INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
End-Autumn Semester Examination 2023-24

Date of Examination: __17 November 2023__ Session: _FN_ Duration: _3 Hrs_ Full Marks: _80_

Subject No. : __AI60003__ Subject : _____Artificial Intelligence for Economics_____

Department/Center/School:_____Centre of Excellence in Artificial Intelligence_____

Specific charts, graph paper, log book etc., required _____

Special Instructions (if any) : _ALL PARTS OF SAME QUESTION MUST BE ANSWERED TOGETHER_

PART A (ANSWER __ANY 2__ QUESTIONS)

Q1. A) Give an example from Economics to illustrate why correlation does not imply causation. **[2 marks]**

B) Explain the concept of "confounders" with respect to causal graphical models with an example. **[3 marks]**

C) Discuss the shortcomings of Granger Causality, and how they can be overcome. **[3 marks]**

D) A state government wants to understand if scaling up public transport results in improvement in urban air quality. Accordingly, they carry out a Randomized Control Trial over 10 towns in that state. The Air Quality Index is measured once before the intervention, and again after it, 6 months later. The details of their experiment are given in the table below. Based on this trial, they conclude that there does exist a causal relation (improvement of public transport-> better air quality). Discuss whether their conclusion is justified or not. [Low Air quality index: better air quality] **[6 marks]**

Town	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
%Area of Green Cover	24	32	15	8	18	25	21	3	30	22
Population	5Lakh	2L	14L	10L	5L	6L	10L	15L	8L	5L
Initial Bus Fleet Size	80	30	60	120	72	84	140	180	90	75
Initial Air Quality Index	58	42	145	75	65	80	115	245	64	96
Scale-up done	Y	Y	Y	Y	Y	N	N	N	N	N
Present Air Quality Index	52	39	104	78	60	74	105	251	54	89

E) A market survey agency has estimated the "satisfaction score" of 150 different regions, by interviewing people living there. I want to understand the main driving factor(s) behind the "satisfaction score" (Y, measured on a scale 0-100) in different regions using Shapley Value Analysis. My understanding is that the

possible factors that cause satisfaction are X1=Human Development Index, X2=Per Capita Income, X3=Net GDP of the region. In the dataset below of 10 regions, I have estimated two sets of Shapley Values (S_A, S_B) of these factors for 10 regions, based on two different predictive models (f_A, f_B). What is the expected value of Y? Which set of values should I consider, and which factors can I conclude as the main drivers of satisfaction? For each of the 10 regions, discuss the possible values of the 3 factors (relative to their means), and the nature of their contributions to the happiness of the region. **[6 marks]**

ID	1	2	3	4	5	6	7	8	9	10
Y	45	57	23	37	65	44	78	31	28	50
$f_A(X)$	44	59	25	36	69	40	73	35	28	52
$f_B(X)$	45	60	15	45	60	45	75	30	30	45
$S_A(X1)$	-10.7	9.3	-15.4	-8.1	8.8	-5.4	15.4	-14.6	1.7	-3.6
$S_A(X2)$	7.1	-0.5	-12.8	-2.1	6.9	1.1	17.2	-2.8	-16.4	7.4
$S_A(X3)$	0.8	0.2	3.2	-0.8	1.3	0.3	-2.6	0.4	-5.3	-1.8
$S_B(X1)$	-9.6	8.7	-15.2	-7.8	5.9	-3.2	10.6	-7.1	-2.6	1.1
$S_B(X2)$	7.4	-1.4	-12.5	-2.6	7.4	-0.5	16.8	-10.5	-17.1	1.7
$S_B(X3)$	2.2	1.7	3.7	-0.6	3.7	-0.3	2.6	0.6	-0.3	-0.8

Q2 A) The number of new jobs J(t) created, the number of existing jobs abolished F(t), and the number of new persons entering job market E(t) in a country in year 't' depends on the annual growth G(t) of the GDP. Based on the data provided below, represent the situation as a Hidden Markov Model and estimate its state transition and emission parameters based on relative frequencies, using any suitable emission distributions and number of latent states. **[6 marks]**

t	1	2	3	4	5	6	7	8	9	10
GDP	305	306	310	321	322	322	327	334	340	341
New Jobs Created	80	25	65	85	15	10	48	65	72	5
Existing jobs abolished	12	50	10	2	40	85	8	10	5	45
New job candidates	15	5	25	40	10	0	20	28	24	6

B) Consider, the country had 100 employed and 100 unemployed people in the job market at t=0. Assuming that no job post remains vacant, and using the HMM parameters calculated above, estimate the expected number of employed and unemployed persons at t=11. **[4 marks]**

C) You want to test if there is a linear causal relation between number of jobs abolished and the total number of unemployed persons, by considering each time-point as an independent observation. Sketch a causal graph indicating the different variables involved, based on the above data and the HMM model. Explain how you can use the Double-ML technique with Frisch-Waugh-Lovell Theorem to answer the question. **[5 marks]**

D) You want to predict the number of employed persons each year based on the annual GDP growth, knowing the employment numbers at t=0 and initial GDP (t=0) of 296. Formulate an RNN with a 3D hidden state. Explain how you will explain the parameters of the RNN. Show how you will estimate any one parameter, assuming others are known. **[5 marks]**

Q3 A) Give an example to explain why the heuristic function of A* must underestimate the true cost to a goal node. What is the problem if we use 0 as the constant heuristic value at all nodes? **[5 marks]**

B) Two countries A and B, both having a GDP of 100 units initially, engage in a competition to increase their GDP. They do this by increasing their investments in industrial development, which unfortunately results in a decrease in their social sector spending (health, education etc), resulting in a decrease of their Human Development Index and may also increase carbon emissions.

At each step, country A can set their industrial investment XA to 1 or 2 units, while for country B, this investment XB can be 0 or 3 units. In case of A, the GDP GA grows according to the rule GA(new) = GA(old) + 2*XA, while for country B this rule is GB(new) = GB(old) + XB. The Human Development Index HA of country A varies with XA as HA(new) = HA(old) − 0.05*XA, while for country B, this varies as HB(new) = HB(old) − 0.08*XB. The carbon emissions CA of country A increases by an amount that follows N(5*XA, 2), while for country B the carbon emissions CB increases by an amount that follows N(3*XB, 6).

i) Construct a game tree between A and B, showing the state values (GDP) and considering the reduction of HDI as the edge cost at each step. Go upto depth 4 (2 steps for each country) starting with country A. Identify the optimal move for both at each step, considering the valuation of each leaf state as gain of GDP minus 10 times the loss of HDI for A w.r.t. B. **[5+5=10 marks]**

ii) What is the expected change in carbon emissions of both A and B, if both move optimally? If A follows a policy that it will never allow its expected carbon emission to exceed 75% of its maximum value, then which path will be followed? **[2+3=5 marks]**

PART B (ANSWER <u>ALL</u> QUESTIONS)

Q4 Consider an auction with one buyer and 5 sellers with valuations 10, 12, 15, 5, 9 respectively for the item being sold. However, the valuation of player i is known to that player only. Each player believes that the valuation of every other player is distributed uniformly randomly from the interval [0,20]. Suppose you are the second player and standard game theoretic assumptions apply. Justify your answer in all these cases.

i) Suppose the first price auction is used. Then what will you bid? **[6 marks]**

ii) Suppose the second price auction is used. Then what will you bid? **[5 marks]**

iii) Suppose the third price auction is used, i.e. the lowest bidder wins buy receives the third minimum bid among all the bids as his/her payment Then what will you bid? **[3 marks]**

iv) Suppose the fourth price auction is used, i.e. the lowest bidder wins buy receives the fourth minimum bid among all the bids as his/her payment. Then what will you bid? **[3 marks]**

v) Suppose the fifth price auction is used, i.e. the lowest bidder wins buy receives the fifth minimum bid among all the bids as his/her payment. Then what will you bid? **[3 marks]**

Q5. A) Two players simultaneously announce an integer from [0, 1, 2, ..., 100]. The player, whose announcement is an integer closer to 2/3 of the average announcement, gets 1 and the other player gets 0. In case of tie, each gets 1/2.

i) Construct the payoff matrix

ii) Find the pure strategy Nash Equilibrium (Equilibria if more than one)   **[3+4=7 marks]**

B) Three men – Adway, Palash & Dripto reside on three floors of an apartment building somewhere in Kharagpur. They are deciding whether to employ a security guard at the entrance to the building. Assume that the guard costs 1 per resident. Each resident has a value (not including the cost of hiring) of the guard of either 2 or −2 (it can be negative because some individual resent the loss of privacy). If the guard is NOT hired, all residents receive a net utility of zero (Status Quo!). The three residents adopt the following procedure: they report their value (i.e either 2 or −2) and the guard is hired if the number of residents reporting the positive value, is at least α where α is either one, two or three. Note that different values of α represent different procedures - if α is one, the guard is hired as if at least one resident wants it, if α is two, a majority is required and α is three would mean that hiring takes places only if the residents are unanimous. Show that reporting their value truthfully is a weakly dominant strategy for each resident, for all values of α.   **[8 marks]**

[A strategy is weakly dominant if, regardless of what any other players do, the strategy earns a player a payoff at least as high as any other strategy, and, the strategy earns a strictly higher payoff for some profile of other players' strategies. Hence, a strategy is weakly dominant if it is always at least as good as any other strategy, for any profile of other players' actions, and is strictly better for some profile of others' strategies. If a player has a weakly dominant strategy, than all others are weakly dominated. If a strategy is always strictly better than all others for all profiles of other players' strategies, than it is strictly dominant.]

C) In a cricket match between AUS & IND, Virat bets on IND & offers a bet of 30:1 i.e If I bet Re. 1 with Virat that "AUS will win" & AUS indeed wins Virat will pay me Rs. 30 & if IND wins, I will pay Virat Re.1. Steve on the other hand bets on AUS & offers a bet of 7:5 i.e If I bet Re. 1with Steve that "IND will win" & IND indeed wins Steve will pay me Rs. 7/5 & if AUS wins I will pay Steve Re. 1. I have Rs. 100 in my wallet. How should I bet to eliminate risk? What is the maximum guaranteed payoff I can earn?   **[5 marks]**