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Using Hierarchical Object Oriented Timed Colored Petri Nets for Design Radar Display

Dr. Qaysar S. Mahdi[1*]

Abstract

In this work the hierarchical Colored Petri Nets Program Language is used to model and simulate the radar display. The targets are built using object oriented idea, thus a class is being built for the targets so that each target is made as an object which belongs to the same class. As each object is created it is made as a thread so that the objects are made to operate concurrently, in addition the radar monitor is created as a thread so that it operates concurrently with the objects (targets). A system called Simulated Radar Monitor using hierarchical object oriented timed Colored Petri Nets (SRMCPN) is built. This system is implemented under windows environment using Borland C++ programing language is executed on a Pentium 3 processor with clock of 1 GHz. In this work the radar display is designed and the radar performance is improved with optimized advantageous such as the object oriented concept, timing concept, concurrency concept, and dynamic concept. The simulated radar display is built using Hierarchical Object Oriented Timed Colored Petri Nets. This model is built to show the CPN capabilities to represent time and concurrency.

Key Words: Concurrency, Dynamic, Petri Nets, Program, Radar.

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Introduction

To simulate any system one needs a modeling tool, which has the right properties, that suits the required system. The Hierarchical Object Oriented Timed Colored Petri Net (HOOTCPN) have all the requirements needed in the simulation process. In this work the HOOTCPN which is chosen has many properties like (i) the object oriented concept, (ii) timing concept, (iii) concurrency concept, (iv) dynamic concept. Object oriented programming is defined in [1] as ``Object oriented programming is an approach that provides a way of modularizing programs by creating partitioned memory area for both data and functions that can be used as templates for creating copies of such modules on demand``.

The use of the object oriented concept in the implementation of the HOOTCPN will give the model all the object oriented advantages. The timing concept of the HOOTCPN is necessary for providing write timings in the model. In realty the radar operation is independent of targets flights. Therefore the concurrency concept of the HOOTCPN is applied to simulate this realty. Petri Nets have proven to be a useful formalism to express concurrency. Problems related to concurrent processes are getting more and more important to be managed, i. e. solved [2].

Concurrency is implemented using threads, and any application that uses multiple threads can be called a multi-threaded application [3]. There are other modeling tools like fault tree analysis which is an approach to the identification of process hazards [4] [5] [6]. Another modeling tool is the Real Time Logic (RTL) and is used in the area of checking timing constraints in a real time system [7][8][9].

Literature Survey

In 1998, Steven and Jonathan [10] modeled and analyzed the communication mechanisms of a missile engagement simulator. The simulator is developed as a testing platform for missile guidance and control algorithms. The

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Corresponding author: Dr. Qaysar S. Mahdi
Address: 1*Professor, Mechatronics Engineering Department, Tishk International University, Erbil, Kurdistan, Iraq.
1*E-mail: qaysar.mahdy@tiu.edu.iq

simulation uses concurrency and remote execution concepts to enhance performance. In 1998, Bulach, et al. [11] designed a novel hardware platform for processing algorithms based on Colored Petri Nets. Colored Petri Net processor is aimed at embedded discrete-event control applications and is characterized by its natural incorporation of external stimuli into the computation fow. The processor consists of two layers of hardware: one for determining when and which computations will take place, and another for effectively performing the actual computations. A hybrid architecture and hardware organization is described in detail. The process of software development is presented, and augmented with an illustrative example. In conclusion, comments on advantages and possible future implementations are made. In 2002, Maro [12] presented a technique for generating test cases for an object oriented program classes using Hierarchical Colored Petri Nets (HCPN). Nilabja [13], described a novel technique to select the optimal number of threads of a target-tracking application using a simulation-based Colored Petri Nets (CPNs) model. In 2018, Jan [14], presented and provided the combination of reconfigurable Petri Nets and hierarchical Petri Nets yielding a hierarchical structure of reconfigurable Petri Nets. Hierarchical are established by substituting transitions and subnets. These subnets are themselves reconfigurable, so they are supplied with their own set of rules, so-called rules. Moreover, global rules that can be applied in the entire net are provided, Hierarchical, Reconfigurable Petri Nets [14].

Basic Principles

Colored Petri Nets (CP-nets or CPN) were introduced by Jensen in 1988 to model computation as well as data flow. It is a graphical oriented language for design, specification, simulation and verification of systems. The development of CPN has been driven by the desire to develop a modeling language. CPN has got its name because it allows the use of tokens that carry data values and can hence be distinguished between each other [15].

A. Componets of Coloured Petri Nets [15]

Colored petri nets consist of a set of arcs, circles called places, rectangles called transitions and inscriptions called net inscriptions as shown in Fig (1).

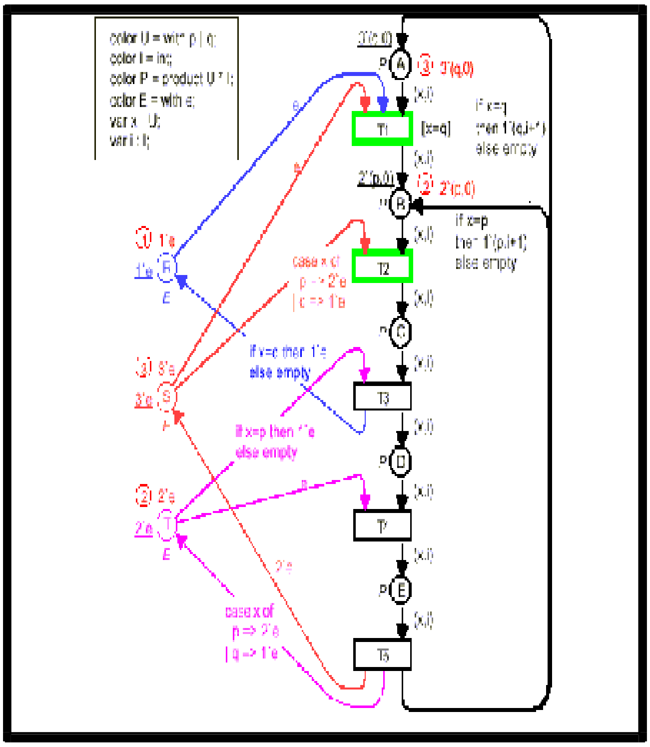


Fig. 1. CPN describing the resource allocation system [15]

Figure (1) models a set of processes, which share a common pool of resources. There are two different kinds of processes (called p-processes and q-processes) and three different kinds of resources (called r-resources, s-resources and t-resources). The processes could be computer programs while the resources could be different facilities shared by the programs (e.g. Tape drives, laser printers and plotters). Each process is cyclic and during the individual parts of its cycles, the process needs to have exclusive access to a varying amount of resources.

B. Structure of Hierachical CPN [15]

Structure of a HCPN is given by,

HCPN = (S, SN, SA, PN, PT, PA, FS, FT, PP) satisfying the requirements below

S: is a finite set of pages such that

- Each page s· S is a non-hierarchical CPN:

  (· $_s$, P_s, T_s, A_s, N_s, C_s, G_s, E_s, T_s)

- The set of net elements are pairwise disjoint:

  · s_1, s_2 · S:[s1 · s2 · $(P_{s_1}$ · T_{s_1} · $A_{s_1})$ · $(P_{s_2}$ · T_{s_2} · $A_{s_2})$ · · 1

SN · T: is a set of substitution nodes

SA: is a page assignment function. It is defined from SN into S such that

- No page is a subpage of itself

  · s · S^* · N · · · · · SA· S · ·

PN · P: is a set of port nodes

PT : is a port type function. It is defined from PN into {in, out, I/O, general}

PA : is a port assignment function. It is defined from SN into binary relations such

That:

- Socket nodes are related to port nodes:

  · t · SN : PA(t) · X(T) x $PN_{SA(T)}$

- Socket nodes are of the correct type:

  · t · SN· (p_1, p_2) · PA(t):[PT(p_2) · general · ST(p_1,t) = PT(p_2)]

- Related nodes have identical color sets and equivalent initialization expressions:

  · t · SN· (p_1, p_2) · PA(t):[C(p_1) = C(p_2) · I(p_1) = I(p_2)]

FS · PS : is a finite of fusion sets such that:

- Members of fusion set have identical colour sets and equivalent initialization expressions:

  · fs · FS : · p_1,p_2 · fs : [C(p_1) = C(p_2) · I(p_1) = I(p_2)]

FT : is a fusion type function. It is defined from fusion sets into {global, Page, instance} such that

- Page and instance fusion sets belong to a single page:

  · fs · FS : [FT(fs) · global · · s · S : fs

- P_s] PP· S_{MS} : is a multi set of prime pages

C. Timed CPN[16]

To investigate the performance of systems, i.e., the speed at which they operate, it is convenient to extend the CPN with a time concept. To do this, we introduce a global clock. The clock values represent the model time, and they may either be discrete (e.g. integers) or continuous (e.g. reals). In addition to the token color, we allow each token to carry a time value, also called a time stamp. In a timed CPN a transition is to be color enabled when all its input color tokens are available. However, to be enabled, it must be ready. This means all the time stamps of the removed tokens must be less than or equal to the current model time. To model that an activity/operation takes Δr time units, we let the corresponding transition t create time stamps for its output tokens that are Δr time units larger than the clock value at which it occurs. This implies that the tokens produced by t are unavailable for Δr time units. It can be argued that it would be more natural to delay the creation of the output token, so that they did not come into existence until Δr time units after the occurrence of t had begun. However, such an approach would mean that a timed CPN would get intermediate markings which do not correspond to markings in the corresponding untimed CPN, because there would be markings in which input tokens would have been removed but output tokens not yet generated. Hence we would get a more complex relationship between the behavior of timed and untimed nets.

The execution of a timed CPN is time driven. The system remains at a given model time as long as there are color enabled binding elements that are ready for execution. When no more binding elements can be executed, at the current model time, the system advances the clock to the next model time at which binding elements can be executed. The occurrence of binding elements is instantaneous.

To see how a timed simulation works, let us consider Fig (2), which contains a timed CPN for the resource allocation system. For this system, we use a discrete clock, starting at 0. From the third and fourth lines of the declarations, we see that P-tokens are timed (i.e. carry time stamps), while the E tokens are not. This means E tokens are always ready to be used. The small rectangle below the declarations indicates that the current model time is 641.

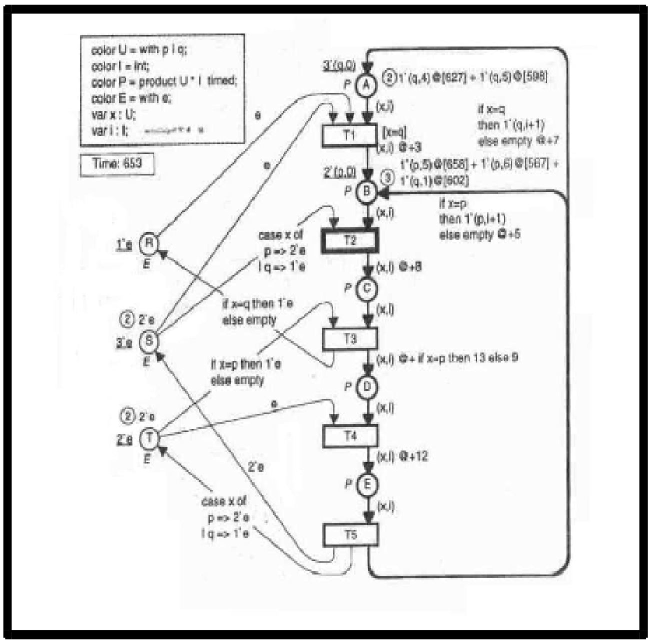
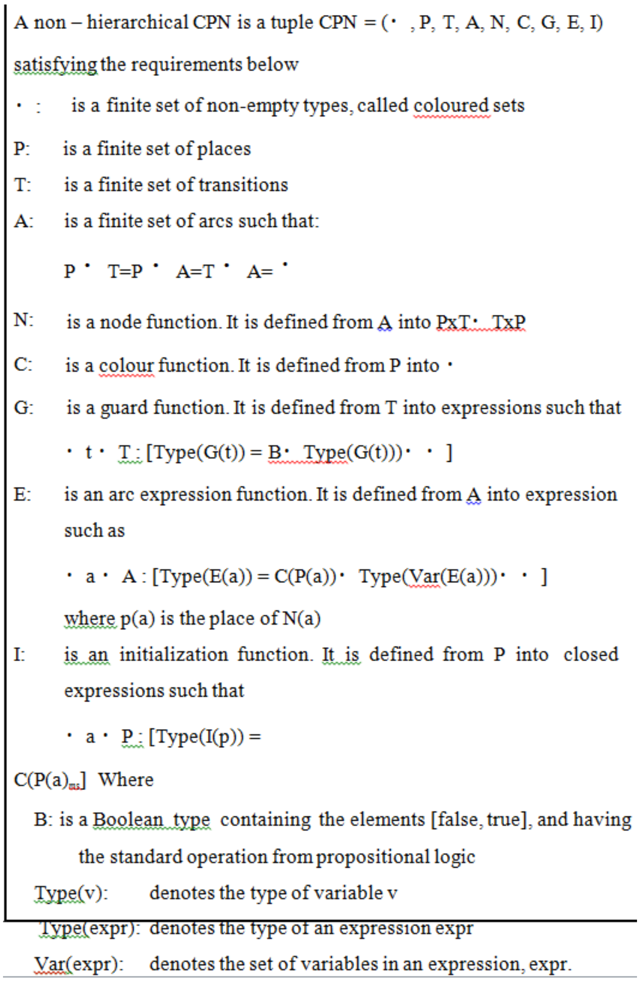


Fig. 2. Timed Colored Petri Net [16]

D. Structure of Timed CPN [16]

The structure of time non-hierarchical CPN is given by


A non – hierarchical CPN is a tuple CPN = (· , P, T, A, N, C, G, E, I)

satisfying the requirements below

· : is a finite set of non-empty types, called coloured sets

P: is a finite set of places

T: is a finite set of transitions

A: is a finite set of arcs such that:

P · T=P · A=T · A= ·

N: is a node function. It is defined from A into PxT· TxP

C: is a colour function. It is defined from P into ·

G: is a guard function. It is defined from T into expressions such that

· t · T : [Type(G(t)) = B· Type(G(t))· ·]

E: is an arc expression function. It is defined from A into expression such as

· a · A : [Type(E(a)) = C(P(a))· Type(Var(E(a)))· ·]

where p(a) is the place of N(a)

I: is an initialization function. It is defined from P into closed expressions such that

· a · P : [Type(I(p)) =

C(P(a)ms] Where

B: is a Boolean type containing the elements [false, true], and having the standard operation from propositional logic

Type(v): denotes the type of variable v

Type(expr): denotes the type of an expression expr

Var(expr): denotes the set of variables in an expression, expr.

A time non-hierarchical CPN is a tuple TCPN = (CPN, R, r_0) CPN: satisfies the requirements of non-hierarchical CPN R : is a set of time values, also called time stamps

r_0 : is an element of R, called the start time.

Modeling And Simulation Of Radar Display

In this work the modeling of the simulated radar monitor is done by using the Hierarchical Object Oriented Timed Colored Petri Net (HOOTCPN). The object oriented idea is implemented in the generation of targets, where target movements are assumed in different directions, each target is made as an object. The timing concept present in the CPN is used to control the speed of the trace movement in addition to control the objects. The concurrency is implemented by operating each object as a thread, and in addition, the trace operation is made as thread.

A system is built and named SRMCPN standing for Simulated Radar Monitor using Colored Petri Nets.

A. DirectX

DirectX means directly manipulating the hardware, all the graphics presented in this chapter is performed by directly writing to the video adapter, and this provides very high speed for writing to the screen pixels.

The time which is taken to write one pixel to the screen is 30 nanoseconds which is faster than the ordinary used graphics methods.

Also by using DirectX we are able to check the video adapter's hardware capabilities. Generally the video adapter has a primary surface into which all the graphics are written, the adapter may have an overlay surface (one or more). The overlay surface may be thought of as a transparency paper overlaid in front of the screen (primary surface). DirectX provides the tools to check for the adapter's hardware capabilities. So before the overlay surface can be used the adapter's capability for overlay support should be checked.

The primary surface is used to show the fixed things (map), while the overlay surface is used to draw the moving things (the trace and targets). By using the overlay surface some of the programming burden is lifted because when things are drawn on the overlay surface that overlap with things drawn on the primary surface the primary surface is not over-written, so there is no need to draw them again on the primary surface, lot of time is saved by this operation.

B. The SRMCPN System

The structure of the SRMCPN system is shown in Fig (3). Each part of the system will be explained in the following subsections.

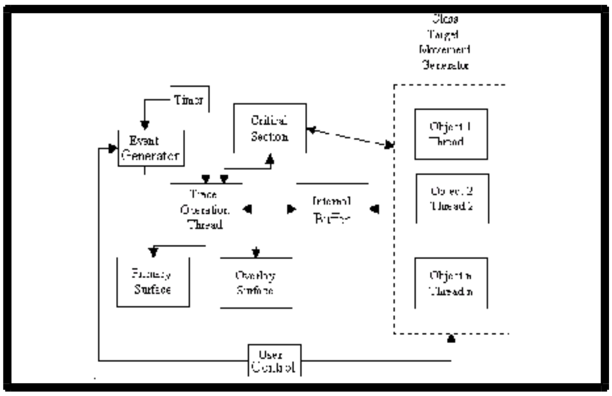


Fig. 3. Structure of the SRMCPN system

C. Hierarchical Object Oriented Timed Coloured Petri Net Model For SRMCPN Systems.

The whole Hierarchical Object Oriented Timed Colored Petri Net model is shown in Fig (3). The model starts its execution at transition T1 as it gets the control token from place P1, where the directX is initialized and the primary and overlay surfaces are prepared for operation and the control token is passed to place P2.

After that the control token is passed to substitution transition T2. It also takes another control token from place P10, where the preparation step for the matrices is done.

The sub-page for this transition is shown in Fig (4). After that transition T2 will pass one of the control tokens to place P3 and the other will go to place P5. At this point substitution transition T3 and transition T4 will work concurrently, where substitution transition T3 will start to draw the trace and targets, and T4 will start to add targets to the model. The sub-page Trace#1 of substitution transition T3 is shown in Fig (5). Transition T4 adds targets to the system by sending target route select information and control token to places P6,…,P7. From there it moves to substitution transitions T5,…,T6 where these transitions are operated concurrently. As each target is out of the radar range the transition stops its execution and passes the control token to place P11.

Transition T7 represents the user control to add targets and to stop the model execution by sending the esc token.

Table (1) shows the sequence of substitution transition execution and their related sub-pages and functions for the SRMCPN model.

Table 1. Type Styles Sequence of Execution for the SRMCPN Model and Functions

Sequence of execution	Subst. Transition or Transition	Sub Page	Function
1	T1	-	Initializes DirectX
2	T2	Initco#1	Initializes matrices
3	T3	Trace#1	Drawing of the trace and targets
3	T4	-	Generates threads
4	T5	TargGen#1	TargMovGen
5	T6	TargGen#1	TargMovGen

The TargMovGen is a Hierarchical Object Oriented timed Colored Petri Net and is shown in Fig (6). Table (2) shows the sequence of substitution transition execution and its related sub-pages and functions for the TargMoveGen model. At transition T1 the x and y coordinates for the target are calculated using one of the equations (5.1,…,5.4) according to the user selection. Then at transition T2 the range and azimuth are calculated from the x and y coordinates.

At substitution transition T4 the target shape is added to the Internal Buffer if the target range is less than 300, if not execution stops at place P10. Substitution transition T4 is shown in Fig (7). After the execution of substitution transition T4 control goes to transition T5, where execution stops for a period equal to one trace revolution.

Table 2. Type Styles Sequence of Execution for the SRMCPN Model

Sequence of execution	Subst. Transition or Transition	Sub Page	Function
1	T1	-	Calculate the x,y coordinates
2	T2	-	Calculate the Range an Azimuth angle
3	T3	-	Target Out of range
3	T4	Draw#1	Addition of target shape to the Internal Buffer
4	T5	-	Sleep One trace revolution time

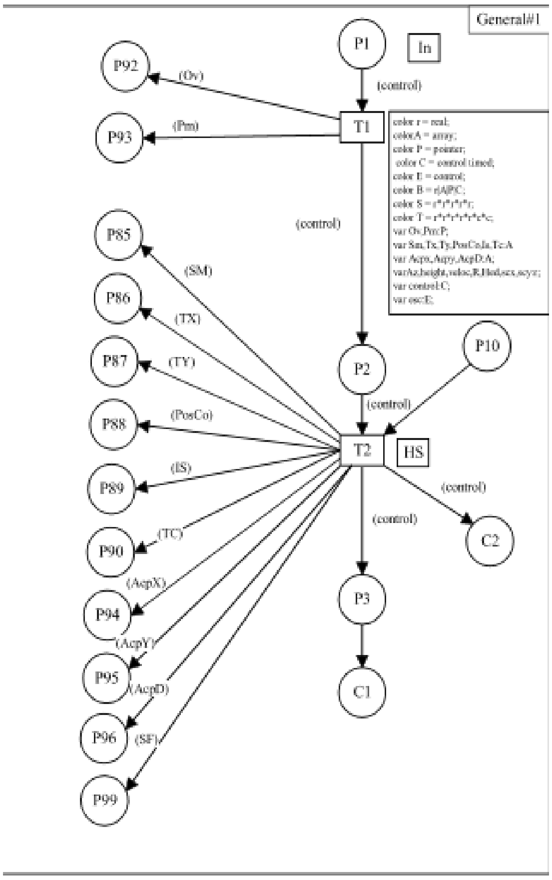


Fig. 3-a. SRMCPN model

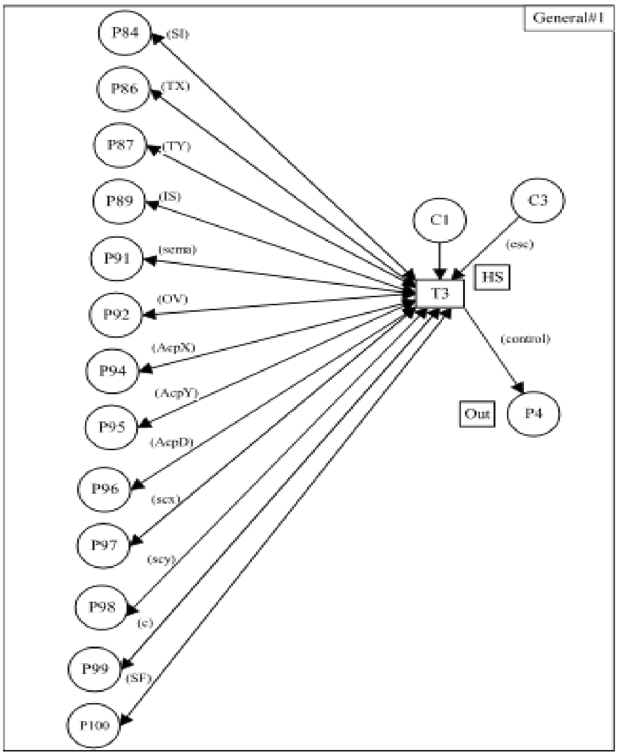


Fig. 3-b. Continued SRMCPN model

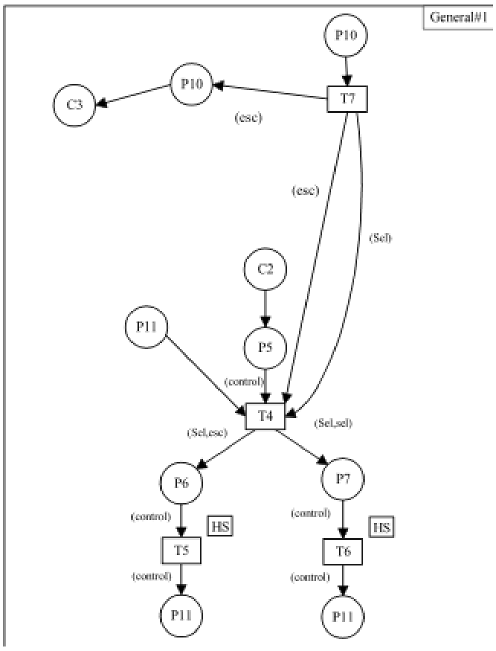


Fig. 3 –c. Continued SRMCPN model

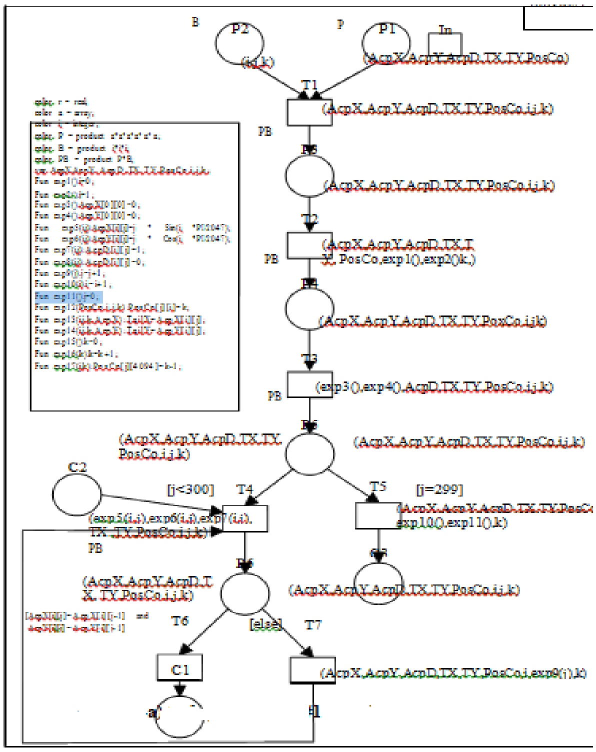


Fig. 4. Sub-page InitCo#1 Initialization of coordinates

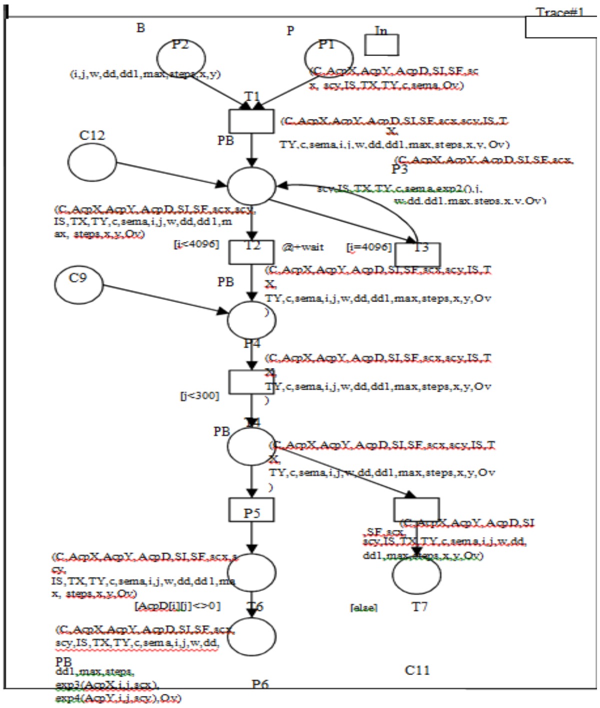


Fig. 5. Sub-page Trace#1 Trace operation

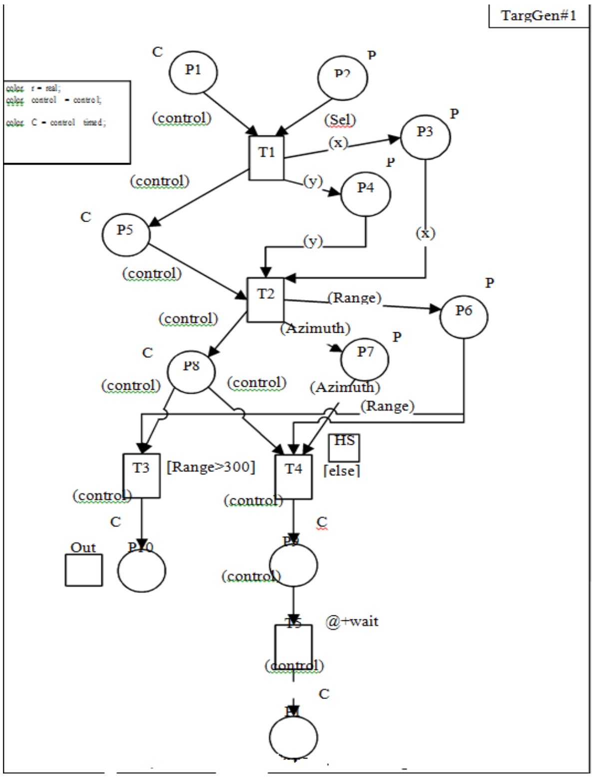
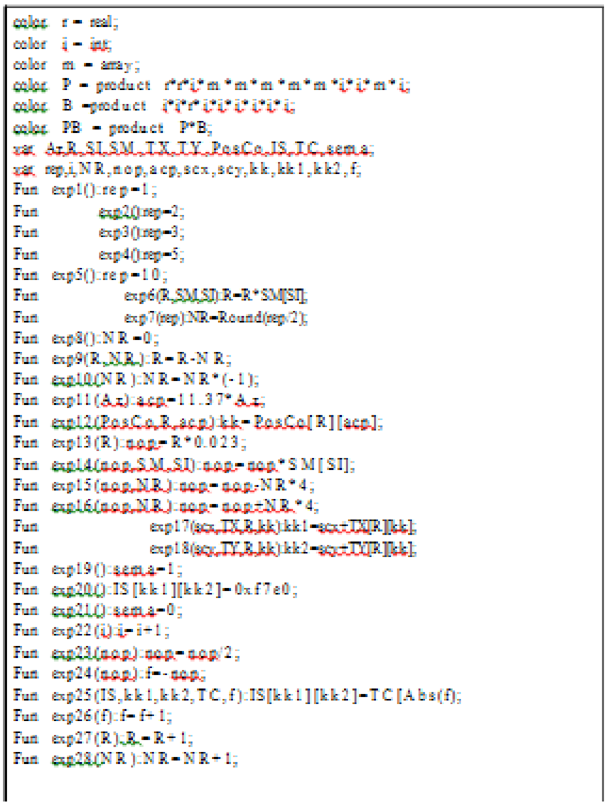


Fig. 6. Sub-page TargGen#1 Target Positions



```
color  r = real;
color  i = int;
color  m  = array;
color  P = product  r*r*i*m*m*m*m*m*i*i*m*i;
color  B =product  i*i*r*i*i*i*i*i*i;
color  PB  = product  P*B;
var  A,z,R,SI,SM,,TX,,TY,,PosCo,,IS,,TC,,sema;
var  rep,i,NR,nop,acp,scx,scy,kk,kk1,kk2,f;
Fun  exp1():rep=1;
Fun        exp2():rep=2;
Fun        exp3():rep=3;
Fun        exp4():rep=5;
Fun  exp5():rep=10;
Fun            exp6(R,SM,SI):R=R*SM[SI];
Fun            exp7(rep):NR=Round(rep/2);
Fun  exp8():NR=0;
Fun  exp9(R,,NR,):R=R-NR;
Fun  exp10(NR):NR=NR*(-1);
Fun  exp11(A,z):acp=11.37*A,z;
Fun  exp12(PosC,o,R,,acp):kk=PosCo[R][acp];
Fun  exp13(R):nop=R*0.023;
Fun  exp14(nop,SM,,SI):nop=nop*SM[SI];
Fun  exp15(nop,NR,):nop=nop-NR*4;
Fun  exp16(nop,NR,):nop=nop+NR*4;
Fun                exp17(scx,,TX,R,kk):kk1=scx+TX[R][kk];
Fun                exp18(scy,,TY,R,kk):kk2=scy+TY[R][kk];
Fun  exp19():sema=1;
Fun  exp20():IS[kk1][kk2]=0xf7e0;
Fun  exp21():sema=0;
Fun  exp22(i):i=i+1;
Fun  exp23(nop):nop=nop/2;
Fun  exp24(nop):f=-nop;
Fun  exp25(IS,kk1,kk2,TC,f):IS[kk1][kk2]=TC[Abs(f);
Fun  exp26(f):f=f+1;
Fun  exp27(R):R=R+1;
Fun  exp28(NR):NR=NR+1;
```

Fig. 7. Sub-page Draw#1 Target shape addition

Implementation of the SRM System

The application of the SRM system is shown in the following figures (8-11). In Figs (8-11) the results of applying the model is presented.

Figures (12 and 13) show two zooming steps of the SRM. Figure (14), shows the four targets on the SRM in addition to the presence of the map on the primary surface.

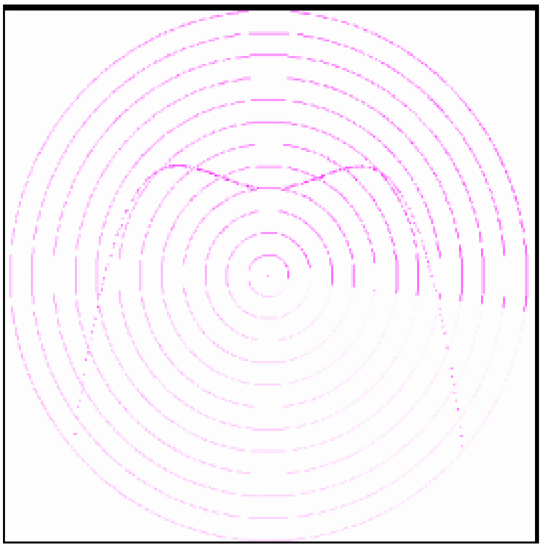


Fig. 8. Application of $y = x^4 - x^2$

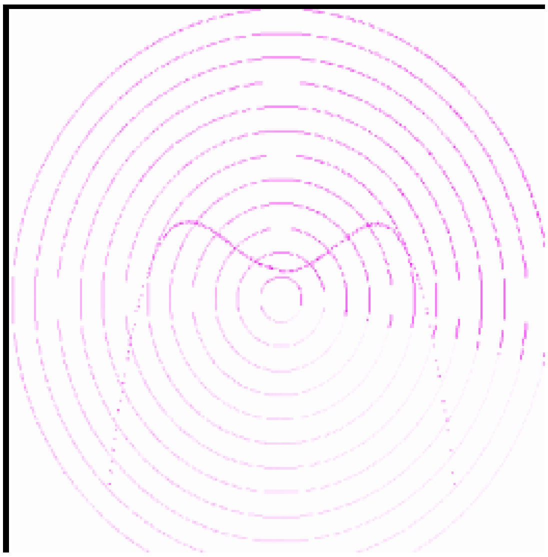


Fig. 9. Application of y = $2x^4-2x^2+1$

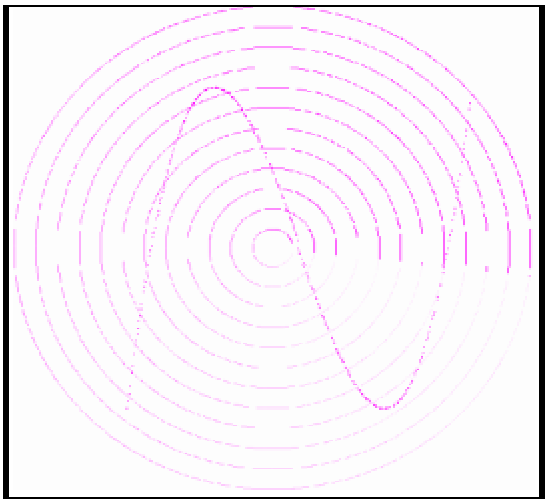


Fig. 10. Application of y = $x^4-2x^3-x^2-2x+2$

Fig. 11. Application of y = 10Sin(x-Sin(x))

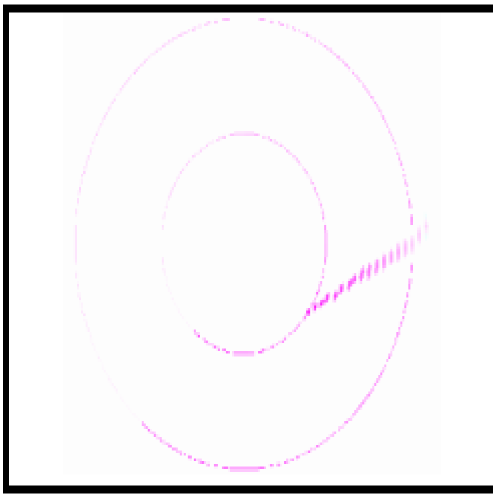


Fig. 12. Target detection at zoom step 9

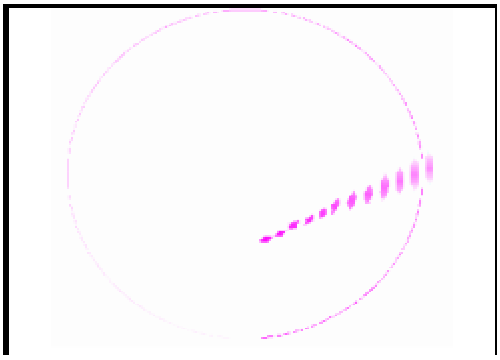


Fig. 13. Target detection at zoom step 10

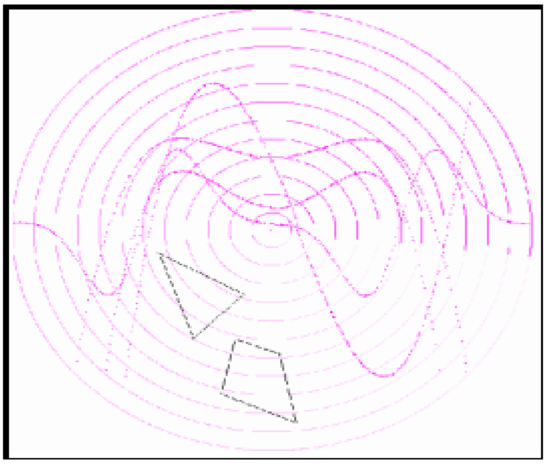


Fig. 14. Four Targets with map

Conclusion

The work shows that Hierarchical Object Oriented Timed Coloured Petri Net is a good modeling tool in that it accommodates the object oriented, timing and concurrency concepts in a single model. The use of overlay surface in addition to the primary surface in drawing saves a lot of time and calculations. The modeling of the SRM which is constructed by this software gives high flexibility for any changes in the future contrary to a display built by hardware. The use of concurrency concept offers the facility that if any of the target objects has stopped its operation because of any error like (division by zero), the operation of the other target objects and trace will not be effected.

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