INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester 2022-23

Date of examination: 26/09/2022 Session (*FN / AN*): AN

Duration: *2 hours* Subject No.: AI60003 Subject: Artificial Intelligence for Economics

Dept: .Centre of Excellence in Artificial Intelligence Full marks: 50 No. of students: 110

Instructions: ***Answer all questions. All parts of a question must be answered together.***

1. A set of **n projects** (P) are to be completed by the Government. There are a set of **r agencies** (A) who apply for taking up the projects. We can assume r >= n. Each agency submits bids for some projects, giving the **cost** requirement for each project that they bid for. For each project they also have to guarantee a minimum amount of **revenue generation** and **number of jobs created.** Each agency can be assigned at most one project.
   Given a **total budget B** available with the Government for completion of **ALL** projects, we are to assign projects to various agencies (one agency can get at most one project) so as to maximize the two objectives, namely total revenue generation and total job creation within the total budget B. The set of non-dominated valid solutions are to be reported. If all projects cannot be completed within the budget B through any combination, then a failure is reported.
   Develop a multi-objective state space heuristic search model for this problem with the following:
   a) Definition of State and its validity condition
   b) State Transformation Rules
   c) Start State
   d) Goal Condition
   e) The multi-objective cost g(n) of any state
   f) A good multi-objective Heuristic estimate h(n), which must overestimate the two objectives.

   Create a non-trivial example problem of 3 projects and 3 agencies where each agency bids for every project and there are at least 3 solutions. Show the working of a Multi-objective A* algorithm **[10 marks]**

2. Write a brief note on **any one of the two**:
   a) Genetic Algorithm to perform Multi-objective Search on the above problem (Question1) explaining all the aspects of representation, selection, crossover, mutation, fitness, etc on the same example of 1(g).
   b) Bayesian Belief Networks with a specific non-trivial realistic example in Economics presenting the Belief Network of at least 10 nodes, edges and probability values.

   [7 marks]

3. A researcher has 100 hours of work which have to be allocated between two research assistants Aditya & Gaurav. If Aditya is allocated x hours of work his utility is $-(x-20)^2$. If Gaurav is allocated x hours of work his utility is $-(x-30)^2$. The researcher is considering two proposals

   I. Aditya is given 60 hours of work & Gaurav is given 40 hours.

   II. Aditya is given 90 hours of work & Gaurav is given 10 hours.

   Which of the following statement is correct? Explain your answer.

   A. Proposal I is pareto optimal but Proposal II is NOT.
   B. Proposal II is pareto optimal but Proposal I is NOT.
   C. Both proposals are pareto optimal.
   D. Neither proposal is pareto optimal. **[3 marks]**

4. In the class we saw that the greedy algorithm did NOT lead to a stable match. Is it necessary that it will fail always? If not, can you provide an example (with 5 boys & 5 girls) where the greedy algorithm succeeds in yielding a stable match. **[3 marks]**

5. Two days before the expiration date Harshad wants to sell a CALL with strike price Rs. 100 i.e she wants to go short on C_{100} (S , t). The interest rate is r = 10%. And the current value of the stock is Rs. 120. Use the PUT – CALL parity equation to find a lower bound on the value of C_{100}. **[4 marks]**

6. Consider an economy where agents are identical and they live for three periods. Suppose in the first period they invest **'e'** in their education and become skilled in the second period where the level of skill $\mathbf{h = e\,\delta}$, $0 < \delta < 1$. The investment in education is done via borrowing from the market at a fixed interest rate **R** per period. In the second period of their life they work using the acquired skill (h). The total wage of an agent with skill level h is given by $\boldsymbol{w.h}$; where w is the exogenously given wage rate. Once they earn wage income $w.h$ in the second period, they repay their total borrowing for education. Assume that the wage income is sufficient to repay this education loan. Further, for simplicity we assume that they do not consume anything in the first period. In the second period they take their consumption and saving decision for the second and the third period. Gross return on saving is the same interest rate **R** per unit per period. Agents do not work in the third period and live on their saving made in the second period. Suppose the life-time utility function is given by:

$\mathbf{U = U(c_2) + \beta\, U(c_3)}$; where c_2 and c_3 are the consumption levels in the second and third periods respectively. The function U(.) is assumed to be strictly positive and strictly concave with $\beta > 0$.

(a) Write down the utility maximization problem of the agents. Clearly derive the first order conditions.

(b) Considering $U(x) = logx$, derive the optimal level of investment in education (e). Describe its relationship with the wage rate (w) and the rate of interest (R).

[8 marks]

7. Consider the following sequence of transactions by 5 users along with their timestamps. Articles purchased in consecutive time-points can be considered to have been purchased together as a transaction. Identify the frequent itemsets of different sizes using Apriori Algorithm. **[5 marks]**

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
U1	A	B	C		A	B		B	A	
U2		C	D		B	C	A		A	C
U3		E	A	C		C		E	A	
U4			B	C		F		A	C	B
U5	D	C		D	A	C		A	C	D

8. A) Consider the following time-series, and two possible autoregressive models for it. Which of these models is a better representation of the time-series?

X: 1 3 4 2 2 0 2 1 1 2 3 5 3 4 4 3

Model 1: $x(t+1) = 1.1x(t) - 0.9x(t-1)$

Model 2: $x(t+1) = 1/3*(x(t) + x(t-1) + x(t-2))$

B) Consider the following two time-series. Do they exhibit auto-correlation at any lag value? Can you identify any cross-correlation across them?

X1	1	4	6	7	5	4	2	2	4	5	8	7	6
X2	15	12	10	8	9	11	12	16	16	15	11	5	8

[3+2=5 marks]

9. We are trying to predict whether a startup company will survive or not. We have considered several attributes in the dataset provided below. Construct a decision stump (i.e. decision tree of depth 1) by choosing the most discriminative feature.

Seed funding (lakhs)	24	80	18	54	37	105	85	45	21
Age of main founder (years)	31	36	40	30	35	27	31	26	22
Number of founders	3	2	4	2	5	8	7	1	1
Survived?	Y	Y	Y	Y	N	N	N	N	N

[5 marks]