

# **ON PETRI NETS AND THEIR APPLICATIONS**

**THESIS  
SUBMITTED IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS  
OF THE AWARD  
OF THE (M. Sc.) DEGREE**

**PRESENTED BY**

***HALA ABD EL-GALIL EL-SAYED***

**Supervised By**

**Prof. Dr. Nashat F. M. Fathy**

Department of Mathematics  
Faculty of Science, Ain Shams University

**Dr. Mahmoud K. A. Khairat**

Department of Mathematics  
Faculty of Science, Ain Shams University

**SUBMITTED TO  
Department of Mathematics  
Faculty of Science  
Ain Shams University**

**CAIRO, EGYPT**

**1996**









# On Petri nets and their applications

\*\*\*\*\*

thesis advisors

Approval

Dr. Nashat Fared Mohamed  
Prof. of Mathematics Dept.  
Faculty of Science  
Ain Shams Univesity

(*Nashat Fared*)

Dr. Mahmoud Khirat Ahmed Khirat  
Prof. of Computer.Sc.  
Faculty of Science  
Ain Shams Univesity

(*[Signature]*)

١.د انتصارات محمد حسن الشبكي

رئيس قسم الرياضيات  
كلية العلوم جامعة عين شمس



## ACKNOWLEDGMENTS

First of all, I do thank Allah for all the gifts he has given me.

I would like to express my utter gratitude and thankfulness to my supervisors, Prof. Dr. **Nashat F. M. Fathy**, Department of Mathematics, Faculty of Science, **Ain Shams** University, for suggesting the problem and for his continuous guidance, kind hearted help and valuable discussions.

Deep thanks are also due to Dr. **Mahmoud K. A. Khairat**, Department of Mathematics, Faculty of Science, **Ain Shams** University, , for his guidance and co. supervision.

I would also, like to express my deep gratitude to Prof. Dr. Yehia Helaly, Head of the department of Space Science Research, National Institute Research of Astronomy and Geyophysics. and to all staff members of the Department.

Finally, I am truly thankful to all of my family for their support.





# *Contents*

.....

## CONTENTS

|  |    |
|--|----|
| SUMMARY  | i  |
| INTRODUCTION   | 1  |
| CHAPTER I : NOTATIONS AND BASIC DEFINITIONS                                      |    |
| 1.1 Petri Net Structure  | 4  |
| 1.1.1 Petri Net Marking  | 9  |
| 1.1.2 Algebraic Representation   | 11 |
| 1.1.3 Petri Net Execution  | 12 |
| 1.2 Event Graph  | 15 |
| 1.2.1 Timed Event Graph  | 16 |
| 1.3 Place Transition Net (P/T- Net)  | 17 |
| 1.3.1 P/T- Marking   | 18 |
| 1.3.2 Linear Algebraic Representation  | 21 |
| 1.4 Condition Event System   | 25 |
| 1.4.1 Conflict and confusion   | 25 |
| 1.4.2 Predicate/Transition Net (Pr/T- Net)                                       | 26 |
| 1.4.3 Temporal Petri Nets  | 30 |
| 1.5 High Level Petri Nets  | 33 |
| CHAPTER II : SOME ESSENTIAL FACTS FROM COMPLEXITY<br>THEORY AND FINITE AUTOMATON |    |
| 2.1 Complexity Analysis  | 35 |
| 2.1.1 An Algorithm on Graphs   | 39 |
| 2.2 Finite Automaton   | 42 |

## CHAPTER III : SOME MODELS RELATED TO PETRI NET MODEL

|  |           |
|--|-----------|
| <b>3.1 Vector Addition Systems</b>             | <b>44</b> |
| <b>3.2 Vector Addition Systems with States</b> | <b>48</b> |
| <b>3.3 Graphs and ordered Sets</b>             | <b>51</b> |
| 3.3.1 Karp and Miller Tree                     | 52        |
| 3.3.2 Covering Graphs                          | 60        |
| <b>3.4 Regular Constraint Graphs</b>           | <b>64</b> |
| <b>3.5 Maximum Cover Pseudomarkings</b>        | <b>71</b> |

## CHAPTER IV : ANALYSIS OF PETRI NETS

|   |           |
|---|-----------|
| <b>4.1 Analysis Of Petri Net Properties</b>   | <b>76</b> |
| 4.1.1 Safeness                                | 76        |
| 4.1.2 Boundedness                             | 76        |
| 4.1.3 Conservation                            | 77        |
| 4.1.4 Liveness                                | 79        |
| 4.1.5 Reachability                            | 79        |
| <b>4.2 Solution Techniques</b>                | <b>80</b> |
| <b>4.2.1 The Reachability Tree Solution</b>   | <b>80</b> |
| 4.2.1.1 Reachability tree analysis            | 84        |
| 4.2.1.2 Advantages of reachability tree       | 85        |
| 4.2.1.3 Disadvantages of reachability tree    | 86        |
| 4.2.2 Karp-Miller Graph                       | 86        |
| 4.2.2.1 Specification of some basic questions | 87        |
| 4.2.2.2 The minimal coverability graph        | 88        |

|   |     |
|---|-----|
| 4.2.2.3 Advantages of minimal coverability graph                        | 89  |
| <b>4.3 Reducibility Between Analysis Problems</b>                       | 90  |
| 4.3.1 Reachability Problems   | 91  |
| 4.3.2 Liveness and Reachability   | 96  |
| <b>CHAPTER V : UNDECIDABILITY AND REACHABILITY PROBLEMS</b>             |     |
| <b>5.1 Undecidability Results</b>                                       | 102 |
| 5.1.1 The Polynomial Graph Inclusion Problem                            | 104 |
| 5.1.2 Weak Computations   | 108 |
| <b>5.2 The equality Problem For the Set Of Firing Sequences</b>         | 123 |
| <b>5.3 Self_stabilizing Petri nets</b>                                  | 130 |
| 5.3.1 A characterization of self_stabilizing bounded ordinary Petri net | 135 |
| 5.3.2 A characterization of self_stabilizing bounded general Petri net  | 136 |

## APPENDIX

