Intelligent Agents
2007
Final Exam
29. January 2008

- 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.
- 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 Planning and Cooperation (40 points)

You want to build a personal agent for a busy executive that has to travel a lot. A major task is to find flights, hotels and plan meetings.

1.1 Planning trips with decision processes (25 points)

Given a set of meetings $m_1, m_2, .., m_k$, you need to plan a trip to attend as many of them as possible. Each meeting m_i takes place in a city $c(m_i)$. We assume that the meetings are relatively short and that the executive can do all meetings in a given city in the same day. In the evening, he can travel to the next city where he has to stay overnight in a hotel, and he will then be in that city on the next day ($next(date)$).

Assume that you have the following functions available (for example through web services or a database):

- find-flight(from,to,date): returns true if there is an acceptable flight on that date.
- find-hotel(city, date): returns true if there is an acceptable hotel on that date.
- possible(meeting,date): returns true if the date is possible for the meeting.

1. (5 points) What is a Markov decision process? What elements are needed to specify a Markov decision process?

   It is specified by a set of states, a set of actions, a matrix specifying the transitions between states when a certain action is taken, and a matrix specifying the reward when taking a certain action in a certain state.

2. (10 points) Show how the trip planning problem above can be formulated as a Markov decision process! Just explain what elements are needed and how they can be specified, without writing them out in detail.

   The states model the meetings that still have to take place, the date and the position of the traveller. In each state, the traveler has several possible actions: wait until the next day, attend a meeting, or travel to one of the other cities. The transition matrix takes him to the same city for the first two (but possibly on the next day), and to another city and next day for the travelling ones. The only rewards are given when attending a meeting in a city, provided that the meeting has to be attended.

3. (5 points) For k meetings, l cities and d dates, give an estimate of the number of states that are needed.

   We need $l * d * 2^k$ *states.*

4. (5 points) Given that the starting city is known, would you solve this problem with a reactive or a deliberative agent architecture? Would your answer be different if the starting city was not known, or if there was uncertainty such as possibilities of flights being cancelled?

If the starting place is known, computing the complete plan with a deliberative agent is going to be faster because not all states have to be explored. If the starting city is not known, a reactive agent might also be competitive. If there is uncertainty, the reactive agent is definitely better.

1.2 Planning trips with factored representations (15 points)

Formulate the trip planning problem above as a planning problem using the STRIPS formalism. Your agent needs to build up the necessary operators, either during planning or before. Note that an agent might have to wait in a city for the next meeting.

1. (5 points) What are the goals?

   For every meeting m*, there is a goal* $h(m)$ *to hold it.*

2. (5 points) What operators achieve the goals? How are they specified (make up notation as required)?

   For every possible meeting date, there is an operator $attend(m, date)$ *with precondition* $at(c(m), date)$ *and* $possible(m, date)$ *and postcondition* $h(m)$*.*

3. (5 points) What other operators do you need? (Hint: combine flight and following hotel stay into a single operator to simplify).

   To formalize the travel: an operator $travel(x, y, date)$ *with preconditions* $at(x, date)$*,* $find-flight(x, y, date)$ *and* $find-hotel(y, date)$ *and postcondition* $at(y, next(date))$*.*

   To model waiting in a city for a meeting: an operator $wait(x, date)$ *with preconditions* $at(x, date)$ *and* $find-hotel(x, date)$ *and postcondition* $at(x, next(date))$*.*

2 Negotiation (30 points)

Consider a network of information agents that gather information on the world wide web in response to user requests. They might want to cooperate to share their results and thus avoid duplication of their work.

Two agents, A and B, are asked to respond to the following queries:

- A has to find the average price of hotels in Zermatt in January 2008, and is paid CHF 30 for this.
- B has to find the minimum price of hotels in Zermatt in January 2008, and is paid CHF 20 for this.

Both construct a plan:

- A: get all hotel prices in Zermatt for January 2008 (cost=15 CHF), then take the average (cost=5 CHF).
- B: get all hotel prices in Zermatt for January 2008 (cost=12 CHF), then take the minimum (cost=5 CHF).

Obviously they could benefit by sharing some work.

1. (5 points) What process could be used to merge the plans to construct a joint plan where the data gathering step is done only once? Give a possible joint plan and explain how it could be found in this case.

   Partial Global Planning is an example of such a process. Here, agents decompose their planning problem into operations and subgoals. They try to match subgoals in the plans of different agents to detect possible synergies. Here, they can recognize that obtaining all hotel prices is a common goal, so only one agent needs to achieve it. The joint plan is that the first agent finds the hotel prices, and then each agent computes the average and minimum as required.

2. (5 points) Explain the concepts of *utility* and *rationality*. What are the agent's utilities for their standalone plans as well as a joint plan in this situation?

   Utility is a numerical indication of how useful an outcome is to an agent. It can be interpreted as the amount of money the agent is willing to pay to have the outcome achieved. Rationality is the property that an agent acts so as to maximize its utility.

   In this example, the agents' utilities for their standalone plans are 30-20 =10 for agent A, and 20-27=3 for agent B. In a joint plan where A computes the prices, the utility of B goes up to 15. If B computes the prices, the utility for A increases to 25.

3. (5 points) What is a Nash bargaining solution? (You do not need to reproduce the axioms, give an informal characterization).

The Nash bargaining solution addresses the case where both agents have to agree how to divide the benefits they get from cooperation. It is the solution that maximizes the product of the utility gains of the involved agents.

4. (5 points) What is the Nash bargaining solution in this case, and what is the corresponding plan? Remember to consider mixed deals.

   In this case, the negotiation is to choose with what probability p(A) to execute plan A (where A finds the prices) and B (where B finds the prices). Plan A has no utility gain for A and a gain of 12 for B. Plan B has a gain of 15 for A and no gain for B. Thus, the utility gains are 15(1-p(A)) for A and 12p(A) for B. To maximize the product, they should choose p(A)=0.5, and obtain a gain of 7.5 for A and 6 for B.

5. (10 points) What is a negotiation protocol that would reach this solution? Give an example of how it might work in this example!

   The monotonic concession protocol would work for this case. Here, each agent starts out by proposing the plan that is best for itself, i.e. agent A proposes plan B and agent B proposes plan A. They evaluate the utility gains and the risk, i.e. the ratio of the difference in utility between its own plan and that proposed by the other agent and the utility gain if its own plan is adopted:

$$risk_i = \frac{u_i(D_i) - u_i(D_j)}{u_i(D_i) - u_i(D_c)}$$

   The agent with a smaller risk will make a concession.

   In this example, both agents have the same risk: 15/15 = 12/12 = 1. Let's assume that A will propose plan B with only 2/3 probability, thus making a concession. Then its risk will be unchanged, but the risk of agent B will now be 7/12. Now B will have to make the next concession until it proposes plan A with less than 2/3 probability. The process ends when both agents offer both plans with probability 0.5.

3 General questions (5 points each)

1. What is a strategy for a Markov decision process? What is a strategy in game theory? What is the difference between a pure and mixed strategy?

   For each state, a selected action. In game theory, it's the same. In a pure strategy, actions are chosen deterministically (always the same action in the same state), whereas in the mixed strategy, actions are chosen according to some probability distribution.

2. What search algorithm would you use to plan moves in a game with an adversary such as chess? How does this algorithm choose moves and what is the assumption it makes about the adversary?

   You would use minimax search. It gives each node a numerical value that indicates what is the expected score when that sequence of moves is played. It assumes that the adversary is rational, i.e. that it always plays the move that minimizes our gain.

3. How does the contract net protocol deal with several simultaneous requests? Does it always find a solution when there is one?

   It considers them one after the other, in the order of arrival or in random order. It may not find a solution even if there is a feasible one.

4. What is a Nash equilibrium? Are there games that do not have one?

   A Nash equilibrium is a set of strategies so that no player can gain by deviating if all others play the same strategy. All games have at least one Nash equilibrium.

5. For rational, risk-neutral agents with completely private values, can an auctioneer expect a higher revenue in an English auction or in a Dutch auction? What if the the values are correlated or commmon?

   The revenue would be the same, by the revenue equivalence theorem. However, with correlated values the English auction yields a higher revenue.

6. What is the main architectural difference between Corba and Web Services?

   Corba requires a third party to run the middleware (ORB).