems
  - Parallel initiatives

State of the Art: Initiative in Dialogue Systems

- Variable results on efficiency, depending on tasks, capabilities of systems
- Users don't like system initiative
  - except when learning system
- Few systems can handle free-choice input or user-directed interaction
  - except for very circumscribed domains

Non-mixed initiative Transaction Dialogue

S Welcome to the flight confirmation system.
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U United 123 on August 8th from Los Angeles
S What is your departure city?
S I told you, Los Angeles, on August 8th
S I'm sorry, I didn't understand. What is your departure city?
S Los Angeles leaving august 8th.
S What is the day of departure?
S You don't listen you bloody machine August 8th
S Please say the day of departure?
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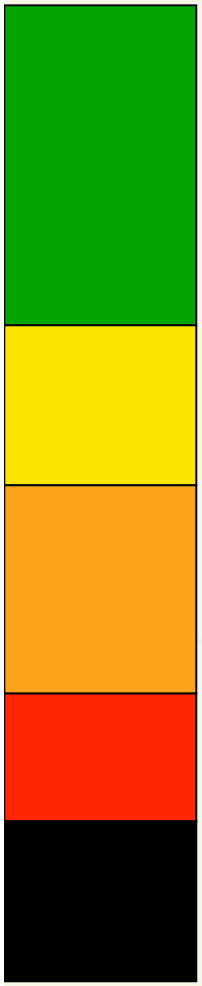
Immersion and Breakdown



- Immersion: human feels engaged in the conversation, communication feels natural, enjoyable
  - Focus on task
- Diagnostic: human having trouble communicating, trying to cooperatively get back to immersion
  - Focus on communication
- Breakdown: human gives up, feels unable or unwilling to proceed naturally
  - Focus on escape/diversion

Grounding and Repair

- Interpretations are uncertain
- Strategies
  - Positive feedback
    - Acknowledgement
    - Explicit confirmation
    - Implicit confirmation
  - Negative feedback
    - Rejection of understanding
    - Request repeat
    - Request re-prhrase
    - clarification
  - Request Feedback

Some Styles of Verbal Response

1	**Sys:**	Where do you want to go?
2	**User:**	Boston.
3a	**Sys:**	When would you like to go?
3b		Tell me more about your travel plans.
3c		When would you like to go to Boston?
3d		Do you want to go to Boston?
3e		Did you say Boston?
3f		Boston?
3g		Boston or Austin?
3h		Where?
3i		Please Repeat.

How to deal with Understanding Errors

- Prevent them
  - Structure dialogue to simplify language of user
  - Check correctness of understanding (verification)
- Ignore them
  - Structure dialogue to partition responses at a state
  - Predictions of appropriate responses
- Cope with them
  - Ground Content: Acknowledge, Request repair, clarify, signal lack of or mis-understanding

Frame-based Approach

- Also called form-based (MIT)
- Central data structure is frame with slots
  - DM is monitoring frame, filling in slots
- Used for transaction dialogues
- Generalizes finite-state approach by allowing multiple paths to acquire info
- Frame:
  - Set of information needed
  - Context for utterance interpretation
  - Context for dialogue progress
- Allows mixed initiative

Frames

- Information needed for query or task
- E.g flight info
  - Flight number
  - Departure city
  - Arrival city
  - Date
  - Departure time
  - Arrival time
  - Need certain patterns of info
    - Arrival or Departure city can be inferred from flight #
    - Arrival time & departure time can be inferred from flight # and departure or arrival city
    - Flight number can be inferred from departure and arrival and time

Example: MIT Wheels system

- Domain: searching used car ads
- Transaction domain + constraint satisfaction
- No slots are mandatory,
  - try to find the best set of matches
  - Try to find an appropriate # of matches

Example: MIT Jupiter System (1)

- Retrieval of weather forecast domain
  - Multiple sources
  - Content processing
  - Information on demand
  - Context
- +1-888-573-8255

MIT Jupiter System (2)

- Uses Galaxy architecture
  - SUMMIT ASR
    - 2000 word vocabuluary, 1-9% OOV
  - TINA NL understanding
    - Creates semantic frames from text
    - Used for both query understanding (user)
    - Content understanding (web-based weather text)
  - GENESIS generation
    - User text
    - SQL queries
    - Keyword-value
  - Dialogue control table
    - Conditions for operations
    - context

Problems with Frames

- Not easily applicable to complex tasks
  - May not be a single frame
  - Dynamic construction of information
  - User access to “product”

Example: Complex Information

- Travel Plans
  - Goal: get from Paris to Hamburg
  - Options: fly, train, drive
  - Flight: airline, airport, price, date
  - Train: station, class, discount?, reservation?
  - Drive: directions, fastest or cheapest?

Agenda + Frame (CMU Communicator)

- Product:
  - hierarchical composition of frames
- Process:
  - Agenda
    - Generalization of stack
    - Ordered list of topics
    - List of handlers

TRINDI Project

- Task-Oriented Instructional Dialogue
- European Union Telematics, 2yr project (1998-2000)
- ~15 Researchers
- Consortium: U Gothenburg, U Edinburgh, U Saarlandes, SRI Cambridge, Xerox

Motivating Problems

- Dialogue theories are largely incomparable
  - despite often similar intended coverage
  - e.g., motivation for answering questions:
    - cooperativity vs. obligations vs. QUD structure
  - Heterogeneous building blocks
- Large gap between dialogue models in systems and broad-coverage theories
- Dialogue systems are hard to build
  - despite rapid progress in ASR, TTS, NLP
  - hard to convert systems to new domains
  - insufficient attention to `theoretical' concerns

Deficiencies of Previous Dialogue Theories

- Inappropriate for direct implementation
  - Some aspects too vague
    - e.g., Relevance Theory (a la Sperber and Wilson)
  - some aspects too complex for efficient computation
    - e.g., Implicit Belief using Modal Predicate Logic
- Hard to evaluate/compare with other theories
    - even when covering same dialogue phenomena
    - Heterogeneous building blocks
  - How to combine, e.g., mentalistic and structural

Deficiencies of Previous Dialogue Systems

- Software engineering challenge
  - combining heterogeneous sub-systems
- Domain/Task specific design
  - little carried over to next system
- Insufficient attention to dialogue structure
  - Dialogue usually conceived as FSM
    - inflexible interaction
    - does not scale to large tasks

Partial Solution: Dialogue Toolkits

- Software Integration
  (OAA, Trains/Trips, Verbmobil)
- FSM Dialogue Kits (Nuance, OGI, …)
- Slot-Filling (Phillips)
- Development Kits:
  - Utterance-based (DARPA Communicator)
  - ⇒ Information-based (TrindiKit)

Approach to Problems

- Information State approach to formalizing theories of dialogue modelling
- Dialogue Move Engine (TrindiKit) for implementing a dialogue modelling theory
- Example implementations
- Comparative experimentation, enhancements, & evaluation

Information State Theories of Dialogue

- Statics
  - **Informational components** (functional spec)
    - e.g., QUD, common ground, dialogue history, ...
  - **formal representations** (acessibility)
    - e.g., lists, records, DRSes, …
- Dynamics
  - **dialogue moves**
    - abstractions of i/o (e.g., speech acts)
  - **update rules -** atomic updates
  - **update strategy** - coordinated application of rules

Sample GoDiS information state

PRIVATE =
- AGENDA = { **findout(?return)** }
- PLAN = { **findout(?λx.month(x))**, **findout(?λx.class(x))**, **respond(?λx.price(x))** }
- BEL = { }
- TMP = (*same as SHARED*)

SHARED =
- COM = { **dest(paris)**, **transport(plane)**, **task(get_price_info)** }
- QUD = **< λx.origin(x) >**
- LM = { **ask(sys, λx.origin(x))** }

Sample GoDiS update rule

- integrateAnswer

pre:
- in(SHARED.LM, answer(usr, A))
- fst(SHARED.QUD, Q)
- relevant_answer(Q, A)

eff:
- pop(SHARED.QUD)
- reduce(Q, A, P)
- add(SHARED.COM, P)

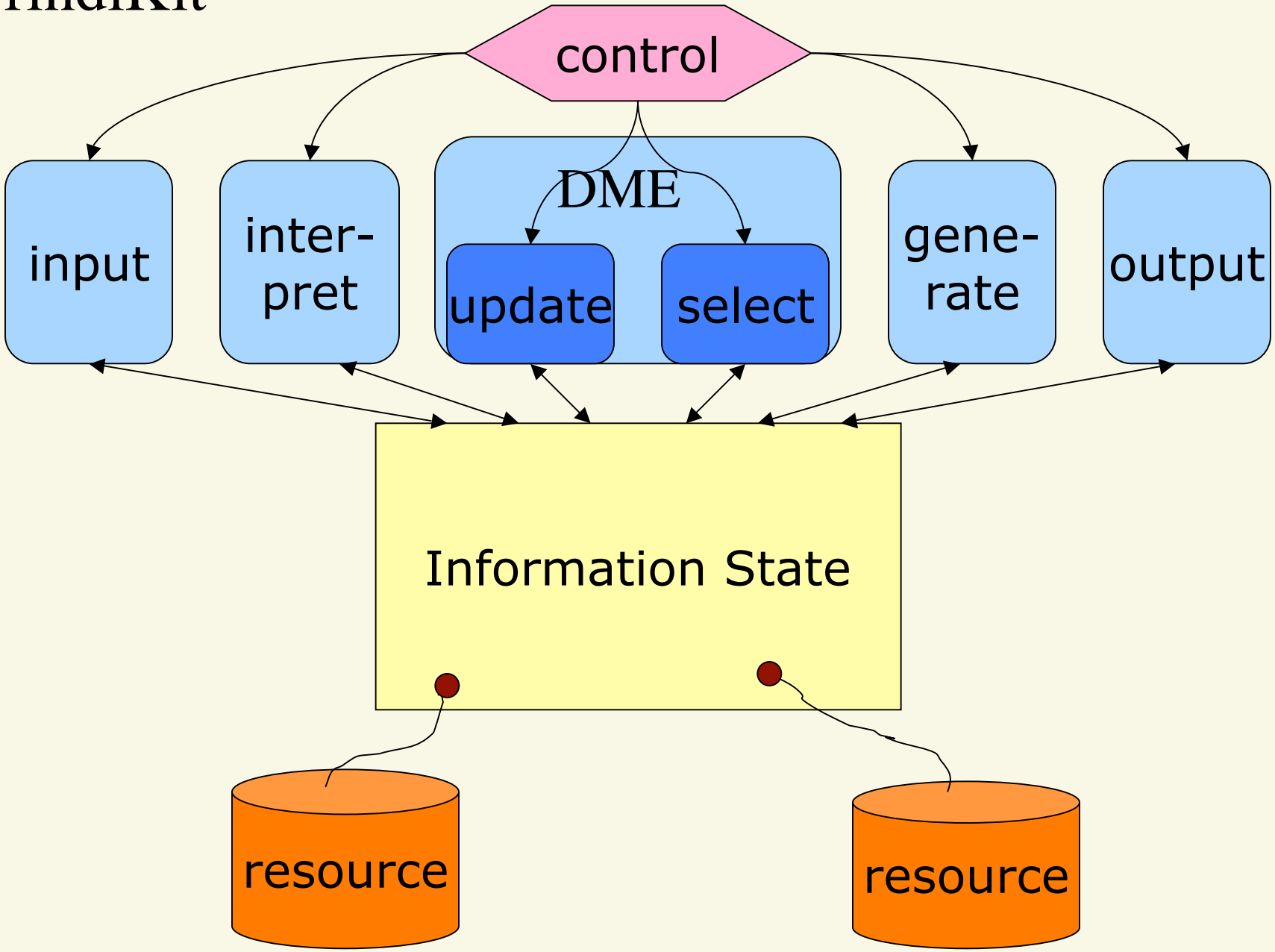
Dialogue Move Engine

- Handles Dialogue Management tasks:
  - consumes observed dialogue moves
  - updates information state
  - produces new dialogue moves to be performed
- Can be implemented as:
  - Update (&Selection) Rules
  - Update Algorithm

TrindiKit

- Architecture based on information states
- Modules (dialogue move engine, input, interpretation, generation, output etc.) access the information state
- Resources (databases, lexicons, domain knowledge etc.)

TrindiKit


control
input
inter-
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output
Information State
resource
resource

TrindiKit Features

- Explicit information state data-structure
  - makes systems more transparent
  - closer to dialogue processing theory
  - easier comparison of theories
- modularity for simple and efficient reconfiguration and reusability
- rapid prototyping

TrindiKiT Includes

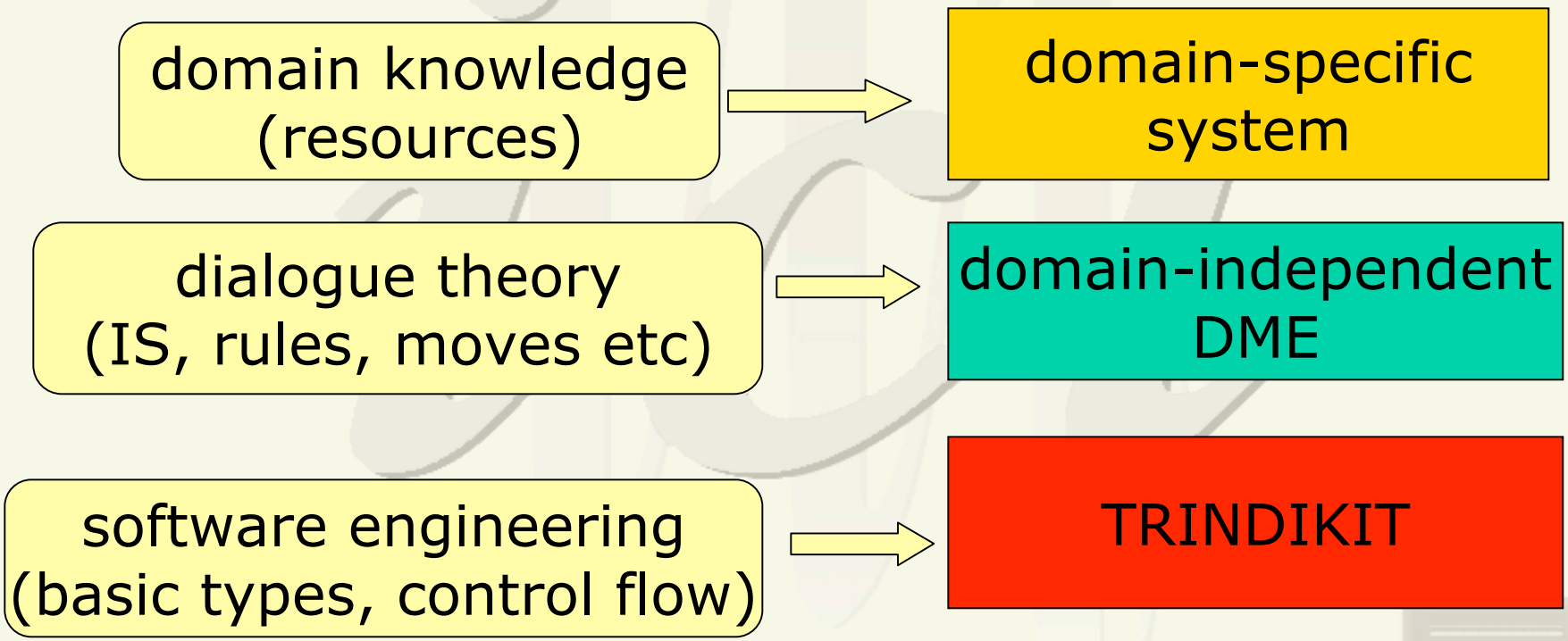
- A library of datatype definitions
  - conditions and operations
- facilities for writing update rules and algorithms
- tools for visualizing information state
- debugging facilities
- A library of basic ready-made modules for i/o, interpretation, generation, etc.
- Resource interfaces

Building a TrindiKit system

Build or select from existing components:

- Type of information state (DRS, record, ...)
- A set of dialogue moves
- Information state update rules,
- DME Module algorithm(s), including control algorithm
- Resources: databases, grammars, plan libraries etc., or external modules

Building a system



TrindiKit Systems

- GoDiS (Larsson et al) – information state: Questions Under Discussion
- MIDAS – DRS information state, first-order reasoning (Bos &Gabsdil, 2000)
- EDIS – PTT Information State, (Matheson et al 2000)
- SRI Autoroute – information state based on Conversational Game Theory (Lewin 2000)

  Robust Interpretation (Milward 1999)

System Comparisons

- Cross-IS Theories: SRI vs. EDIS on AutoRoute Dialogues
- Different formalizations: PTT using DRSes or Records
- Different Update strategies:
  - GoDiS with or without plan accomodation
  - Midas using different grounding strategies
- Different Languages, Tasks, and interactivity
  - GoDiS: English vs. Swedish
  - GoDiS: AutoRoute vs. Travel Agent
  - IMDIS: dialogue vs. text

Potential Impact

- Better development environment for formal dialogue theories
  - easy testing/revision of theories
  - comparison across theories
- Closer integration of theories and systems
- Better dialogue system development
  - Information state vs. dialogue state
  - extension to other domains

Post-Trindi Applications

- Siridus Project (EU 2000-)
  - Command and negotiative dialogues
  - Spanish
  - GoDiS, SRI
- IBL for Mobile Robots (U Edinburgh)
  - Midas
- Tutoring Electricity (U Edinburgh)
  - EDIS

Successor Toolkits

- TrindiKit revisions
- Dipper
- Midiki

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