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I am submitting herewith a thesis written by Pamela Bridgers Thomas entitled "The Petri Net: A Modeling Tool for the Coordination of Asynchronous Processes." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Computer Science.

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THE PETRI NET: A MODELING TOOL FOR THE COORDINATION OF ASYNCHRONOUS PROCESSES

A Thesis

Presented for the

Master of Science

Degree

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ABSTRACT

The Petri net model is presented as a modeling tool for coordination of asynchronous processes. The Petri net is defined and compared with other well-known concurrency models. Petri nets are shown to be one of the more flexible models available for representing parallel computation, and extensions to the Petri representations are presented to describe still more powerful models which can model complex coordination problems with ease and clarity.

A FORTRAN simulation of an extension to the Petri net model is presented to demonstrate the value of Petri nets as a modeling tool; the practical use of the model and its simulation in detecting coordination problem areas and patterns of activity is illustrated by several simulation examples.

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CHAPTER I

INTRODUCTION

Man has great difficulty in comprehending parallel processing, for the human mind seems limited in the number of simultaneous events it can assimilate. Sequential operation is quite satisfactory for many computer applications, but imposing such a restraint on software systems at times results in assigning an artificial time relation to independent concurrent events. Therefore, parallelism and asynchronous operation become fundamental concepts for software development, and man must search for aids to overcome his natural resistance to parallel ideas.

One of the most effective tools introduced to aid in understanding any formidable subject is the model, a small copy or representation of an object or concept. Modeling results in an abstraction of the problem into a similar but simpler structure. The use of modeling tools to clarify concurrency in software systems has been vital to the development of sophisticated systems, for it is by modeling that the designer is able to separate the control aspects of the problem from the computational nature and pictorially grasp the parallelism necessary for efficient operation.

In the past decade many models have been introduced for studying parallelism. One of the most prominent of these is the theory of Petri nets. Extensive studies of Petri nets and variations suggest great versatility and effectiveness in representing many classes of coordination problems. The purpose of this thesis is to explore pragmatically

the capabilities of Petri nets. Chapter II defines the Petri net model, outlines its historical development, and suggests Petri net capabilities and limitations. Chapter III compares Petri nets with other well-known models of concurrency, and Chapter IV describes a high-level language implementation of the Petri net model. Finally, Chapter V concludes the study with an overall evaluation of the Petri net as a modeling tool for concurrent processes.

CHAPTER II

THE PETRI NET MODEL

I. DEFINITIONS

Definition 1[1]

A Petri net $N = \{T, P, A, B^o\}$ is a directed graph consisting of the following:

a. $T = \{t_1,\ldots,t_m\}$ is a finite set of transitions.

b. $P = \{p_1,\ldots,p_n\}$ is a finite set of places.

c. $A = \{a_1,\ldots,a_k\}$ is a finite set of directed arcs of the form $\langle x,y\rangle$ which either connect a transition to a place or a place to a transition.

d. A marking of the Petri net is a function from the place labels into the non-negative integers and is denoted by assigning a number of tokens or markers to each place corresponding to the marking function. A place is considered full if it has at least one marker. $B^o = \{\langle p,n\rangle | p\epsilon P$ and $n\epsilon N\}$ is the initial marking of the net.

A Petri net N is represented graphically as follows:

a. T and P form the nodes of the graph.

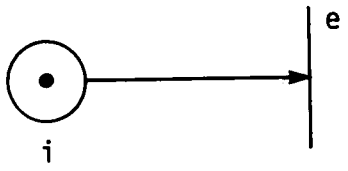
b. Each place is denoted by a circle and represents a condition.

c. Each transition is denoted by a bar and represents an event or process.

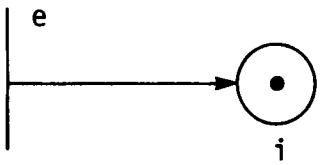
d. Circles and bars are connected by arcs.

e. A marking is represented by drawing a number of tokens or markers into a place. P_i = number of tokens in place p_i.

For example, a place i with $P_i = 1$ connected to a transition e is represented by



and indicates that every occurrence of event e ends one holding of condition i (removes a token from place i). A transition e connected to a place i with $P_i = 1$ is represented by



and indicates that every occurrence of event e begins one holding of condition i (deposits a token in place i).

Definition 2

The set of input places of a transition t_i is the set of all places from which arcs are incident on t_i: $I_i = \{p_j | <p_j, t_i> \epsilon A\}$.

Definition 3

The set of output places of a transition t_i is the set of all places onto which arcs are incident from t_i: $O_i = \{p_j | <t_i, p_j> \epsilon A\}$.

Definition 4

A transition t_i is enabled if each input place of t_i is full.

Definition 5

Two transitions t_i and t_j are in conflict if during the simulation the net reaches a marking where both t_i and t_j are enabled and $I_i \cap I_j \neq \emptyset$ (t_i and t_j share an input place).

Definition 6

Simulation rules are as follows: (1) Whenever a transition t_i is enabled, it may at some arbitrary time fire. At such a time, it reserves a token in each input place and begins firing. No other transition may claim this reserved token. (2) At the completion of firing (a finite but unknown time), the transition removes the reserved tokens and places one token in each of its output places. (3) If two transitions are in conflict, the decision as to which one will fire is absolutely arbitrary and nondeterministic.

Definition 7

A place p_i in a Petri net is safe with respect to a marking M if no simulation of the net starting from M causes more than one token to be placed in p_i. A marking M is safe if all the places in the net are safe with respect to M.

Definition 8

The reachability set of a Petri net from a marking M is the set of markings derived from all possible firing sequences starting at M.

Definition 9

A marking of a Petri net is live if for any marking reachable from the given marking, there is a firing sequence that will enable at least one transition of the net.

An example will serve to illustrate the Petri net basic definitions effectively. Consider the Petri net $N = \{T, P, A, B^{o}\}$ in Figure II.1.[2]

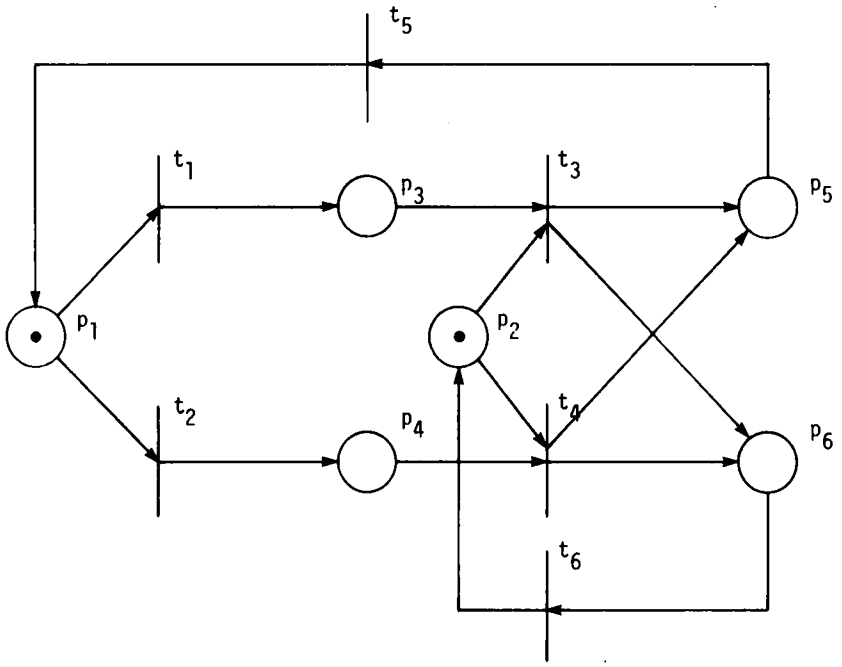


Figure II.1

Petri Net Example

$$T = \{t_1, t_2, t_3, t_4, t_5, t_6\}$$

$$P = \{p_1, p_2, p_3, p_4, p_5, p_6\}$$

$$A = \{\langle p_1,t_1\rangle, \langle p_1,t_2\rangle, \langle p_3,t_3\rangle, \langle p_4,t_4\rangle,$$
$$\langle p_2,t_3\rangle, \langle p_2,t_4\rangle, \langle p_5,t_5\rangle, \langle p_6,t_6\rangle,$$
$$\langle t_1,p_3\rangle, \langle t_2,p_4\rangle, \langle t_3,p_5\rangle, \langle t_3,p_6\rangle,$$
$$\langle t_4,p_5\rangle, \langle t_4,p_6\rangle, \langle t_5,p_1\rangle, \langle t_6,p_2\rangle\}$$

$$B^o = \{\langle p_1,1\rangle, \langle p_2,1\rangle\}$$

The net indicates that t_1 and t_2 are enabled initially and that these two transitions are in conflict. The net is live and safe with respect to B^o. A possible firing sequence is as follows: (1) t_1 chooses to fire, (2) t_3 is enabled, (3) t_3 fires, (4) t_5 and t_6 are enabled, (5) t_5 chooses to fire, (6) t_1 and t_2 are enabled, (7) t_2 chooses to fire, (8) t_6 must then fire before the net can proceed; when t_6 fires, t_4 is enabled, (9) t_4 fires, and (10) t_5 and t_6 are enabled and the simulation continues.

II. HISTORICAL DEVELOPMENT

Petri nets were one of the earliest contributions to the theory of parallel computations. Introduced by Petri[3] less than fifteen years ago, the Petri net model was developed to its present concept by Holt.[4] Since its introduction, exploration of subclasses, extensions, and variations of Petri nets has greatly expanded.

Several subclasses of Petri nets were readily isolated and studied soon after the model's introduction. Two of the most prominent subclasses are (1) marked graphs, which are Petri nets in which

every place has exactly one input and one output transition, and (2) state machines, defined as nets in which every transition has exactly one input place and one output place.[1] Genrich[5] and Holt and Commoner[6] have studied properties such as liveness and safety of marked graphs. Holt and Commoner[6] introduce the concept of information flow through a system in the context of state machines.

Simple nets, Petri nets in which every transition has at most one shared input place, have been used by Patil[7] to establish the correspondence between cooperating sequential processes[8] and Petri nets. Simple nets represent the flow of control in processes where the processes do not use conditional statements and the only synchronizing primitives are Dijkstra's P and V operators.[8]

Applications suitable for Petri nets have been presented by numerous researchers. Dennis[9] has used Petri nets to describe the control mechanism of a computer with multiple functional units. For each of the units in the machine, Petri nets and modular control structures are presented. The control structures use primitive modules whose behavior is specified in terms of p-nets, abbreviated representations of Petri nets extensively used also by Peterson.[10] Dennis maintains that the ultimate goal of his studies is learning how to translate a Petri net specification into an efficient digital system.

Seitz[11] generalizes the Huffman primitive flow tables for asynchronous machines as a special form of Petri net called an m-net. He shows that an m-net can be used to design an asynchronous machine with concurrency in a manner similar to that in which Huffman tables

are utilized. The m-net concept is a practical representation which permits orderly design of machines difficult to design by other methods.

Shapiro and Saint[12] use Petri nets for the solution of an optimization problem, while Noe[13] introduces Petri nets with exclusive OR input, exclusive OR output, and inclusive OR input logics to describe a multiprocessor, multiprogramming system. Miller,[14] Misunas,[15] and Agerwala[1] relate speed-independent circuit theory to Petri net behavior.

Many researchers have attempted to test the power of Petri nets and have proposed extensions to the structure of the model to increase flexibility. Patil[7] presents a coordination problem unsolvable with simple Petri nets and proposes coordination nets, a generalization of Petri nets, in an attempt to reduce details and simplify representation. Kosaraju[16] displays problems unsolvable with general Petri nets. Agerwala[1] develops theorems concerning proof of correctness of Petri nets and proposes extensions to the general Petri net to increase net capabilities. Hack[17] relates Petri nets to Vector Addition Systems and points out decidability questions concerning both representations.

Research continues through the present in the recent concept of Petri net theory and applications. Continuing investigations by scientists strive to bring about additional results concerning net definition, capabilities, and correctness.

III. CAPABILITIES AND LIMITATIONS

The Petri net model is a powerful modeling tool, both because of its capability to represent most coordination problems and because it is easy to use and understand.

Petri nets have graphical appeal which help overcome the human reluctance to accept concurrent concepts, and the movement of tokens is a natural way to retain a history of the system to influence present behavior. It was believed for some time after the model was introduced that it could represent all classes of coordination problems. It is true that a very difficult activity can often be quickly and easily translated to Petri representation. Consider the following problem, for example.

The Cigarette Smokers' Problem

Three smokers are sitting at a table. One of them has tobacco, another has cigarette papers, and the third one has matches--each one has a different ingredient required to make and smoke a cigarette but he may not give any ingredient to another. On the table in front of them, two of the three ingredients will be placed, and the smoker who has the necessary third ingredient should pick up the ingredients from the table, make a cigarette, and smoke it. Since a new set of ingredients will not be placed on the table until this action is completed, the other smokers who cannot make and smoke a cigarette with the ingredients on the table must not interfere with the smoker who can. The process which supplies the ingredients cannot be changed, and no conditional statements can be used.

This problem can easily be modeled with Petri nets as illustrated by Figure II.2.

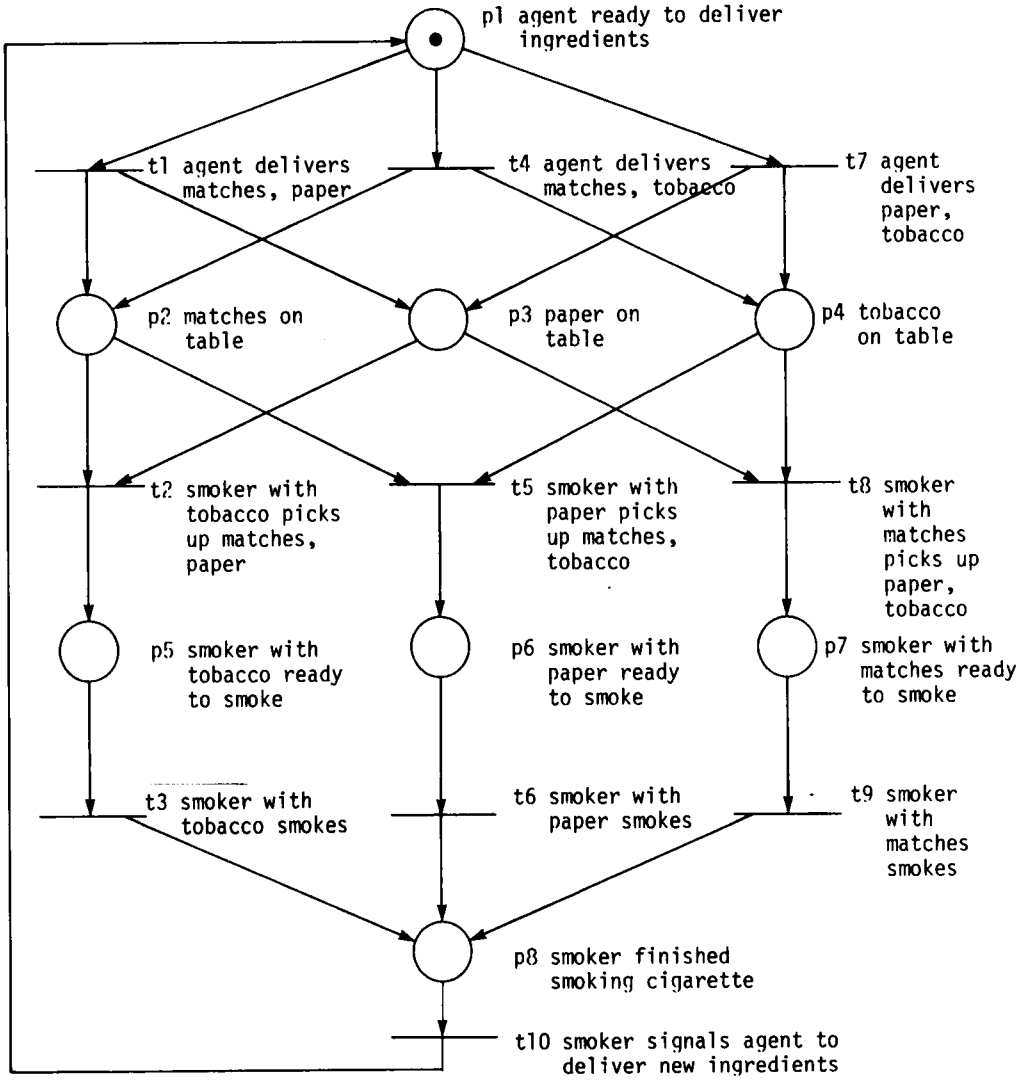


Figure II.2

Petri Net of the Cigarette Smokers' Problem

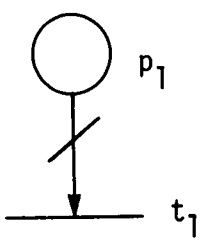
Most other modeling schemes would demand an elaborate representation if they could model the Smokers' Problem at all. Indeed, Dijkstra's P and V operations[8] demand arrays of semaphores, as shown by Parnas,[18] to accomplish the representation.

However, Kosaraju[16] has shown by example that the Petri net model is not complete in that it cannot represent the coordination for the following problem.

The Producer-Consumer Problem

There are four processes: Producer 1, Producer 2, Consumer 1, and Consumer 2. Producers 1 and 2 produce items and place them in unbounded buffers A and B, respectively. These four asynchronous processes must interact in some manner so that a consumer does not try to consume when its buffer is empty. In addition, Consumers 1 and 2 share the channel through which they access their own buffers; Consumer 1 is given priority so that Consumer 2 can consume only if Consumer 1's buffer A is empty.

Various researchers have responded to the challenge to extend the Petri model to attain a complete model for representing asynchronous processes. Agerwala[1] proposes an extended Petri net. It adds to the model another arc between places and transitions:



This arc represents NOT input logic. More formally, in the preceding example, t_1 is enabled if and only if $P_1 = 0$. With this extension, Kosaraju's problem can be easily represented as shown in Figure II.3.

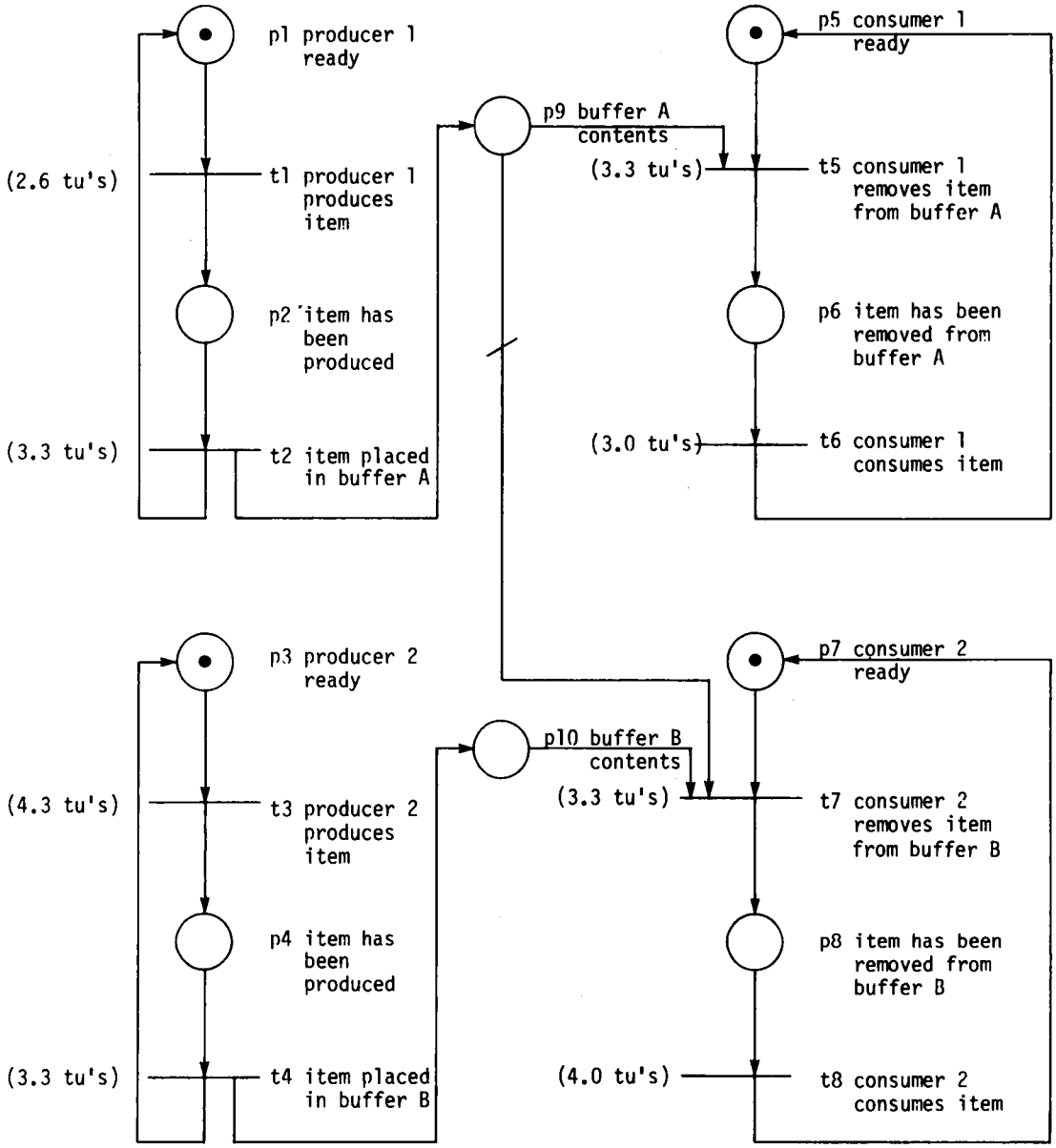


Figure II.3

Petri Net of the Producer-Consumer Problem

It appears that the Petri model is applicable for the vast majority of coordination representations and that Agerwala's extension would comprise a complete model for complex coordination modeling tasks. Patil[19] has used the Petri model as a basis for the development of coordination nets. A coordination net is a Petri net with a constraint set, a set of places which may not simultaneously contain tokens. It is obvious that this extension also could easily represent Kosaraju's problem.

It should be noted that these models possess certain analytical properties related to desired behavior which are difficult to predict. Hack[17] proves that given two Petri nets with the same number of places and each a given initial marking, it is undecidable in general whether every marking reachable in one net is also reachable in the other. Perhaps of greater significance are the problems of determining liveness and reachability sets for a net. Hack suggests that the problems of liveness and reachability in Petri nets are undecidable. It is questionable whether other comparable models can perform more effectively in the areas, but the modeler should be aware of the possible indeterminate situations when using the Petri net model.

CHAPTER III

COMPARISON OF THE PETRI NET MODEL WITH OTHER MODELS OF CONCURRENCY

In the years since Petri proposed the first Petri net model, a large number of models for analyzing the sequences of control in a system of parallel processes have been presented. These models range from the basic, rigid classes to very powerful, generalized models. To evaluate the significance of Petri nets on the state of the art of parallel computation, it is advantageous to examine these other concurrency models in some detail.

I. PRIMITIVE MODELS

One of the more obvious ways to restrict a model is to limit its state space to a finite number of states. Several basic models impose this limit effectively to represent a machine in which the future of an occurrence can depend only on a finite number of different "past histories," or states.

The most well-known finite state model is the finite state machine.[20] A finite state machine is a quintuple $M = (Q, X, Y, \delta, \lambda,)$ where

Q is a finite set of states;

X is a finite set of input symbols;

Y is a finite set of output symbols;

δ: $Q \times X \rightarrow Q$, the next state function;

λ: $Q \times X \rightarrow y$, the next output function.

If given an input x while in state q, the finite state machine will output the symbol $\lambda(q,x)$. λ and δ are together the transition function of the finite state machine. The state of the machine at any given moment depends upon the inputs it has received and upon its previous states.

A state diagram is used to conveniently describe a finite state machine (Figure III.1). Each state is represented by a circle and each transition between states is represented by an arrow. The input symbol causing the transition appears at the tail of the arrow and the corresponding output symbol is inserted in the middle of the arrow.

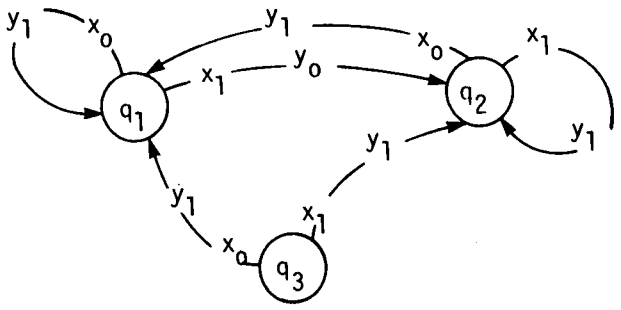


Figure III.1

Finite State Diagram. States q_1, q_2, q_3; Inputs x_0, x_1; Outputs y_0, y_1

The finite state machine can be compared directly to the Petri net model since a finite state machine is a Petri net for which every transition has exactly one input place (state) and exactly one output place (state). Thus, any finite state machine can be represented by the Petri net model.[6]

Several other finite models have been presented by researchers. Another restriction of the Petri net model is the marked graph. A marked graph is defined as a Petri net with no pair of transitions sharing input or output places.[6] This model has received considerable attention because researchers have succeeded in proving a number of theorems about marked graphs concerning deadlocks and finite properties.[21] However, the marked graph model is even less flexible than the finite state machine and cannot model data-dependent decisions.[22]

Bredt has defined a model of parallel processes connected by communication lines.[23] The lines carry signals between processes, and each process is modeled as a finite state machine. Signals propagate along the lines at a finite non-zero speed while the processes execute asynchronously. This model is a finite state machine since the total state of the system is specified by the composition of a finite number of finite state machines and a finite number of communication lines with finite states. Since any finite state machine can be represented by Bredt's model by presenting it as a system whose single process is the finite state machine, Bredt's model and the finite state machine model are equivalent.[22]

Gilbert and Chandler have developed a model whose processes communicate via a common memory.[24] A process when modeled as a finite state machine can read, write, or test the common memory. Since the memory contains a finite number of locations which may have a finite set of values, the Gilbert and Chandler model is equivalent to the finite state machine model.

Still another finite model has been advocated by Rodriguez.[25] His program graph model is a directed graph with nodes representing operations and arcs representing data and control information. Each arc is associated with a ready, idle, blocked, or disabled status. A table of transitions lists the status value combinations which enable an operation and the new status values assigned to arcs after execution. The state of the program graph is the set of statuses of its arcs. There are only a finite number of arcs in the model; therefore, this model is also equivalent to the finite state machine.

The primitive models discussed are rather inflexible and obviously limited in the types of concurrent processes they can represent. However, for the problems which fit into their descriptions, these models can be a most effective, clearly understood tool. Since each can be expressed in terms of Petri nets, the finite models offer nothing beyond the capabilities of the Petri net but may be preferred in appropriate situations where the greater power of Petri nets would serve only to complicate a straightforward process.

II. INTERMEDIATE MODELS

More sophisticated modeling techniques remove the restrictions of a finite space to expand the capabilities of the model. Computation graphs[26] achieve this greater flexibility through modeling based on a labeled directed graph. This model is both data and control oriented and was originally devised as a graphical model to represent parallelism in simple repetitive processes. Each node of the graph is associated with an operation, and each edge represents a first-in first-out queue of data directed from one node to another. Executing an operation takes operands off incoming edges and places results on outgoing edges. An operation is enabled only if there are sufficient operands on incoming edges.

In general, the quadruple M = (A, U, W, T) is associated with each edge where

A is the initial number of items on the edge;

U is the number of results placed on the edge each time the operation at the tail of the edge fires;

W is the number of operands removed from the edge each time the operation at the head of the arrow fires;

T is the number of items required as operands for the operation at the head of the arrow.

The computation graph model (Figure III.2) appears to be similar to the Petri net representation. Indeed, the marked graph, which is a subset of the Petri net, can directly be transformed to a computation graph with U=W=T=1 on each edge and with A=1 where initial tokens were placed on the marked graph and A=0 otherwise.[26] However, upon closer

examination, it appears that computation graphs differ in several ways from Petri nets. An obvious difference is that the computation graph represents both data and control structures while the Petri net is oriented strictly to control, the major concern of this comparison. A more significant difference for evaluating flexibility in modeling concurrent processes is the computation graph's inability to share an edge among nodes. The computation graph is therefore unable to model OR input or output logic and subsequently lacks the Petri facility for conditional branching.

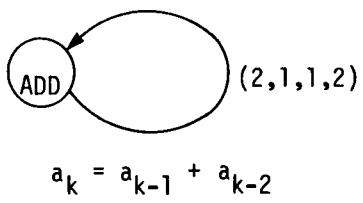


Figure III.2

A Simple Computation Graph

The well-known P/V system model[8] outlined by Dijkstra is more control-oriented and alleviates some of the limitations of computation graphs. An integer semaphore is assigned to each resource; a P operation is performed when the resource is needed and a V operation is performed when a resource is released:

```
P:  SEMAPHORE = SEMAPHORE - 1;
    IF SEMAPHORE ≥ 0
       then Return
    else
       put "Requesting Process" on Wait List for SEMAPHORE,
       mark process blocked,
       exit to Dispatcher.
V:  SEMAPHORE = SEMAPHORE + 1;
    IF SEMAPHORE ≤ 0
       then select a process on Wait List for SEMAPHORE,
       mark process ready,
       Return
    else
       Return.
```

Note that a Return could be a return to the "Requesting Process" or an exit to the Dispatcher depending upon the implementation. The P operation decrements the semaphore and returns if the semaphore is not negative (indicating that the resource is available) or places the requestor in the WAIT state otherwise. The V operation increments the semaphore and returns if the semaphore is not greater than zero (indicating that there are no processes waiting on the resource) or awakens some process waiting for the resource otherwise.

For control processes note that a P/V system with a semaphore associated with each arc is a computation graph; the P/V system can model the computation graph even though computation graphs use AND

logic because there is no possibility of deadlock since arcs are not shared between operations in computation graphs. A finite state machine with each node of the state diagram treated as a process with an input semaphore can easily be transformed into the P/V system. The P/V system is more flexible than any of the previously discussed models because its feature of shared semaphores permits OR input and output logic. On the other hand, the P/V system's inability to model AND logic prevents its equivalence to the Petri model.

Parnas[18] shows that the P/V system model is capable of expressing the desired coordination for the Smokers' Problem discussed in Chapter II. The P/V solution is an involved representation using a semaphore array:

The Agent

R_a		R_b		R_c		
r_a:	P(s) V(b) V(c) go to r_a	r_b:	P(s) V(a) V(c) go to r_b	r_c:	P(s) V(a) V(b) go to r_c	initially s = 1 and a,b,c,X,Y, and Z = 0
β_x:	P(X) V(s) go to β_x	β_y:	P(Y) V(s) go to β_y	β_z:	P(Z) V(s) go to β_z	

The Coordination Processes

```
δa: P(a)          δb: P(b)          δc: P(c)
    P(mutex)          P(mutex)          P(mutex)      initially mutex =
    t=t+1             t=t+2             t=t+4         1, t = 0 and
    V(S(t))           V(S(t))           V(S(t))       semaphore array
    V(mutex)          V(mutex)          V(mutex)      S(1:6) = 0
    go to δa          go to δb          go to δc
```

The Smokers

```
αx: P(S(6))       αy: P(S(5))       αz: P(S(3))
    t=0               t=0               t=0
    (Smoker with      (Smoker with      (Smoker with
     tobacco smokes)   paper smokes)     matches smokes)
    V(X)              V(Y)              V(Z)
    go to αx          go to αy          go to αz
```

Semaphore Overflow Handling

```
δ1: P(S(1))       δ2: P(S(2))       δ4: P(S(4))
    go to δ1          go to δ2          go to δ4
```

Although the P/V system model of the Smokers' Problem is an adequate representation, its complexity contrasts noticeably to the clarity and simplicity of the Petri solution of Figure II.2 on page 11.

A P/V system with message types has been defined as a message transmission system.[27] Each process is modeled by a program in a modeling language which allows messages to be sent and received, the type of messages to be set and tested, and uninterpreted tests and jumps to be made.

These and similar intermediate models move closer to the relative completeness of the Petri net model and are useful for many asynchronous modeling problems.

III. EQUIVALENT MODELS

There are several well-known modeling schemes which have modeling power equivalent to the capabilities of the Petri net. Perhaps the most similar in appearance to the Petri net model is the complex bilogic directed graph, also known as the UCLA graph.[28] It consists of arcs and nodes where the nodes represent operations or computations. At each node there is either OR logic or AND logic between the input arcs and similarly OR or AND logic between the output arcs. OR input signifies that the node can execute if any one of the input arcs is enabled (carries a token). AND input requires all input arcs to be enabled before the node can execute. OR output logic causes a token to be placed on one of the output arcs when the node executes, while AND output will cause a token to be placed on all of the output arcs (Figures III.3 and III.4). Arcs with multiple heads and tails are allowed.

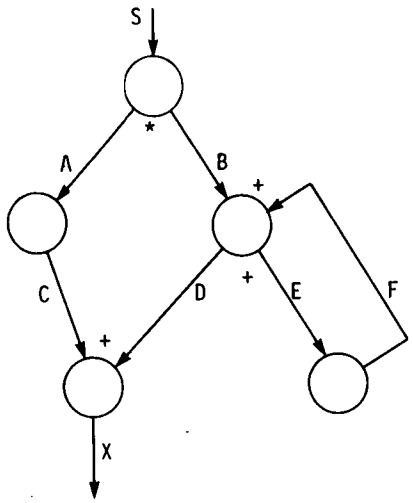


Figure III.3

UCLA Graph Example

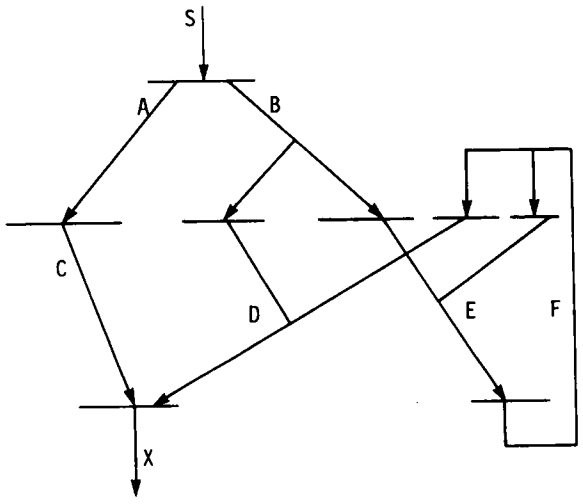


Figure III.4

Petri Conversion of UCLA Graph
Example of Figure III.3

A simple correspondence is established between the Petri net model and the UCLA graph by replacing transition bars with nodes with AND input and AND output logic. To convert a UCLA graph to a Petri net demands replacing a node with AND input and AND output with a transition bar; nodes with OR logic requires special but uniform handling as shown in Figure III.5. Thus the two models are equivalent; choice of use is subject to personal preference and the problem to be modeled.

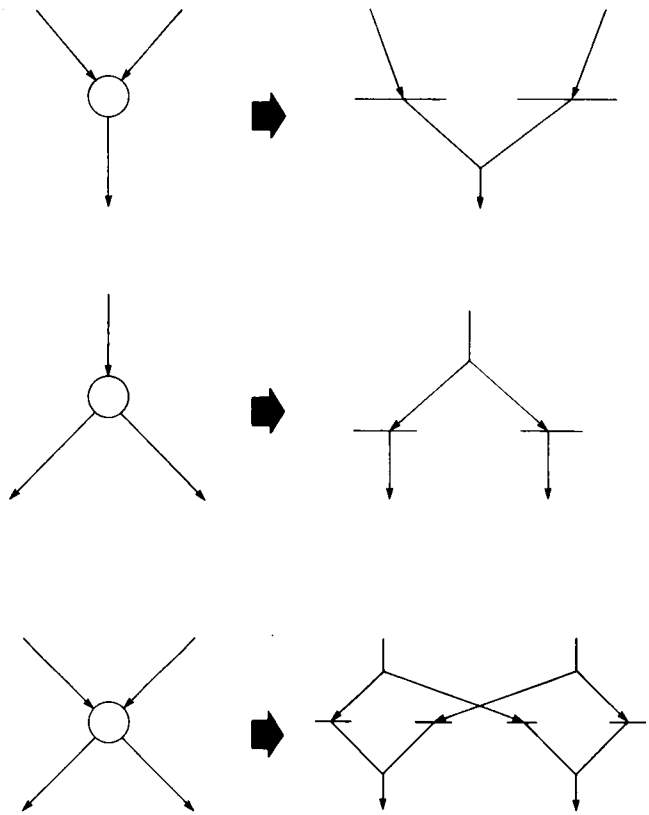


Figure III.5

UCLA-Petri Conversion Rules

Another recognized model similar to Petri nets is the Slutz flow graph schemata.[29] This model is composed of nodes or vertices, counters, and arcs. The vertices represent operations or computations, and the counters represent the control state of the arcs just as the number of tokens on an arc represent the control state of the UCLA graph. An example of a flow graph schemata is given in Figure III.6. Arcs are labeled with numbers to indicate the amount by which a counter is changed when an operation is executed. No explicit representation of input or output logic is provided; if the logic is unspecified by interpretation AND logic is assumed.

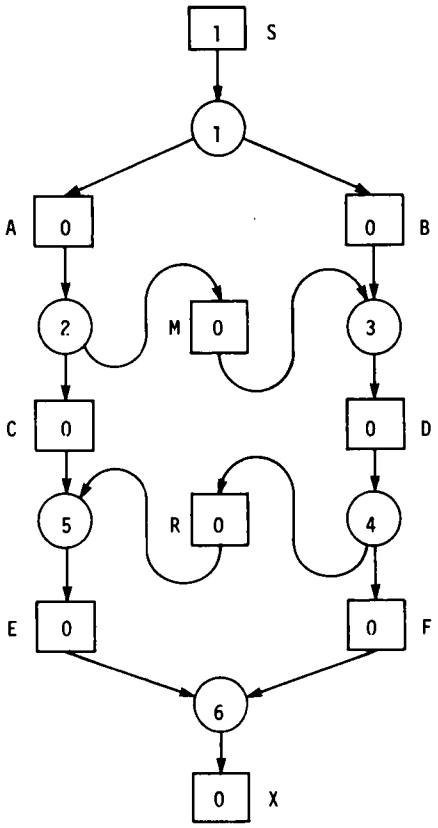


Figure III.6

Slutz Flow Graph Example

Karp and Miller examined flow graph schemata using the vector addition system.[30] A vector is made up of as many elements as there are counters in the schemata, and the value of each element is the change in the value of the corresponding counter. A vector exists for each transition or execution of a vertex in the graph. Figure III.7 illustrates the vector addition system equivalent to the Slutz representation of Figure III.6.

```
 S A B C D E F M R X
-1 1 1 0 0 0 0 0 0 0     S→A,B;
 0-1 0 1 0 0 0 1 0 0     A→C,M;
 0 0-1 0 1 0 0-1 0 0     M,B→D;
 0 0 0 0-1 0 1 0 1 0     D→F,R;
 0 0 0-1 0 1 0 0-1 0     C,R→E;
 0 0 0 0 0-1-1 0 0 1     E,F→X;
```

Figure III.7

Vector Addition System Example

A T-counter transition system[30] has been introduced as a modeling tool equivalent to vector addition systems. Vector replacement systems[31] (VRS) have also been introduced as a generalization or extension of vector addition systems.

Several advantages are derived from examining the relation between Petri nets and vector replacement systems, the most important of which is that both net markings and the action of a transition's firing can be expressed as vectors. The behavior of a Petri net model can thus be expressed using very simple vector arithmetic.

A vector replacement system is a system having a possibly infinite set of distinguishable states, a finite set of transitions that describe state changes, and an initial state. A VRS is defined as a quadruple, (q_0, Σ, U, V), where:

1) The set of states is contained in or equivalent to IN^r, where IN = non-negative integers and r = the dimension of the VRS
2) q_0 is the initial state, q_0 in Q
3) Σ is the set of transitions, $\Sigma = \{t_1, t_2, \ldots, t_s\}$
4) U and V are r-dimensional vectors (functions) with the following properties (for some transition t_i):
   a) $U(t_i)$ is called a <u>test vector</u> for t_i,
   b) $V(t_i)$ is called a <u>replacement vector</u> for t_i,
   c) $U(t_i) \leq V(t_i)$,
   d) t_i changes the state of the VRS from q to q′ if $q + U(t_i) \geq 0$ and $q + V(t_i) = q'$.

With the above definitions, the relations between a VRS and a Petri net can be established. The dimension, r, of a VRS is equivalent to the number of places in a Petri net. The initial state q_0 is equivalent to the initial marking of the Petri net. The negative coordinates of $U(t_i)$ define the places in the Petri net with arcs incident upon t_i, and the number of tokens which must be in each of those places before t_i may fire (positive coordinates of a test vector $U(t_i)$ do not matter; all such coordinates could just as well be set to zero). $V(t_i)$ simply describes the effect of firing t_i and gives the new marking. The set of states Q is the reachability set.

It is apparent that Petri nets and vector replacement systems are equivalent, and that any problem expressed in one can be translated easily into the other. The graphical appeal of Petri nets permits a better grasp for intuitive arguments, while the language of VRS's is convenient when studying such properties as liveness and reachability.

All of the models discussed in this section can represent the classes of problems modeled by the Petri net model; in a great number of cases the ease of use of the Petri net model rules it the logical choice for the parallel coordination problem. However, a specific problem may lend itself favorably to the use of one of the equivalent models due to the particular nature of the computation to be modeled.

IV. HIERARCHY OF WELL-KNOWN MODELS

It is useful to structure the classes of parallel computation models to determine more clearly their power relative to the Petri net model. Peterson gives such a hierarchy as shown in Figure III.8.[22] Three models appear more powerful than the ordinary Petri net: coordination nets, parallel program schemata, and finishing schemata.

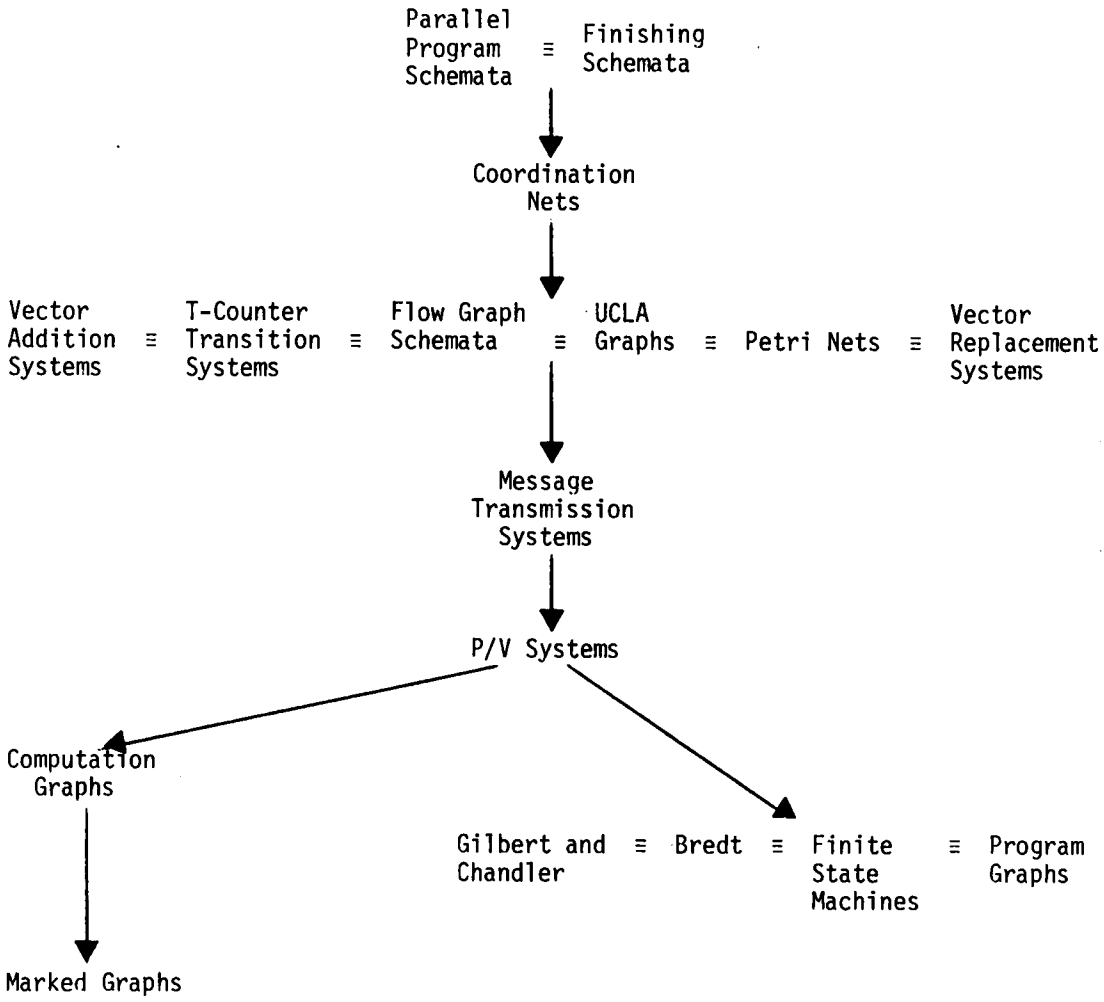


Figure III.8

Hierarchy of Well-known Models of Parallel Computation

The parallel program schemata[30] and finishing schemata[32] models are general models with domain and range locations for an operation defined but with the particular functions computed by a performance of an operation left undefined. An interpretation of the schemata specifies the functions.

As defined in Chapter II, a coordination net is a Petri net with a constraint set, i.e., a set of places which may not simultaneously contain tokens. Agerwala claims that coordination nets "are a generalization of Petri nets but do not add more variety to the class of coordinations represented by Petri nets."[1] This statement is disputed since Peterson[22] indicates that coordination nets are more powerful than Petri nets because they can generate $(a^n b^n)^*$ as a computation sequence set, a demand that Petri nets cannot meet. However, it is easily shown that Agerwala's extended Petri net with NOT input logic meets Peterson's criteria of generating $(a^n b^n)^*$ as a computation sequence set. The representation is straightforward as indicated in Figure III.9. The initial marking n in p1 corresponds to the specified n in the computation set. Close examination reveals a solution capable of generating $(a^n b^n)^*$ with no timing problems.

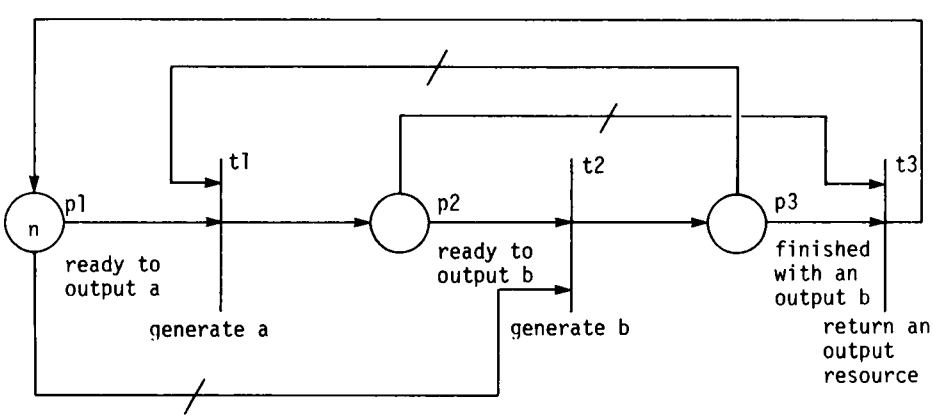


Figure III.9

Petri Representation of $(a^n b^n)^*$

The Peterson hierarchy can be modified to include the extended Petri net. The preceding discussion shows only that extended Petri net models are more powerful than ordinary Petri nets. Agerwala[33] has shown that extended Petri nets are computationally equivalent to Turing Machines; thus these models occupy the position at the very top of the hierarchy.

A simple proof of this result has been suggested by Hughes[34] and is achieved by showing that extended Petri nets are as powerful as register machines, which in turn are equivalent to Turing Machines. The following definitions and example illustrate this approach:

An n-register machine is a machine which has n registers, each capable of storing an arbitrarily large natural number. Manipulation of register contents is done by a program in which each instruction has a numeric label. The first instruction is labeled 1, the second 2, etc. Program execution begins at the instruction labeled 1 and terminates by a branch to label M+1 where the program contains M instructions. The instructions are each of the following form:

ADD_x (y) - add 1 to register x and jump to label y

SUB_x (y;z) - if register x = 0, jump to y; else subtract 1 from register x and jump to z.

The extended Petri net can easily model the coordination of the register machine. Figure III.10 illustrates a representative register machine program.

1. SUB_2 (3;2)
2. ADD_1 (1)
3. <terminate>

Figure III.10

A Representative Register Machine Program

This program adds register 2 to register 1 and places the result in register 1. The contents of register 2 are destroyed. Figure III.11 is an extended Petri net which can achieve the desired coordination for this program. Note that this net is live for some initial marking B^0 = {<p1, v2>, <p4, v1>} if and only if the register machine does not halt when register 1 equals v1 and register 2 equals v2.

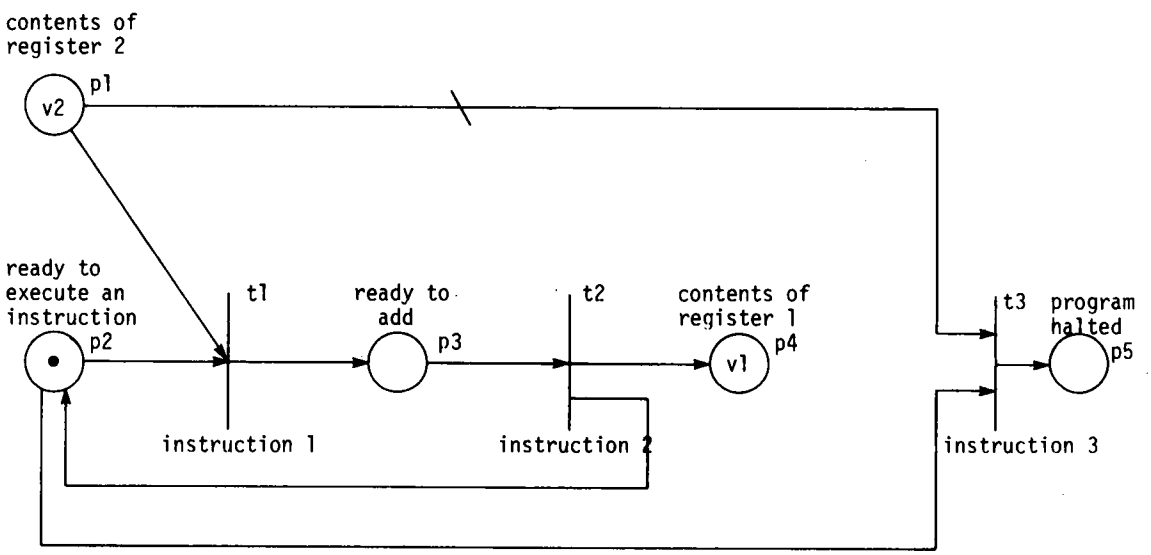


Figure III.11

Petri Representation of Figure III.10

This example illustrates that extended Petri nets can model register machines; therefore, the extended Petri net is computationally equivalent to the Turing Machine.

Agerwala shows the equivalence between extended Petri nets and Turing Machines by depicting a Turing Machine model as in Figure III.12.

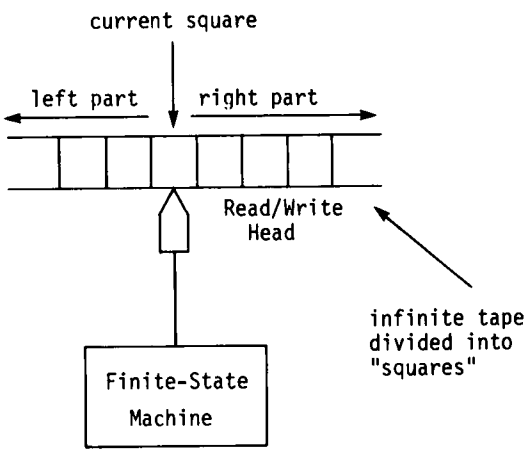


Figure III.12

A Turing Machine Model

In this model, in any one step, the finite state machine reads the current "square" under the head. Depending on the symbol read and the current state, it proceeds in one of the two ways: either (1) it prints a symbol on the current "square," moves the head left or right one "square" or leaves it where it is, and goes into a new state or (2) it decides to go into a special HALT state.

The effect of executing a step can be characterized by the effect on the current "squares" and on the left and right parts of the tape. Viewing the contents of these items as binary numbers, Agerwala uses the Petri net to develop "multiply nets" and "divide nets" which compute new binary values as the machine executes. Using these "nets," Figure III.13 gives the extended Petri net which simulates a left shift by the Turing Machine model. It is not difficult to see that this net could then be extended to completely model the behavior of the Turing Machine.

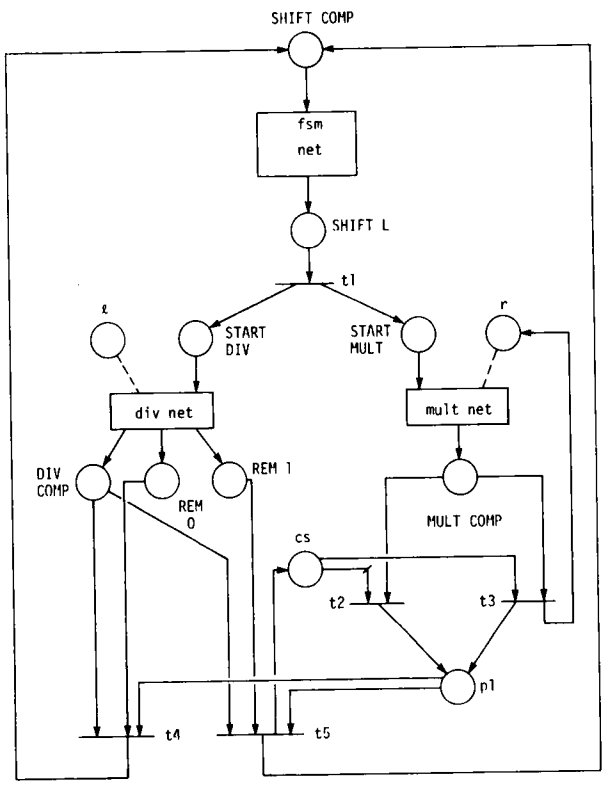


Figure III.13

Petri Net to Simulate a Turing Machine Left Shift

CHAPTER IV

IMPLEMENTATION OF PETRI MODEL

I. GOALS OF IMPLEMENTATION

The goal of Petri net model implementation is to attain a complete simulation of a concurrent process modeled with Petri nets in order to detect potential problem areas and better analyze process behavior. To accomplish this objective, it is desirable to construct an implementation with the following features:

a. Ability to simulate a wide variety of concurrent processes

b. Capability of terminating simulation according to predetermined requirements

c. Provision for statistical analysis of model simulation behavior

d. Flexibility in choice of selection among enabled transitions

e. Capability of specifying time units expended by transition firing.

II. LANGUAGE AND METHODS

A FORTRAN IV level G version 21 program was written to implement the Petri net simulation (see Appendix). The Agerwala extended Petri net was chosen as the model to be simulated because of its powerful

features and its simplicity in concept. If the NOT input feature is not utilized in the model input, the implementation becomes the classic Petri net model defined by Holt.[4]

Since information concerning such an implementation is either non-existent or unknown, an original scheme for implementation was devised. The model is described from input data containing information to be assembled as follows:

a. TINPT: array specifying all of the input places for each transition
b. NTINPT: array specifying all of the NOT input places for each transition
c. TOTPT: array specifying all of the output places from each transition
d. PMARK: initial marking of the net.

The above data are assembled and edited for Petri net validity rules, such as insuring that a place does not input and output the same transition. The program permits a variable number of transitions and places depending on modeling requirements and core availability. The examples herein use approximately 288 thousand bytes on an IBM 360 System and are capable of accepting 100 transitions and 200 places with as many as 50 places inputting one transition, 25 NOT places inputting one transition, and 50 places allowed as output from a single transition.

Specific time units may be assigned through input data to each transition of the model in array TRTIME to provide throughput data and other time associated calculations. If no time is specified, a default

value of one time unit is used. Weights may also be assigned to any transition for array TWEIGH. These weights are used to determine which transition is to fire when more than one transition is enabled. At the same time, this feature in effect provides the capability of assigning priorities to transitions to detect a wider range of behavior patterns. If all the transitions enabled are of the same weight or if no weights are assigned, a random selection of transition to be fired is made to imitate the arbitrary firing rule of Petri nets.

An optional interpretation of places and transitions may be provided from input data to be assembled in PDESC and TDESC respectively. This interpretation does not enhance the operation of the net, but it facilitates the user's working with the simulation.

Much attention is given in the program to termination specifications to increase the analytical capabilities of the implementation. There are five ways the user may terminate a simulation:

a. Deadlock

b. Completion of the requested time units

c. Completion of the requested total number of transition firings

d. Attainment of a minimum reachability set: each place in the net contains at least the number of tokens specified for that place

e. Attainment of a specified number of firings for each transition: each transition has fired at least the specified number of times.

It should be noted that there is always a default number of transition firings if a total number of firings is not specified in the termination input in order to avoid a simulation which cannot terminate because of the lack of reachability for the termination specifications for this simulation.

Statistics during and after the simulation form the heart of the implementation of the extended Petri net model. Before each firing, the marking of the net and the enabled transitions are displayed along with an indication of which transition is selected for firing. After the simulation has ended, very detailed statistical results of activity for each transition are provided along with a summary of activity for the entire simulation. These results include such data as the percent of time units and percent of firings each transition was enabled, firing percentages, and distribution of reasons the enabled transition did not fire. Wait statistics are detailed in a similar manner. In short, the statistics provide all the information necessary to analyze the activity of the concurrent process being modeled.

III. EXPERIMENTAL RESULTS

The Cigarette Smokers' Problem and the Producer-Consumer Problem discussed in Chapter II illustrate the power of the implementation.

The Cigarette Smokers' Problem was implemented exactly according to the problem description given in Chapter II. The Petri model in Figure II.2 on page 11 ensures continued smoking of cigarettes without reaching a deadlock. Interpretations and place and transition numbers

on the net diagram correspond to the simulation on the following pages in Tables IV.1 through IV.4. Choice for firing of ready transitions is random. Note that a time unit of one was assigned to each transition since time is not of great interest in this particular problem.

The Cigarette Smokers' Problem ably illustrates the simulation features and the Petri net ease of representation of a problem difficult for other modeling tools to model.

The Producer-Consumer Problem displays the analytical powers of the implementation. The problem is implemented as stated in Chapter II. Figure II.3 on page 13 shows the desired coordination and indicates the interpretations and place and transition numbers used by the simulation. In the simulation solution in Tables IV.5 through IV.8 on the following pages, choice for firing of enabled transitions is random. Characteristics of time units have been added to this problem as indicated in Figure II.3. Note that Process 1 is considerably faster than Process 2 according to an arbitrary enhancement of the stated problem. This simulation was terminated by at least 410.0 time units of transition firing time.

As is expected, Consumer 1's consumption process is ready more often than Consumer 2's process (47.1% of simulation time units versus 12.3%). However, what perhaps is not expected is a seemingly disproportionate backlog of items in Consumer 2's buffer B. Consumer 1 consumed 18 items with 1 item remaining in its buffer, while Consumer 2 consumed only 3 items with 17 items remaining in its buffer.

Simulation statistics reveal that Consumer 1's transition which removes an item from its buffer fires 32.1% of time ready, while

Table IV.1 Parameters for Petri Simulation of the Cigarette Smokers' Problem

```
ISIMULATION LIMITED BY BELOW SPECIFICATIONS!
NO. TRANSITIONS TO BE FIRED THIS RUN:  50
-------------------------------------------
TRANSITION TIME UNITS:
   1:    1.000
   2:    1.000
   3:    1.000
   4:    1.000
   5:    1.000
   6:    1.000
   7:    1.000
   8:    1.000
   9:    1.000
  10:    1.000
-------------------------------------------
INITIAL MARKING OF PETRI NET:
PMARK (I),I=  1 TO  200
   1:    1
-------------------------------------------
PLACE INPUT TO TRANSITIONS:
TINPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
   1     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     2
   2     3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     3
   5     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     4
   1     0    0 )  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     5
   2     4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     6
   6     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     7
   1     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     8
   3     4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     9
   7     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER    10
   8     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
-------------------------------------------
-NOT- PLACE INPUT TO TRANSITIONS:
NTINPT(I,J),J=  1   TO   25;   I=  1 TO  100
(NO NON-ZERO MEMBERS OF ARRAY)
```

Table IV.1 (Continued)

```
PLACE OUTPUT FROM TRANSITIONS:
TOTPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
    2    3     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     2
    5    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     3
    8    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     4
    2    4     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     5
    6    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     6
    8    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     7
    3    4     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     8
    7    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     9
    8    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER    10
    1    0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
-----------------------------------------
TRANSITION INTERPRETATIONS:
TDESC      1 :AGENT DELIVERS MATCHES AND PAPER
TDESC      2 :SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER
TDESC      3 :SMOKER WITH TOBACCO SMOKES
TDESC      4 :AGENT DELIVERS MATCHES AND TOBACCO
TDESC      5 :SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO
TDESC      6 :SMOKER WITH PAPER SMOKES
TDESC      7 :AGENT DELIVERS PAPER AND TOBACCO
TDESC      8 :SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO
TDESC      9 :SMOKER WITH MATCHES SMOKES
TDESC     10 :SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS
-----------------------------------------
PLACE INTERPRETATIONS:
PDESC      1 :AGENT PREPARED TO DELIVER NEW INGREDIENTS
PDESC      2 :MATCHES ON TABLE
PDESC      3 :PAPER ON TABLE
PDESC      4 :TOBACCO ON TABLE
PDESC      5 :SMOKER WITH TOBACCO PREPARED TO SMOKE
PDESC      6 :SMOKER WITH PAPER PREPARED TO SMOKE
PDESC      7 :SMOKER WITH MATCHES PREPARED TO SMOKE
PDESC      8 :SMOKER FINISHED SMOKING CIGARETTE
```

Table IV.2 Petri Simulation of the Cigarette Smokers' Problem

```
|====S I M U L A T I O N  S T A R T E D====|
-------------------------------------------
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    4     FIRED*:AGENT DELIVERS MATCHES AND TOBACCO              FIRING #    1
.....
MARKING:    0    1    0    1    0    0    0    0
READY:    5
*TRANSITION    5     FIRED*:SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO  FIRING #    2
.....
MARKING:    0    0    0    0    0    1    0    0
READY:    6
*TRANSITION    6     FIRED*:SMOKER WITH PAPER SMOKES                        FIRING #    3
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #    4
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    1     FIRED*:AGENT DELIVERS MATCHES AND PAPER                FIRING #    5
.....
MARKING:    0    1    1    0    0    0    0    0
READY:    2
*TRANSITION    2     FIRED*:SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER  FIRING #    6
.....
MARKING:    0    0    0    0    1    0    0    0
READY:    3
*TRANSITION    3     FIRED*:SMOKER WITH TOBACCO SMOKES                      FIRING #    7
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #    8
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    7     FIRED*:AGENT DELIVERS PAPER AND TOBACCO                FIRING #    9
.....
MARKING:    0    0    1    1    0    0    0    0
READY:    8
*TRANSITION    8     FIRED*:SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO  FIRING #   10
.....
MARKING:    0    0    0    0    0    0    1    0
READY:    9
*TRANSITION    9     FIRED*:SMOKER WITH MATCHES SMOKES                      FIRING #   11
```

Table IV.2 (Continued)

```
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   12
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    1     FIRED*:AGENT DELIVERS MATCHES AND PAPER                 FIRING #   13
.....
MARKING:    0    1    1    0    0    0    0    0
READY:    2
*TRANSITION    2     FIRED*:SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER   FIRING #   14
.....
MARKING:    0    0    0    0    1    0    0    0
READY:    3
*TRANSITION    3     FIRED*:SMOKER WITH TOBACCO SMOKES                       FIRING #   15
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   16
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    4     FIRED*:AGENT DELIVERS MATCHES AND TOBACCO               FIRING #   17
.....
MARKING:    0    1    0    1    0    0    0    0
READY:    5
*TRANSITION    5     FIRED*:SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO   FIRING #   18
.....
MARKING:    0    0    0    0    0    1    0    0
READY:    6
*TRANSITION    6     FIRED*:SMOKER WITH PAPER SMOKES                         FIRING #   19
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   20
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    1     FIRED*:AGENT DELIVERS MATCHES AND PAPER                 FIRING #   21
.....
MARKING:    0    1    1    0    0    0    0    0
READY:    2
*TRANSITION    2     FIRED*:SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER   FIRING #   22
```

Table IV.2 (Continued)

```
MARKING:    0    0    0    0    1    0    0    0
READY:    3
*TRANSITION    3     FIRED*:SMOKER WITH TOBACCC SMOKES                    FIRING #   23
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   24
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    1     FIRED*:AGENT DELIVERS MATCHES AND PAPER              FIRING #   25
.....
MARKING:    0    1    1    0    0    0    0    0
READY:    2
*TRANSITION    2     FIRED*:SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER   FIRING #   26
.....
MARKING:    0    0    0    0    1    0    0    0
READY:    3
*TRANSITION    3     FIRED*:SMOKER WITH TOBACCO SMOKES                    FIRING #   27
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   28
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    1     FIRED*:AGENT DELIVERS MATCHES AND PAPER              FIRING #   29
.....
MARKING:    0    1    1    0    0    0    0    0
READY:    2
*TRANSITION    2     FIRED*:SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER   FIRING #   30
.....
MARKING:    0    0    0    0    1    0    0    0
READY:    3
*TRANSITION    3     FIRED*:SMOKER WITH TOBACCC SMOKES                    FIRING #   31
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   32
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    4     FIRED*:AGENT DELIVERS MATCHES AND TOBACCO            FIRING #   33
```

Table IV.2 (Continued)

```
MARKING:    0    1    0    1    0    0    0    0
READY:    5
*TRANSITION    5     FIRED*:SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO   FIRING #   34
.....
MARKING:    0    0    0    0    0    1    0    0
READY:    6
*TRANSITION    6     FIRED*:SMOKER WITH PAPER SMOKES                         FIRING #   35
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   36
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    7     FIRED*:AGENT DELIVERS PAPER AND TOBACCO.                FIRING #   37
.....
MARKING:    0    0    1    1    0    0    0    0
READY:    8
*TRANSITION    8     FIRED*:SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO   FIRING #   38
.....
MARKING:    0    0    0    0    0    0    1    0
READY:    9
*TRANSITION    9     FIRED*:SMOKER WITH MATCHES SMOKES                       FIRING #   39
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TC DELIVER NEW INGREDIENTS  FIRING #   40
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    7     FIRED*:AGENT DELIVERS PAPER AND TOBACCO                 FIRING #   41
.....
MARKING:    0    0    1    1    0    0    0    0
READY:    8
*TRANSITION    8     FIRED*:SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO   FIRING #   42
.....
MARKING:    0    0    0    0    0    0    1    0
READY:    9
*TRANSITION    9     FIRED*:SMOKER WITH MATCHES SMOKES                       FIRING #   43
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TC DELIVER NEW INGREDIENTS  FIRING #   44
```

Table IV.2 (Continued)

```
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    7     FIRED*:AGENT DELIVERS PAPER AND TOBACCO                FIRING #   45
.....
MARKING:    0    0    1    1    0    0    0    0
READY:    8
*TRANSITION    8     FIRED*:SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO   FIRING #   46
.....
MARKING:    0    0    0    0    0    0    1    0
READY:    9
*TRANSITION    9     FIRED*:SMOKER WITH MATCHES SMOKES                      FIRING #   47
.....
MARKING:    0    0    0    0    0    0    0    1
READY:   10
*TRANSITION   10     FIRED*:SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS  FIRING #   48
.....
MARKING:    1    0    0    0    0    0    0    0
READY:    1    4    7
*TRANSITION    4     FIRED*:AGENT DELIVERS MATCHES AND TOBACCO               FIRING #   49
.....
MARKING:    0    1    0    1    0    0    0    0
READY:    5
*TRANSITION    5     FIRED*:SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO   FIRING #   50
.....
**********REQUESTED NO. FIRINGS COMPLETED**********
```

Table IV.3 Transition Summary Statistics for Petri Simulation of the Cigarette Smokers' Problem

```
SUMMARY OF ACTIVITY FOR TRANSITION    1            AGENT DELIVERS MATCHES AND PAPER

..FIRING STATISTICS:
   READY:  26.0% OF SIMULATION TIME UNITS   ---  13.0 TIME UNITS      (  13  FIRINGS)
   FIRED:  38.5% OF TIME READY   ---   5 FIRINGS   ---   5.0 TU'S     (  10.0% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  30.8% OF TIME READY OR    4    FIRINGS TRANSITION    4    SELECTED INSTEAD  AGENT DELIVERS MATCHES AND TOBACCO
   -  30.8% OF TIME READY OR    4    FIRINGS TRANSITION    7    SELECTED INSTEAD  AGENT DELIVERS PAPER AND TOBACCO
..WAIT STATISTICS:
   WAITING:  74.0% OF SIMULATION TIME UNITS   ---  37.0 TIME UNITS     (  37  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    1 AGENT PREPARED TO DELIVER NEW INGREDIENTS
..LAST FIRING WAS FIRING #   29 ..LAST TIME READY WAS FIRING #   49


SUMMARY OF ACTIVITY FOR TRANSITION    2            SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER

..FIRING STATISTICS:
   READY:  10.0% OF SIMULATION TIME UNITS   ---   5.0 TIME UNITS      (   5  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   5 FIRINGS   ---   5.0 TU'S     (  10.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  90.0% OF SIMULATION TIME UNITS   ---  45.0 TIME UNITS     (  45  FIRINGS)
   REASONS NOT READY:
   -  82.2% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    2 MATCHES ON TABLE
                                                       PLACE    3 PAPER ON TABLE
   -   8.9% OF WAIT TU'S OR    4.0 TU'S (   4 FIRINGS) WAITING ON PLACE    3 PAPER ON TABLE
   -   8.9% OF WAIT TU'S OR    4.0 TU'S (   4 FIRINGS) WAITING ON PLACE    2 MATCHES ON TABLE
..LAST FIRING WAS FIRING #   30 ..LAST TIME READY WAS FIRING #   30


SUMMARY OF ACTIVITY FOR TRANSITION    3            SMOKER WITH TOBACCO SMOKES

..FIRING STATISTICS:
   READY:  10.0% OF SIMULATION TIME UNITS   ---   5.0 TIME UNITS      (   5  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   5 FIRINGS   ---   5.0 TU'S     (  10.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  90.0% OF SIMULATION TIME UNITS   ---  45.0 TIME UNITS     (  45  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   45.0 TU'S (  45 FIRINGS) WAITING ON PLACE    5 SMOKER WITH TOBACCO PREPARED TO SMOKE
..LAST FIRING WAS FIRING #   31 ..LAST TIME READY WAS FIRING #   31
```

Table IV.3 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION    4            AGENT DELIVERS MATCHES AND TOBACCO

..FIRING STATISTICS:
   READY:  26.0% OF SIMULATION TIME UNITS   ---  13.0 TIME UNITS      (  13  FIRINGS)
   FIRED:  30.8% OF TIME READY   ---   4 FIRINGS   ---   4.0 TU'S     (   8.0% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  38.5% OF TIME READY OR    5    FIRINGS TRANSITION    1    SELECTED INSTEAD  AGENT DELIVERS MATCHES AND PAPER
   -  30.8% OF TIME READY OR    4    FIRINGS TRANSITION    7    SELECTED INSTEAD  AGENT DELIVERS PAPER AND TOBACCO
..WAIT STATISTICS:
   WAITING:  74.0% OF SIMULATION TIME UNITS   ---  37.0 TIME UNITS     (  37  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    1 AGENT PREPARED TO DELIVER NEW INGREDIENTS
..LAST FIRING WAS FIRING #   49 ..LAST TIME READY WAS FIRING #   49


SUMMARY OF ACTIVITY FOR TRANSITION    5            SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO

..FIRING STATISTICS:
   READY:   8.0% OF SIMULATION TIME UNITS   ---   4.0 TIME UNITS      (   4  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   4 FIRINGS   ---   4.0 TU'S     (   8.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  92.0% OF SIMULATION TIME UNITS   ---  46.0 TIME UNITS     (  46  FIRINGS)
   REASONS NOT READY:
   -  80.4% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    2 MATCHES ON TABLE
                                                       PLACE    4 TOBACCO ON TABLE
   -  10.9% OF WAIT TU'S OR    5.0 TU'S (   5 FIRINGS) WAITING ON PLACE    4 TOBACCO ON TABLE
   -   8.7% OF WAIT TU'S OR    4.0 TU'S (   4 FIRINGS) WAITING ON PLACE    2 MATCHES ON TABLE
..LAST FIRING WAS FIRING #   50 ..LAST TIME READY WAS FIRING #   50


SUMMARY OF ACTIVITY FOR TRANSITION    6            SMOKER WITH PAPER SMOKES

..FIRING STATISTICS:
   READY:   6.0% OF SIMULATION TIME UNITS   ---   3.0 TIME UNITS      (   3  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   3 FIRINGS   ---   3.0 TU'S     (   6.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  94.0% OF SIMULATION TIME UNITS   ---  47.0 TIME UNITS     (  47  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   47.0 TU'S (  47 FIRINGS) WAITING ON PLACE    6 SMOKER WITH PAPER PREPARED TO SMOKE
..LAST FIRING WAS FIRING #   35 ..LAST TIME READY WAS FIRING #   35
```

Table IV.3 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION    7            AGENT DELIVERS PAPER AND TOBACCO

..FIRING STATISTICS:
   READY:  26.0% OF SIMULATION TIME UNITS   ---  13.0 TIME UNITS      (  13  FIRINGS)
   FIRED:  30.8% OF TIME READY   ---   4 FIRINGS   ---   4.0 TU'S     (   8.0% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  38.5% OF TIME READY OR    5    FIRINGS TRANSITION    1    SELECTED INSTEAD  AGENT DELIVERS MATCHES AND PAPER
   -  30.8% OF TIME READY OR    4    FIRINGS TRANSITION    4    SELECTED INSTEAD  AGENT DELIVERS MATCHES AND TOBACCO
..WAIT STATISTICS:
   WAITING:  74.0% OF SIMULATION TIME UNITS   ---  37.0 TIME UNITS      (  37  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    1 AGENT PREPARED TO DELIVER NEW INGREDIENTS
..LAST FIRING WAS FIRING #   45 ..LAST TIME READY WAS FIRING #   49


SUMMARY OF ACTIVITY FOR TRANSITION    8            SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO

..FIRING STATISTICS:
   READY:   8.0% OF SIMULATION TIME UNITS   ---   4.0 TIME UNITS      (   4  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   4 FIRINGS   ---   4.0 TU'S     (   8.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  92.0% OF SIMULATION TIME UNITS   ---  46.0 TIME UNITS      (  46  FIRINGS)
   REASONS NOT READY:
   -  80.4% OF WAIT TU'S OR   37.0 TU'S (  37 FIRINGS) WAITING ON PLACE    3 PAPER ON TABLE
                                                       PLACE    4 TOBACCO ON TABLE
   -   8.7% OF WAIT TU'S OR    4.0 TU'S (   4 FIRINGS) WAITING ON PLACE    3 PAPER ON TABLE
   -  10.9% OF WAIT TU'S OR    5.0 TU'S (   5 FIRINGS) WAITING ON PLACE    4 TOBACCO ON TABLE
..LAST FIRING WAS FIRING #   46 ..LAST TIME READY WAS FIRING #   46


SUMMARY OF ACTIVITY FOR TRANSITION    9            SMOKER WITH MATCHES SMOKES

..FIRING STATISTICS:
   READY:   8.0% OF SIMULATION TIME UNITS   ---   4.0 TIME UNITS      (   4  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---   4 FIRINGS   ---   4.0 TU'S     (   8.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  92.0% OF SIMULATION TIME UNITS   ---  46.0 TIME UNITS      (  46  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   46.0 TU'S (  46 FIRINGS) WAITING ON PLACE    7 SMOKER WITH MATCHES PREPARED TO SMOKE
..LAST FIRING WAS FIRING #   47 ..LAST TIME READY WAS FIRING #   47
```

Table IV.3 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION   10          SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS

..FIRING STATISTICS:
   READY:  24.0% OF SIMULATION TIME UNITS   ---  12.0 TIME UNITS      (  12  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---  12 FIRINGS   ---  12.0 TU'S     (  24.0% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  76.0% OF SIMULATION TIME UNITS   ---  38.0 TIME UNITS     (  38  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR   38.0 TU'S (  38 FIRINGS) WAITING ON PLACE    8 SMOKER FINISHED SMOKING CIGARETTE
..LAST FIRING WAS FIRING #   48 ..LAST TIME READY WAS FIRING #   48
```

Table IV.4 Simulation Summary Statistics for Petri Simulation of the Cigarette Smokers' Problem

```
SIMULATION TERMINATED BY COMPLETION OF   50  REQUESTED TRANSITION FIRINGS
FINAL MARKING OF PETRI NET:
  PLACE     6 :    1              SMOKER WITH PAPER PREPARED TO SMOKE
FIRING STATISTICS:   TOTAL # FIRINGS =  50   ---  TOTAL TIME UNITS =  50.0
-TRANSITION     1: AGENT DELIVERS MATCHES AND PAPER
  .# FIRINGS =      5  OR    10.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     5.0  OR    10.0% OF TOTAL TIME UNITS
-TRANSITION     2: SMOKER WITH TOBACCO PICKS UP MATCHES AND PAPER
  .# FIRINGS =      5  OR    10.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     5.0  OR    10.0% OF TOTAL TIME UNITS
-TRANSITION     3: SMOKER WITH TOBACCO SMOKES
  .# FIRINGS =      5  OR    10.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     5.0  OR    10.0% OF TOTAL TIME UNITS
-TRANSITION     4: AGENT DELIVERS MATCHES AND TOBACCO
  .# FIRINGS =      4  OR     8.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     4.0  OR     8.0% OF TOTAL TIME UNITS
-TRANSITION     5: SMOKER WITH PAPER PICKS UP MATCHES AND TOBACCO
  .# FIRINGS =      4  OR     8.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     4.0  OR     8.0% OF TOTAL TIME UNITS
-TRANSITION     6: SMOKER WITH PAPER SMOKES
  .# FIRINGS =      3  OR     6.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     3.0  OR     6.0% OF TOTAL TIME UNITS
-TRANSITION     7: AGENT DELIVERS PAPER AND TOBACCO
  .# FIRINGS =      4  OR     8.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     4.0  OR     8.0% OF TOTAL TIME UNITS
-TRANSITION     8: SMOKER WITH MATCHES PICKS UP PAPER AND TOBACCO
  .# FIRINGS =      4  OR     8.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     4.0  OR     8.0% OF TOTAL TIME UNITS
-TRANSITION     9: SMOKER WITH MATCHES SMOKES
  .# FIRINGS =      4  OR     8.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =     4.0  OR     8.0% OF TOTAL TIME UNITS
-TRANSITION    10: SMOKER SIGNALS AGENT TO DELIVER NEW INGREDIENTS
  .# FIRINGS =     12  OR    24.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =    12.0  OR    24.0% OF TOTAL TIME UNITS
```

Table IV.5 Parameters for Petri Simulation 1 of the Producer-Consumer Problem

```
ISIMULATION LIMITED BY BELOW SPECIFICATIONS!
NO. TRANSITIONS TO BE FIRED THIS RUN:1000
TOTAL # TIME UNITS TO BE FIRED THIS RUN: 410.000
-----------------------------------------
TRANSITION TIME UNITS:
   1:   2.600
   2:   3.300
   3:   4.300
   4:   3.300
   5:   3.300
   6:   3.000
   7:   3.300
   8:   4.000
-----------------------------------------
INITIAL MARKING OF PETRI NET:
PMARK (I),I=  1 TO  200
   1:   1
   3:   1
   5:   1
   7:   1
-----------------------------------------
PLACE INPUT TO TRANSITIONS:
TINPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
   1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     2
   2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     3
   3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     4
   4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     5
   5    9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     6
   6    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     7
   7   10    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     8
   8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
-----------------------------------------
-NOT- PLACE INPUT TO TRANSITIONS:
NTINPT(I,J),J=  1   TO   25;   I=  1 TO  100
MEMBER     7
   9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

Table IV.5 (Continued)

```
PLACE OUTPUT FROM TRANSITIONS:
TOTPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
   2     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     2
   1     9     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     3
   4     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     4
   3    10     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     5
   6     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     6
   5     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     7
   8     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
MEMBER     8
   7     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
-----------------------------------------
TRANSITION INTERPRETATIONS:
TDESC      1 :PRODUCER 1 PRODUCES ITEM
TDESC      2 :PRODUCER 1 PLACES ITEM IN BUFFER A
TDESC      3 :PRODUCER 2 PRODUCES ITEM
TDESC      4 :PRODUCER 2 PLACES ITEM IN BUFFER B
TDESC      5 :CONSUMER 1 REMOVES ITEM FROM BUFFER A
TDESC      6 :CONSUMER 1 CONSUMES ITEM
TDESC      7 :CONSUMER 2 REMOVES ITEM FROM BUFFER B
TDESC      8 :CONSUMER 2 CONSUMES ITEM
-----------------------------------------
PLACE INTERPRETATIONS:
PDESC      1 :PRODUCER 1 READY
PDESC      2 :ITEM PRODUCED BY PRODUCER 1
PDESC      3 :PRODUCER 2 READY
PDESC      4 :ITEM PRODUCED BY PRODUCER 2
PDESC      5 :CONSUMER 1 READY
PDESC      6 :CONSUMER 1 READY TO CONSUME AN ITEM
PDESC      7 :CONSUMER 2 READY
PDESC      8 :CONSUMER 2 READY TO CONSUME AN ITEM
PDESC      9 :NO.ITEMS IN BUFFER A
PDESC     10 :NO.ITEMS IN BUFFER B
```

Table IV.6 Petri Simulation 1 of the Producer-Consumer Problem

```
|====S I M U L A T I O N  S T A R T E D====|
-------------------------------------------
MARKING:    1    0    1    0    1    0    1    0    0    0
READY:    1    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #    1
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #    2
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:    2    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #    3
.....
MARKING:    0    1    1    0    1    0    1    0    0    1
READY:    2    3    7
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #    4
.....
MARKING:    1    0    1    0    1    0    1    0    1    1
READY:    3    1    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #    5
.....
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:    3    5    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #    6
.....
MARKING:    0    1    0    1    1    0    1    0    1    1
READY:    5    2    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #    7
.....
MARKING:    0    1    0    1    0    1    1    0    0    1
READY:    2    4    6    7
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #    8
.....
MARKING:    1    0    0    1    0    1    1    0    1    1
READY:    4    6    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #    9
.....
MARKING:    1    0    0    1    1    0    1    0    1    1
READY:    4    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   10
.....
MARKING:    1    0    0    1    0    1    1    0    0    1
READY:    4    1    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #   11
```

Table IV.6 (Continued)

```
MARKING:    1    0    0    1    0    1    0    1    0    0
READY:      4    1    6    8
*TRANSITION    6      FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   12
.....
MARKING:    1    0    0    1    1    0    0    1    0    0
READY:      4    1    8
*TRANSITION    1      FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   13
.....
MARKING:    0    1    0    1    1    0    0    1    0    0
READY:      4    8    2
*TRANSITION    2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   14
.....
MARKING:    1    0    0    1    1    0    0    1    1    0
READY:      4    8    1    5
*TRANSITION    4      FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   15
.....
MARKING:    1    0    1    0    1    0    0    1    1    1
READY:      8    1    5    3
*TRANSITION    3      FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   16
.....
MARKING:    1    0    0    1    1    0    0    1    1    1
READY:      8    1    5    4
*TRANSITION    8      FIRED*:CONSUMER 2 CONSUMES ITEM                          FIRING #   17
.....
MARKING:    1    0    0    1    1    0    1    0    1    1
READY:      1    5    4
*TRANSITION    5      FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   18
.....
MARKING:    1    0    0    1    0    1    1    0    0    1
READY:      1    4    6    7
*TRANSITION    1      FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   19
.....
MARKING:    0    1    0    1    0    1    1    0    0    1
READY:      4    6    7    2
*TRANSITION    7      FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B             FIRING #   20
.....
MARKING:    0    1    0    1    0    1    0    1    0    0
READY:      4    6    2    8
*TRANSITION    2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   21
.....
MARKING:    1    0    0    1    0    1    0    1    1    0
READY:      4    6    8    1
*TRANSITION    8      FIRED*:CONSUMER 2 CONSUMES ITEM                          FIRING #   22
```

Table IV.6 (Continued)

```
MARKING:    1    0    0    1    0    1    1    0    1    0
READY:    4    6    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   23
.....
MARKING:    0    1    0    1    0    1    1    0    1    0
READY:    4    6    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   24
.....
MARKING:    0    1    1    0    0    1    1    0    1    1
READY:    6    2    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   25
.....
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:    2    3    5
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   26
.....
MARKING:    0    1    0    1    1    0    1    0    1    1
READY:    2    5    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   27
.....
MARKING:    0    1    1    0    1    0    1    0    1    2
READY:    2    5    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   28
.....
MARKING:    1    0    1    0    1    0    1    0    2    2
READY:    5    3    1
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   29
.....
MARKING:    1    0    1    0    0    1    1    0    1    2
READY:    3    1    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   30
.....
MARKING:    1    0    0    1    0    1    1    0    1    2
READY:    1    6    4
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   31
.....
MARKING:    1    0    0    1    1    0    1    0    1    2
READY:    1    4    5
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   32
.....
MARKING:    1    0    1    0    1    0    1    0    1    3
READY:    1    5    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   33
```

Table IV.6 (Continued)

```
MARKING:    1    0    0    1    1    0    1    0    1    3
READY:    1    5    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   34
.....
MARKING:    1    0    0    1    0    1    1    0    0    3
READY:    1    4    6    7
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   35
.....
MARKING:    0    1    0    1    0    1    1    0    0    3
READY:    4    6    7    2
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   36
.....
MARKING:    0    1    0    1    0    1    0    1    0    2
READY:    4    6    2    8
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   37
.....
MARKING:    1    0    0    1    0    1    0    1    1    2
READY:    4    6    8    1
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                       FIRING #   38
.....
MARKING:    1    0    0    1    0    1    1    0    1    2
READY:    4    6    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   39
.....
MARKING:    1    0    0    1    1    0    1    0    1    2
READY:    4    1    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   40
.....
MARKING:    0    1    0    1    1    0    1    0    1    2
READY:    4    5    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B             FIRING #   41
.....
MARKING:    0    1    1    0    1    0    1    0    1    3
READY:    5    2    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   42
.....
MARKING:    1    0    1    0    1    0    1    0    2    3
READY:    5    3    1
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   43
.....
MARKING:    1    0    1    0    0    1    1    0    1    3
READY:    3    1    6
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   44
```

Table IV.6 (Continued)

```
MARKING:    0    1    1    0    0    1    1    0    1    3
READY:    3    6    2
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   45
.....
MARKING:    1    0    1    0    0    1    1    0    2    3
READY:    3    6    1
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   46
.....
MARKING:    1    0    0    1    0    1    1    0    2    3
READY:    6    1    4
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   47
.....
MARKING:    0    1    0    1    0    1    1    0    2    3
READY:    6    4    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   48
.....
MARKING:    0    1    1    0    0    1    1    0    2    4
READY:    6    2    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   49
.....
MARKING:    1    0    1    0    0    1    1    0    3    4
READY:    6    3    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   50
.....
MARKING:    0    1    1    0    0    1    1    0    3    4
READY:    6    3    2
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   51
.....
MARKING:    0    1    1    0    1    0    1    0    3    4
READY:    3    2    5
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   52
.....
MARKING:    0    1    0    1    1    0    1    0    3    4
READY:    2    5    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   53
.....
MARKING:    0    1    1    0    1    0    1    0    3    5
READY:    2    5    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   54
.....
MARKING:    1    0    1    0    1    0    1    0    4    5
READY:    5    3    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   55
```

Table IV.6 (Continued)

```
MARKING:    0    1    1    0    1    0    1    0    4    5
READY:    5    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   56
.....
MARKING:    0    1    0    1    1    0    1    0    4    5
READY:    5    2    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   57
.....
MARKING:    0    1    0    1    0    1    1    0    3    5
READY:    2    4    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   58
.....
MARKING:    0    1    1    0    0    1    1    0    3    6
READY:    2    6    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   59
.....
MARKING:    0    1    0    1    0    1    1    0    3    6
READY:    2    6    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   60
.....
MARKING:    0    1    1    0    0    1    1    0    3    7
READY:    2    6    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   61
.....
MARKING:    0    1    0    1    0    1    1    0    3    7
READY:    2    6    4
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   62
.....
MARKING:    0    1    0    1    1    0    1    0    3    7
READY:    2    4    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   63
.....
MARKING:    0    1    0    1    0    1    1    0    2    7
READY:    2    4    6
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   64
.....
MARKING:    1    0    0    1    0    1    1    0    3    7
READY:    4    6    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   65
.....
MARKING:    1    0    0    1    1    0    1    0    3    7
READY:    4    1    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   66
```

Table IV.6 (Continued)

```
MARKING:    0    1    0    1    1    0    1    0    3    7
READY:      4    5    2
*TRANSITION 2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A              FIRING #   67
.....
MARKING:    1    0    0    1    1    0    1    0    4    7
READY:      4    5    1
*TRANSITION 1     FIRED*:PRODUCER 1 PRODUCES ITEM                        FIRING #   68
.....
MARKING:    0    1    0    1    1    0    1    0    4    7
READY:      4    5    2
*TRANSITION 4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B              FIRING #   69
.....
MARKING:    0    1    1    0    1    0    1    0    4    8
READY:      5    2    3
*TRANSITION 3     FIRED*:PRODUCER 2 PRODUCES ITEM                        FIRING #   70
.....
MARKING:    0    1    0    1    1    0    1    0    4    8
READY:      5    2    4
*TRANSITION 2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A              FIRING #   71
.....
MARKING:    1    0    0    1    1    0    1    0    5    8
READY:      5    4    1
*TRANSITION 5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A           FIRING #   72
.....
MARKING:    1    0    0    1    0    1    1    0    4    8
READY:      4    1    6
*TRANSITION 4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B              FIRING #   73
.....
MARKING:    1    0    1    0    0    1    1    0    4    9
READY:      1    6    3
*TRANSITION 1     FIRED*:PRODUCER 1 PRODUCES ITEM                        FIRING #   74
.....
MARKING:    0    1    1    0    0    1    1    0    4    9
READY:      6    3    2
*TRANSITION 6     FIRED*:CONSUMER 1 CONSUMES ITEM                        FIRING #   75
.....
MARKING:    0    1    1    0    1    0    1    0    4    9
READY:      3    2    5
*TRANSITION 3     FIRED*:PRODUCER 2 PRODUCES ITEM                        FIRING #   76
.....
MARKING:    0    1    0    1    1    0    1    0    4    9
READY:      2    5    4
*TRANSITION 4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B              FIRING #   77
```

Table IV.6 (Continued)

```
MARKING:    0    1    1    0    1    0    1    0    4   10
READY:    2    5    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   78
.....
MARKING:    0    1    0    1    1    0    1    0    4   10
READY:    2    5    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   79
.....
MARKING:    0    1    0    1    0    1    1    0    3   10
READY:    2    4    6
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   80
.....
MARKING:    1    0    0    1    0    1    1    0    4   10
READY:    4    6    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   81
.....
MARKING:    1    0    0    1    1    0    1    0    4   10
READY:    4    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   82
.....
MARKING:    1    0    0    1    0    1    1    0    3   10
READY:    4    1    6
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   83
.....
MARKING:    0    1    0    1    0    1    1    0    3   10
READY:    4    6    2
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   84
.....
MARKING:    0    1    0    1    1    0    1    C    3   10
READY:    4    2    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   85
.....
MARKING:    0    1    0    1    0    1    1    C    2   10
READY:    4    2    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   86
.....
MARKING:    0    1    1    0    0    1    1    0    2   11
READY:    2    6    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   87
.....
MARKING:    0    1    0    1    0    1    1    C    2   11
READY:    2    6    4
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   88
```

Table IV.6 (Continued)

```
MARKING:    0    1    0    1    1    0    1    0    2   11
READY:    2    4    5
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   89
.....
MARKING:    0    1    1    0    1    0    1    0    2   12
READY:    2    5    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   90
.....
MARKING:    0    1    0    1    1    0    1    0    2   12
READY:    2    5    4
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   91
.....
MARKING:    1    0    0    1    1    0    1    0    3   12
READY:    5    4    1
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   92
.....
MARKING:    1    0    1    0    1    0    1    0    3   13
READY:    5    1    3
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   93
.....
MARKING:    1    0    1    0    0    1    1    0    2   13
READY:    1    3    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   94
.....
MARKING:    1    0    0    1    0    1    1    0    2   13
READY:    1    6    4
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   95
.....
MARKING:    0    1    0    1    0    1    1    0    2   13
READY:    6    4    2
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   96
.....
MARKING:    0    1    0    1    1    0    1    0    2   13
READY:    4    2    5
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   97
.....
MARKING:    0    1    1    0    1    0    1    0    2   14
READY:    2    5    3
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   98
.....
MARKING:    0    1    1    0    0    1    1    0    1   14
READY:    2    3    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   99
```

Table IV.6 (Continued)

```
MARKING:    0    1    0    1    0    1    1    0    1   14
READY:    2    6    4
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  100
.....
MARKING:    0    1    0    1    1    0    1    0    1   14
READY:    2    4    5
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #  101
.....
MARKING:    1    0    0    1    1    0    1    0    2   14
READY:    4    5    1
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  102
.....
MARKING:    1    0    1    0    1    0    1    0    2   15
READY:    5    1    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  103
.....
MARKING:    1    0    0    1    1    0    1    0    2   15
READY:    5    1    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #  104
.....
MARKING:    1    0    0    1    0    1    1    0    1   15
READY:    1    4    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  105
.....
MARKING:    1    0    1    0    0    1    1    0    1   16
READY:    1    6    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  106
.....
MARKING:    1    0    1    0    1    0    1    0    1   16
READY:    1    3    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  107
.....
MARKING:    0    1    1    0    1    0    1    0    1   16
READY:    3    5    2
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #  108
.....
MARKING:    0    1    1    0    0    1    1    0    0   16
READY:    3    2    6    7
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  109
.....
MARKING:    0    1    1    0    1    0    1    0    0   16
READY:    3    2    7
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #  110
```

Table IV.6 (Continued)

```
MARKING:    1    0    1    0    1    0    1    0    1   16
READY:    3    1    5
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  111
.....
MARKING:    1    0    0    1    1    0    1    0    1   16
READY:    1    5    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #  112
.....
MARKING:    1    0    0    1    0    1    1    0    0   16
READY:    1    4    6    7
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  113
.....
MARKING:    1    0    1    0    0    1    1    0    0   17
READY:    1    6    7    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  114
.....
MARKING:    0    1    1    0    0    1    1    0    0   17
READY:    6    7    3    2
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #  115
.....
MARKING:    1    0    1    0    0    1    1    0    1   17
READY:    6    3    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  116
.....
MARKING:    1    0    1    0    1    0    1    0    1   17
READY:    3    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #  117
.....
MARKING:    1    0    1    0    0    1    1    0    0   17
READY:    3    1    6    7
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  118
.....
MARKING:    0    1    1    0    0    1    1    0    0   17
READY:    3    6    7    2
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  119
.....
MARKING:    0    1    1    0    1    0    1    0    0   17
READY:    3    7    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  120
.....
MARKING:    0    1    0    1    1    0    1    0    0   17
READY:    7    2    4
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #  121
```

Table IV.6 (Continued)

```
MARKING:    0    1    0    1    1    0    0    1    0   16
READY:    2    4    8
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A              FIRING #  122
.....
MARKING:    1    0    0    1    1    0    0    1    1   16
READY:    4    8    1    5
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B              FIRING #  123
.....
**********REQUESTED # TIME UNITS COMPLETED**********
```

Table IV.7 Transition Summary Statistics for Petri Simulation 1 of the Producer-Consumer Problem

```
SUMMARY OF ACTIVITY FOR TRANSITION     1            PRODUCER 1 PRODUCES ITEM

..FIRING STATISTICS:
   READY:  44.2% OF SIMULATION TIME UNITS   --- 181.5 TIME UNITS      (  57  FIRINGS)
   FIRED:  33.3% OF TIME READY   ---   19 FIRINGS   ---  49.4 TU'S     ( 12.0% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  12.3% OF TIME READY OR    7    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  14.0% OF TIME READY OR    8    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -  19.3% OF TIME READY OR   11    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  14.0% OF TIME READY OR    8    FIRINGS TRANSITION    6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -   1.8% OF TIME READY OR    1    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -   5.3% OF TIME READY OR    3    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  55.8% OF SIMULATION TIME UNITS   --- 228.8 TIME UNITS      (  66  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  228.8 TU'S (  66 FIRINGS) WAITING ON PLACE    1 PRODUCER 1 READY
..LAST FIRING WAS FIRING #  118 ..LAST TIME READY WAS FIRING #  123


SUMMARY OF ACTIVITY FOR TRANSITION     2            PRODUCER 1 PLACES ITEM IN BUFFER A

..FIRING STATISTICS:
   READY:  55.8% OF SIMULATION TIME UNITS   --- 228.8 TIME UNITS      (  66  FIRINGS)
   FIRED:  28.8% OF TIME READY   ---   19 FIRINGS   ---  62.7 TU'S     ( 15.3% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  21.2% OF TIME READY OR   14    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  19.7% OF TIME READY OR   13    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -  10.6% OF TIME READY OR    7    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  15.2% OF TIME READY OR   10    FIRINGS TRANSITION    6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -   4.5% OF TIME READY OR    3    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
..WAIT STATISTICS:
   WAITING:  44.2% OF SIMULATION TIME UNITS   --- 181.5 TIME UNITS      (  57  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  181.5 TU'S (  57 FIRINGS) WAITING ON PLACE    2 ITEM PRODUCED BY PRODUCER 1
..LAST FIRING WAS FIRING #  122 ..LAST TIME READY WAS FIRING #  122
```

Table IV.7 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION    3            PRODUCER 2 PRODUCES ITEM

..FIRING STATISTICS:
   READY:  44.1% OF SIMULATION TIME UNITS   --- 180.9 TIME UNITS      (  51  FIRINGS)
   FIRED:  41.2% OF TIME READY   ---  21 FIRINGS   ---  90.3 TU'S     (  22.0% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  17.6% OF TIME READY OR    9    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  15.7% OF TIME READY OR    8    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  11.8% OF TIME READY OR    6    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  13.7% OF TIME READY OR    7    FIRINGS TRANSITION    6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  55.9% OF SIMULATION TIME UNITS   --- 229.4 TIME UNITS      (  72  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  229.4 TU'S (  72 FIRINGS) WAITING ON PLACE    3 PRODUCER 2 READY
..LAST FIRING WAS FIRING #  120 ..LAST TIME READY WAS FIRING #  120


SUMMARY OF ACTIVITY FOR TRANSITION    4            PRODUCER 2 PLACES ITEM IN BUFFER B

..FIRING STATISTICS:
   READY:  55.9% OF SIMULATION TIME UNITS   --- 229.4 TIME UNITS      (  72  FIRINGS)
   FIRED:  29.2% OF TIME READY   ---  21 FIRINGS   ---  69.3 TU'S     (  16.9% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  13.9% OF TIME READY OR   10    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  15.3% OF TIME READY OR   11    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  16.7% OF TIME READY OR   12    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  15.3% OF TIME READY OR   11    FIRINGS TRANSITION    4    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -   5.6% OF TIME READY OR    4    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -   4.2% OF TIME READY OR    3    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  44.1% OF SIMULATION TIME UNITS   --- 180.9 TIME UNITS      (  51  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  180.9 TU'S (  51 FIRINGS) WAITING ON PLACE    4 ITEM PRODUCED BY PRODUCER 2
..LAST FIRING WAS FIRING #  123 ..LAST TIME READY WAS FIRING #  123
```

Table IV.7 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION     5            CONSUMER 1 REMOVES ITEM FROM BUFFER A

..FIRING STATISTICS:
   READY:  47.1% OF SIMULATION TIME UNITS   --- 193.3 TIME UNITS      (  56  FIRINGS)
   FIRED:  32.1% OF TIME READY   ---  18 FIRINGS   ---  59.4 TU'S     (  14.5% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  10.7% OF TIME READY OR    6    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  12.5% OF TIME READY OR    7    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  21.4% OF TIME READY OR   12    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  21.4% OF TIME READY OR   12    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -   1.8% OF TIME READY OR    1    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  52.9% OF SIMULATION TIME UNITS   --- 217.0 TIME UNITS     (  67  FIRINGS)
   REASONS NOT READY:
   -  15.5% OF WAIT TU'S OR   33.6 TU'S (  10 FIRINGS) WAITING ON PLACE    9 NO.ITEMS IN BUFFER A
   -  21.1% OF WAIT TU'S OR   45.8 TU'S (  15 FIRINGS) WAITING ON PLACE    5 CONSUMER 1 READY
                                                       PLACE    9 NO.ITEMS IN BUFFER A
   -  63.4% OF WAIT TU'S OR  137.6 TU'S (  42 FIRINGS) WAITING ON PLACE    5 CONSUMER 1 READY
..LAST FIRING WAS FIRING #  117 ..LAST TIME READY WAS FIRING #  123


SUMMARY OF ACTIVITY FOR TRANSITION     6            CONSUMER 1 CONSUMES ITEM

..FIRING STATISTICS:
   READY:  44.7% OF SIMULATION TIME UNITS   --- 183.4 TIME UNITS      (  57  FIRINGS)
   FIRED:  31.6% OF TIME READY   ---  18 FIRINGS   ---  54.0 TU'S     (  13.2% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  19.3% OF TIME READY OR   11    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  14.0% OF TIME READY OR    8    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  12.3% OF TIME READY OR    7    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  14.0% OF TIME READY OR    8    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -   5.3% OF TIME READY OR    3    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -   3.5% OF TIME READY OR    2    FIRINGS TRANSITION    9    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  55.3% OF SIMULATION TIME UNITS   --- 226.9 TIME UNITS     (  66  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  226.9 TU'S (  66 FIRINGS) WAITING ON PLACE    6 CONSUMER 1 READY TO CONSUME AN ITEM
..LAST FIRING WAS FIRING #  119 ..LAST TIME READY WAS FIRING #  119
```

Table IV.7 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION     7            CONSUMER 2 REMOVES ITEM FROM BUFFER B

..FIRING STATISTICS:
   READY:  12.3% OF SIMULATION TIME UNITS   ---  50.4 TIME UNITS      (  16  FIRINGS)
   FIRED:  25.0% OF TIME READY   ---    4 FIRINGS   ---  13.2 TU'S     (   3.2% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  25.0% OF TIME READY OR     4    FIRINGS TRANSITION     1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  25.0% OF TIME READY OR     4    FIRINGS TRANSITION     2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -   6.3% OF TIME READY OR     1    FIRINGS TRANSITION     3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -   6.3% OF TIME READY OR     1    FIRINGS TRANSITION     4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -  12.5% OF TIME READY OR     2    FIRINGS TRANSITION     6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  87.7% OF SIMULATION TIME UNITS   --- 359.9 TIME UNITS     ( 107  FIRINGS)
   REASONS NOT READY:
   -   2.8% OF WAIT TU'S OR   10.2 TU'S (   3 FIRINGS) WAITING ON PLACE    10 NO.ITEMS IN BUFFER B
   -  83.9% OF WAIT TU'S OR  302.1 TU'S (  90 FIRINGS) WAITING ON PLACE     9 NO.ITEMS IN BUFFER A
   -   3.4% OF WAIT TU'S OR   12.2 TU'S (   4 FIRINGS) WAITING ON PLACE     7 CONSUMER 2 READY
                                                        PLACE    10 NO.ITEMS IN BUFFER B
   -   2.0% OF WAIT TU'S OR    7.3 TU'S (   2 FIRINGS) WAITING ON PLACE     7 CONSUMER 2 READY
                                                        PLACE    10 NO.ITEMS IN BUFFER B
                                                    -NOT-PLACE     9 NO.ITEMS IN BUFFER A
   -   4.3% OF WAIT TU'S OR   15.6 TU'S (   4 FIRINGS) WAITING ON PLACE     7 CONSUMER 2 READY
                                                    -NOT-PLACE     9 NO.ITEMS IN BUFFER A
   -   1.6% OF WAIT TU'S OR    5.9 TU'S (   2 FIRINGS) WAITING ON PLACE    10 NO.ITEMS IN BUFFER B
                                                    -NOT-PLACE     9 NO.ITEMS IN BUFFER A
   -   1.8% OF WAIT TU'S OR    6.6 TU'S (   2 FIRINGS) WAITING ON PLACE     7 CONSUMER 2 READY
..LAST FIRING WAS FIRING #  121 ..LAST TIME READY WAS FIRING #  121


SUMMARY OF ACTIVITY FOR TRANSITION     8            CONSUMER 2 CONSUMES ITEM

..FIRING STATISTICS:
   READY:  10.2% OF SIMULATION TIME UNITS   ---  41.7 TIME UNITS      (  12  FIRINGS)
   FIRED:  25.0% OF TIME READY   ---    3 FIRINGS   ---  12.0 TU'S     (   2.9% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -   8.3% OF TIME READY OR     1    FIRINGS TRANSITION     1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  33.3% OF TIME READY OR     4    FIRINGS TRANSITION     2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -   8.3% OF TIME READY OR     1    FIRINGS TRANSITION     3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  16.7% OF TIME READY OR     2    FIRINGS TRANSITION     4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -   8.3% OF TIME READY OR     1    FIRINGS TRANSITION     6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  89.8% OF SIMULATION TIME UNITS   --- 368.6 TIME UNITS     ( 111  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  368.6 TU'S ( 111 FIRINGS) WAITING ON PLACE     8 CONSUMER 2 READY TO CONSUME AN ITEM
..LAST FIRING WAS FIRING #   38 ..LAST TIME READY WAS FIRING #  123
```

Table IV.8 Summary Statistics for Petri Simulation 1 of the Producer-Consumer Problem

```
SIMULATION TERMINATED BY COMPLETION OF AT LEAST  410.000 REQUESTED TIME UNITS
FINAL MARKING OF PETRI NET:
   PLACE     1 :    1                PRODUCER 1 READY
   PLACE     3 :    1                PRODUCER 2 READY
   PLACE     5 :    1                CONSUMER 1 READY
   PLACE     8 :    1                CONSUMER 2 READY TO CONSUME AN ITEM
   PLACE     9 :    1                NO. ITEMS IN BUFFER A
   PLACE    10 :   17                NO. ITEMS IN BUFFER B
FIRING STATISTICS:   TOTAL # FIRINGS = 123   ---  TOTAL TIME UNITS = 410.3
-TRANSITION     1: PRODUCER 1 PRODUCES ITEM
  .# FIRINGS =    19  OR    15.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =    49.4  OR    12.0% OF TOTAL TIME UNITS
-TRANSITION     2: PRODUCER 1 PLACES ITEM IN BUFFER A
  .# FIRINGS =    19  OR    15.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =    62.7  OR    15.3% OF TOTAL TIME UNITS
-TRANSITION     3: PRODUCER 2 PRODUCES ITEM
  .# FIRINGS =    21  OR    17.1% OF TOTAL FIRINGS
  .# TIME UNITS USED =    90.3  OR    22.0% OF TOTAL TIME UNITS
-TRANSITION     4: PRODUCER 2 PLACES ITEM IN BUFFER B
  .# FIRINGS =    21  OR    17.1% OF TOTAL FIRINGS
  .# TIME UNITS USED =    69.3  OR    16.9% OF TOTAL TIME UNITS
-TRANSITION     5: CONSUMER 1 REMOVES ITEM FROM BUFFER A
  .# FIRINGS =    18  OR    14.6% OF TOTAL FIRINGS
  .# TIME UNITS USED =    59.4  OR    14.5% OF TOTAL TIME UNITS
-TRANSITION     6: CONSUMER 1 CONSUMES ITEM
  .# FIRINGS =    18  OR    14.6% OF TOTAL FIRINGS
  .# TIME UNITS USED =    54.0  OR    13.2% OF TOTAL TIME UNITS
-TRANSITION     7: CONSUMER 2 REMOVES ITEM FROM BUFFER B
  .# FIRINGS =     4  OR     3.3% OF TOTAL FIRINGS
  .# TIME UNITS USED =    13.2  OR     3.2% OF TOTAL TIME UNITS
-TRANSITION     8: CONSUMER 2 CONSUMES ITEM
  .# FIRINGS =     3  OR     2.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =    12.0  OR     2.9% OF TOTAL TIME UNITS
```

Consumer 2's removal transition fires 25% of time ready. Further examination reveals that 50% of the time Consumer 2 was ready for removal and not fired Process 1 was preparing an item for buffer A--hence, causing immediate or an increased probability of disablement of Consumer 2's removal transition.

Let us assume it is desired to achieve optimum total throughput in the specified time units of the simulation. The above statistical analysis implies it would be desirable to allow Consumer 2 to remove an item from buffer B and consume it every time ready.

Therefore, the simulation might be changed to attempt this modification. Consumer 2's removal and consumption transitions are assigned a top priority so that they will fire when ready, and the simulation is executed again as shown by Tables IV.9 through IV.12 on the following pages.

The statistics for the second simulation indicate a dramatic change in net activity. In approximately the same number of time units, Consumer 1 consumed 16 items and Consumer 2 consumed 13 items. Process 1 had 1 item left in its buffer, and both processes were ready to consume a removed item. The alternate simulation has provided a gain of 8 consumptions or a 38% increase in total throughput.

Table IV.9 Parameters for Petri Simulation 2 of the Producer-Consumer Problem

```
ISIMULATION LIMITED BY BELOW SPECIFICATIONS]
NO. TRANSITIONS TO BE FIRED THIS RUN:1000
TOTAL # TIME UNITS TO BE FIRED THIS RUN: 410.000
-----------------------------------------
TRANSITION FIRING WEIGHTS:
TWEIGH(I),I=  1 TO  100
   7:   2
   8:   2
-----------------------------------------
TRANSITION TIME UNITS:
   1:   2.600
   2:   3.300
   3:   4.300
   4:   3.300
   5:   3.300
   6:   3.000
   7:   3.300
   8:   4.000
-----------------------------------------
INITIAL MARKING OF PETRI NET:
PMARK (I),I=  1 TO  200
   1:   1
   3:   1
   5:   1
   7:   1
-----------------------------------------
PLACE INPUT TO TRANSITIONS:
TINPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
   1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     2
   2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     3
   3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     4
   4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     5
   5    9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     6
   6    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     7
   7   10    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     8
   8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

Table IV.9 (Continued)

```
-NOT- PLACE INPUT TO TRANSITIONS:
NTINPT(I,J),J=  1   TO   25;   I=  1 TO  100
MEMBER     7
   9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
-----------------------------------------------
PLACE OUTPUT FROM TRANSITIONS:
TOTPT (I,J),J=  1   TO   50;   I=  1 TO  100
MEMBER     1
   2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     2
   1    9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     3
   4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     4
   3   10    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     5
   6    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     6
   5    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     7
   8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
MEMBER     8
   7    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
-----------------------------------------------
TRANSITION INTERPRETATIONS:
TDESC      1 :PRODUCER 1 PRODUCES ITEM
TDESC      2 :PRODUCER 1 PLACES ITEM IN BUFFER A
TDESC      3 :PRODUCER 2 PRODUCES ITEM
TDESC      4 :PRODUCER 2 PLACES ITEM IN BUFFER B
TDESC      5 :CONSUMER 1 REMOVES ITEM FROM BUFFER A
TDESC      6 :CONSUMER 1 CONSUMES ITEM
TDESC      7 :CONSUMER 2 REMOVES ITEM FROM BUFFER B
TDESC      8 :CONSUMER 2 CONSUMES ITEM
-----------------------------------------------
PLACE INTERPRETATIONS:
PDESC      1 :PRODUCER 1 READY
PDESC      2 :ITEM PRODUCED BY PRODUCER 1
PDESC      3 :PRODUCER 2 READY
PDESC      4 :ITEM PRODUCED BY PRODUCER 2
PDESC      5 :CONSUMER 1 READY
PDESC      6 :CONSUMER 1 READY TO CONSUME AN ITEM
PDESC      7 :CONSUMER 2 READY
PDESC      8 :CONSUMER 2 READY TO CONSUME AN ITEM
PDESC      9 :NO.ITEMS IN BUFFER A
PDESC     10 :NO.ITEMS IN BUFFER B
```

Table IV.10 Petri Simulation 2 of the Producer-Consumer Problem

```
|====S I M U L A T I O N   S T A R T E D====|
-------------------------------------------
MARKING:    1    0    1    0    1    0    1    0    0    0
READY:    1    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #    1
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #    2
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:    2    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #    3
.....
MARKING:    0    1    1    0    1    0    1    0    0    1
READY:    2    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B             FIRING #    4
.....
MARKING:    0    1    1    0    1    0    0    1    0    0
READY:    2    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                          FIRING #    5
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:    2    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #    6
.....
MARKING:    1    0    1    0    1    0    1    0    1    0
READY:    3    1    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #    7
.....
MARKING:    0    1    1    0    1    0    1    0    1    0
READY:    3    5    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #    8
.....
MARKING:    0    1    0    1    1    0    1    0    1    0
READY:    5    2    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #    9
.....
MARKING:    0    1    0    1    0    1    1    0    0    0
READY:    2    4    6
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   10
.....
MARKING:    1    0    0    1    0    1    1    0    1    0
READY:    4    6    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   11
```

Table IV.10 (Continued)

```
MARKING:    1    0    0    1    1    0    1    0    1    0
READY:    4    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   12
.....
MARKING:    1    0    0    1    0    1    1    0    0    0
READY:    4    1    6
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   13
.....
MARKING:    1    0    0    1    1    0    1    0    0    0
READY:    4    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   14
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:    4    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B             FIRING #   15
.....
MARKING:    0    1    1    0    1    0    1    0    0    1
READY:    2    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   16
.....
MARKING:    0    1    1    0    1    0    0    1    0    0
READY:    2    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                       FIRING #   17
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:    2    3
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                       FIRING #   18
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:    2    4
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   19
.....
MARKING:    1    0    0    1    1    0    1    0    1    0
READY:    4    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   20
.....
MARKING:    1    0    0    1    0    1    1    0    0    0
READY:    4    1    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B             FIRING #   21
.....
MARKING:    1    0    1    0    0    1    1    0    0    1
READY:    1    6    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   22
```

Table IV.10 (Continued)

```
MARKING:    1    0    1    0    0    1    0    1    0    0
READY:      1    6    3    8
*TRANSITION     8      FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #   23
.....
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:      1    6    3
*TRANSITION     6      FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   24
.....
MARKING:    1    0    1    0    1    0    1    0    0    0
READY:      1    3
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   25
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:      3    2
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   26
.....
MARKING:    1    0    1    0    1    0    1    0    1    0
READY:      3    1    5
*TRANSITION     5      FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   27
.....
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:      3    1    6
*TRANSITION     6      FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   28
.....
MARKING:    1    0    1    0    1    0    1    0    0    0
READY:      3    1
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   29
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:      3    2
*TRANSITION     3      FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   30
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:      2    4
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   31
.....
MARKING:    1    0    0    1    1    0    1    0    1    0
READY:      4    1    5
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #   32
.....
MARKING:    0    1    0    1    1    0    1    0    1    0
READY:      4    5    2
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   33
```

Table IV.10 (Continued)

```
MARKING:    1    0    0    1    1    0    1    0    2    0
READY:    4    5    1
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   34
.....
MARKING:    1    0    1    0    1    0    1    0    2    1
READY:    5    1    3
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   35
.....
MARKING:    1    0    1    0    0    1    1    0    1    1
READY:    1    3    6
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   36
.....
MARKING:    0    1    1    0    0    1    1    0    1    1
READY:    3    6    2
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   37
.....
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:    3    2    5
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A                FIRING #   38
.....
MARKING:    1    0    1    0    1    0    1    0    2    1
READY:    3    5    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                          FIRING #   39
.....
MARKING:    0    1    1    0    1    0    1    0    2    1
READY:    3    5    2
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   40
.....
MARKING:    0    1    1    0    0    1    1    0    1    1
READY:    3    2    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   41
.....
MARKING:    0    1    0    1    0    1    1    0    1    1
READY:    2    6    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   42
.....
MARKING:    0    1    1    0    0    1    1    0    1    2
READY:    2    6    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   43
.....
MARKING:    0    1    1    0    1    0    1    0    1    2
READY:    2    3    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   44
```

Table IV.10 (Continued)

```
MARKING:    0    1    1    0    0    1    1    0    0    2
READY:      2    3    6    7
*TRANSITION     7      FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   45
.....
MARKING:    0    1    1    0    0    1    0    1    0    1
READY:      2    3    6    8
*TRANSITION     8      FIRED*:CONSUMER 2 CONSUMES ITEM                       FIRING #   46
.....
MARKING:    0    1    1    0    0    1    1    0    0    1
READY:      2    3    6    7
*TRANSITION     7      FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   47
.....
MARKING:    0    1    1    0    0    1    0    1    0    0
READY:      2    3    6    8
*TRANSITION     8      FIRED*:CONSUMER 2 CONSUMES ITEM                       FIRING #   48
.....
MARKING:    0    1    1    0    0    1    1    0    0    0
READY:      2    3    6
*TRANSITION     3      FIRED*:PRODUCER 2 PRODUCES ITEM                       FIRING #   49
.....
MARKING:    0    1    0    1    0    1    1    0    0    0
READY:      2    6    4
*TRANSITION     6      FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   50
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:      2    4
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   51
.....
MARKING:    1    0    0    1    1    0    1    0    1    0
READY:      4    1    5
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   52
.....
MARKING:    0    1    0    1    1    0    1    0    1    0
READY:      4    5    2
*TRANSITION     4      FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B             FIRING #   53
.....
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:      5    2    3
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   54
.....
MARKING:    1    0    1    0    1    0    1    0    2    1
READY:      5    3    1
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   55
```

Table IV.10 (Continued)

```
MARKING:    0    1    1    0    1    0    1    0    2    1
READY:      5    3    2
*TRANSITION     5      FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   56
.....
MARKING:    0    1    1    0    0    1    1    0    1    1
READY:      3    2    6
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   57
.....
MARKING:    1    0    1    0    0    1    1    0    2    1
READY:      3    6    1
*TRANSITION     6      FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   58
.....
MARKING:    1    0    1    0    1    0    1    0    2    1
READY:      3    1    5
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   59
.....
MARKING:    0    1    1    0    1    0    1    0    2    1
READY:      3    5    2
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   60
.....
MARKING:    1    0    1    0    1    0    1    0    3    1
READY:      3    5    1
*TRANSITION     3      FIRED*:PRODUCER 2 PRODUCES ITEM                       FIRING #   61
.....
MARKING:    1    0    0    1    1    0    1    0    3    1
READY:      5    1    4
*TRANSITION     5      FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   62
.....
MARKING:    1    0    0    1    0    1    1    0    2    1
READY:      1    4    6
*TRANSITION     6      FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   63
.....
MARKING:    1    0    0    1    1    0    1    0    2    1
READY:      1    4    5
*TRANSITION     1      FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   64
.....
MARKING:    0    1    0    1    1    0    1    0    2    1
READY:      4    5    2
*TRANSITION     2      FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   65
.....
MARKING:    1    0    0    1    1    0    1    0    3    1
READY:      4    5    1
*TRANSITION     5      FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   66
```

Table IV.10 (Continued)

```
MARKING:    1    0    0    1    0    1    1    0    2    1
READY:    4    1    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   67
.....
MARKING:    1    0    1    0    0    1    1    0    2    2
READY:    1    6    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   68
.....
MARKING:    1    0    1    0    1    0    1    0    2    2
READY:    1    3    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   69
.....
MARKING:    1    0    1    0    0    1    1    0    1    2
READY:    1    3    6
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                          FIRING #   70
.....
MARKING:    1    0    1    0    1    0    1    0    1    2
READY:    1    3    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A             FIRING #   71
.....
MARKING:    1    0    1    0    0    1    1    0    0    2
READY:    1    3    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B             FIRING #   72
.....
MARKING:    1    0    1    0    0    1    0    1    0    1
READY:    1    3    6    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                          FIRING #   73
.....
MARKING:    1    0    1    0    0    1    1    0    0    1
READY:    1    3    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B             FIRING #   74
.....
MARKING:    1    0    1    0    0    1    0    1    0    0
READY:    1    3    6    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                          FIRING #   75
.....
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:    1    3    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                          FIRING #   76
.....
MARKING:    1    0    0    1    0    1    1    0    0    0
READY:    1    6    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B                FIRING #   77
```

Table IV.10 (Continued)

```
MARKING:    1    0    1    0    0    1    1    0    0    1
READY:    1    6    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #   78
.....
MARKING:    1    0    1    0    0    1    0    1    0    0
READY:    1    6    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                       FIRING #   79
.....
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:    1    6    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   80
.....
MARKING:    0    1    1    0    0    1    1    0    0    0
READY:    6    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                       FIRING #   81
.....
MARKING:    0    1    0    1    0    1    1    0    0    0
READY:    6    2    4
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   82
.....
MARKING:    1    0    0    1    0    1    1    0    1    0
READY:    6    4    1
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   83
.....
MARKING:    0    1    0    1    0    1    1    0    1    0
READY:    6    4    2
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A             FIRING #   84
.....
MARKING:    1    0    0    1    0    1    1    0    2    0
READY:    6    4    1
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                       FIRING #   85
.....
MARKING:    1    0    0    1    1    0    1    0    2    0
READY:    4    1    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #   86
.....
MARKING:    1    0    0    1    0    1    1    0    1    0
READY:    4    1    6
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                       FIRING #   87
.....
MARKING:    0    1    0    1    0    1    1    0    1    0
READY:    4    6    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B             FIRING #   88
```

Table IV.10 (Continued)

```
MARKING:    0    1    1    0    0    1    1    0    1    1
READY:    6    2    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   89
.....
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:    2    3    5
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #   90
.....
MARKING:    1    0    1    0    1    0    1    0    2    1
READY:    3    5    1
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #   91
.....
MARKING:    1    0    0    1    1    0    1    0    2    1
READY:    5    1    4
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   92
.....
MARKING:    1    0    0    1    0    1    1    0    1    1
READY:    1    4    6
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #   93
.....
MARKING:    1    0    0    1    1    0    1    0    1    1
READY:    1    4    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #   94
.....
MARKING:    1    0    0    1    0    1    1    0    0    1
READY:    1    4    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #   95
.....
MARKING:    1    0    0    1    0    1    0    1    0    0
READY:    1    4    6    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #   96
.....
MARKING:    1    0    0    1    0    1    1    0    0    0
READY:    1    4    6
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #   97
.....
MARKING:    1    0    1    0    0    1    1    0    0    1
READY:    1    6    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #   98
.....
MARKING:    1    0    1    0    0    1    0    1    0    0
READY:    1    6    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #   99
```

Table IV.10 (Continued)

```
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:    1    6    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  100
.....
MARKING:    0    1    1    0    0    1    1    0    0    0
READY:    6    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  101
.....
MARKING:    0    1    0    1    0    1    1    0    0    0
READY:    6    2    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  102
.....
MARKING:    0    1    1    0    0    1    1    0    0    1
READY:    6    2    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #  103
.....
MARKING:    0    1    1    0    0    1    0    1    0    0
READY:    6    2    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #  104
.....
MARKING:    0    1    1    0    0    1    1    0    0    0
READY:    6    2    3
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #  105
.....
MARKING:    1    0    1    0    0    1    1    0    1    0
READY:    6    3    1
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  106
.....
MARKING:    1    0    0    1    0    1    1    0    1    0
READY:    6    1    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  107
.....
MARKING:    1    0    1    0    0    1    1    0    1    1
READY:    6    1    3
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  108
.....
MARKING:    1    0    1    0    1    0    1    0    1    1
READY:    1    3    5
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A       FIRING #  109
.....
MARKING:    1    0    1    0    0    1    1    0    0    1
READY:    1    3    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #  110
```

Table IV.10 (Continued)

```
MARKING:    1    0    1    0    0    1    0    1    0    0
READY:    1    3    6    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #  111
.....
MARKING:    1    0    1    0    0    1    1    0    0    0
READY:    1    3    6
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  112
.....
MARKING:    1    0    0    1    0    1    1    0    0    0
READY:    1    6    4
*TRANSITION    6     FIRED*:CONSUMER 1 CONSUMES ITEM                    FIRING #  113
.....
MARKING:    1    0    0    1    1    0    1    0    0    0
READY:    1    4
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  114
.....
MARKING:    1    0    1    0    1    0    1    0    0    1
READY:    1    3    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B       FIRING #  115
.....
MARKING:    1    0    1    0    1    0    0    1    0    0
READY:    1    3    8
*TRANSITION    8     FIRED*:CONSUMER 2 CONSUMES ITEM                    FIRING #  116
.....
MARKING:    1    0    1    0    1    0    1    0    0    0
READY:    1    3
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  117
.....
MARKING:    0    1    1    0    1    0    1    0    0    0
READY:    3    2
*TRANSITION    3     FIRED*:PRODUCER 2 PRODUCES ITEM                    FIRING #  118
.....
MARKING:    0    1    0    1    1    0    1    0    0    0
READY:    2    4
*TRANSITION    2     FIRED*:PRODUCER 1 PLACES ITEM IN BUFFER A          FIRING #  119
.....
MARKING:    1    0    0    1    1    0    1    0    1    0
READY:    4    1    5
*TRANSITION    1     FIRED*:PRODUCER 1 PRODUCES ITEM                    FIRING #  120
.....
MARKING:    0    1    0    1    1    0    1    0    1    0
READY:    4    5    2
*TRANSITION    4     FIRED*:PRODUCER 2 PLACES ITEM IN BUFFER B          FIRING #  121
```

Table IV.10 (Continued)

```
MARKING:    0    1    1    0    1    0    1    0    1    1
READY:    5    2    3
*TRANSITION    5     FIRED*:CONSUMER 1 REMOVES ITEM FROM BUFFER A          FIRING #  122
.....
MARKING:    0    1    1    0    0    1    1    0    0    1
READY:    2    3    6    7
*TRANSITION    7     FIRED*:CONSUMER 2 REMOVES ITEM FROM BUFFER B          FIRING #  123
.....
**********REQUESTED # TIME UNITS COMPLETED**********
```

Table IV.11 Transition Summary Statistics for Petri Simulation 2 of Producer-Consumer Problem

```
SUMMARY OF ACTIVITY FOR TRANSITION    1          PRODUCER 1 PRODUCES ITEM

..FIRING STATISTICS:
   READY:  54.8% OF SIMULATION TIME UNITS   --- 225.4 TIME UNITS      (  70  FIRINGS)
   FIRED:  25.7% OF TIME READY   ---  18 FIRINGS   ---  46.8 TU'S     (  11.4% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -   7.1% OF TIME READY OR    5   FIRINGS TRANSITION    3   SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  10.0% OF TIME READY OR    7   FIRINGS TRANSITION    4   SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -  17.1% OF TIME READY OR   12   FIRINGS TRANSITION    5   SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  17.1% OF TIME READY OR   12   FIRINGS TRANSITION    6   SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -  17.1% OF TIME READY OR   12   FIRINGS TRANSITION    7   SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -  11.4% OF TIME READY OR    8   FIRINGS TRANSITION    8   SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  45.2% OF SIMULATION TIME UNITS   --- 186.2 TIME UNITS      (  53  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  186.2 TU'S (  53 FIRINGS) WAITING ON PLACE    1 PRODUCER 1 READY
..LAST FIRING WAS FIRING #  120 ..LAST TIME READY WAS FIRING #  120


SUMMARY OF ACTIVITY FOR TRANSITION    2          PRODUCER 1 PLACES ITEM IN BUFFER A

..FIRING STATISTICS:
   READY:  45.2% OF SIMULATION TIME UNITS   --- 186.2 TIME UNITS      (  53  FIRINGS)
   FIRED:  32.1% OF TIME READY   ---  17 FIRINGS   ---  56.1 TU'S     (  13.6% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  17.0% OF TIME READY OR    9   FIRINGS TRANSITION    3   SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  13.2% OF TIME READY OR    7   FIRINGS TRANSITION    4   SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -   9.4% OF TIME READY OR    5   FIRINGS TRANSITION    5   SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -   7.5% OF TIME READY OR    4   FIRINGS TRANSITION    6   SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -  11.3% OF TIME READY OR    6   FIRINGS TRANSITION    7   SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -   9.4% OF TIME READY OR    5   FIRINGS TRANSITION    8   SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  54.8% OF SIMULATION TIME UNITS   --- 225.4 TIME UNITS      (  70  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  225.4 TU'S (  70 FIRINGS) WAITING ON PLACE    2 ITEM PRODUCED BY PRODUCER 1
..LAST FIRING WAS FIRING #  119 ..LAST TIME READY WAS FIRING #  123
```

Table IV.11 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION     3            PRODUCER 2 PRODUCES ITEM

..FIRING STATISTICS:
   READY:  63.8% OF SIMULATION TIME UNITS   --- 262.8 TIME UNITS      (  76  FIRINGS)
   FIRED:  18.4% OF TIME READY   ---   14 FIRINGS   ---  60.2 TU'S    (  14.6% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  14.5% OF TIME READY OR   11    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  10.5% OF TIME READY OR    8    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  11.8% OF TIME READY OR    9    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  11.8% OF TIME READY OR    9    FIRINGS TRANSITION    6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -  17.1% OF TIME READY OR   13    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -  15.8% OF TIME READY OR   12    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  36.2% OF SIMULATION TIME UNITS   --- 148.8 TIME UNITS      (  47  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  148.8 TU'S (  47 FIRINGS) WAITING ON PLACE     3 PRODUCER 2 READY
..LAST FIRING WAS FIRING #  118 ..LAST TIME READY WAS FIRING #  123


SUMMARY OF ACTIVITY FOR TRANSITION     4            PRODUCER 2 PLACES ITEM IN BUFFER B

..FIRING STATISTICS:
   READY:  36.2% OF SIMULATION TIME UNITS   --- 148.8 TIME UNITS      (  47  FIRINGS)
   FIRED:  29.8% OF TIME READY   ---   14 FIRINGS   ---  46.2 TU'S    (  11.2% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  14.9% OF TIME READY OR    7    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  19.1% OF TIME READY OR    9    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  17.0% OF TIME READY OR    8    FIRINGS TRANSITION    5    SELECTED INSTEAD  CONSUMER 1 REMOVES ITEM FROM BUFFER A
   -  14.9% OF TIME READY OR    7    FIRINGS TRANSITION    6    SELECTED INSTEAD  CONSUMER 1 CONSUMES ITEM
   -   2.1% OF TIME READY OR    1    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -   2.1% OF TIME READY OR    1    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  63.8% OF SIMULATION TIME UNITS   --- 262.8 TIME UNITS      (  76  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  262.8 TU'S (  76 FIRINGS) WAITING ON PLACE     4 ITEM PRODUCED BY PRODUCER 2
..LAST FIRING WAS FIRING #  121 ..LAST TIME READY WAS FIRING #  121
```

Table IV.11 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION    5          CONSUMER 1 REMOVES ITEM FROM BUFFER A

..FIRING STATISTICS:
   READY:  29.0% OF SIMULATION TIME UNITS   --- 119.5 TIME UNITS      (  37  FIRINGS)
   FIRED:  45.9% OF TIME READY   ---  17 FIRINGS   ---  56.1 TU'S     (  13.6% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -  21.6% OF TIME READY OR    8    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -  16.2% OF TIME READY OR    6    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -   8.1% OF TIME READY OR    3    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -   8.1% OF TIME READY OR    3    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
..WAIT STATISTICS:
   WAITING:  71.0% OF SIMULATION TIME UNITS   --- 292.1 TIME UNITS      (  86  FIRINGS)
   REASONS NOT READY:
   -  28.0% OF WAIT TU'S OR   81.8 TU'S (  24 FIRINGS) WAITING ON PLACE    9 NO.ITEMS IN BUFFER A
   -  48.3% OF WAIT TU'S OR  141.1 TU'S (  40 FIRINGS) WAITING ON PLACE    5 CONSUMER 1 READY
                                                       PLACE    9 NO.ITEMS IN BUFFER A
   -  23.7% OF WAIT TU'S OR   69.2 TU'S (  22 FIRINGS) WAITING ON PLACE    5 CONSUMER 1 READY
..LAST FIRING WAS FIRING #  122 ..LAST TIME READY WAS FIRING #  122


SUMMARY OF ACTIVITY FOR TRANSITION    6          CONSUMER 1 CONSUMES ITEM

..FIRING STATISTICS:
   READY:  51.1% OF SIMULATION TIME UNITS   --- 210.3 TIME UNITS      (  62  FIRINGS)
   FIRED:  25.8% OF TIME READY   ---  16 FIRINGS   ---  48.0 TU'S     (  11.7% OF SIMULATION TIME UNITS)
   REASONS NOT FIRED:
   -   8.1% OF TIME READY OR    5    FIRINGS TRANSITION    1    SELECTED INSTEAD  PRODUCER 1 PRODUCES ITEM
   -   8.1% OF TIME READY OR    5    FIRINGS TRANSITION    2    SELECTED INSTEAD  PRODUCER 1 PLACES ITEM IN BUFFER A
   -  11.3% OF TIME READY OR    7    FIRINGS TRANSITION    3    SELECTED INSTEAD  PRODUCER 2 PRODUCES ITEM
   -  12.9% OF TIME READY OR    8    FIRINGS TRANSITION    4    SELECTED INSTEAD  PRODUCER 2 PLACES ITEM IN BUFFER B
   -  17.7% OF TIME READY OR   11    FIRINGS TRANSITION    7    SELECTED INSTEAD  CONSUMER 2 REMOVES ITEM FROM BUFFER B
   -  16.1% OF TIME READY OR   10    FIRINGS TRANSITION    8    SELECTED INSTEAD  CONSUMER 2 CONSUMES ITEM
..WAIT STATISTICS:
   WAITING:  48.9% OF SIMULATION TIME UNITS   --- 201.3 TIME UNITS      (  61  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  201.3 TU'S (  61 FIRINGS) WAITING ON PLACE    6 CONSUMER 1 READY TO CONSUME AN ITEM
..LAST FIRING WAS FIRING #  113 ..LAST TIME READY WAS FIRING #  123
```

Table IV.11 (Continued)

```
SUMMARY OF ACTIVITY FOR TRANSITION    7          CONSUMER 2 REMOVES ITEM FROM BUFFER B

..FIRING STATISTICS:
   READY:  11.2% OF SIMULATION TIME UNITS   ---  46.2 TIME UNITS      (  14  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---  14 FIRINGS   ---  46.2 TU'S     (  11.2% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  88.8% OF SIMULATION TIME UNITS   --- 365.4 TIME UNITS     ( 109  FIRINGS)
   REASONS NOT READY:
   -  34.1% OF WAIT TU'S OR  124.7 TU'S (  37 FIRINGS) WAITING ON PLACE   10 NO.ITEMS IN BUFFER B
   -  12.0% OF WAIT TU'S OR   44.0 TU'S (  11 FIRINGS) WAITING ON PLACE    7 CONSUMER 2 READY
                                                       PLACE   10 NO.ITEMS IN BUFFER B
   -  19.1% OF WAIT TU'S OR   69.8 TU'S (  22 FIRINGS) WAITING ON PLACE   10 NO.ITEMS IN BUFFER B
                                                       -NOT-PLACE   9 NO.ITEMS IN BUFFER A
   -  32.5% OF WAIT TU'S OR  118.9 TU'S (  37 FIRINGS) WAITING ON PLACE    9 NO.ITEMS IN BUFFER A
   -   2.2% OF WAIT TU'S OR    8.0 TU'S (   2 FIRINGS) WAITING ON PLACE    7 CONSUMER 2 READY
..LAST FIRING WAS FIRING #  123 ..LAST TIME READY WAS FIRING #  123


SUMMARY OF ACTIVITY FOR TRANSITION    8          CONSUMER 2 CONSUMES ITEM

..FIRING STATISTICS:
   READY:  12.6% OF SIMULATION TIME UNITS   ---  52.0 TIME UNITS      (  13  FIRINGS)
   FIRED: 100.0% OF TIME READY   ---  13 FIRINGS   ---  52.0 TU'S     (  12.6% OF SIMULATION TIME UNITS)
..WAIT STATISTICS:
   WAITING:  87.4% OF SIMULATION TIME UNITS   --- 359.6 TIME UNITS     ( 110  FIRINGS)
   REASONS NOT READY:
   - 100.0% OF WAIT TU'S OR  359.6 TU'S ( 110 FIRINGS) WAITING ON PLACE    8 CONSUMER 2 READY TO CONSUME AN ITEM
..LAST FIRING WAS FIRING #  116 ..LAST TIME READY WAS FIRING #  116
```

Table IV.12 Summary Statistics for Petri Simulation 2 of the Producer-Consumer Problem

```
SIMULATION TERMINATED BY COMPLETION OF AT LEAST  410.000 REQUESTED TIME UNITS
FINAL MARKING OF PETRI NET:
  PLACE     2 :    1                ITEM PRODUCED BY PRODUCER 1
  PLACE     3 :    1                PRODUCER 2 READY
  PLACE     6 :    1                CONSUMER 1 READY TO CONSUME AN ITEM
  PLACE     8 :    1                CONSUMER 2 READY TO CONSUME AN ITEM
FIRING STATISTICS:   TOTAL # FIRINGS = 123   ---  TOTAL TIME UNITS = 411.6
-TRANSITION     1: PRODUCER 1 PRODUCES ITEM
  .# FIRINGS =    18  OR   14.6% OF TOTAL FIRINGS
  .# TIME UNITS USED =   46.8  OR   11.4% OF TOTAL TIME UNITS
-TRANSITION     2: PRODUCER 1 PLACES ITEM IN BUFFER A
  .# FIRINGS =    17  OR   13.8% OF TOTAL FIRINGS
  .# TIME UNITS USED =   56.1  OR   13.6% OF TOTAL TIME UNITS
-TRANSITION     3: PRODUCER 2 PRODUCES ITEM
  .# FIRINGS =    14  OR   11.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =   60.2  OR   14.6% OF TOTAL TIME UNITS
-TRANSITION     4: PRODUCER 2 PLACES ITEM IN BUFFER B
  .# FIRINGS =    14  OR   11.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =   46.2  OR   11.2% OF TOTAL TIME UNITS
-TRANSITION     5: CONSUMER 1 REMOVES ITEM FROM BUFFER A
  .# FIRINGS =    17  OR   13.8% OF TOTAL FIRINGS
  .# TIME UNITS USED =   56.1  OR   13.6% OF TOTAL TIME UNITS
-TRANSITION     6: CONSUMER 1 CONSUMES ITEM
  .# FIRINGS =    16  OR   13.0% OF TOTAL FIRINGS
  .# TIME UNITS USED =   48.0  OR   11.7% OF TOTAL TIME UNITS
-TRANSITION     7: CONSUMER 2 REMOVES ITEM FROM BUFFER B
  .# FIRINGS =    14  OR   11.4% OF TOTAL FIRINGS
  .# TIME UNITS USED =   46.2  OR   11.2% OF TOTAL TIME UNITS
-TRANSITION     8: CONSUMER 2 CONSUMES ITEM
  .# FIRINGS =    13  OR   10.6% OF TOTAL FIRINGS
  .# TIME UNITS USED =   52.0  OR   12.6% OF TOTAL TIME UNITS
```

IV. VALUE OF IMPLEMENTATION

The value of the Petri net implementation is typically illustrated by the above Producer-Consumer Problem. The simulation aids in deadlock detection as well as detects patterns of action which contribute to the analysis of net correctness. In addition, such an implementation provides an extremely valuable tool for improving the accuracy and efficiency of the net through the variation of simulation parameters and subsequent modification of the net after the simulation has been analyzed.

CHAPTER V

CONCLUSION

The evaluation of Petri nets is far from complete; much research remains to fully explore proofs of correctness, decidability, completeness, and applications for Petri net theory. However, this study of the pragmatic value of the Petri net model suggests that the model surpasses most well-known concurrent representations in aiding man's understanding of the nature of parallel processing. The experimental implementation of an extended Petri net model displays the practical nature of the model for representing typical behavior patterns in asynchronous systems and thus for analyzing the correctness and efficiency of proposed systems.

Since Agerwala's extended Petri net model is equivalent to the complete Turing Machine model, the Petri model is the basis for representing the most complex of coordination problems. The fact that the model is easy to understand and easy to use makes it one of the most powerful asynchronous modeling tools available in spite of the fact that some analytical properties of the model appear to be indeterminate.

The clarity of the Petri model perhaps causes it to merit consideration by the scientific community for development and implementation of high-level language primitives based on the model. Most certainly the Petri net and its extensions will have impact on concurrent software development accuracy and efficiency in the future.

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APPENDIX

PETRI SIMULATION PROGRAM LISTING

```
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C    B A S I C  P E T R I  N E T  M O D E L  S I M U L A T I O N
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C  AUTHOR: P. B. THOMAS      11-75
C  FEATURES: INCLUDES EXTENDED NET FEATURES -NOT-PLACE DESCRIBED
C            BY AGERWALA.
C           PROGRAM SIMULATES FIRING FROM READY LIST IN WEIGHTED
C            PRIORITY ORDER; IF NO WEIGHTS GIVEN, FIRES IN RANDOM
C            ORDER.
C           PROGRAM FIRES UNTIL DEADLOCKS OR REACHES 1)TOTAL # FIRINGS
C            REQUESTED 2)# FIRINGS REQUESTED FOR SPECIFIED TRANSITIONS
C            3)# TOKENS REQUESTED ON SPECIFIED PLACES OR 4) TOTAL
C            # OF TIME UNITS REQUESTED COMPLETED.
C           SPECIFIC FIRING STATISTICS FOR TRANSITIONS FIRED ARE
C            PRINTED DURING SIMULATION & COMPLETE SIMULATION SUMMARY
C            STATISTICS ARE PRINTED AFTER SIMULATION. STATISTICS ARE
C            BASED ON TOTAL # UNITS OF TIME REQUIRED FOR NET EXECUTION
C            AS CALCULATED BY ADDING THE UNITS OF TIME ASSIGNED TO A
C            TRANSITION TO TOTAL TIME REQUIRED FOR EXECUTION EACH TIME
C            THE TRANSITION IS FIRED.
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      INTEGER*2 TINPT(100,50),NTINPT(100,25),TOTPT(100,50),TWEIGH(100),
     -  PLIMIT(200),PMARK(200),READY(100),WKLIST(200),PAGENO,
     -  EJECTP,LINECT,FRLIMT(100),NCHOSN(100,100),WATLST(100,150)
      INTEGER WALIST
C (ARRAY ITEMP IN SUBROUTINE SRTAR2 MUST BE .GE. GREATEST STRING
C  LENGTH OF NOPIN,NONPIN,NOPOT)
      REAL*8 TDESC(100,6),PDESC(200,6),DESC(1,6),NAMET1,NAMET2,NAMET3,
     -  NAMETW,NAMEPM,NAMETD,NAMEPD,NAMEPL,NAMEFR,NAMEWT,NAMEWA,
     -  NAMEWK,TITLE(1,6),TITLX(1,6),BLANK,ICTYPE,IDPDSC,IDTDSC,IDEND,
     -  IDTITL
      DIMENSION INDATA(14),WAIT(100,350),TRSTAT(100,6),TRTIME(100)
      DATA BLANK/' '/,NOTRNS/100/,NOPCON/200/,NOPIN/50/,INPT70/0/,
     -  NONPIN/25/,NOPOT/50/,INPTT/0/,INPTTW/0/,WALIST/350/,INPT50/0/,
     -  INPT40/0/,NAMEPL/'PLIMIT'/,NAMEFR/'FRLIMT'/,NAMEWA/'WAIT'/,
     -  NAMET1/'TINPT'/,NAMET2/'NTINPT'/,NAMET3/'TOTPT'/,INPTP/0/,
     -  NAMETW/'TWEIGH'/,NAMEPM/'PMARK'/,IDPDSC/'P'/,IDTDSC/'T'/,
     -  IDEND/'E'/,NAMETD/'TDESC'/,NAMEPD/'PDESC'/,ITEIRE/200/,
     -  IFIRCT/0/,MXREDY/0/,NAMEWK/'WKLIST'/,NAMEWT/'WATLST'/,
     -  IDTITL/'X'/,TITLX(1,1)/' '/,TITLX(1,2)/' '/,
     -  TITLX(1,3)/' '/,TITLX(1,4)/' '/,
     -  TITLX(1,5)/' '/,TITLX(1,6)/'        '/,FRTIME/0.0/,
     -  MXPLCE/0/,IWATNO/150/,IWKNO/200/
      COMMON TITLE,LINECT,PAGENO,EJECTP
C* * * * * * * * * *D A T A  D E S C R I P T I O N S* * * * * * * * * * *
C  TINPT(I,J)==> PLACES J  INPUTING TRANSITION I
C  NTINPT(I,J)==> -NOT-PLACES J INPUTING TRANSITION I
C  TOTPT(I,J)==> PLACES J OUTPUTING TRANSITION I
C  TWEIGH(I)==> PRIORITY WEIGHT OF TRANSITION I WHEN TRANSITION READY
C  PMARK(I)==> # TOKENS IN ITH PLACE
C  TDESC(I,J)==> J X 8 CHARACTERS INTERPRETING ITH TRANSITION
C  PDESC(I,J)==> J X 8 CHARACTERS INTERPRETING ITH PLACE
C  READY(I)==> TRANSITIONS READY TO FIRE THIS FIRING
C  WKLIST(I)==> USED FOR READY MEMBERS OF EQUAL WEIGHT OF GREATEST
C    PRIORITY
C  WATLST(I,J)==> USED TO COMPILE LIST J OF REASONS TRANSITION I IS
C    NOT READY THIS FIRING
C  NOTRNS==> MAXIMUM # TRANSITIONS ALLOWED BY PROGRAM
C  NOPCON==> MAXIMUM # PLACES ALLOWED BY PROGRAM
C  NOPIN==> MAXIMUM # PLACES ALLOWED AS INPUT TO 1 TRANSITION
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C  NOPOT==> MAXIMUM # PLACES ALLOWED AS OUTPUT FROM 1 TRANSITION
C  NONPIN==> MAXIMUM # -NOT-PLACES ALLOWED AS INPUT TO 1 TRANSITION
      CONTINUE
C  IWKNO==> MAXIMUM # MEMBERS ALLOWED ON WKLIST: SHOULD BE EQUAL TO
C     NOTRNS TO ACCOMODATE MAXIMUM CASE
C  IWATNO==> MAXIMUM # MEMBERS ALLOWED ON WATLST: SHOULD BE EQUAL TO
C     (NOPIN+NONPIN)*2 TO ACCOMODATE MAXIMUM CASE
C  TRSTAT(I,J)==> J=1:# TIMES ITH TRANSITION READY
C                 J=2:# TIME UNITS ITH TRANSITION READY
C                 J=3:LAST FIRING # THAT ITH TRANSITION WAS READY
C                 J=4:# TIMES ITH TRANSITION FIRED
C                 J=5:# TIME UNITS ITH TRANSITION FIRED
C                 J=6:LAST FIRING # THAT ITH TRANSITION FIRED,
C  NCHOSN(I,J)==> JTH MEMBER CONTAINS # TIMES JTH TRANSITION CHOSEN
C     FROM READY LIST INSTEAD OF ITH TRANSITION WHEN ITH TRANSITION READY
C  WAIT(I,J)==> LIST J IS # TIMES & CONDITIONS CAUSING ITH TRANSITION
C     TO WAIT. FORMAT OF SET OF CONDITIONS IS AS BELOW:
C        -1ST MEMBER:# TIMES ITH TRANSITION HAS WAITED ON THIS SET
C        -2ND MEMBER:# TIME UNITS ITH TRANSITION HAS WAITED ON THIS SET
C        -3RD MEMBER:1ST PLACE CAUSING WAIT
C        -4TH MEMBER:=1 IF PLACE CAUSING WAIT;=0 IF -NOT-PLACE CAUSING IT
C        -5TH MEMBER:2ND PLACE CAUSING WAIT
C        -6TH MEMBER:=1 IF PLACE CAUSING WAIT;=0 IF -NOT-PLACE CAUSING IT
C        -ETC.
C        -LAST MEMBER OF THIS SET OF CONDITIONS:-2
C        -NEXT SET OF CONDITIONS, ETC.
C        -LAST ACTIVE MEMBER OF LIST:-100 (SIGNIFIES END OF ALL SETS)
      CONTINUE
C  WALIST==> J LIST LENGTH OF WAIT(I,J)
C  ITFIRE==> # TIMES TRANSITIONS TO BE FIRED DURING THIS SIMULATION;
C     IF NO VALUE IS INPUT, DEFAULT PROVIDED IN DATA STATEMENT.
C  IFIRCT==> # TIMES TRANSITIONS HAVE BEEN FIRED
C  PLIMIT(I)==> # MARKS NECESSARY ON ITH PLACE TO TERMINATE SIMULATION
C  FRLIMIT(I)==> # TIMES ITH TRANSITION MUST HAVE FIRED TO TERMINATE
C     SIMULATION
C  TRTIME(I)==> UNITS OF TIME REQUIRED TO FIRE TRANSITION I; IF NO
C     VALUE IS INPUT, DEFAULT IS 1.
C  FRTIME==> TOTAL UNITS OF TIME REQUIRED TO FIRE NET AS INDICATED BY
C     THIS SIMULATION
C-----------------------------------------------------------------------
C INITIALIZE PLACE & TRANSITION ARRAYS & INTERPRETATIONS
C-----------------------------------------------------------------------
      MXTRNS = 0
      LINECT = 0
      EJECTP = 1
      PAGENO = 1
      DO 10 I=1,6
   10 TITLE(1,I) = TITLX(1,I)
      DO 100 IT=1,NOTRNS
      DO 20 IP=1,NOPIN
   20 TINPT(IT,IP)=0
      DO 30 IP=1,NONPIN
   30 NTINPT(IT,IP)=0
      DO 40 IP=1,NOPOT
   40 TOTPT(IT,IP)=0
      DO 78 J=1,6
      TDESC(IT,J) = BLANK
   78 TRSTAT(IT,J) = 0
      DO 90 J=1,NOTRNS
   90 NCHOSN(IT,J) = 0
      WAIT(IT,1) = -100
      DO 95 J=2,WALIST
   95 WAIT(IT,J) = 0
      READY(IT) = 0
      FRLIMT(IT) = 0
      TRTIME(IT) = 1
  100 TWEIGH(IT)=0
      DO 150 IP=1,NOPCON
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      DO 145 J=1,6
  145 PDESC(IP,J) = BLANK
      PLIMIT(IP) = 0
  150 PMARK(IP)=0
      DO 160 I=1,IWKNO
  160 WKLIST(I) = 0
C-------------------------------------------------------------------------
C BUILD ALL PLACE & TRANSITION ARRAYS FROM FORMAT I TYPE INPUT
C-------------------------------------------------------------------------
C FORMAT I INPUT:
C  POS.1-2==> ID CODE:10=TINPT ARRAY INPUT
C                     20=NTINPT ARRAY INPUT
C                     30=TOTPT ARRAY INPUT
C                     40=FRLIMT ARRAY INPUT
C                     50=PLIMIT ARRAY INPUT
C                     60=TRTIME INPUT
C                     70=TOTIME INPUT
C                     80=TWEIGH ARRAY INPUT
C                     90=PMARK ARRAY INPUT
C                     95=ITFIRE INPUT
C                     99=END OF FORMAT I INPUT
C  POS.3-6==> TRANSITION OR PLACE # ASSOCIATED WITH INPUT FOR THIS
C    ID CODE FOR CODES 10,20,30,40,50,60,80,& 90; FOR CODE 95=> TOTAL
C    # TRANSITION FIRINGS REQUESTED THIS RUN
C  POS.7-10,11-14,...,63-66==>TRANSITIONS OR PLACES INPUTING TRANSITION
C    OR PLACE IDENTIFIED BY ID CODE FOR CODES 10,20,30
C  POS.7-10==> # FIRINGS OF TRANSITION REQUESTED FOR SIMULATION FOR
C    CODE 40 INPUT; # TOKENS OF PLACE REQUESTED FOR CODE 50 INPUT;
C    WEIGHT OF TRANSITION FOR CODE 80 INPUT; INITIAL MARKING OF PLACE
C    FOR CODE 90 INPUT
C  POS.67-74==> # TIME UNITS (REAL NUMBER) ASSIGNED TO TRANSITION FOR
C    CODE 60 INPUT; TOTAL # TIME UNITS REQUESTED FOR SIMULATION FOR
C    CODE 70 INPUT
C  POS.75-80==> COMMENTS
C-------------------------------------------------------------------------
  200 READ(5,210) IDCODE,IMEMBR,(INDATA(I),I=1,14),TIMEUT
  210 FORMAT (I2,1514,F8.3)
      WRITE(20,215) IDCODE,IMEMBR,(INDATA(I),I=1,14),TIMEUT
  215 FORMAT (' INPUT:',16(' ',I4),2X,F8.3)
      IF (IDCODE .EQ. 99) GO TO 400
      IF (IDCODE .NE. 10) GO TO 220
C-ADD TO TINPT ARRAY-
      IF (IMEMBR - MXTRNS) 217,217,216
  216 MXTRNS = IMEMBR
  217 CALL ADTRNS(NAMET1,INDATA,TINPT,IMEMBR,NOTRNS,NOPIN,MXPLCE)
      GO TO 200
  220 IF (IDCODE .NE. 20) GO TO 240
C-ADD TO NTINPT ARRAY-
      IF (IMEMBR - MXTRNS) 230,230,228
  228 MXTRNS = IMEMBR
  230 CALL ADTRNS(NAMET2,INDATA,NTINPT,IMEMBR,NOTRNS,NONPIN,MXPLCE)
      GO TO 200
  240 IF (IDCODE .NE. 30) GO TO 250
C-ADD TO TOTPT ARRAY-
      CALL ADTRNS(NAMET3,INDATA,TOTPT,IMEMBR,NOTRNS,NOPOT,MXPLCE)
      GO TO 200
  250 IF (IDCODE .NE. 40) GO TO 270
C-BUILD FRLIMIT MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOTRNS) GO TO 260
      PRINT 255,IMEMBR,NOTRNS
  255 FORMAT (' FRLIMT TRANSITION NO.',I4,' NOT IN RANGE OF 1-',I4,
     -' ALLOWED BY PROGRAM--JOB CANCELLED')
      STOP
  260 FRLIMT(IMEMBR) = INDATA(1)
      INPT40 = 1
      GO TO 200
  270 IF (IDCODE .NE. 50) GO TO 285
C-BUILD PLIMIT MEMBER-
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      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOPCON) GO TO 280
      PRINT 275,IMEMBR,NOPCON
  275 FORMAT (' PLIMIT TRANSITION NO.',I4,' NOT IN RANGE OF 1-',I4,
     -' ALLOWED BY PROGRAM--JOB CANCELLED')
      STOP
  280 PLIMIT(IMEMBR) = INDATA(1)
      INPT50 = 1
      GO TO 200
  285 IF (IDCODE .NE. 60) GO TO 300
C-BUILD TRTIME MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOTRNS) GO TO 295
      PRINT 290,IMEMBR,NOTRNS
  290 FORMAT (' FRTIME TRANSITION NO.',I4,' NOT IN RANGE OF 1-',I4,
     -' ALLOWED BY PROGRAM--JOB CANCELLED')
      STOP
  295 TRTIME(IMEMBR) = TIMEUT
      GO TO 200
C-BUILD TOTIME-
  300 IF (IDCODE .NE. 70) GO TO 315
      INPT70 = 1
      TOTIME = TIMEUT
      GO TO 200
  315 IF (IDCODE .NE. 80) GO TO 330
C-BUILD TWEIGH MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOTRNS) GO TO 320
      PRINT 310,IMEMBR,NOTRNS
  310 FORMAT (' TWEIGH TRANSITION NO.',I4,' NOT IN RANGE OF 1-',I4,
     -' ALLOWED BY PROGRAM--JOB CANCELLED')
      STOP
  320 TWEIGH(IMEMBR) = INDATA(1)
      INPTTW = 1
      GO TO 200
  330 IF (IDCODE .NE. 90) GO TO 360
C-BUILD PMARK MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOPCON) GO TO 350
      PRINT 340,IMEMBR,NOPCON
  340 FORMAT (' PMARK PLACE NO.',I4,' NOT IN RANGE OF 1-',I4,
     -' ALLOWED BY PROGRAM--JOB CANCELLED')
      STOP
  350 PMARK(IMEMBR) = INDATA(1)
      GO TO 200
  360 IF (IDCODE .NE. 95) GO TO 367
      ITFIRE = IMEMBR
      GO TO 200
  367 PRINT 370,IDCODE
  370 FORMAT (' UNIDENTIFIED INPUT CODE:',I2,'---JOB CANCELLED')
      STOP
C-PRINT FORMAT I PARAMETERS-
  400 CALL PAGECK
      CALL PAGECK
      PRINT 402
  402 FORMAT (' ------------------------------------------')
      CALL PAGECK
      PRINT 403
  403 FORMAT (' |SIMULATION LIMITED BY BELOW SPECIFICATIONS|')
      IF (ITFIRE .EQ. 0) GO TO 406
      CALL PAGECK
      PRINT 405,ITFIRE
  405 FORMAT (' NO. TRANSITIONS TO BE FIRED THIS RUN:',I4)
  406 IF (INPT70 .NE. 1) GO TO 410
      CALL PAGECK
      PRINT 407,TOTIME
  407 FORMAT (' TOTAL # TIME UNITS TO BE FIRED THIS RUN:',F8.3)
  410 IF (INPT40 .NE. 1) GO TO 420
      CALL PAGECK
      PRINT 415
  415 FORMAT (' TRANSITION FIRING LIMITS:')
      CALL PRTAR1(NAMEFR,FRLIMT,IMEMBR,NOTRNS)
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  420 IF (INPT50 .EQ. 0) GO TO 424
      CALL PAGECK
      PRINT 422
  422 FORMAT (' PLACE MARKING LIMITS:')
      CALL PRTAR1(NAMEPL,PLIMIT,IMEMBR,NOPCON)
  424 EJECTP = -1
      CALL PAGECK
      PRINT 402
      IF (INPTTW .NE. 1) GO TO 426
      CALL PAGECK
      PRINT 425
  425 FORMAT (' TRANSITION FIRING WEIGHTS:')
      IMEMBR = 0
      CALL PRTAR1(NAMETW,TWEIGH,IMEMBR,NOTRNS)
      EJECTP = -1
      CALL PAGECK
      PRINT 402
  426 CALL PAGECK
      PRINT 427
  427 FORMAT (' TRANSITION TIME UNITS:')
      DO 429 I=1,NOTRNS
      IF (TINPT(I,1) .EQ. 0 .AND. NTINPT(I,1) .EQ. 0) GO TO 429
      PRINT 428,I,TRTIME(I)
  428 FORMAT (' ',I4,':',F8.3)
  429 CONTINUE
      EJECTP = -1
      CALL PAGECK
      PRINT 402
      CALL PAGECK
      PRINT 430
  430 FORMAT (' INITIAL MARKING OF PETRI NET:')
      CALL PRTAR1(NAMEPM,PMARK,IMEMBR,NOPCON)
      EJECTP = -1
      CALL PAGECK
      PRINT 402
C (SORT CONSTRUCTED TRANSITION ARRAYS AND PRINT)
  450 IMEMBR = 0
      CALL SRTAR2(TINPT,NOTRNS,NOPIN)
      CALL PAGECK
      PRINT 460
  460 FORMAT (' PLACE INPUT TO TRANSITIONS:')
      CALL PRTAR2(NAMET1,TINPT,IMEMBR,NOTRNS,NOPIN)
      EJECTP = -1
      CALL PAGECK
      PRINT 402
      CALL SRTAR2(NTINPT,NOTRNS,NONPIN)
      CALL PAGECK
      PRINT 463
  463 FORMAT (' -NOT- PLACE INPUT TO TRANSITIONS:')
      CALL PRTAR2(NAMET2,NTINPT,IMEMBR,NOTRNS,NONPIN)
      EJECTP = -1
      CALL PAGECK
      PRINT 402
      CALL SRTAR2(TOTPT,NOTRNS,NOPOT)
      CALL PAGECK
      PRINT 470
  470 FORMAT (' PLACE OUTPUT FROM TRANSITIONS:')
      CALL PRTAR2(NAMET3,TOTPT,IMEMBR,NOTRNS,NOPOT)
      EJECTP = -1
      CALL PAGECK
      PRINT 402
C-----------------------------------------------------------------------
C EDIT TRANSITION ARRAYS FOR TEXT VALIDITY
C-----------------------------------------------------------------------
C-CHECK FOR DUPLICATION OF PLACES IN EACH ROW-
      CALL EDTDUP(NAMET1,TINPT,NOTRNS,NOPIN)
      CALL EDTDUP(NAMET2,NTINPT,NOTRNS,NONPIN)
      CALL EDTDUP(NAMET3,TOTPT,NOTRNS,NOPOT)
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C-VERIFY THAT EACH PLACE SERVES EACH TRANSITION IN AT MOST 1 CAPACITY-
C    AND THAT EACH PLACE IS A VALID PLACE NUMBER-
       DO 1000 IMEMBR=1,NOTRNS
C (CHECK 1ST ARRAY AGAINST ALL OTHERS)
       DO 670 IT1=1,NOPIN
       IPLACE = TINPT(IMEMBR,IT1)
       IF (IPLACE .GT. 0 .AND. IPLACE .LE. NOPCON)   GO TO 495
       IF (IPLACE .EQ. 0) GO TO 710
  475  PRINT 480,IMEMBR,NOPCON,IPLACE
  480  FORMAT (' PLACE INPUT TO ONE OF TRANSITION INPUT ARRAYS, MEMBER ',
      -I4,' IS NOT WITHIN RANGE OF 0-',I4,'PLACE INPUT:',I4,'JOB CANCEL',
      -'LED')
       STOP
  495  DO 600 IT2=1,NONPIN
       ICOMPR = NTINPT(IMEMBR,IT2)
       IF (ICOMPR .EQ. 0) GO TO 610
       IF (IPLACE - ICOMPR) 610,500,600
  500  PRINT 550,IPLACE,IMEMBR
  550  FORMAT (' PLACE ',I4,' APPEARS MULTIPLE TIMES IN TRANSITION',
      -' ARRAYS FOR TRANSITION ',I4,'.JOB CANCELLED')
       STOP
  600  CONTINUE
  610  DO 630 IT3=1,NOPOT
       ICOMPR = TOTPT(IMEMBR,IT3)
       IF (ICOMPR .EQ. 0) GO TO 670
       IF (IPLACE - ICOMPR) 670,500,630
  630  CONTINUE
  670  CONTINUE
C (CHECK 2ND ARRAY AGAINST ALL BUT 1ST ARRAY)
  710  DO 900 IT2=1,NONPIN
       IPLACE = NTINPT( IMEMBR,IT2)
       IF (IPLACE .GT. 0 .AND. IPLACE .LE. NOPCON)   GO TO 715
       IF (IPLACE .EQ. 0) GO TO 910
       GO TO 475
  715  DO 750 IT3=1,NOPOT
       ICOMPR = TOTPT(IMEMBR,IT3)
       IF (ICOMPR .EQ. 0) GO TO 900
       IF (IPLACE - ICOMPR)900,500,750
  750  CONTINUE
  900  CONTINUE
C (CHECK 3RD ARRAY FOR PLACE VALIDITY)
  910  DO 950 IT3=1,NOPOT
       IPLACE = TOTPT(IMEMBR,IT3)
       IF (IPLACE .GT. 0 .AND. IPLACE .LE. NOPCON) GO TO 915
       IF (IPLACE .EQ. 0) GO TO 1000
       GO TO 475
  915  IF (TINPT(IMEMBR,1) .NE. 0 .OR. NTINPT(IMEMBR,1) .NE. 0)
      -     GO TO 950
       CALL PAGECK
       PRINT 918,IMEMBR,NAMET3
  918  FORMAT (' TRANSITION ',I4,' HAS OUTPUT PLACE IN ',A8,
      -' BUT NO INPUT PLACES--TRANSITION IGNORED')
  950  CONTINUE
 1000  CONTINUE
C-----------------------------------------------------------------------
C BUILD AND PRINT DESCRIPTION ARRAYS FROM FORMAT II TYPE INPUT
C-----------------------------------------------------------------------
C FORMAT II INPUT:
C POS.1==> ID CODE: T=TDESC INPUT
C                   P=PDESC INPUT
C                   X=TITLE OF SIMULATION PRINTOUT
C POS.2-5==> TRANSITION OR PLACE ASSOCIATED WITH INPUT FOR THIS ID CODE
C              FOR CODES T & P
C POS.6-53==> DESCRIPTION OF TRANSITION OR PLACE OR TITLE
C POS.75-80==> COMMENTS
C-----------------------------------------------------------------------
 1005  READ(5,1010) IDTYPE,IMEMBR,(DESC(1,I),I=1,6)
 1010  FORMAT(A1,I4,6A8)
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      IF (IDTYPE .EQ. IDEND) GO TO 1500
      IF (IDTYPE .NE. IDTDSC) GO TO 1200
C-BUILD TDESC MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOTRNS) GO TO 1100
      PRINT 1050,NAMETD,IMEMBR,NOTRNS
 1050 FORMAT (' ATTEMPT TO INPUT ',A6,' ARRAY WITH MEMBER ',I4,
     -',NOT WITHIN RANGE SET BY PROGRAM OF 1-',I4,'.JOB CANCELLED.')
      STOP
 1100 DO 1110 I=1,6
 1110 TDESC(IMEMBR,I) = DESC(1,I)
      INPTT = 1
      GO TO 1005
 1200 IF (IDTYPE .NE. IDPDSC) GO TO 1400
C-BUILD PDESC MEMBER-
      IF (IMEMBR .GT. 0 .AND. IMEMBR .LE. NOPCON) GO TO 1300
      PRINT 1050,NAMEPD,IMEMBR,NOPCON
      STOP
 1300 DO 1310 I=1,6
 1310 PDESC(IMEMBR,I) = DESC(1,I)
      INPTP = 1
      GO TO 1005
 1400 IF (IDTYPE .NE. IDTITL) GO TO 1440
C-BUILD TITLE-
      DO 1410 I=1,6
 1410 TITLE(1,I) = DESC(1,I)
      GO TO 1005
 1440 PRINT 1450,IDTYPE
 1450 FORMAT (' UNRECOGNIZED FORMAT II INPUT TYPE-',A1,
     -',JOB CANCELLED')
      STOP
C-PRINT TDESC MEMBERS-
 1500 IF (INPTT .EQ. 0) GO TO 1610
      PRINT 1475
 1475 FORMAT (' TRANSITION INTERPRETATIONS:')
      DO 1600 I=1,NOTRNS
      IF (TDESC(I,1) .EQ. BLANK) GO TO 1600
      CALL PAGECK
      PRINT 1550,NAMETD,I,(TDESC(I,J),J=1,6)
 1550 FORMAT (' ',A6,' ',I4,' :',6A8)
 1600 CONTINUE
      EJECTP = -1
      CALL PAGECK
      PRINT 402
C-PRINT PDESC MEMBERS-
 1610 IF (INPTP .EQ. 0) GO TO 1710
      PRINT 1620
 1620 FORMAT (' PLACE INTERPRETATIONS:')
      DO 1700 I=1,NOPCON
      IF (PDESC(I,1) .EQ. BLANK) GO TO 1700
      CALL PAGECK
      PRINT 1550,NAMEPD,I,(PDESC(I,J),J=1,6)
 1700 CONTINUE
      EJECTP = -1
      CALL PAGECK
      PRINT 402
C-------------------------------------------------------------------------
C UPDATE READY LIST FROM TRANSITION INPUT AND MARKING & GATHER WAIT
C   STATISTICS
C-------------------------------------------------------------------------
 1710 EJECTP = 1
      PAGENO = 1
      CALL PAGECK
      PRINT 402
      CALL PAGECK
      PRINT 1800
 1800 FORMAT (' |====S I M U L A T I O N  S T A R T E D====|')
      CALL PAGECK
      PRINT 402
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 1850 DO 2000 IMEMBR=1,NCTRNS
C-INITIALIZE WORK CONSTANTS FOR THIS TRANSITION-
      IREADY = 1
      IWORK = 1
      DO 1855 J=1,IWATNO
 1855 WATLST(IMEMBR,J) = -5
      IF (TINPT(IMEMBR,1) .EQ. 0 .AND. NTINPT(IMEMBR,1) .EQ. 0)
     -    GO TO 2000
C-CHECK TO SEE IF PLACES INPUTING THIS TRANSITION HAVE AT LEAST 1 TOKEN
      DO 1900 IP=1,NOPIN
      IPLACE = TINPT(IMEMBR,IP)
      IF (IPLACE .EQ. 0) GO TO 1950
      IF (PMARK(IPLACE) .GT. 0) GO TO 1900
      IF (IWORK+1 .LE. IWATNO) GO TO 1875
 1860 PRINT 1865,IMEMBR
 1865 FORMAT (' WATLST SIZE INSUFFICIENT FOR TRANSITION ',I4,
     -' IN GATHERING WAIT STATISTICS--JOB CANCELLED')
      CALL PRTAR2(NAMEWT,WATLST,IMEMBR,NOTRNS,IWATNO)
      STOP
 1875 WATLST(IMEMBR,IWORK) = IPLACE
      WATLST(IMEMBR,IWORK+1) = 0
      IWORK = IWORK + 2
 1900 CONTINUE
C-CHECK TO SEE IF -NOT- PLACES INPUTING THIS TRANSITION HAVE NO TOKENS-
 1950 DO 1954 IP=1,NONPIN
      IPLACE = NTINPT(IMEMBR,IP)
      IF (IPLACE .EQ. 0) GO TO 1955
      IF (PMARK(IPLACE) .LE. 0) GO TO 1954
      IF (IWORK+1 .GT. IWATNO) GO TO 1860
      WATLST(IMEMBR,IWORK) = IPLACE
      WATLST(IMEMBR,IWORK+1) = 1
      IWORK = IWORK + 2
 1954 CONTINUE
 1955 IF (IWORK .EQ. 1) GO TO 1985
      IREADY = 0
C-IS THIS TRANSITION ON READY LIST?
      IF (MXREDY .LT. 1) GO TO 1995
 1985 DO 1990 IR=1,MXREDY
      IF (READY(IR) .EQ. 0) GO TO 1995
      IF (READY(IR) .NE. IMEMBR) GO TO 1990
C (YES--IF MEMBER READY, EXIT)
      IF (IREADY .EQ. 1) GO TO 2000
C (YES--IF MEMBER NOW NOT READY, REMOVE FROM LIST & MOVE OTHER MEMBERS)
      READY(IR) = 0
      IEND = MXREDY
      MXREDY = MXREDY - 1
      DO 1988 IMOVE=IR,IEND
      IF (READY(IMOVE+1) .EQ. 0) GO TO 2000
 1988 READY(IMOVE) = READY(IMOVE+1)
      GO TO 2000
 1990 CONTINUE
C (NO--PUT MEMBER ON LIST IF READY)
 1995 IF (IREADY .EQ. 0) GO TO 2000
      MXREDY = MXREDY + 1
      READY(MXREDY) = IMEMBR
 2000 CONTINUE
C-PRINT MARKING FOR THIS STATE OF THE SIMULATION-
      DO 2009 I=1,MXPLCE,24
      CALL PAGECK
      IF (I+23 .GT. MXPLCE) GO TO 2003
      K = I + 23
      GO TO 2004
 2003 K = MXPLCE
 2004 IF (I .NE. 1) GO TO 2007
      PRINT 2005,(PMARK(J),J=I,K)
 2005 FORMAT (' MARKING:',24(' ',I4))
      GO TO 2009
 2007 PRINT 2008,(PMARK(J),J=I,K)
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 2008 FORMAT (9X,24(' ',I4))
 2009 CONTINUE
C-PRINT READY LIST FOR THIS STATE OF THE SIMULATION-
      DO 2045 I=1,MXREDY,25
      EJECTP = -1
      CALL PAGECK
      IF (I+24 .GT. MXREDY) GO TO 2010
      K = I+ 24
      GO TO 2015
 2010 K = MXREDY
 2015 IF (I .NE. 1) GO TO 2030
 2020 PRINT 2025,(READY(J),J=I,K)
 2025 FORMAT (' READY:',25(' ',I4))
      GO TO 2045
 2030 PRINT 2035,(READY(J),J=I,K)
 2035 FORMAT (7X,25(' ',I4))
 2045 CONTINUE
C-------------------------------------------------------------------
C EXAMINE READY LIST FOR SELECTION OF TRANSITION TO FIRE
C-------------------------------------------------------------------
      WKLIST(1) = 0
      IF (READY(1) .NE. 0) GO TO 2100
      PRINT 2050
 2050 FORMAT (' * * * * * * * * * D E A D L O C K - - J O B  ',
     -'A B O R T E D * * * * * * * * *')
      IMEMBR = 0
      CALL PRTAR1(NAMEPM,PMARK,IMEMBR,NOPCON)
      STOP
C-PUT ALL READY MEMBERS OF GREATEST WEIGHT ON WORK LIST-
 2100 MXWGT = 0
      DO 2200 IMEMBR=1,MXREDY
      IF (MXWGT .GE. TWEIGH(READY(IMEMBR))) GO TO 2200
      MXWGT = TWEIGH(READY(IMEMBR))
 2200 CONTINUE
      IWORK = 0
      DO 2250 IMEMBR=1,MXREDY
      IF (TWEIGH(READY(IMEMBR)) .NE. MXWGT) GO TO 2250
      IWORK = IWORK + 1
      IF (IWORK .LE. IWKNO) GO TO 2240
      PRINT 2230
 2230 FORMAT (' WKLIST EXCEEDED IN PREPARING READY LIST FOR FIRING',
     -' SELECTION--JOB CANCELLED')
      IMEMBR = 0
      CALL PRTAR1(NAMEWK,WKLIST,IMEMBR,IWKNO)
      STOP
 2240 WKLIST(IWORK) = READY(IMEMBR)
 2250 CONTINUE
      IF (IWORK .NE. 1) GO TO 2300
      ISELT = WKLIST(1)
      GO TO 2400
C-RANDOMLY SELECT TRANSITION TO FIRE IF MORE THAN 1 OF GREATEST
C   PRIORITY READY-
 2300 BEGIN = 1
      ENDING = IWORK + 1
      CALL FLAT(RAND,BEGIN,ENDING)
      ISELT = WKLIST(RAND)
C-------------------------------------------------------------------
C FIRE SELECTED TRANSITION & GATHER FIRING STATISTICS
C-------------------------------------------------------------------
C-UPDATE FIRING STATISTICS-
 2400 IFIRCT = IFIRCT + 1
C (UPDATE READY & FIRE COUNTS AND TIME UNITS)
      FRTIME = FRTIME + TRTIME(ISELT)
      DO 2410 IMEMBR=1,MXREDY
      TRSTAT(READY(IMEMBR),1) = TRSTAT(READY(IMEMBR),1) + 1
      TRSTAT(READY(IMEMBR),2) = TRSTAT(READY(IMEMBR),2) + TRTIME(ISELT)
      TRSTAT(READY(IMEMBR),3) = IFIRCT
      IF (READY(IMEMBR) .NE. ISELT) GO TO 2407
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```
      TRSTAT(ISELT,4) = TRSTAT(ISELT,4) + 1
      TRSTAT(ISELT,5) = TRSTAT(ISELT,5) + TRTIME(ISELT)
      TRSTAT(ISELT,6) = IFIRCT
      GO TO 2410
 2407 NCHOSN(READY(IMEMBR),ISELT) = NCHOSN(READY(IMEMBR),ISELT) + 1
 2410 CONTINUE
C (UPDATE WAIT LIST WAITING TIME FOR TRANSITIONS WHICH WERE NOT READY)
      DO 2440 IMEMBR=1,NOTRNS
      IF (WATLST(IMEMBR,1) .EQ. -5) GO TO 2440
      J = 0
C  (ATTEMPT TO MATCH WAITING CONDITIONS WITH WALIST CONDITIONS FOR
C      MEMBER)
 2412 J = J + 1
      IF (J .LE. WALIST) GO TO 2420
 2415 PRINT 2416,IMEMBR
 2416 FORMAT (' WAIT LIST EXCEEDED OR IMPROPERLY CONSTRUCTED FOR',
     -' TRANSITION ',I4,'--JOB CANCELLED')
      CALL PRTAR2(NAMEWA,WAIT,IMEMBR,NOTRNS,WALIST)
      STOP
 2420 IF (WAIT(IMEMBR,J) .EQ. -100) GO TO 2430
      JCTIX = J
      J = J + 1
      DO 2425 IWK=1,IWATNO
      IF (WATLST(IMEMBR,IWK) .EQ. -5) GO TO 2426
      J = J + 1
      IF (J .GT. WALIST) GO TO 2415
      IF (WAIT(IMEMBR,J) .EQ. -2) GO TO 2412
      IF (WAIT(IMEMBR,J) .NE. WATLST(IMEMBR,IWK)) GO TO 2428
 2425 CONTINUE
 2426 J = J + 1
      IF (J .GT. WALIST) GO TO 2415
      IF (WAIT(IMEMBR,J) .EQ. -2) GO TO 2429
C   (THIS SET OF CONDITIONS NOT A MATCH--SKIP TO NEXT SET)
 2428 J = J + 1
      IF (J .GT. WALIST) GO TO 2415
      IF (WAIT(IMEMBR,J) .EQ. -2) GO TO 2412
      GO TO 2428
C   (FOUND MATCHING SET OF CONDITIONS:ADD TO WAIT STATISTICS)
 2429 WAIT(IMEMBR,JCTIX) = WAIT(IMEMBR,JCTIX) + 1
      WAIT(IMEMBR,JCTIX+1) = WAIT(IMEMBR,JCTIX+1) + TRTIME(ISELT)
      GO TO 2440
C   (NO MATCHING CONDITIONS:ADD THIS SET TO WAIT LIST)
 2430 WAIT(IMEMBR,J) = 1
      J = J + 1
      WAIT(IMEMBR,J) = TRTIME(ISELT)
      DO 2435 IWK=1,IWATNO
      IF (WATLST(IMEMBR,IWK) .EQ. -5) GO TO 2437
      J = J + 1
      IF (J+2 .GT. WALIST) GO TO 2415
 2435 WAIT(IMEMBR,J) = WATLST(IMEMBR,IWK)
 2437 WAIT(IMEMBR,J+1) = -2
      WAIT(IMEMBR,J+2) = -100
 2440 CONTINUE
C-REMOVE 1 TOKEN FROM EACH INPUT PLACE FOR FIRED TRANSITION-
      DO 2450 IP=1,NOPIN
      IPLACE = TINPT(ISELT,IP)
      IF (IPLACE .EQ. 0) GO TO 2480
 2450 PMARK(IPLACE) = PMARK(IPLACE) - 1
C ******F I R E*******
 2480 EJECTP = -1
      CALL PAGECK
 2500 PRINT 2550,ISELT,(TDESC(ISELT,I),I=1,6),IFIRCT
 2550 FORMAT (' *TRANSITION ',I4,'     FIRED*:',6A8,' FIRIN',
     -'G # ',I4)
      EJECTP = -1
      CALL PAGECK
      PRINT 2560
 2560 FORMAT (' ..................................................',
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```
     -'.....')
C-ADD TOKEN TO ALL OUTPUT PLACES FOR FIRED TRANSITION-
      DO 2600 IP=1,NOPOT
      IPLACE = TOTPT(ISELT,IP)
      IF (IPLACE .EQ. 0) GO TO 2800
      PMARK(IPLACE) = PMARK(IPLACE) + 1
 2600 CONTINUE
C-----------------------------------------------------------------------
C DETERMINE IF SIMULATION HAS REACHED COMPLETION STATUS
C-----------------------------------------------------------------------
C-CHECK FOR COMPLETION OF TOTAL # FIRINGS REQUESTED FOR SIMULATION-
 2800 IF (ITFIRE .EQ. 0) GO TO 3000
      IF (ITFIRE .NE. IFIRCT) GO TO 3000
      PRINT 2900
 2900 FORMAT (' **********REQUESTED NO. FIRINGS COMPLETED**********')
      GO TO 5000
C-CHECK FOR COMPLETION OF TOTAL # TIME UNITS REQUESTED FOR SIMULATION-
 3000 IF (INPT70 .EQ. 0) GO TO 3500
      IF (FRTIME .LT. TOTIME) GO TO 3500
      INPT70 = 9
      PRINT 3100
 3100 FORMAT (' **********REQUESTED # TIME UNITS COMPLETED',
     -'**********')
      GO TO 5000
C-CHECK FOR PMARK MEMBERS .GE. SPECIFIED MARKING REQUESTED FOR
C  SIMULATION-
 3500 IF (INPT50 .EQ. 0) GO TO 4000
      DO 3050 I=1,NOPCON
      IF (PLIMIT(I) .LE. PMARK(I)) GO TO 3050
      GO TO 4000
 3050 CONTINUE
      INPT50 = 9
      PRINT 3075
 3075 FORMAT (' **********SPECIFIED MINIMUM SIMULATION MARKING',
     -' COMPLETED**********')
      GO TO 5000
C-CHECK FOR # FIRINGS FOR TRANSITIONS .GE. SPECIFIED # FIRINGS
C  REQUESTED FOR SIMULATION-
 4000 IF (INPT40 .EQ. 0) GO TO 1850
      DO 4050 I=1,NOTRNS
      IF (FRLIMT(I) .LE. TRSTAT(I,4)) GO TO 4050
      GO TO 1850
 4050 CONTINUE
      PRINT 4075
      INPT40 = 9
 4075 FORMAT (' **********SPECIFIED MINIMUM FIRINGS COMPLETED',
     -'**********')
C-----------------------------------------------------------------------
C PRINT TERMINATION STATISTICS
C-----------------------------------------------------------------------
C-PRINT STATISTICS FOR EACH TRANSITION-
 5000 EJECTP = 1
      CALL PAGECK
      DO 7000 IMEMBR=1,NOTRNS
      IF (TINPT(IMEMBR,1) .EQ. 0 .AND. NTINPT(IMEMBR,1) .EQ. 0)
     -    GO TO 7000
      READCT = TRSTAT(IMEMBR,1)
      READTU = TRSTAT(IMEMBR,2)
      IF (READCT -IFIRCT) 5700,5600,5700
 5600 READYP = 100.00
      GO TO 5800
 5700 READYP = (READTU/FRTIME)*100.00
 5800 FIRECT = TRSTAT(IMEMBR,4)
      FIRETU = TRSTAT(IMEMBR,5)
      IF (FIRECT - IFIRCT) 5900,5850,5900
 5850 FIREPS = 100.00
      GO TO 5950
 5900 FIREPS = (FIRETU/FRTIME)*100.00
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 5950 IF (READCT .NE. 0) GO TO 6000
      FIREPR = 100.00
      GO TO 6003
 6000 IF (FIRECT - READCT) 6002,6001,6002
 6001 FIREPR = 100.00
      GO TO 6003
 6002 FIREPR = (FIRECT/READCT)*100.00
 6003 WAITT = FRTIME - READTU
      WAITT = WAITT + (FRTIME-WAITT-READTU)
      WAITP = 100.00 - READYP
      IF (LINECT - 37) 6005,6005,6004
 6004 EJECTP = 1
 6005 CALL PAGECK
      PRINT 6010
 6010 FORMAT ('                                                              ',
     -'                                                                      ',
     -'      ')
      CALL PAGECK
      PRINT 6020,IMEMBR,(TDESC(IMEMBR,I),I=1,6)
 6020 FORMAT (' SUMMARY OF ACTIVITY FOR TRANSITION ',I4,12X,6A8)
      CALL PAGECK
      PRINT 6010
C (PRINT READY INFORMATION)
      NOFIRE = READCT
      CALL PAGECK
      PRINT 6025
 6025 FORMAT (' ..FIRING STATISTICS:')
      CALL PAGECK
      PRINT 6030,READYP,READTU,NOFIRE
 6030 FORMAT (4X,'READY:',F6.1,'% OF SIMULATION TIME UNITS   ---',
     -F6.1,' TIME UNITS ',5X,'(',I4,'  FIRINGS)')
      NOFIRE = FIRECT
      CALL PAGECK
      PRINT 6035,FIREPR,NOFIRE,FIRETU,FIREPS
 6035 FORMAT (4X,'FIRED:',F6.1,'% OF TIME READY   ---',I4,' FIRINGS',
     -'   ---',F6.1,' TU''S',5X,'(',F6.1,'% OF SIMULATION TIME UNITS)')
      IF (FIRECT .EQ. READCT) GO TO 6052
      CALL PAGECK
      PRINT 6032
 6032 FORMAT (4X,'REASONS NOT FIRED:')
C (PRINT OTHER TRANSITIONS WHICH FIRED WHEN THIS TRANSITION READY)
      DO 6050 J=1,NCTRNS
      WAITCT = NCHOSN(IMEMBR,J)
      IF (WAITCT .EQ. 0) GO TO 6050
      IF (WAITCT - READCT) 6036,6033,6036
 6033 FIREOP = 100.00
      GO TO 6037
 6036 FIREOP = (WAITCT/READCT)*100.00
 6037 CALL PAGECK
      PRINT 6040,FIREOP,NCHOSN(IMEMBR,J),J,(TDESC(J,I),I=1,6)
 6040 FORMAT (4X,'-',F6.1,'% OF TIME READY OR ',I4,'    FIRINGS ',
     -'TRANSITION ',I4,'    SELECTED INSTEAD',2X,6A8)
 6050 CONTINUE
C (PRINT WAIT STATISTICS)
 6052 CALL PAGECK
      PRINT 6055
C  (PRINT REASONS THIS TRANSITION WAITED)
 6055 FORMAT (' ..WAIT STATISTICS:')
      NOFIRE = IFIRCT - READCT
      CALL PAGECK
      PRINT 6060,WAITP,WAITT,NOFIRE
 6060 FORMAT (4X,'WAITING:',F6.1,'% OF SIMULATION TIME UNITS   ---',
     -F6.1,' TIME UNITS',5X,'(',I4,'  FIRINGS)')
      IF (NOFIRE .EQ. 0) GO TO 6300
      CALL PAGECK
      PRINT 6063
 6063 FORMAT (4X,'REASONS NOT READY:')
      IWAITL = 0
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 6065 IWAITL = IWAITL + 1
      IWAITC = WAIT(IMEMBR,IWAITL)
      IF (IWAITC .EQ. -100) GO TO 6300
      IWAITL = IWAITL + 1
      WAITTU = WAIT(IMEMBR,IWAITL)
C    (PRINT 1ST LINE OF REASON)
      IF (NOFIRE - IWAITC) 6068,6066,6068
 6066 WAITP = 100.00
      GO TO 6069
 6068 WAITP = (WAITTU/WAITT)*100.00
 6069 IWCOND = WAIT(IMEMBR,IWAITL+1)
      IF (WAITP - 100.00) 6072,6070,6072
 6070 WAITTU = WAITT
      CALL PAGECK
      IF (WAIT(IMEMBR,IWAITL+2)) 6072,6072,6080
 6072 PRINT 6075,WAITP,WAITTU,IWAITC,IWCOND,(PDESC(IWCOND,J),J=1,6)
 6075 FORMAT (4X,'-',F6.1,'% OF WAIT TU''S OR ',F6.1,' TU''S (',
     -I4,' FIRINGS) WAITING ON PLACE ',I4,1X,6A8)
      GO TO 6100
 6080 PRINT 6085,WAITP,WAITTU,IWAITC,IWCOND,(PDESC(IWCOND,J),J=1,6)
 6085 FORMAT (4X,'-',F6.1,'% OF WAIT TU''S OR ',F6.1,' TU''S (',
     -I4,' FIRINGS) WAITING ON-NOT-PLACE ',I4,1X,6A8)
C    (PRINT REST OF LINES OF REASON)
 6100 IWT = IWAITL + 3
      DO 6150 IWAITL=IWT,WALIST,2
      IWCOND = WAIT(IMEMBR,IWAITL)
      IF(IWCOND .EQ. -2) GO TO 6065
      IF (IWCOND .EQ. -100) GO TO 6300
      CALL PAGECK
      IF (WAIT(IMEMBR,IWAITL+1)) 6120,6120,6140
 6120 PRINT 6130,IWCOND,(PDESC(IWCOND,J),J=1,6)
 6130 FORMAT (67X,'PLACE ',I4,1X,6A8)
      GO TO 6150
 6140 PRINT 6145,IWCOND,(PDESC(IWCOND,J),J=1,6)
 6145 FORMAT (62X,'-NOT-PLACE ',I4,1X,6A8)
 6150 CONTINUE
C (PRINT READY & FIRED FIRE #S FOR THIS TRANSITION)
 6300 EJECTP = -1
      CALL PAGECK
      LASTF = TRSTAT(IMEMBR,6)
      LASTR = TRSTAT(IMEMBR,3)
      PRINT 6375,LASTF,LASTR
 6375 FORMAT (' ..LAST FIRING WAS FIRING # ',I4,' ..LAST TIME READY',
     -' WAS FIRING # ',I4)
      EJECTP = -1
      CALL PAGECK
      PRINT 6010
      EJECTP = -1
      CALL PAGECK
      PRINT 6380
 6380 FORMAT (' ')
 7000 CONTINUE
C-PRINT SIMULATION SUMMARY STATISTICS-
      EJECTP = 1
 7010 CALL PAGECK
      PRINT 6010
      CALL PAGECK
      PRINT 6010
      CALL PAGECK
      PRINT 7310
 7310 FORMAT (' S I M U L A T I O N  S U M M A R Y ')
      CALL PAGECK
      PRINT 6010
      CALL PAGECK
      PRINT 6010
C (PRINT REASON FOR SIMULATION TERMINATION)
      IF (INPT50 .NE. 9) GO TO 8000
      DO 7500 IPLACE=1,NOPCON
```

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      IF (PLIMIT(IPLACE) .EQ. 0) GO TO 7500
      CALL PAGECK
      PRINT 7320,PLIMIT(IPLACE),IPLACE,(PDESC(IPLACE,J),J=1,6)
 7320 FORMAT (' SIMULATION TERMINATED BY AT LEAST:',I4,'  TOKENS ON',
     -' PLACE ',I4,2X,6A8)
      IJ = IPLACE + 1
      DO 7400 IREST=IJ,NOPCON
      IF (PLIMIT(IREST) .EQ. 0) GO TO 7400
      CALL PAGECK
      PRINT 7340,PLIMIT(IREST),IREST,(PDESC(IPLACE,J),J=1,6)
 7340 FORMAT (' ',34X,I4,'  TOKENS ON PLACE ',I4,2X,6A8)
 7400 CONTINUE
      GO TO 9000
 7500 CONTINUE
 8000 IF (INPT70 .NE. 9) GO TO 8080
      CALL PAGECK
      PRINT 8050,TOTIME
 8050 FORMAT (' SIMULATION TERMINATED BY COMPLETION OF AT LEAST ',
     -F8.3,' REQUESTED TIME UNITS')
      GO TO 9000
 8080 IF (INPT40 .NE. 9) GO TO 8900
      DO 8200 ITRANS=1,NOTRNS
      IF (FRLIMT(ITRANS) .EQ. 0) GO TO 8200
      CALL PAGECK
      PRINT 8100,FRLIMT(ITRANS),ITRANS,(TDESC(ITRANS,J),J=1,6)
 8100 FORMAT (' SIMULATION TERMINATED BY AT LEAST:',I4,'  FIRINGS OF',
     -' TRANSITION ',I4,2X,6A8)
      IR = ITRANS + 1
      DO 8175 IREST=IR,NOTRNS
      IF (FRLIMT(IREST) .EQ. 0) GO TO 8175
      CALL PAGECK
      PRINT 8150,FRLIMT(IREST),IREST,(TDESC(IREST,J),J=1,6)
 8150 FORMAT (' ',34X,I4,'  FIRINGS OF TRANSITION ',I4,2X,6A8)
 8175 CONTINUE
      GO TO 9000
 8200 CONTINUE
 8900 CALL PAGECK
      PRINT 8910,IFIRCT
 8910 FORMAT (' SIMULATION TERMINATED BY COMPLETION OF ',I4,
     -'  REQUESTED TRANSITION FIRINGS')
C (PRINT FINAL MARKING OF NET)
 9000 CALL PAGECK
      PRINT 9100
 9100 FORMAT (' FINAL MARKING OF PETRI NET:')
      DO 10000 IPLACE=1,NOPCON
      IF (PMARK(IPLACE) .EQ. 0) GO TO 10000
      CALL PAGECK
      PRINT 9200,IPLACE,PMARK(IPLACE),(PDESC(IPLACE,J),J=1,6)
 9200 FORMAT ('   PLACE ',I4,' :',I4,15X,6A8)
10000 CONTINUE
C (PRINT TRANSITION FIRING STATISTICS)
      CALL PAGECK
      PRINT 11000,IFIRCT,FRTIME
11000 FORMAT (' FIRING STATISTICS:   TOTAL # FIRINGS =',I4,
     -'   ---  TOTAL TIME UNITS =',F6.1)
      DO 13000 ITRANS=1,NOTRNS
      IF (TINPT(ITRANS,1) .EQ. 0 .AND. NTINPT(ITRANS,1) .EQ. 0)
     -   GO TO 13000
      NOFIRE = TRSTAT(ITRANS,4)
      IF (TRSTAT(ITRANS,4) - IFIRCT) 11050,11040,11050
11040 FIREP = 100.00
      TUPCT = 100.00
      GO TO 11090
11050 FIREP = (TRSTAT(ITRANS,4)/IFIRCT)*100.00
11080 TUPCT = (TRSTAT(ITRANS,5)/FRTIME)*100.00
11090 CALL PAGECK
      PRINT 11100,ITRANS,(TDESC(ITRANS,J),J=1,6)
11100 FORMAT (' -TRANSITION ',I4,': ',6A8)
```

```
      EJECTP = -1
      CALL PAGECK
      PRINT 12000,NOFIRE,FIREP
12000 FORMAT ('    .# FIRINGS = ',I4,'  OR ',F6.1,'% OF TOTAL FIRINGS')
      EJECTP = -1
      CALL PAGECK
      PRINT 12100,TRSTAT(ITRANS,5),TUPCT
12100 FORMAT ('    .# TIME UNITS USED = ',F6.1,'  OR ',F6.1,'% OF ',
     -'TOTAL TIME UNITS')
13000 CONTINUE
      PRINT 6010
      PRINT 6010
      STOP
      END
C.....................................................................
C SUBROUTINE ADTRNS  ADDS ALL NON-ZERO I4 MEMBERS OF INPUT DATA TO AN
C                    INTEGER*2 2-DIMENSIONED ARRAY AT 1ST 0 ENTRY
C                    FOR MEMBER. ALSO UPDATES MXPLCE ARGUMENT WITH
C                    PLACE PASSED TO ROUTINE IF A PLACE > MXPLCE IS
C                    SENT.
C --ARGUMENTS--
C    NAMARR==> NAME OF ARRAY TO WHICH DATA IS TO BE ADDED
C    INDATA==> 14 FIELDS OF INPUT DATA ON FORMAT I TYPE POS.7-66
C    IARRAY==> ARRAY TO WHICH DATA IS TO BE ADDED
C    IMEMBR==> ROW I OF IARRAY(I,J) TO WHICH DATA IS TO BE ADDED
C    MAXARR==> GREATEST DIMENSION OF FIRST SUBSCRIPT I OF IARRAY(I,J)
C    MAXSTR==> GREATEST DIMENSION OF SECOND SUBSCRIPT J OF IARRAY(I,J)
C    MXPLCE==> GREATEST PLACE # INPUT TO THIS SIMULATION
C.....................................................................
      SUBROUTINE ADTRNS(NAMARR,INDATA,IARRAY,IMEMBR,MAXARR,MAXSTR,
     -  MXPLCE)
      DIMENSION INDATA(14)
      INTEGER*2 IARRAY(MAXARR,MAXSTR)
      REAL*8 NAMARR
      IF (IMEMBR .LE. MAXARR) GO TO 100
      PRINT 50,NAMARR,IMEMBR,MAXARR
   50 FORMAT (' ',A6,' INPUT ATTEMPTS TO STORE DATA IN ',I4,
     -'TH MEMBER OF ARRAY. EXCEEDS CAPACITY OF ',I4,' MEMBERS.',
     -' JOB CANCELLED.')
      STOP
  100 IXADD = 1
  110 DO 200 ISEARC=1,MAXSTR
      IF (IARRAY(IMEMBR,ISEARC) .NE. 0) GO TO 200
      ISTART = ISEARC
      ISEARC = MAXSTR
      DO 190 IADDPT=ISTART,MAXSTR
  160 IF (IXADD .EQ. 15) GO TO 300
      IF (INDATA(IXADD) .NE. 0) GO TO 180
      IXADD = IXADD + 1
      GO TO 160
  180 IARRAY(IMEMBR,IADDPT) = INDATA(IXADD)
      IF (INDATA(IXADD) - MXPLCE) 190,190,185
  185 MXPLCE = INDATA(IXADD)
  190 IXADD = IXADD + 1
  200 CONTINUE
  250 IF (IXADD .EQ. 17) GO TO 300
      PRINT 260,MAXSTR,IMEMBR,NAMARR
  260 FORMAT (' MORE THAN ',I4,' INPUTS TO MEMBER ',I4,
     -' OF ',A6,' ARRAY,.JOB CANCELLED')
      CALL PRTAR2(NAMARR,IARRAY,IMEMBR,MAXARR,MAXSTR)
      STOP
  300 RETURN
      END
```

```
C.....................................................................
C SUBROUTINE PRTAR1: PRINTS A MEMBER OR ALL NON-ZERO MEMBERS OF A
C                    1-DIMENSIONED INTEGER*2 ARRAY
C --ARGUMENTS--
C    NAMARR==> NAME OF ARRAY TO BE (PARTIALLY) PRINTED
C    IARRAY==> ARRAY TO BE PRINTED
C    IMEMBR==> MEMBER I OF IARRAY(I) TO BE PRINTED. IF IMEMBR=0,
C               EVERY NON-ZERO MEMBER OF IARRAY WILL BE PRINTED
C    MAXARR==> GREATEST DIMENSION OF ARRAY
C.....................................................................
      SUBROUTINE PRTAR1(NAMARR,IARRAY,IMEMBR,MAXARR)
      INTEGER*2 IARRAY(MAXARR)
      REAL*8 NAMARR
      ISTART = IMEMBR
      IEND = IMEMBR
      IF (IMEMBR .NE. 0) GO TO 30
      ISTART = 1
      IEND = MAXARR
      EJECTP = -1
      CALL PAGECK
      PRINT 20,NAMARR,MAXARR
   20 FORMAT (' ',A6,'(I),I=  1 TO ',I4,' ')
      GO TO 35
   30 EJECTP = -1
      CALL PAGECK
      PRINT 33,NAMARR,IMEMBR
   33 FORMAT (' ',A6,' ',I4,':')
   35 DO 100 I=ISTART,IEND
      IF (IARRAY(I) .EQ. 0) GO TO 100
      CALL PAGECK
      PRINT 50,I,IARRAY(I)
   50 FORMAT (' ',I4,':',I4)
  100 CONTINUE
      RETURN
      END
C.....................................................................
C SUBROUTINE PRTAR2: PRINTS ALL 2ND SUBSCRIPT ENTRIES FOR A MEMBER
C                    OR MEMBERS OF AN INTEGER*2 2 SUBSCRIPT ARRAY
C                    IF 1ST ENTRY IS NOT = 0
C --ARGUMENTS--
C    NAMARR==> NAME OF ARRAY TO BE PRINTED
C    IARRAY==> ARRAY TO BE (PARTIALLY) PRINTED
C    IMEMBR==> ROW   I OF IARRAY(I,J) TO BE PRINTED. IF IMEMBR=0,
C               EVERY I ROW FOR WHICH IARRAY(I,1) IS NOT = 0
C               WILL BE PRINTED
C    MAXARR==> GREATEST DIMENSION OF FIRST SUBSCRIPT I OF IARRAY(I,J)
C    MAXSTR==> GREATEST DIMENSION OF SECOND SUBSCRIPT J OF IARRAY(I,J)
C.....................................................................
      SUBROUTINE PRTAR2(NAMARR,IARRAY,IMEMBR,MAXARR,MAXSTR)
      INTEGER*2 IARRAY(MAXARR,MAXSTR)
      REAL*8 NAMARR
      IPRINT = 0
      ISTART = 1
      IEND = MAXARR
      IF (IMEMBR .EQ. 0) GO TO 75
      CALL PAGECK
      PRINT 50,NAMARR,IMEMBR,MAXSTR
   50 FORMAT (' ',A6,'(',I4,',I),J=0001,',I4)
      ISTART = IMEMBR
      IEND = IMEMBR
      GO TO 100
   75 CALL PAGECK
      PRINT 80,NAMARR,MAXSTR,MAXARR
   80 FORMAT (' ',A6,'(I,J),J=  1   TO ',I4,';   I=  1 TO ',I4)
  100 DO 200 ITHMEM=ISTART,IEND
      IF (IARRAY(ITHMEM,1) .EQ. 0) GO TO 200
      IPRINT = 1
      EJECTP = -1
```

```
      CALL PAGECK
      PRINT 130,ITHMEM
  130 FORMAT (' MEMBER ',I4)
      DO 175 IPRT=1,MAXSTR,25
      IENDL = IPRT + 24
      IF (IARRAY(ITHMEM,IPRT) .EQ. 0) GO TO 200
  135 IF (IENDL .LE. MAXSTR) GO TO 140
      IENDL = MAXSTR
  140 CALL PAGECK
      PRINT 150,(IARRAY(ITHMEM,IX),IX=IPRT,IENDL)
  150 FORMAT (25(' ',I4))
  175 CONTINUE
  200 CONTINUE
      IF (IPRINT .EQ. 1) RETURN
      CALL PAGECK
      PRINT 300
  300 FORMAT (' (NO NON-ZERO MEMBERS OF ARRAY)')
      RETURN
      END
C.....
C SUBROUTINE SRTAR2: SORTS EACH ROW OF AN INTEGER*2 2-DIMENSIONED
C                    ARRAY IF 1ST MEMBER IS NOT ZERO BUT LEAVES
C                    ZERO ENTRIES AT END IN PLACE. USED TO SORT
C                    TRANSITION ARRAYS
C --ARGUMENTS--
C    IARRAY==> ARRAY WHOSE ROWS ARE TO BE SORTED
C    MAXARR==> GREATEST DIMENSION OF FIRST SUBSCRIPT I (ROWS) OF
C              IARRAY(I,J)
C    MAXSTR==> GREATEST DIMENSION OF 2ND SUBSCRIPT J OF IARRAY(I,J)
C.....
      SUBROUTINE SRTAR2(IARRAY,MAXARR,MAXSTR)
      DIMENSION IARRAY(MAXARR,MAXSTR)
      INTEGER*2 IARRAY,ITEMP(50)
      KLEN=2
      IDISP=0
      IRECLN=2
      DO 100  IMEMBR=1,MAXARR
      DO 10 I=1,MAXSTR
      IF (IARRAY(IMEMBR,I) .EQ. 0) GO TO 15
   10 ITEMP(I) = IARRAY(IMEMBR,I)
      NOTEMP = I + 1
   15 NCTEMP = I - 1
      IF  (NOTEMP .EQ. 0) GO TO 100
      CALL CHARST(NCTEMP,ITEMP,KLEN,IRECLN,IDISP)
      DO 50 I=1,NCTEMP
   50 IARRAY(IMEMBR,I) = ITEMP(I)
  100 CONTINUE
      RETURN
      END
C.....
C SUBROUTINE EDTDUP: SCANS PROVIDED INTEGER*2 2-DIMENSIONED ARRAY ROWS
C                    FOR DUPLICATE PLACES ON A ROW; USED TO VERIFY
C                    VALIDITY OF  TRANSITION ARRAYS
C --ARGUMENTS--
C    ARRNAM==> NAME OF ARRAY BEING EDITED
C    IARRAY==> ARRAY WHOSE ROWS ARE BEING EDITED
C    MAXARR==> GREATEST DIMENSION OF FIRST SUBSCRIPT (ROW) I OF
C              IARRAY(I,J)
C    MAXSTR==> GREATEST DIMENSION OF 2ND SUBSCRIPT J OF IARRAY(I,J)
C.....
      SUBROUTINE EDTDUP(ARRNAM,IARRAY,MAXARR,MAXSTR)
      INTEGER*2 IARRAY(MAXARR,MAXSTR)
      REAL*8 ARRNAM
  110 DO 200 IMEMBR=1,MAXARR
      DO 200 IX=2,MAXSTR
      IF (IARRAY(IMEMBR,IX) .EQ. 0) GO TO 200
      IF (IARRAY(IMEMBR,IX) .NE. IARRAY(IMEMBR,IX-1)) GO TO 200
      PRINT 50,IARRAY(IMEMBR,IX),IMEMBR,ARRNAM
```

```
   50 FORMAT (' PLACE ',I4,' LISTED MULTIPLE TIMES IN TRANSITION ',
     -I4,' OF ',A6,'.JOB CANCELLED')
      STOP
  200 CONTINUE
      RETURN
      END
C.....................................................................
C SUBROUTINE PAGECK: KEEPS TRACK OF LINES ON PRINTED OUTPUT. SKIPS TO
C                    A NEW PAGE & PRINTS HEADING IF NEEDED.IF EJECTP=1,
C                    UNCONDITIONALLY SKIPS TO NEW PAGE; IF EJECTP=-1,
C                    UNCONDITIONALLY WILL NOT SKIP TO NEW PAGE.
C.....................................................................
      SUBROUTINE PAGECK
      INTEGER*2 LINECT,PAGENO,EJECTP
      REAL*8 TITLE(1,6)
      COMMON TITLE,LINECT,PAGENO,EJECTP
      IF (EJECTP) 100,50,75
   50 IF (LINECT .LT. 50) GO TO 100
   75 PRINT 85,(TITLE(1,I),I=1,6),PAGENO
   85 FORMAT (1H1,6A8,63X,'PAGE ',I4)
      PRINT 86
   86 FORMAT ('  ')
      PAGENO = PAGENO + 1
      LINECT = 2
  100 LINECT = LINECT + 1
      EJECTP = 0
      RETURN
      END
```

VITA

Pamela Bridgers Thomas was born in Detroit, Michigan on September 19, 1946. Enrolling in The University of Tennessee at Knoxville in 1964, she was elected to Phi Beta Kappa in 1967. After serving as a student programmer at Union Carbide Corporation, Nuclear Division, in the summer of 1967, she graduated from The University of Tennessee magna cum laude with a Bachelor of Arts degree in Mathematics in 1968. From 1968 to 1969, she worked as a computer programmer for Computer Sciences Corporation at Redstone Arsenal in Huntsville, Alabama. She married W. Cecil Thomas, Jr., in 1969 and worked from 1969 to 1973 as a programmer for Cessna Aircraft Company in Wichita, Kansas. In 1973 she returned to Knoxville to work for Union Carbide, where she is now a Computer Programmer/Analyst.