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PN Toolbox Efficacies for Analysis of Data Computation Model

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ABSTRACT: Petri Net Toolbox software is used for Petri Nets under MATLAB. This toolbox can deal with untimed, transition-timed, place-timed, stochastic and generalized stochastic Petri Nets. The user-friendly graphical interface of toolbox allows analysis such as incidence matrix, coverability tree, structural properties (such as boundedness, conservativeness, repetitiveness and consistency), behavioral properties, time dependent performance indices. Utilization of toolbox enhanced after integration with MATLAB in the area of discrete event systems. This toolbox can be used in many domains of engineering to demonstrate its value as an educational aid through examples. This paper presents the introduction to Petri Net toolbox and illustrative examples to study various properties of a data computation model, both theoretical background and the implementation in Petri Net toolbox are presented to illustrate the effectiveness of PN toolbox as well as its use.

KEYWORDS: MATLAB, Petri Net Toolbox, Properties of Petri Nets

I. INTRODUCTION

A Petri Net is one of several mathematical modeling languages for the description of distributed systems. A Petri net is a directed bipartite graph in which the nodes represent transitions (i.e. events that may occur, signified by bars) and places (i.e. conditions, signified by circles). The directed arcs describe which places are pre- and/or post-conditions for which transitions (signified by arrows). Some sources state that Petri nets were invented in August 1939 by Carl Adam Petri- at the age of 13 — for the purpose of describing chemical processes[1].

A Petri net(also known as a place/transition net or P/T net) consists of places, transitions, and arcs. Arcs run from a place to a transition or vice versa, never between places or between transitions. The places from which an arc runs to a transition are called the input places of the transition; the places to which arcs run from a transition are called the output places of the transition.

Graphically, places in a Petri net may contain a discrete number of marks called tokens. In an abstract sense relating to a Petri net diagram, a transition of a Petri net may fire if it is enabled, i.e. there are sufficient tokens in all of its input places; when the transition fires, it consumes the required input tokens, and creates tokens in its output places. A firing is atomic, i.e., a single non-interruptible step.

II. PN TOOLBOX

There are many software tools for analysis and simulation of PN models [2] but The Petri Net Toolbox (PN Toolbox) is a software tool for simulation, analysis and design of discrete event systems, based on Petri net (PN) models. This software is embedded in the MATLAB environment and its usage requires the MATLAB version 6.1 or higher.

Unlike other PN software, where places are meant for having finite capacity (because of the arithmetic representation used by the computational environment), our toolbox is able to operate with infinite-capacity places, since MATLAB includes the built-in function Inf, which returns the IEEE arithmetic representation for positive infinity. The PN Toolbox was designed and implemented at the Department of Automatic Control and Applied Informatics of the Technical University „Gh. Asachi" of Iaşi, Romania.

In the current version of the PN Toolbox, five types of classic PN models are accepted, namely: untimed, transition timed, place-timed, stochastic and generalized stochastic. The timed nets can be deterministic or stochastic, and the stochastic case allows using the appropriate distribution function.

The PN Toolbox has an easy to exploit Graphical User Interface (GUI), whose purpose is twofold. First, it gives the user the possibility to draw PNs in a natural fashion, to store, retrieve and resize (by Zoom-In and Zoom-Out features) such drawings. Second, it permits the simulation, analysis and design of the PNs, by exploiting all the computational resources of the environment, via the global variables stored in the MATLAB's Workspace.

After drawing a PN model, the user can gather a lot of information about the Petri Net which is given below. User can visualize the Incidence Matrix, which is automatically built from the net topology. User can explore the Behavioral Properties (such as liveness, boundedness, reversibility etc.) by consulting the Coverability Tree, which is automatically built from the net topology and initial marking. The Structural Properties (such as structural boundedness, repetitiveness, conservativeness and consistency) can be explored. Use can calculate P-Invariants and T-Invariants. User can run a Simulation experiment and can display current results of the simulation using the Scope and Diary facilities. The global Performance Indices (such as average marking of places, average firing delay of transitions, etc.) can be evaluated; a Max-Plus Analysis (restricted to event-graphs) can be performed and a configuration with suitable dynamics (via automated iterative simulations) can be designed.

The PN Toolbox is equipped with an easy to exploit GUI, which allows drawing PNs and permits simulation, analysis and synthesis. This GUI becomes operational once the command >> pntool is typed at the MATLAB's prompt. There are two modes in which the PN Toolbox may be exploited, namely the Draw Mode that allows the user to build a new PN model or modify the properties of an existing one, and the Explore Mode that enables the user's access to simulation, analysis and design tools. The GUI exhibits eight control panels: Menu Bar, Quick Access Toolbar , Drawing Area , Drawing Panel , Draw/Explore Switch , Simulation Panel , Status Panel and a Message Box.

The Menu Bar displays a set of nine drop-down menus, from which the user can access all the facilities available in the PN Toolbox. These menus are enabled in accordance with the exploitation mode of the PN Toolbox. The File menu offers facilities for file-handling operations. This is the only menu available when the PN Toolbox GUI is started. The Modeling menu provides tools for graphical editing (graph nodes, arcs, tokens, labels) a model in the Drawing Area. The View menu allows choosing specific conditions for visualization of the current model. The Properties menu provides computational tools for the analysis of the behavioral and structural properties of the current PN model. Through the Simulation menu the user may control the simulation progress and record the results. At the end of a simulation experiment, the Performance menu allows the visualization of the global performance indices that are stored in an HTML format. These indices are separately recorded for transitions and for places. The Max-Plus menu allows performing the simulation and analysis of an event graph (marked graph) based on its max-plus state-space model. A new MATLAB figure is opened and all the facilities available for max-plus analysis and simulation are accessible. The Design menu is used for the synthesis of timed PN models; this allows simulations for several types of parameterizations considered in the PN architecture. The Help menu provides information for the exploitations of the PN Toolbox and allows visualization of four Flash demo-movies initiating the user in the exploitation of the PN Toolbox. The Drawing Area is provided with a grid, where the nodes of the PN graph are to be placed, and with two scrollbars (on the right and bottom sides) for moving the desired parts of the graph into view. The Drawing Area is an axes MATLAB object and it is organized as a matrix of cells with 50 rows and 50 columns. In one cell the user can draw a single node (place or transition). The Drawing Panel presents five image buttons that facilitate user access to Edit Objects, Add Place, Add Transition, Add Arc and Add Token commands. Similarly, the Simulation Panel presents buttons for Reset, Step, Run Slow and Run Fast commands. It also provides two instruments for visualizing the progress of the simulation.

Although initially intended just for internal usage, numerous improvements has been done to previous models [3], [4] and the current version of the PN Toolbox can serve various instructional tasks, due to the wide range of topics covered by its facilities. It is suitable for applications illustrating the theoretical concepts provided by courses on PNs with different levels of difficulty. Furthermore, the PN Toolbox allows relevant experiments for studying the event-driven dynamics of physical systems encountered in many technical fields such as flexible manufacturing systems (FMSs), computer systems, communication protocols, power plants, and power electronics. [5]

III. DATA COMPUTATION MODEL ANALYSIS

A large number of systems modeled by PNs has been investigated in order to assess the facilities developed in this toolbox. Various properties and analysis methods for Petri Nets are studied in this paper taking two simple examples.

Consider the expression $x = \frac{a+b}{a-b}$The Petri net model for this can be constructed[6][7] as Figure 1.

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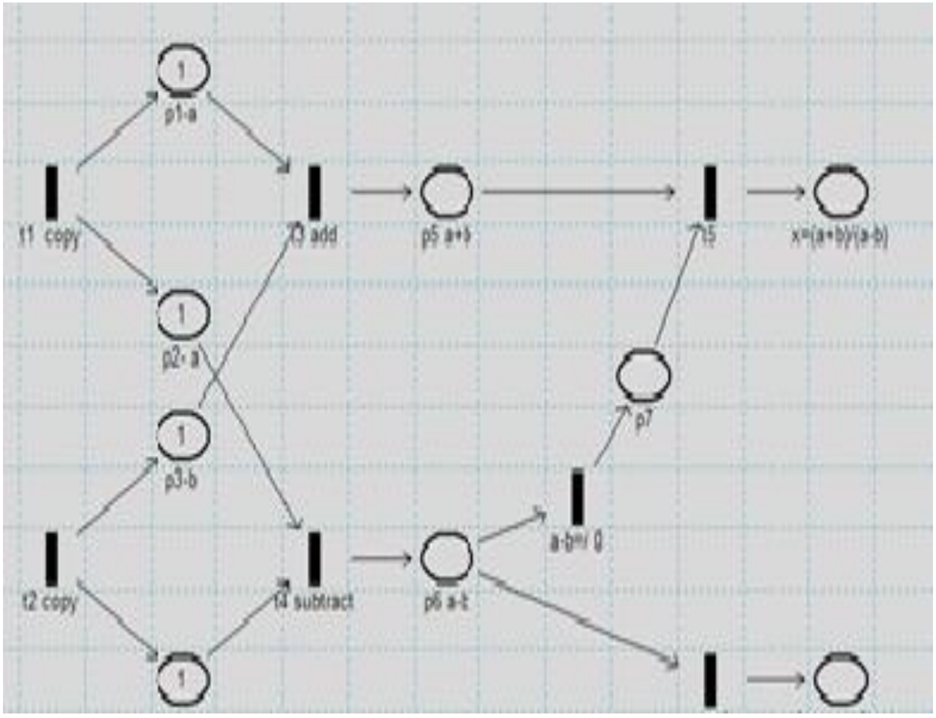
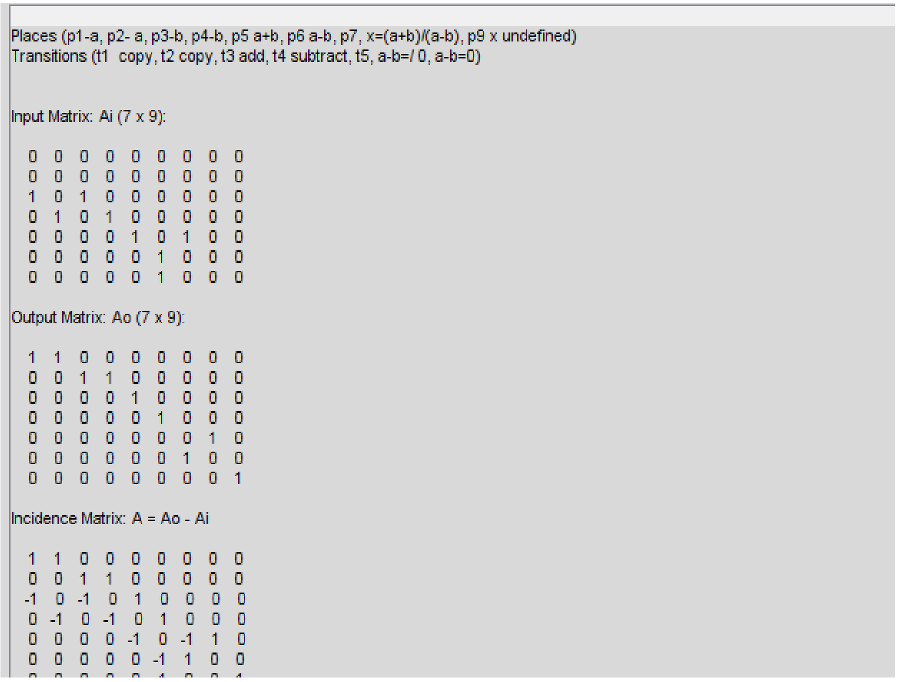


Figure 1 Data Computaion Model

Now let us study various properties for this model

The incidence matrix can be calculated as given below in figure 2



Places (p1-a, p2- a, p3-b, p4-b, p5 a+b, p6 a-b, p7, x=(a+b)/(a-b), p9 x undefined)
Transitions (t1 copy, t2 copy, t3 add, t4 subtract, t5, a-b=/ 0, a-b=0)

Input Matrix: Ai (7 x 9):

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0
0	0	0	0	1	0	1	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	1	0	0	0

Output Matrix: Ao (7 x 9):

1	1	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0
0	0	0	0	1	0	0	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	1

Incidence Matrix: A = Ao - Ai

1	1	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0
-1	0	-1	0	1	0	0	0	0
0	-1	0	-1	0	1	0	0	0
0	0	0	0	-1	0	-1	1	0
0	0	0	0	0	-1	1	0	0

Figure 2 Incidence Matrix

This net lies in the subclass of free choice net as Figure 3

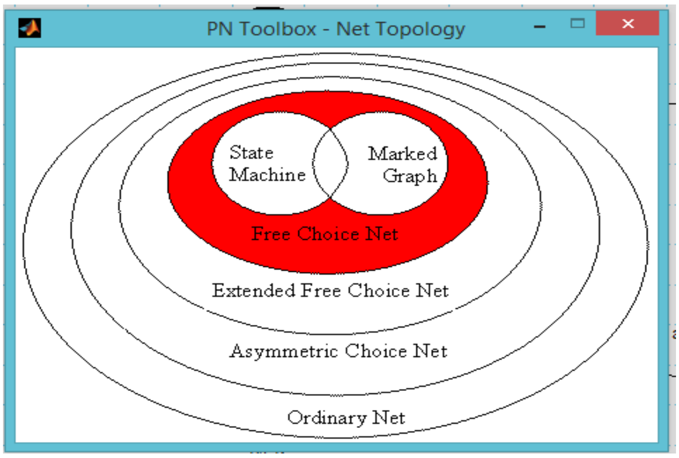


Figure 3 Subclass diagram

The net is live as all the transitions can be fired at least once as shown in firure 4

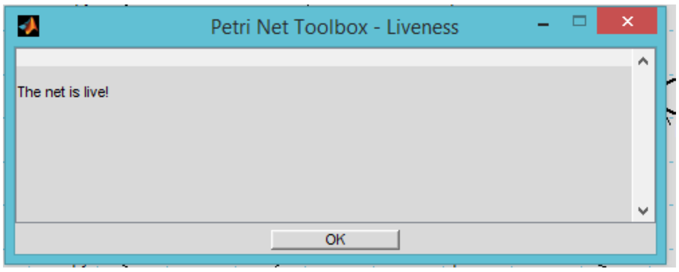


Figure 4 Liveness of Model

The structural properties like conservativeness, consistency etc. of the net can also be studied (Fig 5. Fig 6)

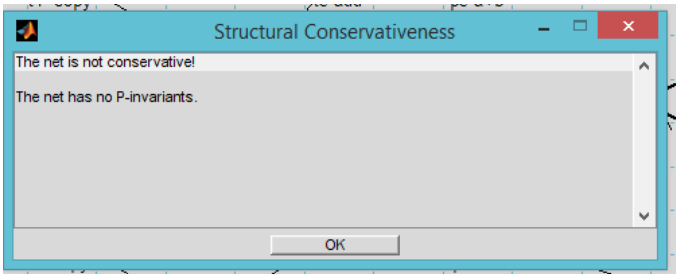


Figure 5 Conservativeness of Model

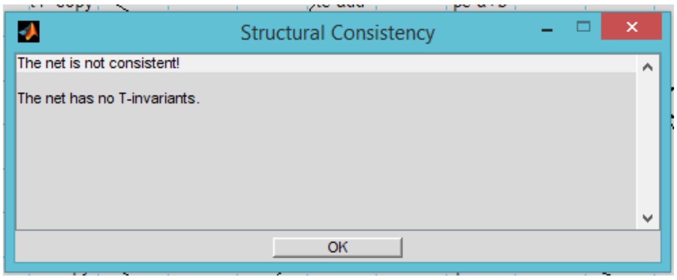


Figure 6 Consistency of Model

IV. CONCLUSION

The development of the PN Toolbox has been exposed by the fact that MATLAB is very popular software in various areas of engineering and especially in automatic control, although the Petri net theory has been frequently used in technical scenarios during the last decade.

The standard approach to boundedness, conservativeness, repetitiveness and consistency of Petri nets, which relies on the compatibility of systems of linear inequalities, has been converted into a MATLAB related problem, which allowed the MATLAB implementation of software modules devoted to the analysis of structural properties, which have been successfully implemented into the PN Toolbox. The newly designed instruments are able to test the compatibility of systems of linear inequalities, although the MATLAB environment does not offer proper functions for computing the solutions to such systems. The PN Toolbox offers instruments which are easy to use by people accustomed to the MATLAB philosophy. As compared to the two MATLAB-based products PN Toolbox provides a user-friendly graphical interface which ensures its independence of other software resources and makes it more attractive by concealing the direct manipulation of the mathematical functions. By the facilities created for simulation, analysis and design, the PN Toolbox is utilizedin many types of applications as illustrated by the example presented in the text.

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