Grundlagen der Künstlichen Intelligenz
Exercise 1: Intelligent Agents – Solutions 25th October 2019
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1 Presented Problems

Problem 1.1: Rational Agents

Problem 1.1.1: Which actions does a rational agent select?

A rational agent selects an action that is expected to maximize its performance measure, given the prior percept sequence and its built-in knowledge.

Problem 1.1.2: Which of these games would a rational agent always win or draw at and why? Is it physically possible to build such an agent?

a. Poker

No – environment is only partially observable.

b. Tic-Tac-Toe

Yes – environment is deterministic and fully observable. In Tic-Tac-Toe there is an algorithm that guarantees a win or a draw no matter how your opponent plays. A rational agent would make use of this algorithm. See: `xkcd.com/832`

c. Chess

Yes[1] *– environment is deterministic and fully observable; however, the state space of chess is enormous (10^{43} board positions, 10^{120} possible games). A winning/drawing strategy has not yet been explicitly found and thus it is currently computationally infeasible to construct a rational agent using current techniques.*

Problem 1.2: Intelligent Agents

Problem 1.2.1: Suggest performance measures for each of the agents, and which type of agent should be used.

a. GPS route guidance

Performance measure: e.g. time to reach goal, fuel expended to reach goal, speed limits on roads, avoiding toll routes and low bridges (for Heavy Goods Vehicles), motorways avoided/preferred, traffic jams avoided etc.
Type of agent: Utility-based Agent

b. Kettle (*Wasserkocher*)

Performance measure: Is water boiled?
Type of agent: Simple Reflex Agent

[1] Since chess has not yet been solved, it is not known whether a winning strategy exists for each player. What we do know, according to `Zermelo's theorem`, is that either a winning strategy exists for one player, or both sides can force a draw at least. See also: `http://en.wikipedia.org/wiki/Solving_chess`

c. Bi-directional Escalator on Munich Underground

Performance measure: e.g. number of persons transported in a certain amount of time, reciprocal of the number of changes of direction in a certain amount of time, or penalize the number of people waiting at the bottom.
Type of agent: Utility-based Agent

Problem 1.2.2: (adapted from *Russell & Norvig*, q. 2.9) Consider the Vacuum Cleaner environment from the lecture notes (slide 11, lecture 2), in which the agent's performance measure awards three points for each clean floor at the end of the time of operation and penalises one point for each movement during operation. It can only perceive the room it is in.

a. Can a simple reflex agent be rational for this environment?

No. The reward for cleaning a floor is greater than the penalty for moving there. A rational agent should maximise the expected performance measure given its percept sequence, so should therefore clean all floors with as few moves as possible (i.e. maximally 1).

If the reflex agent attempted this, it must implement the algorithm on slide 13 of lecture 2, and would continually oscillate between floors (If it had recently cleaned A, it would then move to B to clean it, but then it would move back to A, incurring another penalty.)

However, if it just stayed stationary when the room it was in was clean, it would still not be able to clean all floors. Thus it is impossible to maximise the expected performance measure as a simple reflex agent.

b. What about a reflex agent with state?

Yes, it could be. It could have a percept sequence longer than just the present, and realise that it does not need to go back into a room once it has cleaned it. Its percepts do not allow it to see the next room, so it is still maximising expected performance measure to move into the other room, even if the room is clean, if it is not on the percept sequence.

Problem 1.3: Environments

Problem 1.3.1: Andrea says: "a game of billiards is deterministic: a player's action is determined by the state of the table and where the ball is."

Bernhard says: "A game of billiards is stochastic, as one player doesn't know what the other player will do."

Catherine says: "A game of billiards is stochastic because it is impossible to know exactly where the ball is and what the shape of the ball and the table are. When the player hits the ball, it might go somewhere else than intended."

Who do you agree with?

To Bernhard: We can regard the other players as other agents; then the environment is multi-agent and not necessarily stochastic (similar to the deterministic and multi-agent environment of chess, see Russell & Norvig, 3rd ed.*, p. 43). If we regard the other players not as agents but as part of the environment, then the environment is stochastic.*

To Andrea and Catherine: The environment is fully observable and in principle, you should be able to calculate exactly using the laws of physics, where the ball will go under a particular action. However, in practice and in the real world, the table may not be perfectly flat, the balls may be slightly damaged, the player might not be skilled enough to execute a perfect shot, etc. For example, one might say to oneself "I could go for that ball on the other side of the table, but I have a better chance of potting this ball closer to me." This shows that humans consider billiards an (at least partially) stochastic environment.
As such, it is really the agent's perspective (or model of the world) that matters. Perhaps one day we will build an amazing billiards robot that can calculate the exact trajectory of the ball and execute a perfect

shot based on a deterministic environment model. Until then, billiards-playing robots will probably use a stochastic environment model. In robot football, see for example:
sciencedirect.com/science/article/pii/S1474667017321079

2 Additional Problems

Problem 1.4: Intelligent Agents

Problem 1.4.1: Suggest performance measures for each of the agents, and which type of agent should be used.

a. Weather forecast

> *Performance measure: e.g. penalise false forecasts, reward true forecasts, maximise precision & recall for specific weather events.*
> *Type of agent: Goal-based, Utility, Learning*

b. Bomb disposal agent

> *Performance measure: Bomb does not explode.*
> *Type of agent: Goal-based, possibly utility-based if there is a time constraint (to evaluate two different actions in terms of their trade-off between effectiveness and time-efficiency).*

c. Chess/strategy game on clock

> *Performance measure: win on time*
> *Type of agent: Goal-based, Reflex Agent with state (due to time constraints, moves could be preprogrammed), Learning*

Problem 1.4.2: Think of further agents. For each, propose a performance measure and decide which type of agent can be used.

You can discuss your solution with fellow students and unclear cases in moodle. However, note that often several solutions exist for the same problem.

Problem 1.4.3: (from *Russell & Norvig*, q. 2.2) Both the *Performance Measure* and the *Utility Function* measure how well an agent is doing. What is the difference between the two?

*Performance Measure is a specification from the designer or programmer (external to the agent) to specify what the agent **should** do. If an agent always acts to maximise or achieve the Performance Measure, this is a **Rational Agent**.*

*Not all agents have a Utility Function, for example, reflex agents do not. The Utility Function is used internally by the robot itself to evaluate the best course of action is to **optimally** achieve/maximise the Performance Measure(s), given its perceived state.*

Problem 1.5: Environments

Problem 1.5.1: (adapted from *Russell & Norvig 3^{rd} ed.*, q. 2.4) For each of the following activities, give a PEAS description of the task environment and characterise it in terms of the properties listed in slides 19-25 from Lecture 2.

1. Playing football.

Performance Measure	*Environment*	*Actuators*	*Sensors*
Scoring more goals than the opponent, as few players sent off/yellow carded as possible	*Football field*	*Legs, feet, head, chest, hands (for goalkeeper, or if you're Diego Maradona)*	*Eyes, ears, balance, pain receptors, touch (skin)*

partially observable, multi-agent, stochastic, sequential, continuous, dynamic, unknown

2. Repair robot for subsea cables.

Performance Measure	*Environment*	*Actuators*	*Sensors*
Cable repaired, good quality of repair, minimum fuel expenditure, minimum time	*The ocean*	*Propulsion system, robot arm for repairs*	*Camera, ultrasound, radar, accelerometer, GPS etc.*

partially observable, single-agent, stochastic, sequential, continuous, dynamic, unknown.

3. Price query for a product on the internet.

Performance Measure	*Environment*	*Actuators*	*Sensors*
The best priced product	*Internet*	*Search queries*	*Automatic text analysis*

partially observable, single-agent, stochastic, episodic, continuous, dynamic, unknown

4. Bidding on an item at an auction.

Performance Measure	*Environment*	*Actuators*	*Sensors*
Obtaining the item (if wanted), price paid	*Auction House / eBay*	*Placing a bid (vocally, by telephone, electronically)*	*Eyes, ears*

partially observable, multi-agent, deterministic (or stochastic, in the event of a tie, where two agents bid at the same time and the winner is decided by chance), episodic, continuous, dynamic, known.