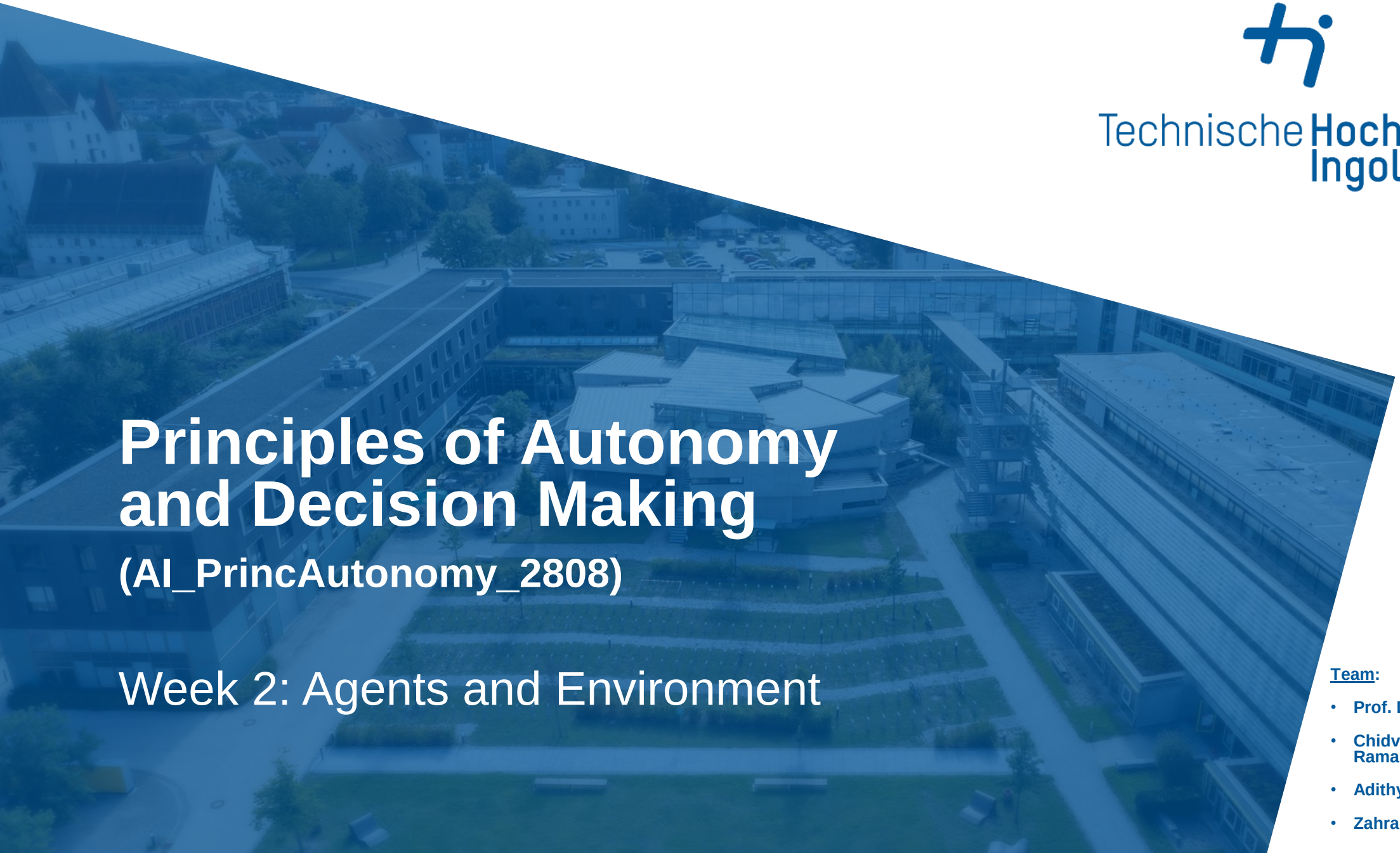

Technische Hochschule Ingolstadt

Principles of Autonomy and Decision Making

(AI_PrincAutonomy_2808)

Week 2: Agents and Environment

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Week 2: Agents and Environment

Nature

- Life forms act in nature
- Nature responds with stimulus
- Life forms have evolved due to constant interaction (iteratively) with nature
  - BBC: animal-nature interactions
- Natural evolution is an ongoing process where life forms (agents) interact with and adapt to nature (environment)

Fig 1. Chameleon

Fig 2. Rattle snake

Fig 3. Dead Leaf Mantis

Problem Formulation

- Components:
  - Agent
  - Environment
  - State (s_t)
  - Action (a_t)
  - Reward (R_t)

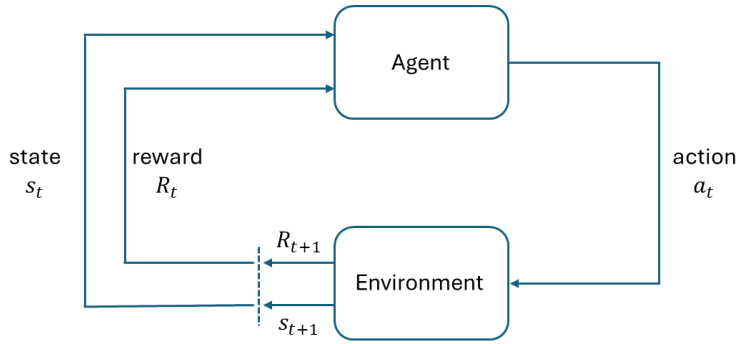

Fig 1. Agent-environment interaction cycle

- Breakout Atari game:
  - Agent: red paddle
  - Environment: the whole game
  - State: current situation of the environment
  - Action: left, right and stay
  - Reward: score

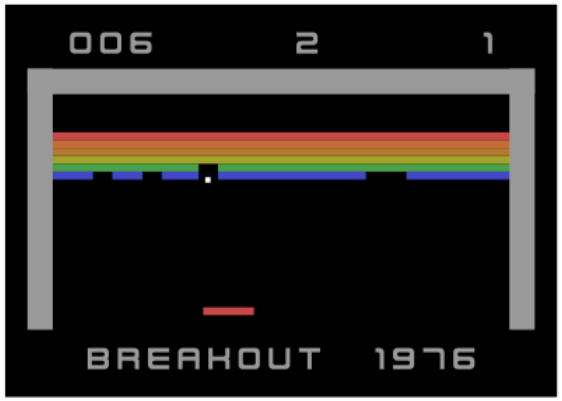

Fig 2. Breakout Atari game

State and Action

- State (s_t):
  - Representation of the status of the environment at a given time
  - A state must be,
    - Complete
    - Unique
    - Relevant

- Action (a_t):
  - An action is what the agent can do at a given time
  - An action must be,
    - Feasible
    - Relevant
  - Note: An action may or may not change the state

- Example: Autonomous Driving
  - State: {Ego's (position, orientation, velocity, acceleration), SV's (position, orientation, velocity, acceleration), Weather, Traffic signs, Traffic light, …}
  - Action: {steering angle, acceleration, braking, signalling, …}

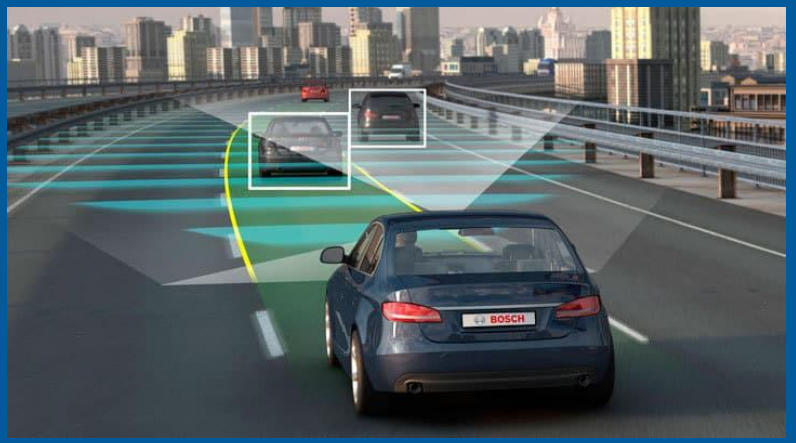

Fig 1. What would you consider as state and action in autonomous driving?

Agent

- Agent: “An autonomous entity that perceives the environment and takes actions”
- An agent can be a hardware entity (robot) or a software entity (software)
- A hardware agent perceives through sensors and takes action through actuators
- A software agent receives data as input and acts upon it
- Types of agents:
  - Simple reflex agents
  - Model-based reflex agents
  - Goal-based agents
  - Utility-based agents
  - Learning-agents

Fig 1. Not the agent we are talking about! Or is it? 🤔

Types of Agents

- Simple reflex agents
  - Simply acts based on the current percept
  - Decisions are based on condition-action rules
  - The current context or history is not considered
  - Example: Autonomous Emergency Braking (AEB)

- Model-based reflex agents
  - Performs actions based on the current percept and an internal representation of the world
  - Decisions are also based on condition-action rules but the internal state is also taken into account
  - Example: Adaptive Cruise Control (ACC)
    - In ACC, the model of the world includes the current velocity of the cars, distance to the car, relative velocity and so on

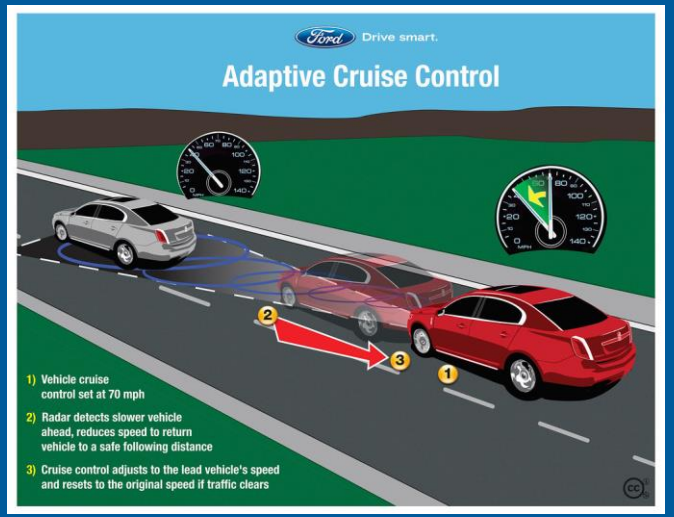

Fig 1. ACC concept by Ford

Types of Agents

- Goal-based agents:
  - Performs actions by considering the current percept and a goal
  - Decisions are made based on future actions, their outcomes and choosing actions that bring the agent closer to the goal
  - Example: Navigation system
    - The agent plans a route from the current location to a specified destination
    - The goal is to reach the destination

- Utility-based agents:
  - Performs actions based on the current percept, a goal and a utility function
  - Aim is to achieve the goal by maximizing the overall utility
  - Useful in situations where the required goal comes with varying levels of risk
  - Example: An advanced navigation system
    - Also considers driving comfort, traffic, road-conditions, weather and so on

Fig 1. Navigation system

Types of Agents

- Learning agents:
  - Decision-making mechanism is learned
  - The agents improve their performance through experience and adapt to new circumstances over time
  - Essential in dynamic environments where predefined rules don‘t suffice
  - Example: Autonomous Driving
    - The system uses a learning algorithm that learns from past experiences/data
    - Decisions are refined and the driving behaviour is adjusted

Fig 1. Bosch IoT shuttle

Environment

- Environment: „The surrounding in which the agent acts“
- The environment encompasses everything apart from the agent
- An environment can be perceived by the agent
- Types of environments:
  - Discrete vs. Continuous
  - Static vs. Dynamic
  - Episodic vs. Sequential
  - Deterministic vs. Stochastic
  - Fully observable vs. Partially observable

Fig 1. Earth is one of the most complex environments we know

Discrete vs. Continuous

- The classification arose due to the varying computational and mathematical requirements of each type

- Discrete environment:
  - Deals with discrete (finite) values
  - State and action spaces are discrete

- Continuous environment:
  - Deals with continuous (infinite) values
  - State and action spaces are continuous

Fig 1. A robot arm playing chess. Is the state discrete or continuous?

Static vs. Dynamic

- The classification arose due to the varying nature of the environment and the complexities that arise as a result
  - A higher monitoring frequency
  - A higher action frequency

- Static environment:
  - The environment doesn‘t change when the agent is acting

- Dynamic environment:
  - The environment changes when the agent is acting

Fig 1. A robot arm playing chess. Is the environment static or dynamic?

Episodic vs. Sequential

- Classification is based on the nature of the action
- Episodic:
  - Each action is independent of previous actions
- Sequential:
  - Current action affects future decisions

Fig 1. A robot arm playing chess. Is it episodic or sequential?

Deterministic vs. Stochastic

- Classification arose to equip agents to handle uncertainty
  - How to learn?
  - How to plan?
  - How to predict?
  - How to handle uncertainty?

- Deterministic:
  - The outcome of actions is predictable

- Stochastic:
  - The outcome of actions has randomness/uncertainty

Fig 1. A robot arm playing chess. Is the environment deterministic or stochastic?

Fully observable vs. Partially observable

- Classification arose to equip agents to handle incomplete perception
  - Perception greatly affects decision-making
  - Belief states
  - Partially observable techniques

- Fully observable:
  - The agent has access to all relevant information for decision-making

- Partially observable:
  - The agent has access to partial information for decision-making

Fig 1. A robot arm playing chess. Is it fully observable or partially observable?

Agent-Environment Interaction

- Workshop: Discuss in detail the decision-making process in the following examples

Fig 1. Robot vacuum cleaner

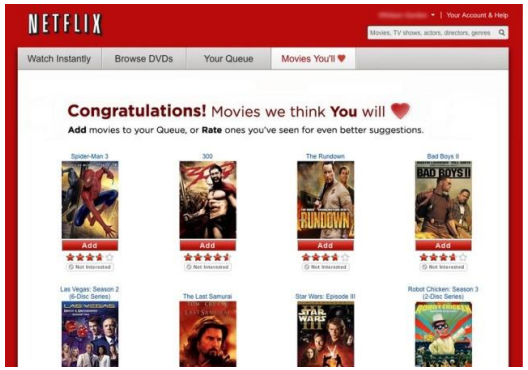

Fig 2. Recommendation systems

Fig 3. Smart traffic light control

Fig 4. Social media content moderation

Fig 5. Autonomous drones for agriculture