Openstream.ai®
Delivering Intelligence

Platform for Collaborative Multimodal Plan-Based Multiparty Dialogue Systems

Phil Cohen
Openstream, Inc.

Heralding the Intelligent Enterprise

With thanks to Sateesh Anthapu, Lucian Galescu, Eli Pincus, and Raj Tumuluri

© 2021 Openstream Inc. All rights reserved

Purpose

Show that the collaborative multimodal, multi-party plan-based approach can improve upon the state-of-the-art in virtual assistant dialogue systems.

© 2022 Openstream Inc. Pats. Pending

Current "Frame-based" or "Task-Oriented" Dialogue Systems

(see Bobrow et al., 1977; Grosz, 1974; 1977)

Very limited goal --

- System is to perform actions – e.g., Book movie tickets, Reserve restaurants
- System determines which action, and prompts user to provide values for the "slots" (parameters) in the desired action "frame";

NLP is (mostly) "action/'intent' classification" + "slot-filling"

Prompt user for missing "slot" values;

- E.g, the date & time you want to eat, number of people, etc.
- User supplies atomic value(s) — such as "*Monday*" "*at 7 pm*"

Learn "optimal" slot-filling dialogue policies from data

- Mostly academic research competitions, conducted on artificial data, often generated from a user simulator, often operating at the speech act level

© 2022 Openstream Inc. Pats. Pending

Openstream.ai

Some Limitations of Slot-filling systems

U: “***Please book me a table at Guillaume***

S: “what time do you want to eat?”

U: ***“before 7 pm”,*** **or**
“not before 7 pm”
“between 7 and 8 pm”
“the earliest time available”

U: “”Friday before 10”

U: ***“what’s the earliest time available?”***
S: “6 pm”
U: ***“too early”***
S: “how about 7 pm?”
U: “*OK*”

No slot value is provided, only a constraint.

Over-answering, with constraints

Collaborative mixed initiative – User **doesn’t** fill slot -- parties collaboratively fill the slot.

© 2022 Openstream Inc. Pats. Pending

Collaborative Plan-Based Approach to Dialogue

Origin Story (1975-1980)

- Shopper: Where are the chuck steaks you advertised for 88 cents per pound?

- Butcher: How many do you want?

People infer each others' plans and attempt to help them overcome obstacles to their success.

Communicative actions are part of those plans

© 2022 Openstream Inc. Pats. Pending

Openstream.ai

Collaborative Plan-Based Approach to Dialogue

- Plan-based
  - People can plan their (task-related) communications in the same way as planning domain actions

    See Allen/Perrault, 1980; Allen et al., 1995; Appelt, 1982; Brown, 1980; Bruce, 1975; Carberry, 1985; Cohen, 1978; Cohen/Perrault, 1979; Cohen/Levesque, 1990; Ferguson/Allen, 2007; Koller/Stone, 1997; Lesh et al., 1999; Litman/Allen, 1987; Perrault/Allen, 1980; Pollack, 1990; Poesio/Traum, 1997/8; Sadek, 1992; Sidner, 1983/5; Traum/Allen, 1994, and *many many others*. See also Allen et al's TRIPS, TRAINS, COGENT systems.

  - Plan communicative actions to affect participants' mental states ("Theory of Mind")
    - See Cohen & Perrault, "Elements of a plan-based theory of speech acts", *Cog Sci,* 1979
      Perrault & Allen, "A plan-based analysis of indirect speech acts", *Comp Ling*, 1980
      Cohen & Levesque, "Intention is Choice plus Commitment", *AIJ*, 1990

  - Recognize how utterances/speech acts fit into a plan

  - Represent communicative and domain acts as operators in planning system

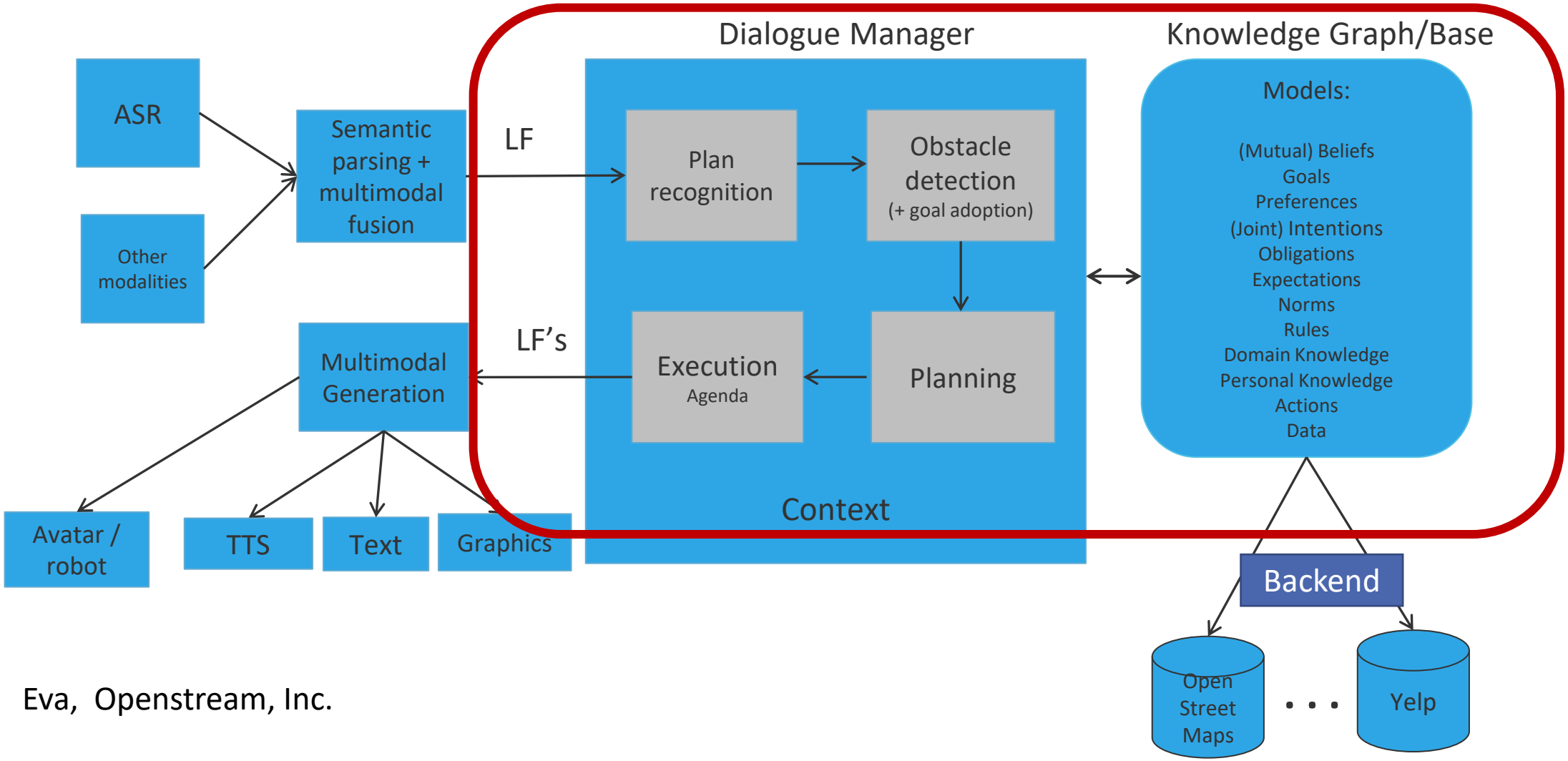
- Collaborative
  - Joint Commitment/Shared Plans (Cohen/Levesque, 1991; Grosz/Sidner, 1986/90; Levesque et al., 1990)
  - Leads to helping where needed, to tell partner when joint goal is achieved or impossible
  - Dialogue as Joint Action (Allen et al., 2001; Clark , 1996; C&L, 1991/94; Ferguson/Allen, 2005; Grosz/Sidner, 1986/90; Rich/Sidner, 1997/8 ; Subramanian et al., 2006), …
  - Cogent Dialogue Shell Galescu et al. (2018)
  - Others…

© 2022 Openstream Inc. Pats. Pending

Openstream.ai

Collaborative Dialogue

Via Plan-based Dialogue Management



Eva, Openstream, Inc.

© 2022 Openstream Inc. Pats. Pending

Plans

Plans as complex mental structures (vs data structures) whose elements are:

Formulas, which can be first-order logic formulas, or logical modality operators applied to Formulas.

- *Modalities*: Belief (***bel),*** Persistent Goal (***pgoal***), and ***Intend*** (<action>).
- *Attitudes towards Actions --*
  - *eg,* ***Intend(do (Action)), pgoal(do(Action)), bel(done(Action))***

    bel(mary, bel(john, pgoal (mary, do(reserve(john, vittorios, Monday, 7 pm))))).
  - *"Mary believes that John thinks that Mary wants to reserve Vittorio's for Monday at 7 pm"*
- *Relations* between actions and formulas, such as *Achieves*, *Enables*

© 2022 Openstream Inc. Pats. Pending

Collaborative Plan-based Dialogue Demo

- Constraints
- Mixed initiative
- Multi-agent/person
- Multi-utterance*
- Implicit slot-filling
- Explanation
- Obstacle detection
- Use of context

*Separate demo

© 2022 Openstream Inc. Pats. Pending

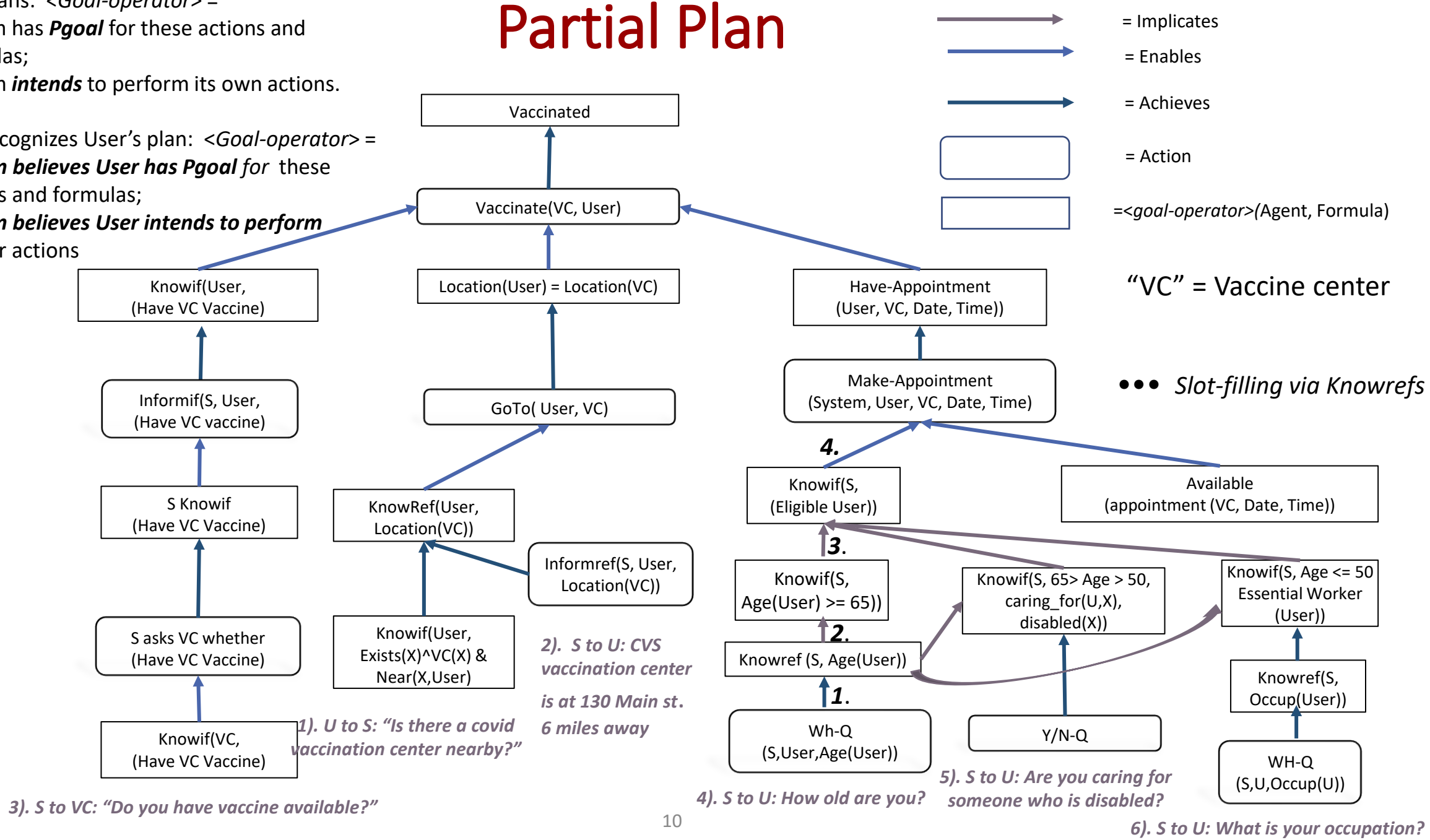
When S plans: *<Goal-operator>* =

- System has ***Pgoal*** for these actions and formulas;
- System ***intends*** to perform its own actions.

When S recognizes User's plan: *<Goal-operator>* =

- ***System believes User has Pgoal*** *for* these actions and formulas;
- ***System believes User intends to perform*** his/her actions

Partial Plan



Openstream.ai

Simple Planning

Backward chaining

- *Effect → Action, Action → Precond, (backward chaining)*
  - *Action → Body (hierarchical planning)*

Special Rules:

- *Know-value* – in order to do an action with obligatory arguments, the agent needs to know what those arguments are,
- *Know-if* – if Agent wants to achieve P, Agent needs to know whether P.
- *Reverse a negative state* – If Agent is in a negative state, Agent wants to be in the corresponding positive one

© 2022 Openstream Inc. Pats. Pending

Simple Plan Recognition

Plan Recognition Rules – forward chaining from action, (Allen &Perrault, 1980)

- *Precond* → *Action, Action* → *Effect, Body* → *Action* (plan parsing)
- *KnowPos, KnowNeg* (if you want to know whether P, you may want P to be true/false)

Special Rules

- *Normal Activity* (people want to go places to do the normal activities there),
- *Neg State* → *Positive state.*

  (If you are in a neg state (e.g., car is broken), you want to be in corresponding positive state (car is fixed)
- *Knowif-exists: Knowif(Exists(X)^P(X))* → *Knowref(X^P(X))*
- ….

© 2022 Openstream Inc. Pats. Pending

Openstream.ai

Knowref

- Knowref – agent knows the referent of the description X^p(X) (^ means such that).
  - E.g., John knows Mary's phone number – ***knowref(john,Ph^phone_number(mary, Ph))***
  - Is a "quantified-in" expression ***∃(Ph) bel(john, phone_number(mary,Ph))***
  - ***Stronger than John knows Mary has a phone number***
- Can quantify into other mental state operators too:
  - ***∃X#day^pgoal(john,do(john, reserve(john, Vittorio#restaurant, X#day)))*** --
    meaning there is a day that john wants to reserve Vittorio's restaurant
  - ***knowref(mary, variable:X#day, pred:pgoal(john,***
    do(john, reserve(john, Vittorio#restaurant, X#day))))
    meaning Mary knows the day that john wants to reserve Vittorio's
  - ***pgoal(mary, knowref(mary, variable:X#day,***
    pred:pgoal(john, do(mary, reserve(john, Vittorio#restaurant, X#day))))
    meaning Mary wants to know the day that John wants Mary to reserve Vittorio's for John

© 2022 Openstream Inc. Pats. Pending

Speech Acts

- Inform, offer, request, suggest, confirm, informref, informif, whq, ynq,
- Apologize, propose, accept, recommend, greet, …
- Reason about speech acts just like physical acts

Example: Wh-question

Speaker **asks a Whq** to Listener about the referent of Var such that Pred

"^"

Precond: Listener knows the referent of Var^Pred

Mary's phone number

Ph^phone_number(mary,Ph)

Effect: Speaker knows the referent of Var^Pred

(*Note: Effect doesn't become true by doing the speech act;*
Speaker has pgoal that it becomes true and Listener believes that)

Ask someone whom you think knows the answer! → Multi-person/agent dialogue

Openstream.ai

Example of slot-filling question

What time do you want to make an appointment?

System **asks a Whq** to Usr about *the time Usr wants to make an appointment*

Slot – quantifying-into a goal

Precond: Listener knows the referent of *the time Usr wants to make appointment*

Effect: Speaker knows the referent of *the time Usr wants to make appointment*

Dialogue occurs when this question is constructed from the Action definitions (e.g., Make-appointment), via Know-val inference during the planning process, and then the plan is executed.

Openstream.ai

Explanation

- Major issue for AI systems,

  especially those based on Deep Learning

- *"Why did you say that?"*
- Plan-based systems are *inherently* explainable
- Actions achieve goals, which enable other actions
- Explain an action *relative to the plan* itself (cf Winograd, 1972)
- Example: Why did system ask "4). how old are you?"
- System asked 4) in order to determine if
  - User is eligible for a covid vaccination, which enables
  - System's making an appointment for User.

© 2022 Openstream Inc. Pats. Pending

Openstream.ai

Advantages

(see also Cogent system (Galescu et al., 2018))

- ***Principled approach to dialogue***
  - Principled basis for assisting a user by inferring/debugging plans
  - Principled approach to multi-agent/multi-person interaction
- ***Don't "design/script dialogues"***
  - Specify the domain actions and knowledge
  - Speech act interpretation and planning/plan recognition/inference do the rest
  - System reasons about what to say, and why user said what s/he did
- ***Domain-independent reasoning process applied to domain dependent data***
  - Enough reasoning for advances in commercial state-of-the-art
- ***Explanation***
  - System has a plan for everything it says/does; system knows what it is doing
  - Explanation is derived from the plan
- ***Factors the variability***
  - More in the ASR/NLP, less in the Dialogue Manager
  - Of course, need to have better NLU/NLG, for which we use NNs
- ***Basis for choosing emotional expressions for avatars (see Gratch and Marsella, 2004, …)***

© 2022 Openstream Inc. Pats. Pending

Concluding Remarks

- Principled approach to dialogue
- Virtual Assistant System that actually *assists* its user
- Explainable
- Factors variability
- Basis for multiparty communication
- Basis for multimodal communication

© 2022 Openstream Inc. Pats. Pending