Synchronized Performance of Multimedia Presentations

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Abstract: *The present paper deals with problems concerning the interstream and intrasteram synchronization of multimedia streams and objects. The indefiniteness of their delays during the performance time, as well as their influence on the synchronization have been studied.*
Key words*: interstream synchronization, intrasteram synchronization, multimedia stream, multimedia object, delay.*

INTRODUCTION

In multimedia presentations multimedia streams and objects of one and the same type are time related. In the first case there is interstream synchronization between multimedia streams (MMS). In the second case there is intrastream synchronization between the objects of one and the same multimedia stream [7,9,10].

Defining the delays of several multimedia objects (MMO) and the quality of service (QoS) based on extended fuzzy-timing Petri nets has been carried out in [9]. A method for defining the maximum delay between the synchronizing points for a definite number of MMO per 1 s, for a given delay between MMO and distance between synchronizing points in a number of objects by the triangular membership function has been presented. The delay of MMO at the both ends of the synchronized points defines QoS. It has been carried out by comparison of the areas in the triangular membership function. A Dynamic Fuzzy Petri net for navigated learning has been presented in [7]. An Object Oriented Fuzzy Petri Net for Complex Knowledge System Modeling has been used in [10].

A study of the interstream and intrastream synchronization based on Dynamic Fuzzy Multimedia Petri net [8] by using the Gaussian combination membership function, being a better approximation to the multimedia objects' real behavior compared with the triangular membership function has been done in the present article. In addition, the sigmoidal membership function has been used for considerable delays resulting in break of the synchronization.

FUZZY LOGIC FOR SYNCHRONIZED FULFILLMENT OF MMS AND MMO

In the process of distribution of audio and video objects there is indeterminateness in their delay. That is why Fuzzy logic is used to define their synchronized fulfillment. Via the operations $\cup$ (or) and $\cap$ (and) a system of logical statement is presented as [2,3,5]:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} \quad c \quad weight \quad w_{jp}\right) \rightarrow y = d_j, j = \overline{1,m} \ , \tag{1}$$

and defines a value of the output variable. The set of input variable quantities is $X = (x_1, x_2, ...x_n)$, the set of resolutions of the output variable *y* is $D = \{d_1, d_2, ..., d_m\}$. *i* defines a given input variable, *j* is the number of the output variable-solution, and *p* is the number of the row consisting of conjunctions included in a given disjunction. k_j defines the number of conjunctions included in the disjunction for the j output. $a_{i,jp}$ is the linguistic appreciation of the variable x_i. w_{jp} is the weight of $a_{i,jp}$ in output j.

In order to transform from fuzzy set to interval $\left[\underline{y}, \overline{y}\right]$, it is necessary [3]:

1) to cut the membership function $\mu_{d_j}(y)$ of level $\mu_{d_j}(X^*)$;

2) to aggregate the resulting fuzzy sets,

$$\tilde{y} = \underset{j=\overline{1,m}}{agg}\left(\int_{\underline{y}}^{\overline{y}} \min\left(\mu_{d_j}(X^*),\right)\mu_{d_j}(y)\Big/ y\right), \tag{2}$$

where *agg* is the unification of fuzzy sets, which are mainly realized in the operation for defining the maximum and X^* is the input vector.

The precise value of the output *y*, X^* is defined by the defuzzification of the fuzzy set $\tilde{y}$. For defuzzification by the centroid of area method, the value of output y_c is:

$$y_c = \frac{\int_{\underline{y}}^{\overline{y}} \tilde{y} \cdot \mu_{\tilde{y}}(y) dy}{\int_{\underline{y}}^{\overline{y}} \tilde{y} \cdot \mu_{\tilde{y}}(y) dy}. \qquad (3)$$

MEMBERSHIP FUNCTIONS

The distribution of audio and video signals is a physical process [6], and the deviations of the physical quantities follow the standard distribution. The deviations define the multimedia objects' delays. That is why neither the triangular-shaped distribution, nor the trapezoidal-shaped [1,5,6,9] one have been used, but the standard distribution has been used instead. The MMO' delays define quality of service.

The input variables in FIS (fuzzy inference system) are the delays of the MMO. A delay comparable with the duration of the MMO is an interval with a lower degree in relation to the performance time of a MMO - Δt_k, $(1-9)\Delta t_k 10^{-1}$. Then minimal delay comparable with the duration of the i-th MMO is $\Delta t_{d_i} \geq 10\% \Delta t_k$. For frequency of frames $\nu = 1/\Delta t_k$, the maximum possible delay is $d_{\max} = 10\% \Delta t_k$. This means that for a delay defined by the interval $0 - d_{\max}$ the objects arrive on time. For the sensibility of the human sensory organs $\nu = 1/\Delta t_k = 10Hz$, the maximum possible delay is 10 ms.

The Gaussian combination membership function has been used to define the time interval about which QoS are satisfied. One and the same membership functions have been used to describe the two input variable, because the current processes of broadcasting audio and video data are one and the same. The Gaussian combination membership function [2,3,5] is defined by:

$$\mu(x) = \begin{cases} e^{\frac{-(x-m_1)^2}{2\sigma_1^2}}, & x < m_1 \\ 1, & m_1 \leq x \leq m_2 \\ e^{\frac{-(x-m_2)^2}{2\sigma_3^2}}, & x > m_2 \end{cases} \qquad (4)$$

where m_1 and σ_1, m_2 and σ_2 are the mathematic expectation and the standard deviation of the first and the second Gaussian distributions. Between the two maximums the value of the membership function is 1. In the moment $0\,ms$ $\mu(x) = 1$, $m_1 = 0\,ms$. In addition, in the moment $d_{\max} = 10\% \Delta t_k$ there is the condition $\mu(x) = 0$, because the MMO does not start its performance on time. $m_2 = 90\% d_{\max}$, so that the maximum of the right Gaussian function to be at 10% from the end of $d_{\max}$ interval. It is known that in the interval $m \pm 3\sigma$ 99.7 % of the area under the normal distribution curve is placed [1]. Hence $3\sigma_2 = d_{\max} - m_2$, and for symmetry $\sigma_1 = \sigma_2$.

For delays bigger than $d_{\max}$, QoS gets worse, hence the introduction of the sigmoidal membership function. It defines that the delay probability is in the interval 0–1 [2,3,5]:

$$f(x) = \frac{1}{1 + e^{-a(t-c)}}. \quad (5)$$

In the sigmoidal membership function, in order to define the values of the parameters a and c, the fact that $e^{-a(t-c)}$ tends to infinity or 0, when the absolute value of exponent is higher than 5, has been taken into consideration. Parameters are defined by the boundary conditions:

$$\begin{aligned} t &\geq \eta d_{\max} \quad ms, \quad f(t) \to 1 \\ t &\leq d_{\max} \quad ms, \quad f(t) \to 0 \end{aligned},$$

where η is the coefficient defining the maximum increase of $d_{\max}$, after which the quality deteriorates, and $\eta = 1{,}5$. Then:

$$a \geq \frac{2k}{d_{\max}(\eta - 1)}, \quad c \geq \frac{d_{\max}}{2}(\eta + 1), \quad (6)$$

where k is the value of exponent of $e^{-a(t-c)}$. The parameter c does not depend on k and, in addition in $t = c$ the sigmoidal membership function has an inflexion point. Towards it stretching and shrinkage of the membership function curve are in progress. The output variable, defining the whole delay of the multimedia objects of a given stream, as well as the membership functions are the same as those of the input variables.

The performance delay of two corresponding MMO from different MMS is defined by:

$$\text{if } d_{tp} > d_{\max} \text{ then } d_{tp} = d_{\max} + d_{tpsigm} \text{ and the QoS is deteriorated,}$$
$$\text{if } d_{tp} < d_{\max} \text{ then } d_{tp} = d_{tpgaus} \quad (7)$$

where d_{tp} is the fuzzy delay, d_{tpgaus} and d_{tpsigm} are the delays of the Gaussian combination membership function and sigmoidal membership function.

The MMO delays break the synchronization and QoS. The approximate synchronization (ε-synchronization) is defined with precision to ε about the processes $X_1(t)$ and $X_2(t)$:

$$|X_1(t) - X_2(t)| \leq \varepsilon. \quad (8)$$

The QoS is defined by frames' frequency and the maximum possible tolerance.

Fuzzy logic, as well as the Gaussian combination membership function and the sigmoidal membership function have been used to research the synchronized performance of multimedia streams and multimedia objects by the help of MATLAB.

INTRASTREAM SYNCHRONIZATION OF AUDIO AND VIDEO OBJECTS

The OR method has been used in the linguistic rules for consecutive performance, in order to take into consideration the total delay of the objects by the *sum* operation [2,3,5]. It presents the maximum delay of the two objects. In the logical inference the initial membership function *min* cuts in height the corresponding level. The composition has been organized by the *sum* operation, presenting the maximum possible delay, because it sums the results of all rules. The *centroid* operation has been used for defuzzification, to account for the average value of the delays.

The synchronizing points do not allow multimedia presentation (MMP) to exceed a given maximum deviation as a result of the delays. Synchronization of four MMO has been done. The synchronized points are at a distance of four MMO. The time distance of the starting times for consecutive MMO from one and the same multimedia stream is limited from beneath by:

$$|s_i - s_j| \geq k\pi(\tau), \text{ and } |i - j| = k \quad (9a)$$

and from above by:

$$|s_i - s_j| \leq k(d_{\max} + k\pi(\tau)), \quad (9b)$$

where *i* and *j* are ordinal numbers of multimedia objects, k is an integer, s_i and s_j are the starting times of MMO, $\pi(\tau)$ is the MMO performance time with indefinite beginning τ.

Table 1. Defuzzification of four audio or four video objects for 10 Hz.

№	1				2				3				4				5			
objects	a1	a2	a3	a4	a1	a2	a3	a4	a1	a2	a3	a4	a1	a2	a3	a4	a1	a2	a3	a4
delay, ms	0	15	30	45	4,5	19,5	34,5	49,5	9	24	39	54	10	25	40	55	15	30	45	60
defuzzification,ms	47,1				47,1				47,1				46,1				54,5			

The defuzzification values about membership functions' values and frame frequency 10 Hz are given in table 1. The first tree values are one and the same, because the interval $[m_1 - m_2]ms$ is considered, as the Gaussian combination membership function is 1.

INTERSTREAM SYNCHRONIZATION OF AUDIO AND VIDEO OBJECTS

The OR method between two corresponding objects from different streams has been used in the logical rules, in order to take into account the total delay of the objects by the *max* operation [2,3,5]. The operator gives the bigger one of the two types MMO' delays. The operators for logical inference, composition and defuzzification are the same as those in the intrastream synchronization.

In order to synchronize two corresponding MMO of different MMS the following is necessary:

$$\left|s_{1i} - s_{2j}\right| \le d_{tp}(\tau). \tag{10}$$

The value of $d_{tp}(\tau)$ defines the QoS.

The objects are parallel four by four. The function of the input variable *ex* on the variables 4th audio object *a4* and 4th video object *v4* for *k=20* and 30 Hz have been presented in fig. 1.

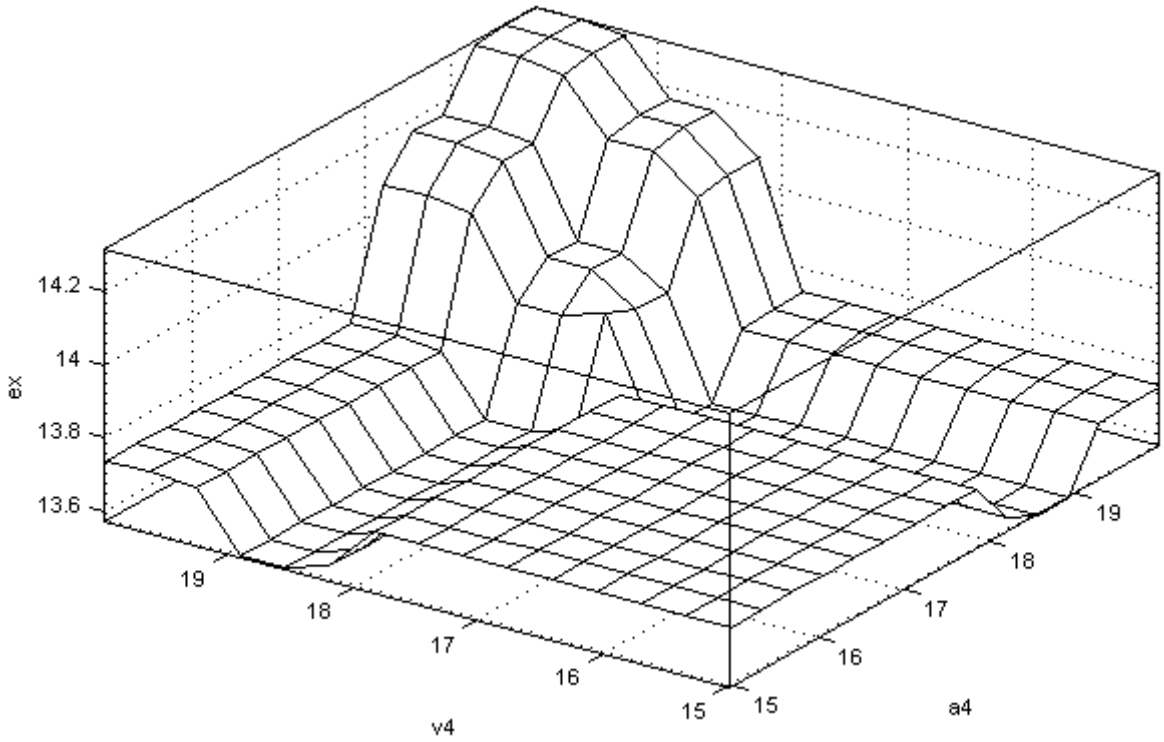

Fig. 1

The starting points of the second, third, and fourth objects are moved away, which results in objects' delay increase and break in the synchronization. For one and the same frames' frequency, the average value of the maximum delay of the two streams has a small increase with the increase of *k*. The delays' values for 10 Hz are about tree times bigger than the delays' values for 30 Hz. The smaller delays for 30 Hz define the higher quality of reproduction. The synchronizing points for 30 Hz meet the synchronization requirements easier.

The plain area in fig.1 defined by the intervals $[15-18]ms$ for *a4* and $[15-18]ms$ for *v4* defines synchronized performance. The interval $[18-18.33]ms$ for the two types of objects defines deterioration of the synchronization, and beyond $18.33ms$ for the two types of objects the synchronization is broken.

NON-BREAKING PERFORMANCE QUALITY DELAYS

The time interval for the performance of multimedia streams with and without multimedia object delay is defined by:

$$T_{all0} = N\Delta t_k, \qquad T_{all} = N\Delta t_k + \sum_{i=1}^{i=N-1} \Delta t_{d_i}\ , \tag{11}$$

where N is the number of frames, MMO respectively. Δt_k is the multimedia object performance time, and Δt_{d_i} is its delay time. The delays Δt_{d_i} are different in general. T_{all0} and T_{all} are the multimedia presentation performance times, corresponding to all multimedia objects in the best case without and with delays. The ratio $incr = T_{all}/T_{all0}$ defines the relative increase of the performance time, caused by the delays:

$$incr = 1 + \frac{1}{N}\sum_{i=1}^{i=N-1} \frac{\Delta t_{d_i}}{\Delta t_k}\,. \tag{12}$$

A multimedia object's delay is defined by the Gaussian combination membership function and the sigmoidal membership function. The former defines the delays, whose quality is not much deteriorated, the latter defines the delays' increase, whose quality is deteriorated to such extent, that it is impossible to perform a multimedia presentation.

Study of the delays caused by the Gaussian combination membership function by use of MATLAB has been done here. The charts of the relative delays of two flows for 30 Hz frequency of the frames in the multimedia presentation by use of (12) are presented in fig. 2a),b),c). The x-axis shows the number of frames. The relative delay values of the two streams do not differ considerably. There is no deviation outside the interval 1.0420-1.0520.

The results are about 0-10000 frames. About 100000 frames the relative delay values for the two streams are within the same interval. And about the three frame frequencies 10 Hz, 20 Hz and 30 Hz the relative delay values are within the interval 1.036-1.052 for 0-100000 frames.

The relative delays for the tree frame frequencies about the Gaussian combination membership function are about 0.040. Their values define the synchronization between the two multimedia streams. In addition, the differences between the relative delays of the two MMS for 30 Hz about the whole range of the values of the MMO are smaller than 0.01 and hence satisfy the approximate synchronization condition, according to (8).

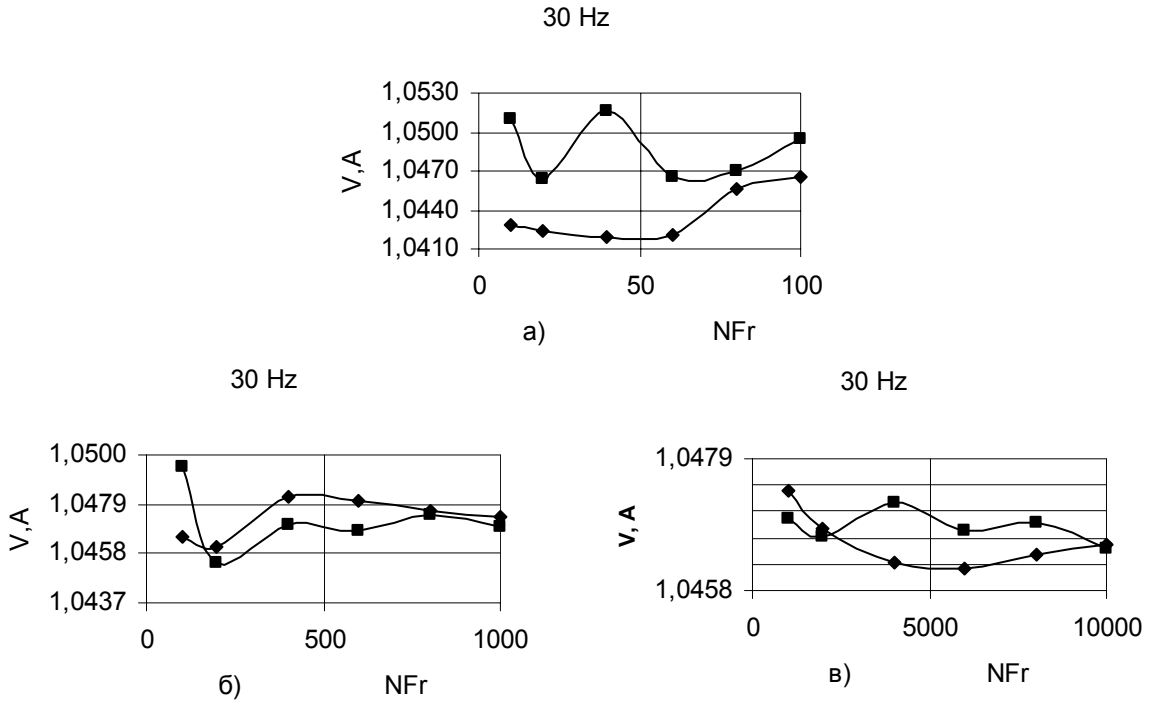

Fig. 2 Dependence of the delay interval for 30 Hz and the Gaussian combination membership function on the number of frames.

CONCLUSIONS AND FUTURE WORK

Study of the delays between multimedia objects of one and the same and of different type, as well as the delays of multimedia streams by use of the Gaussian combination membership function and the sigmoidal membership function for presentation of delays has been done. The Gaussian combination membership function defines the delays that do not deteriorate QoS. The sigmoidal membership function defines the delays deteriorating the quality of performance.

Future studies in this field include influence of the user interaction on deterioration of QoS, increase of the performance time as a result of interactions, study of the delays deteriorating the quality of supply.

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