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Modeling the Railway Traffic Systems

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Abstract

This paper proposes a new time-placed net model for simulation of railway traffic systems. This model contains three modules: Transport Planning Module, Transport Control Module and Priority Control Module. For modeling the railway traffic systems we introduce a strategy in timed-place Petri net model to solve the collision and traffic jam problems of vehicles.

Key words*: Petri net, planning module, control module, railway traffic, traffic jam.*

Introduction

Petri nets are useful tools for modeling and analysis and scheduling of a production system; they can provide accurate models of the procedure relations and concurrent, asynchronous events. Besides, they are also useful in synthesizing plausible control for discrete event dynamic systems. In this paper, a Petri net model is built to model the detailed behavior of a railway system and a schedule, related on that Petri net model is to optimize some a priori assigned performance criterion. The ordinary Petri net model is not sufficient to capture the timed-related system nature, and hence, timed-place Petri net have been defined and used. In the timed-placed Petri net (TPPN), time is associated only with places and all transition firings are instantaneous; this is the model we selected for our simulating a railway system. We notice that this paper held only a qualitative analysis of the railway systems further papers will perform a quantitative analysis. Markings of the TPPN are deterministic during the evolution of the pertaining firing sequence from the initial marking. So, we can directly use the markings of the TPPN model to genuinely describe the states of the system and all the reachable markings can represent the state space of the modeled system.

Modelling the railway system

The timed-place Petri net model contains three major modules: Transport Planning Module, Transport Control Module and Priority Control Module. The three modules, of course, interact with each other to undertake the necessary actions in response to the triggering from another.

The Transport Planning Module

The purpose of the Transport Planning Module is to model the layout of the transport system. When a vehicle (trolley, waggon, or railway engine) needs to move from the current stop to the next adjacent stop, it needs to receive a "ticket" of movement first to know its destination. Then, the vehicle acquires the control right of the next adjacent stop to make sure that stop is free at the moment. If both of these conditions are satisfied, it can start its traveling to the next adjacent stop. In the same time, the control right of the current stop will be released to allow another vehicle to use it as a destination or pass-by stop. The Transport Planning Module consists of a number of Elementary Transport Layout Module, as shown in (Fig.1). The notations of places used in (Fig.1) are explained as follows:

- st i, $i \in N$ represents the stop at a workstation. A token in st i means a vehicle is now staying at stop i.
- ctrl i, $i \in N$, represents the control right of Stop i. If the place ctrl i is marked, it means that Stop i is freed now and all vehicles are allowed to move to Stop i; otherwise, it means there is a vehicle right at the stop so that no other can move to that stop.
- mv ij, $i,j \in \{0,\ldots,4\}$, with an arc connecting Stop i and Stop j in the layout directed graph, represents the status of the vehicle movement from Stop i to Stop j. A token in the place mv ij means that a vehicle is currently moving from Stop i to Stop j.
- tk ij, $ij \in \{0,\ldots,4\}$, with an arc connecting Stop i and Stop j in the layout directed graph represents the "ticket" of the path segment from Stop i to Stop j. If there is a token in the place tk ij, it means that a vehicle wants to move from Stop i to Stop j.
- mv ok represents the status of completing the vehicle movement along a segment path. A token in the place mv ok means that the vehicle has completed the segment path movement.

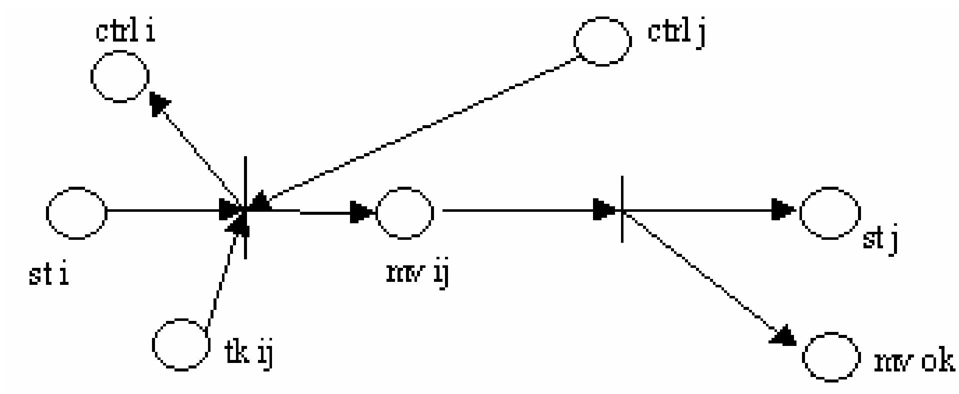

Fig. 1. Elementary Transport Layout Module.

As an example we consider five workstations as shown in (Fig.2). The process flow is: a convoy of railway trucks leaves the garage line (LG) and is sorted for to complain job1, respectively to load/unload the waggons at line number 1 or number 3 and then it follows job 2: to load/unload the sorted waggons at line number 2. The next operation is to return the waggons back to the garage line passing through the expedition lines of the shunt board and to return the flaw waggons to lines 1 or 3. The Transport Planning Module for the layout directed graph in (Fig.2) is shown in (Fig.3).

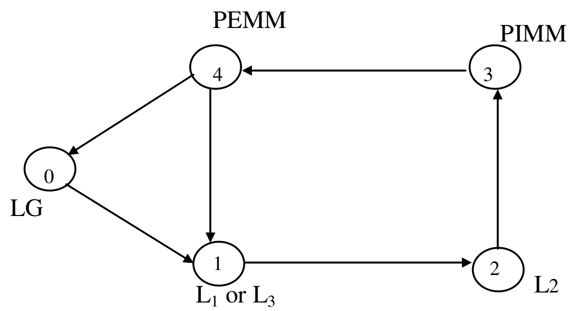

Fig. 2. Layout directed graph.

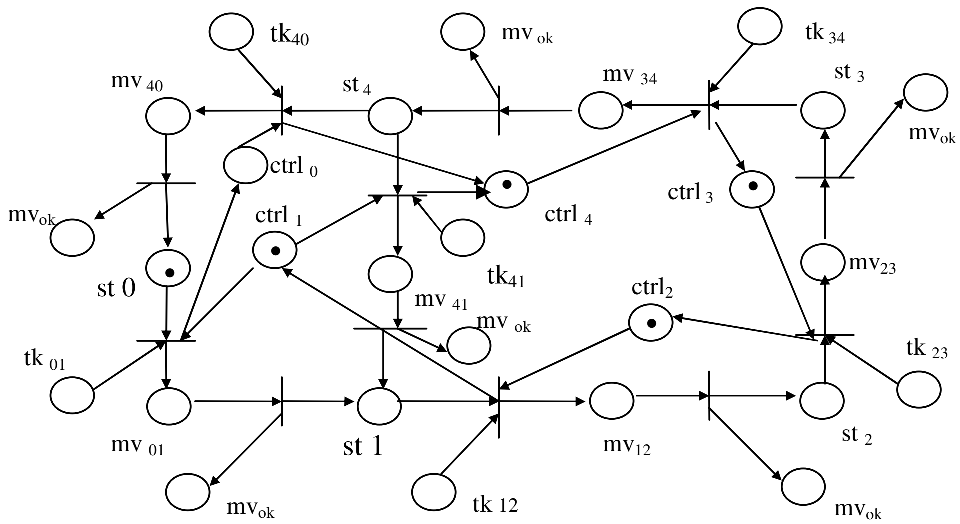

Fig. 3. The Transport Planning Module of Fig.2.

The Transport Control Module

This module corresponds to the decision-making Petri net model for vehicle routing. Each time a vehicle wants to move from the current stop to some other stop, it must determine its route of movement first. The determined route can be sent to the Transport Planning Module through "ticket" places tk ij to entail the vehicle to move along that route. Therefore, for each stop, we need to have a corresponding Petri net model guiding the traveling path from other stop to it.

Fig.4 illustrates the Transport Control Module for a vehicle to move from the current stop to Stop 3. The notations of places different from those in the Transport Planning Module are:

- mv st i represents the request of a vehicle movement from the current stop to Stop i;
- at st i represents the request of a vehicle movement from the current stop to Stop i is fulfilled;
- mv wait i means a waiting for the mv ok condition to generate a "ticket" for the next segment path.

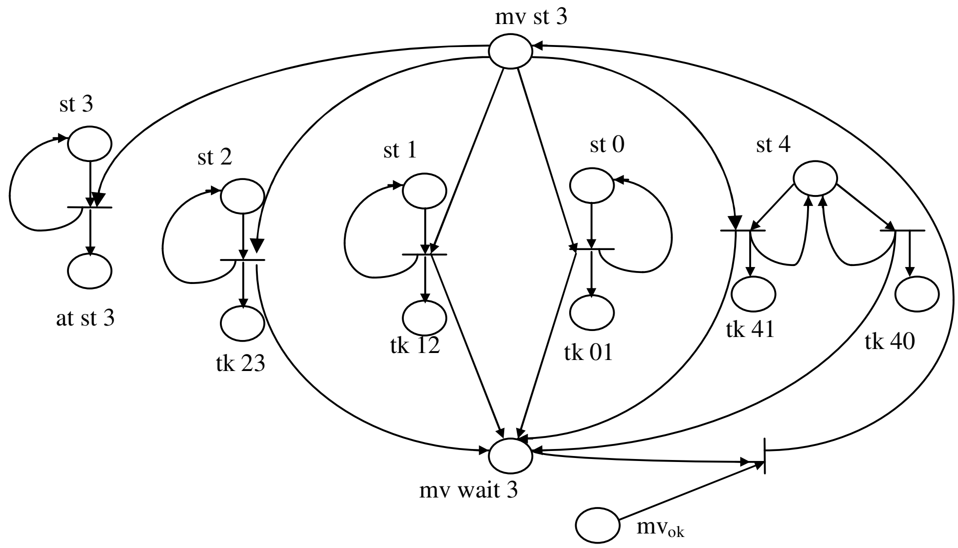

Fig. 4. The Transport Control Module.

The Priority Control Module

The objective of the Priority Control Module is to introduce a control method into the Petri net model with an aim to guaranteeing the jam-free conditions among vehicles. The method is described as follows: when a mission vehicle found a stop on its traveling route was occupied by another vehicle, it will send a command to that vehicle to ask it to leave that stop. After a "ticket" is sent to that vehicle, it starts to move to its next adjacent stop and releases the occupancy of its prior residing stop. When the stop is completely released, the mission vehicle can resume its traveling on the same route path. Because the command may be sent to any other vehicle, we must construct such models for every pair of vehicles to avoid this kind of traffic problem. The effectiveness of this strategy is limited to the layout geometry and the number of vehicles. But, unfortunately, this is the reality of physical system. The Priority Control Model given in Fig.6 is constructed based on the Elementary Priority Control Model from (Fig.5).

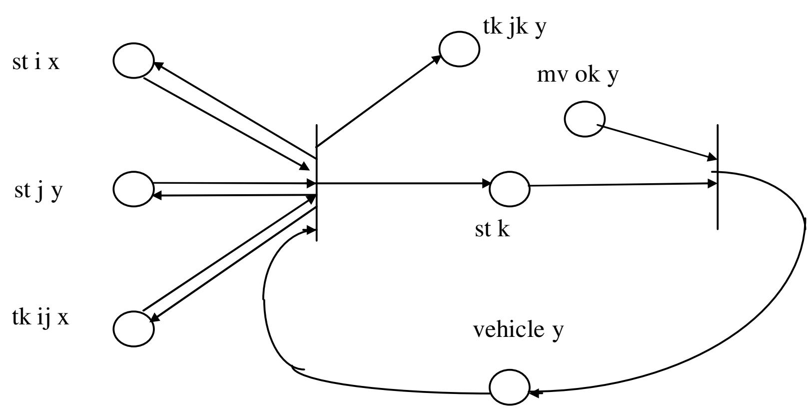

Fig. 5. Elementary Priority Control Module.

To distinguish the places associated with different vehicles, we add the subscript x to a place to represent that the underlying place is used by vehicle x. Consider every three adjacent stop points. If vehicle x is at Stop i and vehicle y is at Stop j and vehicle x wants to move to Stop j while vehicle y is idle, then vehicle y will be “pushed” by vehicle x to the other stop point, e.g., Stop k. So, this module sends a token to the place tk jk y in the Transport Planning Module and, when vehicle y completes its movement, the module will send a token to mv ok y so as to inform vehicle x to start its movement. In Fig.6 we show the Priority Control Module for the layout directed graph in (Fig.2) when vehicle 1 “pushes” vehicle 2.

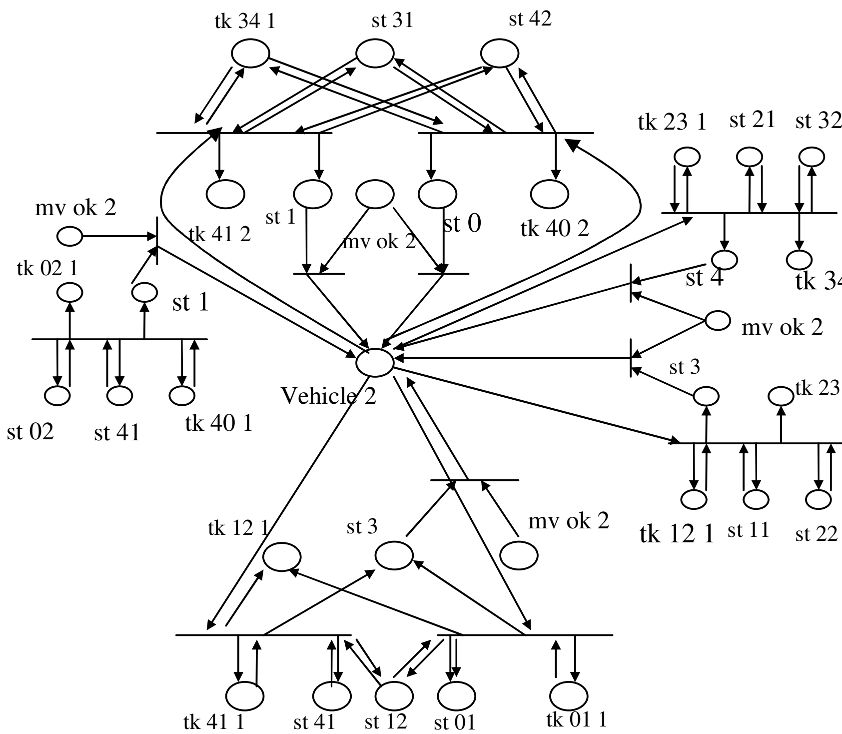

Fig. 6. Priority Control Module.

Conclusions

In this paper we proposed three basic models to construct the Petri net model of a railway system. The objective of the Petri net is to optimize the behavior of a vehicle traveling from the stop at which it currently stays to its destination stop, which must also ensure that vehicle collisions and traffic jam are avoided. The efficiency of the proposed method is limited to the layout geometry and the number of vehicles.

The present study may be extended by designing a discrete event controller where there exist choices to perform a route.

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Modelarea sistemelor de trafic feroviar

Rezumat

In aest articol este propus un nou model pentru simularea sistemelor de trafic feroviar. Modelul prezentat conţine trei module: Modulul pentru Planificarea Transportului, Modulul pentru Controlul Traficului şi Modulul pentru Controlul Priorităților. Pentru modelarea sistemelor feroviare am introdus o clasă de rețele Petri temporale, capabile să evite blocajele din trafic sau coliziunile dintre vehiculele feroviare.