

Modeling
Elevator System
with
Coloured Petri Nets

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Modeling Elevator System With Coloured Petri Nets

MODELING ELEVATOR SYSTEM WITH COLOURED PETRI
NETS

BY
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A THESIS
SUBMITTED TO THE DEPARTMENT OF SOFTWARE ENGINEERING
AND THE SCHOOL OF GRADUATE STUDIES
OF MCMASTER UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF APPLIED SCIENCE

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Master of Applied Science (2015)
(Software Engineering)

McMaster University
Hamilton, Ontario, Canada

TITLE: Modeling Elevator System With Coloured Petri Nets

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NUMBER OF PAGES: xiii, 94

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.

Acknowledgements

First and foremost, all the praises and thanks are due to Allah Almighty for giving me the ability and strength to accomplish this thesis. Then, I would like to extend my sincere gratitude and appreciation to my supervisor Prof. Ryszard Janicki for his thoughtful guidance, continuous support, and constructive feedback through my MASc Journey.

I would also like to express my appreciation to my examination committee, Prof. Alan Wassyng and Prof. Emil Sekerinski for their valuable comments. As well, I would like to acknowledge my colleague Mohammed Alqarni for the productive discussions and insightful suggestions that have contributed significantly to the progress of this thesis. In addition, I am grateful to Prince Sattam bin Abdulaziz University for providing the financial support to undertake this work.

Last, but certainly not least, I wish to extend my heartfelt gratitude to my inspiring parents, my dear siblings, my beloved wife, and my sweet daughters for their endless love, prayers, and encouragement that have made all of my achievements possible.

Contents

Abstract	iv
Acknowledgements	v
1 Introduction	1
1.1 The Elevator System	1
1.2 Objectives	2
1.3 Related Works	3
1.4 Contributions	4
1.5 Thesis Outline	5
2 Coloured Petri Nets	6
2.1 Overview	6
2.2 Informal Introduction to CPN	7
2.2.1 The Structure of CPN-based Models	7
2.2.2 CPN ML Language	8
2.2.3 A Simple Example	10
2.3 Formal Definitions	12
2.4 Computer Tools	14

3	The Abstract Version of CPN-based Model of the Elevator System	16
3.1	Introduction	16
3.2	The Abstract Car-Structure Sub-model	20
3.2.1	Dynamic Initialization of Places	23
3.3	The Abstract Hall-Call Sub-model	24
3.4	The Abstract Car-call Sub-model	31
3.5	The Abstract System-cycle Sub-model	34
4	The Timing Version of CPN-based Model of the Elevator System	39
4.1	Introduction	39
4.2	The Timing Car-Structure Sub-model	40
4.3	The Timing Hall-call Sub-model	44
4.4	The Timing Car-call Sub-model	48
4.5	The Timing System-cycle Sub-model	51
5	The Parking Optimizer Model	55
5.1	Introduction	55
5.2	The Election Sub-model	57
5.3	The Assignment Sub-model	61
5.4	The Position Sub-model	63
6	The Analyses	68
6.1	Introduction	68
6.2	The Reachability Analysis	69
6.3	The Simulation-based Performance Analysis	75

7	Conclusion	87
7.1	Discussion	87
7.2	Future Work	88

List of Figures

2.1	The basic components of CPN-based models	7
2.2	The process of illuminating buttons (as an example)	11
2.3	An example of a hierarchical CPN-based model	12
2.4	An example of the visualization extension	15
3.1	The sub-models of the elevator system	17
3.1	The development phases of the proposed model	20
3.2	The abstract car-structure sub-model	21
3.3	The abstract hall-call sub-model	25
3.4	Assigning hall calls to cars	26
3.5	Generating arbitrary and identified floors' numbers	29
3.6	Adding directions to the produced floor numbers	31
3.7	The abstract car-call sub-model	32
3.8	Coordinating between cars and their car calls	33
3.9	Producing arbitrary car calls	33
3.10	Producing specified car calls	34
3.11	The abstract system-cycle sub-model	35
3.12	The maintenance stage	36
3.13	The transition stage	37

3.14	The arrival stage	38
4.1	The timing car-structure sub-model	41
4.2	The timing hall-call sub-model	44
4.3	Releasing hall calls	46
4.4	Assigning timing hall calls	48
4.5	The timing car-call sub-model	49
4.6	The timing system-cycle sub-model	51
4.7	The arrival stage of the timing system-cycle sub-model	52
4.8	The maintenance stage of the timing system-cycle sub-model	54
5.1	The parking optimizer model	56
5.2	The election sub-model	57
5.3	Counting the placed hall calls	58
5.4	Sorting the floors of the placed hall calls	59
5.5	Electing the most requested floors	60
5.6	The assignment sub-model	61
5.7	Processing the floors by the assignment sub-model	62
5.8	Altering the cars' parking floors by the assignment sub-model	63
5.9	The position sub-model	64
5.10	Identifying the scope of floors	65
5.11	Completing the information of scopes	66
5.12	Altering the cars' parking floors by the position sub-model	67
6.1	The standard report of the abstract version (1)	71
6.1	The standard report of the abstract version (2)	72
6.2	The standard report of the timing version (1)	73

6.2	The standard report of the timing version (2)	74
6.3	The monitors' statistics of the abstract version	77
6.4	Produced calls from the abstract version	78
6.5	Results from the abstract version	79
6.6	Observing different experiments through the Visualization Extension	80
6.7	The monitors' statistics of timing version	81
6.8	The calls of the timing version	82
6.9	Results from the timing version	83
6.10	Results from the techniques of the parking optimizer model	84
6.11	The comparison between two different algorithms	85
6.12	The comparison between different numbers of cars	86

List of Tables

2.1	The definitions of the simple example	11
3.1	The colour set Cars	21
3.2	The colour set Database	23
3.3	The essential parameters of the car-structure sub-model	24
3.4	The colour set Hall Call	26
3.5	The parameters of the abstract hall-call sub-model	30
3.6	The colour set Specific Floors	33
3.7	The parameters of the car-call sub-model	34
3.8	The parameter of the system-cycle sub-model	36
4.1	The colour set Timing Cars	41
4.2	The colour sets Timing Database	43
4.3	The extra parameter of the timing car-structure sub-model	43
4.4	The colour set Hall's Buttons	45
4.5	The parameters of the timing hall-call sub-model	46
4.6	The colour sets Requested Hall Call and Coordinator	48
4.7	The colour sets Car's Buttons and Calls' Counters	50
4.8	The parameters of the timing car-call sub-model	50
4.9	The colour sets of the arrival stage	53

5.1	The parameters of the parking optimizer model	56
5.2	The colour sets of the election sub-model	59
5.3	The colour set Identified Floor	61
5.4	The colour sets Scope and Scope Statistics	64

Chapter 1

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 fulfils 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); Eteessami 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.

