Skier behaviour modeling with multi-agent systems

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Multi-agent systems basics

What is an agent?

An agent is a software entity that can act independently and make decisions, towards a goal.

- software entity - a well-defined program
- act independently - can act without human intervention
- make decisions - based on behaviour, available information, environment, etc.
- goal - an objective set for the agent to achieve

Multi-agent systems

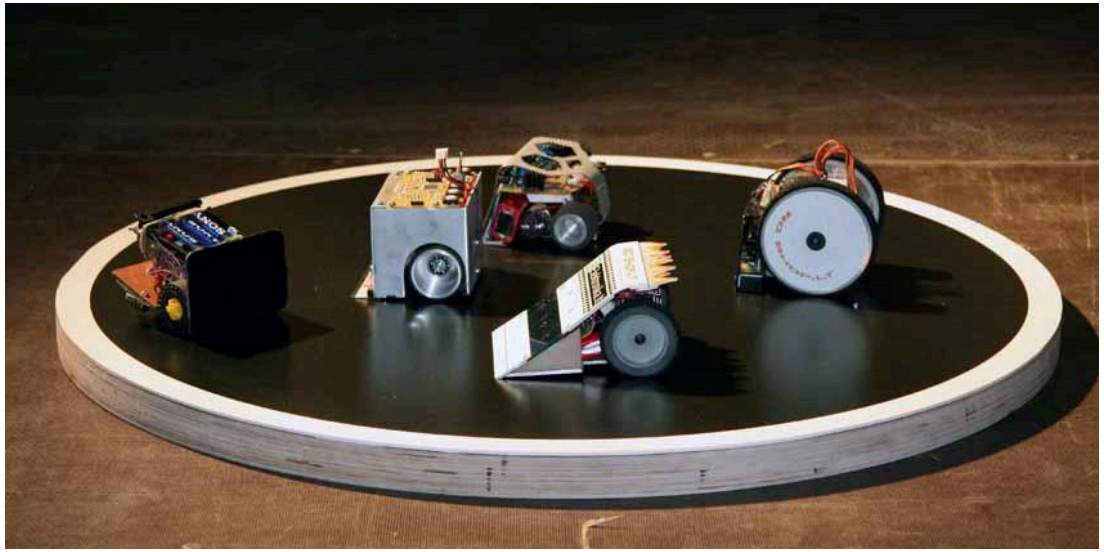
A multi-agent system is a system that consists of multiple agents acting togather in a well-defined environment.

The environment represents a key element of the system, as it defines:

- the boundaries of the system
- the context in which the agents operate

Example

- Let's take an example from robotics.
- Each robot is an agent (through the software entity)
- The environment is the arena
- The goal is to push the opponent out of the arena
- Robots make decisions based on the available information (e.g. the position of the opponent)



Environment models

- Environments are key components when defining the multi-agent system

We can define environments using a set of features:

- accessibility
- observability
- determinism
- static/dynamic
- discrete/continuous
- real time

Accessibility

An accessible environment is one where agents can reach all parts of the environment.

- An inaccessible environment is one where agents cannot reach all parts of the environment.

Example: a game of chess is an accessible environment, as the board is accessible to both players.

Observability

In an observable environment, agents can get full information about the environment state

- In a partially observable environment, agents can get only partial information about the environment state

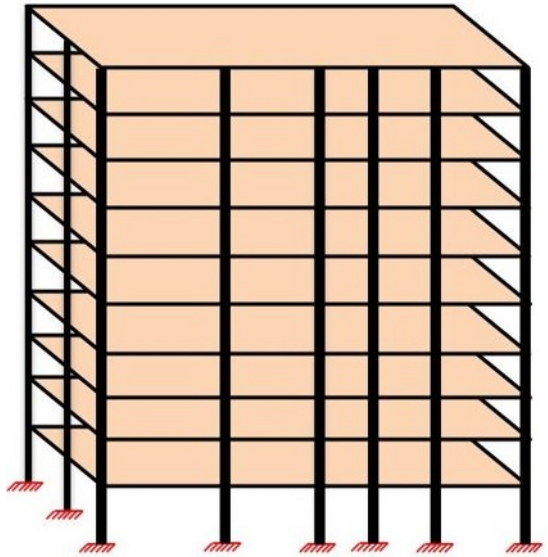
Example: A game of chess is an observable environment, as the state of the game is visible to both players.

Can you think of an example of a partially observable environment?

Determinism

When all agent actions have a guaranteed effect on the environment, the environment is deterministic.

- If the effect depends on probabilities, the environment is stochastic or non-linear.

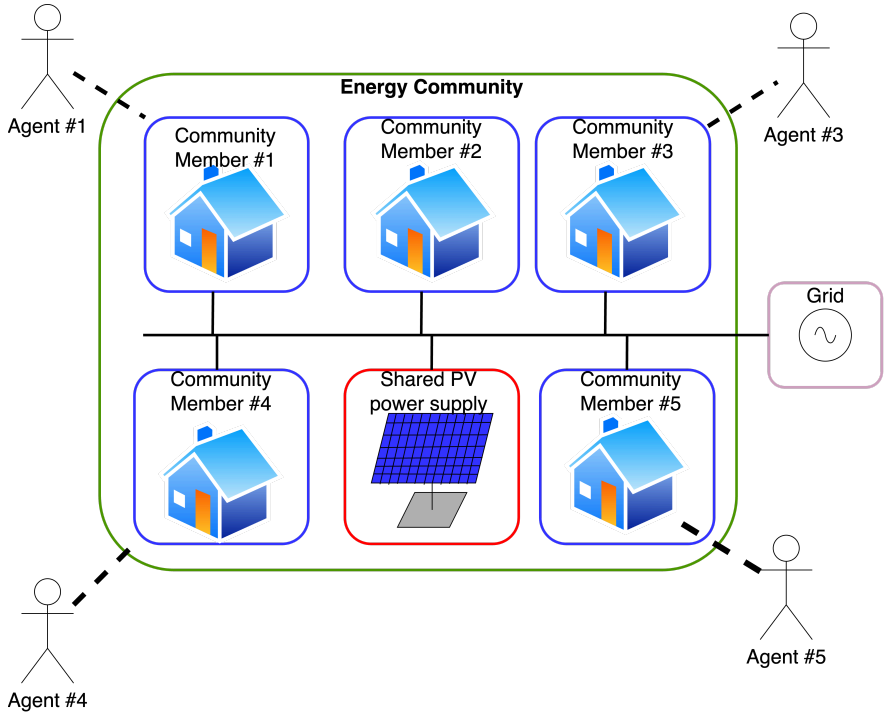


Example: simulating the reaction of a builiding to an earthquake, where:

- *an agent can be a person and may have a different reaction to the earthquake.*
- *the building may have different structural elements (each store is an agent), which may have different non-linearreactions to the earthquake.*

Static/Dynamic

- A static environment is one where the environment does not change in time or as a consequence of agent actions.
- A dynamic environment is one where the environment changes over time.



For example, an energy community may be a dynamic environment if the structure of the grid changes over time.

Discrete/Continuous

- A discrete environment evolves a in fixed number of steps.
- A continuous environment evolves in a continuous manner.

Typically, we use discrete environments for simulations, as they are easier to implement and analyze.

Real-time

- A real-time environment is one where the environment changes according to the current time.
- A non-real-time environment is one where an artificial time-span is used to simulate the environment.

Example:

- a simulation of the car traffic in a city can be done over a limited time-span

Key takeaways

- Typically, innaccesible, non-deterministic, dynamic, continuous, real-time environments are the most challenging to model (classified as *open* enviroments (Hewitt, 1986)).
- To simplify the modelling of such environments, we must focus on the problem that must be solved by the system.

Behaviour modeling

Agent attributes

Agents typically have 3 main attributes:

- Perception - how agents aquire information
- Decision making - the process of selecting an action based on the environment, state, goals, etc.
- Actions - how agents act in the environment and/or with other agents
- Goals - the global objective of the agent

Other attributes can be added to the agent, depending on the problem domain:

- Memory - how agents store and retrieve information
- State - how agents maintain a state

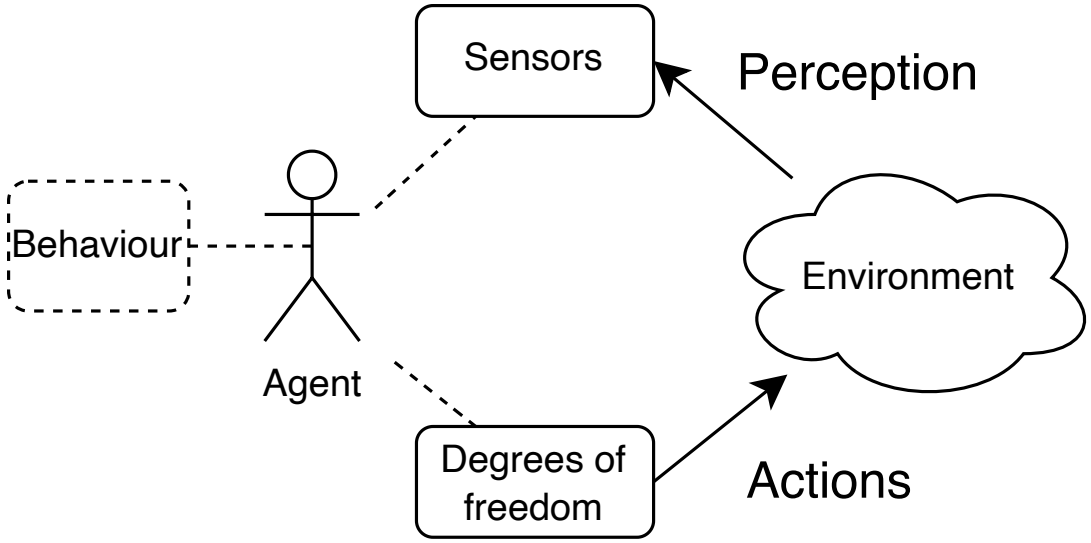
Agent attributes

Many of the attributes can be modeled cosnidering the problem domain.

However, the most challenging part is to model the behaviour of the agent which acts as a support for decision making.

Behavioural traits

- Reactivity
- Pro-activeness
- Social ability
- Mobility
- Learning ability

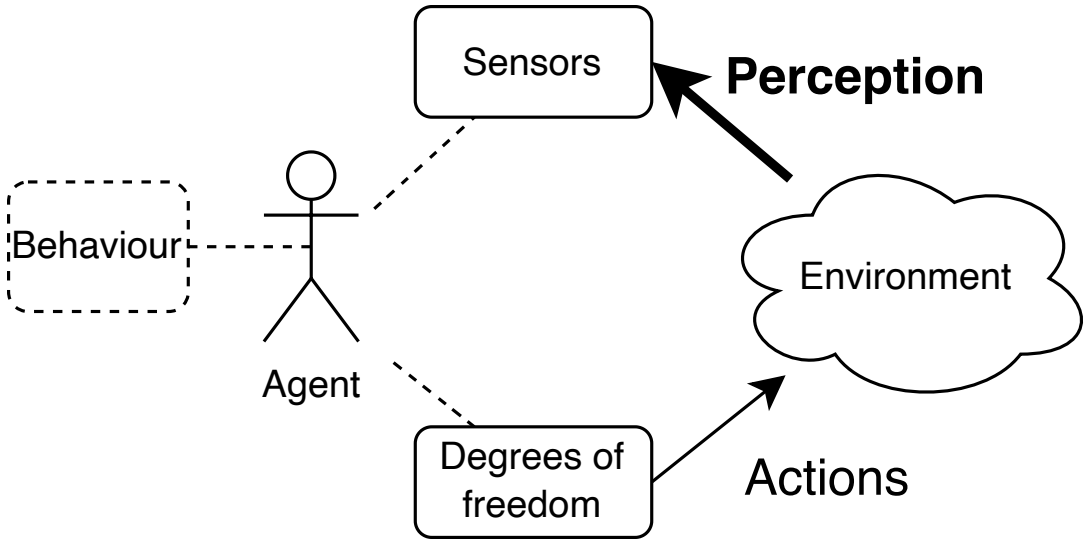


Reactivity

Reactivity is the ability of an agent to react to the environment or other agents.

- The agents can be:
  - fully reactive - no other behaviour, only reactions to events or actions
  - partially reactive - they continously exhibit some behaviour, but also also capable of reacting to events or actions

Example: a software antivirus can be seen as fully reactive agent, as it only reacts when it notices a threat.



Pro-activeness

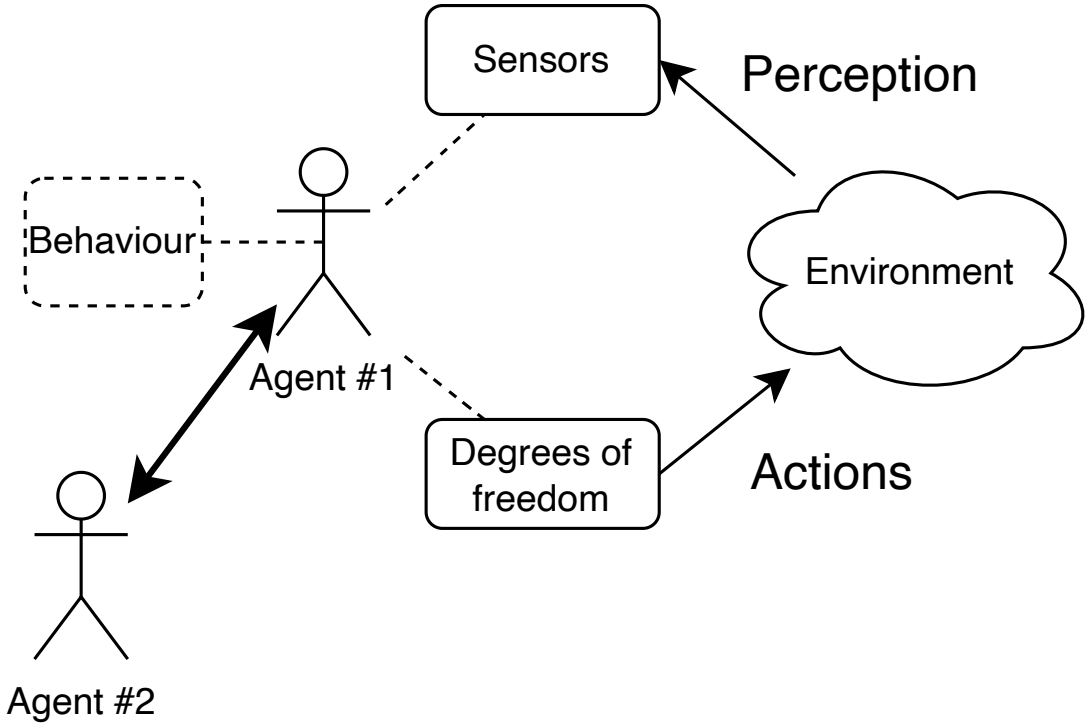
Pro-activeness is the ability of an agent to take initiative and act towards a goal.

This is what we typically desire from an agent in a problem-solving multi-agent system.

Social ability

Social ability is the ability of an agent to interact with other agents through cooperation/coordination or negotiation.

- cooperation is when agents work together to achieve a common goal
- coordination is when agents work in turns, possibly managing limited environment resources
- negotiation is when agents work to achieve compromises, with offers and counter-offers



Social ability examples

- cooperation: a video game where different agents play together
- coordination: an assembly line in a factory, where different agents work in turns to produce a product
- negotiation: a negotiation between a buyer and a seller, where the buyer and seller negotiate the price of the product

Mobility

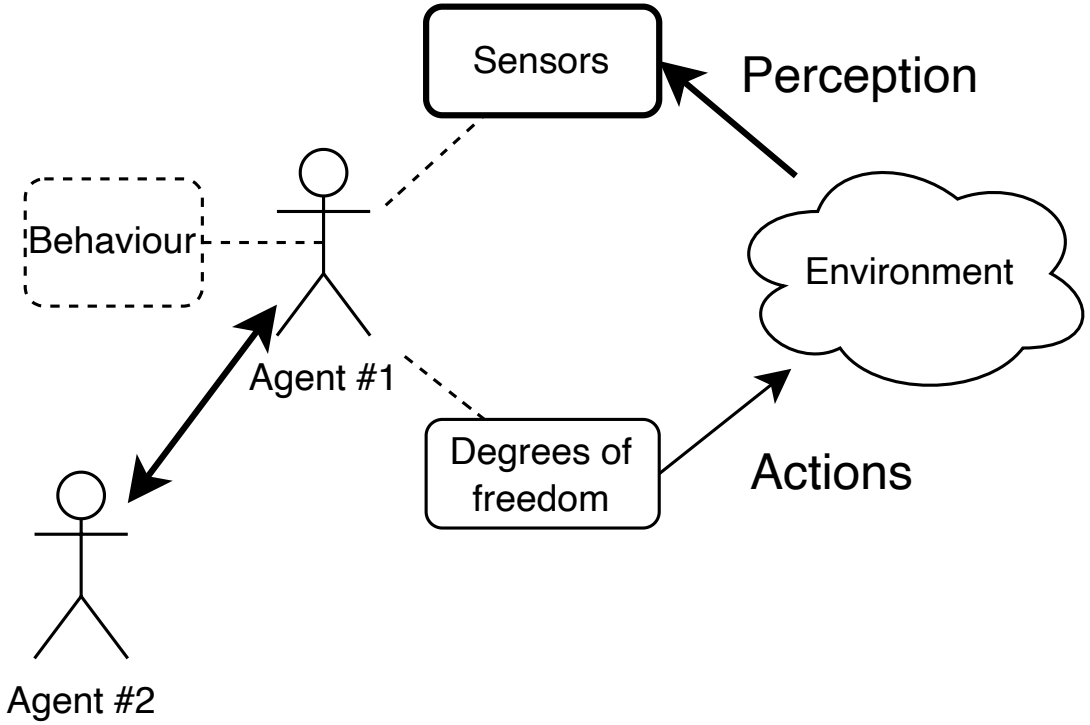
Mobility is the ability of an agent to move in the environment.

- This is strictly dependend on the environment type
- It might be valid only in some environments (i.e. a robot in a maze)

Learning ability

- Learning ability is the ability of an agent to learn from the environment or other agents.

- To do this, the agent must be able to:
  - perceive the environment
  - be able to memorize some information
  - be able to use the memorized information to make decisions

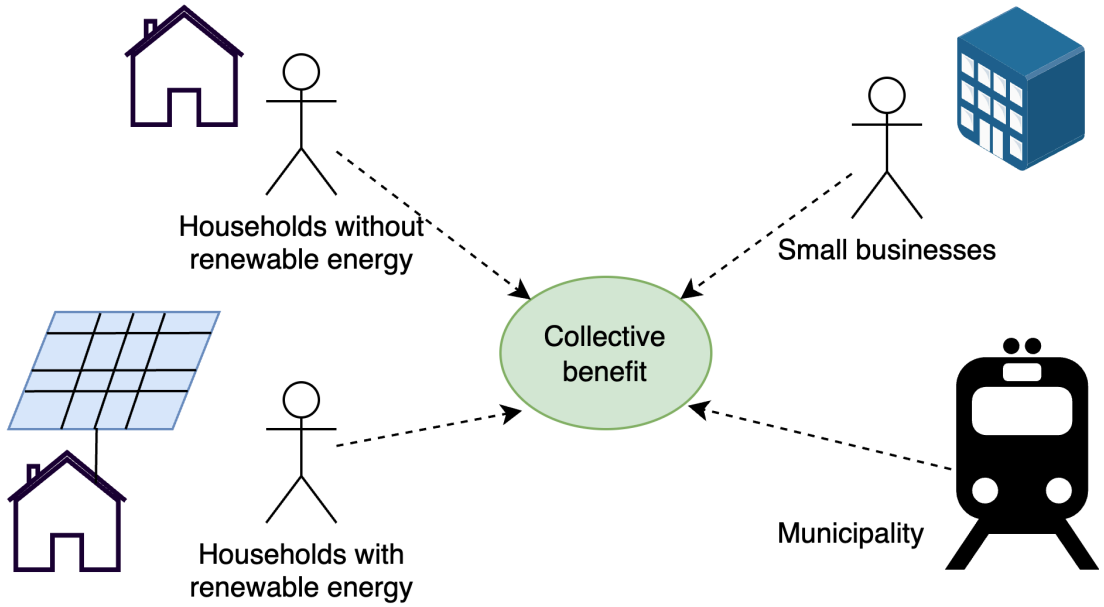


Applications

Energy community

A group of people/small to medium enterprises/local authorities who voluntarily participate in democratic energy sharing mechanisms to obtain a certain environmenal/social/economic benefit.

Example: a residential neighbourhood of residential homes, sharing their solar panels, batteries, etc. to obtain a certain environmenal/social/economic benefit.



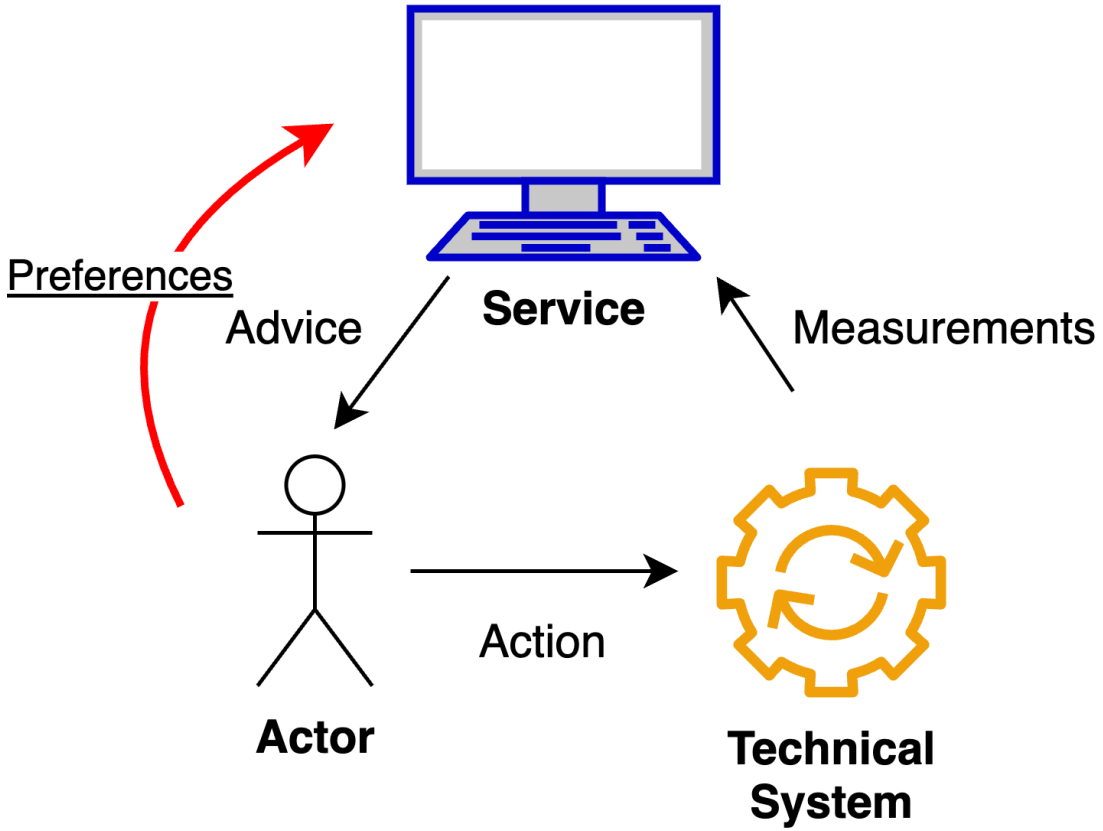
Energy community

Let's imagine there is a service giving indications to the community to modify their energy consumption and maximise environmenal/social/economic benefits.

Environment components: grid, the PV plant.

Multi-agent environment:

- observability: partially observable, as members of community can see limited information about the community
- determinism: non-deterministic, as the service can give different indications to different members of the community
- static/dynamic: dyanmic, as community members may leave or join the community
- real time: simulation based to see impact



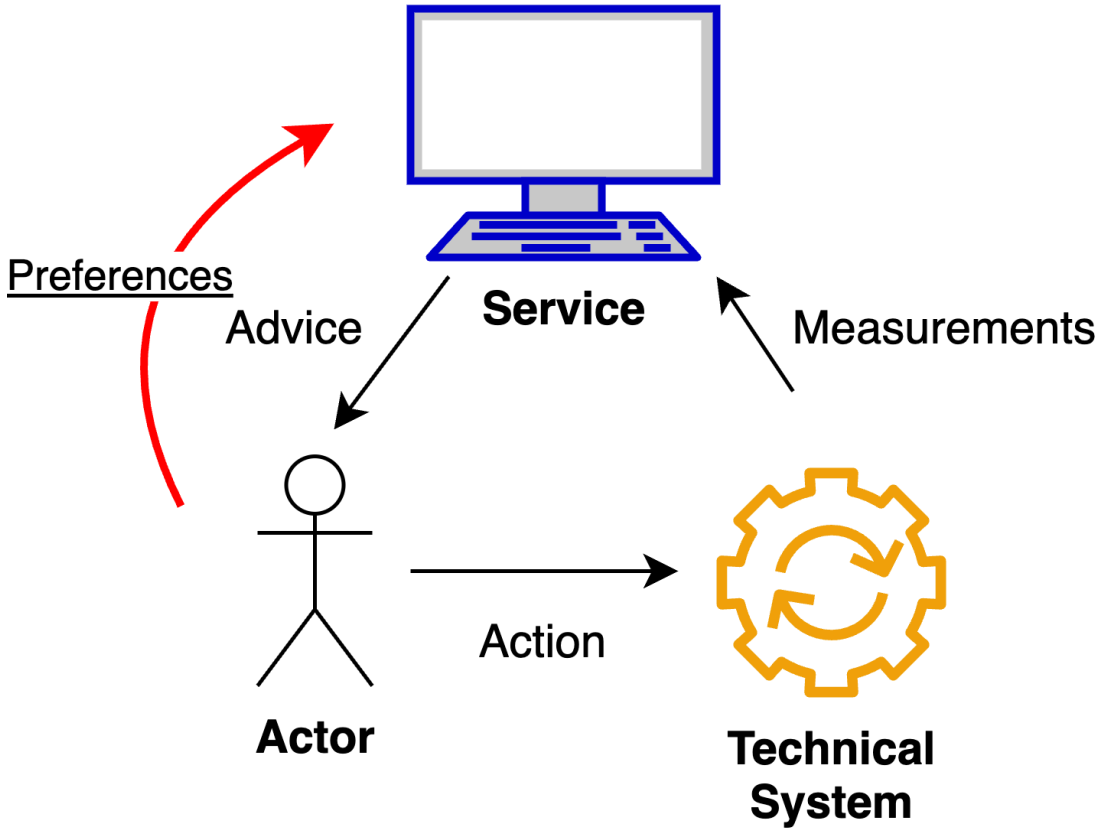
Energy community

Agent attributes:

- the service: simple indications, measuring community consumption, shared goal with the community members
- the community members: complex behaviour on consumption, shared goal with the service

Agent behaviour:

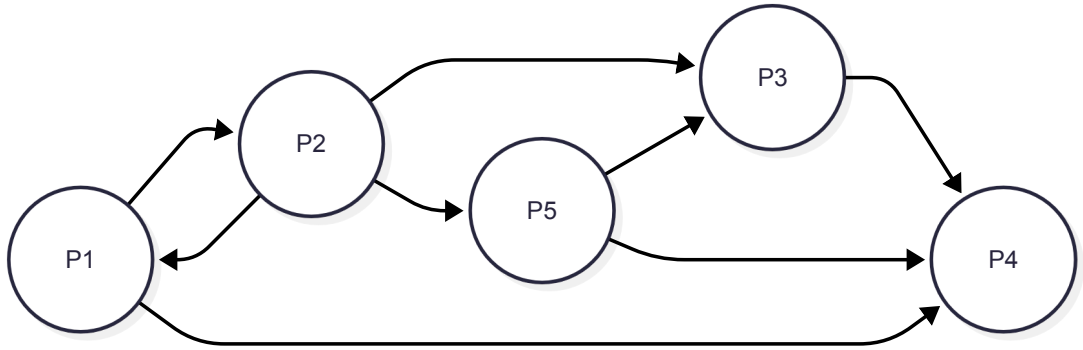
- the service: pro-active (possibly reactive), not social, not mobile, learning
- the community members: reactive/pro-active, not social, not mobile, learning
- the community members - reactive/pro-active, not social, not mobile, learning



Ski resort environment

The environment is a geo-spatial directed graph, where:

- nodes represent positions
- edges represent slopes or skilifts
- edges can have weights (travel time, difficulty, etc.)

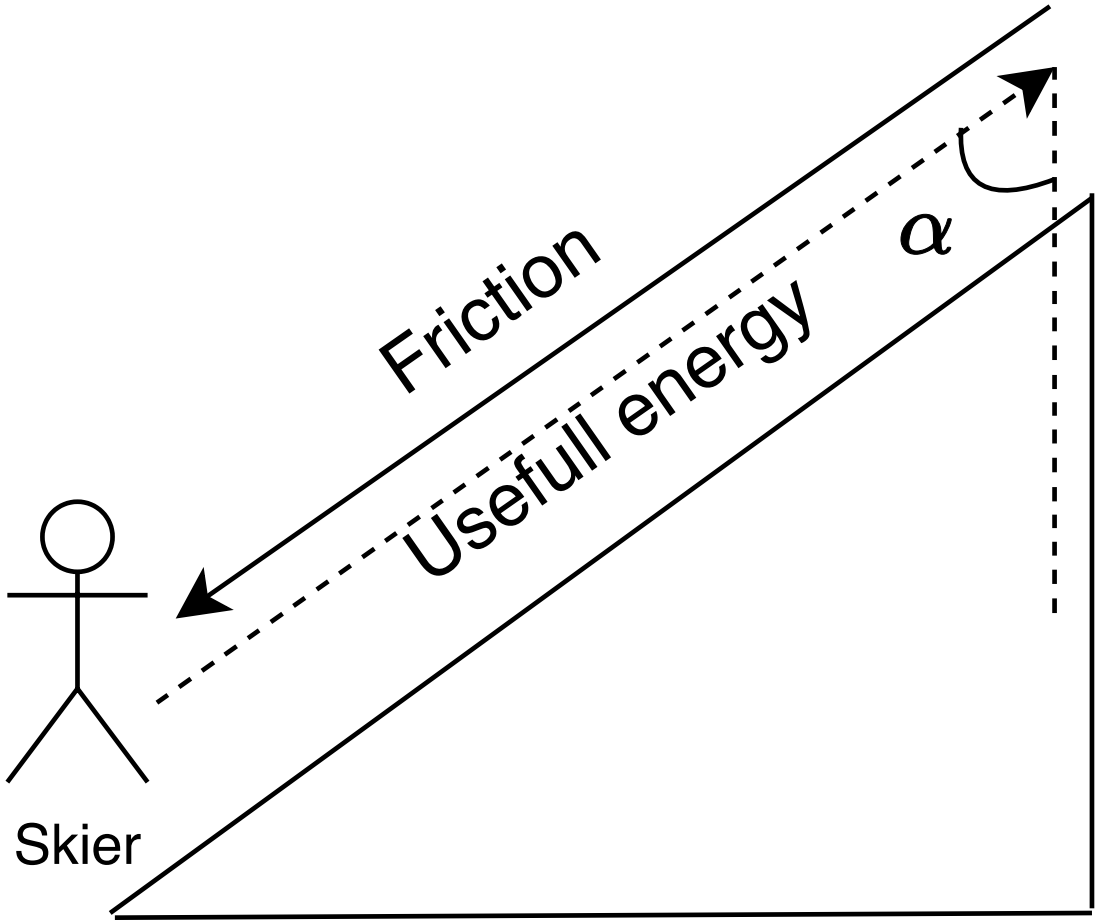


The environment is:

- partially accessible, as some positions are not accessible (e.g. the top of the mountain)
- partially observable, as the agent can only see the positions around him
- deterministic, as the agent can only move in the directions of the edges
- dynamic, as skilifts can be closed for maintenance, thus changing the graph structure
- simulation based to see impact

Goal - the energy model

- The skiers go up using skilifts and therfore energy.
- There is a cost in terms of potential energy (a force multiplies by a distance) to move the skiers up.
- The cost depends on the slope, the number of skiers, the weight of a vehicle, the length of the lift, the speed of the lift + other auxilliary parameters (motor efficiency, friction, etc.)



Behavioural models

Determine:

- what is the goal of the agent?
- what are the possible actions of the agent?
- what are the possible states of the agent?
- can an agent have memory/learning ability?

About the behaviour:

- determine if the agent is reactive, pro-active and why
- determine if the agent is mobile and his mobility constraints
- determine if the agent has learning ability

Thank You!

Multi-agent systems

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Next Workshop: Investigating skier behaviour: a data-driven approach

Reference: Wooldridge, M. (2009). An Introduction to MultiAgent Systems. John Wiley & Sons.