Design of Physically Grounded Communication System
実世界指向コミュニケーション特論

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Real World Interaction

Willie

You say "Willie, bring me a beer." The robot replies "OK, boss." Twenty minutes later, you screech "Willie, why didn't you bring that beer?" It answers "Well, I intended to get you the beer, but I decided to do something else." Miffed, you send the wise guy back to the manufacturer, complaining about a lack of commitment.

Definition 3.24. $(\text{A-GOAL x p}) \stackrel{\text{def}}{=} (\text{GOAL x (LATER p)}) \wedge (\text{BEL x } \neg\text{p})$.

(A-GOAL w (bring beer boss)) = (GOAL w (LATER (bring beer boss)) ^ (BEL w ¬(bring beer boss))

Willie can drop the A-GOAL because GOAL depends on the belief of Willie .

Proposition 3.26. $\models (\text{BEL x p}) \supset (\text{GOAL x p})$.

(BEL w (bring beer boss)) ⊃ (GOAL w (bring beer boss))

Willie does not have a program of "intention" for achieving an action.

Willie with Model C

After retrofitting, Willie is returned, marked "Model C: The Committed Assistant." Again, you ask Willie to bring a beer. Again, it accedes, replying "Sure thing." Then you ask: "What kind did you buy?" It answers: "Genessee." You say "Never mind." One minute later, Willie trundles over with a Genessee in its gripper. This time, you angrily return Willie for overcommitment.

Definition 6.1. WC never finishes the action (bring beer).

$$(\text{INTEND}_1\ x\ a) \stackrel{\text{def}}{=} (\text{P-GOAL x } [\text{DONE x } (\text{BEL x } (\text{HAPPENS a}))?;a])\ ,$$

(INTEND1 wc (bring beer)) = (P-GOAL wc [DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))].

Definition 4.1.

$$(\text{P-GOAL x p}) \stackrel{\text{def}}{=} (\text{GOAL x (LATER p)}) \wedge (\text{BEL x } \neg\text{p}) \wedge [\text{BEFORE } ((\text{BEL x p}) \vee (\text{BEL x } \Box\neg\text{p}))\ \neg(\text{GOAL x (LATER p)})]\ .$$

Moreover, the boss cannot stop the WC action.

(P-GOAL wc [DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))]
= (GOAL wc (LATER [DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))] ^
(BEL wc ¬[DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))] ^
[BEFORE ((BEL wc [DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))] v
(BEL wc □¬[DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))])),
¬(GOAL wc [DONE wc (BEL wc (HAPPENS (bring beer))?; (bring beer))]].

Willie with Model C2

After still more tinkering, the manufacturer sends Willie back, promising no more problems with its commitments. (edit), but as a test, you ask it to bring you your last beer. Willie again accedes, saying "Yes, Sir." (Its attitude problem seems to have been fixed.) The robot gets the beer and starts towards you. As it approaches, it lifts its arm, wheels around, deliberately smashes the bottle, and trundles off. Back at the plant, when interrogated by customer service as to why it had abandoned its commitments, the robot replies that according to its specifications, it kept its commitments as long as required---commitments must be dropped when fulfilled or impossible to achieve. By smashing the last bottle, the commitment became unachievable.

Definition 8.3.

$$(\text{INTEND}_2\ x\ p\ q) \stackrel{\text{def}}{=} (\text{P-R-GOAL x } \exists e\,(\text{DONE x } [(\text{BEL x } \exists e'\,(\text{HAPPENS x e';p?})) \wedge \neg(\text{GOAL x } \neg(\text{HAPPENS x e;p?}))]?;e;p?)\ q)\ .$$

(INTEND2 WC2 (bring beer boss) (request boss wc2)) =
(P-R-GOAL wc2 ∃ e(DONE wc2 [BEL wc2 ∃ e' (HAPPENS wc2 e'; (bring beer boss) ?))^
¬(GOAL wc2 ¬(HAPPENS wc2 e; (bring beer boss)?))]?;e; (bring beer boss) ?)
(request boss wc2)).

Willie with Model C2

Definition 8.1. *Persistent, relativized goal:*

$$(\text{P-R-GOAL x p q}) \stackrel{\text{def}}{=} (\text{GOAL x (LATER p)}) \wedge (\text{BEL x } \neg\text{p}) \wedge [\text{BEFORE } [(\text{BEL x p}) \vee (\text{BEL x } \Box\neg\text{p}) \vee (\text{BEL x } \neg\text{q})]\ \neg(\text{GOAL x (LATER p)})]\ .$$

(P-R-GOAL wc2 ∃ e(DONE wc2 [BEL wc2 ∃ e' (HAPPENS wc2 e'; (bring beer boss) ?))^
¬(GOAL wc2 ¬(HAPPENS wc2 e; (bring beer boss)?))]?;e; (bring beer boss) ?)
(request boss wc2)).

the robot replies that according to its specifications, it kept its commitments as long as required---commitments must be dropped when fulfilled or impossible to achieve. By smashing the last bottle, the commitment became unachievable.

Why did Willie smash the bottle even though P-R-GOAL prevents it to do an action which makes the goal impossible?

Social Commitment and Social Rule

Definition 8.3.

$$(\text{INTEND}_2\ x\ p\ q) \stackrel{\text{def}}{=} (\text{P-R-GOAL x } \exists e\,(\text{DONE x } [(\text{BEL x } \exists e'\,(\text{HAPPENS x e';p?})) \wedge \neg(\text{GOAL x } \neg(\text{HAPPENS x e;p?}))]?;e;p?)\ q)\ .$$

(INTEND2 a (obey a rule) (obey b rule)): A obeys the rule while b obeys the rule.

(INTEND2 b (obey a rule) (obey a rule)): B obeys the rule while a obeys the rule.

A and B keeps a social rule based on mutual commitment.

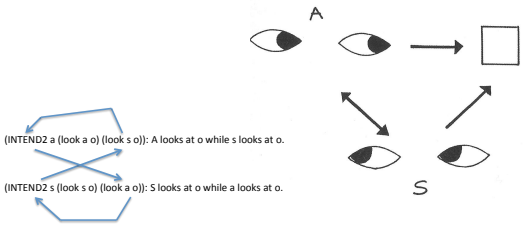
Joint Attention for a social communicaiton

- Pay their attentions to the same thins
- Base of social interaction
  - Mind-reading

Joint Attention for a social communicaiton

- Development of an infant
  - Interaction between a mother and her baby
  - Studies on autism children (自閉症児)

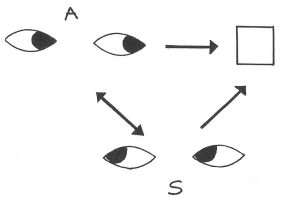
Joint attention



A and B pay their attention to o based on mutual gaze awareness

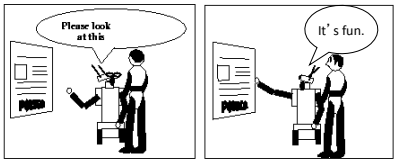
Joint attention

- People understand what the other says based on Joint Attention (especially when using a pronoun).

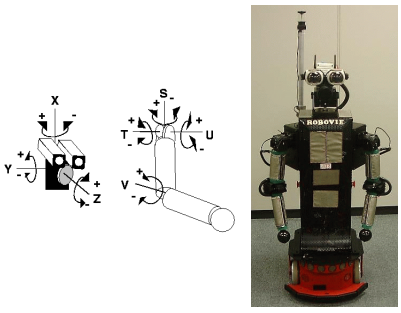


The Effect of Joint attention for Pointing Behavior

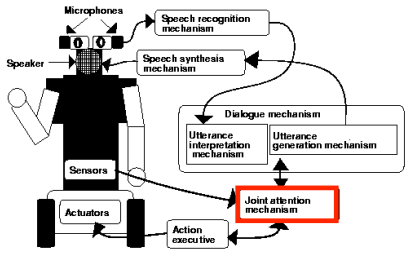
- Joint attention toward the poster



5.5.11 Communication Robot Robovie

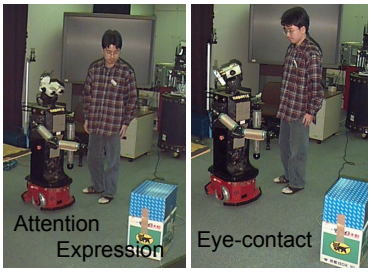


Joint Attention Mechanism II



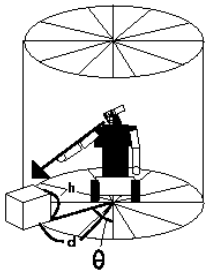
Real world interaction

Joint Attention Mechanism II
Pointing Behavior and Gaze Motion



Real world interaction

Attention Coordinate



Real world interaction

Experiment

- Confirm the effect of eye-contact and attention Expression on a pointing behavior.
  - Condition1 Pointing behavior with eye-contact and attention expression
  - Condition2 Pointing behavior without them

Real world interaction

Experiment

- Twenty subjects
  - Condition1 Pointing behavior with eye-contact and attention expression
  - Condition2 Pointing behavior without them
- They were given an instruction.
  - Please obey a robot's utterance.

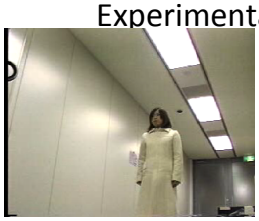
Real world interaction

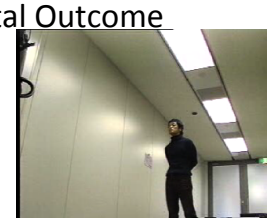
Experiment

- Prediction
  - Condition1 Pointing behavior with eye-contact and attention expression
    - Subjects will understand what the word "this" refers to.
  - Condition2 Pointing behavior without them
    - Subjects wont.

Real world interaction

Experimental Outcome





Condition1: with eye-contact and attention Expression

All subject (10 persons) looked at the poster.

condition2: without them

Only one person (10 persons) looked at it.

The other 9 looked at the hand.

The effect of Joint Attention for a communication

- Theory of Mind Model

EDD and SAM

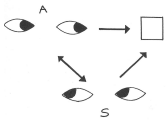
- EDD: Eye Direction Detector <- a brain function
  - Detects someone directs gaze to me.
- SAM: Shared Attention Mechanism
  - Detects the establishment of joint attention.
- EDD and SAM are acquired in the course of evolution to maintain social activities.

(INTEND2 a (obey a rule) (obey b rule)): A obeys the rule while b obeys the rule.

(INTEND2 b (obey a rule) (obey a rule)): B obeys the rule while a obeys the rule.

EDD

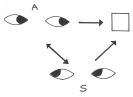
- What does someone look at?
  - Identify where is an enemy.



- The basis of joint attention
- Insufficient for joint attention

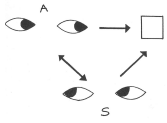
EDD

- Dyadic representation (二項表象)
  1. [agent -relation- self] , bidirectional
     - [mother -look-at- me], [I -look-at- mother]
  2. [agent -relation- proposition], one way
     - [mother -look-at- bus]
  3. [agent1 -relation- agent2], bidirectional
     - [mother -look-at- father], [father -look-at- mother]
  4. [self -relation- proposition], one way
     - [I -look-at- house]



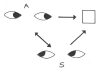
SAM

- Triadic representation (三項表象)
  - Identify whether the other pays attention to the same thing.
  - Only EDD cannot recognize the affair.



SAM

- Triadic representation (三項表象)
  - Nest structure
    1. [self -relation- (other -relation- proposition)]
       - bidirectional
       - [I -look-at- (mom -look-at- bus)]
       - [mom -look-at- (I -look-at- bus)]
    2. [self -relation- (other1 -relation- other2)]
       - bidirectional
       - [I -look-at- (mom -look-at- dad)]
       - [I -look-at- (dad -look-at- mom)]
       - [mom -look-at- (I -look-at- dad)]
       - [mom -look-at- (dad -look-at- me)], etc…

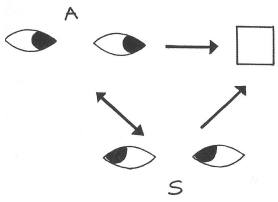


SAM

- Complex structure of triadic representation
  - [self -relation- (other -relation- (self -relation- proposition)]
  - [other -relation- (self -relation- (other -relation- proposition)]
  - [self -relation- (other -relation- (self -relation- (other -relation- .....))]

SAM

- 2D representation of triadic representation



SAM

- Gaze direction
- EDD
- Dyadic representation
- SAM
- Triadic representation

SAM and ToMM

- SAM introduces a viewpoint to consider other's intention or goal in the triadic representation.
  - Humans infer other's intention or motivation form other's gaze direction.
- Base of ToMM (Theory of Mind Mechanism)

SAM and ToMM

- An infant watched eyes to confirm someone's intention.
  - 9th-18th month infants
  - Eye-contact: An experimenter hide a thing intentionally when their hand reaches it.
  - No eye-contact: otherwise.
- Watching eyes is a cue to infer intention.

SAM and ToMM

- 3--4 years old kids

SAM and ToMM

- What sweet does Charlie get?
- What does Charlie want?
- What does Charlie mention?

SAM and ToMM

- EDD -> SAM -> ToMM
  - Evidence of the relation comes form studies on autism.

Joint attention and autism

- Autism kids have EDD but do not have SAM.
  - They recognize that someone is looking at them.
  - They cannot behave based on joint attention.
- They can handle dyadic representation
- but cannot deal with triadic representation.

↓

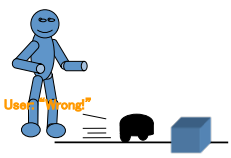
- They cannot read other's mind or intention.

Joint attention and autism

- Autism kids do not carry out eye-contact.
- They are not good at finding an item where someone directs his/her gaze.
- Lack of SAM, although they have EDD.

Theory of Mind and Robot

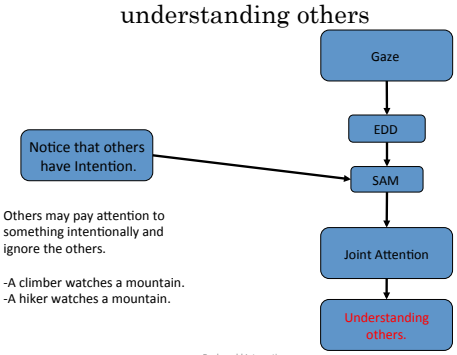
The human must also direct his attetnion.



Theory of Mind and Robot

- Joint attention
- Eye-contact
- Robot's intention

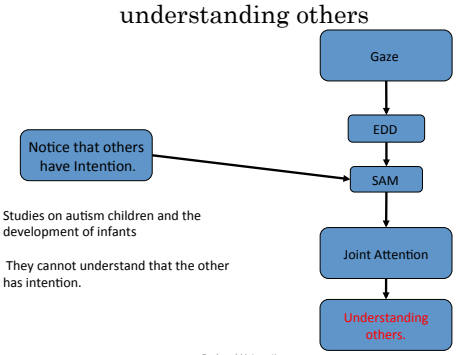
Intention, joint attention, and understanding others



Others may pay attention to something intentionally and ignore the others.

-A climber watches a mountain.
-A hiker watches a mountain.

Intention, joint attention, and understanding others

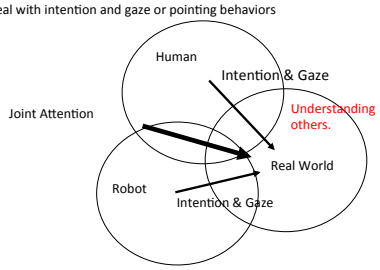


Studies on autism children and the development of infants

They cannot understand that the other has intention.

Intention, joint attention, and understanding others

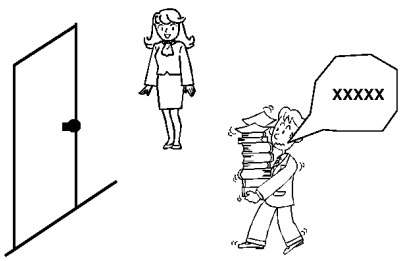
How to deal with intention and gaze or pointing behaviors



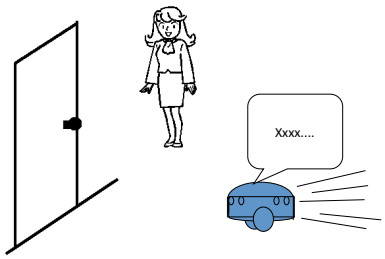
The Effect of ToMM

- A robot requests a human to do a task.
  - Joint Attention
  - Mind reading
  - The development of relationship

The Effect of ToMM



The Effect of ToMM



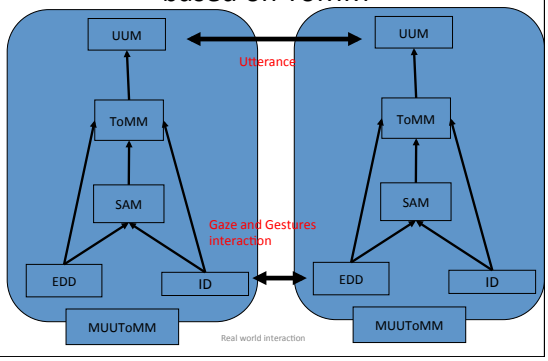
Real world interaction

Hypothesis

- By reading a robot's mind, a human can estimate the robot's intention with ease, and, moreover, the person can even understand the robot's unclear utterances made by synthesized speech sounds.

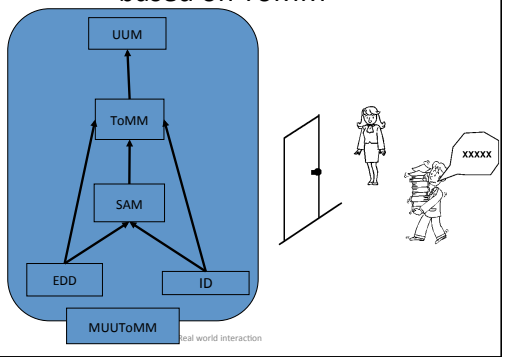
Real world interaction

Model of Utterance Understanding based on ToMM



Real world interaction

Model of Utterance Understanding based on ToMM



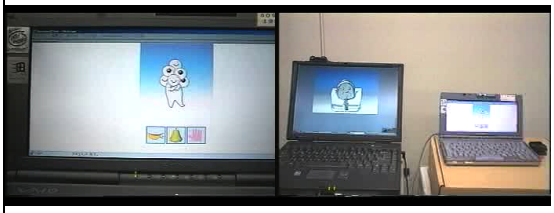
Real world interaction

Robot System

- Lack of appearance to enhance ID, EDD and SAM
  - Without the appearnce, human does not regard robots as autonomous beings with intention
- Agent mediated communication interface

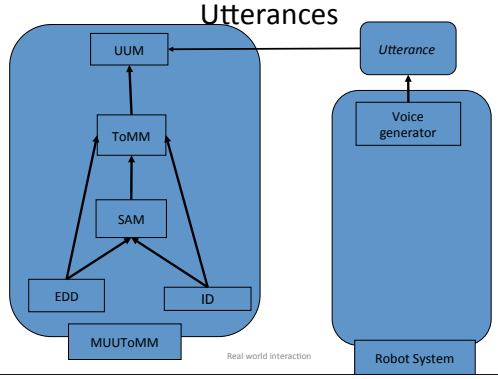
Robot System Agent Migration

- CG character as an autonomous being
- Agent migration gives the robot relationship with the human.

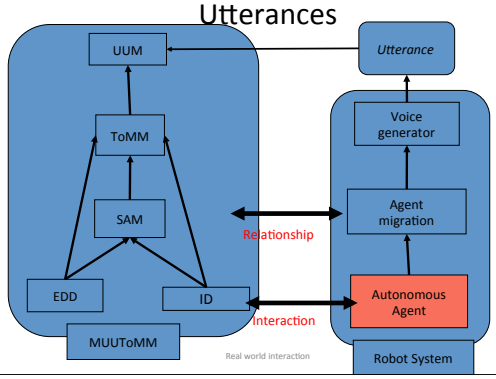


Real world interaction

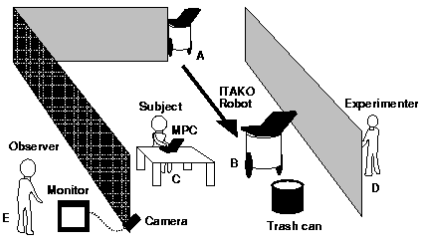
Understanding a Robot's Utterances



Understanding a Robot's Utterances



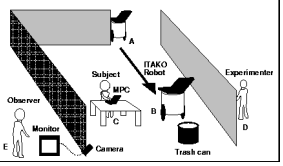
Experiment



Experiment
Experimental Conditions

1. The agent migrates on the robot when the robot generates an utterance
2. The agent does not migrate.

- Twenty subjects were divided into two groups
- The experimenter observes responses of the subjects.



Hypothesis and Prediction

- By reading a robot's mind, a human can estimate the robot's intention with ease, and, moreover, the person can even understand the robot's unclear utterances made by synthesized speech sounds.

Hypothesis and Prediction

1. The subjects will regard the robot as an autonomous entity with intention (ID, EDD).
2. The subjects will first look at the robot and then turn their eyes to the trash can (SAM).
3. The subjects will be able to estimate the robot's intention with ease, and this will facilitate their understanding of the robot's utterance (ToMM, UUM).

Experimental Outcome


	With agent migration	Without agent migration
Utterance Understanding	8/10 persons	3/10 persons
Moving the trash can	8/10 persons	1/10 persons

Experimental Outcome

1. The subjects regarded the robot as an autonomous entity with intention (ID, EDD).
2. The subjects first looked at the robot and then turned their eyes to the trash can (SAM).
3. The subjects estimated the robot's intention with ease, and this facilitated their understanding of the robot's utterance (ToMM, UUM).

The effect of eye-contact

- Experiment on Agent Migration Mechanism
  - Significance of Mind reading
- Primary functions for mind reading
  - EDD -> SAM -> ToMM
- Eye-contact
  - Confirmation of the other's intension

Joint Attention and Theory of Mind for Humanoid-robots

- What factor induces joint attention and mind-reading phenomena for humanoid-robot?

Joint Attention Mechanism

- The effect of eye-contact
- Pointing behavior
- The degree of embodied expressions and language expressions
- The degree of development of joint attention and language expressions