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N-Dimensional Self Organizing Petrinets for Urban Traffic Modeling

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Abstract

This paper highlights the Urban Traffic Simulation using causal petrinets. The focus of this paper is to generate a producer consumer network of networks and have grid simulation of Petrinets. The paper suggests a grid petrinet model with self organizing producer-consumer nets.
Keywords: *Self organizing Network, Causal Producer – Consumer Petrinets*

1. Introduction

1.1 Problem Statement

Traffic Management System addresses the objective of reducing congestion, vehicle delay time, fuel consumption and pollution. The most common technique to regulate and manage Urban Traffic is grouped into two classes:

1. Fixed-Time System.
2. Traffic Responsive System.

The first group has fixed on-off time periods for traffic flow. The second group employs actuated signal timing plans and performs an on-line optimization and synchronization of traffic signals. The real sense sensors/ detectors located on traffic intersection, which feed information on, the actual system state to the real time controller. To achieve traffic control using these strategies Traffic Network has to be appropriately modeled for simulation purpose.

2. Literature survey

The dynamics of Urban Traffic systems depends on the complex interactions of the timing of various discrete events, such as arrivals or departures of vehicles at the intersections and beginning or completion of the various phases in the signal timing plans of the traffic lights as stated by Tzes, Kiran and Mc Shane [8].

An example of colored PNs model of Traffic Light was first proposed by Jensen [6]. Later on Tzes, Gallego and Farges Henry [4] have modified the model of Jensen which shares the idea of adjusting signal controlling according to the distinct tokens deposited in PN controller. The latest paper by List and Cetin [5] discuses the use of PNs in modeling traffic signal controls and performs a structural analysis of the control PN Model by P- invariants, mainly focusing safety rules.

Similarly, Di Febbraro [1, 2, 3] et al presented a model in a timed PN framework, where token are vehicles and places are part s of lanes and intersections. We will be using all these models with modifications with respect to the behavioral aspects of Indian Traffic conditions. The focus will be on spatio-temporal relation of Traffic movement.

3. The model

The Model is divided into two basic parts: The forward propagation petrinet model which focuses on simple cause effect framework.The second part focuses on continuous Petrinet Learning mechanism.

3.1 Forward Propagation of Petri nets

We will discuss each of these frameworks with references to Indian Traffic Movement Conditions.

This model represents the flow of Traffic based on causal runs where:

'e' represents the places.

't' represents the Transitions.

'q' represents the flow of token

For a simple situation of a roadblock we can have a cause and effect relationship shown in figure 1.

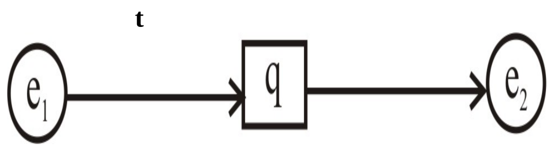

Fig. 1: Simple Petrinet Model

Event e1 can cause event e2 with a transition‘t’. Considering a situation when multiple road jams at the same instances and the traffic by-lanes exists points connected to a single main road.

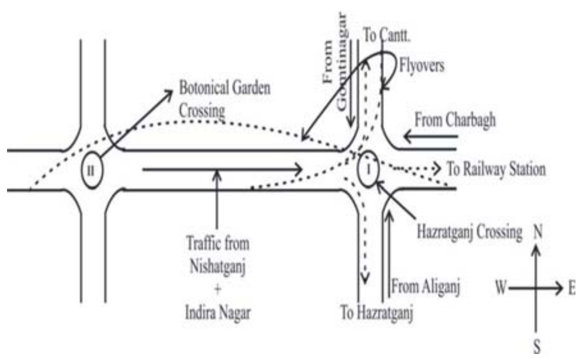

Fig. 2: Road Network

Since these by lanes have an outflow at the main road the flow of traffic is drastically reduced as the vehicle outflow from various by-lanes starts pouring into the main road due to congestion in other parts. Simple producer- consumer nets can represent the workflow of the entire traffic dynamics. (Figure 3).

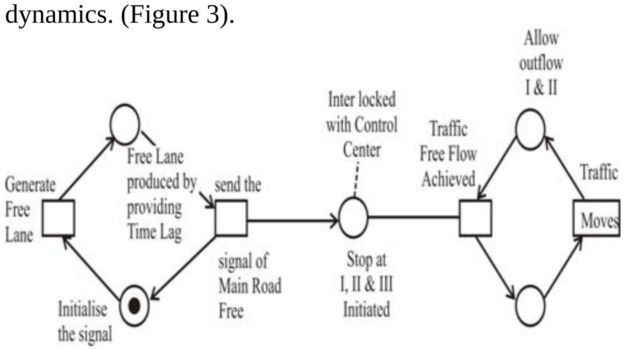

Fig 3. Causal Run of Producer - Consumer of Traffic Flow

Consider this producer - consumer as one single unit denoted by ‘X’. This main - road itself is a part of the entire road grid of the city. Assuming that there is some pattern of traffic movement, which is present at various interval of time. Applying Unidirectional Petrinet Model with tokens moving in Feed Forward mode as shown in the figure 4.

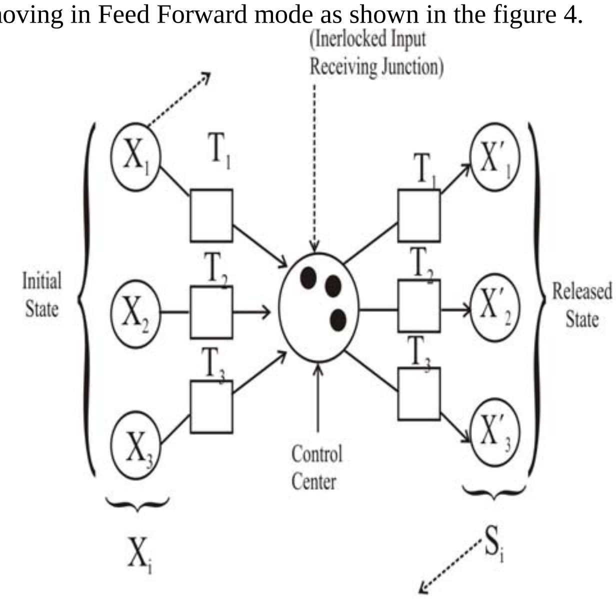

Fig. 4: Dynamic Producer Consumer with Buffer Interlocked with Control Center

The Algorithm for Dynamic Producer Consumer is given as:

Step 1: Initialize each of the Producers- Consumers situation (x). Set the pattern learning rate as 'γ'.

Step 2: Set the control center such that:

Xi = Si is achieved.

Step 3: Let the Token release rate is defined as 1/N; where N is defined as the number of producer consumer initial states.

Step 4: The release of Token are updated as:

x: (producer- old) = xi (producer - new state) + r (pre- post)

Where 'w' is the bulk arrival rate of Tokens.

Step 5: Stop when system has transferred all the tokens and traffic reaches a balancing state.

3.2 Grid Model:

Now consider a situation when we consider the producer consumer network to be trained and the combination of Control Center and Producer - Consumer as one single unit denoted as 'Y' for the first layer, 'Z' for the second and 'N' for the third layer.

It can be shown by the help of two dimensional grid of producer - consumer link with buffer interlocked with Virtual Counter which keeps the track of diversion of Token based on the congestion in the road network (i.e. consumer) and supply of new lanes (i.e. producers) and diversion of traffic through VMS. The counter (M) keeps track of tokens Number stamped by the layer through which is it is being generated and finally arriving at particular layers.

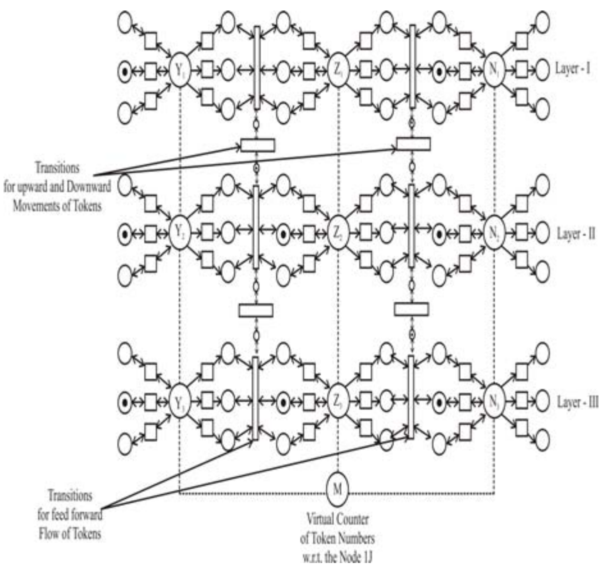

Fig. 5: Grid Network of Producer- Consumer Structure

The purpose of showing the arrow in both the direction has special significance, during the first instance the token moves in forward learning mode and this state is now stored in Virtual Counter.

During the next cycle there is a change in sequence will behave in vice-versa mode the road network which is now having heavy traffic movement will eventually settle down with lesser frequency of traffic with time. This requires a signal from the consumer end to the producer end to check the new status.

This process of adjustment and training of producer-consumer from their nearest neighbors goes on till the entire system becomes stable.

3.3 Training Algorithm**:**

Step 1: Set the Virtual Counter to value; set the stability session the grid has to perform.
Step 2: While stopping condition is false; perform step 3-8.
Step 3: For each layer the compute the complexity of link of the token movement is given as:

$$x(n) = \sum (\text{Layer 1 - Layer n})^2$$

Where 'n' is the layer - n to which token moves.
Step 4: For each of the movement of token freeze the producer - consumer network which has become stable and these are no more to be initiated.
Step 5: After all the forward steps has been performed. Log the virtual counter to current state.
Step 6: Move in the reverse direction this time consumer driving the producer for necessary action calming.
Step 7: This Forward and Backward movement of Tokens takes place till the time entire network is Self- Organized and further flow of token is not required within a particular time frame.
Step 8: Test and store the stopping condition.

The key idea to have a self organizing causal grid net is to find the heavy bottleneck situation in the entire city traffic network and then flow of token starts layer - by-layer to achieve the final stability. The grid works in two modes:

(i) The Initial formation of back- forward flow of tokens.
(ii) Convergence to a stable state.

4. Conclusion and future scope

The paper provides a real time dynamic simulation of Urban Traffic System using the concept of Causal Producer Consumer Theory. It extends the producer-consumer theory to N- dimensional representation where the focus to provide a buffer mechanisms and virtual counter to keeps track of the entire token flow across the grid. The future extension of our work will be simulation of our network using Petrinet Simulator to judge its efficiency with training of each Producer- consumer unit as a single entity. We will try to keep the token time stamped and then analyze how soon the network self organizes itself.

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