Intelligent Agents
2017
Final Exam
20. December 2017

- place your student ID card (carte de legitimation) on the desk in front of you.
- this is a closed-book examination (no documents allowed). However, one sheet of notes is allowed, either printed and one-sided, or hand-written and two-sided (or two one-sided sheets).
- if possible, write your answers in the spaces provided right after the question. If you need to use extra sheets, use a separate one for each question.
- mark the number of your copy on the top of each page, also extra sheets, to make sure we identify all pages of your exam.
- the examination is graded on a point basis and points are indicated with each subquestion. The entire exam is worth 100 points.
- Bonne chance!

Copy No:

1 Taxi Strategies (40 points)

Airport taxis can pick up passengers at terminals A or B, and have to decide which side to go to find a fare. To keep things simple, assume that time is divided into time slots. In either terminal, independent of each other and with probability p, there is exactly 1 passenger in a time slot.

- when there is no taxi, the passenger does not wait but takes the bus,
- when there is exactly one taxi, the taxi can pick up that passenger for a reward of 10,
- when there are multiple taxis, the passenger chooses one of them randomly and that taxi can pick him up with a reward of 10.

The taxis start out in a holding parking with no waiting cost, and have a cost of 2 to drive to either of the terminals from either the holding or the other terminal. Driving to a terminal takes one time slot, and for simplicity we assume that driving the passenger to the destination and returning to the holding takes one time slot and has a cost of 5. When the taxi attempts a pickup but there is no passenger, it looses the time slot and stays in the same place, with a cost of 0.

1.1 Model as Markov Decision Process (10 points)

We want to design an agent that optimizes the decisions for taxi T1. Assume first that there are no other taxis, i.e. it never loses a passenger to the competition. As actions, use:

- DA: drive to terminal A.
- DB: drive to terminal B.
- P: pickup the passenger.

and as states:

- H: in the holding area.
- A: at terminal A.
- B: at terminal B.

1. What is the reward function? (5 points)

2. What is the transition function? (5 points)
   (Notation for uncertain transitions: $\{p_1 : s_1, p_2 : s_2, ...\}$, just write the next state for certain transitions.)

3. Briefly describe the two main algorithms for computing an agent's optimal strategy. Compare to a strategy where an agent chooses its action to maximize its expected reward in the current state without consideration for the future. How does the result of the algorithms differ? (5 points)

4. Now assume that there is competition, and that with probability q there is exactly one other taxi at the terminal, with the same probabilities for both terminals.

   How does this change the reward and transition functions? Only note the changes. (5 points)

5. Now consider that the competition is just one other taxi (T2) with a fixed strategy, and that our agent estimates the probability that the other taxi is at terminal A as q_A^{T2} and B as q_B^{T2}. Assume that q_A^{T2} is much larger than q_B^{T2}. How does this affect the strategies that will be computed by solving the process? (5 points)

6. Assume next that taxi T2 follows exactly the same algorithm as T1 to optimize its strategy. Note that it models the probabilities that T1 is present at either terminal, q_A^{T1} and q_B^{T1}. Assuming that T1 has already adopted the strategy as in the first part of the question, what would be reasonable for these estimates? How do the two work together? Do the combined algorithms converge to a stable set of strategies? (5 points)

1.2 Game-theoretic model (10 points)

7. Due to the high airport traffic during the Christmas period, taxis are not allowed to wait outside the terminals. On the other hand, there is always exactly one passenger waiting at each terminal. Thus, at every time slot, each taxi drives by a terminal and subsequently returns to the holding area, either empty (due to competition with another taxi) at no cost, or after having driven a passenger to his destination. In this scenario taxis do not switch terminals (i.e. the cost of traveling from terminal A to B or from B to A is ∞ due to high traffic). As before, assume there are only two taxis, T1 and T2, and $q_A^{T2} \gg q_B^{T2}$ and $q_B^{T1} \gg q_A^{T1}$. Model the competition as a game. Write down the payoff matrix. Compute the expected payoffs. Is there a Bayes-Nash equilibrium?

2 Task allocation (25 points)

In the future, when cars are autonomous, they will drop off their passenger at the destination and then find themselves a place to park.

We need to design a coordination protocol so that the available parking spots can be allocated among the cars that need to park. The best allocation would minimize the distance of each car to the destination where it dropped off its passengers.

Each car and each parking spot is represented by an agent that carries out the negotiation. Assume that the negotiation happens for all cars arriving with a certain time interval (for example 10 minutes) in the same area of the city, and involves all parking spots that are open at the beginning of this interval. As all traffic is autonomous, there are no other cars that could occupy the spots in the meantime.

Cars have a budget for parking that they can spend on travel distance to the parking spot and the (variable) fee paid to the parking spot agent. As it is always most efficient to allocate a car to the closest parking spots, both parking spots and cars have a preference to be matched that is in order of increasing distance.

As an example, assume that we have 3 cars and 3 open parking spots, with the following matrix of distances:

	Spot		
	a	b	c
1	6	12	18
2	4	5	12
3	9	6	3

2.1 Auction (contract net) (20 points)

This problem can be solved with a simplified version of the contract net protocol, where only one resource has to be allocated for each task.

Assume that the spots are bidding for the cars, with the bids representing the price they charge. As each spot has capacity for only one car, it has to pick one car to bid for. All auctions close when there are no more bids. When they receive multiple bids, cars pick the one that minimizes the sum of driving distance and price. Agents that did not find a match will bid again in the next auction.

1. What is the matching that minimizes the total travel distance? (5 points)

2. Assume that spots bid a constant price of 10, and they bid for the closest car to maximize their chances of being chosen. What will be the sequence of events, i.e. what auctions will happen, who will bid what, what cars get what spot, and what is the total driving distance? (5 points)

3. What if the cars are bidding for the spots, and they bid to spend their entire budget of 20 minus the cost of driving, i.e. (20 -distance)? (5 points)

4. What if the cars are bidding, but with a different strategy that takes into account their risk, where bid = (10-distance) + difference in driving cost to the next closest spot, where the difference in driving cost is 10 if there is no next option. (5 points)

2.2 Market (5 points)

Now assume that the parking spots form a market and each publishes a current market price that starts at 20 and decreases if it doesn't have a taker. Bids are non-binding, i.e. an agent might cancel its acceptance and accept another bid instead. Now what will happen?

3 Voting (15 points)

A group of 9 agents have to make a decision between 3 alternatives a, b and c. Agents preferences fall into the following groups:

group	size	order
1	4	$a > b > c$
2	3	$c > a > b$
3	2	$b > c > a$

Questions (2 points each):

1. What alternative wins in a pairwise majority vote in the order a, b, c?

2. Is there a way the vote organizer can make a win? How would he do that?

3. What alternative wins in a plurality vote? What alternative wins in a plurality vote with elimination?

4. In plurality voting (without elimination), would group 1 be better off by voting non-truthfully and what vote should this group cast?

5. What alternative wins in a vote according to the Borda protocol?

3.1 Randomized Decisions (5 points)

Suppose that instead of choosing the alternative deterministically, we use the following randomized protocol: every agent gets to vote for its most preferred alternative. We assign each alternative a probability which is equal to the fraction of the votes that this alternative received, and make the choice randomly according to this probability distribution.

Is this a truthful protocol? If so, why? If not, why not?

4 General questions (5 points each = 20 points total)

1. What is the difference between a Markov decision process (MDP) and a partially observable Markov decision process (POMDP)? How can the methods for solving an MDP be applied to solving a POMDP? Which is easier to solve, and why?

2. What is the horizon effect: where does it arise, what are its consequences, and could it be avoided?

3. What is the difference between an ex-ante and an ex-post equilibrium in games with uncertain information? Do they always exist?

4. How do we find a uniform clearing price that maximizes the number of transactions in a double auction? What way of determining the clearing price would make the sellers state their price truthfully?