AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
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COMPUTER AND SYSTEMS ENGINEERING



# ABSTRACTION TECHNIQUES FOR STOCHASTIC PETRI NETS

**THESIS**

**Submitted for the partial fulfillment of the requirements
of the
Master of Science Degree in Computer Engineering**



**BY**

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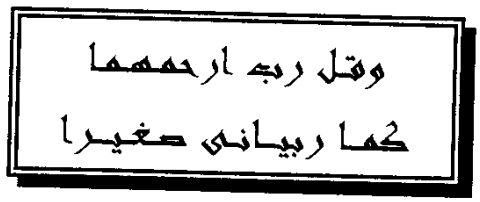
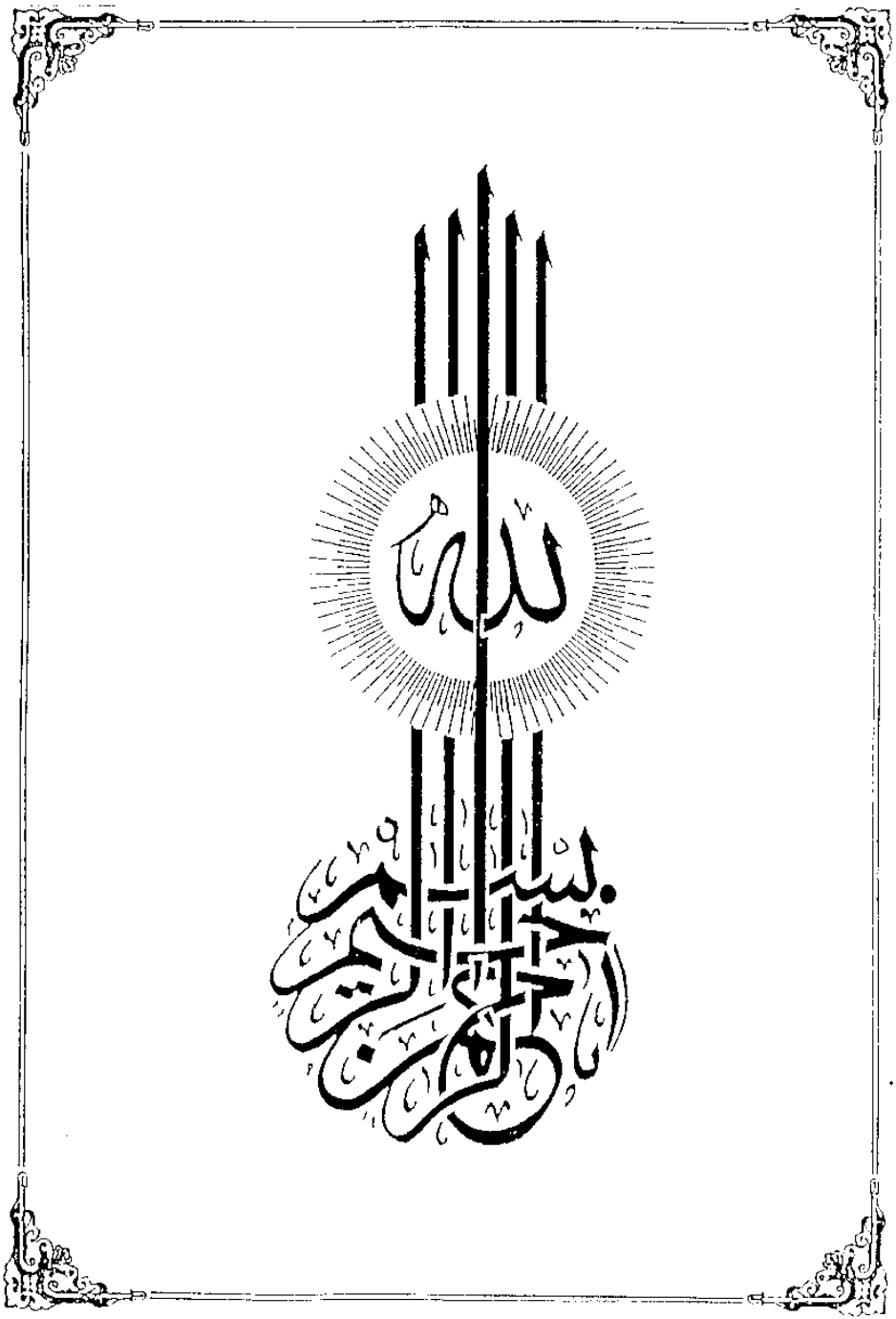
**1994
CAIRO**

## DEDICATION




(سورة الأسراء - اية ٢٤)

*Dedicated To My Parents*
*Who Gave and Still Give a Lot*



# ACKNOWLEDGMENTS

I would like to express my deepest gratitude to

Prof. Dr. Mohammed A.R. Ghonaimy

for his encouragement throughout my study in the Faculty of Engineering, Ain Shams University.

I wish to express my appreciation and thanks to

Dr. Hossam M. A. Fahmy

for his suggestions, supervision and constructive criticism throughout the work.

My thanks go to Eng. Saleh Noor-el-Deen, Suez Canal Insurance Company, who generously gave me great assistance in printing out this thesis.

Finally, I want to express my deep appreciation to my family, who gave encouragement when it was most needed.

# STATEMENT

This thesis is submitted to Ain Shams University for M.Sc. degree in Computer Engineering. The work included in this thesis was carried out by the researcher in the Department of Computer and Systems Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or qualification at any other universities or institutes.

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## EXAMINERS COMMITTEE

The undersigned certify that they have read and recommend to the Faculty of Engineering, Ain Shams University for acceptance of this thesis entitled " Abstraction Techniques for Stochastic Petri Nets", submitted by Eng. Abdel Hafez Mohammed Gamil Abdel Hafez in Computer and Systems Engineering, for the degree of Master of Science in Computer Engineering.

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# ABSTRACT

*S*tochastic *P*etri *N*ets (SPN's) are powerful tools for determining average performance of the models of computer systems models. The explosion in the state space of the reachability graph results in complex *M*arkov *C*hain (MC), and thus hampering the use of SPN's. Partitioning techniques, depending on dividing the net into subnets, are introduced to avoid this dilemma. In *G*eneralized *S*tochastic *P*etri *N*ets (GSPN's) the transitions are divided into immediate and timed transitions. If the net has not immediate transitions, i.e. only timed transitions, no partitioning can be carried out.

For such cases, time scale decomposition technique can be used, where the transitions are divided into slow and fast sets of transitions. It is not always possible to partition the transitions of the net into sets.

A different abstraction technique is introduced in this paper. It is based on replacing a subset of transitions along with their input places by only one equivalent transition and one equivalent place. This reduction in the size of the SPN's leads to a reduction in the size of the RG and MC.

A new classification of SPN's is introduced. Specifically, SPN's reflecting pure sequential operations, and SPN's exhibiting pure concurrent operations. Also, symmetrical and asymmetrical sequential transitions are introduced and defined in this thesis. Moreover, a new type of transitions, called absorbing transitions, is presented. Abstraction techniques for SPN's exhibiting pure sequential operations, concurrent operations, and contending operations are developed. Furthermore, an abstraction method for SPN's having self-loops, loops and contention is taken into consideration. The proposed abstraction technique can be carried out as stated in the presented theorems. Throughout this work, the proposed abstraction methods are applied to

several case studies. The results obtained by analyzing the abstracted models are accurate, and identical to those obtained by analyzing the original models. Using the proposed abstraction methods save efforts and keeps the performance of the net unchanged.

*KEY WORDS:* α-parameter, absorbing transition, concurrent transition rate matrix, Markov process, probabilisticaly-abstracted model, pure concurrent operations, pure sequential operations, symmetrical and asymmetrical sequential transitions, timely-abstracted model.

# Publication

Hossam M.A.Fahmy, Abdel-Hafez M.Gamil, and M.A.R.Ghonaimy, "Abstraction Techniques for Stochastic Petri Nets", Ain Shams University Engineering Bulletin, Cairo, Vol.29, No.2, 1994.

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CHAPTER I

# INTRODUCTION

Petri nets are useful tools to represent sequential and concurrent operations, forking, joining and contention. The original definition of Petri nets [1] did not involve the concept of time. But later, time has been introduced as a Petri net major parameter. In [2], [3], and [4] a fixed time interval is associated with each transition to model the performance of computer systems. A fixed time interval is associated in [5] with each place, so tokens were considered unavailable for that time.

Petri nets are extended by Molloy [6] to Stochastic Petri Nets (*SPN*), by assigning an exponentially distributed firing rate to each transition for continuous time systems or a geometrically distributed firing rate to each transition for discrete time systems. Since the models of computer systems used to determine average performance are stochastic in nature and based on the theories of probability and statistics, the SPN's are powerful tools for the description and the analysis of those systems. SPN's are isomorphic to homogeneous Markov process [6],[15] and are solved by Markov chains (*MC*) that are obtained according to the reachability graph (*RG*).

The size of the RG increases exponentially with both the number of tokens in the initial marking and the number of places in the net [12]. Due to this explosion of state space of the RG, the Markov model becomes complex, and can hardly be solved. To solve such big models, partitioning and abstraction techniques have been introduced for SPN and for untimed PN.

In Generalized Stochastic Petri Nets (*GSPN's*) [7], [8] and time scale decomposition [9], SPN's are analyzed by partitioning. Partitioning techniques that divide the untimed PN under study into subnets, while considering the interactions between each subnet of the divided net are proposed in [16]. Thus, the study of the overall net is avoided by considering only the subnets. For untimed PN abstraction techniques are introduced in [10] and [11]. In net abstraction techniques, only a subset of the net elements of interest is examined, the rest are removed from the net.

The abstraction technique introduced in this research is different. No elements are removed, since in some cases it is not advisable to disregard any part of the net. The proposed abstraction technique is based on replacing a subset of transitions and places by only one transition and one place, while maintaining the performance of the net.

This leads to reduction in the size of the RG and MC to be studied. Analyzing the abstracted model, the average service time and the steady-state probabilities of the original system are obtained accurately. The paper is organized as follows. Petri nets and abstraction techniques are introduced in chapter II. In chapter III the necessary definitions are introduced, and a proposed abstraction method for pure sequential and/or pure concurrent operations is introduced through theorems 1,2,3 and 4. Abstraction techniques for additional structure of SPN's are presented in chapter IV, case studies in chapter V, conclusion in chapter VI.