Modeling Elevator System with Coloured Petri Nets

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MODELING ELEVATOR SYSTEM WITH COLOURED PETRI NETS

BY

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Dedication

To my inspiring parents,

Saad and Sharifah

To my supportive and beloved wife,

Eman

To my sweet daughters,

Lara and Rema

Abstract

A fairly general model of the elevator system is presented. Coloured Petri Nets (CPN) and CPN tools are adopted as modeling tools. The model, which is independent of the number of floors and elevators, covers different stages of the elevator system in substantial detail. The model assists simulation-based analysis of different algorithms and rules which govern real elevator systems. The results prove the compatibility and applicability of this model in various situations and demonstrate the expressive power and convenience of CPN.

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Introduction

This chapter overviews the elevator system. Section 1.1 introduces the elevator system. Section 1.2 defines the thesis objective. Section 1.3 presents related works. Section 1.4 lists the thesis contributions. Finally, section 1.5 presents the thesis outline.

1.1 The Elevator System

Elevator systems are an integral aspect of buildings from the point at which they are first designed. Transportation between floors, especially with heavy goods, is almost impossible using stairs for ordinary people at least. With high-rise buildings being the typical candidate for elevator systems, such systems are usually very complex. Multiple elevators must be controlled by a centralized control mechanism. The complexity of these elevator systems arises from factors such as scheduling needs, resource allocation, and stochastic control, to name a few. Handling these jobs usually results in systems behaving as discrete event systems Ramadge and Wonham (1989). Moreover, the differences among the types of buildings and their traffic patterns arise also the complexity of the elevator systems. For example, passenger elevators may exist in residential, institutional, or commercial buildings with some or mix of these popular traffic patterns [George R. Strakosch (2010); Barney (2003a)]: up-peak traffic (also called incoming traffic) where the traffic flows mostly from the first floor to other floors, down-peak traffic (also called outgoing traffic) where the traffic flows mostly to the first floor from other floors, and balanced traffic (also called random traffic) where none of the two previous patterns dominates.

1.2 Objectives

This thesis focuses on proposing a model of the elevator system that fulfilments the constraints of the following definition [Ghezzi *et al.* (2003)]: An *elevator system* is to be installed in a building with m floors and n cars. The elevator and the control mechanisms are supplied by the manufacturer. The internal mechanism of an elevator system is assumed (given). The problem concerns the logistics of moving cars between floors according to the following constraints:

1. Each elevator's car has a set of buttons - one for each floor. These buttons illuminate when pressed and signal the elevator to move to the corresponding floor. The illumination is cancelled when the corresponding floor is visited by the car.

2. On the wall outside the elevator each floor has two buttons (with the exception of the ground and the top floors). One button is pressed to request an upward

moving elevator and another button is pressed to request a downward moving elevator. If both buttons are pressed, then each direction is assigned to a different car. These buttons illuminate when pressed. The illumination is cancelled when the assigned car visits the floor.

3. When an elevator has not received any requests for service, it should be held at its parking floor with its doors closed until it receives further requests.

4. All requests for elevators from floors (i.e. hall calls) must be serviced eventually. The applied algorithm controls the priority of floors.

5. All requests for floors within elevators (i.e. car calls) must be serviced eventually, with floors usually serviced sequentially in the direction of travel.

6. Each elevator's car has an emergency button which when pressed causes a warning signal that is sent to the site manager. The car is then deemed "out of service". Each car has a mechanism to cancel its "out of service" status.

1.3 Related Works

The elevator system is one of the software engineering benchmarks which are frequently used to test the expressive power, readability, and convenience of various formal specification techniques Ghezzi *et al.* (2003). Petri Nets is one formal specification technique.

The elevator system is one of the software engineering benchmarks that are frequently used to test the expressive power, readability and convenience of various formal specification techniques [Ghezzi *et al.* (2003)]. It has been modeled many times in the past, and that includes Petri Nets.

In [Lin and Fu (1996)] and [Huang and Fu (1998)], dynamic scheduling of the elevator system was modeled by Petri Nets, and hybrid Petri Nets. Timed Petri Nets, Abstract Petri Nets and Elevator Control Petri Nets were used in [Cho *et al.* (1999); Etessami and Hura (1989); Ahmad *et al.* (2014)], respectively. Furthermore, the elevator system was modeled by Coloured Petri Nets in [Fernandes *et al.* (2007)], and Timed Coloured Petri Nets in [Liqian *et al.* (2004)] and [Ye *et al.* (2011)].

Nevertheless, all of these previous models are either static or dependent on a particular number of elevators and floors (often one place was required for each elevator car), the concept of colour as a data type was not fully utilized, or other formalisms such as UML were substantially involved.

1.4 Contributions

Modeling the elevator system by means of Coloured Petri Nets supports the proposed model to not only fulfilment the thesis objective (section 1.2), but also to distinguish by the following attributes:

- The proposed model is independent of the number of floors and cars. (i.e. the number of places and transitions is fixed for any given number of floors and cars). This is not only because of the appropriate choice of the modelling language, but also because of the proper structure of the model.

- The proposed model covers different stages of the elevator system in substantial detail through the division of the model into sub-models to simplify the structure and also to allow easier tracking of errors and faults.

- The proposed model is flexible enough to be adapted to different algorithms and rules that govern real elevator systems, and may eventually evolve into a 'standard' formal model of the elevator system.

1.5 Thesis Outline

The structure of this thesis is as follows:

- **Chapter 2** introduces the principles of Coloured Petri Nets (CPN), which is the modeling language of the proposed model.
- **Chapter 3** demonstrates the abstract version of the elevator system, which concerns the logistics of moving the elevator system.
- **Chapter 4** presents the timing version of the elevator system, which extends the abstract version to include more features.
- **Chapter 5** discusses two techniques of the parking optimizer model, which is expected to reduce the waiting time.
- **Chapter 6** provides the analyses of the proposed model through two techniques.
- **Chapter 7** concludes this thesis and mentions future work.

A fairly general model of the elevator system is presented. Coloured Petri Nets (CPN) and CPN tools are adopted as modeling tools. The model, which is independent of the number of floors and elevators, covers different stages of the elevator system in substantial detail. The model assists simulation-based analysis of different algorithms and rules which govern real elevator systems.

The results prove the compatibility and applicability of this model in various situations and demonstrate the expressive power and convenience of CPN.

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