

# Emergence of Communication among Cooperative and Competitive Agents

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## MOTIVATION

The emergence of language is a significant problem in linguistics, psychology and computer science. Giving artificial agents, especially neural networks, the ability to exchange information and interact can:

- help understanding the emergence of language in humans
- make neural networks more flexible and, maybe, more explainable
- develop artificial agents able to interact with humans

## SETTING

- **Communication is emergent from scratch:** agents are provided with a discrete communication channel with no predefined meaning. During the learning the agents assign a shared meaning to the symbols.
- Learning takes place using **Reinforcement Learning**.

Many studies showed how communication emerges in multi-agent collaborative scenarios, but there is little work in **competitive and mixed motives scenarios**.

### Current Research Questions

- Can communication foster cooperation over competition?
- Can competition foster the emergence of a more complete and explanative communication?
- What happens to the communication if the agents, instead of having only communicative actions, can also take “real” actions?

## WHY COMPETITION?

If the objectives of the agents are not aligned, communication is not guaranteed.

However, many game theoretic papers show how, if competitive agents send **costly signals**<sup>4</sup>:

- communication can emerge
- agents are able to realign their goals.

## EXPLAINABILITY

In the emergent communication setting, explainability may relate to different questions. Explainability may mean:

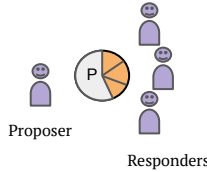
- study features of the emerging language
- understand how to measure effective communication
- explainable (deep) Reinforcement Learning (XRL)

## PROPOSED SCENARIOS



### Public Good Game

- Each player has some coins and decides how many of those to put in the public pot
- The coins in this pot are then multiplied by a factor and the “public good” payoff is evenly divided among players
- The general equilibrium of those games is **free-riding**: no-one contributes to the common pool.

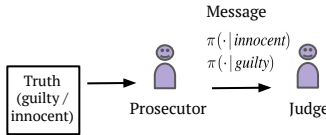


### Ultimatum Game

- Multiplayer game composed by  $N \geq 2$  players
- A proposer offers a certain fraction  $p$  of some valuable good to the other  $N-1$  players, which will receive  $p/N$  amount of the good each.
- The total group accepts the proposal if at least 50% (or a defined quorum) of the receivers accept the proposal.

### Bayesian Persuasion

- The judge must choose if to acquit or convict a defendant
- The defendant is either guilty or innocent
- The judge gets utility 1 for choosing the correct action (convict when guilty and acquit when innocent) and utility 0 for choosing the incorrect action. The prosecutor gets utility 1 if the judge convicts and utility 0 if the judge acquits, regardless of the state.
- The prosecutor chooses  $\pi$  and must honestly report the signal realization to the judge.



## ONGOING WORK

- Implementation of reinforcement learning agents playing the game (neural networks with two linear layers).

Currently addressing the following points:

- How to insert communication in the game and how to perform learning on it
- Vary the degree of competitiveness of the game.
- What is the role of uncertainty in learning to communicate?
- How to measure effective communication?<sup>1</sup>

## REFERENCES

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