# Modeling of Interaction on Multimedia Streams and Objects by Application of Petri Nets

Jordan Shterev

***Abstract:*** *The present paper deals with some problems concerning the influence on multimedia streams and objects through Petri nets. Some problems related to interactive multimedia, branches according to new scenarios, its state in time, as well as the indefiniteness of the human interaction have been described. A model of Petri net for interactive multimedia with branches, an equation of its state have been proposed, including the indefiniteness of time.*

***Key words:*** *Petri nets, multimedia stream, multimedia object, interaction.*

## INTRODUCTION

In multimedia presentations the multimedia streams have been presented in definite temporal relationships and the element of each multimedia stream - in definite consequence. In the first case the multimedia streams have intermedium temporal properties and in the second case – intramedia temporal properties. These properties produce the correct disposition of multimedia streams and their components during the time, i.e. their synchronization, according to the information that they contain. Thus any multimedia presentation system must handle both intramedia and intermedia synchronization of its components. The development of the interactivity in the multimedia presentation combined with improving possibilities for representation of the information by displays is a main trend in the research of the multimedia systems [1,2]. There is a model of interactive multimedia, in which the user is able to apply the following approaches of work: to reverse the flow of the presentation; to skip forward or backward to a new point; to scale the speed up or down; to freeze and then restart the presentation, typical for the traditional video [3].

Further development in this sphere is the realization of the user interaction from any place in the multimedia presentation, with a different plot of the presentation – i.e. interactive multimedia. It is regarded as an important characteristic of the applications for the realization of the multimedia presentations [4, 5]. The realization of user interaction changes the linear reproduction of the presentation and the result depends on the selected moment of time.

A Dynamic Fuzzy Multimedia Petri Net (DFMN) has been offered in this paper in order to supply an adequate structure for modelling the dynamic influence on multimedia streams. Some problems connected with dynamic influence and indefiniteness, caused by the user on multimedia documents, have been revealed.

## PETRI NETS

The Petri nets are graphical and mathematical tools applied to a number of systems. They are used to describe and study the processes of information systems which are described by competitiveness, synchronization and asynchronization, distributiveness, parallelism, determination, stochastic. As a graphical tool, they are used for visual communication. The tokens in them are used to simulate dynamic and competitive processes. As a mathematical tool, they define the state equations, algebraic equations of models for systems management.

In [6] Extended Fuzzy Time Petri Net – EFTPN is presented, where one transition has more than one input places and one place has more than one input transitions – i.e. transitions are in structural conflict. A finely structured time model with fuzzy scenario for distributed multimedia presentation is presented.

In [7] Dynamic Fuzzy Petri Net appropriate for dynamic teaching supporting structure is offered.

## DYNAMIC FUZZY MULTIMEDIA PETRI NET - DFMN

A DFMN is defined, which increases the flexibility of the interaction between the user's behavior and the multimedia in order to offer branches of the multimedia scenario - figure 1. DFMN is presented by:

*(P, T, A, $M_0$, R, SYN, FD, FT, TI)* where:

*P* is a finite set of places, *p* – place, $p \in P$ , $P = \{p_1, p_2, ...p_m\}$ ;

*T* is a finite set of transitions, *t* – transition, $T = \{t_1, t_2, ...t_n\}$ . The transitions are associated with synchronizing and transition rules when choosing the performance direction of a multimedia presentation – figure 2;

$A \subseteq (P \times T) \cup (T \times P)$ is a finite set of arcs which connect places and transition;

$M_0$ - the initial marking, $\mathrm{M} : \mathrm{P} \rightarrow \mathrm{I}, \mathrm{I} = \{0,1,2,...\}$ is the marking (the number of tokens) in the places in the net. Each token is associated with a multimedia stream, consisting of the relevant objects and passing from one place to another, it executes the relevant object;

$\mathrm{R}, \mathrm{P} \rightarrow \{\mathrm{r}_1, \mathrm{r}_2, \mathrm{r}_3, ...\mathrm{r}_\mathrm{k}\}$ is a mapping from places to resources;

*SYN: T →{strong, weak, master}* is a mapping from the set of interstream synchronization transition into a type of firing rule;

The master synchronization rule is driven by master stream. If two streams are presented simultaneously, when the higher priority stream finishes, the other has to stop, which is defined by $d_{tp}(\tau)$. The multimedia continues after that.

The strong synchronization rule is driven by the earliest stream. If either one of the two streams finishes, the other one has to stop, defined by $d_{tp}(\tau)$.

The weak synchronization rule is driven by the latest stream.

When a multimedia presentation finishes, two tokens arrive simultaneously in the last transition in figure 1. That is why it is not necessary to introduce indefiniteness of time to assure predominant transition of one of the tokens.

*FD* is a set of all *fuzzy delays* $d_{tp}(\tau)$ associated with arcs *(t,p)* from transition t to place p. It expresses the arriving variations of a token to the next place;

*FT* is a set of fuzzy timestamps, where *fuzzy timestamp* $\pi(\tau) \in FT$ is associated with each place. The execution time of an object is fuzzy timestamp. Because of the fuzzy delay $d_{tp}(\tau)$ the object does not always start on time.

*TI: T→[0,1]* is a mapping from a set of transitions to interaction. In the transitions where interaction is possible, the transition takes value 1, otherwise – 0.

In figure 1 a Petri net of parallel multimedia streams and objects – audio and video is presented. The places in the Petri net are associated with the resources for multimedia objects performances and with their durations.

## PROBABILITY DISTRIBUTION

Simultaneous performance of parallel multimedia objects on audio and video is not performed because of their fuzzy delays due to different kinds of processes on the net, as well as local delays.

During their performance two media objects may have one and the same temporal distribution of their beginning, while their starting times are totally different. The temporal distance between their starting times is defined by:

$$\left|s_i - s_j\right| = \int_{s_{i\min}}^{s_{i\max}} \int_{s_{j\min}}^{s_{j\max}} Fs_i(x) Fs_j(y) \left|x - y\right| dx dy \quad , \qquad (1)$$

where $Fs_i(x)$ and $Fs_j(y)$ are the temporal distributions of the starting times of objects *i* and *j*, *x* and *y* are the temporal variables, and $s_{imin}$, $s_{imax}$, $s_{jmin}$, $s_{jmax}$ are the minimal and maximal values of the start of the two objects.

The deviation of the physical quantities' values is described by the normal distribution. So, it is reasonable to use this distribution in order to show the fuzziness of time intervals, not the triangle or trapezium one[6,10].

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(t-\mu)^2}{2\sigma^2}} \quad (2)$$

The quantity *t*, describes the temporal pulsations at the start of a media object. The average value of deviations is $\mu=0$ and $f(t)_{\max} = \frac{1}{\sigma\sqrt{2\pi}}$.

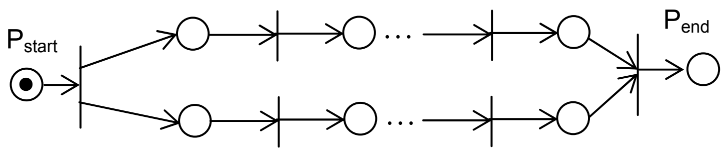


Fig.1 Multimedia streams and objects, presented by Petri nets.

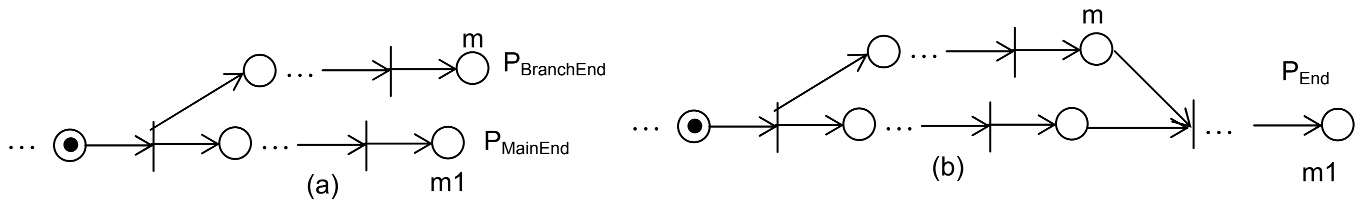


Fig. 2 Branching of multimedia streams, presented by Petri nets.

The quantity of service – QoS is defined by the maximum possible deviation (pulsation) of a media object of the nominal period of reproduction.

It is known about the normal distribution that: $\mu \pm \sigma$ comprises $68{,}27\%$ of the whole area under the normal curve, $\mu \pm 2\sigma - 95{,}45\%$ and $\mu \pm 3\sigma - 99{,}9\%$ [10]. It is certain about any interval that the requirements for QoS within the region of the indicated probability are fulfilled. The fulfillment of QoS in the last case is nearly 100%. So, it is possible to assume that the maximum deviation is $3\sigma$.

It is necessary to choose synchronizing points of multimedia streams of such an interval of multimedia objects for the QoS given, so that they will fulfill QoS. If the requirements for maximum possible deviation are too high, then the distance between the synchronizing points should be shortened. This way intermedia synchronization between multimedia streams and intramedia synchronization of multimedia objects are carried out. Synchronization points control the temporal distance between media objects. Unless the requirements for maximum possible pulsation of multimedia objects are strictly followed the synchronizing points may not satisfy the QoS and will be rarely situated.

## DURATION OF A MULTIMEDIA OBJECT

Any multimedia object is presented by its start and also by its duration. It may be nominal, maximal and minimal. The starting time and duration define *2D* temporal space. On figure 3 $\Delta t$ is the normal duration of a multimedia object, while *dr* is the real time of reproduction. The relation $dr/\Delta t = tg\alpha$ defines more rapid or slower reproduction i.e. – the speed of reproduction. In the SMIL language [11] control on the speed of reproduction is carried out. What is more, it performs accelerating and decelerating movement of video-objects and this way makes the virtual movement close to the real one.

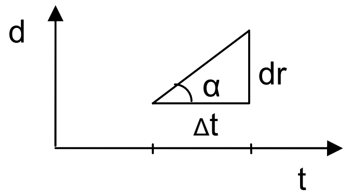


Fig.3 Normal *Δt* and real duration *dr* of a multimedia object.

**REDUCTION OF PETRI MULTIMEDIA NETS**

Petri nets about multimedia streams and objects are too large. That is why it is necessary to reduce nets to equivalent ones. The places of the Petri nets correspond to performance of multimedia objects, while the transitions – to passing from one state to another, i.e. intramedia synchronization. Figure 4 shows the rules about reducing of Petri multimedia nets for multimedia presentations:

a) 2 places with transition are reduced to one place;
b) 2 transitions with one place are reduced to one transition;
c) 2 transitions and 2 parallel places are reduced to 2 transitions with 1 place.

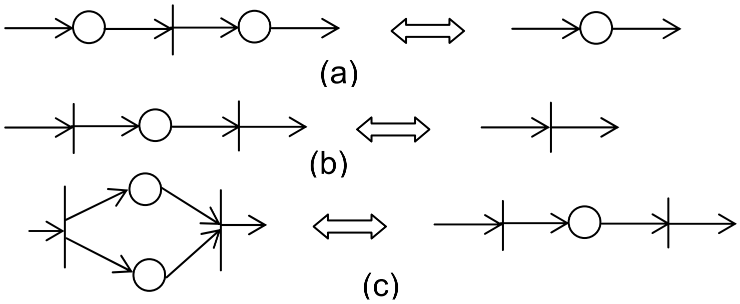


Fig. 4 Reduction of Petri multimedia nets.

By these rules it is possible to reduce the net on figure 1 to 1 consecutive stream, with sufficiently small length. Thus one may assume that the nets on figure 2 consist of 2 multimedia streams. Branches are of importance here. The nets on figure 2 can be reduced to nets depicting their branches, i.e. their structural characteristics only.

**STATE EQUATION**

The incidence matrix $A=[a_{ij}]$ for Petri nets with *n* transitions and *m* places is an *nxm* matrix of integers and is defined by:

$$a_{ij} = a_{ij}^{+} - a_{ij}^{-},$$

where $a_{ij}^{+} = w(i,j)$ is the weight of the arc from *i* transition to *j* output place and $a_{ij}^{-} = w(j,i)$ is the weight of the arc from *j* input place to *i* transition. $a_{ij}^{+}$, $a_{ij}^{-}$, $a_{ij}$ presents the number of the tokens added, gone or changed, when *i* transition is being fired. The transition for firing is allowed then and only then when $a_{ij}^{-} \le M(j) \quad j = 1,2,...,m$, where *M(j)* is the marking of *j* place.

$M_0$ is the initial marking. After the *k* firing of transition the marking is $M_k$, as *mx1* is vector-column. The *j* element presents the number of tokens immediately after the *k* firing.

Furthermore, the *k* firing defines *nx1* vector-column $u_k$ of the transitions from *n-1* zeros and one non-zero element, a 1 in the *i*th position, defining that the *i*th transition is fired after the *k* firing.

In the incidence matrix *A,* the *i*th row describes the change of marking as a result of the *j*th transition firing. The equation of state is [8, 9]:

$$M_k = M_{k-1} + A^T u_k \qquad k = 1,2,... \tag{3}$$

The equation expresses the recurrent link between the markings of the places. The link between the initial marking $M_0$ and any $M_k$ is a result of the summing of the consecutive recurrent links:

$$M_k = M_0 + A^T \sum_{l=1}^{k} u_l \tag{4}$$

or $\Delta M = A^T x$

The incidence matrix for Petri net for parallel audio and video streams in figure 1 is:

$$A = \begin{pmatrix} -1 & 1 & 1 & 0 & 0 & 0 & . & . & . & . \\ 0 & -1 & 0 & 1 & 0 & 0 & . & . & . & . \\ 0 & 0 & -1 & 0 & 1 & 0 & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & . & 0 & -1 & -1 & 1 \end{pmatrix}$$

Also from figure 1 the link between the number of places m and transitions *n* is *n= m-2*, and the vector-columns for $M_0$, $M_{end}$ – at the end of the presentation and x presented as rows in order to economize space are:

$$M_0 = (1 \quad 0 \quad . \quad 0),\ M_{end} = (0 \quad . \quad .0 \quad 1),\ x = (1 \quad 1 \quad . \quad 1)$$

Except for the initial and the last transition, all other transitions are fired in pairs, because of the parallelism of the streams.

The matrix of incidence for Petri net in figure 2a) for type tree branching contains -1, 1 and all the rest are zeros up to the end of the first row. In the second row they are 0, -1, 1 and zeros up to the end. All other rows up to the one describing the branching have the same consequence -1, 1 by adding an extra zero at the beginning of each following row. The row describing the branching has -1, 1 in the position of the branching of the linear presentation and in the position of branching 1. The next lines also contain -1, 1 in the corresponding places and zeros. The branching which is a linear presentation contains -1, 1 and the zeros corresponding. The last row has -1, 1 in the last positions.

The presentation finishes in two places. Then for each one:

$$M_{m1} = M_0 + A^T x1,\ M_m = M_0 + A^T x2, \text{ and}$$

$$M = M_{m1} + M_m = 2M_0 + A^T x \quad u \quad x1 + x2 = x \tag{5}$$

is a general state equation. The vector-columns written as rows are:

$$M_0 = (1 \quad 0 \quad . \quad . \quad . \quad . \quad . \quad 0),\ M = (0 \quad . \quad 0 \quad 1 \quad 0 \quad . \quad 0 \quad 1),\ x = (2 \quad . \quad 2 \quad 1 \quad . \quad 1 \quad 1 \quad . \quad 1)$$

The two units in the vector- column of the final states in the places in *M* indicate the two final states at the end of the presentation. The elements of the vector-column of the firings x with value 2 indicate the transitions of passing in both cases.

The incidence matrix for Petri net in figure 2b) for branching with return to the main presentation contains -1,1 and all the rest are zeros up to the end of the first row. In the second row there are 0, -1, 1 and zeros up to the end. All other rows up to the one describing the branching contain the same sequence -1, 1 by adding an extra zero at the beginning of each following row. The row describing the branching contains -1, 1 in the position of the branching from the linear presentation and towards branching 1. The next rows also contain -1, 1. The row where the branching and the main presentation merge contains zeros -1, -1, 1 and zeros. The next rows are also with zeros, -1, 1 and zeros. The rows corresponding to the branches contain zeros, -1, 1 and zeros. The last row has -1, 1 in the last positions.

By analogy with the previous case about the state equation with and without passing through the branching:

$$M_{m1} = M_0 + A^T x1,\ M_m = M_0 + A^T x2, \text{ and}$$

$$M = M_{m1} + M_m = 2M_0 + A^T x \quad u \quad x1 + x2 = x \tag{6}$$

is a general state equation. The vector-columns given as rows are:

$$M = (0 \;\; . \;\; 0 \;\; 2 \;\; 0 \;\; . \;\; 0),\; x = (2 \;\; . \;\; 2 \;\; 1 \;\; . \;\; 1 \;\; 2 \;\; . \;\; 2 \;\; 1 \;\; . \;\; 1)$$

The value 2 in the vector-column indicates that the final state at the end of the presentation is one and the same in both cases. The elements in the vector-columns of the firings *x* with value 2 indicate the transitions of passing in both cases.

## CONCLUSIONS AND FUTURE WORK

The matter discussed in this paper is useful in the process of design and development of multimedia presentation. The use of Petri nets for visualization and mathematical analysis of multimedia with indefiniteness in time assures qualitative pre-planning and pre-designing of presentations. The use of hipper-text documents and links has been developed and their application will further follow.

Interaction is a typical characteristic of multimedia. Interaction resulting in new versions of the main multimedia scenario has been presented in the paper. Its realization requires profound research of the stochastic user interaction and clearing up the place of temporal interval logic in multimedia. In addition, research of fuzziness during the performance of parallel multimedia streams and objects will be done.

## REFERENCES

[1] KatsumiTadamura, Eihachiro Nakamae, Synchronizing computer graphics animation and audtio, Multimedia, V5, №4, 1998.

[2] Meleod Dennis, Neumann Ulrich, Nikias L.Chrysostomos, Sawchuk A.Alexander, Integrated Media System, IEEE Signal Processing Magazine, January, 1999.

[3] Chung-Ming Huang, Chian Wang, Synchronizion for Interactive Multimedia Presentation, Multimedia, V5, №4, 1998.

[4] Shterev J., Estimation of User Interactions on the Multimedia Presentations by Application of Markovski Processes, UNITECH 2001, Gabrovo.

[5] J. Shterev, M. Todorova ESTIMATION OF THE INTERACTIONS OF MULTIMEDIA STREAMS AND OBJECTS BY APPLYING THEORY OF GRAPHS, CompSysTech'2000, Sofia.

[6] Yi Zhou, Tadao Murata, MODELING AND ANALISYS OF DISTRIBUTED MULTIMEDIA SYNCHRONIZATION BY EXTENDED FUZZY-TIMING PETRI NETS, Transaction of the SDPS, December 2001.

[7] Juei-Nan Chen, Yueh-Min Huang, USING DYNAMIC FUZZY PETRI NETS FOR NAVIGATION LEARNING, Exploring Innovation in Education and Research, Tainan, Taiwan, 1-5 March 2005.

[8] Tadao Murata, Petri Nets: Properties, Analysis and Applications, Proceeding of the IEEE, Vol. 77, No4, April 1989.

[9] A. Bourjij, M. Boutayb, Linear Algebra and Petri nets, Радіоелектроника, інформатика, управления, №1, 2001.

[10] Апостол Обретенов, Вероятностни и статистически методи, София, НИ, 1976.

[11] http://www.w3.org/TR/2001/PR-smil20-20010605/, Synchronized Multimedia Integration Language (SMIL 2.0) Specification.

## ABOUT THE AUTHOR

Chief assistant Jordan Shterev, Department of Communications and Informations Systems, National Military University of Veliko Turnovo, E-mail: jshterev@abv.bg.