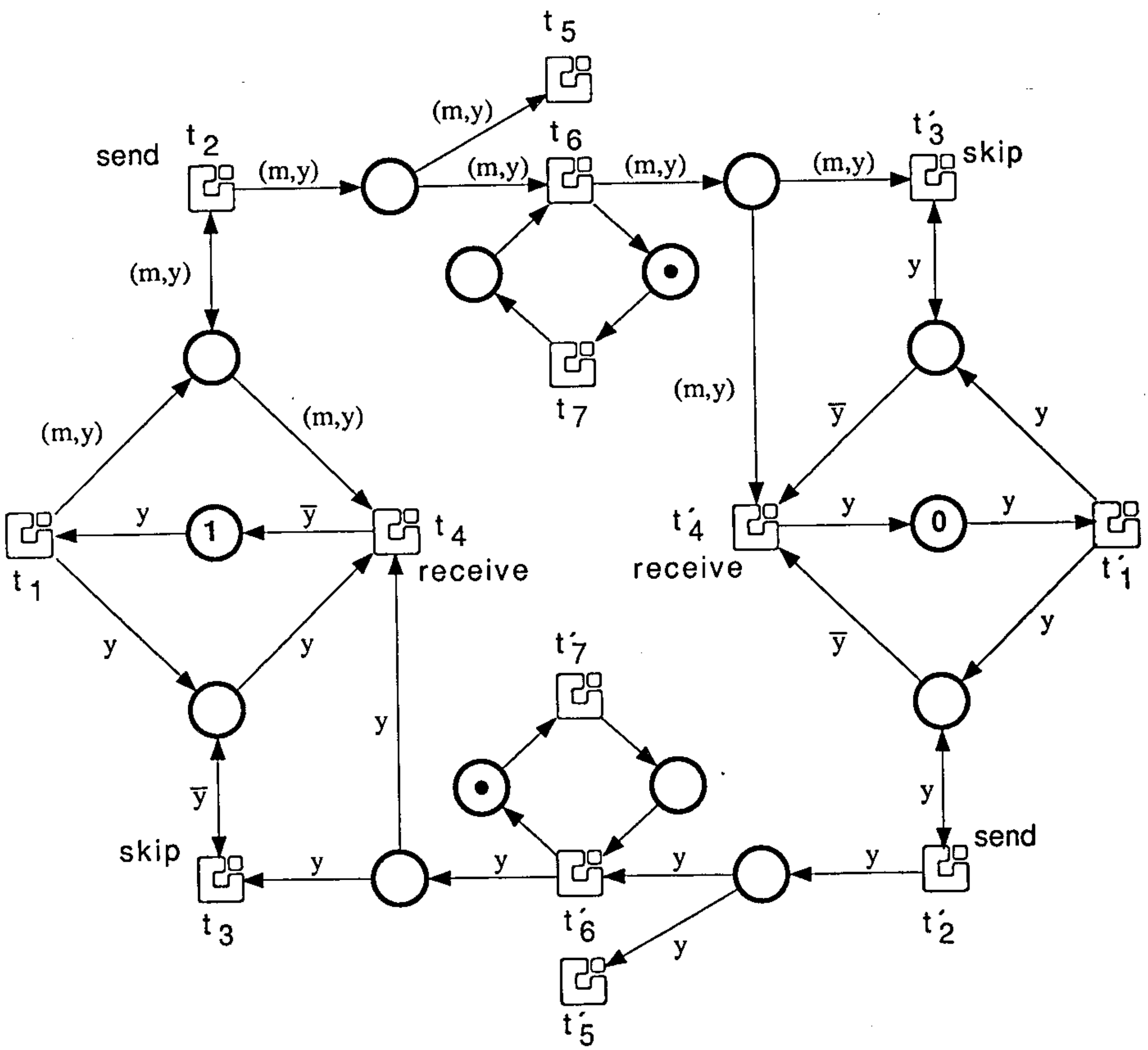
Petri Net Newsletter 35

April 1990

published by Gesellschaft für Informatik

Special Interest Group on Petri Nets and related System Models



Contents

Imprint 2

... from the editors 2

Cover Picture Story

J. Desel, W. Reisig, R. Walter: The Alternating Bit Protocol 3

Technical Contributions

G. Berthelot, A. Finkel, C. Johnen, L. Petrucci: A Generic Example for Testing Performance of Reachability and Covering Graphs Construction Algorithms 6

C. A. Petri, C. Y. Yuan: On Technical Safety and Security (continued) 8

W. Seiche: Control Synthesis Based on a Graph-Theoretical Petri Net Analysis 16

Z. Suraj: GRAPH : A Graphical System for Petri Net Design and Simulation 32

I. G. Tabakow: PN-Fault Detectability and Circuit Realization Fault Detectability are Equivalent 37

Reports on Conferences

W. M. Zuberek: PNPM'89 — The Third International Workshop on Petri Nets and Performance Models 44

E. R. Olderog: Report on the 2nd Workshop on Concurrency and Compositionality 51

Conference Announcements

Eleventh International Conference on Application and Theory of Petri Nets and Petri Nets Tutorial — Program and general information 54

Sommerschule Hildesheim 1990; Petrinetze: Systementwurf und Werkzeuge — Programm und allgemeine Information 59

Recent Publications 62

Imprint: "Petri Net Newsletter" • 900 copies printed • Price per year: DM 20.–.
This newsletter is an information service for the members of the Special Interest Group 1.1.2 "Petri Nets and Related System Models" of Gesellschaft für Informatik, Godesberger Allee 99, D-5300 Bonn 2, West Germany. Three issues a year are being published.

Scope of concern: This newsletter serves as a medium for the rapid distribution of any information about Petri Nets and related system models all over the world. Topics include:

- technical contributions
- information on software packages
- correspondence
- problems and puzzles
- conference announcements
- conference reports
- reports on departments, institutes, companies, projects, research, education
- available reports
- abstracts of recent publications
- book reviews

Subscription: Application forms can be obtainend from Gesellschaft für Informatik and from the editors. As a simplified procedure, just send an informal letter and include cash.
For legal reasons, subscription of the Newsletter implies the membership in the Special Interest Group 1.1.2 of the GI. This causes no further obligations or charges.

Contributions: They should be sent to one of the editors. Any contributions to the field are welcome. They are not refereed. As they will be printed as submitted, make sure that no space is wasted.

Forms of payment

An excellent opportunity is the annual International Conference on Application and Theory of Petri Nets. Another simple form is to send cash to:

Gesellschaft für Informatik
Godesberger Allee 99
D-5300 Bonn 2

All kinds of payment should include the subscription number as given in the upmost line of your address label (GI–*nnn* or PN–*nnn*).

For transfers by account, the cheapest way is a transfer from a post-office transfer account (not from a banking account) to the post-office transfer account of the Gesellschaft für Informatik no. 1981 39-502 at Cologne (BLZ 370 100 50).

Another cheap way is a cheque in DM or, where the national regulations allow it, a cheque in some other convertible currency. Please use the most recent rate of exchange for buying foreign bills in DM (we get the cheque cashed free of charge).

A third cheap way is paying in cash at a post office for credit to our post-office transfer account ("Mandat de versement international", form MP 16).

Thus the deduction of banking charges from the invoice amount can be avoided.

If you charge a bank with the transfer, a notice such as "free of charge for the payee" does not always work; some intermediate banks deduct DM 7.00 or more. So, please transfer only to the account of the Gesellschaft für Informatik no. 46 581 at the Sparkasse Bonn (BLZ 380 500 00) and increase invoice amount by DM 7.00.

...from the editors

It is high time to apply for participation in the 11th International Conference in Paris. You will find the program, which appears again very attractive, in this issue.

Do not hesitate to submit any relevant material in the area of Petri Nets to the forthcoming issues of the newsletter.

Hoping to meet you in Paris

O. Herzog

IBM Germany Scienctific Center
Institute for Knowledge Based Systems
Dept. 3527, 7000-75
P.O. Box 80 08 80
D-7000 Stuttgart 80
Phone: *49-711-6695-501

W. Reisig

Institut für Informatik
TU München
P.O. Box 20 24 20
D-8000 München 20
Phone: *49-89-2105-2405
Telefax: *49-89-2105-8207
e_mail:
reisig@lan.informatik.tu-muenchen.dbp.de

R.Valk

FB Informatik
Universität Hamburg
Rothenbaumchaussee 67-69
D-2000 Hamburg 13
Phone: *49-40-4123-5675

Cover Picture Story

The Alternating Bit Protocol[1]

Fairness Versus Priority

Jörg Desel, Wolfgang Reisig and Rolf Walter
Technische Universität München
Institut für Informatik
Arcisstr. 21, D-8000 München 2

One of the most popular paradigms in protocol specification dealing with fairness problems is the *Alternating Bit Protocol* (ABP) [Bartlett et al 69]. The cover picture shows a model with all fairness assumptions replaced by priority requirements and progress assumptions (i.e., weak fairness according to [Francez 86]).

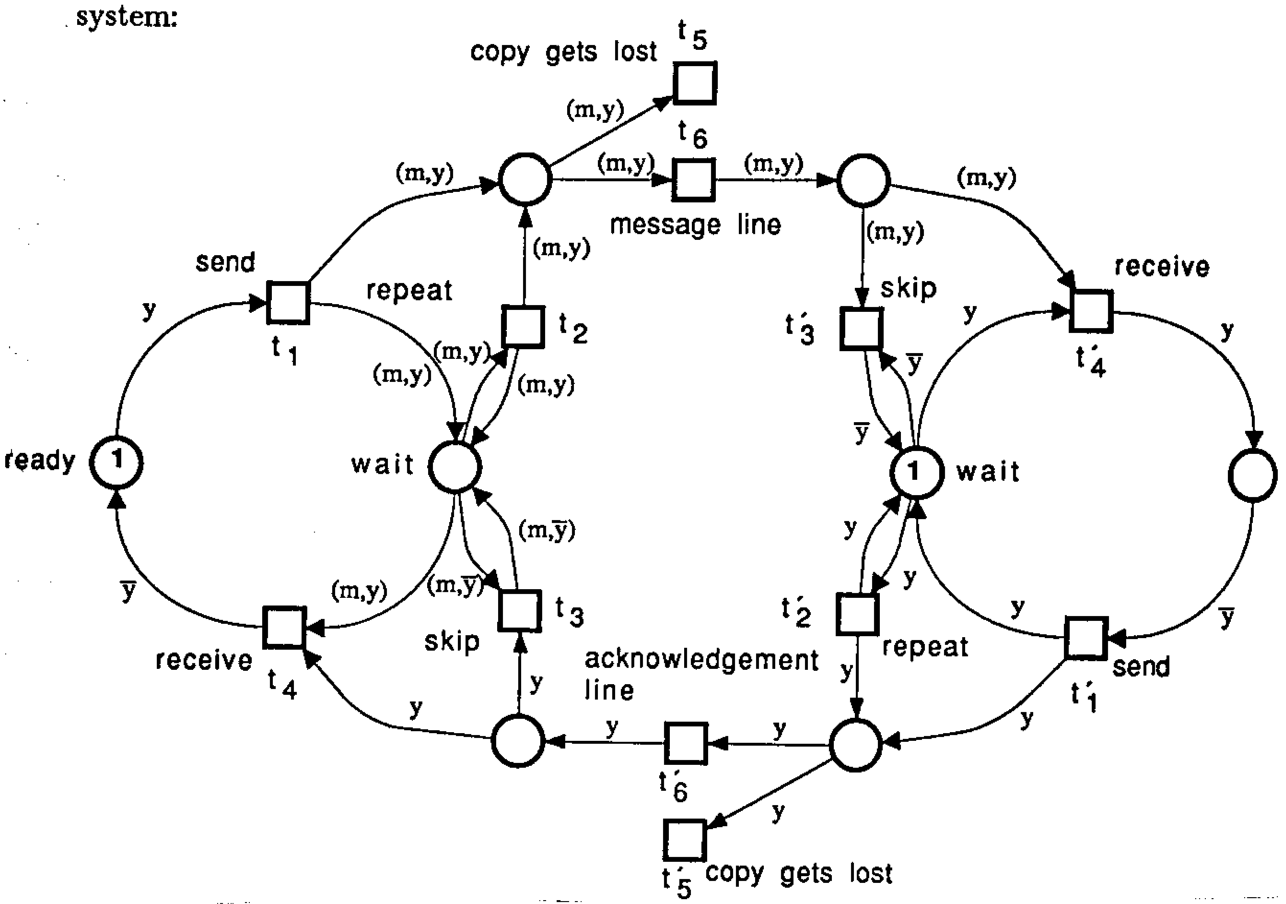
The problem solved by the ABP is how to ensure a correct transfer of sequences of messages from a sender to a receiver, thereby using only 'faulty' channels. A channel is said to be 'faulty' if each message is either transfered correctly or dropped completely. Moreover, we assume that a 'faulty' channel does not break down completely, dropping all subsequent messages. So only finitely many subsequent messages are dropped out by faulty channels.

The key idea of the ABP can roughly be scetched as follows:
The sender is prepared to send several copies of each message. Each copy is given an additional bit. The value of this bit is altered with each *new* message to ensure that a new message can be distinguished from copies of the old message. Whenever a copy of a message has reached the receiver, the receiver acknowledges it by sending back the control bit. Since each copy can get lost the sender repeats sending copies of each message until its reception is acknowledged. We assume that the acknowledgements are also transfered via a faulty channel. Hence the receiver repeats sending copies of the same acknowledgement until its reception by the sender is acknowledged – by means of a new message.

The protocol ensures the complete and correct transfer of any sequence of messages as long as both channels do not break down completely.
A translation of this informal specification to Petri Nets may yield the following formal

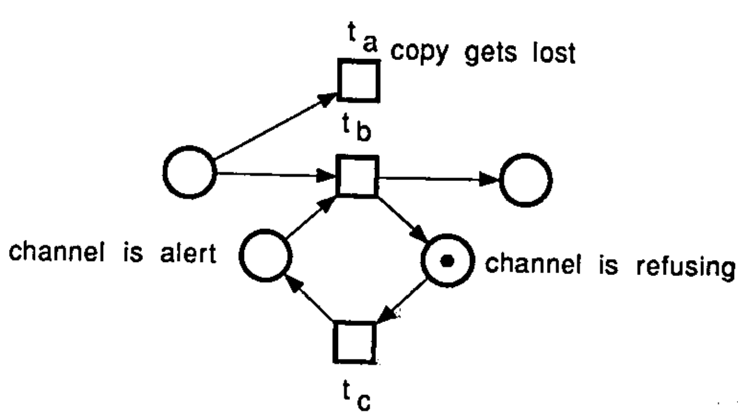
[1]supported by Esprit Basic Research Action No. 3148: DEMON and DFG-SFB 342 Working Group A3: SEMAFOR

system:



Several fairness properties have to be assumed. Firstly, the channels have to behave fairly, i.e., t_5 (t'_5, respectively) has to be fair w.r.t. t_6 (t'_6, respectively) to describe the channel behaviour correctly. Moreover, once an acknowledgement for a message could be received the sender should stop copying the message. Hence t_4 (t'_4) is assumed to behave fairly w.r.t. t_2 (t'_2). With these assumptions the system still does not necessarily work properly: the sender will never get an acknowledgement if the receiver is busy all the time with skipping the subsequently sent copies. So, t_2 (t'_2) has to be fair w.r.t. t_3 (t'_3) .

Is it possible now to replace all these fairness assumption by priority requirements? On the cover picture, a channel is replaced by the following structure:



This picture describes that a channel is either refusing or alert and that refusing channels can eventually get alert, such that t_b can eventually occur. The transition t_c is permanently enabled when the channel is refusing.Hence with a progress assumption which requires that each enabled transition gets disabled again (i.e. occurs, in this example) and the assumption that t_b has a higher priority than t_a, the cover picture channel models correctly the intended behaviour. To stop copying of a message when the corresponding acknowledgement can be received, is clearly a priority matter: t_4 (t'_4) must have priority over t_2 (t'_2).

But how in the above picture replace the required fair behaviour between transitions t_2 (t'_2) and t_3 (t'_3) by priority requirements? If *skip* has priority over *repeat* the system can run into the following livelock: If the first copy of a message is dropped and the receiver starts copying acknowledgements the sender is forced to skip them all without the possiblity to copy the lost message. A similar livelock can arise if *repeat* has priority over *skip*.

Now consider the system depicted on the cover picture. The main difference between the above system and the cover picture is the structure of the sender (receiver, respectively). The task of sending messages (acknowledgements) and receiving acknowledgements (messages, respectively) are concurrent in the cover picture: A fair scheduling of the actions 'send' and 'receive' is not necessary but both parts can do their tasks independently.

What remains, are the following priority assumptions:

A message that has been correctly acknowledged shouldn't be sent anymore. Hence the transition t_4 (t'_4) has a higher priority than t_2 (t'_2).

References:

[Bartlett et al 69] Bartlett, K.A.; Scantlebury, R. A.; Wilkinson, P. T.: A Note on Reliable Full-Duplex Transmission over Half Duplex Links, Communications of the ACM, Vol. 12, No. 5, (May 1969).

[Francez 86] Francez, N.: Fairness, Springer Verlag, (1987).

Technical Contributions

A generic example for testing performance of reachability and covering graphs construction algorithms

G. Berthelot (*), A. Finkel (**) (***), C. Johnen (***), L. Petrucci (****)

(*) CEDRIC-IIE, 18 Allés Jean Rostand, BP 77, F-91002 EVRY cedex
(**) ENS Cachan, Laboratoire d'Informatique Fondamentale et Appliquée de Cachan, 61 Avenue du Président Wilson, F-94235 CACHAN cedex
(***) LRI, Bât 490, Université Paris-Sud, F-91405 ORSAY
(****) MASI, tour 65, Université Pierre et Marie Curie (Paris 6), 4 Place Jussieu, F-75252 PARIS cedex 05

It is difficult to evaluate algorithms for building reachability or covering graphs. In general, the number of nodes and arcs of these graphs is unknown. So, after some time of computation, one can suppose that the graph to generate is quite big. Thus, it may be interesting to test the algorithm on a Place/Transition net such that the number of nodes in its covering graph is already known.
That is our goal in this paper : we present a generic Place/Transition net (which may be more or less large according to the tests to perform), we give a simple formula to calculate the number of nodes in its covering graph (we prove that this graph is unique).

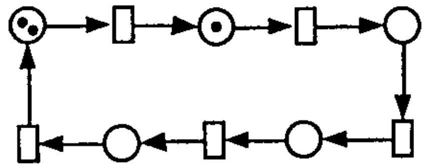
Let us consider cyclic Place/Transition nets. There is only one cycle in which transitions and places alternate : a transition has one and only one entry (resp. exit). Let p be the number of places. We start with an initial marking such that the whole number of tokens in places is t.

<u>Property</u> : The covering graph of such a Place/Transition net is also the graph of reachable markings, hence unique.

<u>Proof</u> : To increment the number of tokens inside a place, it is necessary to decrement the number of tokens within another one. So two comparable states can only be equal.

Computing the number of nodes in the covering graph consists in computing the number of possibilities to distribute t tokens into p places. That is a simple combinatorial problem, the result of which is : $C_t^{p+t-1} = (p+t-1)! / t! \, (p-1)!$.

Example : p = 5, t = 3. The number of nodes in the covering graph is 35.



For p = 10, t = 3, the number of nodes in the reachability graph is 220.
For p = 10, t = 4, the number of nodes in the reachability graph is 715.
For p = 10, t = 5, the number of nodes in the reachability graph is 2002.

Such a net may be used to test an algorithm in two ways : firstly to know about the performance in time, by using a high number of tokens in order to create a big graph, and secondly, increasing the number of places and decreasing the number of tokens allows to have a graph with a quite constant size, but increases the size of nodes as concerns memory occupation.

So, we presented a particular sort of Place/Transition nets. We gave a very simple formula to calculate the number of nodes in their reachability and covering graphs which are unique. This short result may be useful to test the performances of algorithms which construct covering graphs. This sort of nets may play a role comparable to Fibbonacci sequences which are useful to test the calculus speed of processors. They would allow to evaluate performances of algorithms for the construction of reachability and covering graphs.

Petri网通讯 第 2 期
中国计算机学会Petri网研究会 1989年11月

On Technical Safety and Security (continued)

C. A. Petri, C. Y. Yuan

October 20, 1989

A railway system is of course expected to be both *safe* and *live*. In other words, there should be no accidents caused by control logic and trains should be able to move one after another. This paper concentrates on the safety problem. In the previous paper the difference between train safety and token safety was discussed and based on this difference, (token) *security* as a system property was defined. What was done in that paper has set a good example for net application, since it is clear now that the difference between net concepts (e.g. tokens) and reality (e.g. trains) must be taken into account in net applications.

Our net models for trains should be live since otherwise it would be of no importance no matter how safe or secure they might be. We'll keep this demand of liveness in mind through this paper, but put no emphasis to it.

The purpose of this paper is:

- to point out the essence of safety and security in more details; and
- to show the structure of *general* $n \times k$ secure transmission lines.

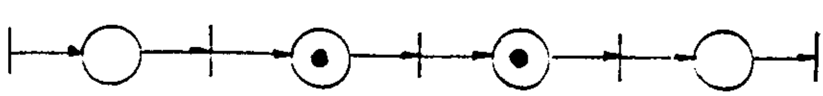
1 Evolution of Models

Several models were introduced in the previous paper (See Newsletter No 1).

1.1 One_Track Model

A model with one track and no control signal is as shown below:

$\Sigma_{1,0}$

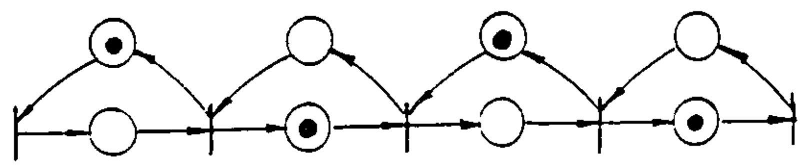


where trains are represented by tokens. It is clear that this model is not safe: the picture depicts a contact situation. To avoid contact, permit signals are employed to modify the model.

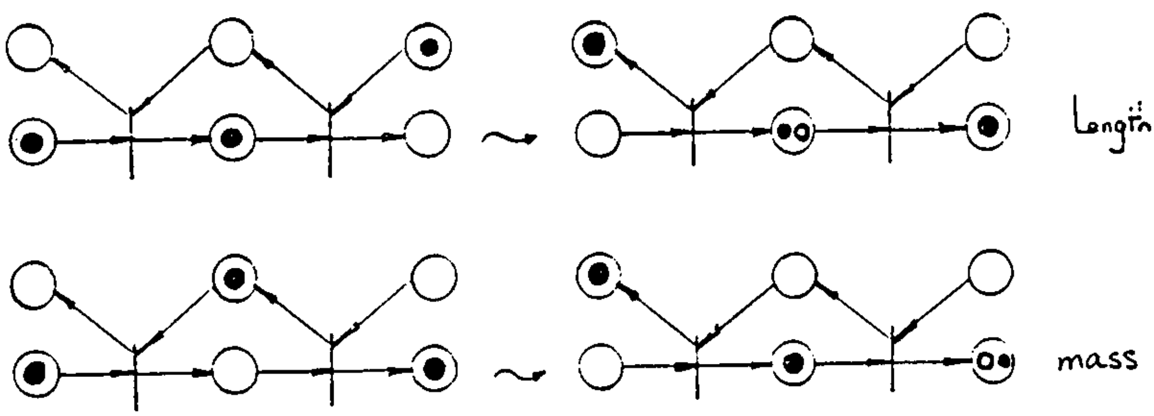
1.2 Model With One_Track and One_Signal_Line

In the following model, the signals are used to issue permit for trains to enter a track segment:

$\Sigma_{1,1}$



This model is safe as far as tokens are concerned. But trains are still not safe due to the nonzero length and nonzero mass nature of trains. The picture below illustrates why.

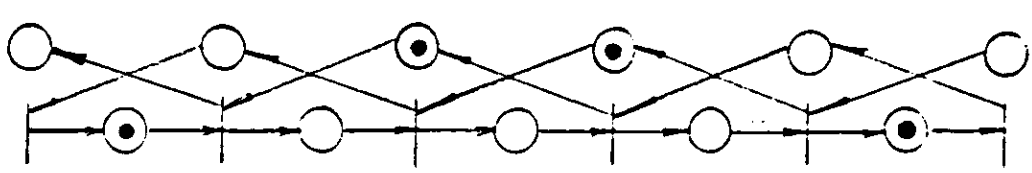


where represents unmodelled part of a train. This unmodelled part is either the tail of a train when train length is concerned, or the train head if the distance for a train to come to a full stop should be taken into account.
Trains have to be separated by empty segments in order to avoid such accidents. To this end, two or more signal lines are necessary.

1.3 Model With Two Signal_Lines

The following figure shows the model with two permit_signal lines:

$\Sigma_{1,2}$



Trains are now separated by at least one empty segment. It is usually the case in reality that a railway segment (i.e. a section between two adjacent stations) is longer than the length of a train plus the distance needed for a train to come to a full stop. Theoretically, and generally speaking, we have the following formula:

$$n = \lfloor m \rfloor + 2$$

where

n is the number of segments reserved for a train (at least $n-1$ empty segments between two trains).
$m = Max\{l_\alpha/s + d_\beta/s \mid \alpha, \beta \text{ are trains}\}$
$\lfloor m \rfloor$ is the maximal integer no greater than m
$l_\alpha =$ length of train α
$d_\beta =$ distance needed for train β to come to a full stop
$s = Min\{length(\sigma) \mid \sigma \text{ is a segment}\}$

$\Sigma_{1,2}$ shows the case when $n = 2$. $n = 3$ was required in the previous paper so that one empty segment was reserved for train length and one empty segment for train mass. We are better off now since the above formula tells precisely how to add up the two factors together.

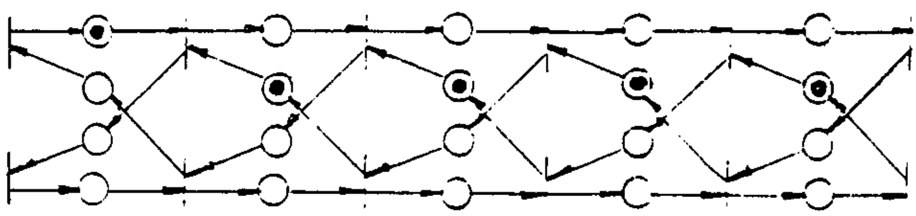
Note that m is in fact the maximal length of all trains plus the maximal braking distance for all trains.

As pointed out in the previous paper, the trains are still not safe in this model due to the nonzero length of signals. That is to say, signals should be separated as well, say by at least one segment on the signal line.

1.4 Model With Two Tracks and Two Signal Lines

By "two tracks" we mean one railway track and one signal line with the signals going in the direction the trains go. Signals on this line are not permit signals.

$\Sigma_{2,2}$



Similar to the way in which trains are separated from each other, two tracks (two lines in the train direction) leave at least one empty segment between two adjacent permit signals.

Assuming that the length of (permit) signals is less than the length of a segment on a signal line, we can now conclude that the tokens as well as the trains, when $n = 2$, are *safe* in $\Sigma_{2,2}$. With train safety, an informal concept in railway systems, as our goal in developing the net model, we have arrived at $\Sigma_{2,2}$. It has turned out that this model is not only *safe* in the formal sense in net theory, but also secure as defined in the previous paper. Now, *security* as a formal concept in net theory resembles the informal safety of trains in reality.

Let us recall the definition of security:

Definition

Secure(S,T; F,C): $\iff$

$$\bigwedge t \in T, \bigwedge c \in C:$$

$$\left.\begin{array}{lllll} 1) & {}^{\bullet}t \subseteq c & \rightarrow & t^{\bullet} \cap c = \emptyset & \textit{no forward contact} \\ 2) & t^{\bullet} \subseteq c & \rightarrow & {}^{\bullet}t \cap c = \emptyset & \textit{no backword contact} \end{array}\right\} \text{"}\textit{safe}\text{"}$$

$$\left.\begin{array}{lllll} 3) & {}^{\bullet}t \cap c \neq \emptyset & \rightarrow & t^{\bullet} \cap c = \emptyset \\ 4) & t^{\bullet} \cap c \neq \emptyset & \rightarrow & {}^{\bullet}t \cap c = \emptyset \end{array}\right\} \textit{no transjunction};\ 3) \iff 4)$$

What is new in the concept of security is "transjunction", short for "con*junction* of conditions across a *trans*ition".

2 Transjunction

Definition: A transition t is in **transjunction** in a case c if and only if some input condition and some output condition of t are holding in the case c.

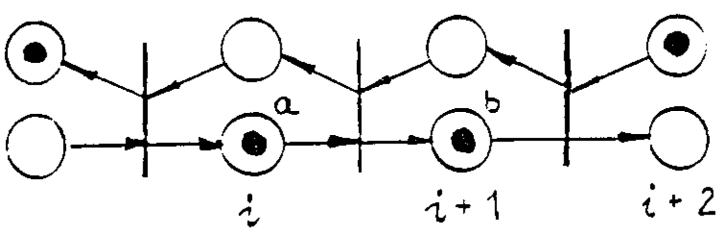
Formally:

Transjunction (t,c): $\iff$ ${}^{\bullet}t \cap c \neq \emptyset$ and $t^{\bullet} \cap c \neq \emptyset$

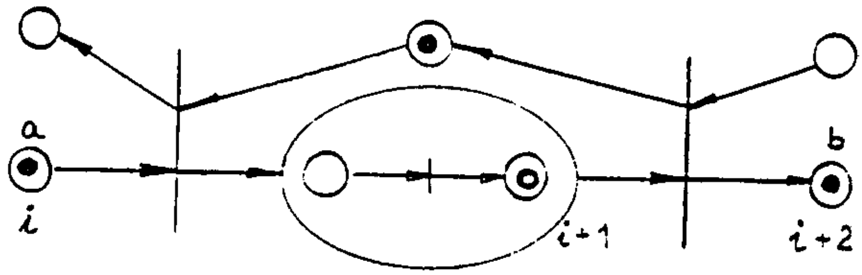
We have ruled out, in the above process of developing a secure net model for railway systems, three possible transjunction situations besides contact (forward as well as backward contact). Let us ask now why each of the three possibilities for transjunction has to be avoided:

2.1 Train to Train Transjunction

The picture below illustrates such transjunction:



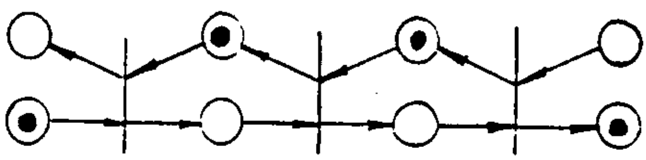
where in both segment i and segment $i+1$ there is a train (token): train a on segment i is not permitted to move now but train b on segment $i+1$ is permitted. If the body or tail of train b is modelled explicitly, the situation should look like, after train b enters segment $i+2$, as below:



where, as shown, place $i+1$ has been decomposed and in one of the detailed inner places appears the train body (" "). Now, train a gets the permit signal to enter segment $i+1$. Within segment $i+1$, train a can move freely, or as fast as it likes to. Thus comes the danger: it may crash into the body of train b in case the latter is not moving quickly enough. So this type of transjunction reflects *insufficient separation* (of trains).

2.2 Signal to Signal Transjunction

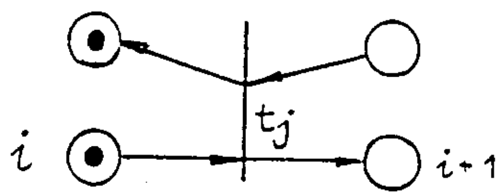
Pictorially, such a transjunction can be illustrated as below:



The danger is that when two permit signals "crash" into each other (as explained for train to train transjunction), chaos may occur, since they may merge and their identification may be impossible. Again, this type of transjunction reflects *insufficient separation* (of signals).

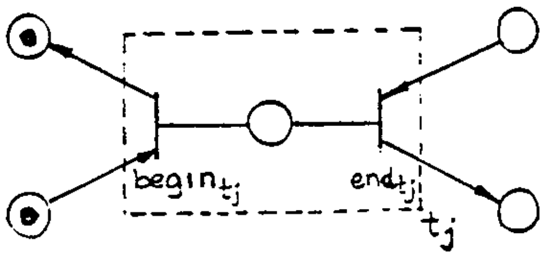
2.3 Train to Signal Transjunction

The following is a train to signal transjunction:

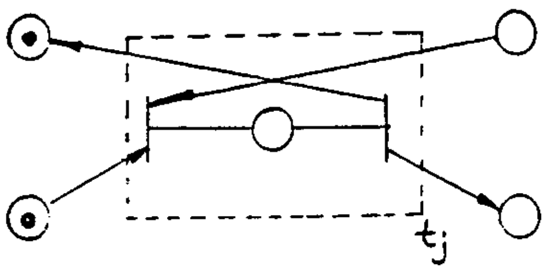


and it is not immediately clear why this possibility must be excluded, too. Transition t_j

in the picture may be decomposed (or implemented) as below:



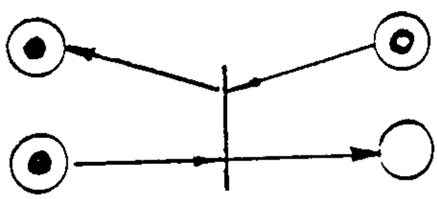
where a contact situation is detected around transition $begin_{t_j}$. Thus, a transjunction situation allows unsafe implementation. A proper implementation could be:



This decomposition of t_j can generate new output tokens only after having absorbed tokens from all inputs; therefore, if the net containing t_j is safe, it remains safe after this proper decomposition. Proper decomposition *preserves* safety (and security).

However, the possibility of unsafe decomposition is *not* the reason why we have to exclude train_to_signal transjunction! Unsafe decomposition may make even a secure net unsafe; it must be forbidden anyway.

Consider again train_to_signal transjunction t_j:



A signal token is shown in s; since even the shortest signal have some length, it is possible that part of the signal is still in s'. Therefore, the "door" t_j must open for that part of the signal, and thus it is open for the train. We have to keep in mind that transitions are like *signal* doors, open to all or to none. Therefore again, this type of transjunction reflects *insufficient separation*: between non_corresponding trains and permit signals. To sum up: all three transjunction situations should be avoided in a secure system, and therefore it is now apparent why security has been defined as no contact and no transjunction.

Note that "no transjunction" does not imply "no contact" since it may appear that $^\bullet t = \emptyset$ or $t^\bullet = \emptyset$ as illustrated by the pictures below:

As we all know, it is always possible, by S_complementation, to remove "contact" from a system, but it doesn't help in case of transjunction. The removal of transjunction requires to go into more system detail.

We have mentioned *backward contact* several times so far. We have the following two reasons to exclude (not only forward contact, but also) backward contact:

- If $^\bullet t \neq \emptyset \neq t^\bullet$ for some $t \in T$, then backward contact around t implies transjunction.
- Trains may move backwards.

So far we have talked about railway systems all the time. The difference between a train and a signal, as far as our model is concerned, lies in the mass property: it is nonzero for trains, but may be zero for permit signals. We have seen in section 1.3 that the properties and possible differences of trains and signals show up only in the *separation numbers*, n for trains and n' for permit signals. Both n and n' are ≥ 2 by definition. To achieve this separation, we need

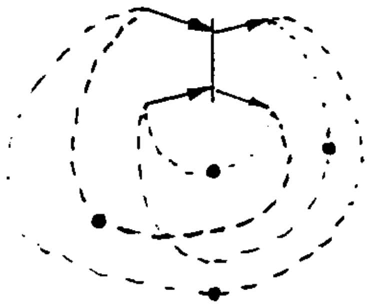
1. n backward lines
2. n' forward lines
3. the structural property of security

Otherwise, trains and permit signals can and must be treated alike.

Therefore, our net model $\Sigma_{2,2}$ describes also a *secure transmission line for messages* when all signals (now "message signals" and "permit signals" which may also be used for messages) are shorter than one segment: $n = n' = 2$. Such a transmission line has to be secure instead of merely safe since signals have nonzero length. Here is the security criterion:

- For marked directed graph (digraph for short):

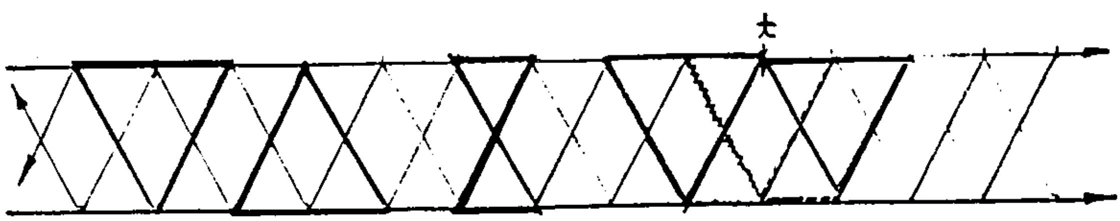
every *pair* of successive arcs must lie on a *basic circuit*:



A *basic circuit* is a (uniformly) directed circuit (mesh in net terminology) with exactly one edge marked.

- For (elementary) nets: Every transition with m inputs (preconditions) and n outputs (postconditions) must lie on $m \times n$ basic *domains* covering $^{\bullet}t^{\bullet} = {}^{\bullet}t \cup t^{\bullet}$, where *domain* is to be defined. Informally, a domain is a set of S_elements with a constant number of tokens; a basic domain is a domain where that constant is 1.

The following picture shows the three types of basic circuits for the simplest secure transmission line $\Sigma_{2,2}$, and the six basic circuits on which transition t lies:



3 Cycloids

Cycloids may serve as the basis for general $n \times k$ secure transmission lines. See next issue for an introductory discussion.

CONTROL SYNTHESIS BASED ON A GRAPH-THEORETICAL PETRI NET ANALYSIS

W. Seiche

Institut für Regelungstechnik der RWTH Aachen
Steinbachstr. 54, D-5100 Aachen, FRG

1. INTRODUCTION

Modern control theory provides a great number of methods concerning the system analysis and the control synthesis for continuous systems. The importance of an investigation of discrete-event systems has recently grown and requires other mathematical models and methods. It appears that Petri nets are an appropriate model and several authors have applied them to the modelling, analysis and synthesis of discrete-event control systems (e.g./A1/,/A2/,/B1/,/D1/,/P1/,/R1/,/S1/,/U1/).

This contribution tries to point out possibilities of synthesizing (minimum) control actions that are able to correct deficient dynamic properties of the so far specified control system. We follow /B4/ in considering control as restrictions of behaviour. Our basic idea is to restrict the firing behaviour of a system in such a way that certain undesired state transitions - detected by a graph-theoretical net analysis - cannot occur any more. Since these restrictions are modelled by means of Petri nets, the current dynamic properties of the overall system can be investigated through net analysis at any time.

The method consists of three steps. First it is checked whether and how the desired property can be enforced by restrictions. Therefore information about critical transitions, whose occurrences have to be restricted, are derived from the condensation of the reachability graph. Obtainable properties are deadlock freeness, liveness and repeatability. In the next step a set of places that is sufficient for a unique identification of all the critical occurrences of these transitions is looked for. Finally the Petri net is extended by self-loops in such a manner that only 'admissible' occurrences can be performed.

2. GRAPH-THEORETICAL NET ANALYSIS

The systems we are concerned with are technical ones (flexible manufacturing systems, process engineering plants etc.) and each component can assume only a finite number of states. Consequently the net models of such systems will be finite and bounded and therefore a reachability graph can be constructed.

Throughout this paper the term "Petri net" refers to a subclass of the P/T-systems defined in /B2/, namely finite P/T-systems with finite capacities. Furthermore it should be mentioned here, that the so-called 'resource oriented concession rule' is used as the enabling condition in the transition rule. Generally we follow the terminology given in /B2/. All the formal notations and definitions that differ are summarized below.

Definition 1:

A sixtuple $N = (S,T;F,K,W,M_0)$ is called a Petri net iff

(i) $S = \{s_1,s_2, \ldots ,s_{|S|}\}$ is a non-empty, finite set of places,

(ii) $T = \{t_1,t_2, \ldots ,t_{|T|}\}$ is a non-empty, finite set of transitions,

(iii) $F \subseteq (S \times T) \cup (T \times S)$ is a non-empty set of arcs,

(iv) K: $S \to \mathbb{N}^+$ is a capacity function,

(v) W: $F \to \mathbb{N}^+$ is a weight function and

(vi) M_0: $S \to \mathbb{N}$ is an initial marking function that satisfies $M_0(s) \leq K(s)$ for all $s \in S$.

<u>Definition 2</u>:

Let $N = (S,T;F,K,W,M_0)$ be a Petri net.

(i) M: $S \to \mathbb{N}$ is called a marking of N iff it satisfies $M(s) \leq K(s)$ for all $s \in S$;

(ii) A vector $\underline{m} \in \mathbb{N}^{|S|}$ is called marking vector iff $(m_i) = M(s_i)$;

(iii) A vector $\underline{\kappa} \in \mathbb{N}^{+|S|}$ is called capacity vector iff $(\kappa_i) = K(s_i)$;

(iv) A vector $\underline{t}_j^+ \in \mathbb{Z}^{|S|}$ is called positive transition vector

$$\text{iff } (t_{j_i}^+) = \begin{cases} W(t_j,s_i) & \text{for all } t_j F s_i \\ 0 & \text{otherwise} \end{cases} ;$$

(v) A vector $\underline{t}_j^- \in \mathbb{Z}^{|S|}$ is called negative transition vector

$$\text{iff } (t_{j_i}^-) = \begin{cases} -W(s_i,t_j) & \text{for all } s_i F t_j \\ 0 & \text{otherwise} \end{cases} ;$$

(vi) A transition $t_j \in T$ is enabled at $\underline{m}$ iff its transition vectors satisfy $-\underline{t}_j^- \leq \underline{m} \leq \underline{\kappa} - \underline{t}_j^+ - t_j^-$ by each component;

(vii) The firing of an enabled transition yields a new marking vector $\underline{m}'$ according to $\underline{m}' = \underline{m} + \underline{t}^+ + \underline{t}^-$.

Definition 3:

Let $N = (S,T;F,K,W,M_0)$ be a Petri net.

(i) N is live iff $\forall t \in T$: t is live;

(ii) N is deadlock free iff $\forall M \in [M_0>$ $\exists t \in T$: t is enabled at M;

(iii) N is repeatable iff $\forall M \in [M_0>$: M is reproducible.

Definition 4:

Let N be a Petri net and E_N be the reachability graph of N.

(i) A subgraph E_N' of E_N is called a strong component of E_N iff E_N' is strongly connected, i.e. between every pair of nodes in E_N' exists a directed path;

(ii) A strong component E_N' is called live iff $\forall t \in T$: at least one arc of E_N' is labelled with t;

(iii) A strong component E_N' is called dead iff $\nexists t \in T$: at least one arc of E_N' is labelled with t;

(iv) The graph E_N^K whose nodes are all the strong components of E_N and whose arcs are labelled with all the transitions that lead from one strong component to another is called the condensation of E_N.

While total deadlocks are already recognizable from the reachability graph, more comprehensive properties like liveness and repeatability can be proved by means of the condensation. A Petri net is live if and only if neither total nor partial deadlocks occur, i.e. if every drain of the condensation includes all transitions of the net. It is repeatable if and only if its reachability graph is strongly connected, i.e. if its condensation consists of exactly one strong component. This component is both source and drain.

The procedures of graph-theoretical net analysis are formally summarized in

Lemma 1 /A1/:

Let N be a Petri net, E_N be its reachability graph and E_N^K the condensation of the reachability graph.

(i) N is deadlock-free iff no drain of E_N^K is a dead component;

(ii) N is live iff every drain of E_N^K is a live component;

(iii) N is repeatable iff E_N is strongly connected, i.e. E_N^K consists of exactly one component.

3. DERIVATION OF THE CONTROL TASKS

The condensation of the reachability graph can be used directly to specify the control tasks for an enforcement of the desired net properties. The control has to prevent the occurrence of events, that correspond with so-called critical transitions, labelling certain arcs of the condensation. It depends on the control goal, which transitions are critical ones and which of their occurrences have to be restricted.

Suppose E_N, E_N^K and $\tilde{E}_N$, $\tilde{E}_N^K$ respectively denote the reachability graphs and their condensations before and after the net correction. If the correction is done by firing restrictions, $\tilde{E}_N^K$ will be a subgraph of E_N^K (and $\tilde{E}_N$ a subgraph of E_N). For an enforcement of lifeness or deadlock-freeness, every drain of $\tilde{E}_N^K$ has to include all the transitions (in case of lifeness) or at least one transition (in case of deadlock-freeness). We can derive the desired condensation $\tilde{E}_N^K$ iteratively from E_N^K by a repeated elimination of all the drains that do not satisfy these properties. For the enforcement of repeatability we can find $\tilde{E}_N^K$ more easily, because it must consist of nothing but the source node in E_N^K.

The determination of $\tilde{E}_N^K$ represents the first synthesis step of a net correction. Utilizing this desired condensation we can directly find the respective reachability graph $\tilde{E}_N$, which we compare with the initial graph E_N in order to determine all the critical transitions. Every arc in E_N is labelled with a critical transition, if and only if it connects a node which is also included in $\tilde{E}_N$ to one of the eliminated nodes. The occurrences that correspond to these arcs have to be prevented. This prevention can be done either by disabling every critical transition whenever its firing causes such an 'entrance' into an eliminated node or by enabling it only when the subsequent marking is still 'admissible'.

Definition 5:

Let N be a Petri net, t_j be a critical transition of N and let $\tilde{E}_N$ be the desired reachability graph of the corrected Petri net $\tilde{N}$.

(i) A vector $\underline{e}^j \in \mathbb{N}^{|S|}$ is called enabling marking vector for t_j iff

(a) $\underline{e}^j$ is included in $\tilde{E}_N$ and

(b) t_j is enabled at $\underline{e}^j$ in N and

(c) $\underline{m}' = \underline{e}^j + \underline{t}_j^+ + \underline{t}_j^-$ is <u>also</u> included in $\tilde{E}_N$.

(ii) A vector $\underline{d}^j \in \mathbb{N}^{|S|}$ is called disabling marking vector for t_j iff

(a) $\underline{d}^j$ is included in $\tilde{E}_N$ and

(b) t_j is enabled at $\underline{d}^j$ in N and

(c) $\underline{m}'' = \underline{d}^j + \underline{t}_j^+ + \underline{t}_j^-$ is <u>not</u> included in $\tilde{E}_N$.

The occurrence restrictions for a critical transition t_j can be realized by means of all the vectors $\underline{e}_i$ or $\underline{d}_i$ alternatively. Suppose there are $|E^j|$ enabling and $|D^j|$ disabling marking vectors for t_j. Thus the first condition can be stated as

$$\begin{array}{ll} \text{IF} & \{\underline{m}=\underline{e}_1^j \vee \underline{m}=\underline{e}_2^j \vee \ldots \vee \underline{m}=\underline{e}_{|E^j|}^j\} \\ \text{THEN} & \{\text{enable } t_j\} \quad , \end{array} \qquad (3\text{-}1)$$

and the alternative condition would be

$$\begin{array}{ll} \text{IF} & \{\underline{m}=\underline{d}_1^j \vee \underline{m}=\underline{d}_2^j \vee \ldots \vee \underline{m}=\underline{d}_{|D^j|}^j\} \\ \text{THEN} & \{\text{disable } t_j\} \end{array}$$

$$\Longleftrightarrow \begin{array}{ll} \text{IF} & \{\underline{m}\neq\underline{d}_1^j \wedge \underline{m}\neq\underline{d}_2^j \wedge \ldots \wedge \underline{m}\neq\underline{d}_{|D^j|}^j\} \\ \text{THEN} & \{\text{enable } t_j\} \quad . \end{array} \qquad (3\text{-}2)$$

The additional firing conditions (3-1) and (3-2) formalize the control tasks. Both conditions can be applied, but (3-2) can lead to extensive net modifications if more than one disabling marking vector exists.

4. MODIFICATION OF THE NET

The final synthesis step is the extension of the Petri net by self-loops in such a manner, that either condition (3-1) or condition (3-2) is satisfied. A self-loop connects a place s and a transition t by two arcs with different directions. According to Definition 2 such a loop enables t at any $\underline{M(s)\geq n}$, if n denotes the weight of the participating arcs.

An enabling at markings $\underline{M(s)\leq n}$ can be done by utilizing the so-called complementary place of s, which has to be added to the net if necessary.

Definition 6:

Let $N = (S,T;F,K,W,M_0)$ be a Petri net and $s,\bar{s} \in S$. The places s and $\bar{s}$ are called complementary places iff

(i) $\cdot s = \bar{s}\cdot$ and

(ii) $s\cdot = \cdot\bar{s}$ and

(iii) $W(t,s) = W(\bar{s},t) \quad \forall t\in T$ and

(iv) $W(t,\bar{s}) = W(s,t) \quad \forall t\in T$ and

(v) $M_0(s) + M_0(\bar{s}) = K(s) = K(\bar{s})$.

Lemma 2:

Let $N = (S,T;F,K,W,M_0)$ be a Petri net and $s,\bar{s} \in S$ be complementary places. Every reachable marking M of N satisfies $M(s) + M(\bar{s}) = K(s) = K(\bar{s})$.

Proof. The transition rule for the calculation of reachable markings yields

$$M'(s) = M(s) - W(t,s) + W(s,t) \quad (4\text{-}1)$$

$$M'(\bar{s}) = M(\bar{s}) - W(t,\bar{s}) + W(\bar{s},t) \quad . \quad (4\text{-}2)$$

The substitution of Def. 6(iii),(iv) in (4-1) results in

$$M'(s) = M(s) - W(\bar{s},t) + W(t,\bar{s}) \quad . \quad (4\text{-}3)$$

The addition of (4-3) and (4-2) leads to

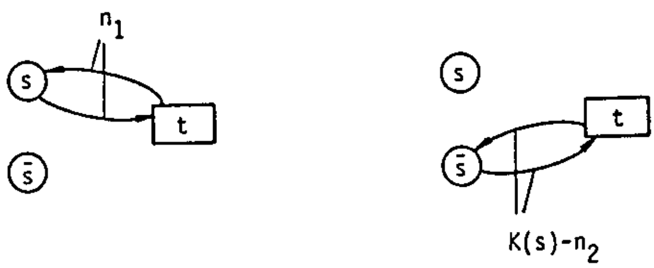
$$\begin{aligned} & M'(\bar{s}) + M'(s) = M(\bar{s}) + M(s) \\ \Leftrightarrow\ & M'(s) + M'(\bar{s}) = M(s) + M(\bar{s}) \quad , \end{aligned} \quad (4\text{-}4)$$

and applying Def. 6(v) finally yields

$$M'(s) + M'(\bar{s}) = K(s) = K(\bar{s}) \quad (4\text{-}5)$$

for every marking M', that is reachable starting from M_0 ∎

The additional consultation of complementary places extends the tool for the net correction. With respect to Lemma 2 the enabling condition $\underline{M(s) \le n}$ can be transformed into $\underline{M(\bar{s}) \ge K(s)-n}$ and thus also be realized by self-loops. Both constructions are shown in Fig.1.



a) t enabled at $M(s) > n_1$

b) t enabled at $M(s) < n_2$

Fig.1: Self-loops for additional firing conditions

The control conditions (3-1) and (3-2) consist of logically connected expressions. We can decompose them step by step. A first decomposition of (3-1) and (3-2) leads to terms like

$$\underline{m} = \underline{e} \iff M(s_1) = E(s_1) \wedge M(s_2) = E(s_2) \wedge \dots \wedge M(s_{|S|}) = E(s_{|S|}) \qquad (4\text{-}6)$$

$$\underline{m} \ne \underline{d} \iff M(s_1) \ne D(s_1) \vee M(s_2) \ne D(s_2) \vee \dots \vee M(s_{|S|}) \ne D(s_{|S|}) \quad , \qquad (4\text{-}7)$$

that can be further decomposed according to

$$M(s_i) = E(s_i) \iff M(s_i) \ge E(s_i) \wedge M(s_i) \le E(s_i) \qquad (4\text{-}8)$$

$$M(s_i) \ne D(s_i) \iff M(s_i) \ge D(s_i) + 1 \vee M(s_i) \le D(s_i) - 1 \quad . \qquad (4\text{-}9)$$

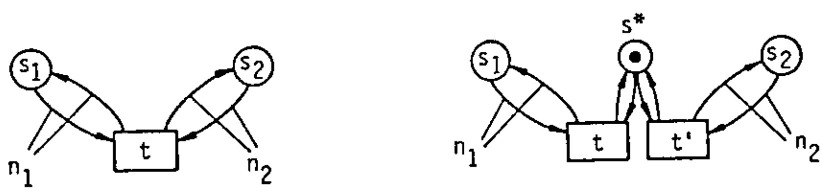
This procedure results in boolean expressions with elementary logical operands which are connected by disjunction and conjunction operators. These expressions can be minimized if necessary (cf. e.g./B3/). The elementary operands are realizable by self-loops (as shown in Fig.1) whereas a realization of the logical disjunction additionally requires the 'splitting' of transitions.

Definition 7:

Let $N = (S,T;F,K,W,M_0)$ be a Petri net and $t,t' \in T$. The transitions t and t' are called similar transitions iff

(i) $\cdot t = \cdot t'$ and
(ii) $t\cdot = t'\cdot$ and
(iii) $W(t,s) = W(t',s) \quad \forall s \in S$ and
(iv) $W(s,t) = W(s,t') \quad \forall s \in S$.

The 'splitting' of a critical transition into two or more similar transitions completes the tool for a net correction because now both con- and disjunctions are constructable (Fig. 2).



a) t enabled at $M(s_1) \geq n_1 \wedge M(s_2) \geq n_2$

b) t enabled at $M(s_1) \geq n_1 \vee M(s_2) \geq n_2$

Fig.2: Conjunction and disjunction[1] realized by self-loops

---

1 The additional place s* in Fig.2b evokes a conflict between t and t' in order to realize the 'exclusive-or' disjunction as the exact negation of the conjunction in Fig.2a.

The net correction is definitively completed, if all the decomposed terms of either expression (3-1) or (3-2) are realized in the above-mentioned way. This corresponds with an application of every place $s \in S$ to the detection of the enabling conditions. Such an approach will certainly not be useful because the modelled system is a distributed one and should therefore be controlled by a distributed control. In a distributed system, states are local states and events are effective locally. Only on certain places the number of tokens renders a marking to be a disabling one or an enabling one. This means that most of the self-loops can be omitted without risking the correction result. Therefore finally a reduction method will be presented that helps to find all the so-called significant places which are sufficient for a correct realization.

Basis of the method is a matrix which is built by subtracting every disabling from every enabling marking vector for a critical transition t_j according to the following definition.

Definition 8:

Let t_j be a critical transition, let $E^j = \{\underline{e}_1^j, \underline{e}_2^j, \ldots, e_{|E^j|}^j\}$ and $D^j = \{\underline{d}_1^j, \underline{d}_2^j, \ldots, \underline{d}_{|D^j|}^j\}$ be the sets of all the enabling and disabling marking vectors for t_j.

(i) A vector $\underline{\delta}_{pq}^j \in \{0,1\}^{|S|}$ is called distinctive vector for t_j iff $(\delta_{pq_i}^j) = \begin{cases} 1 & \text{for all } (e_{p_i}^j) - (d_{q_i}^j) \neq 0 \\ 0 & \text{otherwise} \end{cases}$;

(ii) A matrix $\underline{\Delta}^j$ is called distinctive matrix for t_j iff $\underline{\Delta}^j = [\underline{\delta}_1^j : \underline{\delta}_2^j : \ldots : \delta_{|E^j|\cdot|D^j|}^j]$

A non-zero element of this matrix $\underline{\Delta}^j$ means, that the respective enabling and disabling marking vectors have different numbers of tokens on the corresponding place. Hence this place could be used for an identification. If every element of a row-vector of $\underline{\Delta}^j$ is non-zero, the corresponding place is sufficient for an unique identification of all the enabling markings, because the number of tokens in every enabling marking vector differs from the number in every disabling one on this place.

It should be mentioned that in the general case more than one (but less than every) place will have to be considered for the identification. In case that $\underline{\Delta}^j$ does not contain a row-vector with only non-zero elements, such a vector has to be generated by a linear combination of the rows. Then, the participating rows point out the sufficient significant places. The vector notation of this linear combination is the diophantine matrix inequality

$$(\underline{\Delta}^j)^T \cdot \underline{e} \geq \underline{1} \quad ; \ \underline{e} \in \{0,1\}^{|S|} \qquad (4\text{-}10)$$

that can be solved similar to the calculation of S- and T-invariants. Generally several solutions of (4-10) exist. Each solution $\underline{e}_K$ points to a set of significant places which correspond to the elements $(e_{k_i}) = 1$. Any solution $\underline{e}_K$ may be selected for the realization of the net correction. However, a solution with a minimum number of non-zero elements should be preferred because it corresponds to a minimum number of additionally required firing conditions. If more of such solutions exist, it is arbitrary, which of them is chosen.

A simplified example shall finally illustrate the working of the synthesis procedure. Suppose the Petri net of Fig.3 describes the flow of workpieces in a flexible manufacturing cell, which consists of 2 different machines (places s_7 and s_8), 2 pallet parking positions (place s_9) and a transportation robot[1]. Two types of workpieces shall be processed (t_1, s_1, t_2, s_2, t_5 and $t_6, s_4, t_7, s_5, t_{10}$ resp.) or parked if re-

---

[1] For our purpose the respective place ist dispensable and has been omitted.

quired (t_3, s_3, t_4 and t_8, s_6, t_9). Notice the different processing sequences that can cause a deadlock, if too many workpieces are fed into the cell (by firing of t_1 and t_6). Therefore a transportation control based on the Petri net model will be incomplete since if leaves too many degrees of freedom.

The critical transitions are t_1 and t_6 and for each of them just one disabling marking exists. According to (3-2) the firing of t_1 and t_6 has to be prevented at $\underline{d}^1 = (0,0,1,1,0,1,1,0,0)^T$ and $\underline{d}^6 = (1,0,1,0,0,1,0,1,0)^T$ respectively. The places $s_4 \wedge s_9$ have been chosen as significant places for t_1 and $s_1 \wedge s_9$ as significant ones for t_6. Thus the additional firing conditions are

$$\begin{aligned}&\text{IF} \quad \{M(s_4) \neq D^1(s_4) \vee M(s_9) \neq D^1(s_9)\}\\&\text{THEN } \{\text{enable } t_1\} \quad ,\end{aligned} \tag{4-11}$$

$$\begin{aligned}&\text{IF} \quad \{M(s_1) \neq D^6(s_1) \vee M(s_9) \neq D^6(s_9)\}\\&\text{THEN } \{\text{enable } t_6\} \quad .\end{aligned} \tag{4-12}$$

Their further decomposition (applying (4-9) and Def. 6) leads to

$$\begin{aligned}&\text{IF} \quad \{M(\bar{s}_4) \geq 1 \vee M(s_9) \geq 1\}\\&\text{THEN } \{\text{enable } t_1\} \quad ,\end{aligned} \tag{4-13}$$

$$\begin{aligned}&\text{IF} \quad \{M(\bar{s}_1) \geq 1 \vee M(s_9) \geq 1\}\\&\text{THEN } \{\text{enable } t_6\} \quad .\end{aligned} \tag{4-14}$$

They require the splitting of the transitions t_1 and t_6 as well as the complementation of the places s_1 and s_4.

The complete construction is shown in Fig.4 and its deadlock freeness (and liveness and repeatability) can be verified. Thus a transportation control based on this net model will work correctly.

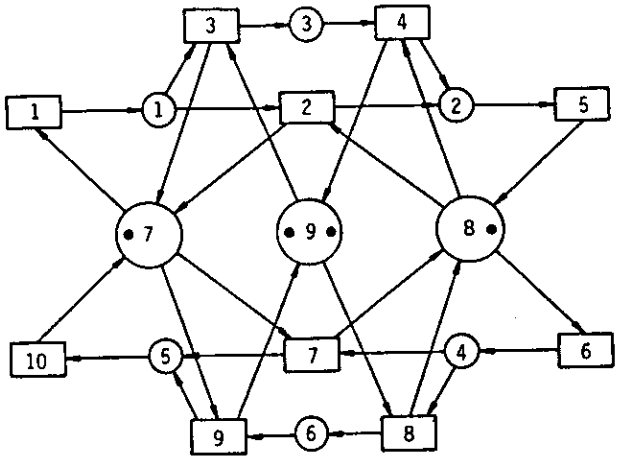


Fig.3: Petri net before correction

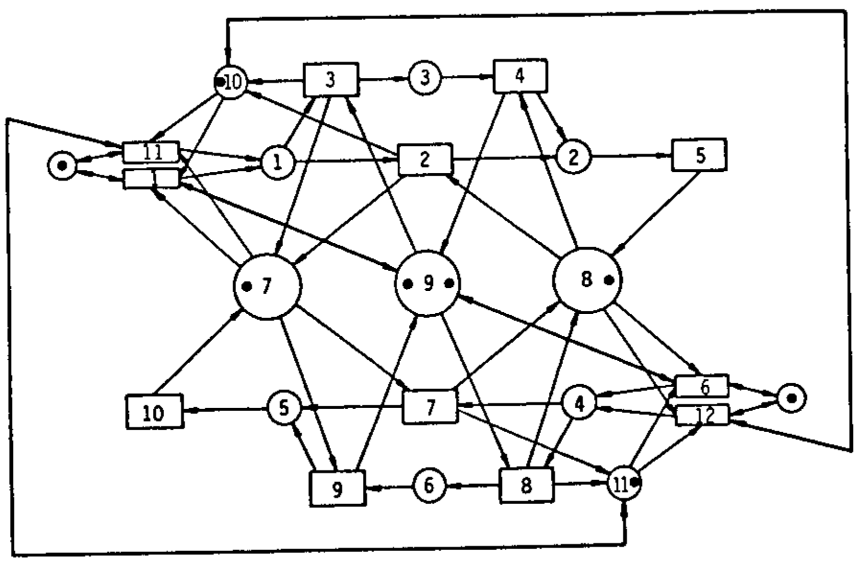


Fig.4: Petri net after correction

5. CONCLUDING REMARKS

This contribution tries to provide a component of a formal control synthesis for discrete-event systems. The derivation of net extensions from analysis results can help to correct deficient net properties found in the graph-theoretical net analysis. Since the Petri net is the model of a discretely controlled system, these extensions represent control interactions that are able to correct the behaviour of the closed loop system.

It must be mentioned that an application of the synthesis method can generally create new dead transions in order to make the rest of the net deadlock free, live, or repeatable. This phenomenon will occur each time that the net structure principally bars an enforcement of the chosen behaviour by restrictions. On the other hand this occurrence is an indication of an incorrect modelling process, unless the modelled system itself bars such an enforcement - e.g. an irreversible process, which cannot be made reversible just by restrictions. The application of T-invariants can answer how promising the synthesis procedure will be for a given system. In case of boundedness of the net they supply necessary conditions for the liveness property (cf. e.g./A1/). If they exclude liveness, a net correction by self-loops obviously cannot work, because a self-loop does not have any influence on the T-invariants since the loop will not appear in the incidence matrix of the net.

6. REFERENCES

/A1/ Abel, D. (1987): Modellbildung und Analyse ereignisorientierter Systeme mit Petri-Netzen. Fortschritt-Berichte VDI Reihe 8, VDI-Verlag, Düsseldorf.

/A2/ Abel, D. (1988): Modellbildung und Analyse diskret gesteuerter Systeme mit Petri-Netzen. Automatisierungstechnik 36, Heft 12.

/B1/ Banaszak, Z.; Abdul-Hussin, M. H. (1987): Petri Net Approach to Automatic Real-Time Programm Synthesis. Petri Net Newsletter 27, pp. 10-28.

/B2/ Best, E.; Fernández, C. (1986): Notations and Terminology on Petri Net Theory. Arbeitspapiere der GMD 195.

/B3/ Bronstein, I.N.; Semendjajew, K.A.: Taschenbuch der Mathematik (Ergänzende Kapitel). B.G. Teubner Verlagsgesellschaft, Leipzig 1979, pp. 197 ff.

/B4/ Burkhard, H.-D. (1985): Fair Controls and their Realization. Lecture notes in Computer Science 222, Springer-Verlag, Berlin, pp. 59-82.

/D1/ Datta, A.K.; Ghosh, S.; Harms, D.; Elmagarmid, A.K. (1988): Deadlock-Avoidance Mechanisms in Distributed Systems. Computer Systems Science and Engineering Vol. 3, No. 2, pp. 67-82.

/P1/ Peterson, J.-L. (1981): Petri-Net Theory and the Modelling of Systems. Prentice Hall Inc., Englewood Cliffs.

/R1/ Reisig, W. (1982): Petri-Netze, eine Einführung. Springer-Verlag, Berlin.

GRAPH : A Graphical System for Petri Net Design and Simulation

Zbigniew Suraj
Institute of Mathematics
Pedagogical University
Rejtana Str. 16a, PL-35-310 Rzeszów

ABSTRACT. The practical use of Petri nets is very dependent on the existence of adequate computer tools, which may assist the user to cope with the many details of a large description [1]. For Petri nets there is a need for tools supporting construction of nets, as well as modification and analysis [5]. Graphical work stations (or at least graphical terminals) provide the opportunity to work - not only with textual representations of Petri nets - but also directly with the graphical representations.

This paper describes some graphical tools which are needed in the Petri net area.

Keywords : Petri net tools, computer based tools.

Contents :

1. Introduction
2. Facilities
   2.1. General
   2.2. Net creation and manipulation
   2.3. Interactive and automatic net simulation
   2.4. Structural analysis
3. Implementation environment
4. Applications
References

1. Introduction

The graphical tools described in the following have been accomplished in the Institute of Mathematics at Pedagogical University in Rzeszow.
Development of an early prototype began in 1987. A major revision occurred in early 1989, radically altering the user interface, simulation and graphical facilities.

Our aim was to support the development of complex distributed systems, i.e. the prototyping, the verification of the behaviour by animated simulation, and the analysis of a Petri net structure.

As a model, Petri nets [6,7,9] were chosen for their excellent ability to represent concurrency. The other reasons for this selection were its graphical representation, its widely elaborated theoretical background, and that it may be executed by a simulator. Both the structure and the behaviour of a system can be described with the same graphical notation. Finally, there exist some textual interesting computerized tools [10] which can assist the user in applying different analysis techniques and thus gain information about the properties of Petri nets.

To support the practical use of Petri nets, we have built a graphical editor and a fully integrated simulator. These tools have been called as GRAPH.

GRAPH is a computer aid developed for the creation, manipulation and simulation of Petri nets. It is based on place/transition nets and self-modifying nets, known as P/T-nets [7] and SM-nets [13], respectively. SM-nets have been introduced in order to increase an efficiency of Petri nets.

2. Facilities

2.1. General

GRAPH facilities have been developed in a hierarchy. At each level the user is prompted by a menu of commands. Two of these commands are always present: EXIT and HELP. The user may always exit to the next highest level (or exit from GRAPH), or may ask for help at the level he is at. Care has been taken to ensure that helpful error messages are provided for exception handling.

GRAPH may be operated in interactive or automatic mode. All preliminary specifications and analysis will be handled interactively, but sometimes it is convenient to submit large simulation jobs in automatic mode.

GRAPH facilities cover three main areas: interactive/automatic net creation, manipulation, interactive/automatic net simulation, and structural analysis of a net graph.

These are summarised in the following subsections. A detailed description of each facility is given in a comprehensive User's Manual [11].

2.2. Net creation and manipulation

The graphical editor has been designed according to modern principles of user interfacing [4]. The editor's user interface has been implemented on the basis of windows, pop-up menus and the mouse as a pointing device. To a large part, the use of the editor is self explanatory. The system is developed by creating transitions (boxes), places (circles) and connectors (arcs) and performing operations on them.

The graphical editor is aware of the connectivity of the graph elements which it operates. Thus movement of a node will automatically ensure that the connecting arcs are also moved appropriately. Arcs are drawn as straight lines or curves. Labels are automatically placed near graph elements. The graphical editor can work directly with the textual representation of Petri nets. It is possible automatically to construct the graphical representation of a Petri net from its textual representation [2].

Moreover, our editor constructs the different textual representations of a Petri net from its graphical representation.
It also is important that GRAPH and the Petri-Net-Machine [10] made by P. Starke at Humboldt University create a consistent set of tools where the individual elements complement each other in a fruitful way.
It is possible automatically to translate a constructed graphical representation of a net into an equivalent textual representation which can then be modified and analysed by the Petri-Net-Machine. Analogously, some of the analysis results obtained from the Petri-Net-Machine or the DEADLOCK system [12] can be represented directly on the graphical representation while others are more easily expressed in terms of one of the textual representations.

In particular, the graphical editor supports among others the following functions (cf. [5]):

- add and delete net elements (if a node is deleted, all its arcs are deleted too),
- rescale nodes (it also is possible to choose different line types),
- reposition nodes (if a node is repositioned, all its arcs are automatically adjusted too),
- add, delete and reposition text elements,
- rescale the entire net or a subnet (this changes both the view and the final product),
- copy subnets,
- merge a set of subnets into a single net,
- produce output at different quality and speed (it also is possible to output only part of a net).

2.3. Interactive and automatic net simulation - playing the token game

Once the net has been created and checked, the user may wish to increase her/his understanding of the net (or the system being modelled by the net), by observing its operation. The net may be executed interactively in SINGLESTEP or MULTISTEP mode by the user selecting which event(s) is (are) to occur at each marking.
In MULTISTEP mode the user can select a simple step [8] or a general step [8] of simulation.
A simple step is a non-empty set of transitions such that in a given marking, all transitions can fire simultaneously.
In GRAPH has been also implemented a concept of a simple step in the sense of [3]. There it is required that the elements of a step have pairwise disjoint pre- and postsets.
In a general step of simulation is allowed to fire a transition simultaneously with itself. Consequently, this means that a general step is not a set of transition, but a multiset (bag) of transitions.
In our system three firing rules of transitions for nets are possible:

- weak rule [6,11],
- middle rule [9,11],
- strong rule [3,7,11].

The net is given an initial marking in its definition. GRAPH will display the transitions that are enabled at this marking, and wait (in interactive mode) for the user to choose one. GRAPH will fire the chosen transition(s), generating a new marking and will display the new set of transitions that are enabled. The user can continue to explore the behaviour of the net in this fashion. At any stage a previous marking can be selected, and the net will be reset to the new marking. If a terminal marking is reached (i.e. one in which no transisions can occur), then a previous marking may be selected. At each stage the user may access details of the current marking or exit from SINGLESTEP or MULTISTEP.

Net simulation is performed graphically. The graphics mode provides animation, where at each step, the distribution of tokens in the net is displayed. This allows the user to observe the flow of control (e.g. a local system state) and data (e.g. a message in a protocol) in the specificion simultaneously.
Interactive net simulation is extremely useful in the early stages of the specification of distributed systems as it allows the designer to test each part of the specification as it is completed, and can provide considerable insight into the system's behaviour. It may also be used for debugging and learning about the specification. Interactive simulation is therefore useful in educational applications where the principles of operation of distributed systems (e.g. communication protocols) can be clearly illustrated.

The net may also be executed automaticly in SINGLESTEP or MULTISTEP mode (in which case the occurring transitions (the sets of transitions) are selected by the system, in general by some random generator). Automatic simulation is used to perform lengthy simulations - testing some of the many different combinations of states, which may occur in a complicated system, e.g. a communication protocol. The simulator executes also some kinds of statistics about the simulated occurence sequences.

2.4. Structural analysis

GRAPH guaranties some qualities of the products. It prevents the user from breaking the formal rules of net theory - e.g. connecting two transitions by an arc, without an intervening place; or leaving a dangling arc when a node is deleted. This kind of structural control is similar to the use of syntax-directed editors for programming languages. The generated errors on a stage of the structural analysis are stored at textual files, and then they can be analysed by the user.

3. Implementation environment

GRAPH has been developed under a DOS environment running on IBM PC /XT /AT computers. The programs have been written in Pascal - TURBO version 5.0 for portability.
For monochromatic graphics the Hercules card is proposed. If colour graphics are to be used, then VGA or EGA cards are preferred. Black and white graphics hardcopy can be obtained using e.g. STAR printer. It is also possible to use e.g. ROLAND plotter as terminals for obtaining colour graphics hardcopy. Moreover, this yields much better typographical quality.

4. Applications

GRAPH can be applied to designing and analysing of concurrent system models using Petri nets. It may also be used for learning about the specification. Besides interactive simulation is useful in educational applications where the principles of an operation of distributed systems can be clearly illustrated. At last GRAPH is also possible to use as specialized graphical editor for drawing different kind of graphs , flowcharts etc.

References

[1] Feldbrugge F.H.J.: Petri Net Tools. Lecture Notes in Computer Science Vol. 222: Advances in Petri Nets 1985/ Rozenberg G. (ed.) - Springer-Verlag, pp. 203-223 (1986)

[2] Gąsior T., Suraj Z. :A System for Automatic Drawing Petri Nets - AGRAPH, Report of Researches in Departamental Problem RP I.09, WSP, Rzeszow, 1989, in Polish

[3] Genrich H., Stankiewicz-Wiechno E. : A Dictionary of Some Basic Notions of Petri Nets, in W. Brauer (ed.) : Advanced Course on General Net Theory of Processes and Systems, Hamburg 1979, Lectures Notes in Computer Science, 84, Springer-Verlag (1980)

[4] Goldberg A. : SMALLTALK-80 : The Interactive Programming Environment, Addison - Wesley 1984

[5] Jensen K.: Computer Tools for Construction, Modification and Analysis of Petri Nets.Lecture Notes in Computer Science Vol.255: Advances in Petri Nets 1986, Part II/Brauer W., Reisig W., Rozenberg (eds.) - Springer-Verlag, pp. 4-19 (1987)

[6] Peterson J.L., Petri Net Theory and the Modeling of Systems, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1981

[7] Reisig W. : Petri Nets. EATCS Monographs on Theoretical Computer Science, Vol. 4, Springer Publ. Company (1985)

[8] Reisig W. : On the semantics of Petri Nets, Formal Models in Programming, IFIP 1985, North Holland, pp. 347 - 372 (1985)

[9] Starke P.H. : Petrinetze. VEB Deutscher Verlag der Wissenschaften, DDR, Berlin (1980)

[10] Starke P.H. : Petri-Netz-Machine - A Software Tool for Analysis and Validation of Petri Nets. Systems Analysis and Simulation, Proc. of the 2nd Int. Symp., Berlin 1985. - Oxford: Pergamon, pp. 474 - 475 (1985)

[11] Suraj Z. et al. : A Graphical System for Petri Net Design and Simulation - GRAPH, Report of Researches in Departamental Problem RP I.09, WSP, Rzeszow, 1989, in Polish

[12] Suraj Z., Chrobak R. : A System for Modification of Concurrent Programs - DEADLOCK, Report of Researches in Departamental Problem RP.I.09, WSP, Rzeszow, 1989, in Polish

[13] Valk R.: Self-Modifying Nets: a Natural Extension of Petri Nets, Lecture Notes in Computer Science Vol.62: Automata, Languages and Programming /Ausiello G.;Bohm C.(eds.) - Berlin, Springer-Verlag, pp. 464-476 (1978)

PN-FAULT DETECTABILITY AND CIRCUIT REALIZATION FAULT DETECTABILITY ARE EQUIVALENT

I.G. Tabakow
Dpt. Computer Systems and Control
Higher Inst. for Mech. and Elect.
Engg , Sofia 1156 , Bulgaria

1. Introduction

In [1] , the problem of test generation for a (synchronous sequential) circuit realization S of a given Boolean interpreted Petri net N was presented. The class of these nets (originally introduced in [2]) we shall denote by CPN ("conforme" PNs, i.e. any $N \in CPN$ iff N is safe, live and without conflict). Also by $R(N)$ we shall denote the set of all circuit realizations S of $N \in CPN$.

The aim of this note is to show there exists some (rather strict) correspondence between the fault detectability considerations under $S \in R(N)$ and under $N \in CPN$. Below are used the following designations:

$SM(N)$ - the finite-state sequential machine corresponding to $N \in CPN$;

$M(S)$ - the finite-state sequential machine associated with $S \in R(N)$;

$b\approx$ ($b\not\approx$) - the net behaviour equivalence (distinguishability) relation in CPN ($b\not\approx \overset{df}{=} (b\approx)'$: see Df.1, given in the next Section) ;

$\approx$ ($\not\approx$) - the state machine equivalence (distinguishability) relation ;

$\alpha, \alpha_0, \alpha_1, \ldots$ - any faults for $S \in R(N)$, the set of all such faults is denoted by F ;

S_α, $M(S_\alpha)$, N_α - are S, $M(S)$ and N, modified for $\alpha \in F$ (instead of $N_{pnf(\alpha)}$ the faulty net specified for (N,S,α) is denoted by N_α and $PNF \overset{df}{=} \{ pnf(\alpha) \,/\, \alpha \in F \}$, where $pnf(\alpha)$ is the Petri net fault model for $\alpha \in F$) ;

"SMN(...)" - is used for "State-Machine Net corresponding to ..." .

The finite-state machine $SM(N)$ can be obtained in an unique way by means of "production of truth tables from Petri nets"-procedure, given in [2] (for any $N \in CPN$).

2. The Main Result

In the next considerations we shall assume the fault-free behaviour of S will have to be adequate to that of N (if $S \in R(N)$), i.e:

Assumption 1

$$\forall N \in CPN, S \in R(N) \quad (M(S) \approx SM(N))$$

In like manner we shall assume the faulty behaviour of N_α will have to be adequate to that of S_α (if $S \in R(N)$ and $\alpha \in F$), i.e:

A s s u m p t i o n 2

$$\forall N \in CPN,\ S \in R(N),\ \alpha \in F \ (\ SM(N_\alpha) \approx M(S_\alpha)\ )$$

The next two definitions were introduced in [5]:

D e f i n i t i o n 1

$$\forall N_1, N_2 \in CPN \ (\ N_1 \ b\!\approx N_2 \ \text{ iff } \ SM(N_1) \approx SM(N_2)\ )$$

D e f i n i t i o n 2

$\forall \beta$ (β is a <u>PN-detectable fault</u> iff $\exists \alpha \in F$ ($\beta =$
$= pnf(\alpha) \wedge N_\alpha \ b\!\not\approx N$))

The fault equivalence ($\sim \ \subseteq F \times F$) and PN-fault equivalence ($b\!\sim \ \subseteq PNF \times PNF$) relations can be defined as follows:

D e f i n i t i o n 3

$$\forall \alpha_1, \alpha_2 \in F \ (\alpha_1 \sim \alpha_2 \ \text{ iff } \ M(S_{\alpha_1}) \approx M(S_{\alpha_2})\ )$$

D e f i n i t i o n 4

$\forall \beta_1, \beta_2 \in PNF$ ($\beta_1 \ b\!\sim \beta_2$ iff $\beta_1 = pnf(\alpha_1), \beta_2 =$
$= pnf(\alpha_2)$ and $N_{\alpha_1} \ b\!\approx N_{\alpha_2}$)

If $\beta_1 \ b\!\sim \beta_2$ we shall say β_1 and β_2 are a pair of <u>behavioral-equivalent faults</u>.

The following two propositions are satisfied:

P r o p o s i t i o n 1

Let $N \in CPN$, $S \in R(N)$, $\alpha \in F$.

(i) $N \ b\!\approx SPN(M(S))$,

(ii) $N_\alpha \ b\!\approx SPN(M(S_\alpha))$.

P r o o f:

For any finite-state machine M: $SM(SMN(M)) \approx M$. Also "$b\approx$" is an equivalence relation in the usual sense (i.e. reflexive, symmetric and transitive). Hence:

(i) (1) $SM(N) \approx M(S)$

(2) $SMN(SM(N)) \; b\approx \; SMN(M(S))$

(3) $N \; b\approx \; SMN(SM(N))$

$N \; b\approx \; SMN(M(S))$

(ii) In like manner. ■ $\{$Assmp.1 - 2, Df.1$\}$

P r o p o s i t i o n 2

$\forall \alpha_1, \alpha_2 \in F : \beta_1, \beta_2 \in PNF \; (\beta_1 = pnf(\alpha_1) \wedge \beta_2 = $
$= pnf(\alpha_2) \implies (\beta_1 \; b\sim \beta_2 \;$ iff $\; \alpha_1 \sim \alpha_2))$

P r o o f:

Assume that $\beta_1 = pnf(\alpha_1)$ and $\beta_2 = pnf(\alpha_2)$ (for any $\alpha_1, \alpha_2, \beta_1$ and β_2). Then we can obtain:

$\beta_1 \; b\sim \beta_2$ iff $N_{\alpha_1} \; b\approx N_{\alpha_2}$

iff $SM(N_{\alpha_1}) \approx SM(N_{\alpha_2})$

iff $M(S_{\alpha_1}) \approx M(S_{\alpha_2})$

iff $\alpha_1 \sim \alpha_2$. ■ $\{$Assmp.2, Df.1, 3, 4$\}$

Of course, $pnf(\alpha_1) = pnf(\alpha_2)$, if $\alpha_1 = \alpha_2$. But the converse of this implication is not true (since $M(S_{\alpha_1}) \approx$ $\approx SM(N_{\alpha_1}) = SM(N_{\alpha_2}) \approx M(S_{\alpha_2})$, $\alpha_1 \sim \alpha_2$).

Below we shall use the following

D e f i n i t i o n 5

$\forall \alpha \in F$ (α is a <u>detectable fault</u> iff $M(S) \not\approx M(S_\alpha)$)

T h e o r e m 1

Let $N \in CPN$, $S \in P(N)$, $\alpha \in F$ and $\beta = pnf(\alpha)$. Then:

α is detectable iff β is PN-detectable.

P r o o f:

Assume that α is a detectable fault for $S \in P(N)$.

Hence:

(1) $\alpha \in F$

(2) $\beta = pnf(\alpha)$ {By assmp., Df.5}

(3) $M(S) \not\approx M(S_\alpha)$

(4) $N \; b\!\approx SMN(M(S))$

(5) $N_\alpha \; b\!\approx SMN(M(S_\alpha))$ {Prop.1}

(6) $SMN(M(S)) \; b\!\not\approx SMN(M(S_\alpha))$ {(3),Df.1}

(7) $N \; b\!\not\approx N_\alpha$ {(4,5,6)}

(8) $\exists \alpha \in F \; (\beta = pnf(\alpha) \wedge N_\alpha \; b\!\not\approx N)$ {+∃: (1,2,7)}

β is PN-detectable. {Df.2}

Conversely, assume that β is a PN-detectable fault for $N \in CPN$. Let now α is not detectable for S . Then:

(1) $\alpha \in F$

(2) $\beta = pnf(\alpha)$

(3) $\exists \alpha \in F \; (\beta = pnf(\alpha) \wedge N_\alpha \; b\!\not\approx N)$ {By assmp., Df.2,5}

(4) $M(S) \approx M(S_\alpha)$

(5) $\alpha_0 \in F$

(6) $\beta = pnf(\alpha_0)$ {-∃: (3)}

(7) $N_{\alpha_0} \; b\!\not\approx N$

(8) $\alpha \sim \alpha_0$ {(2,6),Prop.2}

(9) $M(S_\alpha) \approx M(S_{\alpha_0})$ {(8),Df.3}

(10) $M(S) \approx M(S_{\alpha_0})$ $\{(4,9)\}$

(11) $N\ h \approx SMN(M(S))$ $\{$Prop.1(i)$\}$

(12) $SMN(M(S))\ h \approx SMN(M(S_{\alpha_0}))$ $\{(10)$, Df.1$\}$

(13) $N_{\alpha_0}\ h \approx SMN(M(S_{\alpha_0}))$ $\{$Prop.1(ii)$\}$

(14) $N_{\alpha_0}\ h \approx N$ $\{(11,12,13)\}$

Contradiction. ■ $\{(7,14)\}$

Let $\alpha \in F$ is a detectable fault for $S \in R(N)$. Hence there exists an input test sequence (e.g. $X_S(\alpha)$) which detects α . According to the above theorem the fault $\beta = pnf(\alpha)$ is PN-detectable. So, there exists an input test sequence (e.g. $X_N(\beta)$) which detects β . It can be shown $X_N(\beta) = X_S(\alpha)$ (and vice versa, if we assume $\beta = pnf(\alpha)$ is a PN-detectable fault for $N \in CPN$).

3. Conclusions

The above described approach shows a possibility of conversion of the problem of test generation for $S \in R(N)$ to the problem of test generation for $N \in CPN$. This approach is applicable for any type of faults (not only s-a-fault models can be considered) and for any type of circuit realizations of a giv Boolean interpreted Petri net. In particular this type of conver-sion may be attractive when an adequate (to the Petri net structure) circuit realization is assumed. Finally, the above present analysis can be generalized for the class of multi-valued interpreted Petri nets.

References

[1] Tabakow,I.G., Test Generation for Sequential Logic Circuit Using Petri Nets. Petri Net Newsletter I5 (I983), 5 - I0.

[2] Auguin,M.,Boeri,F. and André,C., Systematic Method of Realization of Interpreted Petri Nets. Digital Processes 6 (I980), 55 - 68.

[3] Tabakow,I.G., Boolean Interpreted Petri Nets: The Behaviour Equivalence, Reduction and PN-Fault Detectability Considerations. Petri Net Newsletter 32 (I989), 8 - I7.

Reports on Conferences

PNPM'89 – THE THIRD INTERNATIONAL WORKSHOP ON PETRI NETS AND PERFORMANCE MODELS

PNPM'89 held in Kyoto, Japan, in December 1989, followed similar workshops organized in Torino, Italy, in 1985, and in Madison, Wisconsin, in 1987. The emphasis of this workshop was on Petri net based models for performance evaluation of computer and communication systems. Increasing interest that Petri net based models have been receiving recently is due to the fact that they very conveniently represent systems for which classical queueing techniques are difficult to apply (e.g., distributed and parallel systems).

Prof. Atsunobu Ichikawa (Tokyo Institute of Technology, Yokohama) served as General Chairman with Profs. Sadatoshi Kumagai and Shojiro Nishio (both of Osaka University) as Program Co-Chairmen. Tutorial Committee was chaired by Prof. T. Hasegawa (Kyoto University), Organizing Committee by Prof. Shinzo Kodama (Osaka University), and International Committee by Prof. Kenji Onaga (Hiroshima University). There was no chance of overlooking, forgetting or neglecting anything with such a team supervising the workshop, and indeed, everything went as smoothly as possible, with plenty of big smiles and deep bows (it takes some time to perfect both, especially when concurrency is involved). The workshop was sponsored by The Society of Instrument and Control Engineers in cooperation with IEEE Computer Society, ACM - SIGMETRICS, Institute of Electronics, Information and Communication Engineers, IFIP Working Group 10.2, Institute of Systems, Control and Information Engineers and The Institute of Management Science Japan Chapter.

Kyoto, the ancient capital of Japan, set at the bottom of picturesque hills, contains innumerable cultural treasures. There is an imposing imperial palace complex in the middle of the city, and an impressing shogun's Nijo castle not far from the palace; there are hundreds of temples and shrines with the remarkable Golden Temple that is often used as the Kyoto's symbol; there are beautiful complexes of temples overlooking the city from the slopes of the surrounding hills; there are streets in the old part of the city so narrow that you can reach both sides at the same time; there are many traditional wooden houses with sliding doors and characteristic curved roofs which are hidden between modern concrete structures in an amazing mixture of "old" and "new". The only disadvantage of organizing a conference in Kyoto, as Prof. Ichikawa observed in his opening remarks, is that the numerous attractions may (and certainly will) lure the participants away from the meeting rooms.

The Workshop started with a tutorial day. Kurt Jensen (Aarhus University, Denmark, and Meta Software, Cambridge, MA) gave a thorough overview of "**Coloured Petri nets**" (he took over Grzegorz Rozenberg's session; Grzegorz arrived with some delay and presented his tutorial on the next day). Mark Holliday (Duke University, Durham, NC) discussed "**Some issues in timed Petri nets**" using several more advanced examples as illustrations. Marco Ajmone Marsan (University of Milano, Italy) presented "**An introduction to stochastic Petri nets**" in which he covered many basic concepts of performance evaluation. Tadao Murata (University of Illinois, Chicago, IL) discussed "**High-level Petri nets for logic programming and AI applications**", discussing several relationships between elements of logic programming and concepts of net theory. Grzegorz Rozenberg (University of Leiden, The Netherlands) gave a well-rehearsed overview of "**Elementary**

net systems" using beautiful JB-tokens (i.e., tokens owned by Jonathan B. — could a small set of JB-tokens be included in the registration package next time ?) and occasionally making a point in Japanese (with which we all seemed to be quite familiar by that time). Both Marco and Grzegorz left some interesting topics "for later" making sure that they will continue their tutorials "next time". Indeed, it seems to me that a general overview of stochastic approach as well as a selection of more advanced topics of net theory are excellents candidates for tutorials at the next workshop.

The "proper" workshop included a keynote address, nine presentation sessions and two panels. Three presentations were scheduled for each presentation session, and there were four sessions per day with ample coffee and lunch breaks for discussions. Also, there was the official banquet with a charming formal hostess (I know who she was but do not even ask me), there was the "best paper" award during the banquet, and at least one hundred different Japanese dishes (I think that Grzegorz tried most of them, which kept him so busy that he missed the dessert; I missed many dishes but I know that the dessert was simply great), and *sake* was served in small wooden boxes that most of us brought home (I mean boxes, not sake, but the characteristic aroma is still there ...)

Michael K. Molloy (Hewlett-Packard, Fort Collins, CO) was the keynote speaker; his address **"Petri net modeling - the past, the present, the future"** presented a personal retrospective on significant events over more than twenty five years of Petri net modeling; a period that brought a diverse and sometimes confusing set of models and results. Good standards in notation, nomenclature and specification of net models are needed to enhance communication between researchers and research groups.

The 27 papers (one invited and 26 selected from 57 submissions) are grouped (rather arbitrarily) here into three streams: analysis, new and extended models, and applications.

ANALYSIS

The "best paper" (and also the first paper presented at the workshop) was **"Aggregation methods in exact performance analysis of stochastic Petri nets"** by W. Henderson (University of Adelaide, Australia) and P.G. Taylor (University of Western Australia). The authors extended previous work on product form solutions for stochastic Petri nets (SPNs) with arbitrarily distributed enabling and firing times, probabilistic input and output bags as well as coloured tokens. They proposed an embedding procedure which reduces a complex SPN to a skeleton SPN. By choosing an appropriate embedding, exact results for the skeleton SPN can be obtained.

In **"Matrix product form solution for closed synchronized queueing networks"**, G. Florin and S. Natkin (both of CEDRIC du CNAM, Paris, France) presented a new method of finding steady state probabilities of closed synchronized queueing networks corresponding to bounded and monovaluated stochastic Petri nets with strongly connected reachability graphs and constant firing rates. The solution is similar to the Gordon-Newell product form with matrix and vectors instead of scalars.

A method to aggregate states of a particular class of colored nets in order to avoid the construction of the whole reachability graph was proposed by C. Dutheillet and S. Haddad (both of Univeriste Pierre et Marie Curie, Paris, France) in **"Aggregation of states in**

colored stochastic Petri nets - application to a multiprocessor architecture". The method uses a graph of symbolic markings in which states represent classes of markings rather than individual markings.

Colored Petri nets (CPNs) were also considered by G. Chiola and G. Franceschinis (both of Universita di Torino, Italy). In "**Colored GSPN models and automated symmetry detection**" they proposed a method which automatically exploits the symmetries intrinsic in a model, reducing the size of the reachability graph. The method can be applied to a subclass of CPNs called regular nets (RN). Some nontrivial examples show that the automatically achieved reductions are comparable to those devised for the same systems by thoroughly studying their behavior.

W.H. Sanders (The University of Arizona, Tucson, AZ) and J.F. Meyer (University of Michigan, Ann Arbor, MI), in "**Reduced base model construction methods for stochastic activity networks**", discussed evaluation of large-scale models, and in particular the size and complexity of the stochastic process derived from the underlying net model; this net model serves as a "base model" for a subsequent solution of performance measures. It appears that for stochastic activity networks (SANs), dramatic reductions in state-space size can be obtained by accounting for symmetries in SAN structure and by developing base model construction methods tailored to a specific performance measure (e.g., response time, time to failure, etc.). Moreover, unlike state aggregation methods that rely on explicit knowledge of the detailed state space, the proposed technique permits direct construction of a reduced base model.

In "**The cost of eliminating vanishing markings from generalized stochastic Petri nets**", A. Blakemore (University of Maryland, College Park, MD, and Software Productivity Consortium, Herndon, VA) showed that the asymptotic complexity of a matrix based algorithm grows quadratically with the number of tangible states. He also examined a simpler graph based algorithm which executes much faster on typical models, and discussed some alternatives to elimination.

J.A. Carrasco (Universitat Politecnica de Catalunya, Barcelona, Spain) presented "**Automated construction of compound Markov chains from generalized stochastic high-level Petri nets**", in which he derived a formalism for the description of compound markings that uses a symbolic firing of the net to obtain a compound Markov chain with correct state grouping. The construction of the compound Markov chain requires an algorithm to test the equivalence of compound markings. For bounded number of rotation groups this problem is shown polynomially equivalent to the graph isomorphism problem.

In "**Performance evaluation using unbounded timed Petri nets**", W.M. Zuberek (Memorial University of Newfoundland, St. John's, Canada) proposed a reduction (or "folding") of the infinite state space into an equivalent finite number of (infinite) "similarity" classes, using structural regularity of this infinite space. The reduced space can then be described by a finite system of nonlinear equilibrium equations which determine the stationary probabilities of the (original) states. The proposed approach can overcome the "state explosion" problem of some models by using unbounded but simple approximations to bounded but complex models.

"**Tight polynomial bounds for steady-state performance of marked graphs**" were analyzed by J. Campos, J.M. Colom, M. Silva (all of Universidad de Zaragoza, Spain) and G. Chiola (Universita di Torino, Italy). To compute tight (i.e., reachable) bounds for the throughput of transitions for live and bounded marked graphs with time associated with transitions, they proposed to use linear programming problems defined on the incidence matrix of the underlying Petri nets. These bounds depend on the initial marking and the mean values of the delays but not on the probability distributions, and thus cover both the deterministic and the stochastic cases.

In a companion presentation, "**Properties and steady-state performance bounds for Petri nets with unique repetitive firing count vector**", J. Campos, G. Chiola and M. Silva observed an obvious relation between the concepts of steady-state behavior and repeatable firing sequences; sequences of transitions that are repatable only a finite number of times cannot contribute to the steady-state performance of the model. A unique firing count vector corresponds either to a decision-free case, or to a case when the decision policy (in resolving conflicts) is irrelevant from the performance viewpoint.

Tight bounds for steady-state token probabilities can give a good estimate of the error produced when decompositions and aggregations are used to compute various performance measures. In "**On bounds for token probabilities in a class of generalized stochastic Petri nets**", S.M.R. Islam and H.H. Ammar (both of Clarkson University, Potsdam, NY) proposed a method to compute the best lower and upper bounds for conditional token probabilities for a class of GSPN subnets; the estimates can then be improved if additional information about other subnets is available.

Computational complexity of reachability problems for a new class of Petri nets composed of subnets of state machines was studied in "**A class of Petri nets and a reachability problem solvable in deterministic polynomial time**" by K. Nakamura, K. Nakamura and A. Ichikawa (all of Tokyo Institute of Technology, Japan). Sufficient conditions on initial and target markings were given under which the reachability problem is solvable in deterministic polynomial time.

Computational complexity of "**Legal firing sequences and related problems of Petri nets**" were studied by T. Watanabe, Y. Mizobata and K. Onaga (all of Hiroshima University, Japan). They showed that legal firing sequence problem is NP-complete for consistent free-choice nets and it is polynomial for persistent nets and state machines with unit arc weights. Several other complexity results were presented.

New and Extended Models

In "**Extensions to coloured Petri nets**", J. Billington (Telecom Australia Research Laboratories, Australia) extended Jensen's coloured Petri nets (CPNs) by including capacity and threshold inhibitor functions. It appears that the extended CPNs can be transformed into CPNs in a way that preserves their interleaving behaviour. The transformations are based on the notion of complementary places defined for Place/Transition nets and involve the definition and proof of a new extended complementary place invariant for CPNs.

Jonathan Billington also presented the invited paper on "**Many-sorted high-level nets**", i.e., high-level nets that combine abstract data types and Petri nets within the same algebraic framework, and include inhibitor arcs and place capacities. Such nets can be defined at two different levels of abstraction. At an abstract level, markings and capacities are defined by terms; this is suitable for specifying classes of systems. At the concrete level.

a many-sorted algebra is used for markings and capacities. Both abstract and concrete definitions can be given an interpretation in terms of coloured Petri nets extended by place capacities and inhibitors.

In the context of stochastic timed Petri nets, firing times are almost always exponentially distributed, but in some cases other distributions may be required. Several **"Alternative methods for incorporating non-exponential distributions into stochastic timed Petri nets"** were proposed by P-Z. Chen, S.C. Bruell (both of University of Iowa, Iowa City, IA) and G. Balbo (Universita di Torino, Italy). The proposed approach is based on an observation that an entity arriving at the series of identical exponential stages is equivalent to a group of entities being in front of an exponential stage; non-exponential distributions are converted into generalized stochastic subnets, and then the expanded net is analyzed by known methods.

In **"Logic simulation with interval-labelled net model"**, P.P.K. Chiu (Hong Kong Polytechnic, Hung Hom, Hong Kong) and Y.S. Cheung (University of Hong Kong, Pokfulam, Hong Kong) used nets with time intervals assigned to arcs (interval-labelled nets) for representation of timing among concurrent processes. By means of the interval-labelled net model, logic circuit properties including timing information can be specified and simulated in a multiprocessor-based environment.

J. Magott and K. Skudlarski (both of Technical University of Wroclaw, Poland) used a combination of GSPNs and PERT networks to reduce the computational complexity involved in performance evaluation of systems of processes modelled by GSPNs. In **"Combining generalized stochastic Petri nets and PERT networks for the performance evaluation of concurrent processes"** they proposed several algorithms for lower and upper bounds to the mean completion time of different classes of GSPNs (safe acyclic GSPNs sand safe cyclic GSPNs).

APPLICATIONS

Exact results for the average customer waiting and sojourn times in systems composed of a number of finite-capacity queues cyclically attended by several servers were derived by M. Ajmone Marsan (Universita di Milano, Italy), S. Donatelli (Universita di Torino, Italy) and F. Neri (Politecnico di Torino, Italy) in **"GSPN models of multiserver multiqueue systems"**. The results were obtained numerically by means of GreatSPN, a software tool for analysis of GSPNs.

A Petri net based automatic method for computing the expected job execution times was proposed by H. Someya, T. Tashiro, T. Murata and N. Komoda (all of Hitachi Systems Development Laboratory, Kawasaki, Japan) in **"Performance evaluation of job operation flows in computer systems by timed Petri nets"**. Using a complete specification of all operations for every fault, a workstation-based system automatically evaluates the expected execution times.

O.C. Ibe, A. Sathaye, R.C. Howe (Digital Equipment Corporation, Andover, MA) and K.S. Trivedi (Duke University, Durham, NC) analyzed the Markov model of a VAXcluster system availability. Since such a model suffers from state space explosion as the number of computers in the cluster increases, in **"Stochastic Petri net modeling of VAXcluster system availability"** they used an SPN model with variable input/output arcs (to represent reboot operations), priority assignment on timed and immediate transitions and inhibitor arcs. The SPNP package was used to obtain a series of numerical results.

Modeling of flexible manufacturing systems (FMSs) under uncertainty and evaluation of a rule base for on–line scheduling was discussed by I. Hatono, N. Katoh, K. Yamagata and H. Tamura (all of Osaka University, Japan) in "**Modeling of FMS under uncertainty using stochastic Petri nets**". Continuous-time and discrete-time stochastic Petri nets with hierarchical structure were used to represent uncertain events in FMSs, such as failure of machine tools, repair time and processing time. To obtain an efficient schedule of FMS with on-line real-time basis, a rule base was constructed and its performance evaluated.

G. Ciardo (Software Productivity Consortium, Reston, VA), J. Muppala and K.S. Trivedi (both of Duke University, Durham, NC) described "**SPNP - stochastic Petri net package**" developed at Duke University. SPNP includes marking-dependent arc multiplicities, enabling functions, arrays of places and transitions, and subnets. It also provides an interface to the C programming language to increase the flexibility of net descriptions. Steady-state and transient solvers are available, and cumulative and up-to-absorption measures can be computed. Finally, SPNP was compared with two other SPN-based packages, GreatSPN and METASAN.

In "**A simulation model of a uniform interface for layered protocol architectures**" by M. Ajmone Marsan, G.P. Rossi and F. Salvi (all of Universita di Milano, Italy), a simulation model of an interface in a layered protocol architecture was proposed. The interface is designed to operate between any two protocol layers relieving the protocol machines of the management of data unit queues. The simulation model was developed using PROTOB, an object-oriented simulation environment based on Prot nets, a class of colored Petri nets with timed transitions.

Modelling of a one-way data transfer protocol (such a protocol is used in the class 0 transport protocol) was considered by G. Juanole (LAAS du CNRS, Toulouse, France) and J.L. Roux (Verilog, Toulouse, France) in "**On the pertinence of the extended time Petri net model for analyzing communication activities**". The model of this protocol has an unbounded reachability tree, so it cannot be analyzed using (any) stochastic Petri net models (SPN, GSPN, ESPN), for which the underlying Petri net must be bounded. Extended time Petri nets (firing interval is associated with each transition with quite arbitrary probability density function over the interval) make qualitative as well as a quantitative analysis of such models possible, but a software tool for analysis of such nets is badly needed.

H.H. Ammar, S.M.R. Islam and S. Deng (all of Clarkson University, Potsdam, NY) used time scale decomposition and a hierarchy of two levels for "**Performability analysis of parallel and distributed algorithms**". At the lower level, the performance submodel describes the activities in the application program; at the higher level, the component failure and repair submodel for the underlying architecture defines the current configuration of processors and communication links available for the computation. These two submodels define the reward model needed for performability analysis. Two parallel FFT algorithms on a hypercube architecture were presented to illustrate the above modeling technique.

The paper "**The algorithm of a synthesis technique for concurrent systems**" by Y. Yaw, F. Law and W-D. Ju (all of New Jersey Institute of Technology, Newark, NJ) was not presented at the workshop.

PANEL SESSIONS

The first of two panel sessions was devoted to "**Work-in-Progress**". It was chaired by Prof. S. Kumagai (Osaka University, Japan) and it included several presentations: "Petri net simulator with external logic controller and its application to production line control" by K. Omura, T. Takahashi and M. Konishi (Kobe Steel Ltd., Japan); "Petri net based programming system for flexible manufacturing system" by Y. Nagao, T. Yamauchi, H. Ohta, H. Urabe (Kawaski Heavy Industries, Japan) and S. Kumagai and S. Kodama (Osaka University); " Support system for specification phase of communication software" by Y. Ueda (Oki Electric Industry, Japan); "GreatSPN architecture and features" by G. Chiola (University of Torino, Italy); "Design/CPN : an editor and simulator for hierarchical coloured Petri nets" by P. Huber (Meta Software Corp., USA). A small software tool exhibition was organized during the workshop to provide practical illustrations to these presentations.

The second panel discussed "**Applications of Performance Petri Nets**"; it was chaired by Prof. J.B. Dugan (Duke University, Durham, NC) with participation of G. Ciardo (Software Productivity Consortium, USA), B. Sanders (The University of Arizona, USA), Y. Sugasawa (Nihon University, Japan), and G. Chiola (University of Torino, Italy).

CLOSING SESSION

The Advisory Committee for the International Workshops on Petri Nets and Performance Models was established to coordinate future workshops; presently the members are:

Prof. M. Ajmone Marsan	University of Milano, Italy
Dr. J. Billington	Telecom Australia Research Lab., Australia
Prof. G. Florin	CEDRIC du CNAM, Paris, France
Dr. M.K. Molloy	Hewlett-Packard, Fort Collins, CO
Prof. T. Murata	University of Illinois, Chicago, IL
Prof. K. Onaga	Hiroshima University, Japan

The next workshop was enounced to be held in Melbourne, Australia, at the end of November or beginning of December of 1991, with Dr. Jonathan Billington of Telecom Australia Research Laboratories, 770 Blackburn Road, Clayton North, Victoria 3168, Australia, as the General Chairman.

The workshop was attended by 153 participants from 12 countries: Japan (113), USA (13), Italy (8), France (5), Australia (4), Canada (2), Spain (2), Holland (2), Hong Kong (1), P.R. China (1), Korea (1), and Finland (1).

Obviously PNPM'89 was a very successful event, and the organizers clearly deserve a very warm *arigato* for their dedicated efforts.

The proceedings of this workshop are available from the IEEE Computer Society Press, IEEE-CS Order Number 2001, IEEE Catalog Number 89TH0288-1, ISBN 0-8186-2001-3.

W.M. Zuberek
Memorial University of Newfoundland
St. John's, Canada A1C-5S7

Report on the 2nd Workshop on Concurrency and Compositionality San Miniato/Italy, February 28 - March 3, 1990

This workshop took place in a completely renovated former monasty at San Miniato, a beautiful Toscane village situated half way between Pisa and Florence. Carefully planned by a program committee and perfectly organized by Rocco DeNicola and his team, the workshop attracted some 60 invited participants from various countries. The scientific programme of the workshop was extremely dense: it included 24 invited talks of half an hour duration, 12 short presentations in two "wild cat" sessions, and one panel discussion on the impact of liveness and fairness on compositionality organized by A. Pnueli.

The talks focussed on the foundations of concurrency and dealt mainly with the following topics:

- operational semantics based on rewrite rules as a universal technique for describing concurrent systems (talks by E. Astesiano, G. Berry and U. Montanari),
- relationship between interleaving and true concurrency (talks by S. Abramsky, A. Kiehn, M. Nielsen, F. Vaandrager),
- concepts and methods from category theory for a uniform treatment of models and operators for concurrency (talks by J. Mesequer and J. Zwiers),
- refinement of actions (talks by U. Goltz and P. Darondeau),
- new techniques for model checking (talks by C. Stirling and G. Winskel),
- new logics for the specification of concurrent systems (talks by W. Penczek and P.S. Thiagarajan),
- application of concepts from concurrency theory to program verification (talks by S. Katz and E.-R. Olderog)

As interesting new concepts the "chemical abstract machine" by G. Berry and G. Boudol and "causal trees" by P. Darondeau and P. Degano were discussed or used.

Most participants were very satisfied with this workshop, either because they felt updated to the very edge of the current research into the foundations of concurrency or because they could discuss their work in very great detail with colleagues working on similar problems. I would have liked to see one or two more talks illuminating the interplay between abstract concurrency theory and concrete design or verification problems. Of course, this is an area where more work remains to be done.

Let me close with the complete list of invited talks and "wild cat" presentations given at San Miniato. A report containing the (extended) abstracts of the invited talks is available from R. DeNicola, IEI-CNR, via S. Maria 46, 56100 Pisa, Italy.

E.-R. Olderog, Univ. Oldenburg, F.R.G.

Invited Talks

S. Abramsky (Imperial College, London)
"Causal Semantics in Process Algebra"

E. Astesiano (Univ. of Genoa)
"Processes as Data Types"

G. Berry (INRIA, Sophia Antipolis)
"The Chemical Abstract Machine"

E. Best (Univ. of Hildesheim)
"Petri Net Semantics of Priorities"

G. Boudol (INRIA, Sophia Antipolis)
"A λ-Calculus for Concurrency"

P. Darondeau (IRISA, Rennes)
"Causal Trees and Event Structures"

G. De Michelis (Univ. of Milan)
"Domains of EN Systems"

U. Goltz (GMD, Bonn)
"Refinement of Actions in Causality Based Models"

J. Gunawardena (HP, Bristol)
"Boolean Algebras for Concurrency"

A. Kiehn (Sussex University)
"Distributed Bisimulation"

S. Katz (The Technion, Haifa)
"When Interleaving sets are Useful"

V. Kotov (Novosibirsk)
"Compositionality in Designing Petri Nets Calculus"

J. Meseguer (SRI International, Stanford)
"A Theory of Parallel Term Rewriting"

U. Montanari (Univ. of Pisa)
"Toward an Algebraic Theory of Concurrency"

M. Nielsen (Univ. of Leiden)
"Elementary Net and Transition Systems"

E.-R. Olderog (Univ. of Oldenburg)
"Correctness Proofs of Program Transformations"

W. Penczek (Academy of Science, Warsaw)
"A Generalization of the Computation Tree Logic"

W. Reisig (Technical Univ. of Munich)
"A Compositional Semantics for Hierarchies in Petri Nets and Statecharts"

C. Stirling (Univ. of Edinburgh)
"Model Checking Infinite State Spaces"

P. S. Thiagarajan (Inst. Math., Madras)
"A Modal Logic for Prime Event Structures"

F. Vaandrager (CWI, Amsterdam)
"SOS and Partial Ordering Semantics"

J. Winkowski (Academy of Sci., Warsaw)
"Timed Behaviours in Nets"

G. Winskel (Univ. of Aarhus)
"Compositional Model Checking"

J. Zwiers (Univ. of Eindhoven)
"Predicates are Predicates Transformers: A Unified Compositional Theory of Concurrency"

"Wild Cat" Presentations

M. Bednarczyk (Polish Academy of Sciences, Gdansk)
"Testing Theory from Non-Interleaving Perspective"

S. D. Brookes (CMU, Pittsburgh)
"Parallel and Sequential Algorithms for OR"

J. Esparza (Univ. of Hildesheim)
"Synthesis of Free-Choice Nets"

G. Ferrari (Univ. of Pisa)
"Linear Logic"

R. van Glabbeek (Technical Univ. of Munich)
"Button Pushing Scenarios and Temporal Trees"

S. Katz (The Technion, Haifa)
"Semantics of Self-Stabilization"

A. Labella (Univ. of Rome)
"Bicategories"

K. Larsen (Univ. of Aalborg)
"Equation Solving Using Modal Transition Systems"

W. Rehder (HP, Pisa)
"The HP-Pisa University Science Centre"

J. Sifakis (LGI-IMAG, Grenoble)
"Algebra of Timed Processes"

M. Venturini-Zilli (Univ. of Rome)
"Process Nets"

W. Vogler (Technical Univ. of Munich)
"Interval Words and Refinements of Actions"

Panel
A. Pnueli (Weizmann Institute, Rehovot)
"Liveness and Fairness: do we really need them, and what impact they have on compositionality"
with M. Broy, E.-R. Olderog, W. Reisig, W. P. de Roever and C. Stirling as panelists.

Conference Announcements

Eleventh International Conference on Application and Theory of Petri Nets
Wednesday, 27th - Friday, 29th June 1990

and

Petri Nets Tutorial
Monday, 25th - Tuesday, 26 June 1990
Paris, France

Organized by
University of Paris VI and Bull
FIRTECH Systèmes et Télématique

Under the auspices of
AFCET SIG "Systèmes Parallèles et Distribués" , CNRS-C^3, AICA, BCS SIG "Formal Aspects of Computing Science", EATCS and GI SIG "Petri Nets and Related System Models"

Program Committee

G.F. Balbo, Italy
E. Best, FRG
J. Billington, Australia
G. Cutts, Great Britain
C. Girault, France
K. Jensen, Denmark
S. Kodama, Japan
V. Kotov, USSR
P. Lauer, Canada
G. Memmi, France
T. Murata, USA
R. Shapiro, USA
M. Silva, Spain
C. Simone, Italy
P.S. Thiagarajan, India
R. Valk, FRG (Chairman)
A. Valmari, Finland

Steering Committee

H.J. Genrich, FRG
J. Jensen, Denmark
G. de Michelis, Italy
C.A. Petri, FRG (honorary member)
G. Roucairol, France
G. Rozenberg, The Netherlands

Organizing Committee

P. Estraillier
G. Florin
C. Girault
G. Memmi
C. Perrichon

For Information

Mrs V. Varenne
Laboratoire MASI, Tour 65
4, place Jussieu - F-75252 Paris cedex 05
Tel : (33)-1-43-29-51-88
Fax : (33)-1-46-34-19-27
email : icpn @ masi.ibp.fr

General Information

Conference Site

The Tutorial and the Conference will be accomodated at
Ministère de la Recherche et de la Technologie
1, rue Descartes
75005 Paris
All tutorial and conference sessions and the tool exhibition will be held at this Ministry.

Registration

Registration of participants should be made on the enclosed registration form, to be sent to Mrs. V. Varenne (address see Organizing Committee). Registration will be made on a first come, first served basis.

Registration fees

The fee for members of ACM, AFCET, AICA, BCS, EATCS, GI or IEEE is 800 FF for the Tutorial and 1100 FF for the Conference. Non-members pay 1000 FF for the Tutorial and 1300 FF for the Conference. Surcharge for registration or payment after MAY 20th, 1990 is 200 FF.

The fee includes proceedings and other conference material, tea and coffee during breaks, lunches and the Conference Dinner.

Lunches will be provided at the conference site.

Payment of fees

Payment should be made in French Francs, net of bank charges.
The fee may be paid by international money transfer or cheques **payable to ICPN**
No credit cards can be accepted.

For french participants cheques should be made payable to Agent Comptable de l'Université Paris 6, and sent to Mrs. V. Varenne Laboratoire MASI, Tour 65
4, place Jussieu - F-75252 Paris cedex 05

Confirmation

Confirmation of registration will be sent to participants after receipt of the registration form and payment

Cancellation and Refund

Payment will be refunded if a cancellation letter is received before June 10th, 1990. After June 10th, 1990 no refunds will be given.

Arrival and Registration

The registration desk both for tutorial and conference will be opened from 9.00 to 18.00 from Monday 25th to Friday 29th.

Information Desk

The Conference Office in the Hall of Amphitheatre Poincaré will be open during Tutorial and Conference hours.

Grants

Some grants are available for graduate and postgraduate students and for researchers with limited expenditure capability. The grants do not cover travel expenses but only tutorial and conference registration as well as accomodation and lunches.
Persons applying for a grant should complete the enclosed registration form and send it - with a letter motivating the application and/or a letter by their scientific supervisor - to the Organizing Committee.

Accomodation

Accomodation will be provided at various hotels. Several reservation-forms are provided to offer a larger choice. The prices for accomodation are indicated on each form. Participants should state their choice on one of the enclosed registration form.

Participants preferring to live in other hotels should contact :
Tourist-Information Paris
127 avenue des Champs-Elysées, 75008Paris,
tel 33-1-47-23-61-72

Please note that the end of June is a very loaded period in PARIS.
Thus it is suitable to book hotels very early.

Excursion

An excursion is planed on Saturday June 30. Registrations will be done during the conference.

TUTORIAL PROGRAM

Monday, June 25

8.30 - 9.15 *Registration*

9.15 - 10.00 W. Reisig
Informal Introduction to Petri Nets

10.15 - 11.00 P.S. Thiagarajan
Elementary Net Systems (I)

11.00 - 11.30 Coffee Break

11.30 - 13.00 G. Rozenberg
Elementary Net Systems (II)

13.00 - 15.00 Lunch

15.00 - 16.30 W. Reisig
Place/Transition Systems

16.30 - 17.00 Coffee Break

17.00-18.30 H. Genrich
High Level Nets

Tuesday, June 26

9.15- 10.45 K. Jensen
Coloured Petri Nets (I)

10.45 - 11.15 Coffee Break

11.15 - 12.00 K. Jensen
Coloured Petri Nets (II)

12.15 - 13.00 M. Ajmone Marsan
Timed and Stochastic Nets and Performance Evaluation (I)

13.00 - 15.00 Lunch

15.00 - 15.45 M. Ajmone Marsan
Timed and Stochastic Nets and Performance Evaluation (II)

15.45- 16.15 Coffee Break

16.15 - 17.45 M. Silva, R.Valette
Flexible Manufacturing Systems and Petri Nets

CONFERENCE PROGRAM

Wednesday, June 27

9.00 - 9.30 *Registration*

9.30 - 10.00 *Opening Session*

10.0 - 11.00 *Invited Talk*
H. Genrich
Subject on High Level Nets

11.00 - 11.30 Coffee Break

11.30 - 13.00 *Reachability Analysis*

A. Finkel
A Minimal Coverability Graph for Petri Nets
M. Lindqvist
Parameterized Reachability Trees for Predicate Transition Nets
A. Valmari
Compositional State Space Generation

13.00 - 15.00 Lunch

15.00 - 16.30 *Modularity of Nets*

J. Esparza , M. Silva
Top-Down Synthesis of Live and Bounded Free Choice Nets
G. Chehaibar
Validation of Phase-Executed Protocols Modelled with Colored Petri Nets
Y. Souissi
On Liveness Preservation by Composition of Nets via a Set of Places

16.30 - 17.00 Coffee Break

17.00 - 18.30 *Methods in System Modelling*

R. Di Giovanni
Petri Nets and Software Engineering : HOOD Nets
T. Hildebrand , H. Nieters , N. Trèves
The Suitability of Net-based GRASPIN Tools for Monetics Applications
V.O. Pinci , R.M. Shapiro
Development and Implementation of a Strategy for Electronic Funds Transfer by Means of Hierarchical Colored Petri Nets

19.15 Cocktail

Thursday, June 28

9.00 - 10.00 *Invited Talk*

C. Girault
Subject on Petri Net Methods for Design and Analysis of Distributed Systems

10.00 - 11.00 *Analysis of High Level Nets*

C. Dimitrovici , U. Hummert , L. Petrucci
The properties of Algebraic Nets Schemes in Some Semantics
J.M. Couvreur
The General Computation of Flows for Coloured Nets

11.00 - 11.30 Coffee Break

11.30 - 13.00 *Hardware Structures and Net Implementation*

R.M. Shapiro
Validation of a VLSI Chip Using Hierarchical Colored Petri Nets
A. Yakovlev, A. Petrov
Petri Nets and Parallel Bus Controller Design
R. Valette, B. Bako
Software Implementation of Petri Nets and Compilation of Rule-based Systems

13.00 - 15.00 Lunch

15.00 - 16.30 *Partial Order and Temporal Logical*

H. Carstensen
The Complexity for Testing Equivalence of Transition Sequences
R. Janicki , M. Koutny
Implementation of Optimal Simulations
J.C. Bradfield
Proving Temporal Properties of Petri Nets

16.30 - 17.00 Coffee Break

17.00 - 18.00 **Panel : Flexible Manufacturing Systems**

20.30 Conference Dinner

Friday, June 29

9.00 - 10.00	*Invited Talk*
	E.R. Olderog **Subject on Systematic Construction of Petri Nets from Terms and Formulas**
10.00 - 11.00	*Net Transformations*
	G.M. Pinna , A. Maggiolo Schettini **Transformations of Pr/T nets via Translation into Structure Grammars** A.V. Kovalyov **On Complete Reducibility of Some Classes of Petri Nets**
	11.00 - 11.30 Coffee Break
11.30 - 13.00	*Timed and Stochastic Nets*
	C. André **Delays in Synchronized Elementary Net Systems** R. David, H. Alla **Autonomous and Timed Continuous Petri Nets** G. Chiola , C. Dutheillet , G. Franceschinis , S. Haddad **On Well Formed Colored Nets and their Symbolic Reachability Graph**
	13.00 - 15.00 Lunch
15.00 - 16.30	*Logic and Languages*
	T. Watanabe , Y. Mizobata , K. Onaga **A Petri Net Based Analysis of the Satisfiability Problem in the Horn Clause Propositional Logic** T. Murata , V.S. Subrahmanian , T. Wakayama **A High Level Petri Net Model for Reasoning in the Presence of Inconsistency** C. Autant , Z. Belmesk , Ph. Schnöbelen **A Net-theoretic Approach to the Efficient Implementation of the FP2 Parallel Language**
16.30 - 17.00	*Closing Session*

TOOL EXHIBITION

Tuesday, June 26 - Friday, June 29

The number and the potential of practice-oriented tools for designing and analyzing net models is growing rapidly. Thie tool exhibition will be at separate rooms in the conference building.

This year the exhibition will be extended in order to begin on Tuesday morning allowing participants to have a lot of time aside the conference itself.

Sommerschule Hildesheim, 6.–10. August 1990

Petrinetze: Systementwurf und Werkzeuge

Die Gesellschaft für Mathematik und Datenverarbeitung (Sankt Augustin), die Humboldt-Universität Berlin, die Universität Hildesheim und das EG-Projekt DEMON (Design Methods Based on Nets) veranstalten eine Sommerschule zum Zweck der Vermittlung von Erfahrungen und Erkenntnissen über die Verwendung von Petrinetzen beim Entwurf von Systemen. Das Spektrum der vorgestellten Methoden reicht von theoretischen Hilfsmitteln bis zu implementierten Werkzeugen. Ausstellungen und Vorführungen sind geplant. Die Tagungssprache ist Deutsch.

Programm:

A) Systementwurf im Großen: Requirements und Spezifikation.

W.Reisig, Technische Universität München: Entwurfsprinzipien und -techniken anhand praktischer Beispiele.

R.Valk, Universität Hamburg: Modellierungserfahrungen.

K.Voss, Gesellschaft für Mathematik und Datenverarbeitung: Datenbank- und Schnittstellenmodellierung.

B) Systementwurf im Kleinen: Programmiersprachen und Verifikation.

E.Best, Universität Hildesheim: Petrinetz–Semantik von Occam–2.

U.Goltz, Gesellschaft für Mathematik und Datenverarbeitung: Horizontales Design: Komposition; Kalküle; Semantik.

W.Vogler, Technische Universität München: Vertikales Design: Verfeinerung; Vergröberung; Äquivalenz.

C) Werkzeuge und Anwendungen.

H.J.Genrich, Gesellschaft für Mathematik und Datenverarbeitung: Ausführbare höhere Netze.

P.H.Starke, Humboldt-Universität Berlin: Analyse von Petrinetzen: Erreichbarkeitsuntersuchung; Invarianten; Struktureigenschaften.

W.Fengler, Technische Hochschule Ilmenau: Netzorientierte Entwurfsmethodik für industrielle Computersysteme.

R.Grützner, A.Neumann, Universität Rostock: Modifizierte zeitbewertete Netze und das System MARS; Analyse von stochastischen Netzen.

P.Paetzold, Akademie der Wissenschaften der DDR: Modellierung von SDL-Spezifikationen mit Platz/Transitionsnetzen.

G.R.Friedrich, Akademie der Wissenschaften der DDR: Die Bearbeitung höherer zeitbewerteter Petrinetze mit DIOGENES.

Vorführungen:

Fa. C.I.T., Berlin: Entwurfswerkzeuge Design/CPN und Design/ML.

Fa. P.S.I., Berlin: Analysewerkzeuge PAN und CPNA.

TH Ilmenau: PN-Case-System PENECA.

Univ. Rostock: MARS.

Akademie der Wissenschaften der DDR: DIOGENES.

Organisation:

Gesellschaft für Mathematik und Datenverarbeitung, Sankt Augustin.

Universität Hildesheim.

Humboldt-Universität Berlin.

Esprit-Basic-Research-Projekt Nr.3148 DEMON.

Tagungsort:

Hildesheim hat ca. 100 000 Einwohner und liegt etwa 30 km südlich von Hannover. Die Universität Hildesheim ist ca. 10 Busminuten vom Stadtkern entfernt. Die Unterbringung erfolgt in Hotels der Stadt Hildesheim.

Kosten:

Kosten belaufen sich auf Anfahrt, Übernachtungs- und Tagungsgebühr. Die Hotelpreise liegen zwischen DM 40.- und DM 80.- pro Person und Nacht für ein Zimmer mit Frühstück. Die Tagungsgebühr von **DM 200.-** schließt ein Exemplar des im Springer-Verlag erschienenen Bandes 'Concurrency and Nets' sowie Material der Vortragenden ein.

Es wird davon ausgegangen, daß die Kosten von der Ausbildungsstätte bzw. vom Arbeitgeber der Teilnehmer übernommen werden. Aus Mitteln der GMD und des Projektes DEMON stehen jedoch Stipendien in begrenzter Anzahl zur Verfügung. Stipendien werden vorzugsweise an Teilnehmer aus der DDR vergeben. Andere Anträge müssen begründet und mit einem Empfehlungsschreiben versehen werden; bitte verwenden Sie das beiliegende Formular.

Anmeldungen:

Bis zum **30. Juni 1990** an:

Prof. Dr. Eike Best, Institut für Informatik, Universität Hildesheim, Samelsonplatz 1, 3200 Hildesheim, Tel: 05121 - 883 741/740, Fax: 05121 - 869 281, E-mail: E.Best@infhil.uucp

oder an:

Dr. Klaus Voss, GMD-F1.P, Postfach 1240, 5205 Sankt Augustin 1, Tel: 02241 - 14 2802, Fax: 02241 - 14 2889, Tlx: 889469 gmd d, E-mail: gsfp11@dbngmd21.bitnet

Die Teilnehmerzahl ist begrenzt. Eine frühe Anmeldung ist daher ratsam.

— — — — (Bitte abtrennen) — — — —

Ich nehme an der Sommerschule 'Petrinetze: Systementwurf und Werkzeuge' in Hildesheim, 6.–10.8.1990, teil.

Name:

Adresse: (bitte mit Telnr. und ggf. Fax)

Unterschrift: **Datum:**

Zutreffendes bitte ankreuzen:

- ☐ Die Teilnehmergebühr von DM 200.- lege ich als Verrechnungsscheck bei.
- ☐ Die Teilnehmergebühr habe ich überwiesen auf das Konto Nr. 100 050 307 der Stadtsparkasse Hildesheim, BLZ 259 500 01, unter dem Stichwort 'Sommerschule'.
- ☐ Ich beantrage ein Stipendium. ☐ Ein Empfehlungsschreiben liegt bei.
  - Bestätigung der Ausbildungsstätte / des Arbeitgebers:
    Zu den Kosten können wir höchstens folgenden Beitrag leisten:
    - ☐ Reise: DM ......
    - ☐ Übernachtung: DM ......
    - ☐ Teilnehmergebühr: DM ......

    Unterschrift/Stempel der Institution/Firma:

Recent Publications

This list is not claimed to be exhaustive. As we can refer only to papers we know about, please send appropriate hints to

Petri Net Newsletter
GMD–F1
Post Box 1240
D–5205 St. Augustin 1

ALLA, H.; DAVID, R.: *Modelling of Management/Production by Continuous Petri Net.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 105–118 (1988), in French

Continuous Petri nets have been introduced to avoid the explosion of the number of reachable markings in a classical Petri net when this net contains a great number of tokens. By means of an elementary example, the paper shows that the model can be used to model a system with concurrency, synchronisation, parallelism and where the concerned entities are heterogeneous.

ANISHEV, P.A.; BANDMAN, O.L.: *Algorithms and Programs for Analyzing Properties of Petri Nets.* Akad. Nauk SSSR Sibirsk. Otdel., Vychisl. Tsentr, Novosibirsk, Preprint. (1988), in Russian

ANTON, M.D.; BRETSCHNEIDER, M.: *Formulas, Processes, and Petri Nets Applied to the Specification and Verification of a HDLC Protocol.* Lecture Notes in Computer Science, Vol. 352; TAPSOFT '89, Vol. 2: Advanced Seminar on Foundations of Innovative Software Development, II, and Colloquium on Current Issues in Programming Language (CCIPL) / Diaz, J.; et al. (eds.) — Berlin: Springer-Verlag, pp. 140–154 (1989)

In specifying a variant of a HDLC protocol a method is illustrated that addresses three problems: decomposition of a complex system into simple components, hierarchical design of a protocol and modular verification of the protocol w.r.t. the service specification. Descriptions of basic protocol functions are obtained considering projections of the global protocol behaviour. The behaviour is formalized using formulas, process terms and Petri nets.

ARCHETTI, F.; SCIOMACHEN, A.: *Development, Analysis and Simulation of Petri Net Models: an Application to AGV Systems.* CISM Courses and Lectures, 306; Operations Research Models in Flexible Manufacturing Systems — Vienna: Springer, pp. 91–113 (1989)

ASSIMAKOPOULOS, N.: *Distributed Decision Making in Cybernetic Systems.* Found. Control Eng., Vol. 13, No. 1, pp. 3–13 (1988)

The control of complex cybernetic systems involves decision making networks which operate on the "Command, status and message layers" of concurrent decision making activity. Decision making "nodes" function as multitasking operators on all three layers. Aspects of real-time concurrency in hierarchical command decomposition are analyzed in this paper, using mainly concepts and tools of Petri-net theory.

ATANASSOV, K.; ATANASSOVA, L.; DIMITROV, E.; GARGOV, G.; KAZALARSKI, I. et al.: *Generalized Nets and Expert Systems.* Methods of Operations Research, 59. Proceedings of the 12th Symposium on Operations Research of the Gesellschaft für Mathematik, Ökonomie und Operations Research, 1987, Passau — Frankfurt a.M.: Athenaeum, pp. 301–310 (1989)

The main problem in designing, implementing, and using of an expert system is to select the knowledge representation formalism. Most of expert systems apply the rule-based approach. The paper presented deals with another representation means, namely a generalisation of Petri nets and discusses how the rule-based approach can be viewed through the new formalism with all the ensuing consequences.

AUGUSTIN, L.: *PNEAS — a Contribution to Tool Concepts in the Development of Communications Software.* Nachrichtentechnik, Elektronik; Vol. 39, No. 8, pp. 298–301 (1989), in German

PNEAS stands for Petri net editor, analysis and simulation. A survey is given of digital communications systems and the conventional development of software. The work involved is described and future plans for PNEAS outlined including models projected by the ORCAD graphics system.

BAGCHI, K.K.; OLSON, O.; SORENSON, L.; KRISTENSON, A.: *A Transputer Based Real-Time Kernel and its Verification.* Proceedings of the Second International Conference on Software Engineering for Real Time Systems, 1989, Cirencester, UK — London, UK: IEE, pp. 165—169 (1989)

Based upon a transputer network, the authors have developed real-time software in Occam. They describe a verification methodology of an embedded message based distributed real-time software. In order to verify that this software is free from errors and to test each module for its desired performance, the authors have chosen a version of Petri nets called Occam-net as their design and verification tool. An analysis based on a type of net which corresponds to various constructs of Occam is used.

BALDASSARI, M.; BRUNO, G.; RUSSI, V.; ZOMPI, R.: *PROTOB, a Hierarchical Object-Oriented CASE Tool for Distributed Systems.* Lecture Notes in Computer Science, Vol. 387; ESEC '89. Proceedings of the 2nd European Software Engineering Conference, 1989, Coventry, UK / Ghezzi, C.; et al. (eds.) — Berlin: Springer-Verlag, pp. 242-445 (1989)

The paper presents PRTOB, an object-oriented CASE system based on high level Petri nets called PROT nets. It consists of several tools supporting specification, modelling and prototyping activities within the framework of operational software life cycle paradigm. As its major application area it addresses distributed systems, such as real-time embedded systems, communication protocols and manufacturing control sytems. The paper illustrates a case stuydy involving the design of a distributed file system.

BANASZAK, Z.; ABDUL-HUSSIN, M.H.: *Petri Net Approach to Automatic Real-Time Program Synthesis.* Control and Cybernetics, Vol. 17, No. 4, pp. 361–75 (1988)

The paper deals with a Petri net approach to the automatic design of control programs which are aimed at supervision of concurrent, pipeline-like flowing processes. Its objective lies in the formal investigation of the conditions necessary for the design of a class of deadlock-free Petri nets. The nets considered serve as control-programs representations. The results obtained allow for automatic conversion of a process specification, via a net model of a control flow, into the relevant control program.

BANASZAK, Z.: *Control Oriented Models of Interprocess Cooperations.* Syst. Sci., Vol. 14, No. 2, pp. 31-59 (1988)

In order to find out the strategies of concurrent processes interactions, the Petri net representation is used. The nets provide a suitable framework for searching dynamic properties of admissible controls. Attention is paid to the synchronization mechanism involved in the control procedures aimed at the cooperation of deadlock-free processes. The results obtained can be directly applied to designing real-time controllers (in the flexible manufacturing systems) as well as in designing planning systems.

BARKAOUI, K.; LEMAIRE, B.: *Contribution aux methodes d'analyse des reseaux de Petri par la theorie des graphes.* Thesis (Inform.), Univ. Paris 06 — CNRS-T Bordereau (1988)

On introduit la notion de composante preconservative minimale (theoreme). On fournit une nouvelle caracterisation de la minimalite des verrous et des trappes. On etablit un lemme permettant d'etendre le domaine de validite de la propriete COMMUNER (condition suffisante de vivacite).

BAUSE, P.; BEILNER, H.: *Eine Modellwelt zur Integration von Warteschlangen- und Petri-Netz-Modellen.* Informatik-Fachberichte, Vol. 218, pp. 190–204 (1989)

Rechensysteme werden sowohl bzgl. funktionaler Aspekte (z.B. Deadlocks) als auch hinsichtlich quantitativer Aspekte (z.B. Durchsatz) untersucht. Der Einsatz von Petri-Netzen bzw. Warteschlangennetzen bietet sich hierbei an. Diese Arbeit stellt eine Modellwelt vor, welche Warteschlangennetz- und Petri-Netz-Beschreibungen vereint und so den Beschreibungsaufwand reduziert. Ferner wird untersucht, inwieweit funktionale Ergebnisse Aussagen über das quantitative Modell zulassen.

BECHTA DUGAN, J.; CIARDO, G.: *Stochastic Petri Net Analysis of a Replicated File System.* IEEE Trans. Software Eng., Vol. 15, No. 4, pp. 394–401 (Apr., 1989)

The authors present a stochastic Petri net model of a replicated file system in a distributed environment where a voting algorithm is used to maintain consistency. A model sufficiently detailed to include file status as well as failure and repair of hosts where copies or witnesses reside, is presented. Two different majority protocols are examined, one where a majority of all copies and witnesses is necessary to form a quorum, and the other where only a majority of the copies and witnesses on operational hosts is needed.

BELDICEANU, N.; GIRAULT, C.: *Langage de regles et moteur d'inferences bases sur des contraintes et des actions : application aux reseaux de Petri.* Thesis (Inform.), Univ. Paris 06 — CNRS-T Bordereau (1988)

Le langage presente sert de base a un systeme expert de deduction de proprietes des reseaux de Petri.

BELMESK, Z.: *Methodologie de specification et de programmation des protocoles de communication avec le langage FP2. Cas etudie: le niveau liaison du protocole x25.* Rapport de recherche: Informatique et mathematiques appliquees de Grenoble, No. IMAG-RR 748-I — Saint-Martin d'Heres, France: IMAG, Laboratoire d'informatique fondamentale et d'intelligence artificielle; CNRS-17660 (1988)

Developpement, pour une implementation parallele de la couche liaison du protocole X25, d'un modele hybride et original dont le formalisme beneficie de la notion de complementarite de ces composants qui sont: le langage FP2 et les reseaux d'evaluation derives des reseaux de Petri.

BEST, E.: *Design Methods Based on Nets: Esprit Basic Research Action DEMON.* Hildesheimer Informatik-Berichte 1/90 — Universität Hildesheim (1990)
also: To appear in "Advances in Petri Nets", Lecture Notes in Computer Science

The paper describes the rationale and the workplan of the ESPRIT Basic Research Action No. 3148 DEMON (Design Methods Based on Nets).

BLOOM, S.L.; SUTNER, K.: *Shuffle Equations, Parallel Transition Systems and Equational Petri Nets.* Lecture Notes in Computer Science, Vol. 351; TAPSOFT '89, Vol. 1: Advanced Seminar on Foundations of Innovative Software Development, I, and Colloquium on Trees in Algebra and Programming (CAAP '89) / Diaz, J.; et al. (eds.) — Berlin: Springer-Verlag, pp. 134–148 (1989)

The paper begins with the question of describing the sequences of atomic actions performable by a flowchart algorithm which admits explicit nondeterminism and a forking type of parallelism. The kind of flowchart scheme is made precise in the definition of a parallel transition system; the corresponding systems of equations are the shuffle equations. The same equations were determined by a subclass of free choice Petri nets called equational Petri nets. Thus, shuffle equations, parallel transition system and equational Petri nets are equivalent descriptions of this class of algorithm scheme. The authors concentrate on the equational Petri nets.

BOKR, J.: *Flow Diagrams.* Automatizace, Vol. 32, No. 4, pp. 93–95 (Apr., 1989), in Czech

The author describes the development of a flow diagram for a technological process which combines the Petri nets concept and the flowcharting approach.

BOUDOL, G.; CASTELLANI, I.: *Permutation of Transitions: An Event Structure Semantics for CCS and SCCS.* Lecture Notes in Computer Science Vol. 354: Linear Time, Branching Time and Partial Order in Logics and Models for Concurrency. / de Bakker, J.W.; et al. (eds.) — Springer Verlag, pp. 411–427 (1989)

The authors apply Berry and Léviy's notion of equivalence by permutations to CCS and MEIJE/SCCS, thus obtaining a pomset transition semantics for these calculi. They show that this provides an operational counterpart for an event structure semantics for CCS and SCCS similar to the one given by Winskel.

BOURBAKIS, N.; FOTAKIS, D.; TABAK, D.: *On Data Flow Based Functional Model for the HERMES Multiprocessor Vision System.* ICS 87. Proceedings of the Second International Conference on Supercomputing, 1987, San Francisco, CA, USA: Supercomputing '87; Vol. 3 — St.Petersburg, FL, USA: Int. Supercomputing Inst., pp. 314-323 (1987)

A data flow functional model for the multiprocessor HERMES vision machine (an autonomous image processing system) is described. The structural model of HERMES is represented as a large scale Petri Net, composed out of previously proposed decision-making primitives. The primitives table has been expanded in this project in order to make it fit the particular properties of HERMES. The modeling methodology provides a tool to analyze large-scale image processing systems by simulation on a variety of computing systems without the need of any hardware construction.

BOURNEY, J.P.; GENTINA, J.C.: *Structuring of the Procedural Part of the Control System of Flexible Manufacturing Cells.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 233-242 (1988), in French

The paper presents a structuring tool which allows the user to build rigorously and systematically the procedural part of the control system of flexible manufacturing systems. This tool allows the production of a control graph (coloured structured Petri nets) where the parallelism and the concurrency of the system are shown. The authors propose a set of structuring primitives based on a functional analysis of the initial model of the production system.

BROGI, A.; GORRIERI, R.: *A Distributed, Net Oriented Semantics for Delta Prolog.* Lecture Notes in Computer Science, Vol. 351; TAPSOFT '89, Vol. 1: Advanced Seminar on Foundations of Innovative Software Development, I, and Colloquium on Trees in Algebra and Programming (CAAP '89) / Diaz, J.; et al. (eds.) — Berlin: Springer-Verlag, pp. 162–177 (1989)

A truly distributed operational semantics for Concurrent Logic Languages is defined here, differently from those

semantics based on interleaving models. Delta Prolog and the underlying Distributed Logic are taken as case studies. A scheme for translating a Delta Prolog system into a 1-safe Petri net is given and properties of (perpetual) processes based on the notion of causality, e.g. fairness and deadlock, are addressed.

BROWN, C.: *Relating Petri Nets to Formulae of Linear Logic.* LFCS Series, Report ECS-LFCS-89-87 — University of Edinburgh, UK, Laboratory for Foundations of Computer Science (1989)

The author investigates a connection between linear logic and Petri nets. From the basis that the ⊗ operator applies to two events which may occur concurrently and independently, while linear implication reflects causal dependency between events, the author builds up a correspondence between Petri nets and certain formulas of linear logic.

BROWN, C.: *Petri Net Quantales.* LFCS Series, Report ECS-LFCS-89-96 — University of Edinburgh, UK, Laboratory for Foundations of Computer Science (1989)

The work presented here was motivated by the desire to understand more fully the connection between Peteri nets and linear logic. It is well-known that evolution in Petri nets corresponds to linear proof. The author shows that quantales are models of linear logic. This makes it possible to interpret a large fragment of linear logic using the behaviour of Petri nets.

BRUNO, G.; BALSAMO, A.: *Ada-Based Executable Modelling of Distributed Systems.* Ada-components: libraries and tools. Proceedings of the Ada-Europe International Conference, 1987, Stockholm, Sweden / Tafvelin, S. (ed.) — New York, NY: Cambridge University Press, pp. 279–292 (1987)

This work presents a methodology for systems modeling based on PROT nets, which exploits the formal properties of the PROT graphical notation in a way that makes it suitable for use with automated techniques. Specifications created from a combination of PROT diagrams and textual input using Ada syntax are shown to be executable in the sense that compilable Ada source code can be produced from them. This approach exploits "advanced tasking and structuring" mechanisms of Ada. Emphasis is placed on object-oriented analysis and software reuse.

BUDINAS, B.L.: *Solvability of the Reachability Problem for Petri Nets (a Review of the Problem).* Akademiya Nauk SSSR., Avtomatika i Telemekhanika Avtomat. i Telemekh., No. 11, pp. 3–39 (1988), in Russian

BUDINAS, B.L.: *Decidability of the Petri Net Reachability Problem.* Automation and Remote Control, Vol. 49, No. 11, pp. 1393-1422 (Nov. 1988)
also: Translation of: Avtomatika i Telemekhanika, Vol. 49, No. 11, pp. 3–39 (Nov., 1988)

The paper reviews the current status of the reachability problem for Petri nets. Following the ideas of Mayr (1984), a complete decidability proof of the reachability problem is presented. Some related topics are also considered: decidability of Presburger arithmetic, semilinear sets, vector addition graphs, reachability graphs, etc.

BUSCH, R.: *Entwurf eines Systems zur integrierten Fertigung (CIM) mit Petri-Netzen.* Zeitschrift für Betriebswirtschaft, Vol. 59, No. 8, pp. 822–838 (1989)

In der Arbeit wird gezeigt, wie Petri-Netze bei der Entwicklung eines Konzepts zur integrierten Fertigung (CIM) methodisch durchgängig den Entwurf unterstützen können. Am Beispiel eines Leitstandkonzepts wird diskutiert, wie aus der jeweiligen Sicht der beteiligten Planer ein integriertes System entwickelt werden kann. Mit dem Übergang zum dynamischen Verhalten werden die Möglichkeiten der Spezifikation des Systems und die darauf basierenden Simulationen dargelegt.

CALIN, S.: *A Type of Propositional Logic Derived from Petri-Net Models.* Bul. Inst. Politehn. Bucuresti Ser. Automat. Calc. 50 ; 21, No. 11, pp. 3–12 (1988), in Romanian

CASTELLANI, H.; ZHANG, G.Q.: *Parallel Product of Event Structures.* Inst. Nat. Recherche Inf. Autom., Report No. 1078 — Le Chesnay, France (Aug., 1989)

The parallel product operator may be defined very easily on flow event structures. The authors show that for such structures satisfying a particular constraint, which is preserved by usual process operators, this product may be characterized as a categorical product.

CASTELLANI, I.; HENNESSY , M.: *Distributed Bisimulations.* Journal of the Association for Computing Machinery, Vol. 36, No. 4, pp. 887-911 (1989)

A new equivalence between concurrent processes is proposed. It generalizes the well-known bisimulation equivalence to take into account the distributed nature of processes. The result is a noninterleaving semantic theory; concurrent processes are differentiated from processes that are non-deterministic but sequential. The new equivalence, together with its observational version, is investigated for a subset of the language CCS, and various algebraic characterizations are obtained.

CHAPPE, D.; BOURJAULT, A.: *A Methodology for Assembly Systems Design.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 147–156 (1988), in French

The authors present a coherent method for different possible structures evaluation of a flexible assembly system. The input data is the assembly sequence. A functional diagram is used to describe all the functions to be realized. The possible workstation and cells distributions are developed with the corresponding equipment assignment. A timed Petri net is automatically deduced providing a simulation of the corresponding assembly system performances.

CHERKASOVA, L.A.; KOTOV, V.E.: *Concurrent Nondeterministic Processes: Adequacy of Structure and Behaviour.* Lecture Notes in Computer Science, Vol. 379; Mathematical Foundations of Conputer Science 1989 / Kreczmar, A. ; et al. (eds.) — Springer-Verlag, pp. 67–87 (1989)

The theory of Petri nets establishes a model of concurrency without a calculus for verification of statements about processes. The algebra of finite processes AFP_i proposed in this paper is intended to combine the mechanism for the description of nondeterministic concurrent processes and the derivation of their behavioural properties. In AFP_i, specifying the structural relation between process elements (ie a process structure), the author defines a process with the same behavioural properties.

CHRISTODOULAKIS, D.N.: *Modeling the Semantics of Smalltalk-80 with Petri Nets.* SIGPLAN Notices, Vol. 24, NO. 4, pp. 156–158 (1989)

The authors use Petri nets in order to describe the semantics of object oriented languages, especially, of Smalltalk-80. Main objective of the paper is to give an outline of the semantic function.

Concurrency and Compositionality. Extended abstracts of the 2nd Workshop on Concurrency and Compositionality, 1990, San Miniato. Università degli Studi di Pisa, Dipartimento di Informatica, Technical Report TR-5/90 (1990)

The objective of the workshop was to investigate various proposed formalisms for describing distributed systems and compositional proof methods for studying properties of these systems. New semantic models were discussed which emphasize nonsequentiality. The general aim was to develop a theory of concurrency, in which the distributed nature of processes is properly taken into account. (cf this Newsletter, Report on Conferences.)

COOKE, D.E.: *Formal Specifications of Resource-Deadlock Prone Petri Nets.* The Journal of Systems and Software, Vol. 11, No. 1, pp. 53–69 (Jan., 1990)

The definition of a class of resource-deadlock prone Petri nets is developed using first-order predicate calculus. From this definition characteristics of resource deadlock can be ascertained. These characteristics form the specifications of a program to be written in Prolog which can detect deadlock in parallel processes represented as Petri nets. An important feature of this class is that it characterizes deadlock in networks that contain nested parallel structures. This methodology allows for the prior detection of deadlock, preventing the need for unecessary overhead in dynamic deadlock detection.

CORNELIS, E.: *Traduction de Réseaux de Petri Colorés.* Annales de la Société Scientifique de Bruxelles, Vol. 102, No. 4, pp. 121–150 (1988)

This paper gives the rule for translation of a coloured Petri net into a "classical" place/transition net which can be more easily analyzed. Then, an algorithm performing this translation is sketched.

COUSIN, B.; GIRAULT, C.: *Methodologie de validation des systemes structures en couches par reseaux de Petri : application au protocole transport.* Thesis (Inform.), Univ. Paris 06 — CNRS-T Bordereau (1987) Availability: CNRS-T Bordereau, France

COUSIN, B.; ESTRAILLIER, P.: *Study of the Resynchronisation of a Communication Protocol.* Technique et Science Informatiques, Vol. 6, No. 3, pp. 243–253 (1987), in French
also: Translation in: Technology and Science of Informatics

An original modelling approach is applied, using Petri nets with predicates, to services offered by the network layer of the OSI model during the data transfer phase. Special attention is paid to the treatment of failures of network stations, with description of the mechanism of transmission resynchronisation. The minimal model is validated functionally to the extent that its properties are equated to those which define the service.

DEITERS, W.; GRUHN, V.; SCHAFER, W.: *Systematic Development of Formal Software Process Models.* Lecture Notes in Computer Science, Vol. 387; ESEC '89. Proceedings of the 2nd European Software Engineering Conference, 1989, Coventry, UK / Ghezzi, C.; et al. (eds.) — Berlin: Springer-Verlag, pp. 100–117 (1989)

A structured approach to the incremental development of generic models for software processes is proposed.

ncremental means that it is possible to test incomplete specifications; generic means that suitable mechanisms re provided to adapt a particular model to specific requirements. The approach is based on a formal language hich merges three existing approaches, namely a data definition language, function nets, and graph replacement ystems. It is explained how this language provides a suitable means to specify the static features, the dynamics, nd the modifications of processes.

MAEL, J.J.; LEVIS, A.H.: *Generation of a Variable Structure Airport Surface Traffic Control System.* ssachusetts Inst. of Tech., Cambridge. Lab. for Information and Decision Systems, Technical report DS-P-1899 (Aug., 1989)

quantitative approach for modeling variable structure decision making organizations is presented. In these rganizations, the interactions between the decisionmakers can change, depending on the task being processed. sing Colored Petri Nets, an algorithm is presented for generating such variable structures. The approach is lustrated through the modeling and design of a hypothetical Airport Surface Traffic Control System.

MAEL, J.J.; LEVIS, A.H.: *Generation of a Variable Structure Distributed Architectures for C^3 ommand Control and Communications) Systems.* Massachusetts Inst. of Tech., Cambridge. Lab. for ormation and Decision Systems, Technical report LIDS-P-1900 (Aug., 1989)

he design of a C^3 system architecture for a submarine is described to illustrate a new quantitative approach r generating variable structure architectures. In these architectures, the interactions between the components the system can change. Colored Petri Nets are used to represent these architectures. An algorithm to compute e variable structures that satisfy design requirements as well as some generic constraints is outlined.

NHAM, M.J.: *A Petri-Net Approach to the Control of Discrete-Event Systems.* NATO Adv. Sci. t. Ser. F: Comput. Systems Sci., Vol. 47: Advanced Computing Concepts and Techniques in Control gineering — Berlin: Springer-Verlag, pp. 191–214 (1988)

he author describes a theory for the synthesis of supervisory controllers for discrete-event systems. The required ehavior is specified by an invariant relation which must hold during operation of the system, and a controller is erived which ensures the required behavior. The theory is based on viewing the Petri net model of the system a two-sorted algebra; and the composition operations as a natural product between two such algebras.

MITROVICI, C.; HUMMERT, U.: *Kategorielle Konstruktionen für algebraische Petrinetze.* Technische iversität Berlin, Foschungsberichte des Fachbereichs Informatik No. 1989/23 (1989)

he authors present several categorial constructions for Pteri nets which can be regarded as a suitable basis for omposition and decompostion concepts. The authors show that the category of place/transition nets and the tegory of algebraic net schemes are cocomplete, ie that coproducts and cokernels exist. The T-invariant functor om the category of place/transition nets into the category of free abelian groups which assigns to each net its roup of T-invariants preserves finite limits whereas the S-invariant functor transforms finite colimits into finite mits.

MITROVICI, C.; HUMMERT, U.; PETRUCCI, L.: *The Properties of Algebraic Nets Schemes in some mantics.* Report LRI–539 — Univ. de Paris-Sud, Centre d'Orsay, Laboratiore de Recherche en ormatique (Jan., 1990)

he purpose of this paper is to have a categorial approach of coloured nets and nets with abstract data types lled schemes. The authors consider, for that last sort of nets, several categories of algebraic net schemes ver a specification SPEC and their interpretations in SPEC-algebras. Different semantics are defined for those tegories, each of them leading to analysis of nets. After having defined the semantics, the authors deduce some tegorial properties. Finally, these approaches are compared.

NG, G.; SEKIGUCHI, T.: *A Method of Determining the Firing Sequence of Petri Net.* Transactions of Society of Instrument and Control Engineers Vol. 25, No. 6, pp. 698–705 (June, 1989), in Japanese

he reachability problem of a Petri net can be solved by checking whether there exists a nonnegative integer olution such that the matrix equation of the net holds true. Even if the solution exists, however, there is still e problem of finding an appropriate firing sequence. A method for determining such a sequence is proposed: n algorithm to determine the firing sequence by tracing backwards from the final marking to the initial one on e places set is presented. The method proposed is applied to the failure diagnosis of a simple type of sequence ontrol system.

APER, C.M.; HOLDING, D.J.: *Specification and Verification of the Real-Time Synchronisation ftware for a Modular Independently Driven High-Speed Machine.* Proceedings of the IEE Colloquium 'Control Systems Software Reliability for Industrial Applications', 1989, London, UK: Digest No. 111 London, UK: IEE, pp. 6/1–4 (1989)

he paper describes research into the design of real-time synchronisation software for a high-speed packaging machine which exploits the flexibility that is introduced by the use of software controlled independent drives. The research includes the specification of the control and synchronisation requirements of the machine using a concurrent language and the design and implementation of a transputer-based distributed control system capable of high-speed performance. This involves software design using the concurrent programming language Occam and software modelling and verification using nets.

DUGAN, J.B.; TRIVEDI, K.S.: *Coverage Modeling for Dependability Analysis of Fault-Tolerant Systems.* IEEE Trans. Comput., Vol. 38, No. 6, pp. 775–787 (June, 1989)

Several different models for predicting coverage (the probability that a system recovers when a fault occurs) in a fault-tolerant system are developed, especially extended stochastic Petri nets. Two types of events that interfere with recovery are examined and methods for modeling such events are given. The sensitivity of system reliability/availability to the coverage parameter and the sensitivity of the coverage parameter to various error-handling strategies are investigated. It is found that a policy of attempting transient recovery upon detection of an error can actually increase the unreliability of the system.

EGGERT, H.: *A Formal Net Specification of the Communication in a Distributed Computer System.* Forschungsberichte Kernforschungs-Zentrum Karlsruhe, Report No. KfK4630 (1989)

The Predicate/Transition Net provides very compact net specifications; so it is possible to describe a concurrent system in a formal manner and to validate its causal behavior already during the design phase. In this environment, a net specification was developed which provides a formal description of an application protocol for a communication system. This communication system is the central part of our distributed Fast Reactor Diagnostic System DESYRE (Diagnostic Expert SYstem for Reactor Surveillance).

ERKMANN, J.; BÖRNER, H.: *Ansätze zur komplexen Modellierung und Simulation von CIM-Strukturen unter Nutzung von Petri-Netzen.* Grundlagen der Modellierung und Simulationstechnik, Vorträge zur 17. Jahrestagung, 1988, Rostock, DDR, pp. 104–106 (1988)

Der vorliegende Artikel zeigt, daß bei Projektierung und Betrieb von flexiblen Fertigungssystemen (FFS) Petrinetze als Modellierungsgrundlage dienen. Im Ergebnis der Arbeit mit modifizierten Petrinetzen werden Grundprinzipien der Modellierung von FFS fixiert.

ETESSAMI, E.S.; HURA, G.S.: *APN-Based Object Oriented Approach to Bounded-Buffer Problem.* Proceedings of the IEEE 1989 National Aerospace and Electronics Conference NAECON 1989, Dayton, OH, USA, pp. 542–548 (1989)

The authors examine the use of the abstract-Petri-net- (APN-) based object-oriented approach to solve the bounded-buffer problem, considered as representative of real-time control problems. It is demonstrated how it is possible to represent various requirements in terms of a set of predicates to obtain the model of the system. It is shown that the moulded system is compact, verifiable, and consistent. Further, the analysis technique ensures the finite termination of the reachability state tree. The executable code (parameterized procedure and functions) of each of the objects can directly be derived from the model.

FINKEL, A.: *A Minimal Coverability Graph for Petri Nets.* Report LRI–501 — Univ. de Paris-Sud, Centre d'Orsay, Laboratiore de Recherche en Informatique (Jun., 1989)

The author presents the minimal coverability graph for Petri nets and for Vector Addition Systems. This graph is based on an optimization of the Karp and Miller's graph. It allows to decide the Finite Reachability Tree Problem, the Finite Reachability Set Problem, the Boundedness Problem, the Coverability Problem, the Quasi-Lifeness Problem and the Regularity Problem. The algorithm given for computing the minimal coverability graph uses as less as possible the memory.

FISCHER, J.; LEIPNER, P.: *Verhaltensanalyse von Rechnersystemen mit Methoden der diskreten Ereignissimulation und der Petrinetztheorie.* Humboldt-Univ. Berlin, Sekt. Math., Seminarber., Vol. 95 (1987)

FONIO, H.R.: *A Modular Approach to a Petri Net Simulation Transformer for the GRASPIN Environment.* ESPRIT Project 125-GRASPIN; Technical Paper — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (Sept., 1989)

This paper describes a modular approach to a Petri net simulation for the GRASPIN environment. The approach is based on interpretations by rewrite modules, so-called Petri modules. These form an abstract programming language allowing for the adequate programming of concurrent problems. A new view on high level Petri nets enables the transformation of these nets to rewrite modules. Rewrite systems representing the total Petri nets are constructed by suitable colimits for Petri modules.

FRANZ, V.: *Planung und Steuerung komplexer Bauprozesse durch Simulation mit modifizierten höheren Petrinetzen.* Dissertation — Gesamthochschule Kassel, Fachbereich Bauingenieurwesen (1989)

Bauprozesse sind komplex und kompliziert; um sie realistisch abbilden zu können, müssen Störfaktoren erfaßt werden. Die Arbeit stellt eine Methode vor, mit deren Hilfe Bauprozesse unter Berücksichtigung der relevanten Systemcharakteristica praxisnah modelliert und simuliert werden können.

FRUTOS ESCRIG, D.; JOHNEN, C.: *Decidability of Home Space Property.* Report LRI-503 — Univ. de Paris-Sud, Centre d'Orsay, Laboratiore de Recherche en Informatique (July, 1989)

The authors present a proof of the decidability of home space property for linear sets of markings, and extend this result to finite unions of linear sets having the same periods. They reduce this property to the same one for submarkings, and finite unions of submarkings having the same support. Decidability of home space property for this last class of sets is proved by applying a new result characterizing the set of reachable markings by means of a finite coinitial part of it.

FURUKAWA, M.; KAKAZU, Y.; OKINO, N.: *Control of Design Process with Petri Net for CAD-Knowledge Representation Based on O/O Dualism.* Journal of the Japan Society of Precision Engineering, Vol. 55, No. 5, pp. 877–882 (May 1989), in Japanese

In order to realize a design model (eg a CAD system) knowledge for the model must be concreted. The authors report on the representation method of the design knowledge. A new representation method, object and operation dualism, is adopted. Object and operation express designing know-how. The Petri net method controls the information flow. Object and operation are coded in a similar way to a frame representation. Examples show how object and operation are built in the design model and how they are controlled by the Petri net.

GERRAND, P.H.: *Experience Gained in Applying Formal Description Techniques to the Design of Complex Real-Time Computing Systems.* J. Electr. Electron. Eng. Aust., Vol 9, No. 1–2, pp. 54–62 (Mar.-Jun., 1989)

This paper describes insights gained from the experience at Telecom Australia's Research Laboratories in applying formal description techniques to the software engineering of complex telecommunications systems. This motivated the development of Call-State Transition Diagrams. The need for rigorous validation of specifications led to the development of Numerical Petri Nets (NPNs). A computer aid (PROTEAN) has been developed to support NPN modelling and analysis.

GHEZZI, C.; MANDRIOLI, D.; MORASCA, S.; PEZZE, M.: *Symbolic Execution of Concurrent Systems Using Petri Nets.* Comput. Lang., Vol. 14, No. 4, pp. 263–281 (1989)

The authors define a method for symbolic execution of concurrent systems, based on an extension of Petri net formalism, called EF nets. In order to support the analysis of a concurrent system or program, at first a general algorithm for symbolically executing an EF net is defined. Then, a more efficient algorithm is given for the particular help in reducing the amount of information needed to characterize a symbolic execution. The usefulness of the proposed method is illustrated by means of a case study.

GONDZIO, M.: *Verification Oriented Approach to Concurrent Microprogramming with the Language C-MIDDLE.* Microprocessing & Microprogramming, Vol. 27, No. 1-5, pp. 607–618 (Aug., 1989)

Digital systems composed of cooperating microprogrammed units are considered. A concurrent microprogramming language C-MIDDLE is proposed; it is an extension of the sequential language MIDDLE. C-MIDDLE has a denotational semantics which constitutes a basis for reasoning about the behavior of concurrent microprograms and their compositions. A Petri-net-based modeling method of C-MIDDLE programs as well as a verification system VECOM are also presented.

GREENE, J.: *Petri Net Design Methodology for Sequential Control.* Measurement and Control, Vol. 22, No. 10, pp. 288–291 (1989)

This paper presents a design method for sequential control where the the control sequence is defined by a Petri net. Later on, each element of this net is augmented in order to determine the hardware necessary for the implementation of the respective part of the sequence. The practical application of the method is demonstrated using a control problem of indusrial robots.

GRENIER, C.; LEBAS, P.; TREVES, N.: *Suitability of Net-Based GRASPIN Tools for Electronic Payment Systems: Evaluation Report.* ESPRIT Project 125-GRASPIN; Technical Paper — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (Sept., 1989)

In order to prepare the industrial exploitation of GRASPIN project results, SLIGOS, as a first pilot user, explored and evaluated the suitability of the net-based tools for the specification and verification of non-sequential systems. The experiments conducted concerned protocol specification for message interchange in electronis payment applications. The conclusion of these experiments is that to fully exploit all the promising results of the GRASPIN project, a technology transfer appears necessary with improvements to the GRASPIN environment.

HAAS, PETER J.; SHEDLER, GERALD S.: *Stochastic Petri Net Representation of Discrete Event Simulations.* IEEE Trans. Software Eng., Vo. 15, No. 4, pp. 381–393 (1989)

A generalized semi-Markov process (GSMP) is the usual model for the underlying stochastic process of a discrete event simulation on a countable state space. The authors study the modeling power of stochastic Petri nets (SPN's) with timed and immediate transitions and show that such Petri nets provide a general framework for simulation. Our principle result is that for any (finite or) countable state GSMP there exists an SPN having a marking process that 'mimics' the GSMP in the sense that the two processes have the same finite dimensional distributions.

HADDAD, S.; COUVREUR, J.M.: *Validation of Parallel Systems with Coloured Petri Nets.* Parallel Processing. Proceedings of the IFIP WG 10.3 Working Conference, 1988, Pisa, Italy / Cosnard, M.; et al. (eds.) — Amsterdam, Netherlands: North-Holland, pp. 377-390 (1988)

This paper presents the coloured Petri net model and the flows computation and the reduction theory developed for it. The authors show how coloured nets can model realistic parallel systems. The reduction rules which transform the net into a smaller one with the same behaviour as the original one is a suitable tool for verifying the lifeness properties. Two significant applications and their validation are given: a data base management and the synchronization of two logical clocks.

HALLMANN, M.: *Ein Vorschlag für eine Prototyping-umgebung, orientiert an den Anforderungen offener Systeme.* Memo No. 8, Progress Report — Univ. Dortmund, Fachbereich Informatik (July, 1986)

In this report the authors propose an integrated prototyping method oriented by the requirements of open systems. They introduce a formal requirement language RELOS (Requirement Language for Open Systems) and a prototyping environment PROTOS based on Petri nets. By a catalog of requirements the authors analyse several specification methods for the ability of prototyping. RELOS supports the user and the developer by the concept of scenario definition, the possibility of hierarchical system development and the separation of data and activity description.

HANEN, C.; CHRETIENNE, P.; CARLIER, J.: *Optimizing Static Microprogrammable Pipelines: a Timed Petri Net Model.* ICS 87. Proceedings of the Second International Conference on Supercomputing, 1987, San Francisco, CA, USA: Supercomputing '87; Vol. 3 — St.Petersburg, FL, USA: Int. Supercomputing Inst., pp. 332–402 (1987)

The paper presents theoretical tools to solve the scheduling problem associated with the throughput optimisation of a microprogrammable pipeline. The authors present a basic pipeline design, an expression of the entire scheduling problem with timed Petri nets, and they prove its validity. Then they build a bivalued graph from their net, called the resolution graph, and they show how optimal microprograms can be deduced from any critical circuit of this graph.

HASSEN, J.: *A Contemporary Approach to Logic Systems Design and its Applications for Implementing Hardwired and Programmed Controllers.* Trends in Control and Measurement Education. Selected Papers from the IFAC Symposium, 1988, Swansea, UK / Linkens, D.A.; et al. (eds.) — Oxford, UK: Pergamon, pp. 27–32 (1989)

The paper concerns experience gained in the field of logic systems design. The method introduced has been developed in order to obtain a systematic and simple synthesis without constraints. Interpreted Petri nets are utilised as a graphical means for the description of a given problem. The model obtained is then transcribed into logic expressions depending on the implementation. Finally, the implementation can be achieved using either hardwired or programmed systems. In order to simulate and to control industrial applications, universal hardwired sequencers and programmable controllers have been realised.

HAVERKORT, B.R.; NIEMEGEERS, I.G.: *Theory of Describing Performability Models.* Memo INF-88-26 — Technische Univ. Twente, Enschede (Netherlands); Dept. of Computer Science (Nov., 1988)

Performance and reliability models are studied. Both are described using queueing networks of Petri nets models. A performability model includes both aspects of performance and of reliability. It is claimed that performability models can be described by two separate models and a connection between these models. A performability modeling technique is proposed.

HENDERSON, W.; LUCIC, D.; TAYLOR, P.G.: *A Net Level Performance Analysis of Stochastic Petri Nets.* J. Austral. Math. Soc., Ser. B, Vol. 31, pp. 176–187 (1989)

Stochastic Petri nets are used extensively to find performance measures for communication protocols. This paper illustrates how equilibrium distributions for the markings of a wide class of nets can be found directly without the need to generate a large state space and than resort to equilibrium balance equations.

HERRTWICH, R.G.; HOMMEL, G.: *Kooperation und Konkurrenz. Nebenläufige, verteilte und echtzeitabhängige Programmsysteme.* Berlin: Springer (1989)

Ausgehend von der sequentiellen Programmierung stellt dieses Buch die grundlegenden Konzepte, Methoden und Techniken der Programmierung nebenläufiger, verteilter und echtzeitabhängiger Systeme im Zusammenhang dar. Die Verwaltung und Synchronisation nebenläufiger Prozesse sowie die prozessübergreifende Kommunikation, z.B. mit Semaphoren, Monitoren, Nachrichten oder Rendezvous, stehen dabei im Mittelpunkt. Konfigurationsmechanismen und Protokolle machen die vorgestellten Verfahren auch für verteilte Systeme anwendbar, und die Berücksichtigung von Zeitschranken erlaubt ihren Einsatz in echtzeitabhängigen Systemen. — In Kapitel 8 (S. 145–161) wird eine kurze Einführung in Theorie der Petri-Netze gegeben.

HEUSER, C.A.: *Modelagem conceitual de sistemas.* (Preliminary edition) Buenos Aires, Argentina: Editorial Kapelusz S.A. (Jan., 1989)

This text is an introduction to conceptual systems modelling. Instead of describing the various techniques known from literature, this appraoch introduces Petri nets as a formalism for conceptual modelling. They serve as foundation for explaining the basic concepts of conceptual modelling as well as other modelling approaches. Topics include channel/agency nets, refining and coarsening of nets (allowing the construction of "structured" system models), high-level Petri nets with condition/event semantics, modelling of static system properties with nets, and, finally, the entity/relationship approach from a Petri net point of view. The text is based on lecture notes developed by the author in 1987 and 1988 for a post-graduate course in Computer Science at Federal University of Rio Grande do Sul.

HEUSER, C.A.PERES E.M.: *Rumo a um modelo conceitual completo: Redes de Petri e Diagramas E/R.* Informática: Teórica e Aplicada, Vol. 1, No. 1, pp. 45–77 (Oct., 1989)

The paper describes the combined use of entity-relationship (E/R) diagrams and Petri nets for conceptual system modeling. The idea is to combine a tool for modeling static system properties with a tool aimed at the description of dynamic system properties. Petri nets can be used also for modeling static properties. Based on this fact, the semantics of E/R diagrams is given in terms of Petri nets. Further, it is shown how to extend the E/R approach using Petri nets to obtain complete conceptual models, which contain both the static and the dynamic properties of the modeled system.

HILLION, H.P.; PROTH, J.M.: *Using Timed Petri Nets for the Scheduling of Job-Shop Systems.* Engineering Costs and Production Economics, Vol. 17, No. 1-4, pp. 149–154 (Aug., 1989)

The authors study the job-shop problem with repetitive demands in steady state. The control is given by the sequencing of the jobs on the machines. Petri nets are used to model and evaluate the system. The authors suggest an algorithm to give the optimal set of sequences, i.e. the set which provides the maximal productivity with the minimal number of transportation resources.

HOLLOWAY, L.E.; KROGH, B.H.: *Efficient Synthesis of Control Logic for a Class of Discrete Event Systems.* Proceedings of the 1989 American Control Conference, Pittsburgh, PA, USA; Vol. 3 — Piscataway, NJ, USA: IEEE Service Center, pp. 2672–2677 (1989)

A computationally efficient solution for a class of forbidden state problems is developed. The authors consider discrete event systems (DESs) which can be modeled as cyclic controlled marked graphs. The distributed representation of the DES state in terms of the CMG marking permits an efficient specification of the forbidden states. It is shown that the graphical representation of the state transition logic in a CMG can be used to synthesize state feedback logic. An application of the results is illustrated in the field of FMS.

HÜMBS, W.; KUZYK, K.: *Systemverklemmung. Charakterisierung und Erkennung.* MC – Die Mikrocomputer-Zeitschrift, No. 10, pp. 74–76,78 (1989)

Vom Straßenverkehr als verständlichem Beispiel wird übergeleitet zur Parallelverarbeitung in der elektronischen Datenverarbeitung, die Bedeutung der Synchronisation besprochen und ihr Mindestmaß aufgestellt. Mit Petri-Netzen wird die Verklemmung beim Erzeuger- Verbraucher-Problem gezeigt, Zyklizität dargestellt, ein System aus nur lebendem Transitionen, ferner die Auflösung der Verklemmung, ein verklemmungsfreies System, die Existenz einer toten Transition und ein Petri-Netz nur aus toten Transitionen behandelt.

HUMMERT, U.: *Algebraische Theorie von High-Level-Netzen.* Dissertation (Informatik) — Berlin: Technische Universität (1989)

In dieser Arbeit werden verschiedene Typen von Petrinetzen behandelt, insbesondere High-Level-Netze (HL-Netze), das sind Petrinetze mit individuellen Token, und algebraische High-Level-Netze, die aus einer Kombination von HL-Netzen und algebraischen Datenspezifikationen bestehen. Basierend auf Konstruktionen in covollständigen Kategorien werden verschiedene Strukturierungskonzepte für beide Netztypen entwickelt. Als horizontales Strukturierungskonzept für Netze werden Zerlegungen über Colimites von Diagrammen definiert, wobei die Objekte eines Diagramms die Netzkomponenten, der Colimes das zerlegte Netz darstellen.

ISLAM, S.M.R.; AMMAR, H.H.: *Performance Analysis of Degradable Multiprocessor Systems.* Proceedings of the Eighth Annual International Phoenix Conference on Computers and Communications, 1989, Scottsdale, AZ, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 109–113 (1989)

A method for performance evaluation of degradable multiprocessor systems with random failure and repair using hierarchical generalized stochastic Petri net (GSPN) model is presented. The GSPN model can be decomposed into a hierarchical sequence of aggregated subnets; they can be solved in isolation and their results combined to get the solution of the hole system. A multiprocessor system is analyzed which is intractable using conventional solution techniques.

ITMI, M.; PECUCHET, J.P.: *Modelisation et simulation par objets des reseaux de Petri : implementation par objets sur machine LISP.* Thesis (Inform.), Univ. Rouen — CNRS-T Bordereau (1989)

Definition d'un modele objet pour implementation d'un reseau de Petri. Ce modele presente l'avantage de tenir compte des conflits et de permettre la realisation d'un outil extensible pour la manipulation et la simulation des reseaux de Petri varies et ou les aspects d'interaction souple et de graphisme s'integrent naturellement.

ITTER, F.; RELEWICZ, C.: *Computer Supported Design of Kanban-Controlled Production Integrated System Analysis and Simulation.* Simulation in Manufacturing. Proceedings of the 5th International Conference: Technology for Tomorrow, 1989, Berlin — Kempston, UK: IFS Publications, pp. 159-170 (1989)

Reorganizing of production in accordance with the Kanban principles requires considerate assistance in the process of decision-making. The authors show how to model, analyse and simulate a Kanban oriented production by using Petri-nets supported by the PSItool NET. A building block developed for a standard production is described. The possibilities are shown to adopt this building block to specific conditions using parameters and to link it with net parts, which represent non-standard-problems.

ITTER, F.; LANG, M.: *Simulation of a Chemical Production System Using Petri Nets.* Computer Application in the Chemical Industry. Papers of a European Symposium; 1989, Erlangen, West Germany / Eckermann, R. (ed.) — Weinheim, West Germany: VCH Verlagsgesellschaft, pp. 493-502 (1989)

Petri nets are principally useful as an aid to describe event orientated simulation processes. As an example the authors show how Petri nets may be used to simulate a chemical production plant in a way which combines interval and event orientated simulation. A special interest is given to the process monitoring.

ITTER, F.: *Rechnergestützte Planung kanbangesteuerter Fertigung durch integrierte Systemanalyse und Simulation mit dem PSItool NET.* Informatik-Fachberichte, Vol. 223; Bericht: GI, 19. Jahrestagung, 1989, München; Vol. 2 / Paul, M. (ed.) — Berlin: Springer, pp. 491–525 (1989)

Das PSItool NET unterstützt Aufgaben der Systemanalyse und der Simulation; die Petrinetztheorie bietet den integrierenden Formalismus dafür. Neben einer Einführung in das Prinzip einer Kanban-Fertigung werden in diesem Papier sogenannte Modellbausteine definiert, die das Modellieren kanbangesteuerter Fertigungen erleichtern. Es handelt sich um vordefinierte Petrinetzteile, die sich in einfacher Weise zu Kanbankreisen, -ketten und -netzen zusammenfügen lassen. Die Funktionalität des PSItools NET wird anhand einer Fallstudie aufgezeigt.

JANCAR, P.: *Decidability of Weak Fairness in Petri Nets.* STACS 89. Proceedings of the 6th Annual Symposium on Theoretical Aspects of Computer Science / Monien, B.; et al. (eds.) — Berlin: Springer-Verlag, pp. 446-457 (1989)

The paper proves the decidability of the problem if there is an infinite weakly fair occurrence sequence for a given Petri net. Thereby an open problem of H. Carstensen (1987) and R. Howell et al. (1988) is solved.

JANICKI, R.; KOUTNY, M.: *Towards a Theory of Simulation for Verification of Concurrent Systems.* Lecture Notes in Computer Science, Vol. 366; PARLE '89, Vol. 2: Proceedings of the Conference on Parallel Architectures and Languages Europe / Odijk, E. (ed.) — Berlin: Springer, pp. 73-88 (1989)

The authors investigate whether it is possible to provide the designer of a concurrent system with a sound and efficient simulation technique. They introduce the notion of a simualtion defined as a subset of the possible execution paths, and demonstrate that under some conditions the simulation provides a sufficient information to reason about a number of interesting properties of the system. They then show that there always exists a simulation which provides the required behavioural information and involves a minimal computational effort.

JOJCZYK, K.; KONIECZNY, J.; KUZAK, T.: *Generalized Nets.* Zesz. Nauk. Uniw. Jagiellon., Vo. 818, Pr. Inf. 3, pp. 48–70 (1987), in Polish

The paper presents a formalism which enables defining different kinds of Petri nets in a uniform way. This allows to compare nets and their classes with respect to their structures and behaviour. The notion of generalized net introduced here precisely describes static and dynamic net structure. The commonly known types of nets (condition/event nets, testing Petri nets, place/transition nets, coloured Petri nets, high-level Petri nets) are defined as generalized nets and relations between them are presented.

JORGENSEN, P.C.; SMITH, W.A.: *Using Petri Net Theory to Analyze Software Safety Case Studies.* COMPASS '89. Proceedings of the Fourth Annual Conference on Computer Assurance Systems Integrity, Software Safety and Process Security, 1989, Gaithersburg, MD, USA, pp. 22–25 (1989)

Research is described regarding the use of Petri net theory to analyze selected software safety case studies. Interpretation of the analysis results produced the following conclusions: (1) all of the Petri nets had instances of 1-connectedness at the point depicting where the software failures occurred; and (2) instances of 1-connectedness similar to those described indicate situations where the software should implement some type of exception-handling capability.

JUANOLE, G.; FAURE, C.: *On Gateway for Internetworking through ISDN: Architecture and Formal Modelling with Petri Nets.* IEEE INFOCOM '89. Proceedings of the Proceedings of the Eighth Annual Joint Conference of the IEEE Computer and Communications Societies. Technology: Emerging or Converging? 1989, Ottawa, Ont., Canada; Vol. 2 — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 458-467 (1989)

Two design steps are presented of a gateway for connecting a local area network (LAN) and a remote computer through an ISDN (integrated services digital network). The first step concerns the specification of the gateway architecture: the inconsistencies have to be considered between the LAN architecture and the communication architecture of the remote computer (which has an ISDN interface). The second step concerns the formal specification of the behavior of the gateway, using Petri nets: this step is essential in order to verify if the specification is complete and correct.

KÄMPER, S.: *Object-Oriented Model Building with Petri Nets Using the Simulation Tool NET.* ESC 89. Proceedings of the 3rd European Simulation Congress, 1989, Edinburgh, UK / Murray-Smith, D.; et al. (eds.) — Ghent, Belgium: SCS Eur., pp. 142–147 (1989)

The article combines the concept of object-oriented model building with Petri nets. A uniform concept of model building is offered: objects of the real world and their relation between each other are represented in the model. It is shown that a well structured and uniform simulation tool for model development is made available, which easily provide modification as well as extension of the models constructed. With the realization of encapsulation, object classes are reuseable.

KAPPEL, G.; SCHREFL, M.: *A Design Method for Object-Oriented Databases.* Arbeitspapiere der GMD Nr. 287 — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (1988)

Contrary to conventional databases the conceptual schema of an object-oriented database contains the description of the operations on the data next to the description of the structures of the data. Therefore a design method for such a database must consider the behavioral aspects of real world objects. The authors present such a method. It is based on the Behavior Integrated Entity Relationship Approach. The structural aspects are represented by entity sets, the behavioral aspects, by activities which correspond to transitions in an entity-state/transition diagram, which is based on a Petri net graph representation.

KIEHN, A.: *A Structuring Mechanism for Petri Nets.* Report TUM-I8902 — München: Technische Universiät, Institut für Informatik (March, 1989)

The structuring mechanism presented in this paper allows the specification and usage of modules; this brings together the advantages of net theory with those of structured programming. The basic idea is to transfer the subroutine mechanism to nets by considering a set of nets instead of one single net and by introducing special caller transitions. Such a transition calls a net by consuming the input tokens and by creating a disjoint copy of the corresponding net structure. This extension of the Petri net model is called 'net system'. The overall standing aim is to bring out to what an extend the augmentation of Petri nets with an subroutine mechanism changes their properties.

KONTOLEON, J.M.; MANDALTSIS, D.: *A Petri Net Approach for the Enumeration of all K-trees and K- Currents and its Application on K-terminal Network Reliability Evaluation.* Microelectronics and Reliability,Vol. 29, No. 5, pp. 819–828 (1989)

This paper presents an approach for enumerating all the K-trees and their corresponding cutsets of a network, which is based on Petri nets. By the use of the above trees or cutsets the K-terminal reliability of a network is then evaluated. This general reliability measure gives as a special case the 2-terminal as well as the overall network reliability.

KÖRNER, H.; FRANZ, V.: *Planung und Steuerung komplexer Bauprozesse.* Baumaschine und Bautechnik, Vol. 36, No. 5, pp. 247-250,252–253,256 (1989)

Bauabläufe sind vorwiegend einmalig ablaufende Prozesse. Dafür wurde eine Modifikation der Netztheorie entwickelt. U.a. werden werden behandelt Grundlagen der Petri-Netztheorie, Schaltregeln und Petri Netze und Netzplantechnik sowie deren Anwendung, insbesondere im Bauwesen. Die Modifizierung der PrT-Netze zur Simulation von Bauprogrammen wird anhand von Beispielen dargestellt.

KOSTURIAK, J.; GREGOR, M.: *New Principles in Modelling and Simulation of Flexible Manufacturing Systems.* MSR (Messen, Steuern, Regeln), Vol. 32, No. 8, pp. 353–356 (Aug., 1989), in German

The authors present principles developed in the Zilina College of Transport and Communications (Czechoslovakia) for the simulation of flexible manufacturing systems. First, Petri nets as tools for modelling and simulation are presented. Fundamentals of simulation and control principles are then considered.

KOSTURIAK, J.: *Enumerative Analysis of Qualitative Properties of Petri nets.* Automatizace, Vol. 32, No. 6, pp. 147–151 (June, 1989), in Slovak

A formal description of Petri nets is presented with particular emphasis on the analysis of their qualitative properties. The main tool used for the qualitative analysis is a generated reachability tree of the Petri nets. Formulation of the graph of reachability, matrix representation of the problem and its software solution are dealt with.

KOTOV, V.E.; CHERKASOVA, L.A.: *Connection of the Network and Logical Approaches to Description of Processes.* Vychisl. Sist., Vol. 122, pp. 97–109 (1987), in Russian

A logical approach to the description of generalized processes is considered. The aim is to eliminate certain contradictions between the description of processes using Petri nets and the logical methods of verification of its correctness. It differs from the approaches of dynamic logics, process logic and temporal logic. The syntax includes "alternative" and "predecessing". The authors differentiate global and local properties of processes (taking place for all and some realizations, respectively).

KRASNOBAEV, V.A.; KRASNOBAEV, L.A.: *Application of Petri Nets for Modeling in Order to Find and Search for Alternating Failures in a Computer.* Automation and Remote Control, Vol. 49, No. 9, part 2, pp. 1198–1204 (1988)

also: Translation of: Avtomat. i Telemekh., No. 9, pp. 111–118 (1988), in Russian

An example is constructed of a Petri net for the purpose given in the paper's title.

KRAUSS, K.G.: *Petri Nets Applied to the Formal Verification of Parallel and Communicating Processes.* Dissertation — Bethlehem, PA: Lehigh University. (1987)

KWIATKOWSKA, M.Z.: *Survey of Fairness Notions.* Information and Software Technology, Vol. 31, No. 7, pp. 371–386 (1989)

Classification of faireess notions has been proposed in many formalisms, but there still seems to be no general agreement on what fairness means and how it should be dealt with. The paper reviews major issues in the area of fairness, the purpose being to present a taxonomy of notions of fairness and to discusss the main directions taken and the implictions of choosing a particular approach. The object of this review is to identify common features of fairness definitions and to examine the adequacy, or, in some cases, the failure, of standard methods when appleid to deal with fairness.

KWIATKOWSKA, M.Z.: *Event Fairness and Non-Interleaving Concurrency.* Formal Aspects of Computing, Vol. 1, pp. 213–228 (1989)

Event fairness suitable for non-interleaving concurrency is proposed. Fairness is viewed with respect to concurrency in the sense that no concurrent component of the system should be delayed indefinitely. The model gives rise to a partial order. A class of generalized notions of (weak, strong and unconditional) event fairness relative to progress requirements is derived. The weakest fairness notion in this class is shown to coincide with maximality with respect to the partial order over traces.

LASERRE, J.B.; MAHEY, P.: *Using Linear Programming in Petri Net Analysis.* RAIRO, Rech. Oper., Vol. 23, No. 1, pp. 43–50 (1989).

LEE, K.H.; FAVREL, J.: *Corrections to Generalized Petri Net Reduction Method.* IEEE Transactions on Systems, Man, and Cybernetics, Vol. 19, No. 5, pp. 1328–1329 (1989)

A reduction method of Petri nets has been proposed by Lee and Favrel (cf Petri Net Newsletter 29, p. 48). In this paper, a modification of the reduction method is given for better conservation of Petri net property.

LESVENTES, G.; KOTT, L.: *Systemes d'automates a compteurs et semi-linearite des ensembles d'etats accessibles : Forlorn hope.* Thesis (Inform.), Univ. Rennes 1 — CNRS-T Bordereau (1989)

Etude des modeles de parallelisme en informatique bases sur les automates. Un nouveau formalisme est propose:

les sytemes d'automates a compteurs. A partir du modele des automates synchronises d'Arnold et Nivat, un modele d'automates communiquant par le biais de compteurs entiers est defini. Une equivalence est etablie entre les systemes d'automates a compteurs et les reseaux de Petri et, a partir de la, le travail est prolonge dans le cadre plus general des systemes d'addition de vecteurs.

LIU, L.C.; HOROWITZ, E.: *A Formal Model for Software Project Management.* IEEE Transactions on Software Engineering, Vol. 15, No. 10, pp. 1280–1293 (Oct., 1989)

A formal model, DesignNet, is developed for the description and management of large-scale software development projects. The DesignNet model uses AND/OR structure operators to describe the breakdown of the development work components and Petri nets to describe the relationships and parallelism between project activities, resources, and output. A 'token' propagation process enables the collection of time-dependent information at different project structure levels.

LODAYA, K.; RAMANUJAM, R.; THIAGARAJAN, P.S.: *A Logic for Distributed Transition Systems.* Lecture Notes in Computer Science Vol. 354: Linear Time, Branching Time and Partial Order in Logics and Models for Concurrency. / de Bakker, J.W.; et al. (eds.) — Springer Verlag, pp. 508–522 (1989)

The authors present a logical characterization of a particular aspect of concurrency called the concurrent step notion. They do so by providing a sound and complete axiomatization of models called distributed transition systems. In these systems an old state is transformaed into a new state through a set of actions occurring concurrently. The logical language has the minimal features of linear temporal logic and that of propositional dynamic logic. The main ressult implies that satisfiability in this logical system is decidable.

LOPEZ-BENITEZ, N.; FORTES, J.A.B.: *Detailed Modeling of Fault-Tolerant Processor Arrays.* FTCS 19: Proceedings of The Nineteenth International Sympsoium on Fault-Tolerant Computing, 1989, Chicago, IL, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 545–552 (1989)

Detailed modeling of fault-tolerant processor arrays entails not only an explosive growth in the model state space but also a difficult model construction process. The latter problem is addressed, and a systematic method to construct Markov models for evaluating the reliability of processor arrays is proposed. This method is based on the premise that the fault behavior of a processor array can be modeled by a stochastic Petri net. However, in order to obtain a more compact representation, a set of attributes is associated with each transition in the Petri net model.

MAGGIOLO-SCHETTINI, A.; WINKOWSKI, J.: *On Equivalence of Behaviour Expressions.* ICS PAS Report 669 — Warsaw, Poland: Polish Academy of Sciences, Institut of Computer Science (Oct., 1989)

A method of representing behaviours by expressions denoting a variant of labelled event structures is defined. The expressions, called behaviour expressions, may contain variables for which other behaviour expressions may be substituted. A concept of equivalence of behaviour expressions is introduced such that equivalences are preserved under substitution.

MAGGIOLO-SCHETTINI, A.; WINKOWSKI, J.: *An Algebraic Model for Timed behaviours.* ICS PAS Report 671 — Warsaw, Poland: Polish Academy of Sciences, Institut of Computer Science (Nov., 1989)

Behaviours of real time systems, called timed behaviours, are considered. A mathematical model for such behaviours is developed using a variant of labelled event sructures. A compositional method of defining the timed behaviours of compound concurrent real time systems from the behaviours of their components is presented. A concept of equivalence of timed behaviours is introduced.

MAGOTT, J.: *Petri Nets in the Performance Evaluation of Computer Systems.* Politechnika Wroclawska; Instytut Cybernetyki Technicznej; Prace Naukowe; Seria Monografie, No. 15 (1989), in Polish

MAMIKONOV, A.G.; KULBA, V.V.: *Synthesis of Optimal Modular Systems in Data Processing.* Moskva: Nauka (1986), in Russian

The book is devoted to designing and constructing optimal modular data processing systems. Various optimality criteria are considered, eg time used for data transmission, reliability, and efficiency. Moreover restrictions imposed on the system are taken into account. The examined questions concern both the optimal decomposition of systems into modules and the optimal database structure. Each problem is reduced to an integer nonlinear programming problem and algorithms for solving these problems are presented. One of the chapters is devoted to applications of Petri nets to the synthesis and analysis of modular systems.

MAMIKONOV, A.G.; DEMETROVICS, J.; KULBA, V.V.; KNUTH, E.; SOKOLOVA, E.B. et al.: *The Use of Petri Nets in the Design of Data Processing Systems.* Vol. 21 — Moscow: Nauka (Nov., 1988), in Russian

MANDALTSIS, D.; KONTOLEON, J.M.: *Enumeration of k-Trees and their Application to the Reliability Evaluation of Communication Networks.* Microelectronics and Reliability, Vol. 29, pp. 733–735 (1989)

In this paper a method is proposed for the enumeration of all the k-trees in a network, and a new algorithm is introduced which uses the k-trees for evaluating the k-reliability, ie the probability that at least k of the network modes are connected. This reliability measure gives the overall reliability as a special case. The proposed method evaluates this measure using the concepts of Petri nets.

MARTI-OLIET, N.; MESEGUER, J.: *From Petri Nets to Linear Logic.* Lecture Notes in Computer Science, Vol. 389; Category Theory and Computer Science / Pitt, D.H.; et al. (eds.) — Springer-Verlag, pp. 313–340 (1989)

In this paper, the authors establish a systematic correspondence between Petri nets, linear logic theories, and linear categories. Such a correspondence sheds new light on the ralationships between linear logic and concurrency, and on how both areas are related to category theory. Categories are here viewed as concurrent systems whose objects are states, and whose morphisms are transitions.

MASSBERG, W.: *Problemneutrales Verfahren zur Simulation, Steuerung und Diagnose von Produktionsanlagen.* CIRP Annals, Vol. 38,No. 1, pp. 421–424 (1989)

The paper deals with Petrinet based tools for the planning and operation phase of sophisticated hierarchically structured production systems. The planning phase includes computer internal analysis and simulation of all functions, whereas control, diagnosis and therapy will be activated during the operation phase. The computer aided tools offer high flexibility. User access to the different moduls will be offered by a graphically interactive surface.

MELNIKOVA, E.V.: *The Use of Petri Nets for Modeling Transport Functions of a Data Transmission Network.* Methods and means for designing discrete systems. / Pogrebinskii, S. B. (ed.) — Kiev: Akad. Nauk Ukrain. SSR, Inst. Kibernet., pp. 72–77 (1988), in Russian

MENG, C.Z.; DICESARE, F.: *Adaptive Design of Petri Net Controllers for Error Recovery in Automated Manufacturing Systems.* IEEE Transactions on Systems, Man and cybernetics, Vol. 19, No. 5, pp. 963–973 (Sept./Oct., 1989)

The concept of Petri net controllers is extended to include automatic error recovery and adaptive design. In the controller, a place that represents an operation or a state of a machine is attached to two functions and a constant so that it can represent a system working with both normal and abnormal states. Four basic Petri net augmentation methods are investigated: input conditioning, alternate path, feedback error recovery, and forward error recovery. The authors demonstrate that then some important properties are guaranteed to be preserved including boundedness or safeness, lifeness, reversibility, and the essentially decision-free property.

MERCIER DES ROCHETTES, R.; DESCOTES-GENON, B.; LADET, P.: *On the Control Specification of a Flexible Assembly System: Coloured Petri Nets Application.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 243–252 (1988), in French

It is difficult to design flexible manufacturing systems. This is the reason why one needs CAD tools. In this paper, the authors are interested in Petri nets and coloured Petri nets, for they allow not only an easy and precise graphic description, but also they can be used during the life of an application. The authors develop the best way to control such systems and describe the different tools used. A realization of an assembly manufacturing system shows the use of this method.

MERCIER DES ROCHETTES, R.; LADET, P.; DESCOTES-GENON, B.: *Sur l'utilisation des reseaux de Petri colores pour la commande des systemes de production : mise en œuvre sur un atelier flexible.* Thesis (Sci.), Univ. I.N.P. Grenoble — CNRS-T Bordereau (1988)

Presentation d'un outil de description des systemes flexibles de production: les reseaux de Petri colores a travers 3 exemples de modelisation appartenant au domaine de la production et de l'informatique. Le modele peut etre utilise pour la synthese de la commande et est alors considere comme un coordonnateur effectuant une fonction de supervision. Validation des resultats par realisation d'un atelier flexible experimental.

MEYER, J.F.; MURALIDHAR, K.H.; SANDERS, W.H.: *Performability of a Token Bus Network under Transient Fault Conditions.* FTCS 19: Proceedings of The Nineteenth International Sympsoium on Fault-Tolerant Computing, 1989, Chicago, IL, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 175–182 (1989)

The authors present the results of a detailed performability evaluation of a local-area network using the IEEE 802.4 protocol. In particular a 30 station IEEE 802.4 token bus network operating in a hostile factory environment is evaluated using stochastic activity networks. Stochastic activity networks, a generalization of stochastic Petri nets, provide a convenient representation for computer networks and are formal enough to permit solution by both analysis and simulation.

MOALLA, M.; BEN AHMED, S.: *Petri Nets and their Extensions for the Modeling and Studying of Production Systems.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 79–94 (1988), in French

The RdPIC model (coloured interpreted Petri nets) is proposed as a design tool for the modeling, analysis and behaviour evaluation of flexible systems of discontinuous production. The authors recall the main characteristics that they wish to find with such a tool. Then, starting from the primitive Petri nets model, the authors define some extensions allowing the RdPIC to respond to the requirements outlined. Certain aspects of these extensions are illustrated within two examples.

MONTANARI, U.; YANKELEVICH, D.N.: *An Algebraic View of Interleaving and Distributed Operational Semantics.* Lecture Notes in Computer Science, Vol. 389; Category Theory and Computer Science / Pitt, D.H.; et al. (eds.) — Springer-Verlag, pp. 5–20 (1989)

The authors describe CCS models in terms of categories of structured transition systems: They define two categories for representing interleaving and "truly concurrent", distributed aspects of CCS. Among the objects of these categories they choose two standard models: The interleaving model essentially coincides with the classical transiton system of CCS, while the distributed model faithfully expresses the issues about decentralized control and multiple representation of agents. Consistency of distributed and interleaving semantics is proved.

MORASCA, S.; PEZZE, M.: *The Rationale of an Environment for Real-Time Software.* Proceedings of the Euromicro Workshop on Real Time. 1989, Como, Italy — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 37–42 (1989)

Some core ideas that lead to the definition of an environment for real-time systems are discussed. It is explained how integration, flexibility, and validation support can be achieved by using a suitable formalism as an underlying kernel for the environment. The kernel formal notation proposed (called environment relationship nets, or ER nets) is an extension of Petri nets where tokens are not anonymous. Rather, they are environments, i.e. mappings between variables and values. The problems connected with the quality assurances of the system being developed are also discussed.

MORASCA, S.; PEZZE, M.: *Validation of Concurrent Ada Programs Using Symbolic Execution.* Lecture Notes in Computer Science, Vol. 387; ESEC '89. Proceedings of the 2nd European Software Engineering Conference, 1989, Coventry, UK / Ghezzi, C.; et al. (eds.) — Berlin: Springer-Verlag, pp. 469–486 (1989)

The authors propose an extension of sequential symbolic execution for Ada tasking. A net based formalism, EF net, is used for representing the Ada task system. EF nets are high level Petri nets, suitable for representing all aspects of Ada tasking, except for time related commands, which are not considered in this paper. Two symbolic execution algorithms are then defined on EF nets. The first one, called SEA, can be used for symbolically executing every concurrent Ada program. The second algorithm allows the execution of a relevant subset of EF nets, and improves the SEA algorithm reducing the produced results.

MORSE, J.A.: *Performance Estimation of Distributed Computer Systems.* Thesis (Ph.D.) — Storrs, CT (US): Univ. of Connecticut. (1988)

Many computer systems are best modeled as sets of independent communicating sequential processes. This thesis presents analytic methods for predicting the performance of these types of systems. The method uses an adaptation of CSP language. A Petri net is constructed from the CSP specification. By doing reachability analysis, a probabilistic grammar is derived that describes the possible sequences of messages. Several unique aspects of this approach are described, including transformation and simplification techniques that help avoid the state explosion problem.

MUCK, T.; VINEK, G.: *Modelling Dynamic Constraints Using Augmented Place Transition Nets.* Information Systems, Vol. 14, No. 4, pp. 327–340 (1989)

Augmented place transition nets with token values are used as a semantic data modelling formalism. This formalism is able to cover relevant aspects of the dynamic behaviour of a database in a concise manner and enables the data engineer to specify constraints for event sequences and object type assignments; therefore it is proposed as a data modelling tool to map object-event interactions from the universe of discourse to the conceptual scheme.

MURTHY, V.K.; SCHROEDER, H.: *Systolic Arrays for Parallel Matrix g-Inversion and Finding Petri Net Invariants.* Parallel Comput., Vol. 11, No. 3, pp. 349–359 (Aug., 19890

Solution of a homogeneous system of linear equations is basic to finding Petri net invariants, dimensional analysis and balancing of chemical equations. This paper describes a new algorithm for this problem based on matrix generalized inverse computation that can be implemented using instruction systolic arrays.

NIELSEN, M.; ROZENBERG, G.; THIAGARAJAN, P.S.: *Behavioural Notions for Elementary Net Systems.* Ditributed Computing, Vol. 4, No. 1, pp. 45–57 (1990)

The authors study the relationships between a number of behavioural notions that have arisen in the theory of distributed computing; they apply the chosen behavioural notions to a basic net-theoretic model of distributed systems called elementary net systems. The behavioural notions that are considered are trace languages, non-sequential processes, unfoldings and event structures. The relationships between these notions are brought out in the process of establishing that for each elementary net system, the trace language representation of its behaviour agrees in a strong way with the event sructure representation of its behaviour.

NOWICKI, T.; WILCZKOWIAK, E.: *Study of Local Area Networks Using Petri Nets.* RELECTRONIC '88. Proceedings of the 7th Symposium on Reliability in Electronics, 1988, Budapest, Hungary; Vol. 2 — Budapest: Hiradatechnikai Tudomanyos Egyesulet, pp. 454–461 (1988)

There are some basic techniques which are used with local area networks (LANs); they are concerned with: network topology, transmission medium, and medium access control methods. The authors concentrate on the latter of these. Timed Petri net models for study of a standby group with renewal, local area network with CSMA-CD, and control token medium access method are proposed. The medium access control protocol can have a profound impact on the overall LAN performance.

OBERWEIS, A.: *Integritätsbewahrendes Prototyping von verteilten Systemen.* Informatik-Fachberichte, Vol. 222; Bericht: GI, 19. Jahrestagung, 1989, München; Vol. 1 / Paul, M. (ed.) — Berlin: Springer, pp. 215–230 (1989)

Prototyping fördert die Kommunikation zwischen Systementwickler und Anwender und ist daher ein wichtiges Hilfsmittel zur inhaltlichen Validierung eines gegebenen Entwurfs. Diese Arbeit stellt Konzepte vor zur Einbeziehung von Integritätsbedingungen beim Prototyping mit Prädikate/Transitionen-Netzen. Es werden sowohl statische als auch dynamische Integritätsbedingungen berücksichtigt. Teilweise sind diese Konzepte bereits implementiert.

OCHMANSKI, E.; PENCZEK, W.: *Inevitability in Diamond Processes.* Informatique théorique et Applications, Vol. 24, No. 1, pp. 37–46 (1990)

The paper deals with the concurrent systems viewed as partially ordered sets. A set of system states is called inevitable if each execution of the system meets this set. Single executions of concurrent systems are represented by maximal directed subsets of this system; they are called processes. A distinguished class of processes, called diamond processes, is defined and investigated. Inevitable subsets of diamond processes are characterized.

OHTA, A.; SAITOH, K.; HISAMURA, T.: *Applications of Timed-Place Petri Nets to Scheduling Problems of Repetitive Processes.* Transactions of the Society of Instrument and Control Engineers, Vol. 25, No. 6, pp. 714–716 (June, 1989), in Japanese

Job-shop type, time-optimal scheduling problems for repetitive processes are modelled by the Petri net with timed places. Assuming the stationary periodic solution, the optimal or the suboptimal solution is obtained by LP and the branch-and-bound method.

PERDU, D.M.; LEVIS, A.H.: *Requirements Specification Using the Cube Tool Methodology.* Technical report LIDS-P-1890 — Massachusetts Inst. of Tech., Cambridge. Lab. for Information and Decision Systems (July, 1989)

Abstract see 'Perdu: Requirements Specification with Petri Nets Using the Cube Tool Methodology.'

PERDU, D.M.: *Requirements Specification with Petri Nets Using the Cube Tool Methodology.* Technical report LIDS-R-1901 — Massachusetts Inst. of Tech., Cambridge. Lab. for Information and Decision Systems (Aug., 1989)

Command and control requires the consideration of both processes and communications. Cube Tool is a methodology used to derive the processing and communication needs for each system function. An approach is introduced for extending the applicability of Cube Tool to the determination of requirements for C^3I systems. First, using Cube Tool for each function, a Petri Net is derived that models all processes and communications. Then these nets are interconnected and the steps of the methodology are applied again to derive the Petri Net that represents requirements for the system. For different modes different Petri Net are obtained which can then be folded together to obtain a Colored Petri Net representation.

PICCIOLO, G.: *Availability Assessment of Complex Distributed Control System of a Petro Chemical Plant.* Reliability Data Collection and Use in Risk and Availability Assessment. Proceedings of the 6th EuReData conference, 1989, Siena, Italy / Colombari, V. (ed.) — Berlin: Springer, pp. 524–530 (1989)

Particular application of reliability techniques is developed to evaluate dependability (availability, integrity and security) of large process distributed control system for an ethylene plant. Each critical plant section is associated to own control subsystem which is analyzed taking into account major field unavailabilities. Control system availability is concerned, evaluating section fault tolerant approach by Stochastic Petri Nets Theory application.

PIZZI, R.; DEGAETANO, A.; GUADALUPI, P.; CHIARA, O.; COLUMBANO, C. et al.: *Prediction of MSOF Evolution by Means of Nine Vital Systems Trajectories.* Expert Systems and Decision Support in Medicine. Proceedings of the 33rd Annual Meeting of the GMDS EFMI, 1988, Hannover, Germany / Rienhoff, O.; et al. (eds) — Berlin: Springer-Verlag, pp. 213-217 (1988)

Multiple System Organ Failure (MSOF) remains a principal cause of death after major operative procedures. In a retrospective analysis of 132 emergency surgical patients, MSOF developed in 21. 240 integrated monitorings were derived from these patients. The records have yielded the first knowledge base for an original procedure developed to study this severe syndrome. The procedure includes a statistical algorithm and a method of knowledge representation and extraction by means of a Petri net system.

POPA, M.: *Petri Nets and Languages.* Languages, logic, mathematical linguistics. Papers of the 10th Natl. Colloq., 1988, Brasov, Romania, pp. 183–191 (1988), in Romanian

The work outlines some of the results of the author's doctor thesis titled "Applications of the theory of graphs and nets in information science: Petri nets", defended in January 1988. It underscores the interdisciplinary character of the thesis through the results reached at, such as the elaboration of algorithms to construct trees and HL-trees, the definition and study of the similar behaviour of two different classes of Petri nets, the achievement of a connection between the formalism of Petri nets and that of the theory of systems, the establishment of a link between programming and Petri nets, the study of flows in PT-labelled Petri nets, etc. The final section of the work highlights the close link between Petri nets and formal languages.

PREUSS, G.: *On the Topological Structures of Nets.* Lecture Notes in Computer Science, Vol. 393; Categorical Methods in Computer Science / Ehrig, H.; et al. (eds.) — Springer-Verlag, pp. 315–324 (1989)

In this paper net theory is studied from a categorial point of view. It turns out that the category *Net* of nets is a universally topological category over the category of pairs of disjoint sets such that products of final maps are final. Consequently, *Net* is a quasitopos with concrete powers. Furthermore, occurrence nets are studied and it is shown that the full subcategory of *Net*, whose objects are all the nets with unbranched conditions, is extremal epireflexive in *Net*.

PULLI, P.J.: *Pattern-Directed Real-Time Execution of SA/RT Specifications.* Proceedings of the Euromicro Workshop on Real Time. 1989, Como, Italy — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 3–9 (1989)

Initial results with an experimental run-time system are reported. The run-time system makes possible real-time execution of software specifications created according to the structured analysis for real-time systems (SA/RT) techniques. The run-time system is capable of executing SA/RT specifications that are generated automatically into object-oriented C language format from high-level Petri-net representation of SA/RT specifications. The run-time system is based on an efficient pattern-directed implementation of the Ward scheduling algorithms.

QUICHAUD, D.; GIRAULT, C.: *Analyse des reseaux bipolaires pour la coherence et l'evaluation des systemes paralleles.* Thesis (Inform.), Univ. Paris 06 — CNRS-T Bordereau (1988)

Presentation d'un modele et description d'un logiciel de reduction des reseaux bipolaires permettant l'etude pratique de la coherence d'un systeme modelise. Evaluation des performances des systemes modelises par des reseaux bipolaires.

REISIG, W.: *Petri Nets and Abstract Data Types.* Report TUM-I8904 — München: Technische Universiät, Institut für Informatik (1989)

Petri nets gain a great deal of modelling power by representing dynamically changing items as structured tokens. Algebraic specifications turn out adequate for dealing with structured items. The author uses this formalism to construct Petri nets with structured tokens. Place- and transition-invariants are useful analysis techniques for conventional Petri nets. The author derives corresponding formalisms for nets with structured tokens, based on term substitution.

RIEU, C.; MERCIER, J.J.: *Outil d'aide a la specification et a l'implementation de protocoles de transfert.* Thesis (Inform.), Univ. Clermont-Ferrand 2 — CNRS-T Bordereau (1989)

Une approche de conception est construite a partir d'une classification fonctionnelle des informations manipulees. Un support graphique permet de decrire la communication a realiser. La technique de description proposee est ensuite verifiee au moyen d'un logiciel de verification de systemes decrits sous forme de reseaux de Petri de type predicats-transitions.

ROSENBLUM, L.Y.; VAGIN, V.N.; ZAKHAROV, V.N.: *Petri Net Inference for Data Processing.* Proceedings of "Artificial Intelligence and Information-Control systems of Robots-87", Smolenice, Czechoslovakia / Plander, I. (ed.) — Amsterdam: North-Holland, pp. 439–440. (1987)

RYZHOV, V.A.: *Dynamic Petri Nets.* Soobshcheniya po Programmnomu Obespecheniyu EVM. (Reports in Software) — Moscow: Akad. Nauk SSSR, Vychisl. Tsentr (1988), in Russian

SAITO, K.; OHTA, A.; HISAMURA, T.: *An Application of Stochastic time Petri Nets to Scheduling Problems with Uncertain Processing Times.* Transactions of the Society of Instrument and Control Engineers, Vol. 25, No. 4, pp. 476–481 (1989), in Japanese

The paper concerns a time optimal job shop type scheduling problem including jobs with uncertain processing times. Modeling the problem by the stochastic time Petri net in which some transitions have statistically varying firing times, the stochastically suboptimal (nondelayed) schedule is derived. The approach is illustrated by two examples and the results are compared with those of Monte Carlo simulations.

SCHMID, G.: *Modellierung gekoppelter Prozesse durch Performance Petri-Netze.* ITG-Fachberichte, Vol. 107; Bericht: ITG-Fachtagung, 1989, Nürnberg, pp. 103–110 (1989)

Performance Petri-Netze sind für die Modellierung und Analyse nebenläufiger, gekoppelter Prozesse geeignet, da sie die gewöhnlichen Petri-Netze durch eine Zeitbewertung der Netzelemente erweitern. Der Verfasser gibt einen Überblick über das Gebiet der Performance Petri-Netze, und stellt die wichtigsten Netzmodelle sowie Methoden zur Analyse vor.

SCHUFFENHAUER, C.: *Modellierung und softwareseitige Realisierung von M-Netzbausteinen zur Simulation von Software der Fertigungsprozeßsteuerung.* Wissenschaftliche Zeitschrift der Technischen Hochschule Karl-Marx-Stadt, Vol. 29, No. 6, pp. 878–882 (1987)

Die Komplexität flexibler Fertigungssysteme zwang den Projektanten, nach transparenten Beschreibungsmitteln für die in diesen Systemen wechselwirkenden Flußsysteme zu suchen. Dabei traten die Petri-Netze immer mehr in den Vordergrund. Erste Applikationen auf der Basis von Modellbausteinen zeigen, daß die automatische Generierung von Netzmodellen für fachgebietsbezogenene Simulationssysteme die Grundvoraussetzung einer effektiveren Nutzung ist.

SHATZ, S.M.; MAI, K.; MOORTHI, D.; WOODWARD, J.: *A Toolkit for Automated Support of Ada Tasking Analysis.* Proceedings of the 9th International Conference on Distributed Computing Systems; 1989, Newport Beach, CA, USA — Washington: IEEE Comput. Soc. Press, pp. 595–602 (1989)

A discussion is presented of research on the development of a toolkit that supports general static analysis using a Petri net framework for Ada tasking. The toolkit comprises special tools for Ada tasking analysis and general-purpose tools to support arbitrary Petri-net-based research. The analysis toolkit contains the front-end translator subsystem, which translates Ada source into a Petri net format, and, the back-end information display subsystem, which receives user queries and presents tasking analysis results.

SHCHUTSKII, V.I.; KOMLEVA, E.V.: *Simulation Modelling of the Operation of an Electric Open Cast Transport with the Aid of Petri Networks.* Izvestiya Vysshikh Uchebnykh Zavedenii, Elektromekhanika, No. 5;, pp. 107–110 (1989), in Russian

The authors describe an approach to the computer-aided design of simulation models of the operation of an electric open cast transport system employing expanded Petri networks. The transport system is described by attributed temporal networks, with dynamically controlled priorities at transitions. The networks, designed by the proposed method, are safe and ensure that only one train is present on any part of the route.

SHIEH, Y.B.; GHOSAL, D.; TRIPATHI, S.K.: *Modeling of Fault-Tolerant Techniques in Hierarchical Systems.* FTCS 19: Proceedings of The Nineteenth International Sympsoium on Fault-Tolerant Computing, 1989, Chicago, IL, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 167-174 (1989)

The authors consider both centralized and distributed fault-tolerant schemes. Based on stochastic Petri net models, they investigate the performance of these two approaches. In the case of decentralized fault tolerance, they consider two different checkpointing strategies. In the first scheme, called the arbitrary checkpointing strategy, each process does its checkpointing independently; as a result, there is the possibility of domino effect. In the planned strategy, checkpointing is done in a manner which ensures that there is no domino effect.

SHIEH, Y.B.; GHOSAL, D.; CHINTAMANENI, P.R.; TRIPATHI, S.K.: *Application of Petri Net Models for the Evaluation of Fault-Tolerant Techniques in Distributed Systems.* Proceedings of the 9th International Conference on Distributed Computing Systems; 1989, Newport Beach, CA, USA — Washington: IEEE Comput. Soc. Press, pp. 151–159 (1989)

Analytical models are presented that use extended Petri nets for fault-tolerant schemes used in distributed systems. Several different schemes are discussed in detail: rollback recovery with checkpointing, recovery blocks, N-version programming, and conversations. A methodology for evaluating a fault-tolerant scheme for a specific system configuration and the steps involved in building a Petri net model are described. The subnet primitives involved in building these models are identified and an algorithm for building the models automatically is described.

SHPAK, V.F.: *Synthesis of Theories of Petri Nets and Formal Grammars for the Logical Representation of Interactive Computer Processes.* Otdelenie Matematiki, Mekhaniki i Kibernetiki, Akademii Nauk Ukrainskoi SSR, Kibernetika, No. 6, pp. 101–105,134 (1988), in Russian

SILVA, W.T.; RICHTER, G.: *Formalização da abordagem orientada a objetos em redes de Petri.* Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Informática; Série: Monografias em Ciência da Computação, No. 4/89 (1989)

The paper proposes a formalization of the main concepts of object-oriented languages in terms of predicate/transition nets.

SIVANANDAN, K.S.; GARG, K.; NANDA, N.K.: *On Supercomputer Modelling and Analysis Using an Advanced Petri Net.* ICS 87. Proceedings of the Second International Conference on Supercomputing, 1987, San Francisco, CA, USA: Supercomputing '87; Vol. 3 — St.Petersburg, FL, USA: Int. Supercomputing Inst., pp. 324–331 (1987)

The paper deals with the modelling and analysis of a typical instruction chaining and execution unit of a supercomputer, using a recently developed advanced Petri net (APN). The APN is a generalization of existing Petri nets, with their most useful features incorporated in it to make it a versatile modelling and analysis tool. To illustrate its use in modelling, an example of instruction chaining in the CRAY-1 supercomputer has been chosen. All aspects of the chaining unit can be readily and effectively modelled by the APN. Analysis of the net is undertaken to do the performance evaluation of the unit in terms of the execution time of the instruction chain.

SMITH, E.: *Zur Bedeutung der Concurrency-Theorie für den Aufbau hochverteilter Systeme.* Berichte der GMD Nr. 180 — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (1989)

Das Buch führt in Begriffe und Methoden ein, die für die Behandlung verteilter Systeme benötigt werden. Im ersten Teil wird das Modell der Petrinetze aus den Gesetzmäßigkeiten von Signalfluß und -interaktion hergeleitet. Dies schließt die Betrachtung von Grundlagen des Informationsflusses in verteilten Systemen ein. Im zweiten Teil wird untersucht, wie sich die Grundsätze des Beobachtens und Messens in der Konstruktion und Handhabung mathematischer Modelle realer Systeme widerspiegeln.

STEFANOV, A.M.; FATKHI, V.A.: *Diagnostic Modelling in the Language of Modified Petri Nets.* Izvestija Akademii Nauk SSSR. Tehniceskaja Kibernetika, No. 3, pp. 115–122 (1989), in Russian

STOTTS, P.D.; FURUTA, R.: *Access Control and Verification in Petri-Net-Based Hyperdocuments.* COMPASS '89. Proceedings of the Fourth Annual Conference on Computer Assurance Systems Integrity, Software Safety and Process Security, 1989, Gaithersburg, MD, USA, pp. 49-55 (1989)

The Petri-net-based Trellis model of hypertext is briefly described, and the access control capabilities that the model provides for hyperdocuments is discussed. Using the Petri-net formalism, a hypertext document can be written so that different classes of readers can be allowed or denied access to various portions of the document. The use of browsing restrictions and multiple document versions to implement access classes is discussed.

STOTTS, P.D.; NEWCOMB, R.W.; NING CAI, Z.: *Modelling the Logical Structure of Flexible Manufacturing Systems with Petri Nets.* Computer Communications, Vol. 12, No. 4, pp. 193-203 (Aug., 1989)

Recent research using Petri-net theory as applied to the design and analysis of flexible manufacturing systems is reviewed. In particular, one of the most flexible of manufacturing line structures is discussed, the robot lattice structure, which is analysed using a new form of timed Petri-nets, termed binary timed Petri Nets (BTPNs). A graphical modelling language for BTPNs is also briefly discussed.

STUDER, R.: *A Conceptual Model for Time.* LILOG-Report No. 2. — Stuttgart: IBM Germany, Dept. 3504 (Dec., 1986)

For capturing static and dynamic aspects of an application domain on a conceptual level THM-Nets being based on semantic data model and Petri net concepts have been proposed. In this paper THM-Nets are generalized

to Timed THM-Nets thus providing modeling concepts for capturing physical and logical time aspects of a slice of reality. These modeling concepts are based on an appropriate notion of physical and logical time within the semantic data model THM.

TAMURA, H.; YAMAGATA, K.; HATONO, I.: *Decision Making for Flexible Manufacturing-OR and/or AI Approaches in Scheduling.* Systems Analysis, Modelling, Simulation; Vol. 6, No. 5, pp. 363–371 (1989)

Decision-making problems for FMS's can be classified into three hierarchical levels: strategic level, administrative level, and operational level. This paper gives a brief survey of decision-making problems at each level. Discussion is given of which tasks are better tackled by OR and which by AI. Attention is focused on job scheduling problems at the administrative level. The limitations of conventional OR approaches for scheduling problems are pointed out. Instead of OR approaches, a method of rule-based scheduling is proposed where the FMS is modelled as a discrete event system using a timed Petri net.

TANKOANO, J.; DERNIAME, J.C.: *Petri Nets and Distributable Applications.* Technique et Science Informatiques, Vol. 8, No. 4, pp. 339–359 (1989), in French

Information systems frequently consist of a set of distributed nodes, especially in the field of industrial control. Petri nets provide a sound basis for such distributed systems, to ensure security and availability, and such methods are in demand in other areas such as hardware configuration and VLSI. The paper proposes such a methodology, not so much for its interest in a well-worked theoretical field, but as an example of its application to computer-aided engineering.

TAUBNER, D.; VOGLER, W.: *Step Failures Semantics and a Complete Proof System.* Acta Informatica, Vol. 27, No. 2, pp. 125–156 (1989)

The authors generalize the (linaer) failures semantics by taking steps (ie multisets of simultaneously occurring actions) instead of single actions as the basic execution. (The notion of step is taken from Petri net theory.) Hence opposed to linear semantics — where parallelism is modelled as arbitrary interleaving — the step failures semantics models parallelism explicitly. In particular a sound and complete proof system is given. Opposed to the linear model divergence is treated uniformly here. The relation to the linear semantics can be establisched using the newly introduced deparallelize operator.

THIAGARAJAN, P.S.: *Some Behavioural Aspects of Net Theory.* Theoretical Computer Science, Vol. 71, pp. 133–153 (1990)

The aim of the paper is to give a general picture of the behavioural aspects of net theory; this is done by presenting a number of behavioural notations which reflect the basic concerns of this theory (eg traces and labelled event structures). The paper concentrates on motivations and basic definitions at the expense of stating theorems.

TIUSANEN, M.: *Some Unsolved Problems in Modelling Self-Timed Circuits Using Petri Nets.* Bull. EACTS, Vol. 36, pp. 152–160 (1988).

The author presents some open problems that have arisen in the context of using conflict-free labelled Petri nets to model so called self-timed or self-synchronizing circuits. These are circuits designed to operate correctly independent of the delays inherent in the components. The problems presented concern the concurrency of transitions in the marking class, formulation of a new concession rule for modelling mass phenomena, and modelling nondistributive Muller-diagrams by Petri nets.

VAANDRAGER, F.W.: *A Simple Definition for Parallel Composition of Prime Event Structures.* Progress Report CS-R-8903 — CWI Amsterdam, Centre for Mathematics and Computer Science, Dept. of Algorithmics & Architecture (March, 1989)

A simple, non-inductive construction is presented for parallel composition of prime event structures with binary conflict. It is shown that the construction determines the same operation as the categorical construction of Winskel (Winskel: Event structures. LNCS 255, 325–392 (1987)) by proving that it is a product in the category of prime event structures with binary conflict.

VALETTE, R.; DUBOIS, D.; CARDOSO, J.: *FMS State Modelling Taking Incidents into Account.* Congres Automatique 1988, Grenoble, France: Quelle Automatique dans les Industries Manufacturieres. — Paris, France: AFCET, pp. 95–104 (1988), in French

The papers shows the interest of introducing uncertainty and imprecision within Petri net based models of FMS's. These two concepts are then introduced within the marking of a Petri net with data structure, and then within the interpretation (external conditions associated with the transitions). It is shown how, in some cases, uncertainty is propagated and how, sometimes, it is possible to return to certainty.

VAN GLABBEEK, R.; GOLTZ, U.: *Equivalence Notions for Concurrent Systems and Refinement of Actions.* Arbeitspapiere der GMD Nr. 366 — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (Feb., 1989)
also: Extended abstract: Lecture Notes in Computer Science, Vol. 379; Mathematical Foundations of Computer Science 1989 / Kreczmar, A. ; et al. (eds.) — Springer-Verlag, pp. 237–248 (1989)

The authors investigate equivalence notions for concurrent systems. They consider 'linear time' approaches as well as 'branching time' approaches where the conflict structure of systems is taken into account. They show that the usual interleaving equivalences, and also the equivalences based on steps are not preserved by refinement of atomic actions. They prove that 'linear time' partial order semantics, where causality in runs is explicit, is invariant under refinement. Finally, they consider various bisimulation equivalences based on partial orders.

VAN GLABBEEK, R.; GOLTZ, U.: *Refinement of Actions in Causality Based Models.* Arbeitspapiere der GMD Nr. 428 — St. Augustin: Gesellschaft für Mathematik und Datenverarbeitung mbH (Jan., 1990)
also: Lecture Notes in Computer Science; Proceedings of the REX Workshop on Stepwise Refinement / J.W. de Bakker, et al. (eds.) — Springer-Verlag (1990)

The authors consider an operator for refinement of actions to be used in the design of concurrent systems. Actions on a given level of abstraction are replaced by more complicated processes on a lower level. This is done in such a way that the behaviour of the refined system may be inferred compositionally from the behaviour of the origianl system and from the behaviour of the processes substituted for actions. The authors define this refinement operation for causality based models like event structures and Petri nets.

VAN HEE, K.M.; SOMERS, L.J.; VOORHOEVE, M.: *A Formal Framework for Simulation of Discrete Event Systems.* ESC 89. Proceedings of the 3rd European Simulation Congress, 1989, Edinburgh, UK / Murray-Smith, D.; et al. (eds.) — Ghent, Belgium: SCS Eur., pp. 113-116 (1989)

A framework is presented for the description of a certain class of systems called discrete event systems. The framework supports the development of prototypes and simulation models. It consists of an abstract model based on Petri nets, a language and a software tool for definition, checking and interactive simulation.

VARSHAVSKIY, V.I.; KISHINEVSKIY, M.A.; KONDRATYEV, A.Y.; ROSENBLYUM, L.Y.; TAUBIN, A.R.: *Models for Specification and Analysis of Processes in Asynchronous Circuits.* Soviet Journal of Computer and Systems Sciences, Vol. 26, No. 5, pp. 61–76 (1989)
also: Translated from: Izv. Akad. Nauk SSSR, Tekhn. Kibernet.,No. 2,, pp. 171–190 (1988), in Russian

A survey of models oriented toward specification of asynchoronous circuits and an investigation of their behavior is presented. Using transition diagrams and systems of Muller's equations as well as signal Petri nets, a comparative analysis is given of available modelling tools and estimation of laboriousness of the analysis procedures. In conclusion, the authors consider a model of the diagram of variations which turns out to be the most efficient, since the algorithms for its analysis possess polynomial bounds on complexity.

VISWANADHAM, N.; JOHNSON, T.L.: *Fault Detection and Diagnosis of Automated Manufacturing Systems.* Industrial Process Control Systems: Reliability, Availability, Maintainability. Proceedings of the IFAC Workshop, 1988, Bruges, Belgium / Boullart, L.; et al. (eds.) — Oxford, UK: Pergamon, pp. 95–102 (1989)

A two-level scheme for monitoring and diagnosis in automated manufacturing systems is proposed and developed. At the first level, there are diagnostic systems for each of the subsystems. At the second level there is an intelligent controller monitoring the part flow and coordinating the local diagnostic systems and controllers. It is assumed that local controllers and diagnostic systems exist for subsystem level fault detection and diagnosis, and a Petri-net-based intelligent controller for system level fault detection and diagnosis is presented.

VOGLER, W.: *Failure Semantics of Petri nets and the Refinement of Places and Transitions.* Interner Bericht TUM-INFO-01-90-I03-350/1.-FMI — München: Technische Universiät, Mathematisches Institut und Institut für Informatik (1990)

The paper deals with equivalences of the type: N_1 is equivalent to N_2 if exchanging N_1 and N_2 in any context preserves behaviour. The behaviour considered on the one hand is being free of deadlocks, on the other hand being free of deadlocks and divergence. The author studies nets whose boundaries in a context consist of transitions only or, of places only. In both cases subclasses are defined where the equivalence is decidable. The results especially apply to the refinement of places and transitions.

WANG, C.J.; WU, C.; NELSON, V.P.: *A Study of the Generalized Multiple Bus-Connected Parallel Computer.* Proceedings of The 2nd Symposium on the Frontiers of Massively Parallel Computation; 1988, Fairfax, VA, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 541–544 (1989)

The generalized multiple bus-connected parallel computer (GMBPC) is studied; it is suitable for optical interconnection and wafer-scale packaging applications and operates as a message-passing multiple-instruction multiple-data (MIMD) machine. The performance of the GMBPC is modeled by generalized stochastic Petri nets (GSPNs). To lessen the exponential distribution assumption used in the GSPN model, a Monte Carlo simulation technique is used to predict the performance probabilistically.

WANG, C.J.; NELSON, V.P.; WU, C.H.: *Performance Modeling of the Modified Mesh-Connected Parallel Computer.* Proceedings of the 9th International Conference on Distributed Computing Systems; 1989, Newport Beach, CA, USA — Washington: IEEE Comput. Soc. Press, pp. 490–497 (1989)

A message-passing computer architecture called the modified mesh-connected parallel computer (MMCPC) is proposed and studied. The MMCPC is designed to be general-purpose parallel architecture suitable for wafer-scale integration. Generalized stochastic Petri nets (GSPNs) are used to model the behavior of the MMCPC. The GSPN performance modeling results show a need for a new processing element (PE). A PE architecture, able to handle data processing and message passing concurrently, is proposed.

WANG, C.J.; NELSON, V.P.: *An Augmented Torus Processing Surface for MIMD.* Proceedings of the Eighth Annual International Phoenix Conference on Computers and Communications, 1989, Scottsdale, AZ, USA — Washington, DC, USA: IEEE Comput. Soc. Press, pp. 97–100 (1989)

An augmented torus processing surface is proposed and operated as a message-passing MIMD machine. The augmented torus is obtained by drawing the torus as a mesh with end-around connections in each row and each column and then augmenting each row and column with a row bus and column bus, respectively. The performance of the augmented torus is modeled using the generalized stochastic Petri nets. The augmented torus has better processing power than the torus and the grid-bus architecture.

WANG, F.Y.; GILDEA, K.; RUBENSTEIN, A.: *A Colored Petri Net Model for Connection Management Services in MMS.* Computer Communication Review, Vol. 19, No. 3, pp. 76–98 (July, 1989)

The authors present a Petri net (PN) model for connection management services (CMS) of the manufacturing message specification (MMS). P-invariants and T-invariants analysis carried out on the connection PN provides useful information on the CMS behavior and specification for its implementation. It is claimed that PNs may offer a hierarchical mathematical description for the entire MMS protocol, a uniform representation for various level of abstraction of MMS protocol and an analytical model for protocol performance evaluation and analysis.

WANG, I.Y.; ROBERTAZZI, T.G.: *Service Stage Petri Net Protocols with Product Form Solution.* Performance Evaluation Review, Vol. 17, no. 1, p. 233 (May, 1989)

Lazar and Robertazzi (cf Petri Net Newsletter 28, p. 35) described a class of stochastic Petri networks with product form solution for the equilibrium state probabilities. This work extends this class to the case where service times consist of a series of distinct exponential stages.

WANG, T.H.: *Repeatable Firing Sequences for Petri Nets Under Conventional, Subset and Timed Firing Rules.* Dissertation — Cleveland, OH: Case Western Reserve University (1988)

WANG, Y.; WU, C.; YAO, W.: *The Performance Evaluation of Concurrent Control Algorithm of DDBS by Using Petri Nets.* Weixing Jisuanji (China), Vol. 7, No. 5, pp. 38–46 (Sep., 1987), in Chinese

An evaluation technique based on Petri nets for concurrency algorithms for DDBS is presented. The authors have developed a communication model to represent various communication modes in the algorithms by using Petri nets. Five typical algorithms and the performance comparison between them are summarized.

WILLSON, R.G.; KROGH, B.H.: *Petri Net Tools for the Specification and Analysis of Discrete Controllers.* IEEE Transactions on Software Engineering, Vol. 16, No. 1, pp. 39–50 (Jan., 1990)

An approach for the specification, modeling and analysis of discrete state systems and controllers is presented. A rule-based state variable specification formalism is translated into Petri net models composed of interconnected state machines. Reduced reachability graphs are introduced to reduce the computational effort required to isolate and analyze subcomponent behavior within the system. Discrete manufacturing systems are the target application.

WINKOWSKI, J.: *An Algebraic Way of Defining Place/Transition Petri Nets.* ICS PAS Report 649 Warsaw, Poland: Polish Academy of Sciences, Institut of Computer Science (1989)

WU, Y.; WU, Y.; LAN, S.: *Proving the Correctness of a Token Bus Protocol by Using Petrinet.* Jisuanji Yanjiu yu Fazhan (China), Vol. 25, No. 5, pp. 16–21 (1988), in Chinese

This papers describes a simplified model of token passing bus protocol with place/transition nets. The divide-and-conquer approach is used, which divides a big problem into several small problems, simplifying problems and facilitating the analysis and proof. Finally, the correctness of the protocol is proved using linear invariants method.

YAO, Y.: *Approach to Formal Specification and Analysis for Time Performance of the Concurrent Real Time System (RTEXS)*. Comput. Ind., Vol. 12, No. 4, pp. 347–354 (Aug., 1989)

An approach to modeling and analyzing a real time concurrent system RTEXS (Real Time EXecuting System) by means of a timed Petri net (TPN) is presented. The performance analysis procedure for the system is provided. The minimum times needed for the completion of one cycle of each sequence under the worst and best case of the system are given.

ZHANG, W.: *Representation of Assembly and Automatic Robot Planning by Petri Net*. IEEE Transactions on Systems, Man and Cybernetics, Vol. 19, No. 2, pp. 418–422 (Mar./Apr., 1989)

The author proposes an approach to represent assembly by Petri nets and presents an algorithm of automatic robot assembly planning based on the Petri-net model. Due to the Petri-net representation of assembly, the plan generation is quite straightforward and the planning algorithm can be easily and efficiently implemented with simple matrix manipulation.