**CS1571  
Assignment 3**

**Due:** Friday, Dec. 6

**Part A – Decision Trees (60 points)**

Say you are building a customer service spoken dialogue chatbot. Each time the chatbot responds to the user is denoted by a *conversational turn.* In each turn, the chatbot has two simple choices: respond to the user’s query (**Respond**), or direct the user to a human customer service representative (**Redirect**). Consider the following decision tree:

Respond

Redirect

Respond

Redirect

(~Resolved)

(Resolved)

(Frustrated)

(~Frustrated)

(Resolved)

(~Resolved)

(Frustrated)

(~Frustrated)

C1

C2

C3

C4

D2

D1

U1

U2

U3

U4

U5

U6

U7

You’ll notice there are two different types of chance nodes. At this point, assume probabilities are the same at every chance node.

* *Resolved* represents the probability that a problem will be resolved after a given turn. P(Resolved) = .10
* *Frustrated* represents the probability that the user was frustrated with the dialogue system on the previous turn. P(Frustrated) = .30

Assume a utility function *U,* and that the number of turns taken so far is represented by *k*. At the first decision made by the chatbot, *k*=1*.* The utility value for redirecting a user to a human if they are NOT frustrated is -100+5*k*. The utility value for redirecting a user to a human if they are frustrated is 5*k*. The utility value for resolving the user’s problem is 100. If your tree has a set number of turns (above the maximum number of terms is 2), assume that the utility value of continuing to respond without resolving the problem or redirecting the user is 0. Note, if the problem is resolved or the user is redirected to a human, no further turns are taken by the chatbot.

1. (10 pts) Given the decision tree above, fill out the expected value of each chance node in the below table, the utility value for each of the outcome nodes. Then, describe the best course of action for the chatbot on the first turn.

|  |  |
| --- | --- |
| Node | Value |
| U1 |  |
| U2 |  |
| U3 |  |
| U4 |  |
| U5 |  |
| U6 |  |
| U7 |  |
| C1 |  |
| C2 |  |
| C3 |  |
| C4 |  |

Best course of action:

1. (30 pts) Implement Expectimax for this particular scenario and test it on these two turns. Does the action returned by the function match your answer? Submit your code and output according to the instructions in the rubric document. In the box below, as described in the rubric document, write the exact function call to use with the exact parameters, and the exact output we are supposed to get when we call your function.
2. (10 pts) Assume the tree is cut off at 30 levels rather than 2. Given the current reward function and probabilities, at which turn is it better to stop the conversation and redirect the user to a human? You can derive your answer through reasoning or code. If using reasoning, show below how you got your answer. If using code, submit the exact function call and the output of your function call (as described in the A3 rubric).
3. (5 pts) Write a new utility function *U’* that prioritizes shorter conversations than the current function (redirecting the user to a human sooner). That is, the function should redirect the user to a human sooner in the conversation than the current function. Explain why the utility function achieves the requirements and is reasonable.
4. (5 pts) Assume the chatbot always has the option to ask a person if they’d like to be directed to a human prior to deciding to redirect them. You can assume if people say yes there is a higher probability they are frustrated, and if they say no, they are likely not frustrated – but sometimes people will say yes even if they are not frustrated or no if they are frustrated. Name two different changes you would make to the decision tree, utility function, or probabilities given that action, and justify why your changes make sense based on how these interactions are likely to unfold in the real world.

**Part B – Conditional Probabilities & Bayes Nets (60 points)**

It is possible to compute the above relevant probabilities in real-time based on new information, rather than fixing them ahead of time. The following is a Bayes Net representing the following random variables:

* Accurate. The accuracy of the speech recognition. Domain: {True,False}
* ProblemSize. The size of the problem the user is having. Domain: {Big, Small}
* ConversationLength. The length of the conversation so far. Domain: {Short, Medium, Long}
* Frustrated. Whether the user was frustrated after the last conversational turn. Domain: {True, False}
* Resolved. Whether this conversational turn will resolve the problem. Domain: {True, False}

Conditional Probability Tables:

|  |
| --- |
| P(Accurate=True) |
| 0.90 |

|  |
| --- |
| P(ProblemSize=Small) |
| 0.90 |

|  |  |  |
| --- | --- | --- |
| Problem\_Size | P(ConversationLength=Short) | P(ConversationLength)=Medium |
| Small | .40 | .40 |
| Big | .20 | .30 |

|  |  |  |
| --- | --- | --- |
| Conversation\_Length | Accurate | P(Resolved) |
| Short | True | .30 |
| Short | False | .20 |
| Medium | True | .50 |
| Medium | False | .30 |
| Long | True | .70 |
| Long | False | .40 |

|  |  |  |  |
| --- | --- | --- | --- |
| Problem\_Size | Conversation\_Length | Accurate | P(Frustrated) |
| Small | Short | True | .20 |
| Small | Short | False | .40 |
| Small | Medium | True | .30 |
| Small | Medium | False | .50 |
| Small | Long | True | .60 |
| Small | Long | False | .80 |
| Big | Short | True | .30 |
| Big | Short | False | .50 |
| Big | Medium | True | .60 |
| Big | Medium | False | .80 |
| Big | Long | True | .70 |
| Big | Long | False | .90 |

1. (10 pts) Write out two different conditional independence relationships within the above Bayes Nets. That is, enumerate two relationships in which two nodes are conditionally independent, given at least one other node.
2. (10 pts) By hand, compute the probability of P(Resolved = True | Conversation\_Length = Long, Problem\_Size = Big, Accurate = True).
3. (15 pts) Write a function or call one of the aima probably functions (e.g., enumerate\_ask) to solve the above problem. As per the requirements in the assignment rubric document, paste your exact function call and expected output below. Your function can be specific to this Bayes Net, but should be generalizable enough to respond to different queries on this Bayes Net.
4. (15 points) Write a program or call one of the aima functions to print out the full joint distribution from the above Bayes Net. Submit your exact function call and expected output below.
5. (10 points) Assume for a specific user-agent interaction, P(Accurate=True) = .90 for every conversational turn and Problem\_Size = Small. If *k* <= 5 turns, Conversation\_Length=Short; if 6 <= *k* <= 10, Conversation\_Length = Medium, otherwise Conversation\_Length=Long. At what point should the chatbot redirect the conversation to a human in the decision tree above. Explain in depth how you got your answer. If you used code to get your answer, submit your exact function call and output.

**Part C –Markov Decision Processes (30 pts)**

1. (20 pts) Explain how you would implement the problem of when to redirect a user to a human operator as a Markov Decision Process by outlining states, actions, transition probabilities, and rewards. The following are the constraints of your implementation:
   1. You should consider the Part B probabilities related to Accurate, Frustrated, Resolved, and ConversationLength in your response. You can assume that the constraints in Question 10 of Part B apply, including the fact that Problem\_Size is fixed at Small.
   2. You can design your own reward function, based on the states that you identify. The reward function should roughly preserve the relative values of different terminal outcomes as described in Part A (to the extent that resolving the problem is better than redirecting if the user is frustrated, which is better than redirecting if the user is not frustrated).

While we are grading your solution, you may want to add a brief explanation of your solution so that we understand what you are trying to accomplish.

1. (5 pts) In what ways do you believe your implementation will function in a different way as the specification in Part A. Explain.
2. (5 pts) Is the general problem of determining when to redirect the user to a human or respond to the user more suitable to implement as a MDP (Part C) or as a decision tree (as in Part A). Explain your answer.

**Part D – Bonus (up to 30 points)**

Implement your design in Part C.