Agent Communication

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Communicating Agents

- Communication: Syntax, Semantics, and Pragmatics
- Communication in Games
- Games in Communication
- Agent Communication Languages

Communication: Syntax, Semantics, Pragmatics

- Syntax: What is well-formed communication? Words, sentences, dialogues and conversations.
- Semantics: What is meaning carried by communication? What is the relation between communication form and the meaning they carry?
- Pragmatics: What are communication contexts and how is communication influenced by it?

Communication in Games: Cheap Talk

In cheap talk, players can communicate before taking actions.

- Communication is costless,
- Communication does not need to be truthful,
- Communication does not imply commitment

Cheap talk can be seen as a two-stage game.

- First stage: Player communicate.
- Second stage: Players decide actions.

	C	D
C	$2,2$	$0,3$
D	$3,0$	$1,1$

Let players be able to communicate before the game, e.g., Row player says he will cooperate. Does this change the game's outcome?

Communication in Games: Cheap Talk

How about this game? Does the game's outcome changes if the Row player declares to play U?

	L	R
U	1, 1	0, 0
D	0, 0	1, 1

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Cheap talk is not Worthless. It can affect the outcome of a game by changing one player's beliefs about another player's actions, and so selecting one equilibrium out of multiple equilibria.

Communication in Games: Cheap Talk

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- Self-Committing Utterance: Once uttered, and assuming it is believed, the declared action is the optimal one.
- Self-Revealing Utterance: Assuming it is uttered with the expectation that it will be believed, it is uttered only when it was the intention to act that way.

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The utterance "I play U" by the Row player is both self-committing and self-revealing.

In coordination games self-commitment and self-revelation are inseparable.

Self-Commitment and Self-revelation

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	Stag	*Hare*
Stag	$9, 9$	$0, 8$
Hare	$8, 0$	$7, 7$

The row player declares to play Stag. Is this self-revealing utterance? Is it a self-committing utterance?

Self-Commitment and Self-revelation

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The row player's utterance to play Stag is not self-revealing because row player would like column player to believe the utterance. The row player has not planned to play Stag as the mixed strategy equilibrium is 7.875 to play Stag (for both players).

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The utterance is self-committing because if row player thinks the column player believes it will plays Stag, then row player prefers to play Stag.

Self-Commitment and Self-revelation

	Stag	*Hare*
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Self-revelation plus self-commitment is certainly very credible. However, self-commitment alone is not credible.

We need intricate reasoning involving risk attitudes.

Revealing and Babbling Equilibria

- Babbling Equilibrium: An equilibrium that is not affected by a cheap talk, i.e., Row player sends a meaningless message and column player ignores it.
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Revealing Equilibria:

- Column player says (honestly) 'Stag' and both hunt Stag. Most likely if column player has a reputation for honest (risk analysis is required).
- Column player says (dishonestly) 'Hare' and both hunt Stag. Most likely if column player has a reputation for dishonesty (risk analysis is required).

Perfectly dishonest people are worth listening to for the same reasons as listening to perfectly honest people.

Revealing and Babbling Equilibria

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Babbling Equilibria:

- Column player says (dishonestly) 'Stag' and both hunt Stag. Most likely if column player is often ignored (risk analysis is required).
- Column player says (dishonestly) 'Stag' and both hunt Hare. Most likely if column player is often ignored (risk analysis is required).

Every cheap talk game has a babbling equilibrium.

Signaling Games: Games with Imperfect Information

Definition: A signaling game is a two-player game in which Nature selects a game to be played according to a commonly known distribution, player 1 is informed of that choice and chooses an action, and player 2 then chooses an action without knowing Nature's choice, but knowing player 1's choice.

A signaling game is an extensive game in which player 2 has incomplete information.

Signaling Games: Games with Imperfect Information

Revealing Private Information Prior to Act instead of revealing Intention to Act

Let the nature decides which game to play, i.e., the nature decides if the first player has High or a Low ability. Then, the first player, who knows his ability (i.e., which game to play), sends a signal to the second player about its ability level. Then, the second player decides which action to take.

	HA game
Signal high ability	3, 1
Signal low ability	0, 0

	LA game
Signal high ability	0, 0
Signal low ability	2, 1

Which signal should the first player send to the second player?

Signaling Games: Games with Imperfect Information

Row player knows which game is selected by the nature (equal probability). Row player chooses his message (U or D) and Column player (who does not know which game is being chosen by the nature) will choose his action (L or R).

	L	R
U	$4, -4$	$1, -1$
D	$3, -3$	$0, 0$

	L	R
U	$1, -1$	$3, -3$
D	$2, -2$	$5, -5$

Which signal should row player sends to column player?

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Which signal should row player sends to column player?

Equilibria are in dominant strategies. So, column player will play R if row player selects U, and L is row player selects D.

$$E(u_1) = (0.5)1 \ + \ (0.5)2 \ = \ 1.5$$

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Which signal should row player sends to column player?

A better strategy for row player is to always select D.

$$E(u_1) = (0.5)(3p + 0(1-p)) \ + \ (0.5)(2p + 5(1-p)) \ = \ 2.5$$

given column player plays L with probability p and R with probability $1 - p$.

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Which signal should row player sends to column player?

It is not always an advantage to exploit the privileged information.

Speech Act Theory

- Communication in multi-agent systems is inspired by Speech Act Theory (Austin, 1962).
- Speech Act Theory is a pragmatic theory of language. How is language used by people for achieve their objectives?
- Utterances are like physical actions, changing the state of the world.
- Declaration of war and marriage, promise, stating, asking, etc.
- Planning can be used to decide how to communicate.

Speech Act Theory: Three Levels of Analysis

- Locution: the act *of* saying something; the emission of a signal carrying a meaning. E.g., There is a car coming in your way.
- Illocution: the act performed *in* saying something; the performance of a conventional force on the receiver through the utterance. E.g., Warning that a car is coming in your way.
- Perlocution: doing something by *by* saying something; the effect of the illocutionary act on the hearer (external to the performance). E.g., Making the hearer to avoid the car.

Speech Acts in Multi-Agent Systems

- - Locution: ”the door is closed”
  - Illocution: Request
  - Perlocution: Please close the door
- - Locution: ”the door is closed”
  - Illocution: Inform
  - Perlocution: the door is closed!
- - Locution: ”the door is closed”
  - Illocution: Inquire
  - Perlocution: is the door closed?

Plan-based Semantics for Speech Acts: $Request(s, h, \phi)$

- pre-condition
  - s believes h can do ϕ
  - s believes h believes h can do ϕ
  - s believes s wants ϕ
- post-condition
  - h believes s believes s wants ϕ

Agent Communication Languages

- KQML: Knowledge Query and Manipulation Language. It defines the outer communication language and provides a set of speech acts (ask-if, perform, tell, reply).
- KIF: Knowledge Interchange Format. It defines the message content.

```
A to B: (ask-if (> (size chip1) (size chip2)))
B to A: (reply true)
B to A: (inform (= (size chip1) 20))
B to A: (inform (= (size chip2) 18))
```

- FIPA: Foundation for Intelligent Physical Agents

```
(inform
    :sender agent1
    :receiver agent5
    :content (price good200 150)
    :language sl
    :ontology hpl-auction
)
```

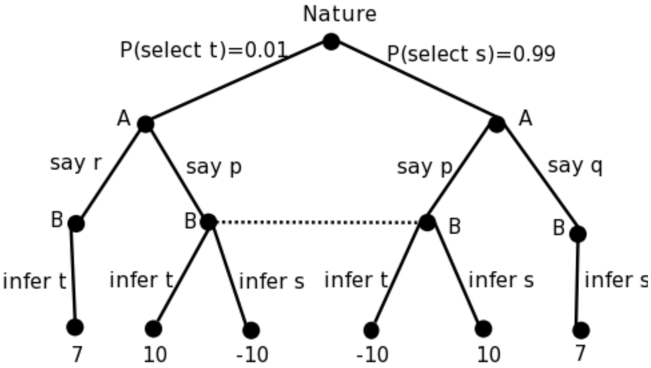
Rules of Conversation

- Grice's Cooperative Principle
  - Quantity: Provide exactly the amount of information required in the conversation.
  - Quality: Provide information that are true or believed to be true.
  - Relation: Prov ide information that are relevant to the conversation.
  - Manner: Provide information clearly and briefly.
- Conversational Implicature: Grice's principle may help avoiding unwanted implicatures.

A Game Theoretic View of Communication

- Two situations S and T, with two players A and B:
  - S: Mugging different people take place at ten-minutes intervals in NYC.
  - T: The same person is repeatedly mugged in NYC.
- Nature selects between S and T according to a distribution known to A & B.
- Nature's choice is revealed to A, but not B.
- A decides between uttering one of the following three sentences:
  - p: Every ten minutes a person gets mugged in NYC.
  - q: Every ten minutes some person or another gets mugged in NYC.
  - r: There is a person who gets mugged every ten minutes in NYC
- B hears A, and decides whether S or T obtains.

A Game Theoretic View of Communication



The equilibria of the game:

- A's Strategy: say q in s and r in t. B's Strategy: when hearing p, select between s and t with equal probability.
- A's Strategy: say p in s and r in t. B's Strategy: when hearing p, select s.