Date :

Mathematical Modelling

⇒ Multi-Agent model uses several agents which highly depend on the agents Action and some external Events and also on the current state.

As railway system is very prone with many environmental disasters. In this scenario, are modelled using Markov Decision Process (MDP) with its states (ω) and Transitions (Ψ).

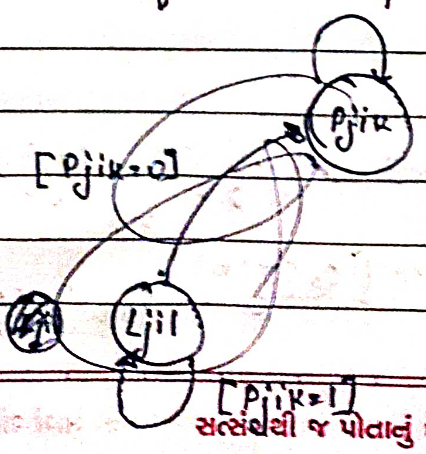
⇒ Set of world state (ω)

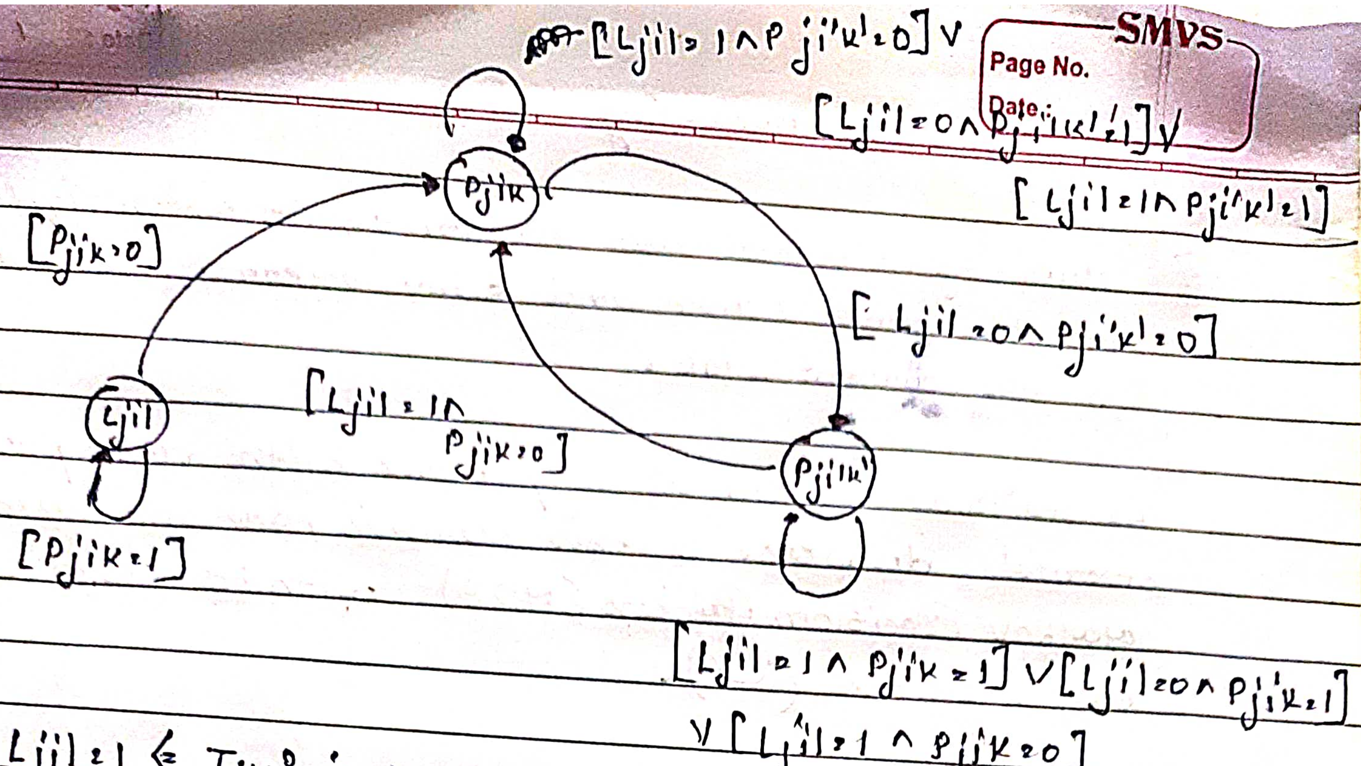
Train agents → have three states:
if S_i is assumed to be a station, where disaster happens then T_j is either on track connecting S_i or at a platform S_i or at a platform of S_i' connected to S_i

$$\text{i.e. } \omega = \{(L_{jil}=1), (P_{jik}=1), (P_{j'i'k}=1)\}$$

⇒ Transition Function: $\Psi(\omega, c, \omega')$, each action c maps to constraints (c) of DCOP to satisfy to reach from state ω to the next state (ω'), where $\{\omega, \omega' \in W\}$

⇒ Every node represents a railway Environment and each arc represents a constraint. The transition only happens if and only if specific constraints followed





⇒ $L_{jil}=1$ ⇐ Train j → present at station i → at lth track
$P_{jik}=1$ ⇐ no platform available
$P_{jik}=0$ ⇐ Platform free
$P_{j'i'k'}=1$ ⇐ Platform at next station not free

⇒ Disaster Handling Approaches:
(1) Delay or stop at the station or on track (Retiming)
(2) Change in departure sequence of trains at the station depending on priority of trains (Reordering)
(3) Reschedule to alternative path (Rerouting)

⇒ Case 1: Partial node deletion from the graph G

A station S_i faces problem due to disaster and the train T_j is on track l, approaching to the station S_i, that is

$L_{jil}=1$

⇒ $P_{jikl}\, x^{AT}_{ji}=1$, if and only if $[Prio(T_j) > Prio(T_{j'}), j \neq j', j \in [1,m]]^{TB}$

$\wedge\, [Re(T_j^n) \mid Prio(T_{j''}) > Prio(T_j) \neq Re(T_j) \mid]^{TB}$

⇒ if Above ~~cond~~ conditions are satisfied then, we can reroute train to any alternative path then reroute train T_j

Route of T_j after departure from S_i at time x_{ji}^{DT} is

$$[\,Rou(T_j')\,|\,t \le x_{ji}^{DT} + Rou(T_j')\,|\,x_{ji}^{AT} > x_{ji}^{DT}\,]$$

that is:

if $Rou(T_j')\,|\,x_{ji}^{AT} > x_{ji}^{DT} = \bigwedge_{i'>i}^{n-1} \cancel{A_{ji}}((P_{ji'k}\,L_{ji'l}) \cup P_{jnk} = 0)$

then reschedule T_j.

⇒ Now if the above condition is invalid, then stop T_j at S_i until the recovery is done, or any other path becomes free. Therefore T_j occupies one of the platform at S_i.

$$(P_{jik} = 1) \text{ and } x_{ji}^{DT} = O_{ji}^{DT} + \delta_j$$

where

$$(\delta_j = t_R - O_{ji}^{DT}) \text{ and } (t_R = t_D + J_R)$$

** Case 1.2

if case 1.1 not satisfied, then stop train T_j on the current track

$$(L_{jil} = 1) \text{ and } (x_{ji}^{AT} = O_{ji}^{AT} + \delta_j)$$

⇒ Now we can Analyse ~~Si~~ size PN2:

$P = \{P1, P2, P3, P4, P5, P6, P7\}$

transitions $TR = \{TR1, TR2, TR3, TR4, TR5, TR6, TR7, TR8\}$

Initial Marking $M_0 = \{1,1,0,0,0,0,0\}$

⇒ Reachability graph Analysis:

(a) The reachability set $R(M_0)$ is finite

(b) Maximum number of tokens that a place can have is 2, so our PND is 2 bounded

⇒ There are no dead transitions.

⇒ Stat Equation

The Structural Behaviour of Petri-Net can Be measured using the Algebric Analysis called the incidence matrix.

Incidence Matrix Represents: Connections B/W places and transitions, the number of total transitions can Be represented through the incidence matrix.

$M_0 \leftarrow$ Initial Marking

$M \leftarrow$ Reachable Marking

⇒ it can Be done as: $M_0 + [A] \times X_\sigma = M$

Incidence Matrix: $A = [e_{uv}]$

The order of the places in the matrix is ~~M~~ P

$P = \{P_1, P_2, P_3, P_4, P_5, P_6, P_7\}$ denoted by rows

and ~~R~~ $TR = \{TR1, TR2, TR3, TR4, TR5, TR6, TR7, TR8\}$ denoted by columns.