Work Integrated Learning Programmes Division
First / 2024-2025

Comprehensive Test
(EC-3 Regular)

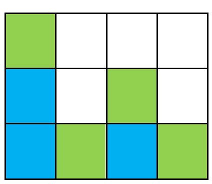
Course No. : AIMLCZG557
Course Title : Artificial and Computational Intelligence
Nature of Exam : Open Book
Weightage : 40%
Duration :
Date of Exam :

No. of Pages = 4
No. of Questions = 5

Note to Students:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Q1 Consider the Connect Three game on a 3x4 board. Player1 has 12 Blue checkers, and Player2 has 12 Green checkers. In Connect Three, the objective is to align three of your checkers either horizontally, vertically, or diagonally before your opponent does. On your turn, place one of your checkers into an open slot at the top of the board. The checkers falls to the lowest unoccupied space in that column, occupying it. Assume that player with Blue colored checkers moves first and answer the following questions: **[3+3+3 = 9 Marks]**

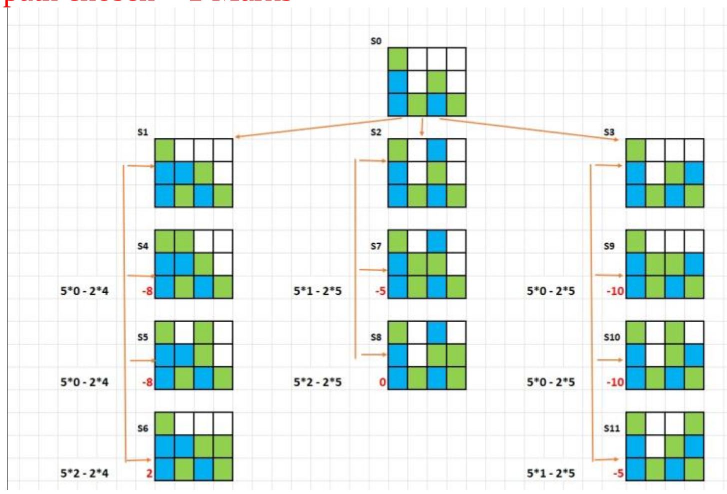
Initial State:

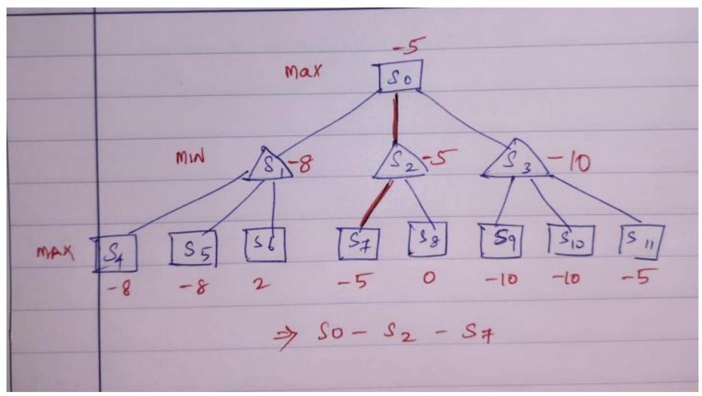


a) Construct the game tree (with neat diagram) from the given current state (0th level) as Start Node up to exactly 2 levels only (1st & 2nd Level - ie., one round for each of the player.)
b) Calculate the utility of the leaves of the tree with below static evaluation function.
Board value = 5*(MAX player chance of Win) – 2 * (MIN player chance of Win)
Player Chance of Win = No. of. Matches possible is this player alone is allowed to fill all the empty cells with its checkers.
c) Apply the Min Max algorithm on the game tree constructed in part a) using static evaluation values calculated in the part b) and highlight the best path chosen by players in the game given.

Sample solution and marking scheme

a. Search Tree for level 1 expansion – 1 mark
   Search Tree for level 2 expansion – 2 marks
b. Calculating static evaluation functions level = 3 Marks
c. Using Min max algorithm game tree construction – 2 Marks
   Best path chosen – 1 Marks





Q2 Not all instances of a low-voltage alert (V) in a smart city's power grid are caused by an absent power station (P). Some alerts may occur due to faulty connections (F) or energy leakage (E). When both a high-load condition (H) and a missing load balancer (L) are detected, the system identifies it as an overloaded segment (O).
Power fluctuations (W) may also be triggered by faulty lines, energy surges (S), or timing mismatches (T). Additionally, if a low-voltage alert (V) occurs without a power fluctuation (¬W), it must indicate a critical failure (C). **[2 + 2.5 + 2.5]**

a. Use propositional logic (without quantifiers) to efficiently represent the knowledge base given as above.
b. W.r.t below knowledge base from the results of part a), convert it into CNF.
c. Find a sample complete BSAT (Binary Satisfiability) solution for the variables using the DPLL algorithm, as explained in class. Provide a step-by-step approach.

Sample solution and marking scheme

Knowledge Base: **[2 Marks]**

R1: V → (P ∨ F ∨ E)
R2: H ∧ L → O
R3: W → (F ∨ S ∨ T)
R4: V ∧ ¬W → C

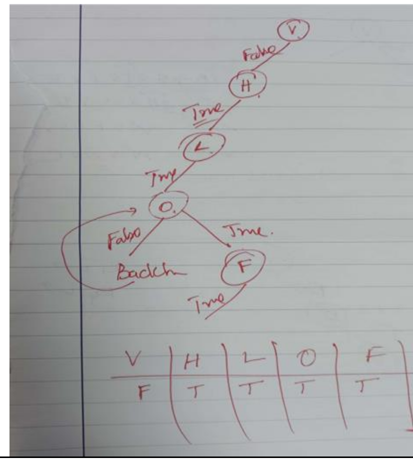
b. Conversion to Conjunctive Normal Form (CNF) **[2.5 Marks]**

Rule name should be specified

R1: ¬V ∨ P ∨ F ∨ E
R2: ¬H ∨ ¬L ∨ O
R3: ¬W ∨ F ∨ S ∨ T
R4: ¬V ∨ W ∨ C

c. DPLL Algorithm for BSAT Solution **[2.5 Marks]**

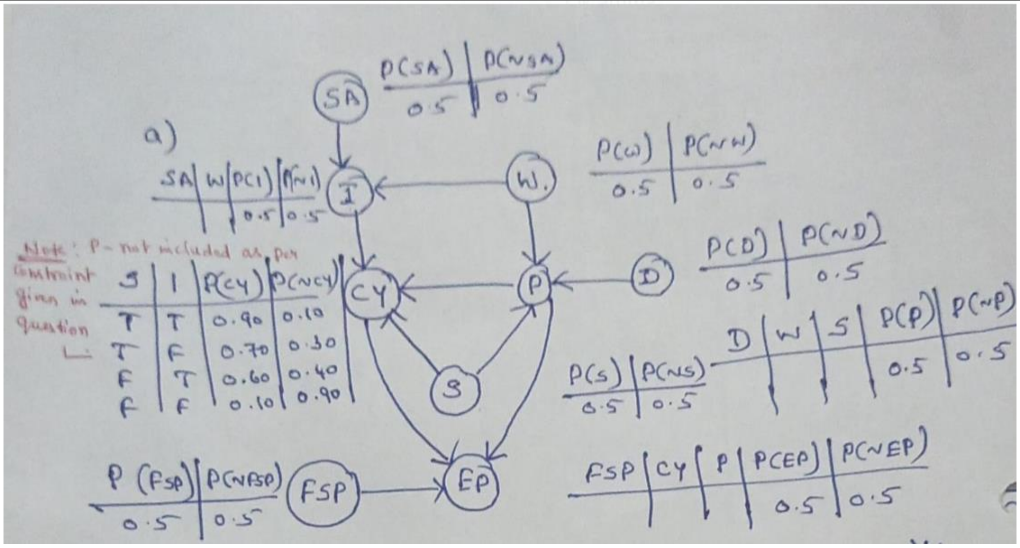
Pure symbols are: V,P,F,E,H,L,O,S,T,C (Need to be specified)



Q3 Ensuring a successful **Crop Yield (CY)** in a smart agriculture setup depends on multiple interrelated environmental and technological factors. The probability of a good crop yield (CY) is influenced by **Soil Health (S)**, **Irrigation Efficiency (I)**, and **Pest Control Measures (P)**.

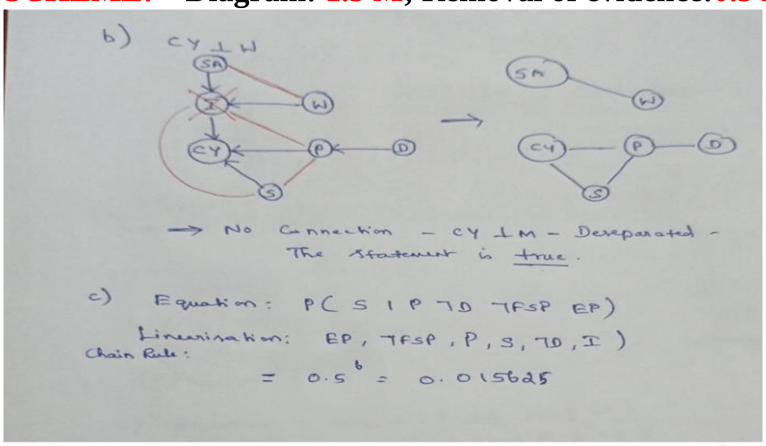
- **Soil Health (S)** plays a critical role in nutrient availability and plant growth. Poor soil quality increases the risk of low yield.
- **Irrigation Efficiency (I)** ensures that crops receive optimal water levels and is **positively influenced by Sensor Accuracy (SA)** and **Weather Forecast Integration (W)**.
- Effective **Pest Control Measures (P)** help in preventing crop damage and are **positively influenced by Monitoring Drones (D)** and **Soil Health (S)**.
- Additionally, **Weather Forecast Integration (W)** directly impacts both **Irrigation Efficiency (I)** and **Pest Control Measures (P)** by enabling proactive decisions.
- The combined status of **Crop Yield (CY)** and **Pest Control (P)** contributes to the **Economic Profitability (EP)** of the agricultural cycle.
- However, **Farmer Support Programs (FSP)** can help mitigate losses and **positively affect Economic Profitability**, even when crop yield is sub-optimal.

	When a system has **Healthy Soil** and **Efficient Irrigation**, the crop yield is highly likely (90%) to be successful. If the soil is healthy but irrigation is inefficient, crop yield is still likely (70%) to be successful. If the soil is poor but irrigation is efficient, crop yield has a moderate (60%) success chance, indicating water can partially compensate. When both soil and irrigation are poor, the success of crop yield drops significantly to 10%. **NOTE:** [Soil Health (S): Good (True) / Poor (False)] [Irrigation Efficiency (I): High (True) / Low (False)] [4+3+2 = 9 Marks] *a.* Draw the complete Bayes net with fully filled conditional probability tables. Consider the random variables embedded & highlighted in above problem statement as significant events, takes only binary values "true" or "false" and assume all the events (conditional or unconditional) are equally likely to occur ***except those which are explicitly specified in the problem statement.*** b. Use D-Separation approach to prove if the below statement is true or false. *"*Crop Yield (CY) is independent of Weather Forecast Integration (W), given we already know the Irrigation Efficiency.*"* c. What is the probability that a farm with Good Soil Health, Efficient Irrigation, and Effective Pest Control, but without Drones and without Farmer Support Programs, will still result in Economic Profitability (EP)? **Sample solution and marking scheme** **a) Bayesian network (4 Marks)** • **Bayesian network structure: (Mark:2)** • **CPT for, Crop Yield - 0.50 M & for others -1.50 M =(Mark:2)**



b) **D-Separation Approach: 3 Marks**

SCHEME: Diagram: 1.5 M; Removal of evidence:0.5 M; Result & Justification: 1 M (3 Marks)



c) **Query Extraction: 0.5M; Linearise the sequence: 0.5M; Chain rule, Computation and final result: 1 M (2 Marks)**

Q4	In a hospital, patients can be in one of three health states: Stable, Under Observation, or Critical. Patients in the Stable state have a 50% chance of remaining Stable, a 40% chance of moving to Under Observation, and a 10% chance of worsening to Critical. Patients in the Under Observation state have a 20% chance of recovering to Stable, a 60% chance of remaining Under Observation, and a 20% chance of deteriorating to Critical. Patients in the Critical state have an 80% chance of remaining Critical and a 20% chance of improving to Under Observation. The observed condition (symptom intensity) of patients is categorized as either **"Mild" or "Severe."** Patients in the Stable state exhibit Mild symptoms 70% of the time; those in Under Observation show Severe symptoms 60% of the time; and patients in the Critical state exhibit Severe symptoms 90% of the time. ***[3+5=8 Marks]***

a. Construct the Markov Model by extracting the transition and emission probability matrices from above pattern. Depict them with neat diagrams in addition to tabular representation. Assume equal likelihood for initial state.

b. Using the sequence of patient outcomes **("Severe", "Mild"),** apply the Viterbi algorithm to determine the most likely sequence of health states followed by the patient. Strictly follow the approach as discussed in class only.

Sample solution and marking scheme

Solution:

Answer for the Question a):

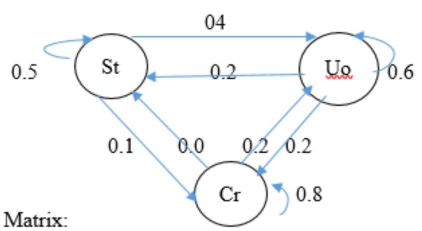
Given three health states: Stable, Under Observation, Critical and are taken as St, Uo and Cr respectively.
Observed health state: Mild (M), Severe (S).

Transition Probability Matrix:

	Stable	Under Observation	Critical
Stable	0.5	0.4	0.1
Under Observation	0.2	0.6	0.2
Critical	0.0	0.2	0.8

.... 1 Mark

Transition Diagram:



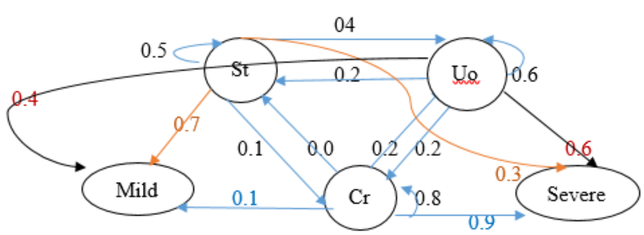
.... 0.5 Mark

Emission Probability Matrix:

State	Mild	Severe
Stable	0.7	0.3
Under Observation	0.4	0.6
Critical	0.1	0.9

.... 1 Mark

Emission Diagram:



.... 0.5 Mark

Answer for the Question b): Viterbi Algorithm

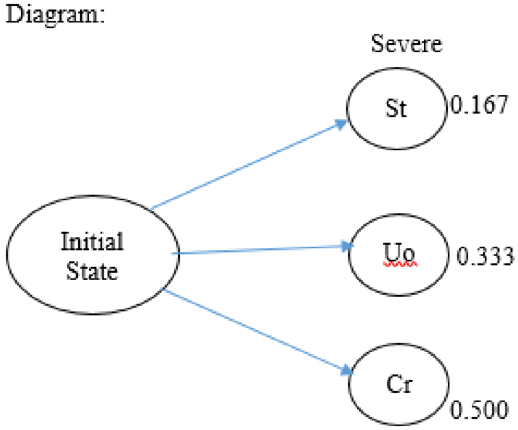
Given that most sequence of health states based on the observed sequence of symptoms: **"Severe", "Mild"**.
Given that we assume an equal likelihood for the initial state. I.e.

$$P(St) = P(Uo) = P(Cr) = 1/3$$ .... 0.5 Mark

Viterbi Algorithm for the sequence Severe to Mild:

for t=1based on the first observation, "Severe":

Diagram:



.... 0.5 Mark

P(State = St at t=1) = P(St) X P(Severe | St) = (1/3)X0.30 = 0.1

P(State = Uo at t=1) = P(Uo) X P(Severe | Uo) = (1/3)X0.6 = 0.2

P(State = Cr at t=1)= P(Cr) X P(Severe | Cr) = (1/3)X0.9 = 0.3

After normalized weights are:
Thus, the initial probabilities at t=1 are:

$V_1(St) = 0.1/(0.1+0.2+0.3) = 0.1/0.6 = 0.167$
$V_1(Uo) = 0.2/(0.1+0.2+0.3) = 0.2/0.6 = 0.333$
$V_1(Cr) = 0.3/(0.1+0.2+0.3) = 0.3/0.6 = 0.500$

.... 1 Mark

Recursion (for t=2 the observation is "Mild"):

For Stable (St):

$V_2(St)$= Max[$V_1(St)$ X P(St/St), $V_1(Uo)$×P(St/Uo), $V_1(Cr)$ X P(St/Cr)] X P(Mild|St))
= Max[0.167X0.50, 0.333X0.20, 0.5X0.00] X 0.70
=Max[0.05845, 0.04662, 0]
=0.058

.... 0.5 Mark

For Under Observation (Uo):

$V2(Uo) = Max[V_1(St) \text{ X } P(Uo/St), V_1(Uo) \times P(Uo/Uo), V_1(Cr) \text{ X } P(Uo/Cr)] \text{ X } P(Mild|Uo))$
$= Max[0.167X0.40, 0.333X0.60, 0.5X0.20] \text{ X } 0.40$
$=Max[0.02672, 0.07992, 0.0400]$
$=0.079$

.... 0.5 Mark

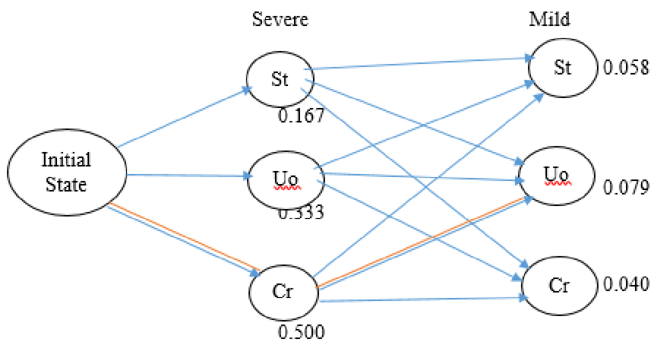
For Critical (Cr):

$V_2(Cr)= Max[V_1(St) \text{ X } P(Cr/St), V_1(Uo) \times P(Cr/Uo), V_1(Cr) \text{ X } P(Cr/Cr)] \text{ X } P(Mild|Cr))$
$= Max[0.167X0.10, 0.333X0.20, 0.5X0.80] \text{ X } 0.10$
$=Max[0.00167, 0.00666, 0.04]$
$=0.040$

.... 0.5 Mark

So the maximum probabilities at t=2 are:

$V_2(Stable)=0.058$
$V_2(Uo)=0.079$
$V_2(Cr)=0.040$



.... 0.5 Mark

Based on above Hidden Markov Model the most likely most likely sequence of health states followed by the patient is **Critical → Under Observation**, as it maximizes the total probability.

.... 1 Mark

Q5 **Answer all the following questions. Vague answers will not be awarded marks.**

[2+2+3=7 Marks]

a. Is it possible that the heuristic designed for informed search technique turns out to be admissible but not consistent? Explain with numerical example with a relatable real world case study.
b. Explain the evaluation process of the Breadth First Search (BFS) algorithm using an example.
c. Calculate the missing probability values and determine the likelihood that a Tata Sky customer's behavior in their monthly channel subscription renewal process follows this specific sequence: (***purchase new channel subscription , Continue Existing Subscription, purchase new channel subscription, purchase new channel subscription***). Calculate the initial probability using the given sequence.

Transition Probability Matrix:

Continue Existing Subscription	Purchase New Channel Subscription	← Previous / Current V
0.6	??	Continue Existing Subscription
??	0.2	Purchase New Channel Subscription

Emission Probability Matrix

Continue Existing Subscription	Purchase New Channel Subscription	Evidence V
0.1	0.4	Opt-for the Deal of the Day
??	0.3	Rent a movie
0.4	??	Watch free channels

Sample solution and marking scheme

a. Define admissibility (never overestimates the true cost) and consistency (satisfies triangle inequality)- **1 Mark**
Provide a numerical real-world example (e.g., GPS navigation with straight-line distance as heuristic; direct route: 50 km vs. indirect route A→B→G with costs that violate triangle inequality yet remain underestimates).- **1 Mark**

b. Breadth First Search Evaluation (2 Marks)

- **Time complexity**
- **Space complexity**
- **Optimality**
- **Completeness**

c. Missing Probabilities & Likelihood Calculation (3 Marks)
Compute missing values in the Transition Matrix: - **1 Mark**

0.6	0.8
0.4	0.2

Compute missing values in the Emission Matrix: -**1 Mark**

0.1	0.4
0.5	0.3
0.4	0.3

Likelihood of sequence: - **1 Mark**

Final answer : 0.064