NEUROFUZZY IN IRRIGATION MANAGEMENT

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Abstract. *In this paper it is presented a new approach for irrigation management. The system takes into account not only the maximization of the crops, but also the needs of other water consumers and, not least, the environmental protection. The presented application is designed with the neurofuzzy theory.*
Keywords: *the irrigation management, neural networks, fuzzy logic controller.*

Introduction

A good management it is about optimal allocation of limited resources to cover the growing needs on short term and on longer term. In Agriculture the irrigation is a very important issue, but we have to consider that the irrigation leads to good aspects (increasing the amount of the crops), but they also have negative impact on the environment. In the same time, when all the consumers are using the same resource, it may become difficult to sustain all the necessary quantity of water. That's why a water allocation system is needed along with an optimal design of the water networks and also with a fair splitting between domestic, industrial and agriculture consume.

Since the number of variables to be considered in the process of decision making is very numerous a simple algorithm would not be enough for an efficient decision. For example, in the water allocation dilemma we first have to decide whether to use more water for industry, for agriculture or for domestic use and then what is the timetable allocation for each subdivision of consumer needs. Technical and subjective elements of decision must be taken into consideration and the goal is to obtain an optimal balance for the whole, not for a single category of consumers. For a rational system that operates a great number of variables and which is dealing with uncertainty we use Fuzzy Logic.

The irrigation management

The irrigation management it is a decision process that requires the following necessary steps:

- *planning* of resources which have to cover the needs.
- *implementing* the agreed plan
- *monitoring the implementation* of the plan and appreciating the success of the process based on well defined performance criteria and on adequate indicators.
- *maintain the communication* between directly and indirectly involved authorities in irrigation process.

The most important step in irrigation management is planning. If we don't seize the necessary quantity and the available water volume we cannot come to a good planning then the subsequent steps won't be realized in satisfactory conditions.

Planning may be on one year term, but most likely is seasonal due to agricultural production requirements. In this stage certain decision factors are taken into consideration from different areas of interests: environment protection, economy social aspects, technical specifications, agriculture. The decision factors suggest potential conflictive interests at some point and diverging plans. Reaching and equilibrium of interests and overall efficiency is resolved through a mathematical modeled scheme: *Fuzzy- Multiple- Participant- Multiple-Criteria- Decision – Making.*

The most important decision factors in planning seasonal irrigation are:

- the structure of cultivated fields
- scheduling of water supplies
- water and fertilizer application

The structure of cultivated fields

Some plants can grow in better conditions on certain types of soil, but this is not an aspect that farmers would always consider. They want to obtain the largest quantity of the most demanded agriculture products.

Regarding the allocation of land we must also consider the environmental aspects. For instance, some plants need an increased quantity of water which will lead to a water shortage in some other domains and to more polluted water. Often, the accent it's put on farming, but the necessary amount of water for the surrounding environment is neglected. What we need it's a fair ratio between agriculture and environment.

Water supplying

Planning of water supplying it's the most complex and disputed part of the process. A water delivery plan must be developed considering the following:

- type of cultivated field
- differentiated life time cycles for different plants
- the amount needed for the rest of the consumers.

The most usual scheduling methods are:

- *Delivery by request*, the process is entirely controlled by farmers. It's the most convenient for the farmers, but in this case not all the parts involved will be content, some will receive water below their necessary. In the same time, the method does not consider environmental issues of irrigation.
- *Scheduled delivery without taking notice of the demands of the farmers.* In this case, farmers' needs are not taken into consideration and the process is guided only through authorities' dispositions. The obvious inconvenient of this practice are, of course, farmers discontent and losing sight of valuable pieces of information which may come from farmers.
- *Scheduled delivery of water preceded by consultations with farmers and authorities.* It requires a good communication between farmers and authorities. It is also the most desirable option in which everyone involved has something to say. Every assertion is entered in the system as a new input variable. The procedure tries to find then the optimal solution considering also the authorities opinion. This solution can be reached also through genetic algorithms.
- *Continuous delivery* is the cheapest in terms of work volume needed for planning, but overall is the most inefficient because no water saving it's being done.

Appling water and fertilizers

Beside major benefits brought by irrigation we must also consider the negative events which occur during this process. These are:

- salinity
- soil erosion
- plant diseases

A correct application of water regards soil-water deficit on the date of irrigation and it is usually estimated through this equation:

$$IRR = \Delta S + RO + ET + DP - IW - GW \qquad (1)$$

Where*:*

IRR = irrigation requirement

ΔS = variation of water quantity in soil

RO = loss of water on the surface

ET = loss of water through crop transpiration

DP = deep percolation

IW = infiltrated water

GW= contribution of ground water by capillary rise.

Both excess and water deficit may cause negative effects. The excess may cause infiltration of nutrients and pesticides into the ground water, or it may cause water saturation around the root of the plant and bad aeration in the soil. We must also consider the other negative impacts of badly planned irrigation on quality of drinking water and public health. Poor quality of water is the main source of plant diseases in irrigation projects.

System modeling

The whole system it's being divided into subsystems, each subsystem having its own inputs and outputs. More, some of a subsystem outputs may be a part of another subsystem inputs.
The decision factors are important due to values taken by the attributes (y_{actual}).
The final objectives can be defined as realizing the proposed value ($y_{proposed}$).

Performance indicators (Y) are represented in:

$$y = \frac{y_{actual}}{y_{proposed}} \qquad (2)$$

Many of the performance indicators may define a system output.
The subsystems in which the system it is divided are:

- Sewing subsystem;
- Water treatment subsystem;
- Water transport subsystem
- The farm subsystem
- The economic subsystem

In this paper will we take into account only the farm's subsystem that is the most complex of them.
The *inputs* for the farm subsystem are:

- TALW – total allocated water
- SCHR – scheme rules

The *outputs* for the farm subsystem are:

- CFDW – Collected Field Drainage Water
- CFEE – Collected Fees
- SAP – Scheme Agricultural Production
- TSED – Transported Sediment

The *objectives* are:

- TALW – completing the needs of all the consumers
- CFDW – protecting public health
- TSED – conservation of the soil.

Performance indicators are:

Correctness in water distribution and completing the requests - Equity is one of the main goals of the process especially when there are many consumers involved. The indicator used for measuring fairness is called inter-quartile ratio:

$$\text{Interquartile Ratio} = \frac{\mathrm{WRBSQ}(\mathrm{m}^3/ha)}{WRWSQ(m^3/ha)} \qquad (3)$$

Where, WRBSQ, stands for water received by best supplied quartile and WRWSQ means water received by the worst supplied quartile.

For measuring the *capacity of completing the requests* we use relative water supply indicator (RWS),

$$RWS = \frac{Irrigation + Rain(mm)}{ET + InfiltrationDraining(mm)} \qquad (4)$$

Where ET = evapo-transpiration.

Protecting of public health - The indicator used for this objective is the potential of pollution PP, which is the relation between the nutrient amounts leaving the farm to the added amount of nutrients.

$$PP = \frac{ANL(ton)}{Amount\_of\_added\_nutrient(ton)} \qquad (5)$$

Where *ANL* = *Amount of nutrient leaving the farms*

Soil conservation - Form diminishing pollution it's necessary to reduce the quantity of sediments leaving the terrain because of the irrigation. Sediment yield is the indicator in this case:
We shall have,

$$SY = \frac{Se\dim ent\_leaving\_farm(ton)}{Farm\_Area(ha)} \qquad (6)$$

Simulation of the model

The application was developed under Matlab.6. For illustration we considered a simplified fuzzy system with only two input indicators.
The two indicators used are:
I_1= water in soil (humidity %)
I_2 = available quantity of water (m^3/s)

And the output is:
O_0 = quantity of water to be applied (m^3/s)

Fuzzification

Table 1. The notations for the first input of the fuzzy system

Input I_1		
Linguistic terms $A_1^{j_1}$	**Membership functions** $\mu_1^{j_1}$	**Degree of member** $V_1^{j_1}$
A_1^1 =Low (L)	μ_1^1	V_1^1
A_1^2 =Medium (M)	μ_1^2	V_1^2
A_1^3 =High (H)	μ_1^3	V_1^3

Table 2. The notations for the second input of the fuzzy system

Input I_2		
Linguistic terms $A_2^{j_2}$	**Membership functions** $\mu_2^{j_2}$	**Degree of member** $V_2^{j_1}$
A_2^1 =Not Enough (NE)	μ_2^1	V_2^1
A_2^2 =Fair (F)	μ_2^2	V_2^2
A_2^3 =Too much (TM)	μ_2^3	V_2^3

Table 3. The notations for output of the fuzzy system

Output O_o		
Linguistic terms $A_0^{j_0}$	**Membership functions** $\mu_0^{j_0}$	**Degree of member** $V_0^{j_0}$
A_0^1 =Very Small (VS)	μ_0^1	V_0^1
A_0^2 =Small (S)	μ_0^2	V_0^2
A_0^3 =Medium (M)	μ_0^3	V_0^3
A_0^4 =Big (B)	μ_0^4	V_0^4
A_0^5 =Very Big (VB)	μ_0^5	V_0^5

We considered the following membership functions:

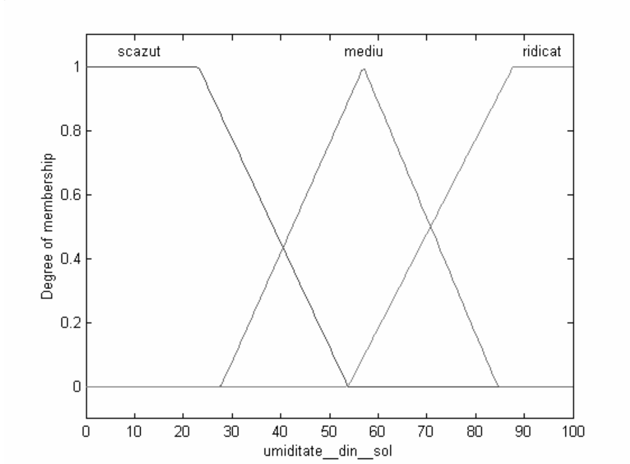

Figure 1. The membership function for the first input.

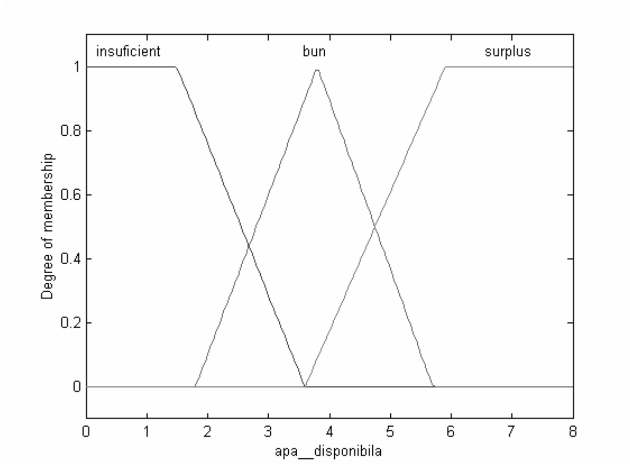

Figure 2. The membership function of the second input.

For the output we considered the following function:

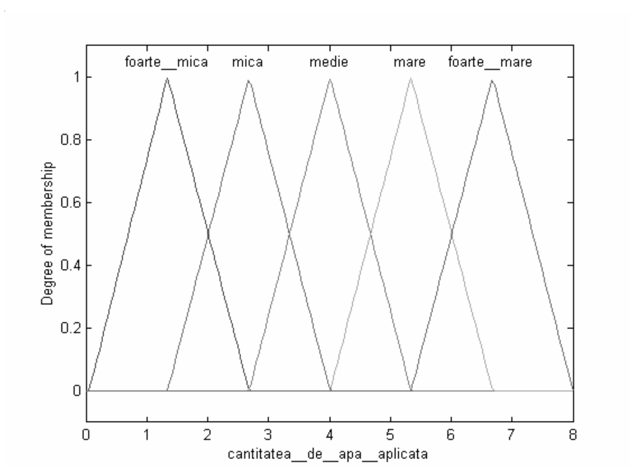

Figure 3.The membership function of the output.

The resulted fuzzy system is represented in the following picture:

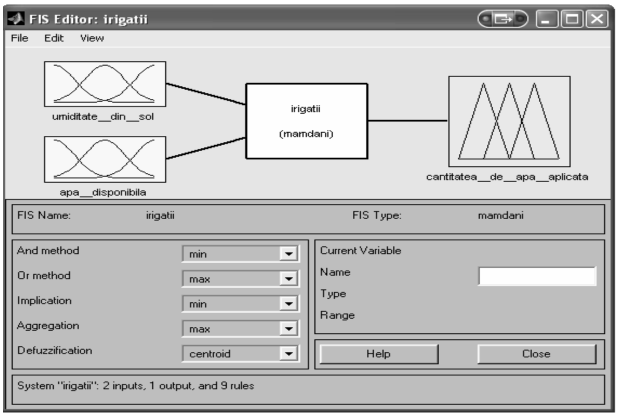

Figure 4. The fuzzy system.

If there are considered the values for the two inputs the fuzzy sets are:

- for $I_1=60\%$
  Low - to the degree (V_1^1) of 0.0
  Medium - to the degree (V_1^2) of 0.9
  High - to the degree (V_1^3) of 0.2
- for $I_2=2\ m^3/s$
  Not Enough - to the degree (V_2^1) of 0.75
  Fair - - to the degree (V_2^2) of 0.1
  Surplus - to the degree (V_2^3) of 0.0

Fuzzy Inference

The rules for the example are:

1. If I_1 is L and I_2 is NE Then O_0 is VS
2. If I_1 is L and I_2 is F Then O_0 is S
3. If I_1 is L and I_2 is S Then O_0 is M
4. If I_1 is M and I_2 is NE Then O_0 is S
5. If I_1 is M and I_2 is F Then O_0 is M
6. If I_1 is M and I_2 is S Then O_0 is S
7. If I_1 is H and I_2 is NE Then O_0 is VS
8. If I_1 is H and I_2 is F Then O_0 is S
9. If I_1 is H and I_2 is S Then O_0 is M

The method used for *defuzzification* is *center of maximum.*

In order to make the fuzzy system more accessible a graphic interface was developed. It allows easy finding of the outputs using numerical values provided by the user for the two inputs. The interface also allows viewing of the membership functions and system functioning based on rules proposed in Matlab toolbox.

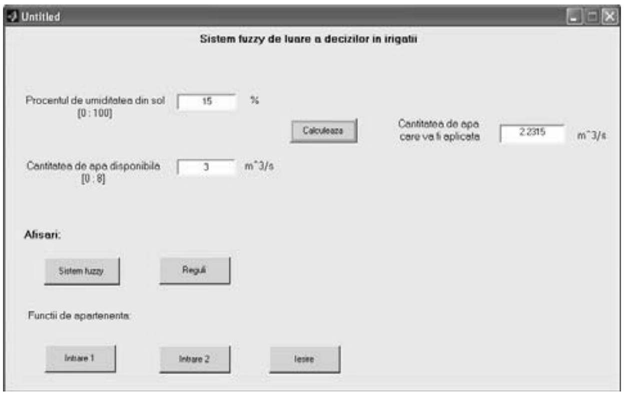

Figure 5. The interface for fuzzy system.

In order to benefit from the capacity of data integration of neural networks a hybrid neurofuzzy system it's being used:

- The input layer of the neural network it's making the fuzzification
- The hidden layers of the neural network functions according to fuzzy rules
- The output layer it's making the defuzzification.

The network performs the ratings and aggregation in a qualitative manner.

The inputs of the model are the presented performance indicators. Each performance indicator will be represented by a linguistic variable described through different linguistic terms $A_{ki}^{l_1}$, $A_k^{l_2}$ and $A_0^{l_3}$. Each float value of indicators Y_{ki} and Y_0 will be represented by membership values $V_{ki}^{l_1}$, $V_k^{l_2}$ and $V_0^{l_3}$.

The training is performed on the principals of backpropagation and competitive learning. The trainings sets are composed of the inputs and corresponding outputs. The inputs are obtained through the simulation of the fuzzy system presented.

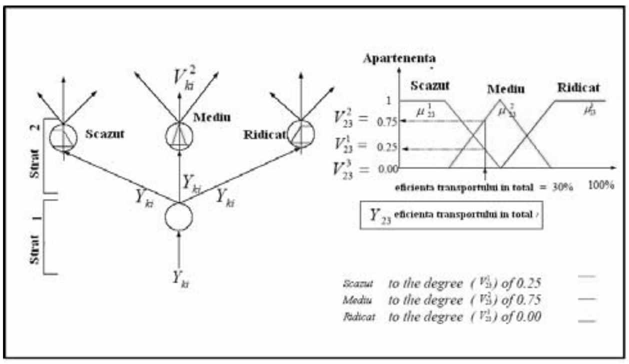

Figure 6. The neurofuzzy system.

The inner layers are forming the sets of economical, technical, social and environmental rules. As we can see in the fig 6 a neuron has a number of inputs *I,* and each input has a weight *w.* The input set for each neuron can be represented as a set $\left(I_1, I_2, \ldots I_n, w_1, w_2, \ldots w_n\right)$, where *n* is the number of inputs for the neuron. Each node is responsible for an output *O.* The process of transformation of inputs into outputs it's described by two functions:

$$Int = \sum_{i=1}^{n} w_i I_i \tag{7}$$

$$Act = \frac{1}{1 + e^{-Int}} \tag{8}$$

Where ***Int*** is the standard form of integration or propagation function a weighted sym for the inputs, and ***Act*** is the standard form of the activation function that computes the output of the neuron.

The neuron on the superior layer it's responsible for defuzzification of membership values which came from the last hidden layer. There are five hidden layers. The float value obtained from the output layer represents the value of the current solution.

Conclusions

In spite of the fact that, in the present, the authorities involved in water distribution in some areas don't use fuzzy logic in irrigation management systems the proven efficiency of these types model of rational decision makes them a suitable option for the future. In the meantime, the environmental problems and the rising of the social conscience on protecting the nature along with recent dramatic changes in global weather will lead to a more careful and intelligent use of water resources.

The advantages of using this technology are easier planning by reducing work time for the decision maker and reducing water waste.

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