Розглянуто застосування нечіткої логіки для апарату Е-мереж при моделюванні функцій якості обслуговування в мультисервісних мережах. Сформульовано основні правила роботи керуючих переходів Е-мереж з нечіткістю в їх предикатах та правила визначення предикатів для МХ і МY переходів

Ключові слова: Е-мережа, нечітка логіка, функція переходу, алгоритм

Рассмотрено применение нечеткой логики для аппарата Е-сетей при моделировании функций качества обслуживания в мультисервисных сетях. Сформулированы основные правила работы управляющих переходов Е-сетей с нечеткостью в их предикатах и правила определения предикатов для МХ и МY переходов

Ключевые слова: Е-сеть, нечеткая логика, функция перехода, алгоритм

This paper considers the application of fuzzy logic for the E-nets to simulating functions quality of service in multiservice networks. The basic rules for control transitions of E-nets with the fuzziness in their predicates and developed rules for determining the predicates of the MX and MY transitions are formulated

Keywords: E-net, fuzzy logic, transition function, algorithm

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APPLICATION OF FUZZY LOGIC IN E-NETS

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1. Introduction

The development of technologies for the transmission of information in the telecommunication systems and in the computer networks is inseparably connected with the problem of integrity and of ensuring high reliability during the whole process of transmission.

The dynamic increase in the speed of information transmission in the communication systems and channels of networks brings about stringent requirements for the performance. Centralized models for network control become ineffective in case when increase requirements to transmission rate, bandwidth, and time reaction to the increasing network load.

At the present time more effective to use a distributed control systems. The main elements of such systems are control agent [1]. In this case the network is controlled by multiple agents who distributed over a network; agents exchange management information among themselves. Set of control agents is generalized distributed network control system. The behavior of control agents can be described by fuzzy logic (FL) [2, 3]. Usage of FL allows more flexibility to implement functions of quality of service (QoS), in the case of multiservice networks.

To investigate such systems are currently the most commonly used methods of simulation. For this purpose, the existing mathematical apparatus made additions that allow describing the fuzziness of the system behavior. In this case using of fuzzy logic modifies the basic properties of the device simulation, which results in inappropriate modeling results and produce incorrect indicators of network quality. Thus, need to develop principles and rules of administration for FL structures by high-level language simulation.

2. The principles of E-net operations

In [4, 5] noted that the one of the most effective tools of networks and communication protocols simulation is an E-net tools.

E-net is means of research and quantitative analysis of complex systems, such as data transmission system (DTS).

Use of E-nets allows:

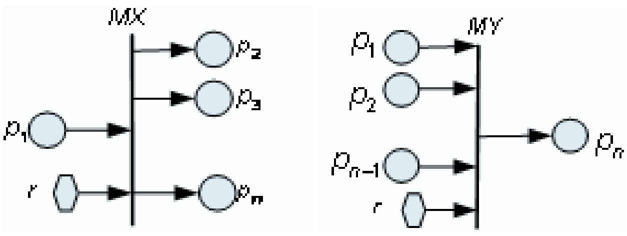
- to simulate asynchronous parallel interacting processes, reflecting the overall dynamics of the discrete system;
- to allow any semantic interpretation of its components, that enables simultaneous modeling of both information flows and hardware, for the whole DTS;
- to allow different interpretation of its elements in terms of abstraction (detail), that allows to build hierarchical models in which transition can be translated to the subnet at a lower level of detail. This reduces conflict between the requirements for simplicity and adequacy of the model.

Formally, E-net is defined as a bipartite directed graph, described by set:

$$E = (P, H, L, D, A, M_0),$$

where P – a finite set of state, called places; H – a finite set of transitions; L – a direct function of incidence; D – inverse function of incidence; A – finite set of characteristics of transition; M_0 – initializes the network.

A distinctive feature of the E-nets is the use of a control transitions MX and MY. MX and MY transactions are shown in fig. 1 (a and b)



a) b)

Fig. 1: a) MX transition, b) MY transition

The control transitions make possible to analyze the processes of control data flow, priority in the processing of information, based on the values of the control predicate r.

The condition for adaptation of fuzzy logic to E-net theory is required to use E-net (in particular, MX and MY transitions) for modeling the fuzzy multi-agent networks.

3. Application fuzzy logic in transition predicates

To prove the possibility by using fuzzy logic in controlling protocol necessary to show that input fuzzy logic in E-net not change the basic rules of the transition [4, 5]

1) Condition of transition activity

The application of fuzzy logic in the MY transition (equal classical):

$$(p_1 \in L(MY)\{M(p_1)=1]\} \vee ... \vee p_{n-1} \in L(MY)\{M(p_{n-1})=1) \wedge p_n \in D(MY)\{M(p_n)=0\}, \quad (1)$$

where M – a markup vector; $M(p_i)$ – vector definition in i-th place, $M: P \to \{0,1\}$, where P – a set of whole states.

If at any point input E-net has token, and output place is empty then the transition is active.

Similarly, for MX:

$$p_1 \in L(MX)\{M(p_1)=1]\} \wedge (p_2 \in L(MX)\{M(p_2)=0 \vee ... \vee p_n \in D(MX)\{M(p_n)=0\}). \quad (2)$$

Its means that transition MX is active now: if the input space p_1 has token and some of output place p_k is empty.

2) Transition function (TF)

Consider this function for control transition MY. Membership function is associated to each input places $\{p_1, p_2, ..., p_{n-1}\}$ [2, 3]. $\{\mu_1, \mu_2, ..., \mu_{n-1}\}$. The data of membership function show a grade of membership of possible transfer of token from a particular input places to the output control transition. Membership function defined on the characteristic set to X, specified by on a particular interval. For example, the characteristic of transition may be a packet blocking probability, input load, etc.

For DTS should be used trapezoidal form of TF, based on necessity to set of properties of uncertainties such as “located in the interval”, the following:

$$\mu_{p_1}(X) = \begin{cases} 0, x \le a \\ \dfrac{x-a}{b-a}, a \le x \le b \\ 1, b \le x \le c \\ \dfrac{d-x}{d-c}, c \le x \le d \\ 0, d \le x \end{cases}, \quad (3)$$

where x – a sample value from X, X determined at a certain interval, for example, blocking probability P_{bl} is [0,1];

a,b,c,d – the numerical parameters, ordered by relation $a \le b \le c \le d$, where parameters a,d characterize the lower base of the trapezoid, and b,c – upper base of the trapezoid.

Respectively, the predicate r of the control transition takes the following values:

$$r = \begin{cases} p_1 = \mu_1, X \in [a,d] \\ p_2 = \mu_2, X \in [d,g] \\ .... \\ p_{n-1} = \mu_{n-1}, X \in [g,h] \end{cases}, \quad (4)$$

where parameters $a < d < g < h \in [X_{min}, X_{max}]$.

A graphical representation is depicted in fig. 2.

In this case, the transition firing rule has the next form:

$$(m,f,f,M(p_m)=1,f,f,M(p_n)=0) \mapsto (\Re,f,f,M(p_m)=0,f,f,M(p_n)=1), \quad (5)$$

where $f \to \{0,1\}$ – the possible token of input places; $\Re$ – undefined value of predicates after the transition firing.

Value of the predicate r is determined from the expression (4). Predicate at the same time takes $n-1$ values. If at the time of the activity transition value of parameters x belongs to interval defined by membership function μ_m, then the predicate has the value M; at the same place the token from p_m will be sent with all the attributes to output space p_n.

Annotation: If place p_m have no token transition function will define by special predetermined rules.

If the value x gets to coincident point of TF transition function will define by the predetermined rules.

For transition MX rule defined as follows:

$$r = \begin{cases} p_2 = \mu_2, X \in [a,d] \\ p_3 = \mu_3, X \in [d,g] \\ .... \\ p_n = \mu_n, X \in [g,h] \end{cases}, \quad (6)$$

$$(m,M(p_1)=1,M(p_2)=0,f,f,M(p_m)=0) \mapsto (\Re,M(p_1)=0,M(p_2)=0,f,f,M(p_m)=1). \quad (7)$$

Value of the predicate r is determined from the expression (6). If at the time of the activity transition value of parameter x belongs to interval defined by membership

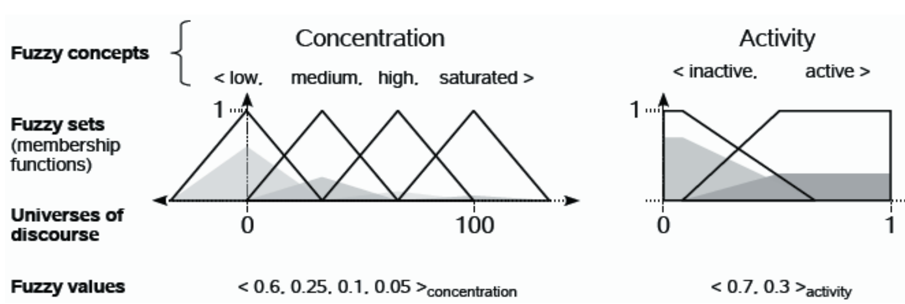


Fig. 2. The value of predicate r

function μ_m, the predicate is set to m. While token of the input space p_1 will be given with all the attributes in the output space p_m.

However, in practice a more interesting case when the same value x will correspond to two or more membership function, as displayed in fig. 3.

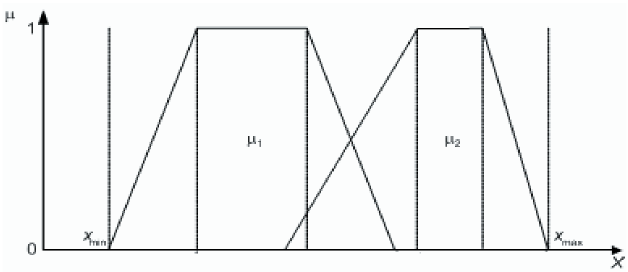


Fig. 3. The values of predicate in the situation when x correspond two or more membership function

For defined the values x occurs uncertainty in the choice of a membership function and in compliance with places for sending/receiving tokens.

To make a decision in this condition of indeterminacy will be used the following algorithms:

Algorithm «triangle area»:

1. Use the expressions (4), (6) to determinate predicate of control transition.

2. Depending on the control transfer to determine the type of transition functions.

3. In the case when in the moment of transition activity x belongs to range of indeterminacy must be calculated exact values of TF for each of input/output places μ_n^x. Exact values calculated by the perpendicular intersection from the point x (fig. 4).

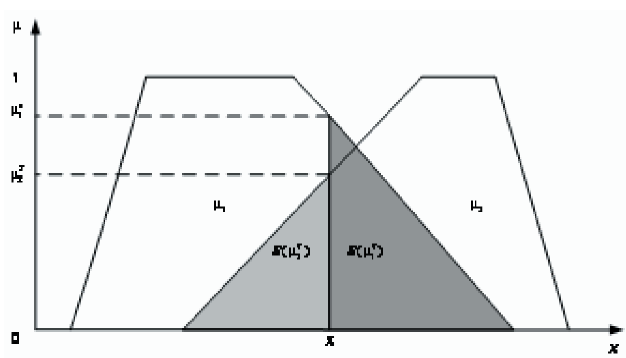


Fig. 4. Algorithm «triangle area»

4. Find the area of the triangles formed by the perpendicular to the step 3.

5. In general, select the triangle with maximum area of a set to $\max\{S(\mu_1^\nabla),S(\mu_2^\nabla),...,S(\mu_n^\nabla)\}$, where $S(\mu_n^\nabla)$ – area of n-th triangle, contained in indeterminacy.

6. Take the value of the predicate r equal to the value of the number of TF with the highest area $\max S(\mu_m^\nabla)$ following rule: $r = m \leftrightarrow \max S(\mu_m^\nabla)$.

7. This value is used in expression (5) for MY and expression (7) for MX in determining the input/output places of sending/receiving tokens with all attributes.

The algorithm maintains efficiency at any number of TF within the indeterminacy.

Annotation: If all the triangles formed by perpendicular, have the same area, the transition will work on the predetermined rules.

If perpendicular creates the no triangle field predicate will possess the value with number of FT which belongs to this area.

Algorithm «rules of the triangle»:

1. Using the expressions (4), (6) to determinate predicate of control transition.

2. Determine the type of transition functions depending on control transition.

3. Find point x', using the expression for trapezoidal (2). Point x' is shown in fig. 5.

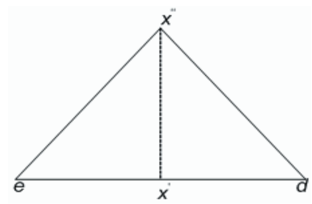


Fig. 5. Algorithm «rules of the triangle»

For the case displayed in fig. 4 sides of the triangle defined by the following equations:

$$y(\mu_1)=\frac{d-x''}{d-c};\ y(\mu_2)=\frac{x''-e}{f-e}. \qquad (8)$$

Where x':

$$x''=x'=\frac{ec-df}{e+c-f-d}. \qquad (9)$$

4. Determine intervals on axis X, formed perpendiculars from the point x'' to the point x', and they belong to a certain TF: $X_1(\mu_1)\in[x',d];\ X_2(\mu_2)\in[e,x')$, where d,e - parameters for first and second TF formed the indeterminacy (fig. 4 and fig. 5).

5. Identify the controlling value of the predicate r equal number of TF according to the following conditions: $r=m\leftrightarrow x\in X_1(\mu_1); r=m+1\leftrightarrow x\in X_2(\mu_2)$. If at the time of transition activity value x lies in the interval defined by m-th TF, the predicate will assumes the value m.

Annotation: If value x falls in the middle of segment, formed by perpendicular from x'' then operates the input/output place will define by the predetermined rules.

For example, consider the case of controlling transition MX of E-net that simulates the processes of routing and the branching processes. This transition models response of control agent area A_r of the node on the probability of congestion which is derived from the value of the packet loss probability (fig. 6).

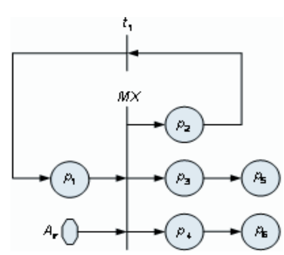


Fig. 6. Illustration for routing and branched processes

In this transition:

p_1 – initial state of communication network (node);

p_2 – state «Congestion is possible, get a transmission time-out»;

p_3 – state «No congestion»;

p_4 – state «Congestion»;

p_5 – further processing of packets in the network;

p_6 – network reaction to congestion;

t_1 – transmission time-out and return to the original state.

Fuzzy predicate which depend on parameter of the packet blocking probability P_{bl}, determined by the following expression:

$$A_r = \begin{cases} \mu(p_2), P_{1;} \in [0,4;0,8]; \\ \mu(p_3), P_{1;} \in [0;0,5]; \\ \mu(p_4), P_{1;} \in (0,8;1] \end{cases}, \quad (10)$$

where interval P_{bl} and shape of TF initialized a priori (experimental value).

The reachability tree for this transition is shown in fig. 7:

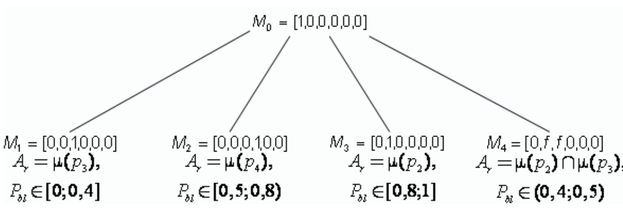


Fig.7. Reachability tree for transition with fuzzy predicate

The corresponding markup $\{M_1 ..., M_4\}$ given by equation (7), based on value of parameter P_{bl}. The uncertainty of the intersection of two transition functions in certain markup disclosed, using the algorithms «triangle area» and «rules of the triangle».

Conclusions

The results of activity (1), (2) and functions for control transition of fuzzy logic (5), (7) do not contradict their definition, obtained in [5] to clear the E-nets, and they are complementary in the case of fuzzy control.

The received definition of the predicate rules and algorithms for the disclosure of the fuzziness do not contradict the classical definition of the predicate.

They can be interpreted in the framework of the well-known simulation system. Accordingly, these rules do not change the logic of E-nets and their properties [5], and therefore do not reduce degree of adequacy of models based on them.

We formulated the basic rules of control transitions with fuzzy predicates. It is allows to create simulation models for DTS which include elements of TF. On the basis of control transitions were received simulation models of distributed fuzzy control system.

On the basis of transitions E-nets with fuzzy logic can be obtained simulations model with distributed fuzzy control system that implements the functions of QoS, built on different protocols such as IP, TCP, UDP, and ATM. This allows us to conclude what type of protocol is more efficient to use as a base for multiservice networks under certain conditions.

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