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FUZZY SETS IN INTERACTIVE COMPUTER MAN-MACHINE SYSTEMS

Summary. The paper deals with some problems of the use of the fuzzy set theory e.g.: linguistic approximation, approximate reasoning in designing of an interactive man-machine systems. The basic definition of linguistic variables constituting the main feature of this kind of systems has been presented in details and illustrated by means of a numerical example. The general structure of the system has been shown and one of the implementations has been presented as well.

1. Introduction

Recently some new ideas on interactive computer systems have been published [8, 13]. The list of human-oriented software programs is extensive (e.g. ELIZA or DEACON [5]). There is no doubt that they form a useful tool for solving a wide class of problems: the designing of complex devices or decision-making in many ill-defined processes.

An introduction of fuzzy set theory and the posibility theory [7, 8] leads to a general class of interactive systems, where a qualitative kind of information can be used and performed. These theories make it possible for us to discuss a new category of models, the so called verbal models [8, 9, 13], which may be systematically analyzed by the use of the fuzzy set theory. It is the aim of this paper to present the use of fuzzy sets in human oriented computer systems, introducing a fuzzy relational equation, a linguistic approximation and the concept of approximate reasoning as a basis of the construction of this kind of systems. At the very beinning we have summarized some theoretical results of a fuzzy relational equation, and a linguistic variable.

2. Linguistic variable and linguistic approximation

A linguistic variable, forming the basis of linguistic algorithms may be defined as follows [11].

DEFINITION 1

A linguistic variable is a system:

$$< L, T(L), X, G, M > \qquad (1)$$

where L, T(L) (or shortly T), $\mathcal{X}$, G, M denote respectively:

L - name of the variable,

T - set of labels of a fuzzy subset of the universe of discourse,

$\mathcal{X}$ - universe of discourse,

G - syntactic rules, commonly defined as generative grammar, which define the well-formed sentences in T,

M - semantics, which consists of rules by which the meaning of the terms in T can be determined.

If X is a term in T, then its meaning (in the denotational sense) is a subset of $\mathcal{X}$. The primary term in T is a term, whose meaning must be defined a priori. It serves as a basis for the computation of the meaning of the non-primary terms in T.

Modifiers (hedges) such as: very, more or less, slightly less, slightly more play a special role in semantics M. They may be defined as follows [11]. For a given value of a linguistic variable $t \in T$ defined by the use of the membership function:

$$\mu_t : \mathcal{X} \to [0,1] \tag{2}$$

the modifier "m" works as follows:

$$\text{modifier } t = \mu_t^m \tag{3}$$

e.g.

$$\begin{aligned} \underline{\text{very}}\ t &\triangleq \mu_t^2 \\ \underline{\text{more or less}}\ t &\triangleq \mu_t^{\frac{1}{2}} \end{aligned} \tag{4}$$

$\underline{\text{slightly less}}\ t = \mu_t^{0,75}$

$\underline{\text{slightly more}}\ t = \mu_t^{1,25}$

Another definition of modifiers may be used as well [4].

Example 1

Let us illustrate a linguistic variable: pressure, expressing basic elements of Def. 1.

L - pressure,

T = {small, middle, big, more or less, small, very small, very very small...}

$\mathcal{X}$ = {10, 20, ..., 100}

G is a grammar:

$$G = \langle V, \Sigma, P, \sigma \rangle$$

where

$V = \{$ small, middle, big, slightly, less, very, slightly more, more or less $\}$

$\Sigma = \{$ value of linguistic variable, modifier, primaty term $\}$

with the following list of productions:

P:

<value of linguistic variable>::=<primary term>|<modifier> <primary term>|<modifier> <value of linguistic variable>

<primary term>::= small | middle | big

<modifier> ::= very | more or less | slightly less | slightly more

σ = <value of linguistic variable

Example 2

Taking into account a linguistic variable pressure as discussed in Ex. 1 and the primary set middle defined by a membership function:

X	10	20	30	40	50	60	70	80	90	100
μ_{middle}	0	.1	.3	.5	1	.5	.3	.1	0	0

the values of linguistic variables created by means of different modifiers are given by eq. (4) and illustrated in Fig. 1.

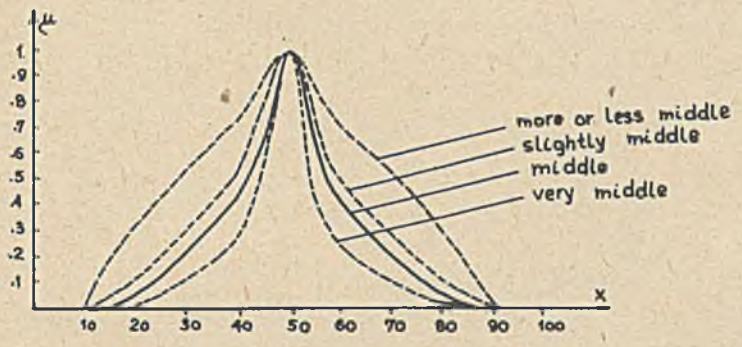

Fig. 1. Primary set middle and the values of linguistic variables created by means of different modifiers

It is interesting to notice a characteristic feature of modifiers. They can be divided into two groups:

- fuzzification modifiers ($m < 1$, e.g. more or less)
- concentration modifiers ($m > 1$, e.g. very)

because the modifiers of the first group increase the degree of fuzziness φ_t of primary sets, i.e.

$$\varphi_t < \varphi_{mt} \tag{5}$$

and using one of the second group the degree of fuzziness is decreased:

$$\varphi_t > \varphi_{mt} \tag{6}$$

where:

$$\varphi_t = \frac{1}{\operatorname*{Max}_{x \in X} \mu_t(x)} \sum_{x \in X} \mu_t(x) \tag{7}$$

One of the basic problems in approximate reasoning might be stated as follows:

- for a given fuzzy set with a membership function fit "best" (in the sense of an appriopriate distance) primary sets and modifiers if the number of modifiers is given, i.e. approximating a fuzzy set by means of the best fitted value of a linguistic variable.

Let us denote:

$\{t_i\}$ $i=1,2,\ldots,m$ - set of membership functions of primary fuzzy sets.

$\{h_j\}$ $j=1,2,\ldots,k$ - set of modifiers hedges

n - length of the chain of modifiers

μ - a given membership function

So we get the problem:

$$\min_{\substack{1 \leq i \leq m \\ 1 \leq j_1,\ldots,j_k \leq k}} \| \mu - \mu_{\overbrace{h_{j_1} \ldots h_{j_k}}^{n} t_i} \| = \| \mu - \mu_{h_{j_{01}} \ldots h_{j_{0k}} t_{i_0}} \| \tag{8}$$

where $\|\cdot\|$ denotes the distance.

The solution of the problem presented above needs a great amount of computation equal to:

$$m+m\cdot k+m\cdot k\cdot k+\ldots+m\cdot k^{n-1}\cdot k = m+m\cdot k+m\cdot k^2+\ldots+m\cdot k^n = m(1+k+k^2+\ldots+k^n) \tag{9}$$

see Fig. 2.

It is convenient to use a simpler, suboptimal strategy in order to find the values of the proper fuzzy set and of the modifiers. This has been illustrated in Fig. 3. This method needs the number of calculation to be equal to:

$$m+m\cdot k + (n-1)\cdot k = m\cdot(1+k) + (n-1)\cdot k \tag{10}$$

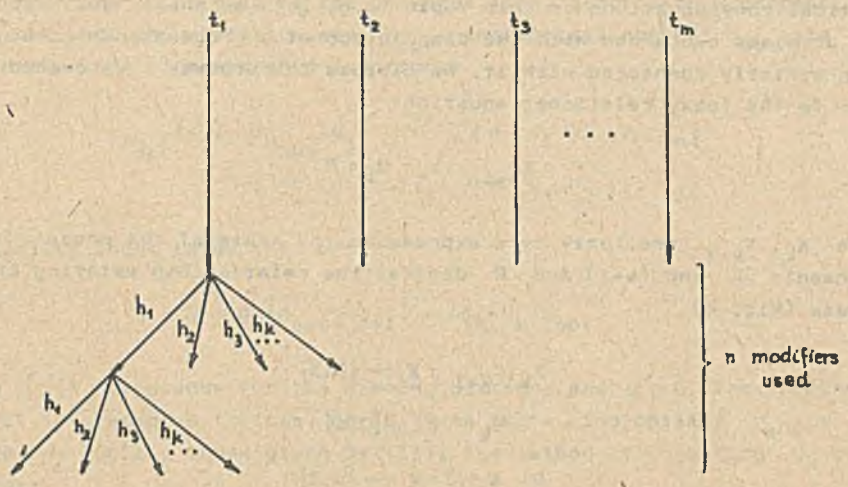

Fig. 2. Illustration of linguistic approximation in the case of n modifiers used

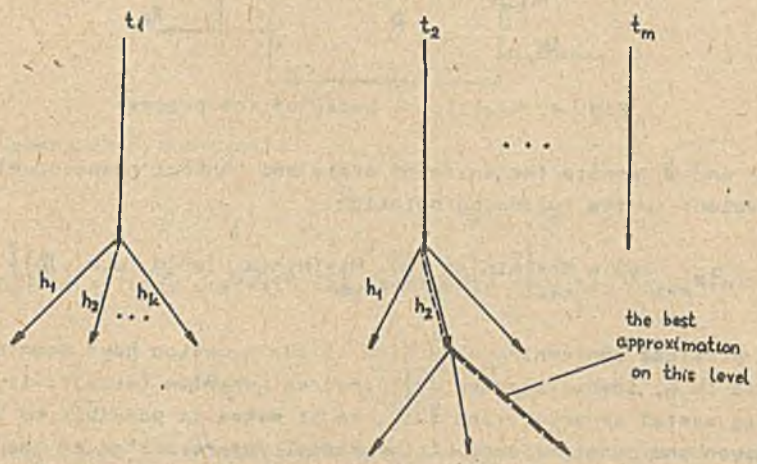

Fig. 3. Illustration of modified linguistic approximation in the case of n modifiers used

3. Fuzzy relational equations

Fuzzy relational equations form useful tool for describing complex, ill-defined processes, where the representation of the process in categories of sets and relations is more adequate than in the categories of points and functions. Because there is a great number of theoretical and

practical considerations on this topic (e.g. [6]) we shall deal with the main problems concerned with the description of a process and some problems strictly connected with it. We discuss the process described by means fo the fuzzy relational equation:

$$X_{k+1} = X_k \circ U_k \circ R \tag{11}$$

where X_k, X_{k+1} are fuzzy sets expressing the state of the process in time moments k and $(k+1)$ and R denotes the relationship existing in the process (Fig. 4)

$$\begin{aligned} X_k, X_{k+1} &: \mathbb{X} \to [0,1] \\ U_k &: \mathbb{U} \to [0,1] \\ R &: \mathbb{U} \times \mathbb{X} \times \mathbb{X} \to [0,1] \end{aligned} \tag{12}$$

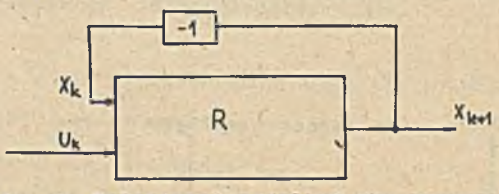

Fig. 4. Relational model of the process

where $\mathbb{X}$ and $\mathbb{U}$ denote the space of state and control respectively. Eq (11) is equivalent to the following notation:

$$\mu_{X_{k+1}}(y) = \operatorname*{Max}_{x \in \mathbb{X}} \left\{ \operatorname{Min}\left[\mu_{X_k}(x), \operatorname*{Max}_{u \in \mathbb{U}} (\operatorname{Min}(\mu_{U_k}(u), \mu_R(u,x,y)))\right] \right\} \tag{13}$$

General problems concerning this kind of the equation have been discussed in detail (e.g. identification [2], inverse problem (sensitivity) [1,7] Eq. 11 is useful in prediction task, so it makes it possible to be used for a given and constant control to predict future states of the process. If X_k and U are given, so using Max-Min composition we get:

$$\begin{aligned} X_{k+1} &= X_k \circ U \circ R = X_k \circ G \\ X_{k+2} &= X_{k+1} \circ U \circ R = X_{k+1} \circ G = X_k \circ G \circ G \\ &\vdots \\ X_{k+p} &= X_k \circ G \circ \ldots \circ G = X_k \circ G^p \end{aligned} \tag{14}$$

where p denotes the horizon of prediction.

Another important task is the one-step local control of a process. Let us assume that the optimal state X_{opt} and optimal control U_{opt} are given in the form of membership functions:

$$\mu_{X_{opt}}(x_i),\ \mu_{U_{opt}}(u_j) \qquad \mathbb{X} = \{x_1, x_2, \dots x_n\}$$
$$1 \leqslant i \leqslant n \quad 1 \leqslant j \leqslant p \quad \mathbb{U} = \{u_1, u_2, \dots u_p\}$$

The quality index takes the form:

$$Q = \varrho_H(X_{opt}, X_{k+1}) + \alpha \varrho_N(U_k, U_{opt}) \tag{15}$$

where $\varrho_H(\cdot,\cdot)$ stands for the Hamming distance and $\alpha \geqslant 0$. The problem of control is stated as follows: For a given state find optimal U_k i.e. minimize the quality index given by (15). The method of computing U_k is as follows:

1. Compute

$$Q(\tilde{U}_j) = \varrho_H(X_{opt}, X_k \circ \tilde{U}_j \circ R) + \alpha \varrho_H(\tilde{U}_j, U_{opt}) \tag{16}$$
$$j = 1, 2, \dots, p \qquad \alpha \geqslant 0$$

where

$$\tilde{U}_j : \mathbb{U} \to [0,1]$$

with the membership function:

$$\mu_{U_j}(u_i) = \delta_{u_i, u_j} \qquad i = 1, 2, \dots, p \tag{17}$$

2. Put U_k as a fuzzy set with the membership function equal to:

$$\mu_{U_k}(u_i) = 1 - \frac{Q(\tilde{U}_i)}{\operatorname*{Max}_{1 \leqslant i \leqslant p} Q(\tilde{U}_i)} \tag{18}$$

The considerations given above are used in the construction of an interactive system.

4. General structure of an interactive computer man-machine system

In this section we present the structure of an interactive man-machine system, which can be used in the case of processing a qualitative form of information. The main blocks of the system are depicted in the Fig. 5 Let us briefly discuss some of them.

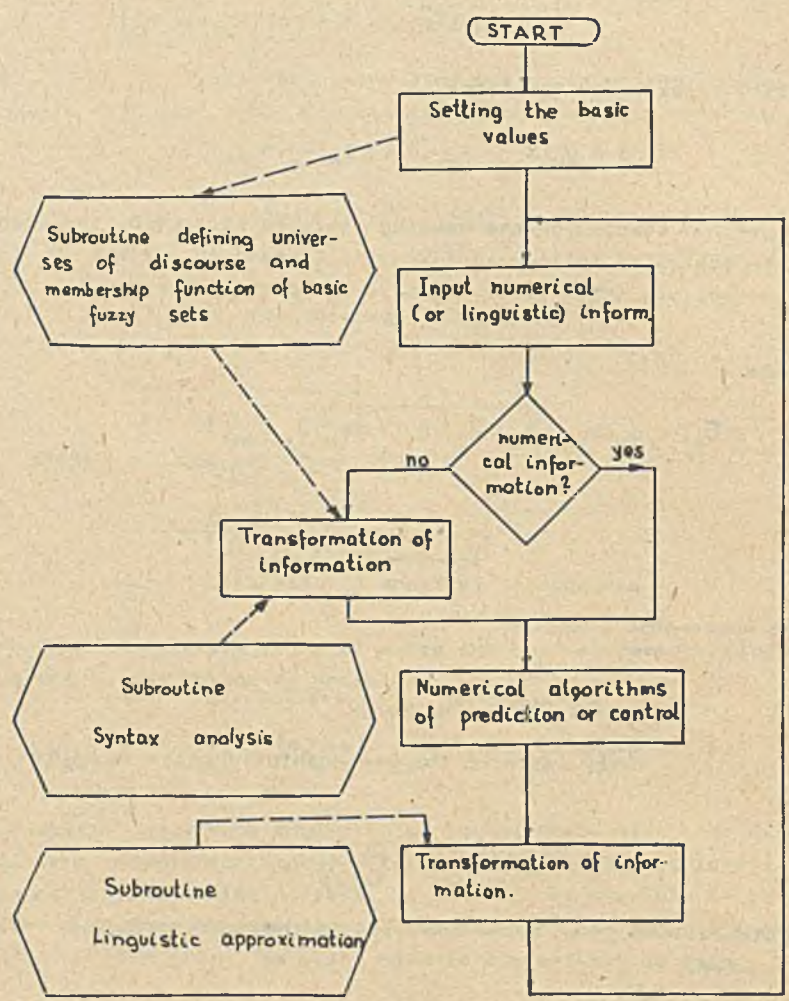

Fig. 5. General structure of an interactive man-machine system

```
      PROGRAM(DIAL)
       INPUT1=CR0
       INPUT2=CR1
       OUTPUT5=LP0
       OUTPUT6=LPT
       TRACE 2
       END
     MASTER
   DIMENSION XOPT(10)
       DIMENSION X(10),Y(10),UOPT(10),U(10)
   COMMON/BLOK10/ALFA
       COMMON/BLOK1/SET(10,10),KK(20,20),MK(10,20),TMOD(10)
   COMMON/BLOK2/N,NN,MM,NK
    COMMON/BLOK3/R(8,8,8)
C     N-DIMENSION OF STATE SPACE
C     NK-DIMENSION OF CONTROL SPACE
   READ(1,2)N,NK,NN,MM
C  NN-NUMBER OF BASIC SETS
C  MM-NUMBER OF HEDGES
       ALFA=.2
2      FORMAT(I010)
40     FORMAT(40A1)
   DO 10 I=1,NN
10  READ(1,20)(SET(I,J),J=1,N)
20  FORMAT(10F0.0)
   READ(1,20)(TMOD(I),I=1,MM)
   DO 30 I=1,NN
30  READ(1,40)(KK(I,J),J=1,20)

   DO 50 I=1,MM-1
50  READ(1,40)(MK(I,J),J=1,20)
   DO 60 I=1,NK
          DO 60 J=1,N
60         READ(1,20)(R(I,J,K),K=1,N)
900  CALL HEAD
          WRITE(6,777)
777       FORMAT(10HPREDICTION,5X,6HMARK=1,/HCONTROL,5X,6HMARK=2)
    READ(2,20)A
       IF(A.EQ.2.) GO TO 500
   WRITE(5,70)
   WRITE(6,70)
70  FORMAT(5X,10HPREDICTION//)
          WRITE(5,73)
88     CONTINUE
    WRITE(5,80)
   WRITE(6,80)
          WRITE(5,71)
71        FORMAT(5X,10(1H-))
80  FORMAT(5X,14HINITIAL VALUES)
    WRITE(5,60)
   WRITE(6,90)
          WRITE(5,71)
90     FORMAT(5X,   20HSTATE OF THE PROCESS)
   DO 100 I=1,N
    WRITE(6,110)
100        READ(2,20)X(I)
110     FORMAT(5X,1HX,I1)
      DO 212 J=1,N
212     WRITE(5,220) J,X(J)
220     FORMAT(10X,1HX,I1,5X,F6.3)
          CALL ALING(X)
   WRITE(5,120)
   WRITE(5,120)
          WRITE(5,71)
120       FORMAT(5X,   22HCONTROL OF THE PROCESS)



   DO 130 I=1,NK
   WRITE(6,115)
115    FORMAT(5X,1HU,I1)
130        READ(2,20)U(I)
116  FORMAT(10F0.0)
      DO 215 J=1,NK
215       WRITE(5,215)  J,U(J)
215       FORMAT(10X,1HU,I1,5X,F6.3)
   WRITE(6,150)
150       FORMAT(5X,    21HHORIZON OF PREDICTION)
       READ(2,1)NP
160  FORMAT(I10)
170  FORMAT(10X,10(F5.3,4X))
   WRITE(5,180)
180       FORMAT(10X,   10HPREDICTION)
       WRITE(5,73)
73        FORMAT(5X,10(1H*))
   DO 190 I=1,NP
          CALL MAXOP(X,U,Y,N,NK)
   WRITE(5,200)
200       FORMAT(10X,18HSTEP OF PREDICTION, I3)
     DO 214 J=1,N
214       WRITE(5,220)J,Y(J)
      CALL ALING(Y)
      DO 1000 J=1,N
1000      X(J)=Y(J)
190    CONTINUE
500  WRITE(5,300)
          WRITE(5,73)
300  FORMAT(10X,7HCONTROL/)
    WRITE(5,310)
    WRITE(6,310)
          WRITE(5,71)
310       FORMAT(10X,   13HOPTIMAL STATE)
     READ(2,20)(XOPT(I),I=1,N)
      DO 314 I=1,N
314      WRITE(5,220)I,XOPT(I)
   WRITE(5,320)
   WRITE(6,320)
          WRITE(5,71)
320       FORMAT(10X,13HOPTIMAL CONTROL)
     READ(2,20)(UOPT(I),I=1,NK)
     DO 312 J=1,NK
312      WRITE(5,215)I,UOPT(I)
   WRITE(5,330)
   WRITE(6,330)
          WRITE(5,71)
330       FORMAT(10X,   20 HSTATE OF THE PROCESS)
     READ(2,20)(X(I),I=1,N)
      DO 316 I=1,N
316       WRITE(5,220)I,X(I)
    WRITE(5,300)
   WRITE(6,300)
          WRITE(5,71)
   CALL OPTIMAL(X,UOPT,XOPT,U)
      DO 717 I=1,NK
          WRITE(5,222)I,U(I)
717       FORMAT(10X,1HU,I1,5X,F6.3)
222
   GO TO 900
    STOP
    END
       SUBROUTINE ALING(X)
       COMMON/BLOK1/SET(10,10),KK(20,20),MK(10,20),TMOD(10)
       DIMENSION X(10),S(10,10)

       COMMON/BLOK2/N,NN,MM,NK
        DO 90 I=1,NN
        DO 90 J=1,MM
          W=0
          DO 100 K=1,N
100       W=W+ABS(X(K)-SET(I,K)**TMOD(J))
90          R(I,J)=W
            JOPT,KOPT=1
            S=R(1,1)
            DO 110 I=1,NN
            DO 110 J=1,MM
            IF(S.LT.R(I,J))GO TO 110
            S=R(I,J)
             JOPT=I
             KOPT=J
110         CONTINUE



            IF(KOPT.EQ.MM)KOPT=0
            IF(KOPT.EQ.0)WRITE(5,130)(KK(JOPT,J),J=1,20)
   IF(KOPT.NE.0)WRITE(5,130)(MK(KOPT,J),J=1,20),(KK(JOPT,J),J=1,20)
130       FORMAT(10X,2HLINGUISTIC APPROXIMATION,5X,40A1)
            RETURN
            END
            SUBROUTINE MAXOP(X,U,Y,NN,NK)
   COMMON/BLOK3/R(8,8,8)
   DIMENSION X(10),S(10),U(10)
   DIMENSION G(10,10)
   DO 30 K=1,NN
   DO 20 J=1,MM
   S=0
   DO 10 I=1,NN
    IF(U(I).GT.R(I,K,J)) S=U(I)
   IF(U(I).GE.R(I,K,J)) S=R(I,K,J)
   IF(S.GT.Z) GO TO 10
   S=Z
10 CONTINUE
20        G(K,J)=S
     DO 30 I=1,NN
   S=0
   DO 40 J=1,NN
   IF(Y(J).LT.G(J,I)) Y(J)=G(J,I)
   IF(G(J,I).LT.X(J)) X(J)=G(J,I)
   IF(S.GT.Z) GO TO 40
   S=Z
40         CONTINUE
30         Y(I)=S
           RETURN
           END
   SUBROUTINE HEAD
   COMMON/BLOK1/SET(10,10),KK(20,20),MK(10,20),TMOD(10)
   COMMON/BLOK2/N,NN,MM,NK
   WRITE(5,10)
   WRITE(5,10)
10         FORMAT(5X,30(1H-))
   WRITE(5,20)
20    FORMAT(5X,29HDEFINED BASIC SETS AND HEDGES)
          WRITE(5,60)
     DO 300 I=1,NN
       WRITE(5,30)(KK(I,J),J=1,20)
30         FORMAT(20A1)
          WRITE(5,50)
40     FORMAT(15X,10F5.2)
      DO 42 J=1,M
42        WRITE(5,41)(SET(I,J)
41         FORMAT(2X,10(F5.3) /
40         FORMAT(2X,10(1H-))
300    CONTINUE
   WRITE(5,70)
70         FORMAT(1X//)
   DO 400 I=1,MM-1
400       WRITE(5,402)(MK(I,J),J=1,20),TMOD(I)
80         FORMAT(2X,20A1,5X(1H-),F5.3)
   WRITE(5,10)
   RETURN
   END
   SUBROUTINE OPTIMAL(X,UOPT,XOPT,U)
   COMMON/BLOK10/ALFA
    DIMENSION Y(10)
   COMMON/BLOK3/R(8,8,8)
   COMMON/BLOK2/N,NN,MM,NK
   DIMENSION X(10),UOPT(10),XOPT(10),U(10),S(10)
   DO 5 I=1,NK
5     S(I)=0
   DO 20 J=1,NK
   DO 10 I=1,NK
10    W(I)=0
   W(J)=1
          CALL MAXOP(X,U,Y,N,NK)
     DO 30 I=1,N
30    S(J)=S(J)+ABS(Y(I)-XOPT(I))
   DO 40 I=1,NK
40    S(J)=S(J)+ALFA*ABS(U(I)-UOPT(I))
20 CONTINUE
   SS=0
   DO 50 I=1,NK
50    IF(SS.LT.S(I)) SS=S(I)
   DO 60 I=1,NK
60    U(I)=1-S(I)/SS
   SS=0



   DO 70 I=1,NK
70    IF(SS.LT.U(I)) SS=U(I)
   DO 80 I=1,NK
80    U(I)=U(I)/SS
   RETURN
    END
   FINISH
```

Fig. 6. Fuzzy relation R describing the process

$$\begin{bmatrix} 1 & .5 & .3 & .2 & .1 & 0 \\ .4 & .6 & 1 & .4 & .3 & .1 \\ .3 & .4 & .7 & 1 & .4 & .3 \\ .1 & .3 & .5 & 1 & .3 & .1 \\ 0 & .3 & .4 & .8 & 1 & .9 \\ 0 & .2 & .3 & .7 & .9 & 1 \end{bmatrix} \quad U=U_1$$

$$\begin{bmatrix} 1 & .9 & .8 & .7 & .5 & .3 \\ 1 & .8 & .5 & .2 & .1 & 0 \\ .9 & 1 & .9 & .5 & .4 & .3 \\ .9 & .9 & 1 & .7 & .3 & .1 \\ .9 & .9 & 1 & .9 & .4 & .2 \\ .1 & .2 & .5 & .6 & 1 & .5 \end{bmatrix} \quad U=U_2$$

$$\begin{bmatrix} .3 & .5 & .9 & 1 & .8 & .7 \\ .4 & .6 & .8 & 1 & .9 & .7 \\ .3 & .5 & 1 & .6 & .3 & .2 \\ .7 & .8 & 1 & .4 & .2 & 0 \\ .9 & .9 & 1 & .8 & .5 & .2 \\ .9 & 1 & .5 & .2 & 0 & 0 \end{bmatrix} \quad U=U_3$$

$$\begin{bmatrix} .3 & .7 & .8 & .9 & 1 & 1 \\ .5 & .8 & .9 & 1 & .2 & .2 \\ .6 & .9 & 1 & .9 & .4 & .4 \\ .5 & .8 & 1 & .6 & .3 & .1 \\ .4 & .5 & .9 & 1 & .3 & .1 \\ .4 & .7 & 1 & .3 & .1 & .1 \end{bmatrix} \quad U=U_4$$

$$\begin{bmatrix} 1 & .4 & .3 & .2 & 0 & 0 \\ .8 & 1 & .5 & .3 & .1 & .1 \\ .4 & .5 & 1 & .2 & .2 & .1 \\ .3 & .8 & 1 & .3 & 0 & 0 \\ .7 & 1 & .8 & .5 & 0 & 0 \\ .5 & .9 & 1 & .1 & 0 & 0 \end{bmatrix} \quad U=U_5$$

Fig. 7. Fuzzy relation R describing the process

Setting of the basic values - In this block the primary fuzzy sets and modifiers are defined and the spaces $\mathbb{X}$ and $\mathbb{U}$ are created.

Transformation of information - Input information is transformed into numerical values by means of defined fuzzy sets and modifiers. Output information can be numerical in character or form the value of a linguistic variable. In the second case the subroutine of linguistic approximation is used. The algorithms of prediction and control have been presented in the previus section. A computer programme based on the general scheme given in Fig. 5 has been realised using FORTRAN 1900 (Fig. 6). Spaces and $\mathbb{U}$ consist of 6 and 5 elements:

$$\mathbb{X} = \{x_1, x_2, x_3, x_4, x_5, x_6\}$$
$$\mathbb{U} = \{u_1, u_2, u_3, u_4, u_5\}$$

and relation R describing the process is presented in Fig. 7. Definitions of basic sets and modifiers (hedges) are given in Fig. 8. Some results obtained by means of this programme are presented in Fig. 9.

```
-----------------------------
-----------------------------
DEFINED BASIC SETS AND HEDGES
-----------------------------

SMALL
-----
X1   1.000
X2   0.600
X3   0.400
X4   0.200
X5   0.000
X6   0.000

MIDDLE
------
X1   0.000
X2   0.300
X3   1.000
X4   0.300
X5   0.000
X6   0.000

BIG
---
X1   0.000
X2   0.200
X3   0.400
X4   0.600
X5   0.700
X6   1.000


VERY            ---2.000
  MORE OR LESS  ---0.500
```

Fig. 8. Definition of basic sets and modifiers (hedges)

```
PREDICTION

 ***********
  INITIAL VALUES
 ------------
  STATE OF THE PROCESS
 ------------
        X1      1.000
        X2      0.000
        X3      0.000
        X4      0.000
        X5      0.000
        X6      0.000
        LINGUISTIC APPROXIMATION      VERY                    SMALL
  CONTROL OF THE PROCESS
 ------------
        U1      0.000
        U2      0.000
        U3      1.000
        U4      0.000
        U5      0.000
        PREDICTION
 ***********
STEP OF PREDICTION  1
        X1      0.300
        X2      0.500
        X3      0.900
        X4      1.000
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
STEP OF PREDICTION  2
        X1      0.800
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.500
        X6      0.500
        LINGUISTIC APPROXIMATION          MORE OR LESS        SMALL
STEP OF PREDICTION  3
        X1      0.700
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
STEP OF PREDICTION  4
        X1      0.800
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
STEP OF PREDICTION  5
        X1      0.800
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
STEP OF PREDICTION  6
        X1      0.800
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
STEP OF PREDICTION  7
        X1      0.800
        X2      0.800
        X3      1.000
        X4      0.800
        X5      0.800
        X6      0.700
        LINGUISTIC APPROXIMATION          MORE OR LESS          BIG
        CONTROL

 ***********
        OPTIMAL STATE
 ------------
        X1      0.100
        X2      0.200
        X3      0.500
        X4      0.900
        X5      1.000
        X6      1.000
        OPTIMAL CONTROL
 ------------
        U1      1.000
        U2      0.400
        U3      0.200
        U4      0.000
        U5      0.000
        STATE OF THE PROCESS
 ------------
        X1      0.500
        X2      0.800
        X3      1.000
        X4      0.400
        X5      0.200
        X6      0.000
        CONTROL

 ------------
        U1      0.909
        U2      0.306
        U3      1.000
        U4      0.579
        U5      0.000
 ------------------------------
```

Fig. 9. Examples of results obtained by means of programme

5. Concluding remarks

The concept of the fuzzy set theory forms a formal frame of expressing vague, ambiguous and ill-defined concepts. A human-oriented computer system,,using the methods of these theories e.g. fuzzy relational equations, linguistic approximation, possibility theory can operate on a qualitative kind of information giving results of linguistic or numerical character, which are used in many areas, where the human factor forms an important element of the system. Otherwise, such a system can form a proper tool for linguistic simulation and for the modelling of complex, not well-defined systems.

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ZBIORY ROZMYTE W INTERAKTYWNYCH SYSTEMACH KOMPUTEROWYCH

S t r e s z c z e n i e

W pracy rozpatrzono niektóre problemy dotyczące zastosowania teorii zbiorów rozmytych (np. aproksymacji lingwistycznej, rozumowania przybliżonego) w projektowaniu interaktywnych systemów komputerowych. Szczegółowo przedstawiono definicję i interpretację zmiennej lingwistycznej grającej istotną rolę w tego rodzaju systemach, jak również podano przykład numeryczny. Praca zawiera ogólną strukturę systemu wraz z jedną z możliwych implementacji.

РАСПЛЫВЧАТЫЕ МНОЖЕСТВА В ИНТЕРАКТИВНЫХ КОМПЬЮТЕРНЫХ СИСТЕМАХ

Р е з ю м е

В работе рассмотрено некоторые проблемы применения теории расплывчатых множеств например лингвистической апроксимации, приближенного рассуждения в проектированию интерактивных компьютерных систем. Дано точное определение и интерпретацию лингвистической переменной играющую основную роль в этого рода системах. Дан числовой пример. В работе представлено общую структуру системы с одной из возможных интерпретаций.