The evolution of communication

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Outline

- ECAgents project
- Communication
  - definitions
- Previous work
- Current results
- Future work ideas

Communication
Merriam - Webster

- 1 : an act or instance **of** transmitting
- 2 a : information communicated b : a verbal or written message
- 3 a : a process by which information is exchanged between individuals through a common system of symbols, signs, or behavior <the function of pheromones in insect communication>; also : exchange of information b : personal rapport <a lack of communication between old and young persons>

Communication
Definitions

1) The coordinated behaviours mutually triggered among the members of a social unity (*Maturana - Varela*)
   - Not (necessarily) result of distinct mechanism but takes place in domain of social behaviours
2) Occurs when the action or cue given by one organism is perceived by and thus alters the probability pattern of behaviour in another organism in a fashion adaptive to either one or both participants (*Wilson*)
3) When an actor does sth which appears to be the result of selection to influence the sense organs of the reactor, so that the latter's behaviour changes to the advantage of the actor (*Krebs – Dawkins*)
4) A matter of causal influence...the communicator must construct an internal representation of the external world, and then...carry out some symbolic behaviour that conveys the content of that representation (*Johnson - Laird*)

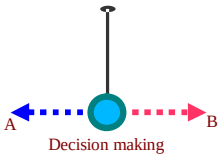
Communication
Examples in Robotics

1) Infra-Red communication
   (i.e. Quinn-Federico)
2) Sound Signaling
   (i.e. Vito)
3) Traction Sensor
   (i.e. Vito)
4) Other – i.e. Colour turret
   (i.e. Shervin)

Communication
Choices - Issues

- Simple Sound System
  - no directionality
  - no intensity features
  - simple threshold (ON/OFF)
- Separated communication channel
- Communication not hard-wired
  - We are interested in its emergence
- How does an effective communication system arise in a group of initially non-communicating agents?

Previous work
Decision Making Mechanisms



What if
- decision making is not fixed in space and time?
- it is difficult for us to disambiguate the actions before and after the decision?

Signaling can facilitate the design of the fitness function in a decision making scenario
- the robot "communicates" its decision to an observer

Previous work
Evolving communicating agents

- The Task:

Env. A *Env.B* *Communication*

- Signaling rewarded – Reaction NOT rewarded
- communicating and non-communicating agents score the same
- communication will emerge if **signaling** and **reacting** to signal acquired adaptive significance

Previous work
Results

- Communication DID emerge – there was reaction to the signal produced
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  - since the signal is there, it will be used....
- So.... Let's also try to evolve the signaling!

Current work

- New Fitness Function
  - The task and the decision making part is not linked to the sound signaling
  - But if during evolution robots have ears and mouth, can they use them???
  - Why? – How?
- Emergence of communication not trivial
- 2 setups :
  - Single sound input-thresholded
  - Separated inputs-thresholded

Current work
Results

- Setup identical as before
  - Target to transfer to reality
- Communication DOES emerge
  - Mechanism similar to predicted for single input case
    - Signaling linked to decision-making (EnvB)
  - Reaction to signal linked to action (go away)

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- Why?
  - No noise setup DID not produce communication!
  - So due to noise!
  - Evaluation of genotype by average of two robots

Testing on real robots

Robustness
Scalability
CTRNN to reality

Beneficial effect of communication due to
Big sensor/motor differences among s-bots

Parallelism

- We have sender-receiver (since the task is carried out first by one robot, due to noise)
- Sender-receiver can send signals with no exogenously specified meaning
- Sender has info about true world state
- Receiver reacts to sender's signal
- Signal acquires ability to transmit info as a result of the evolutionary process

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- **SIGNALING GAMES (LEWIS)**

Signaling games

sender	t	t'
S1	m	m'
S2	m	m
S3	m'	m
S4	m'	m'

$U_S(t,a)=1$, $U_S(t,a')=0$
$U_S(t',a')=1$, $U_S(t',a)=0$

receiver	m	m'
R1	a	a'
R2	a'	a
R3	a	a
R4	a'	a'

$U_R(t,a)=1$, $U_R(t,a')=0$
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Cheap talk
Aligned Utilities

R1	EnvA	EnvB
S1	s<0.5	s>0.5
S2	s<0.5	s<0.5
S3	s>0.5	s<0.5
S4	s>0.5	s>0.5

conventions

R2	s<0.5	s>0.5
R1	stay	leave
R2	leave	stay
R3	stay	stay
R4	leave	leave

Possible only
With separated
inputs setup

For both robots: $U_r(EnvA,stay)=1$, $U_r(EnvA,leave)=0$
$U_r(EnvB,leave)=1$, $U_r(EnvB,stay)=0$

What we want to investigate

- Signaling games theory can provide some sort of “formalisation”
  - Can we give sth back to game theory?
  - Can we gain sth by using game theory?
  - Advantages – differences? (ie. selective attention-the strategy is “changing” during the lifetime of the robots!)
- That was simple case of 2 states, 2 signals, 2 actions
- What about cases that we want
  - >2 ?
  - Not equal among them
- Can we design a task (and solve it!) with ER?
- Homogeneous vs Heterogeneous system
  - Homogeneous takes care of “rationality” assumption for free
  - For signaling games a homogeneous Σ might be able to simulate the game
  - Since every agent plays <S,R>, in the end S will play with R…

What we want to investigate (2)

- Can a signaling system be decoupled from the other mechanisms?
  - Loss of communication in an evolutionary run because the mechanism linked to is not good!
- Particularly interesting case: 2 robots live in a world and the information is spread among them
  - They have to combine it to be successful

COFFEE MACHINE

The end