



#### **Computational Dialogue Models**

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> Proseminar Computational Pragmatics Winter 2019/2020

#### Outline

#### Introduction

Dialogue Systems| Examples

#### Dialogue System Architecture

Components| Tasks

#### **Dialogue Management**

Script-based | Frame-based | Plan-based | Information State Update | Agent-based | ChatBots

#### **Evaluation**

User-based evaluation | Metrics

#### **Development toolkits**

CSLU | LUIS | Virtual Human | OpenDial

#### Introduction

# Multimodal natural-language based dialogue as human-machine interface









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- https://www.youtube.com/watch?v=zlFMq5IWVjI
- https://www.youtube.com/watch?v=t7Krn-DH3tw
- https://www.youtube.com/watch?v=YZizCoOctPo

## Dialogue Systems (general architecture)



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#### Tasks of Dialogue Management

Dialogue flow control

Dialogue modeling →Dialogue context →Dialogue acts

Dialogue act decision making

Dialogue phenomena:

- Error handling
- Initiative and cooperation
- · Adaptivity

#### Dialogue Modelling: approaches

#### Script-based (state machines)

Sequence of pre-defined steps (dialogue script)

#### Frame-based (also: form-filling)

Set of slots to be filled (task template) and corresponding prompts

#### Plan-based

Collaborative problem solving

#### Information-State Update

Declarative rules for updating dialogue context

#### Statistical (PO)MDP-based models

Probability distribution of the events or user states observed/learned from the observed past

#### End-to-End models

sequence2sequence models learned from large amount of data

#### Script-based DM

- Script describes all possible dialogues
- Typically finite state machine
- Set of states and transitions
  - State determines system utterance
  - > User utterance determines transition to next state (deterministic)
- No recursion! (= no nested sub-dialogues)
- Fixed dialogue script
- OK for system-driven interaction

## **Finite State Machine**

#### <States, Init-State, Alphabet, Transition-function>

#### Variants: machines having

- actions associated with states (Moore machine)
- actions associated with transitions (Mealy machine)
- multiple start states
- transitions conditioned on no input symbol (a null)
- more than one transition for a given symbol and state (nondeterministic finite state machine)
- states designated as accepting states (recognizer)
- etc.

See, e.g., NIST http://www.nist.gov/dads/HTML/finiteStateMachine.html"

# **FSM-based Models**

Petukhova



# **FSM-based Models**



# **FSM-based Models**



#### **FSM-Based Models**



# FSM-based Models: sum up

- 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 can make more flexible, but it quickly gets very complex; modular solutions are possible

# Frame-Based DM (form filling)

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: Where do you want to go? U: Paris

S: Where will you travel from? U: From Berlin.

S: When will you travel? U: August 1<sup>st</sup>.

departure city	?
departure_date	?
destination city	Paris
return_date	?

departure\_cityBerlindeparture\_date1/8/05destination\_cityParisreturn\_date?...

0.000

#### **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 1<sup>st</sup>.

"Overanswering"

departure\_cityBerlindeparture\_date1/8/05destination\_cityParisreturn\_date?

### **Frame-Based Models**

- Strategies for deciding what to do next
  - Next unfilled slot
  - Slot-combination weighting
  - > Ontology-based coherence

- Options for database lookup
  - Delayed (typically; after certain slots filled)
  - Immediate (can be "expensive" = take time, but enables more helpful system behavior)

### Frame-Based Models: sum up

#### 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

## **Plan-based Models**

- Communication is a joint activity: participants communicate to establish common ground, participants collaborate to accomplish a task
- Collaborative problem solving by (rational) agents
  - > Neither agent can accomplish the task alone
  - > Need joint goals and mutual understanding
  - > Agents collaborate to establish and achieve their goals
- Agents have knowledge about solving tasks
  - > Decide on goals (objectives): adopt, select, defer, abandon, release
  - Form plans to achieve goals (recipes)

# **Plan-based Models**

Automated planning: STRIPS; planning operators: actions, reconditions, post-conditions

- Executing plans (acting)
- Revising decisions (re-planning, abandoning goals, etc.)

Agents reason about beliefs and actions

Intention recognition

Given: plan for getting a BA

U: I'll take German 101 fall semester.



# **Collaborative Planning & Acting**

User: Send ambulance one to Parma right away

(initiate (c-adopt (action (send amb1 Parma)))) (initiate (c-select (action (send amb1 Parma))))

System: OK. [sends ambulance]

(complete (c-adopt (action (send amb1 Parma)))) (complete (c-select (action (send amb1 Parma))))

System: Where should we take the victim once we pick them up? (initiate (c-adopt (resource (hospital ?x))))

User: Rochester General Hospital (continue (c-adopt (resource (hospital RocGen))))

#### System: OK

(complete (c-adopt (resource (hospital RocGen))))

[Blaylock et al. 2003]

# Plan-Based DM: sum up

- Advantages
  - Flexibility and adaptivity
  - > Any task can be modeled
  - > ... the ultimate solution
- Disadvantages
  - > Specifying planning operators is as hard as writing dialogue scripts
  - Plan recognition is a hard problem
  - Lots of reasoning needed

## **Information State Update**



Interpretation of behaviour



# **Information State**

- . Representation of the current state of dialogue
- Used by system to
  - Interpret user's contribution
  - > Decide which actions to take
  - > Decide what to say
  - Store information (dialogue context representation)
- Utterances update information state
- Approaches to DM differ in how IS is represented, what role it plays, what it contains

# **ISU Dialogue Modelling**

#### Components:

- a description of the information state 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 acts (DAs) triggering the update of the IS
- set of update rules governing the IS updates given various conditions of current IS and performed DAs (e.g. set of selection rules that license 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)

### **IS Update Rules**

Describe possible transitions from one information state to the next

If <conditions-on-IS-values>



#### **ISU:** belief transfer

#### S: It's raining outside

preconditions:

Bel(S; p) Want(S; Bel(A; p))

expected understanding:

```
Bel(S,MBel({S,A},WBel(S,Bel(A;Bel(S, p))))
Bel(S,MBel({S,A},WBel(S;Bel(A;Want(S;Bel(A; p))))))
```

expected adoption:

```
Bel(S,MBel({S,A},WBel(S,Bel(A, p))))
```

#### **ISU:** belief transfer

#### A: no, it isn't

understanding:

Bel(A, MBel({S,A}, Bel(S,p))) Bel(A, MBel({S,A}, Want(S, Bel(A, p))))

adoption: Bel(A, MBel({S,A}, Bel(A,p)))

preconditions:

Bel(A, ¬p) Want(A, Bel(S, Bel(A, ¬p)))

```
expected understanding:
```

```
expected adoption:
```

...

...

#### **ISU:** belief transfer

#### A: yes, it is

understanding:

Bel(A, MBel({S,A}, Bel(S,p))) Bel(A, MBel({S,A}, Want(S, Bel(A, p))))

adoption: Bel(A, MBel({S,A}, Bel(A,p)))

preconditions:

Bel(A, p) Want(A, Bel(S, Bel(A, p)))

expected understanding:

expected adoption:

• • •

...

# State Machine Model as ISU

- . IS: current-state; input
- Update rules:

If [state] & [input] then [output]; [next-state]

### Frame-Based Model as ISU

- 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

# **ISU-based Dialogue Modelling**

- Task- vs. Dialogue-Structure
  - Task --> dialogue
  - > But, dialogue does not have to follow task (execution) structure
- Dialogue planning: creating an agenda
  - > Task model fills agenda with task-related goals
  - > Dialogue manager can add more goals, e.g., for grounding
- Some approaches:
  - > QUD-based: Godis (TRINDI, SIRIDUS)
  - Obligation-based: Edis (TRINDI)
  - Agent-based: collaborative problem solving (TALK)

# **Dialogue Contribution Processing**



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### ChatBots

A ChatBot is a conversational agent that interacts with users using natural language

- First chatbot ELIZA (Weizenbaum 1966), which emulated a psychotherapist:<u>http://nlp-addiction.com/eliza/</u>
- ALICE is a chatbot: ALICE System <a href="http://www.alicebot.org/about.html">http://www.alicebot.org/about.html</a>
- ALICE: the Artificial Linguistic Internet Computer Entity; a software robot that you can chat with using natural language.
- > ALICE language knowledge is stored in **AIML** files.
- > AIML: The Artificial Intelligence Mark up Language.

# ALICE

**•Topics :** each Topic file contains a list of categories

- Categories: contain
  - > **Pattern:** to match with user input
  - > **Template:** represents ALICE output

</topic> </aiml>

...

# ALICE

#### •CATEGORIES (Basic unit of knowledge)

<category> <pattern>HELLO</pattern> <template>Hi there!</template> </category>

#### Consists of: Input Question, Output Answer, [Context]

- Pattern = Initial question (a.k.a. "Stimulus")
- Template = Answer (a.k.a. "Response")
- Context = Optional, "that" or "topic"

#### Yak >> AIML files

If you're new to Pandorabots and <u>AIML</u> you should first try customizing your pandorabot by changing some of its <u>properties</u> or by providing your own custom responses with the <u>training</u> interface.

For more advanced botmasters, this page allows you to download, modify and upload the AIML files for your pandorabot directly.

The tables below show all the AIML files for this pandorabot. To view or edit a file, click on its name.

Filename	Size	Last Mo	odified		Browse	Download	Library	Active	Delete
AI.aiml	32,931	09/15/2003 0	06:05:17	ΡМ	Browse	<u>Download</u>	aaa-09-2003		
ALICE.aiml	36,385	09/15/2003 0	06:05:17	ΡМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Astrology.aiml	1,227	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Atomic.aiml	427,931	09/15/2003 0	06:05:17	ΡМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Biography.aiml	84,535	09/15/2003 0	06:05:17	РМ	Browse	<u>Download</u>	aaa-09-2003		
<u>Bot.aiml</u>	415,844	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Botmaster.aiml	5,350	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
<u>Client.aiml</u>	138,096	09/15/2003 0	06:05:17	ΡМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Computers.aiml	21,925	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Default.aiml	623,077	09/15/2003 0	06:05:17	ΡМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Drugs.aiml	11,905	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Emotion.aiml	15,784	09/15/2003 0	06:05:17	ΡМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Food.aiml	4,901	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
<u>Geography.aiml</u>	167,418	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
<u>History.aiml</u>	1,389	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Humor.aiml	1,215	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Inquiry.aiml	3,298	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
Interjection.aiml	2,613	09/15/2003 0	06:05:17	РМ	<u>Browse</u>	<u>Download</u>	aaa-09-2003		
IU.aiml	1,369	09/15/2003 0	06:05:17	РМ	Browse	Download	aaa-09-2003		
Knowledge.aiml	266,551	09/15/2003 0	06:05:17	РМ	Browse	Download	aaa-09-2003		

## Virtual Human Toolkit: NPCEditor

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# LUIS (Microsoft)

https://www.luis.ai/home

# **OpenDial**

http://www.opendial-toolkit.net/



# **CSLU** toolkit

https://www.youtube.com/watch?v=ZrAlj7GQqjQ

