Expert System for Simulating the Behaviour of the Cybernetic Offenders

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***Abstract* - The importance of the security aspects in computer networks is increased with the extension of electronic data processing and the transmission through internet. People who lead the digital war, encroaching on the security of the information transmitted via networks take very small risks to be caught, and the risk to be judged or even sentenced is almost null. Conventional means do not offer an appropriate protection against internet dangers. A complete of techniques can at least decrease the negative effect of this danger, if not eradicate it. The purpose of this paper is to create assistance systems for simulating the behaviour of the cybernetic offender using artificial intelligence techniques, rules based on knowledge and genetic algorithms.**

I. INTRODUCTION

The behaviour of the cybernetic offender is the result of the simultaneous action of several features and behaviours of the individual. We can also choose as system entries the following characteristics: professional training, social category, and motivation. In the professional training we will take into consideration both the level of education acquired during each education phase, and the level of IT training acquired at the work place. The inputs has to be extended with the evidences attesting and confirming the existence of a cybernetic offence, concretized at the place of the offence, traces found and the witnesses who were present at that place.

II. RELATED WORKS

A. Studies for simulating the behaviour of the cybernetic offender

The profile of the cybernetic offender can be divided into two models: inductive and deductive. The inductive profile is based on the generalization of behavioural models from a statistic analysis of data collected from sentenced offenders. It is based on the inductive logic and argues from general to specific. Zimmerman affirms that all the characteristics predict personality and behaviour features of the offenders in specific cases [1]. Turvey shows that the deductive profile is not based on generalizations to sample groups [2].

Inductive models were the most frequent profiling methods. The studies of [1] and [3] showed that organized offenders are characterized as having an intelligence above the average, are social competent, live with a partner and prefer qualified jobs. Unorganized offender usually has an average intelligence, is socially unadapted, lives alone, prefers unqualified jobs, lives or works in the nearby of the crime scene.

Canter and Youngs developed in 2009 the investigation psychology, using an inductive approach. The investigation psychology is a dynamic methodology in so far as the database of the crime author's characteristics is continuously updated.

Unlike the two first described methods based on inductive logic, in the third model the analysis of behavioural evidences is based on deductive logic. The last is not based on generalization and statistical analysis using the offender databases.

III. THE EXPERT SYSTEM MODEL

Expert systems are programming systems based on artificial intelligence which stores the knowledge of human experts in a well-defined domain and using them to solve problems in this area. Their role is the guidance of the reasons.

The usefulness of the model for the proposed expert system consists in completing the database of persons who perpetrated cybernetic frauds (features) about offenders and determining the potential degree of perpetrating a cybernetic crime. The level to which a person in the database is considered as potential author of a crime can be assessed.

The architecture of the expert system used for the simulation of the cybernetic offender's behaviour is described in Figure 1.

Figure 1. Architecture of the expert system for simulating the cybernetic offender's behaviour

In order to build the expert system model, a database with persons who committed cybernetic frauds as well as with their characteristics is considered. Its structure is presented in Table I.

TABLE I. STRUCTURE OF THE DATABASE FOR THE EXPERT SYSTEM OF SIMULATION OF THE CYBERNETIC OFFENDER'S BEHAVIOUR

Person	Features	Evidences	Crime

The following parameters need to be specified:

- The operation mode of the cybernetic offender that depends on his/her operation knowledge.
- The association of the name of every person in the considered database is achieved as follows: name "i" is associated the variable x_i.

- Name "i" has a certain degree of membership (H, M, L), where the meaning of each degree is:
  - "H" – certainly is "i"
  - "M" – could be "i"
  - "L" – unlikely "i"
- Both the inputs (features) of the expert system and the evidences have a certain degree of membership, which is:
  - -"H" – certainly is a feature or an evidence for person x_i
  - "M" – could be a feature or an evidence for person x_i
  - "L" – unlikely to be a feature or an evidence for person x_i
  - "Z" – is not a feature or an evidence for person x_i

The form of the inference rules for the proposed system is:

$$IF \ \bigwedge_{i=1}^{n}(x_i \in X_i) \ THEN \ \bigwedge_{j=1}^{m}(y_j \in Y_j) \quad (1)$$

where the degree of membership for the output is H=high; M=medium; L=low; F=false.

In this system we can state the question of linking the persons with certain characteristics, evidences or relations to a group (level "H"), possibly, membership to a group (level "L" or "M")

Applying the inference rules, the database will be extended by additional information about offenders, that can be used to obtain a list of the possible offenders in perpetrating a certain type of cybernetic crime.

An example of the above presented method is used to solve the case when the characteristics refer to the offence case:

The offence occurred in town "B":

Using the form of inference rules, one can assert about the person x_i the following:

(x_i was in town "B") ∈ Z – certainly was not in town "B"
(x_i was in town "B") ∈ H - certainly was in town "B"
(x_i was in town "B") ∈ M – could be in town "B"
(x_i was in town "B") ∈ L – unlikely to have been in town "B"

For each person x_i in the database of people with cybernetic criminal record each characteristic mentioned in the database can be analysed using the fuzzy logic technique. Associating more conditions in the inference rules, depending on the membership degree resulted for each set of conditions in the rule, the degree of membership of the committed crime (specified in the considered database) can be obtained.

IV. EXPERT SYSTEM MODEL WITH FUZZY RULES

Zimmermann says that the use of fuzzy logic leads to finding answers and allows the obtaining of conclusions based on vague, ambiguous, inexact information [4]. The studies of [5], [6] and [7] showed that neuro-fuzzy expert systems become useful and effective not only for solving very complex problems, but for simpler management (decision making) problems which include a high level of uncertainty. The choice of fuzzy expert systems is explained by the fact that they have a hardly deductive model, the inputs and parameters values are vague, imprecise and/or incomplete.

In achive this expert system with fuzzy rules the database with the structure described in figure 1 is used, having the purpose to identify the people who could lend themselves to committing crimes, such as, for example: breaking passwords, deciphering secret messages, hiding identity.

The purpose of this model is:

1. Filling in a database with additional data concerning the level of perpetration of a crime, resulted from the degree of membership of the output variable (the offence) from the applied fuzzy rule, for other unsolved cases.
2. Generating a list with the possible offenders for a given case using information about people existing in the studied database.

The architecture of the model based expert systems described in Figure 2 is composed of:

- Facts = inputs of the expert system
- Offenders' list = outputs of the expert system
- Features in the database processed using fuzzy rules

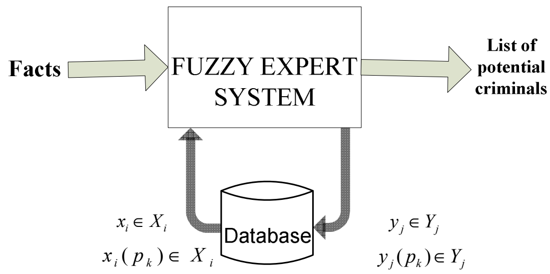

Figure 2. Architecture of the fuzzy expert system for simulating the cybernetic offender's behaviour

The truth levels are:

H= high
M= medium
L= low
Z=has not this feature - zero

A first example is the following: marking with p_k a person in the database, with x_i the feature "computer science training", we can state about this person:

Person p_k has computer science training and it is denoted by:

$x_i \in X_i$ where the domain of X_i is {H, M, L, Z} and has significance:

$x_i(p_k) \in H$ means the person p_k has a very good knowledge in computer science

$x_i(p_k) \in M$ means the person p_k has an average knowledge in computer science

$x_i(p_k) \in L$ means the person p_k has a very low knowledge in computer science

$x_i(p_k) \in Z$ means the person p_k has a no knowledge in computer science.

The computer science education x_i can be quantified and expressed in IT training years in the field of the database concerning to the feature regarding the training in computer science. For the x_i feature "training in IT" the fuzzy rules are:

IF x_i < 1an THEN Z (zero training)
IF 1 year < x_i < 3 years THEN L (low training)
IF 2 years < x_i < 4 years THEN M (average training)
IF x_i > 4 years THEN H (high training)

The fuzzy algorithm for the proposed expert system uses a model based on a set of fuzzy rules. The input X and the output Y vectors are defined as follows:

- $X=[x_1, x_2, \ldots, x_n]$ represents the maximum number of behavioural features, evidences or input facts
- $Y=[y_1, y_2, \ldots, y_m]$ represents the maximum number of features committed crimes

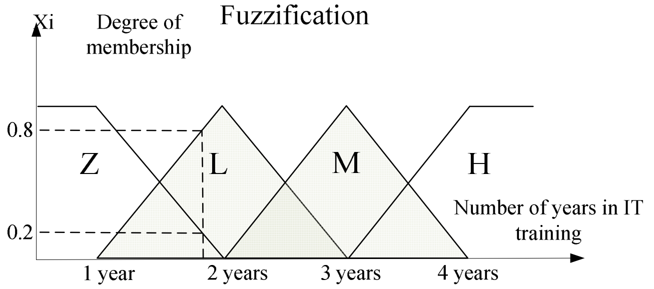

Figure 3. Membership function of corresponding to the input linguistic variables.

Using the membership shown in Figure 3, the vectors X and Y are converted into vectors of linguistic variables through X and Y. Fuzificated variables are expressed in the {Z, L, M, H}. The previous example about the feature "training in computer science" in the fuzzification process, if the feature encoded by the variable x_1 is less than 1 year then it has the logic value Z. If x_1 is a value between 1 year and 3 years then it belongs to L in a degree of membership d_1, to M in a degree of membership d'_1, and to H with a degree of membership 0.

Each variable x_i (i=1, 2,…,n) of the input vector X has its own function of membership. The maximum degree of membership of a variable is 1. The output vector $Y=[y_1, y_2, \ldots, y_m]$ has elements that are expressed in the fuzzy set {Z, L, M, H}.

The form of the inference rules of the expert system with fuzzy rules model is:

$$IF \ \bigwedge_{i=1}^{n}(x_i \in X_i) \ THEN \ \bigvee_{j=1}^{m}(y_j \in Y_j) \tag{2}$$

The extended form of inference rules is:

$$IF\ (x_1 \in X_1)\ AND\ (x_2 \in X_2)\ AND\ \ldots.\ (x_n \in X_n)$$
$$THEN\ (y_1 \in Y_1);\ (y_2 \in Y_2);\ldots;\ (y_m \in Y_m) \tag{3}$$

where X_i, Y_i, C_i belong to the set {Z, H, M, L}; i=1, 2, …

The real values are obtained when are known the membership functions by defuzzification. In the case of a fuzzy expert system for modelling the behaviour of offender information, the defuzzification determines traits or offenses committed by the person p_k in the database and used in the model.

It evaluates each rule and its weight is calculated by performing the logical product of the conditions. Rule weight for a given set of data ($x_1, x_2, \ldots, x_n$) is calculated as the minimum degreee of membership of the terms involved in the logical product of the conditional expression IF-THEN.

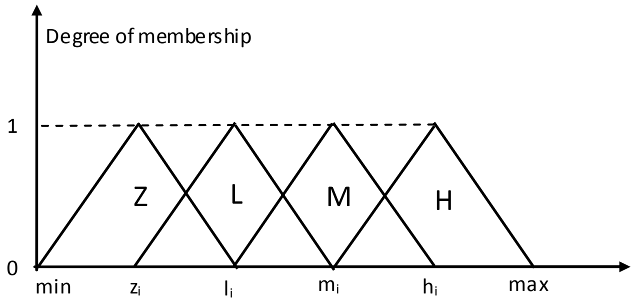

Figure 4. Membership function of corresponding to the defuzzification process.

Figure 4 describes de defuzzification where the logical value y_i must be transformed into feature or offence perpetrated corresponding to the person named "i" from the database used as a model. The membership domains of variables Z, L, M and H are isosceles triangles. The real value calculated in the defuzzification process can be obtained using the centroid method, based on the formula:

$$g_i = \frac{\sum_{j=1}^{m} y_i \cdot \mu(y_i)}{\sum_{j=1}^{m} \mu(y_i)} \tag{4}$$

where $\mu(y_i)$ is the weight of the rule which gives the degree of membership to the logical value y_i.

V. PROPOSED SOLUTION

Given:
- The form of the rules
- A database with resolved cases with the structure presented in Table II.

TABLE II.
STRUCTURE OF THE DATABASE USED IN ESTABLISHING THE SET OF FUZZY RULES

Person	Group	Relevant features						Facts	Offences
		Feat.1	Feat.2	Feat.3	Feat.4	Feat.5	Feat.6		

The following issues appear to be solved:
1. The obtaining the set of fuzzy rules
2. The obtaining the membership function parameters.

In order to increase the performances of the system that simulates the cybernetic offender's features, the two issues can be solved using genetic algorithms. Tomassini said that algorithms are parallel structures achieving a global search technique, which try to copy the behaviour of the natural genetic operators [8]. They explore different points in the parameters' space, and direct the search in the regions where the probability of increasing performances is higher.

A. Obtaining the set of fuzzy rules using genetic algorithms

In order to describe the genetic algorithm used in the set of the fuzzy rules, the chromosome has to be defined. Using the data in the database with solved cases, fuzzy rules can be written obeying the general formula:

$$r_k : IF \ \overset{n}{\underset{i=1}{\wedge}} (x_i \in X_i) \ THEN \ \overset{m}{\underset{j=1}{\vee}} (y_j \in Y_j) \qquad (5)$$

where $r_k \in \{Z, L, M, H\}$.

It is used the database containing data as shown in Table II. Data from database shall be completed such a way as to maximize the index of performance.

For the case when we chose as input variable two features, each of them having the degree of membership in the range {Z, L, M, H}, the chromosome has the structure presented in Table III:

TABLE III. CHROMOSOME STRUCTURE TO DEFINE THE SET OF FUZZY RULES

r_1				r_2				…	r_k			
$v_{1,1}$	$v_{1,2}$	…	$v_{1,16}$	$v_{2,1}$	$v_{2,2}$	…	$v_{2,16}$		$v_{k,1}$	$v_{k,2}$	…	$v_{k,16}$

Marking with:

v_1 = the output value given by the fuzzy expert system for inputs (x_1, x_2)

w_1= the existing output value in the database

Using the data of "n" persons existing in the studied populated database, we build a new database having the structure presented in Table IV, The goal is to fill in the degree of membership for each of the two considered x_1 and x_2, as well as the degree of membership for the existing output in the populated database w_1. The field v_1 will be filled in only after the calculation of the output value given by the fuzzy expert system, respectively the filling in the obtained membership degree.

TABLE IV.
DATABASE FOR COMPARISON PURPOSES OF THE GIVEN-CALCULATED MEMBERSHIP DEGREE

person	x_1	x_2	v_1	w_1
1	L	H	Z	M
2	M	L	L	H
⋮	⋮	⋮	⋮	⋮
N				

We compare the values of the fields „v_1" and „w_1". If the system works perfectly, then for each „i", person where i=1,2,…,n the existing output value in database is equal to the value of calculated exit:

$$w_1(i)=v_1(i) \qquad (6)$$

Since this does not occur in reality, we must define a performance coefficient, in order to evaluate the "target" values $w_1(i)$. Conventionally, the distance from the value of $w_1(i)$ is evaluated by Z=0; L=1; M=2; H=3.

We appreciate that the rule r_1 is correct if it achieves the minimum of the expression:

$$J_1 = \min_{v_{1,1};\ldots;v_{1,16}} \sum_{i=1}^{n} \left(v_{1,i} - w_{1,i}\right)^2 \qquad (7)$$

Formula (7) represents the expression of the fitness function. Generally, such a performance coefficient is defined by all the rules corresponding to the considered database.

B. Obtaining the membership function parameters using genetic algorithms

In order to define the membership function parameters using genetic algorithms, we consider the following example:

For a given person k from database we know two input variables:

- x_1 = training in IT (including the number of years of professional training and the number of years worked for a company with computer activities)
- x_2 = criminal record (including both the existence of criminal record both the possible infringements of the law concerning the perpetration of computer offences)

The problem proposed to be solve is to find the values for a1, a2, a3, a4 in Figure 5, considering that we know the values of maximum and minimum of the membership function.

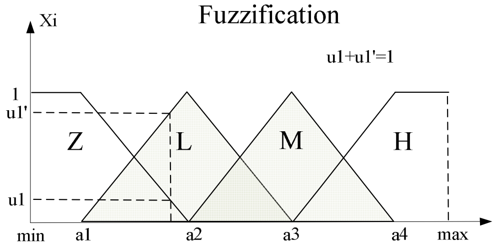

Figure 5. Membership function of the input variables

The chromosome with its parameters: v_i, x_1, x_2 and y_i is presented in the Table V:

TABLE V. CHROMOSOME STRUCTURE FOR DEFINING THE PARAMETERS OF THE MEMBERSHIP FUNCTIONS

v_i				x_1				x_2				y_i			
$v_{i,1}$	$v_{i,2}$	…	$v_{i,16}$	$a_{1,1}$	$a_{1,2}$	…	$a_{1,16}$	$a_{2,1}$	$a_{2,2}$	…	$a_{2,16}$	$b_{i,1}$	$b_{i,2}$	…	$b_{i,16}$

The chromosome factors being binary coded, we can use simple genetic operators [9]. There are used the following operators:

- *Mutation operator:* a gene of the chromosome is randomly selected. Then a random value is assigned in the domain specified using a selected factor.
- *Crossover operator:* two chromosomes are selected from the population. A random cross point is selected and two new chromosomes are built.

In order to select individuals, we use the fitness function.

<u>*Genetic algorithm*</u>

Initialization: n is the chromosome's length presented in Table V

Builds an initial P population of 60 individuals

Evaluates the P population

DO

Reproduction

Selects 20 chromosomes with the lowest J values

Mutation

Selects randomly 20 chromosomes from P for the mutation
Selects 20 chromosomes from P with the highest J value
Builds a new population with the chromosomes selected in the previous steps
Evaluates the P population. The result of the evaluation is the J value
***WHILE** the number of iteration = 60*

Using the genetic algorithm the values b1, b2, b3 and b4 of the output variables are calculated. The output y_i can be an offence or a feature (characteristic) of the cybernet offender. Figure 6 presentes the defuzzification function for the considered example.

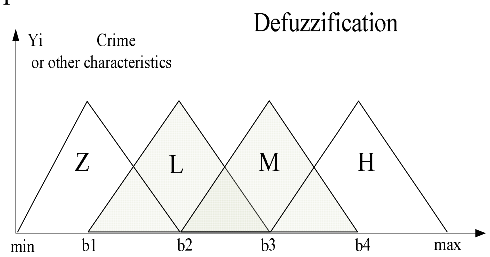

Figure 6. Membership function of the output variables

VI. TESTS, EXPERIMENTS AND ANALYSIS RESULTS

The goal right after the construction of the expert system with fuzzy rules for the modelling of the behaviour of the cybernetic offender is the situation of his/her behaviour in case when two or more rules are simultaneously activated. Considering the example where for constructing the rules use the features

x_1= "age" and x_2= "IT training"

and as system output:

y_1= the crime "bank fraud"

or

the feature "training in copying bank cards"

Fuzzy rules for these two inputs (features) and an output (offence) are: IF ($x_1 \in X_1$) and ($x_2 \in X_2$) THEN ($y_1 \in Y_1$)

The rules for the two features considered for the study of the behaviour of the system are:

r_1: IF (IT Training is Zero) and (Age is Zero) THEN (y_1 is Zero)
r_2: IF (IT Training is Zero) and (Age is Low) THEN (y_1 is Zero)
r_3: IF (IT Training is Zero) and (Age is Average) THEN (y_1 is Zero)
r_4: IF (IT Training is Zero) and (Age is High) THEN (y_1 is Zero)
r_5: IF (IT Training is Low) and (Age is Zero) THEN (y_1 is Low)
r_6: IF (IT Training is Low) and (Age is Low) THEN (y_1 is High)
r_7: IF (IT Training is Low) and (Age is Average) THEN (y_1 is Average)
r_8: IF (IT Training is Low) and (Age is High) THEN (y_1 is Low)
r_9: IF (IT Training is Average) and (Age is Zero) THEN (y_1 is Average)
r_{10}:IF (IT Training is Average) and (Age is Low) THEN (y_1 is High)
r_{11}:IF (IT Training is Average) and (Age is Average) THEN (y_1 is High)
r_{12}:IF (IT Training is Average) and (Age is High) THEN (y_1 is Low)
r_{13}:IF (IT Training is High) and (Age is Zero) THEN (y_1 is High)
r_{14}:IF (IT Training is High) and (Age is Low) THEN (y_1 is High)
r_{15}:IF (IT Training is High) and (Age is Average) THEN (y_1 is Average)
r_{16}:IF (IT Training is High) and (Age is High) THEN (y_1 is Low)

In order to test the rules, the MATLAB environment was used. The values of the membership degree of the output variable function of the two inputs are represented in Table VI, the values' range being {Z, L, M, H}.

TABLE VI. THE VALUES OF THE MEMBERSHIP DEGREES OF THE OUTPUT VARIABLE

Y_1 (Offence or other feature)		**X_1 (Age)**			
		Z	**L**	**M**	**H**
X_2 (IT training)	**Z**	Z	Z	Z	Z
	L	L	H	M	L
	M	M	H	H	L
	H	H	H	M	L

The obtained experimental results are described in Table VII.

TABLE VII.
THE RESULT OF SIMULTANEOUS IMPLEMENTING OF 12 RULES FOR 2 INPUTS

IT Training (years)	**Age (years)**	**Y_1 (%)**	**IT Training (years)**	**Age (years)**	**Y_1 (%)**	**IT Training (years)**	**Age (years)**	**Y_1 (%)**	**IT Training (years)**	**Age (years)**	**Y_1 (%)**
0.5	15	10	1.2	15	30	2.0	15	45	3.0	15	70
0.5	19	10	1.2	20	85	2.0	20	85	3.0	20	85
0.6	15	10	1.2	25	85	2.1	25	85	3.1	25	85
0.6	19	10	1.3	30	85	2.1	30	85	3.1	30	85
0.7	15	10	1.3	35	85	2.2	35	85	3.2	35	85
0.8	15	10	1.3	40	55	2.2	40	70	3.2	40	70
0.9	15	10	1.4	50	55	2.3	50	70	3.3	50	69
0.9	20	10	1.4	60	30	2.3	60	30	3.3	60	30
0.9	30	10	1.4	70	30	2.4	70	30	3.4	70	30
1.0	15	28	1.5	15	30	2.5	15	55	3.5	15	85
1.0	20	85	1.5	20	85	2.5	20	85	3.5	20	85
1.0	25	85	1.6	25	85	2.6	25	85	3.6	25	85
1.0	30	85	1.6	30	85	2.6	30	85	3.7	30	85
1.0	35	85	1.7	35	85	2.7	35	85	3.7	35	85
1.1	40	55	1.7	40	55	2.7	40	85	3.8	40	55
1.1	50	55	1.8	50	55	2.8	50	85	3.8	50	55
1.1	60	30	1.8	60	30	2.8	60	30	3.9	60	30
1.1	70	30	1.9	70	30	2.9	70	30	4.0	70	30

In the case of classification, the membership function has a private form shown in figure 7.

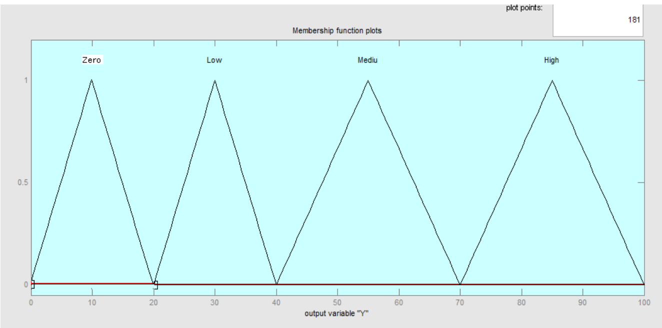

Figure 7. The membership function obtained for the output variable y_1 applying 12 fuzzy rules for 2 inputs

VII. CONCLUSIONS

The study presents a model of the expert system with fuzzy rules to be used for simulation the cybernetic offender's behaviour.

The behaviour model described in this paper offers a mathematical representation of multidimensional interdependence between the variables which define or reflect the offender's behaviour and the perpetrated cybernetic fraud. Using training structural algorithms allow to identify the most significant variables and to calculate how sensitive the linked-up variables are to each other.

This paper presents an approach of the network models of the criminal behaviour which is backed on systems based on knowledge as well as on the domains of criminology and psycho-criminology.

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