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# Computer-Aided Modelling and Investigation of Interactions Described by Petri Nets*

*Hristo Hristov, Rumen Kunchev, Tasho Tashev*

*Institute of Information Technologies, 1113 Sofia*

## 1. Introduction

Modern technologies, used to develop information systems and interactions, require some formal and linguistic tools for specification, that are appropriate for the automation of separate stages, such as modelling, simulation, monitoring or verification of the interactions being designed. In this aspect Petri Nets (PN) with their two isomorph forms - graphical and analytical [1], provide efficient possibilities for the formal description and study of a wide class of systems, characterized as concurrent, asynchronous, distributed, parallel, nondeterministic and/or stochastic.

Recently many university and company institutes and centres show particular interest towards PN apparatus [2–15], expressed in the activity of different research teams, realizing thorough theoretic and applied investigations. The scientific investigations intended to reflect more adequately the variety and specifics of real processes, are directed mainly towards the study or definition of subsets of the "generalized PN" class extensions, such as:

– Timed PN, that have a digital scale called a global clock in generalized PN formalism. This enables the study of models of real processes, running in physical time.

– Coloured PN, characterized by the introduction of the "colour" attribute for the markers. In general this facilitates the process of specification and leads to the increase of the computing procedures in the analysis.

– Stochastic PN, designed to model and analyze processes with probabilistic characteristics and Markovian processes as well.

The applied activity, connected with the scientific investigations, realizes the design and development of some specific software tools, systems for processes modelling and analysis respectively. The structural organization, the functional possibilities and the purpose of these systems have a number of common characteristics, expressed in the following:

The hardware and software structures of the systems correspond to software media and packages rather than to complete independent graph-oriented systems. Such a concept

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leads to the use of auxiliary software like compilers, graph systems, systems for data base control, etc., and of more powerful computer equipment as well. Besides this it is difficult to design problem-oriented and user-friendly interface in similar cases.

A large part of these packages is intended for operation with computers of SUN Sparc, DEC5000, HP9000 type and also:

– on this basis working stations with graphic capacities are created, or

– they are combined with a MAC or PC computer.

In most of the cases the packages require the presence of additional software in order to function, such as compilers (C, $C^{++}$, Smaltalk), systems for data base control (Oracle, Gemstone), documentation tools with graphic potentials (LaTex) and packages analyzing Petri nets.

The packages are graph-oriented, comprising a graph editor for interactive construction of networks models with options to manipulate objects, groups of objects and so on. In many cases when analyzing and simulating PN-models, “animation” is used to demonstrate the current results. The editors are often an extension of some graphic platforms such as Windows, X-Windows and others.

The analyzing possibilities of the separate packages depending on PN subclasses being modelled and on the extensions are based on selected criteria for the analysis of groups of properties. The common set includes the following groups:

– Structural properties (Bounds, Structural bounds, Liveness, Conservation, Repetitive, Stationary repetitive),

– Graph properties (Traps, Deadlocks),

– Linear properties (P-flow, T-semi-flow, P-semi-flow),

– Timing analysis (liveness and safety properties within a given time limit).

The present paper discusses some problems, concerning the design and functioning of a graph-oriented system for modelling and research, involving analysis and to certain extent synthesis of information interactions in open systems. The models are PN-graphs or their analytical descriptions.

## 2. Representation of an approach and a graph-oriented system for information interactions study

The functional capacities of the system for information interactions study arise from the basic problems solved with its help, namely:

a) Graphic modelling and operations with the models

– Design of graphic symbolism (icons) describing systems and interactions;

– PN graphs construction; storing, editing and manipulating (union and subtraction) of graphs;

– Hierarchical description (constructing by parts) of information systems and interactions;

– Control of the correctness in the design, editing and manipulating of PN graphs checking the feasibility of the relations created among the information objects (positions and transitions) in the graph or in the decomposition arrangement of PN hierarchical structures;

– Dynamic control of the graphs in interactions simulation and monitoring;

– Transformation of models (graphs) in analytical (matrix) form and vice versa.

b) Model investigations, that include the analysis of the main properties and characteristics of the interactions modelled and synthesis of model structures with definite (set) properties.

The diagram in Fig.1 shows in a general form the basic technological processes and

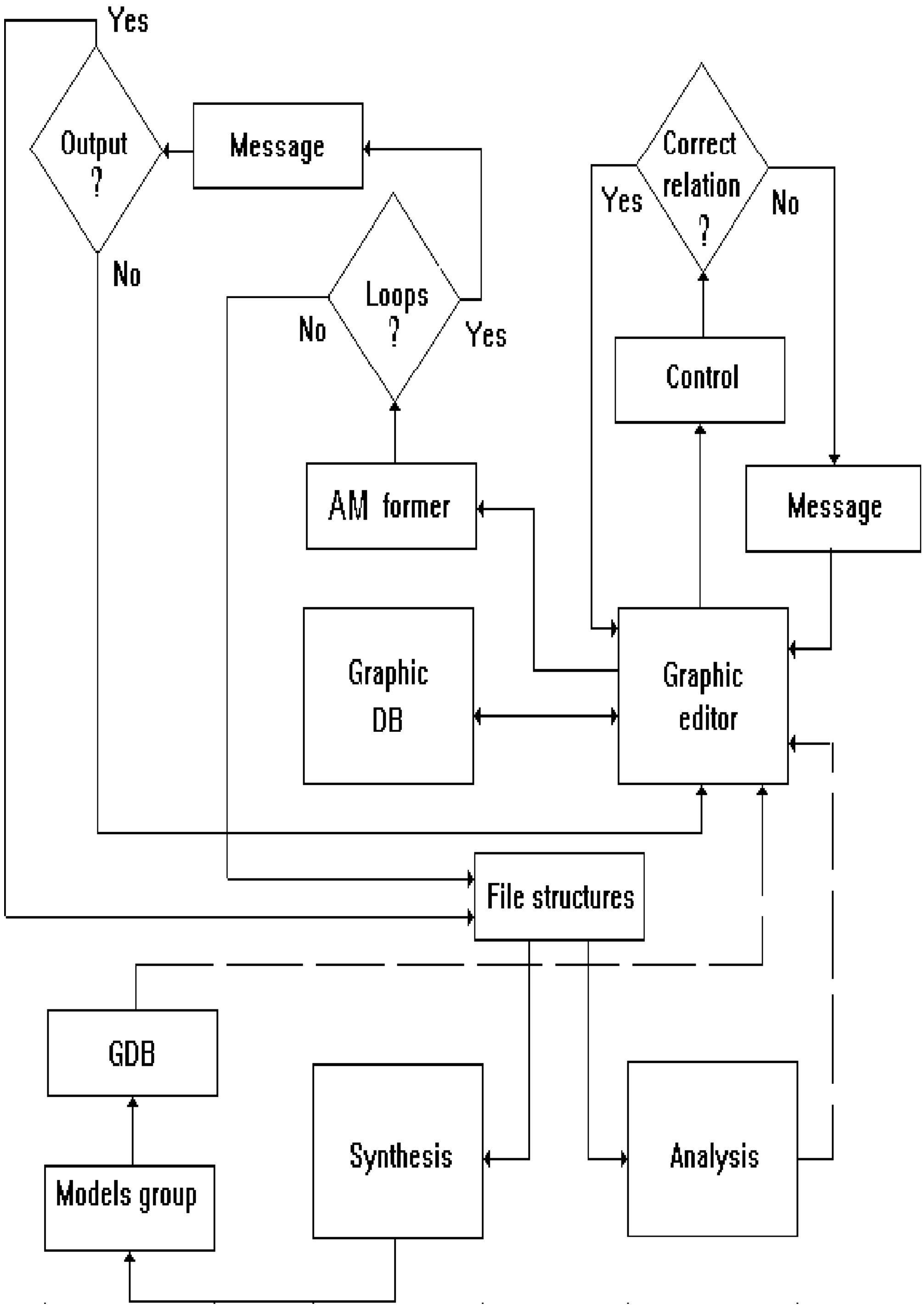
Yes
Output ?
Message
No
Loops ?
No
Yes
Correct relation ?
Yes
No
Control
AM former
Message
Graphic DB
Graphic editor
File structures
GDB
Synthesis
Analysis
Models group

Fig.1

functional tools in the system discussed, realizing the stages (phases) in modelling and investigation.

**Modelling.** It is assumed that the initial stage of each development starts with computer-aided design of a graph model (GM), interactively done by the graph editor. The PN-model describing the interactions, is built with apriori created symbolism for the objects (position and transition) and connections between them (Fig. 2). The feasibility of the relation obtained is automatically checked when the objects are connected. The feasibility conditions are stored in the "control" block. An error message is yielded at each fault and the operation is automatically blocked. The current GM is stored in the "graphic DB" block as a corresponding structure of graphical data.

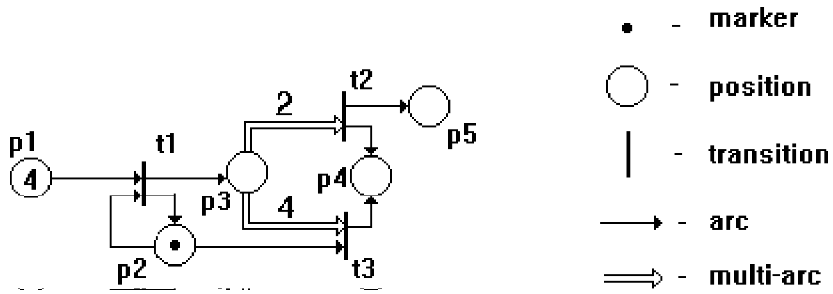


Fig. 2

**Analytical model (AM).** The AM-model is automatically created by the AM-former from the data structure of the GM stored in "graphic DB" block. The model obtained is defined in analytical form by the matrix representation of the input (*I*) and output (*O*) functions of incidence and the initial marking vector. If necessary, AM can be created as a list structure (on the basis of its expressing with the help of completes theory).

Since the solution of PN matrix equation requires the absence of loops, a corresponding check is foreseen. The formal conditions for the absence of loops are:

$$I=I',\ O=O',$$

where $I'$ and $O'$ are the input and output matrices formed in an appropriate way from the incidence generalized matrix.

The process of AM formation includes the check of the conditions above given. In case they are violated, a message is generated and the elements included in loops are visualized on GM. The operator takes a decision whether to work with GM for their transformation with the help of the graphic editor or to undertake model study with the loops available, storing AM in a given file format.

The model investigations on AM are of two types: analysis of the basic properties and characteristics of the interactions modelled by PN; synthesis of model structures with definite properties.

The analysis is done with the corresponding software tools (for example [8, 9, 10], preferred by the operator. The information obtained, which reveals the structural properties, graph properties, linear properties and so on, is the basis for GM modification, if this is considered necessary.

The synthesis is done with the purpose to obtain new model structures on the basis of formal transformations. The "synthesis" block is used as AM input, and a group of models are obtained at its output with the help of tensor transformers [16], based on a model specified as a "base PN" [17, 18]. The graphic description block (GDB) [19], serves for connection with the graphic editor and “closes” the computer-aided modelling cycle. Depending on his aims, the operator can start an iteration process, which is interrupted when the purpose defined is reached.

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# Компьютерное моделирование и исследование взаимодействий, описанных аппаратом сетей Петри

*Х. Христов, Р. Кунчев, Т.Ташев*

*Институт информационных технологий, 1113 София*

(Р е з ю м е)

Предлагается подход и графически-ориентированная система для спецификации и модельных исследований взаимодействий, описанных аппаратом сетей Петри (PN). Данный подход и система описаны диаграммой основных технологических циклов и функциональных средств. В статье дискутируются основные функциональные возможности и задачи для решения, включая анализ свойств и характеристик моделированных взаимодействий и синтез модельнх структур с определенными (заданными) свойствами.