Multi-Agent Systems
- Lab 9 – Tragedy of Commons -

1. Introduction

Objectives of lab:

- Study game theoretical aspects of multi-agent interaction on hand of a classic problem: Tragedy of the Commons
- Exploit communication to determine/influence strategy of other agents
- Achieve a cooperation strategy which maximizes the **social welfare**
- Evaluate student solutions collectively :-)

1. Introduction

Tragedy of the Commons

- Situation that arises when there is a **finite resource** that is **shared** by several agents
- Each agent has a **utility directly proportional** to his **share** of the common resource, **as well as** to how much of it remains for future regeneration
- Examples:
  - William Forster Lloyd (1833)
    - Cattle herders sharing a common parcel of land (the commons) on which they are each entitled to let their cows graze. If a herder put more than his allotted number of cattle on the common, overgrazing could result
    - Each additional animal has a positive effect for its herder, but the cost of the extra animal is shared by all other herders, causing a so-called **“free-rider”** problem. Today’s commons include fish stocks, rivers, oceans, and the atmosphere.

2. Game Setup

- *N* agents
- Each agent *i=1..N* decides on a *share* k_i of a common resource *K* (e.g. air in the atmosphere) to use for its own production utility
- Amount of *free remaining air* is $K - \sum_{i=1}^{N} k_i$

- Each individual agent utility is computed as follows:

$$u(a_i, a_{-i}) = \ln(k_i) + \ln(K - \sum_{i=1}^{N} k_i)$$

- The social utility function is the sum of individual utilities

$$w(a_1, a_2, \ldots, a_N) = \sum_{i=1}^{N} \ln(k_i) + N \cdot \ln(K - \sum_{i=1}^{N} k_i)$$

3. Game Config and Environment

- Game has *nr_rounds* rounds of play (agents do not know *nr_rounds*)
- The game starts out with an amount *nr_resources (K)* of the common resource
- Each round has 2 stages
  - Stage 1: agents provide their initial *share* (k_i) of the amount of resource remaining after the previous round
  - Stage 2: Adjustments
    - All agent receive the k_i shares of every other agent
    - Agents have *nr_adjust_rounds* adjustment rounds to (i) alter their share, (ii) ask that other agents alter their share
  - After *nr_adjust_rounds* or when all agents are content with their utility, the round ends and the resource amount is reduced by the total agent share
  - If the resource amount falls below 0, the game ends abruptly

4. Development

- You only have to implement your own agent strategy
- Three functions
  - `specify_share`: agents return their initial share at beginning of round
  - `negotiation_response`: agent provides his share update and/or desire for altering other agent's shares, based on his utility
  - `inform_round_finished`: agent can react to notification of round finish

5. Tasks

- Implement your own agent strategy
- Double objective: **equity** and **maximal social welfare**
  - Avoid having agents that do not respond to social inequalities :-)
- Create plots of individual **cumulated** agent shares as rounds progress