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Crisis Management and Political Decision Making Using Genetically Evolved Fuzzy Cognitive Maps

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Abstract

This paper examines the use of Fuzzy Cognitive Maps (FCMs) as a technique for modeling political and crisis situations and supporting the decision-making process. FCMs use notions borrowed from artificial intelligence and neural networks to combine concepts and causal relationships, in the form of dynamic models that describe a given political setting. The present work proposes the use of the Genetically Evolved Certainty Neuron Fuzzy Cognitive Map (GECNFCM) as an extension of Certainty Neuron Fuzzy Cognitive Maps (CNFCMs) aiming at overcoming the main weaknesses of the latter, namely the recalculation of the weights corresponding to each concept every time a new strategy is adopted. This novel technique combines CNFCMs with Genetic Algorithms (GAs), the advantage of which lies with their ability to offer the optimal solution without a problem-solving strategy, once the requirements are defined. We demonstrate the value of such a hybrid technique in the context of a model reflecting the complexity of the Cyprus problem. The scenario analysis performed makes decision makers aware of political uncertainties, while multiple scenario analysis brings uncertainty into the decision process by combining it with different future states.

Keywords: Fuzzy Cognitive Maps, Hybrid Modeling, Genetic Algorithms, Decision-Making.

1. Introduction

Decision-making and crisis management in a multiple uncertainty environment are important elements in international relations theory [12]. Decision makers and policy proponents face serious difficulties when approaching significant, real-world systems in such an environment, given that they are usually composed of a number of dynamic concept actors, interrelated in complex ways. Moreover, feedback propagates casual influences in complicated chains, while numerical data may be hard to come by or uncertain. Thus, formulating a mathematical model may be difficult, costly, and even impossible, meaning that efforts to communicate an understanding of the system and propose policies must rely on natural language arguments in the absence of formal models.

During the decade of the seventies, Axelrod described the cognitive maps using directed, inter connected, bilevel valued graphs, and applied them in politico economic decision theory and policy [27]. In 1986, Kosko extended the graphs of Axelrod to the fuzzy mode thus creating FCMs [9] which were originally proposed as a means of explaining political decision-making processes.

Carson and Fuller [10] include a number of reports that describe implementations of FCMs to model specific environments like decision-making and policymaking. Levi and Tetlock [5] offer a simple example of FCM, while a second interesting reference is Henry Kinsinger’ s essay on the Middle east peace [8].

An FCM of a domain, once constructed, allows for qualitative simulation exercises in the context of scenario analysis. This means that policy proponents can use a model of the system under consideration and suggest solutions to policy issues based on simulations in an environment of explicit arguments and assumptions free of ornamental rhetoric.

A novel approach is the use of FCMs as a computationally inexpensive way to "program" the actors in a virtual world. Thus, simulations involving human actors might combine FCMs with expert systems in order to model the combination of the soft, emotional aspect of human decision making to its formal, logical side. To do so, one or more domain experts identify the concepts and their causal relationships by talking about them, since the use of a linguistic label is very useful in fuzzy logic and has direct translation to FCM. The "degree of causality" values in the connecting edges indicate how much one concept causes another. These values can range from –1, indicating a strong negative impact, through 0, or no impact, to +1, a strong positive impact.

The combination of Fuzzy Logic and Neural Networks [9], which have been developed in the world of soft computing [23], creates models that emulate reasoning and the decision-making process using fuzzy causal relationships [27,7]. The flexibility of such models is improved by allowing for a variety of activation levels of each concept thus creating Certainty Neuron Fuzzy Cognitive Maps (CNFCM) that have developed to a reliable technique used in strategy selection and evaluation of possibe solutions in view of intricate political problems [1].

Promising as they may appear, the CNFCMs have two weak points: The first involves the invariability of the weights, which leaves only the activation levels to participate in the configuration of a political problem. The second lies with the inability of the method to model a certain political situation by performing all possible computational simulations following the change of a certain weight or group of weights. This paper aims at solving these problems by combining CNFCMs with Genetic Algorithms (GAs). The CNFCM part of the algorithm computes the final activation levels given the weights and relationships between concepts, while the GA part develops the weight matrix attempting to find the optimal set of weights that satisfy a predefined activation level for a specific concept. A hybrid model of this type, therefore, traces the degree of the causal relationships between the various concepts such that it can "force" them to be activated to a certain level. Such hybrid models are expected to contribute to the effectiveness of decision-making by defining for each concept the activation level achieved with a certain set of weights evolved by the GA.

The hybrid model thus created will be tested to reflect a rather demanding and complicated issue, i.e. the Cyprus problem. The CNFCM model depicting the current political situation in Cyprus makes use of the input provided by a number of field experts, in order to identify the various concepts featuring in the Cyprus issue and trace the causal relationships among them. Next, we allow our model to "run" until it stabilizes at a certain equilibrium state, the validity of which is assessed by comparison to the actual facts. Once the validity and functionality of the model are secured, a scenario-based analysis is used to reach conclusions that can assist the decision making process. This analysis involves the following phases:

i. The static analysis phase, which uses graph theory techniques to identify the vicious or the virtuous cycles through the feedback channels that exist in the model.
ii. The dynamic analysis phase, which uses a number of scenarios aiming at simulating the impact of the political decisions introduced in these scenarios.
iii. The genetically evolved analysis phase: The first step of this analysis involves calculating the activation levels by the CNFCM model at equilibrium using the initial weight matrix defined by the group of experts. The next step is to simulate different scenarios by asking the model to reach a target activation level for a certain concept. The GECNFCM model calculates the new optimal weight matrix,

which is then used by the CNFCM model to recalculate the new activation levels of the participating concepts. The recalculation of all weights involved in the simulation process constitutes the most important difference between the GECNFCM and the simple CNFCM models. Its importance to decision-makers focuses on the fact that they will not base their decision on just the experts' evaluation, but, in addition, on the optimal weights that lead a concept to be activated to a certain predefined degree. Thus, decision-makers are able to introduce hypothetical cases reflected through a target activation level for a certain concept and evaluate the corresponding weights and activation levels for the rest of the concepts that are thus compatible with the predetermined target activation level. Based on this information, the policy maker is therefore able to take decisions leading to the desired simulated solution.

The rest of the paper is organized as follows: Section 2 provides the theoretical background on which the model is based, while section 3 briefly describes the formulation and development of a FCM. Section 4 presents the CNFCM for the Cyprus issue, as well as the static and dynamic analysis of the model through different scenaria. Section 5 introduces the theory of evolutionary computing and Genetic Algorithms describing the development of a GECNFCM hybrid model for the Cyprus issue. Section 5 discusses the experimental results of various simulations conducted through multiple scenario analysis, while the validity of the proposed GECNFCM model is analyzed and discussed in section 6. Finally our conclusions and suggestions for further research on the topic are presented in section 7.

2. Background Theory

2.1 Expert systems and soft computing

The most decisive contribution of decision theory in the area of Artificial Intelligence (AI) can be traced in the case of diagnostic experts systems. This is largely due to the fact that expert systems are often concerned with inference and decision-making under uncertainty. Decision theory provides a certain approach to analytic tasks, particularly to those involving inference and decision-making under uncertainty. As far as an expert system is concerned, this is a computer program that performs a complex decision-making task within a particular narrow problem domain that is normally done by a human expert. The expert system can be easily adapted to scenario analysis [24,14] and gives different future states through the simulation process. This process can serve as a background for evaluation and selection of strategies, exploring the future and identifying possible outcomes as well as making decision-makers aware of political uncertainties. An important feature of a modern decision support system is its ability to handle the experts' knowledge in an environment, characterized by many uncertainty parameters [26].

Soft computing [23] encompasses a range of techniques, namely fuzzy logic, neural network theory, genetic algorithms and probabilistic reasoning [15], generally grouped together to give solutions to specific problems or groups of problems. The technical aspects of the present work are based solely on soft-computing tools, given that soft computing is proposed as a technology in the area of AI, providing the means to contain the information explosion in a manageable level of humans.

2.2 Neural network models

Social scientists find Neural Networks (NNs) attractive [19] because of their relevance to commonly encountered types of problems. Neural Networks can be used for classification problems that involve mapping a large number of inputs onto small number of output classes. They are logically inspired and contain a large number of simple processing elements that perform in a manner analogous to the most elementary functions of neurons. Neural networks learn by experience, generalize from previous experiences to new ones, and can make decisions

A neural network is a parallel distributed processing system [20] composed of processing entities called neurons, the connections strengths between which are weights adjusted to store experiential knowledge and make it available for later use in prediction and classification. NN software is based [20] on multiple neurons also called processing entities or nodes or cells, which pass data to one another, adjusting values according to the logic assigned to each one of them. These emulate the massive parallelism of the human brain on a much smaller scale, while the path from each neuron is assigned a weight value. [19]

Weights determine the relative strength of the connection from an input neuron to the neuron under consideration. Weights are initialized to random values at the outset of the neural network training process, but become meaningful as learning progresses. Essentially weights are ordinarily variable values, which are adjusted during the neural network training process as part of learning. Weighted inputs must be aggregated by the neuron through a summation function, also called a combination function, or adder, which computes the net input. That is, for target neuron k equation (1) is simply the inner product of the input vector of neuron k with its corresponding weight vector, while equation (2) calculates the output of the neuron using a certain nonlinear activation function.

$$s_k = \sum_{j=1}^{n} w_{kj} x_j \qquad (1)$$

$$y_k = \varphi(s_k - \theta_k) \qquad (2)$$

where ,

x_j is the input vector of neuron k signals, n is the number of inputs, w_{kj} are the weights connecting neurons j with k, S_k is the linear output, θ_k is an activation threshold, $\varphi()$ is a nonlinear activation function and y_k is the output of the neuron.

Figure 1 presents the mathematical concept of a nonlinear artificial neuron.

2.3 Fuzzy logic

Zadeh introduced fuzzy Logic in 1965 [21] as a means of representing data and manipulating data that was not precise, but rather fuzzy. The theory of fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive processes, such as thinking and reasoning.

The development of fuzzy logic was motivated in large measure by the need for a conceptual framework that can address the issue of uncertainty. Some of the essential characteristics of fuzzy logic relate to the following [22]:

- Exact reasoning is viewed as a limiting case of approximate reasoning.
- Everything is a matter of degree.
- Knowledge is interpreted as a collection of elastic, equivalent fuzzy constraints on a collection of variables.
- Inference is viewed as a process of propagation of elastic constraints.

- Any logical system can be fuzzified.

There are two main characteristics of fuzzy systems that assist in achieving better performance for specific applications:

- Fuzzy systems are suitable for uncertain or approximate reasoning, especially for systems with a mathematical model that is difficult to drive.
- Fuzzy logic allows decision making based on estimates under incomplete or uncertain information.

Since its first appearance fuzzy logic has been used in a variety of applications, such as image detection of edges, signal estimation, classification and clustering [21]. A fuzzy logic technique represents an alternative solution to the design of intelligent engineering systems. Thus, fuzzy rule-based experts systems are widely used in practice nowadays, this being supported by the fact that fuzzy logic is linguistic, rather than numerical, something which makes it similar to human thinking and hence simpler to understand and put in practice.

2.4 Fuzzy neural systems.

During the past few years, there has been a large and energetic upswing in research efforts aiming at synthesizing fuzzy logic with neural networks [28]. This combination of neural networks and fuzzy logic seems natural because the two approaches generally view the design of "intelligent'' systems from different angles. Neural networks provide algorithms for learning, classification, and optimization, whereas fuzzy logic deals with issues such as reasoning on a higher (semantic or linguistic) level. Consequently, the two technologies complement each other. By integrating neural networks with fuzzy logic, it is possible to bring the low-level computational power and learning of neural networks into fuzzy logic systems.

The combination of neural networks with fuzzy logic takes place by means of a hybrid system wherein some processing stages are implemented with neural networks and some with a fuzzy inference system [28]. An example of such a system would be a tree classifier in which classification at some node can be carried out with a fuzzy inference system and classification at some node could be performed using a neural network. The main advantages of a hybrid system is that where classification is based on expert rules one can use a fuzzy inference system, and where classification is based on training samples one can use a neural network.

Kosko suggested a Fuzzy Cognitive Map model as a technique to overcome some limitations of representing knowledge as a search tree [9]. In general, we cannot combine two or more trees to produce a new tree, while the problem increases with the number of trees combined. This limits the number of knowledge sources or experts who can build the search tree. Nevertheless, a larger expert sample size should produce a more reliable knowledge structure. Instead of abandoning FCM as a graph search we view it as a dynamical system and take its equilibrium behavior as a forward-evolved inference.

3. Fuzzy Cognitive Maps

A Cognitive Map (CM) is a technique based on qualitative reasoning and can be used to cope with knowledge that generally involves many interacting concepts. CM models were introduced by Axelrod [27] in the late 1970's and were mainly used to support political decisions in international relations. Generally, the basic elements of a CM are simple: The concepts used by an individual decision-maker are represented as nodes, and the causal relationships between these concepts are represented as directed arrows. Each arrow is characterized by a weight, a real value that indicates the effect of the causal relationship between nodes. This representation gives a figure of nodes and arrows called a cognitive map in which the various concepts are considered as variables of the system. The advantage of this representation is that it offers a global view of the various links between causal relationships and concepts in the model. Three different types of causal relationships between two nodes *p* and *q* ($p \rightarrow q$) are represented in the map indicating the effects as follows:

- Positive (+) causality, in cases in which *p* promotes, enhances, or is a benefit to *q*, etc. An increase in the cause variable will bring about an increase in the effect variable; a decrease in the cause concept will result to a decrease in the effect concept.
- Negative (-) causality, in cases in which *p* retards, prevents, or is harmful to *q*, etc. In such cases an increase in the cause variable will end up with a decrease of the effect variable and vice-versa.
- No effect (0), when *p* has no effect on, or does not matter for *q*, etc.

The introduction of fuzzy logic gave new capabilities to CM's, indicating both the type of representation of the causal relationships between concepts (i.e. positive, negative, zero) and the degree or strength of this relationship.

Fuzzy Cognitive Maps (FCMs) are soft computing tools, which combine elements of fuzzy logic and neural networks. FCM theory was developed recently [7,9] as an extension of cognitive maps used for planning and decision-making in the fields of international relations, social systems modeling and the study of political developments in the context of such systems. Strictly speaking, a FCM is a figure composed of nodes and edges, the former introducing the qualitative concepts of the analysis while the latter indicate the various causal relationships. Each concept node possesses a numeric state, which denotes the qualitative measure of its presence in the conceptual domain. Thus, a high numerical value indicates that the concept is strongly present in the analysis while a negative or zero value indicates that the concept is not currently active or relevant to the conceptual domain.

A FCM works in discrete steps [9]. When a strong positive correlation exists between the current state of a concept and that of another concept in a preceding period, we say that the former positively influences the latter, indicated by a positively weighted arrow directed from the causing to the influenced concept. By contrast, when a strong negative correlation exists, it reveals the existence of a negative causal relationship indicated by an arrow charged with a negative weight. Two conceptual nodes without a direct link are, obviously, independent.

The activation level of each of the nodes of the system and the weighted arrows are set to a specific value based on the experts' beliefs. Thereafter, the system is free to interact. This interaction continues until the model:

- Reaches equilibrium at a fixed point, with the activation levels, being decimals in the interval [-1 1], stabilizing at fixed numerical values.
- Exhibits a limit cycle behavior, with the activation levels falling in a loop of numerical values under a specific time-period.
- Exhibit a chaotic behavior, with the activation level reaching a variety of numerical values in a non-deterministic, random way.

In order to increase the reliability of the weight matrix, Kosko suggests consulting more than one expert [7]. Assuming that the experts are consulted and that their experience has been scored with a value from 1 to 10, let S_i be the score of expert i and W_i the weight matrix of the FCM defined by that expert. The final weight matrix is then given by a normalized sum according to the following formula:

$$W = \frac{\sum_{i=1}^{N} S_i W_i}{\sum_{i=1}^{N} S_j} \tag{3}$$

In 1997, the introduction of Certainty Neuron Fuzzy Cognitive Maps (CNFCMs) [2,4], provided additional fuzzification to FCMs, by allowing for various activation levels of each concept between the two extreme cases, i.e. activation or not. More specifically, a function *f()* coming from the area of expert systems [3] was used to return the new certainty factor of a fact after receiving new evidence for, or against previous believes based on the present certainty factor.

The updating function of a CNFCM is the following:

$$A_i^{t+1} = f\left(S_i^t A_i^t\right) - d_i \ A_i^t \tag{4}$$

where

$$S_i^t = \sum_{\substack{j=1 \\ j \neq i}}^{n} A_j^t w_{ij} , \tag{5}$$

and A_i is the activation level of concept C_i at some time $(t+1)$ or **(t).**

Equation (5) is the sum of the weighted influences that concept C_i receives at time step t from all other concepts, d_i is a decay factor [3], and

$$f\,m(A_i^t,S_i^t)=\begin{cases}A_i^t+S_i^t(1-A_i^t)=A_i^t+S_i^t-S_i^tA_i^t, if\ A_i^t\geq 0, S_i^t\geq 0\\ A_i^t+S_i^t(1+A_i^t)=A_i^t+S_i^t-S_i^tA_i^t, if\ A_i^t<0, S_i^t<0, |A_i^t|, |S_i^t|\leq 1\\ A_i^t+S_i^t \Big/ \left(1-\min\left(\left|A_i^t\right|,\left|S_i^t\right|\right)\right), otherwise\end{cases} \quad (6)$$

is the function used for the aggregation of certainty factors [4]. The meaning of the above function is that the external influence can affect the activation of a concept just to a certain degree. We propose the following modification to the third case of equity in (6) as follows:

$$A_i^t+S_i^t \Big/ (1-\min(A_i^t,S_i^t)), otherwise\ , \quad (7)$$

to cover the undesirable situation in which one of A_i^t and S_i^t equals to 1 and the other to -1 leading the denominator to zero.

Given the structure of a CNFCM as described above, it is easy to see that its ability to combine the input supplied by domain experts, together with its flexibility, makes it a useful tool for analyzing tough political problems and suggesting plausible solutions in an environment of political uncertainty.

4. A model for political decision-making

4.1 The Cyprus issue

Cyprus is the third largest island in the Mediterranean located **at** its extreme - eastern end. The Republic of Cyprus, which has a population of approximately 750,000 (81.9% Greek Cypriots and 18.1% Turkish Cypriots), gained its independence in 1960. Since 1974, when Turkey launched an invasion "to restore constitutional order" following an abortive coup against the President, Archbishop Makarios, 38% of the island still remains occupied by

Turkish forces, which ignore all United Nations resolutions repeatedly expressing their concern on such a major issue. In fact, both in the Security Council and in the General Assembly of the U.N. have been continuously involved in the Cyprus problem since 1964 concerned about the Turkish threat to Cyprus' sovereignty and independence. The U.N. efforts culminated during the recent past with the submission of various versions of the so called Annan Plan which attempted to work out a viable, however extremely fragile solution to the Cyprus problem. The Cyprus Government, in its turn, making use of extensive support from Greece, has invested a great deal in the course of the accession of Cyprus to the European Union, hoping that this will provide the dynamics for the resolution of the Cyprus problem. The Turkish authorities, however, have declared through reports as well as open statements in the press, that their reaction to Cyprus's full EU membership will be "limitless", an expression which is taken to imply, amongst other things, annexing the occupied part of the island to Turkey. It appears that such a reaction may comply with the long-term Turkish plan to establish a confederation model in Cyprus (Turkish News Agency Anatolia 2.11.2001). It is, therefore, easy to see that this prolonged tension leaves a lot to be desired concerning the possibilities of co-operation on all sides involved for a settlement of the Cyprus issue. It is also more than obvious that this fragile stability prevailing on the island during the last 28 years, can easily turn to a major crisis, in the near future, following the results of the Copenhagen Summit Conference which provides for the accession of Cyprus in the EU without any terms or conditions related to the solution of its political issue. Given that no solution has been attained by the end of February 2003 on the basis of the latest version of the Revised Annan Plan, it appears that the Adhesion Act for the ten new members will be signed in Athens on April 16, 2003 and it will refer to the Republic of Cyprus as one entity. To what extent the EU will be willing to bargain the membership application of Turkey against the settlement of the Cyprus issue is a matter that remains to be seen.

Aiming at relieving the analysis from at least part of the emotional bias involved given the extensive room for normative thought offered by the nature of the Cyprus issue, we have decided to resort to technical analysis. What we do, in fact, is employ the theory of Fuzzy Cognitive Maps, which introduces a decision-making tool widely applicable in the area of International Relations and Politics [11,12]. This will enable us to forecast developments concerning the Cyprus issue and suggest answers to various complications that may arise in the context of such issues. The next subsection presents the CNFCM model and the way in which this method is used, to construct a model describing how the variables involved in the Cyprus issue exert their influence upon the main target, namely, the settlement of this problem. This method is general and can be applied to other political issues by defining the main concepts that influence a problem and the causal links between them. Subsections 4.3 and 4.4 also examine the behavior of the model using static and dynamic analysis.

4.2 A CNFCM Model for the Cyprus issue

The development of our model was based on the method of questionnaires and interviews [18]. The important concepts that influence the Cyprus problem have been identified with the help of a team of domain experts. These experts completed a questionnaire concerning the causal relationships and the weights involved, i.e. the degree to which concepts influence each other, using a positive (+) or negative (-) number between zero and seven, to indicate the direction and intensity of the causal relationships between the concepts. For computational purposes, each number corresponded to the intensity of the casual relationship as follows: Absent 1 (0.0), very weak 2 (0.18), weak 3 (0.36), mediocre 4

(0.54), strong 5 (0.72), very strong 6 (0.9) and decisive 7 (1.0). The general model was then built (Figure 3), in which the various concepts of the model interact with one other, while the central concept was the instability/intensity in Cyprus (C1). On the right side of Figure 3 the weights are presented in a form that indicates the link from the starting concept to the ending concept, with concepts separated by commas. The sixteen concepts that influence the instability in Cyprus appear in Table 1.

The opinion of each expert used to define the weights of the different causal links and the initial activation level for each concept, was given a degree of reliability, the latter expressed by a value between 1 and 10. This value represented the relevance of the expert to the subject and his credibility. Multiplying the degree of reliability of each expert with every weight defined by that expert and then averaging the partial weight matrices, resulted in the final weight matrix (as in equation (3)). This is the usual practice followed for obtaining a normalized weight matrix, which can be considered more representative and objective [29]. The weight values of the normalised weight matrix are given in Table 2.

4.3 Static analysis

The static analysis examines a model that does not change over time. There are two basic types of static analysis: Rule checking and verification. Rule checking ensures that a circuit obeys the restrictions placed on it by the design environment, while verification ensures that a model obeys the restrictions proposed by the experts so that the intended behavior agrees with the actual one [25,17].

The static analysis of the model focuses on the characteristics of the weighted arrows presented in the model using techniques from graph theory. The most important element to consider is the feedback cycles that exist in the graph. Each cycle is accompanied by a sign, which is determined by the multiplication of the signs of the arrows participating in the cycle. If all signs in a cycle are positive or the number of negative signs in the same cycle is even, then the behavior of the entire cycle is positive. Positive cycles are those that behave as amplifiers [25]: A positive change in the activation of a node in the cycle is leading to a constant increase of the activation at the end of the cycle. The negative cycles on the other hand may neutralize or deactivate the activation at the end of the cycle. This means that the activation level of the ending node will be decreased in cases in which an increase is introduced in the activation of any node in the cycle [18].

The model of Figure 3 is rich in cycles: 59 cycles exist, 32 of which are positive and 27 negative. The almost equivalent numbers of positive and negative cycles leads to characterizing the model as rather complex. An example of a positive cycle as this appears in Table 3 is C1+→C11+→C8+→C2+→C1. This cycle begins with concept C1 (Instability/Intensity in Cyprus). Concept C1 influences the Turkish Forces (represented by concept C11) positively, that is, the instability in Cyprus leads to reinforcing the Turkish Army. C11 influences the support to the Turkish forces in Cyprus (C8) positively and this, in its turn, influences the Turkish actions in Cyprus (C2), also positively. Finally, concept C2 leads to an increase of concept C1 revealing increased instability in Cyprus. It is easy to see that if this cycle persists, then instability in Cyprus will constantly increase. An example of a negative cycle as this appears in Table 3, is C1+→C5+→C6+→C4-→C1. The cycle begins with concept C1, which influences the concept representing the Greek Political Support (C5) positively. This situation influences the UN talks for the Cyprus problem (C6) positively, which in its turn affects the solution of the Cyprus Problem (C4) to the same direction, and finally C4 influences the Instability in Cyprus negatively.

According to this cycle the Instability in Cyprus will constantly decrease if a positive change in the activation of any node in the cycle takes place.

If we consider, however, changing the weight w12 from its negative value given by the experts to its positive equivalent, then we must expect a modification in the cycle status of the model as follows: The negative effect of concept C4 (Solution of the Cyprus Problem) on concept C1 (Instability in Cyprus) expressed by w12 will now be altered to positive, expecting an increase of the intensity and instability in Cyprus as a consequence of a solution to the problem. Indeed, when weight w12 becomes positive, the number of positive cycles is greater than the number of the negative ones (33 positive and 26 negative cycles), meaning that an augmentative tendency exists in our model. The point of this example is that the intensity will not necessarily recede even in cases like this in which the solution of the Cyprus problem promotes it.

A second example of static analysis involves a change of the positive sign of weight w10, which links the concept of the Turkish Threats (C3) to that of Instability/Intensity in Cyprus (C1). A negative w10, involving positive Turkish statements rather than threats (C3) will lead to counting 28 positive and 31 negative cycles, which suggests a receding tendency in the model and a decrease of the intensity in Cyprus, a development that contributes to the solution of the Cyprus issue.

The problem with static analysis, however, is that it involves a large number of restrictions while it is very difficult to identify which of the numerous cycles in a model, 59 in our case, will finally prevail and which are the ones with the strongest effect on the model. In other words, the calculation of the interactions between cycles, the change of the weights each time a new scenario is introduced and the determination of the concept and the weights which will eventually prevail can be very complicated, even for models with a much smaller number of concepts than the one currently studied. These problems can be overcome by the use of dynamic analysis based on computational simulations.

4.4 Dynamic analysis

The dynamic analysis involves using our model as a technique for strategic management and decision-making in the context of a scenario approach. In broad terms, a scenario is taken to depict some feasible future state of a political environment, indicating the dynamic sequence of interacting events, conditions and changes that are necessary to reach that state. The scenarios are used for evaluation, selection of strategies, decision-making and identification of future possibilities in face of political uncertainties [14,26].

4.4.1 Model initialization

Our model calculates the new activation levels of the sixteen concepts using equations (4) to (7) converging after 250 iterations (*t* variable in eq. (4) to (7)), when it reaches, in a final immutable situation which can be either an equilibrium, or a limit cycle, or even chaos. Using the weights (w_i) and the activation levels (A_i) as defined by the experts, we left the concepts of the system to interact. The calculated activation levels are presented in Table 4, while Figure 4 indicates that the model reached an equilibrium state.

4.4.2 The politics of the initial state

After running the CNFCM procedure, the model formed the current political situation of Cyprus as follows: The current activation level of concept C1, which is the Instability in Cyprus, was found to be at a high level (A_1=0.69). This has been influenced by the Turkish Actions in Cyprus (C2) with A_2=0.59, a rather high value explained by the continuous support and upgrade of the Turkish troops in Cyprus by Turkey and the continuous violations of the Greek and Cypriot FIR. The instability is also influenced by the Turkish threats (C3) with A_3=0.75, a remarkably high figure given the continuing aggressive statements expressed by various Turkish officials as a result of the accession of Cyprus in the EU without any terms or conditions related to the solution of its political issue.

The third concept which affects the instability in Cyprus, is the solution of the Cyprus problem (C4) with A_4=-0.59, a concept inversely related to the intensity in Cyprus, obviously because the Cyprus problem remains unsolved. Concept C15 which is the International Influence comes up with an activation level of A_{15}= -0.81, indicating that the current period leaves a lot of room for pressure upon the sides that contribute to the decrease of the intensity in Cyprus. The UN talks on the Cyprus problem represented by C6 bear a negative activation level (A_6=-0.44), given that our most recent experience has indicated that the UN alone is not in a position to contribute to the solution of the Cyprus problem effectively. A final concept that appears to exercise an important positive effect is the NATO/EU economic, military and political support represented as C14, with an activation level of A_{14}=0.56

A straightforward conclusion drawn on the basis of these results is that there is a high level of instability in Cyprus, suggesting that as things are described at this initial state, a solution to the problem seems to be just a remote possibility.

4.4.3 Solution of the Cyprus problem: First scenario

This scenario involves differentiating the probability of a solution to the Cyprus problem and changing the weight w12, which is the causal link between concepts C4 and C1, from negative to positive. The value of the weight w12 has been changed from -0.21 to the strongly positive value of 0.7. The meaning of this change is that the solution to the Cyprus problem (C4) is expected to contribute (strongly as the selected value of 0.7 indicates) to the climate of intensity promoting instability in Cyprus (C1). This hypothetical scenario faces a case in which a possible solution may be such that it may not necessarily bring stability and tension reduction. The calculated activation levels reflecting this scenario are given in Table 5 and presented graphically in Figure 5, indicating that the model reaches equilibrium.

The first conclusion drawn based on this scenario is that there is a considerable chance of a solution to the Cyprus problem, given that the activation level of concept C4 has assumed a quite substantial positive value (A_4=0.69). This, however, calls, for a requirement that the Turkish side changes its attitude from aggressive to constructive through a series of positive statements to solve the Cyprus problem. This radical change of attitude is reflected in the dramatic decline of the activation level of concept C3 (Turkish threats) down to A_3=-0.19. Moreover, it is interesting to mention that the rise of the activation level of the talks under the UN auspices (C6) to A_6 =0.48 indicates that such talks can be quite helpful and must be continued, together, of course, with the exercise of what we term “International Influence” (C15). The sign of the latter changes and its value becomes strongly positive, indicating its decisive effect upon the possibility of tracing a solution to the Cyprus Problem. Likewise, concept C14 representing the political, economic and military support by NATO and the EU, assumes an increased activation level of A_{14}=0.85. This last conclusion points out the possibilities that may be offered by these two powerful entities for a solution to the Cyprus issue. Concerning the government stability in all three countries directly involved in this issue (C7, C12, C13) the corresponding activation levels are considerably high, indicating its essential role in all cases.

A further interesting finding in this scenario concerns the reinforcement of the Greek Army (C10) and the military support to the Greek-Cypriots (C9), the states of which were found weak and inadequate to contribute to the solution of the problem (Table 4). It turns out that this scenario reveals that if the Greek Army is strengthened (A_{10}=0.63) and more military support is given to the Greek-Cypriot Army (A_9=0.68), then this may support a solution of the Cyprus issue in the context of a "si vis pacem para bellum" policy (the Latin for "if you want peace prepare for war") [6].

Last, but not least, one must concentrate on a rather striking conclusion of this experiment: It seems that the unstable environment in Cyprus will continue prevailing given its high activation level (A_1=0.67), combined with an almost equally high activation level of the Turkish army on the island (A_2=0.58). This simply means that a solution to the Cyprus issue will not necessarily lead to stability, the latter being adversely affected by the strong presence of the Turkish troops on the island.

4.4.4 Solution of the Cyprus problem: Second scenario

To face the adverse repercussions predicted by the first scenario we have resorted to asking the model to forecast the political impact in cases in which all Turkish forces activity is neutralized. Thus, after setting the weight w9, which represents the causal link between concepts C2 and C1, to zero the model has reached a mixed state of equilibrium and limit cycles as depicted in Figure 6.

It is impressive to notice in Table 6 that the relevant activation level has turned to negative (A_1=-0.11), meaning that there are chances for attaining a stable equilibrium in Cyprus after all! However, combining the concept solution of the Cyprus Problem (C4) with an activation level of A_4=0.07, leads to a neutral environment, implying that in this scenario the Cyprus issue seems to be “frozen”, possibly due to the absence of events causing a general instability that could trigger reactions from the part of the public opinion and give the necessary momentum to the settlement of the problem. This leads to a conclusion very much similar to that of the previous scenario, i.e. that the solution of the Cyprus problem may not, under the circumstances, contribute to the stability in Cyprus. Regarding the International Influence (C15), this assumes a lower activation level compared to the first scenario (A_{15}=0.34) revealing the reluctance of the international factor to become involved with an issue that does not cause intensity to the broader geographical area. Generally speaking, the main conclusion of this scenario refers to the tendency of most concepts to assume a neutral attitude given the absence of actions on behalf of the Turkish troops in Cyprus.

4.4.5 Solution of the Cyprus problem: Third scenario

This scenario involves further reduction of weight w9 that links C2 (Turkish forces actions in Cyprus) with C1 (Instability in Cyprus) down to -0.6. The political meaning of this change is that the actions on behalf of the Turkish troops in Cyprus contribute negatively to the creation of instability in the island, possibly due to a withdrawal of the Turkish forces from Cyprus. As a result the model has reached a chaotic behavior, as depicted in Figure7. These results, however, cannot be discussed due to absence of reliability.

5. The GECNFCM Hybrid Model

5.1 Evolutionary programs and Genetic Algorithms

Genetic algorithms are a part of evolutionary computing [15,30], which is a rapidly growing area of Artificial Intelligence. The structure of an evolution program in pseudocode form is shown in Figure 2. The evolution program is a probabilistic algorithm, which maintains a population of individuals (also called chromosomes) $P_t=(x_1, x_2,\ldots, x_n)$ for each generation (iteration) t. Each individual x_i represents a potential solution to the problem at hand and it is evaluated using some measure of its "fitness". Then we form the new population (iteration) *(t+1)* by selecting the individuals bearing the highest fit (select step). Some members of the new population undergo transformations (alter step) by means of "genetic" operators to form new solutions. There are unary transformations m_i (mutation type), which create new individuals by a small change in a single individual and higher order transformations c_j (crossover type) which create new individuals by combining parts from several (two or more) individuals. After some number of generations the program converges. The best individual represents a near-optimum (reasonable) solution.

Genetic Algorithms (GA) are domain independent, thus they can be useful in many applications. It is not surprising, therefore, that evolution programs, incorporating problem-specific knowledge in the chromosomes data structure and specific "genetic" operators, perform much better. Classical genetic algorithms, which operate on binary string encoding for the individuals require a modification of the original problem to an appropriate binary form for the GA [15]. This would include mapping between potential solutions and binary representation, taking care of decoders or repair algorithms. On the other hand, evolutionary programs would leave the problem unchanged, modifying a chromosome representation of a potential solution; using "natural" data structures and applying appropriate "genetic" operators.

A GA essentially provides a search procedure, which optimises an objective function $\varphi()$ by maintaining and evolving a population P of candidate solutions. The population is evolved through the crossover and mutation operations mentioned earlier which are employed to generate new individuals. The computation procedure of the GA starts with random initialisation of the individuals forming the first generation of the population. The objective function is then evaluated for every individual and according to the fitness of each of these individuals some members are selected for the next generation. These undergo mutation and/or crossover transformations according to some probability and the fitness function is applied on the members of the new generation. The GA procedure is then repeated for a certain number of iterations called epochs or generations. The algorithm terminates if a predefined condition is met or if a maximum number of epochs is reached. The individual yielding the best fitness value throughout all generations gives the optimal solution.

The essence of the Genetically Evolved Certainty Neuron Fuzzy Cognitive Map (GECNFCM) model proposed in this paper lies with tracing the optimal weight matrix corresponding to a desired activation level for a given concept as computed by a simple CNFCM model. More specifically, the GA evolves a population of individuals each of which consists of a weight matrix describing the degree of causal relationships between the concepts of Figure 3. The initial generation contains weights matrices with random values. The evolution of the individuals is performed with the help of the CNFCM model, which computes the final activation levels of the concepts using equations (1) to (4). The activation level of a certain concept in focus denoted by A_i is used to calculate the fitness of each individual-weight matrix WM_i according to the following function:

$$\text{fitness}(WM_i)=1/(1-\text{abs}(A_{d,i}-\text{mean}_{50}(A_{a,i})) \qquad (8)$$

where $A_{d,i}$ is the target (desired) value of the activation level for the concept in focus C_i and $mean_{50}(A_{a,i})$ is the mean value of the last fifty actual activation levels of concept C_i as these are computed by the CNFCM (t variable in equations (4) to (6)). It is clear from equation (8) that the closer to the target value this mean value is, the more appropriate the weight matrix. In fact, the fitness function uses the average of the last fifty activation levels to take into consideration a possible final state of the model which presents limit-cycles, that is, a state in which the $A_{d,i}$ exhibit periodic fluctuations and do not stabilize at equilibrium values. Thus, if the activation level of the concept in focus reaches equilibrium then the corresponding weight matrix in this case can be considered more appropriate compared to another individual-matrix that has resulted to limit cycles or chaos.

All simulations conducted in the next section have been based on the following constant values for the variables involved: The population size has been set equal to 100 and the number of generations equal to 400. The weight values were initialized in the range [-1.0,1.0] while the probability of applying the genetic operator of crossover was set to 0.25 and that of mutation to 0.01.

5.2 Experimental results

Simulations were performed as follows: The first step involved studying the activation levels calculated by the CNFCM model (Table 4) at equilibrium using the initial weight matrix shown in Table 2. The next step was to simulate different scenarios by asking the model to reach a desirable activation level for a certain concept the policy–maker focuses on. The GECNFCM model calculated the new optimal weight matrix, which was then used by the CNFCM model to recalculate the new activation levels of the 16 concepts. The recalculation of all weights that participate in the simulation process constitutes the most important difference between the GECNFCM and the simple CNFCM models. Its importance to the decision-makers is underlined by the fact that they will not base their decision only on the experts' evaluation, but also on the optimal weights that lead a concept to be activated to a certain predefined degree. Thus, decision-makers are able to introduce hypothetical cases reflected through a target activation level for a certain concept in the model and study the corresponding weights and activation levels for the rest of the concepts compatible with the predetermined target activation level. Based on this information, the policy maker is then able to take decisions leading to the desired simulated solution.

5.2.1 Scenario 1: An environment of increased instability

What the model does in this scenario is to calculate the new weight matrix provided that instability in Cyprus rises. This possibility is introduced in the model by increasing A1 from 0.69 to 0.95. Using the optimal weights calculated by the GECNFCM indicated in Table 7 the final activation levels of Table 8 were obtained. As depicted in Figure 8, the model has reached equilibrium. The cause of the increased instability in Cyprus (A_1=0.88) has been traced to the combined result of an increase in influence terms of concepts C2 and C3, representing the Turkish provocative actions (w9=-0.75; A_2=-0.75) and the Turkish threats (w10=-0.53; A_3=-0.59) respectively. The unstable environment is further aggravated given the combination of the negative activation levels of C2 and C3 to the weights that link them with C1 which have turned from positive (Table 2), to negative (Table 7). The activation level of 0.76 which concept C4 (solution of the Cyprus problem) has assumed can only contribute to this instability.

A further interesting point regards the consequences of a reduction to the support offered to the Turkish forces on the island, a possibility which is introduced by reducing the appropriate activation level down to A_8=-0.67 from A_8=0.78 and results in a reduction of the provocative statements, threats and actions from the part of Turkey. In addition, the effectiveness of reducing the support to the Turkish forces is revealed by the increase of the corresponding weight (w20) to twice its original value due to the reduction of the Turkish forces, as indicated by the relevant weights and activation levels. Concluding the experiments describing an environment of instability we have noticed that the pronounced activation level of the international influence (C15) turned from negative to positive, while its impact upon solving the Cyprus problem (w39), rose to three times as much as its baseline value, underlining the importance of the pressure exercised by international organizations or superpowers.

5.2.2 Scenario 2: How to solve the Cyprus problem

This scenario examines the solution of the Cyprus problem in two ways: The first involves simulating the situation under which the potential of a solution to the problem is decreased, while the second investigates the scenery in case this potential is increased. In the former case the simulations were performed with a targeted activation level A_4=-0.9, while in the latter case this level rises to A_4=-0.2.

Decreasing the activation level of C4 to -0.9 the GECNFCM yields the optimal weight matrix depicted in Table 9, which activates the concept almost to its equilibrium target value (A_4=-0.86; Table 10, Figure 9). The concept interaction in this case is the following: Intensity in Cyprus climbs to A_1=0.93, while the Turkish actions decrease to A_2=-0.84 and the Turkish threats are almost neutralized. This high level of intensity comes as a result of the negative A_2 and the negative w9 linking C2 with C1 (Table 9), the multiplication of which contributes positively to increasing A_1. The same holds for A_4 and w12, linking C4 with C1, while the international influence (C15) is negatively activated (A_{15}=-0.83), thus affecting the solution to the Cyprus problem adversely given its positive link to C4. The Turkish government appears quite unstable (A_{13}=-0.75), while the strengthening of the Turkish army is highly activated (A_{11}=0.73). These are certainly expected to contribute to raising tension in the area, given the tendency of the Turkish authorities to "export" their domestic economic, political and social problems in crises form.

Turning to our second alternative used to attain a solution to the Cyprus problem, setting the target A4=-0.2 seems to be more fruitful as the equilibrium values of the results indicate (Tables 11 and 12, Figure 10). While A_4 rises to –0.21, intensity appears to be significantly decreased to the value of A_1=-0.14, unlike the previous case, given the drop of both the level of the Turkish forces actions in Cyprus and that of the Turkish threats. A comparison of these results to those calculated by the CNFCM (Table 4) shows that the level of the negotiations for a solution is reactivated while the support to the Turkish forces on the island is neutralized.

5.2.3 Scenario 3: Increase and decrease of the Turkish threats

This case involves a hypothetical situation in which the Turkish threats increase and decrease (both in terms of intensity and number of cases) in an attempt to examine the corresponding impact on intensity and on the possibility of a solution to the Cyprus problem. Simulations were performed with a targeted activation level A_3=0.9 for increased and A_3=-0.5 for decreased.

Increasing the activation level of C3 yields the optimal weight matrix presented in Table 13, which activates the sixteen concepts as shown in Table 14 and Figure 11. Here we can see that the rise of the Turkish threats causes an increase in the intensity in Cyprus and the

Turkish forces actions (A_1=0.86, A_2=0.84) as one might have expected. In addition, the potential of a solution to the Cyprus problem is quite high (A_4=0.81), possibly due to the fact that when tension is observed in a certain geographical area then the international community focuses on smoothening it out. It is also worth noticing that stability in the three governments is low (A_7=0.13, A_{12}=-0.51, A_{13}=-0.10), something which may actually be the cause of the increase of the Turkish threats (i.e. the Turkish government may be using the Cyprus problem to increase its popularity).

Decreasing the activation level of C3 yields the optimal weight matrix presented in Table 15, which activates the sixteen concepts as shown in Table 16 and Figure 12. The reduction of Turkish threats doesn't reduce the intensity in Cyprus, which remains high (A_1=0.79). This is due to the fact that the possibility of a solution to the Cyprus problem remains too low (A_4=-0.7, w12=-0.5). In addition, weight w11, that is, the causal link between C3 (Turkish threats) and C4 (solution of the Cyprus problem), is 0.82, while in the initial case it was 0.12, indicating the strong influence of this concept (C3) to the solution of the Cyprus problem. Concept C15 is a remarkable concept and its positive value A_{15}=0.66 shows the important international influence in the reduction of Turkish threats.

5.2.4 Scenario 4. Increase and decrease of International Influence

This is a scenario that examines the international influence on the solution of the Cyprus problem in two ways: The first involves simulating the situation under which the international interest of a solution to the problem is decreased, while the second investigates the possibility in case this interest is slightly increased. In the former case the simulations were performed with a targeted activation level A_{15}=-1, while in the latter case this level was A_{15}=-0.4.

Decreasing the activation level of C15 yields the optimal weight matrix presented in Table 17, which activates the sixteen concepts as shown in Table 18 and Figure 13. Decreasing the international influence shows that the instability in Cyprus is increased (A_1=0.88) and the Turkish threats in the absence of international interest are increasing considerably (A_3=0.85, w1=1). The possibility of the solution to the Cyprus problem decreases A_4=-0.74 and there are no talks for its solution A6=-0.58.

The reduction of the International Influence affects the strength of the Greek Army negatively (A_{10}=-0.83) and the strength of Turkish army positively (A_{11}=0.81). The Turkish Cypriots do not seem to approve of the international involvement for the solution to the Cyprus problem (A_{16}=0.73).

The absence of influence of the international factor, in addition, results in stabilizing the governments of Cyprus (A_7=0.8), Turkey (A_{13}=0.51) and Greece (A_{12}=0.86), indicating that a strong presence of the international factor creates instability in the governments of the three countries which are directly involved in the Cyprus issue.

In the second case, we used the model to simulate future developments in cases in which the international influence is increased, putting pressure on the solution of the Cyprus problem. Increasing the activation level of C15 yields the optimal weight matrix presented in Table 19, which activates the sixteen concepts as shown in Table 20 and Figure 14. This pressure has a direct impact on the reduction of the Turkish actions (A_2=-0.52) and Turkish threats (C3) from A_3=0.72 to A_3=0.42. As a consequence, the possibility of solution of the Cyprus problem is increased. The UN talks for the solution of the Cyprus problem assume an activation level of almost zero (A_6=0.07), indicating that when the international influence is highly activated the UN talks may come second best and that alternative ways for achieving a solution to the problem may be used (e.g. USA or EU initiatives).

5.2.5 Scenario 5. Reduction of support to the Turkish Forces in Cyprus

This is a highly unrealistic scenario in which the model calculates the new weight matrix for the hypothetical case in which the Turkish government reduces the support to the Turkish forces in Cyprus. This possibility is introduced in the model by decreasing the activation level A_8 from 0.78 to -0.2. The optimal weight matrix is presented in Table 21, which activates the sixteen concepts as shown in Table 22. Figure 15 shows that the model exhibits a limit cycle behavior, indicating a weak point of the method that permits only cautionary interpretation of the results.

Reduction of military support to the Turkish forces in Cyprus has a minor negative impact on the concept representing the Turkish forces actions in Cyprus (C2) with its activation level reducing to A_2=0.17. Turkish threats (C3) remain almost at the same level (A_3=0.61 from 0.75). A further interesting point to be discussed is the reduction of the reinforcements to the Turkish Army (C11) to the value of A_{11}=0.3. This reduction can only occur in the absence of NATO and EU political, economical and military support (A_{14}=-0.89).

6. Validation of the hybrid model on a real case: The S-300 crisis

Unlike the hypothetical cases examined thus far, the hybrid model is tested in an environment of an actual incident, aiming at measuring its ability to face actual crises. What we do, more specifically, is to consider the so-called S–300 crisis, namely the incident that occurred between January 1997 and December 1998, involving Cyprus, Greece and Turkey. It is briefly reminded that the installation of such an efficient long-range ground to air missile on Cyprus was considered a threat to Turkey, improving the effectiveness of the Greek and Cypriot armed forces in the context of the Integrated Defense Doctrine, while, in parallel, compelling Turkey to resort to purchasing expensive countermeasures to such an alleged threat. The Greek side, in its turn, claimed that the installation of the S-300 would not be enough to disturb the balance of power in the area, given that these missiles would be exposed to a sudden blow from the part of Turkey to which they would be able to respond only if they survived. In such a case, therefore, any form of destabilizing action in the area would only come from the Turkish side, given that the role of the S-300 would have been purely defensive. The strong opposition to this purchase by the USA and Great Britain finally led to the installation of the missiles in the island of Crete and to the purchase of just a short-range ground to air system for Cyprus.

In order to analyze the environment described above, we first simulated the S-300 incident using the CNFCM model of Figure 3 and the weight matrix presented in Table 23. The final activation levels of the sixteen concepts involved are listed in Table 24 and depicted graphically in Figure 16 reflecting a picture characterized by increased tension (A_1=0.79) and strong reactions and threats from the part of Turkey (A_2=0.87 and A_3=0.77 respectively). It is reminded that these threats included attacking and destroying the system once installed and were accompanied by sending F16 air fighters to the occupied airport of Lefkoniko aiming at reinforcing the Turkish position on the island [13]. In short, the results obtained reproduce the atmosphere prevailing on the island during the actual crisis period, when the FIR violations, the support to the Turkish forces on the island and the intense diplomatic activity from the part of Turkey were culminating. These seem to lead to adverse repercussions as regards possibilities of a solution to the Cyprus problem (A_4=-0.77) and chances for peace talks (A_6=-0.63), while both the Cypriot and the Turkish governments suffer destabilizing effects (A_7=-0.41 and A_{13}=-0.71 respectively), results which are strongly supported by historical evidence referring to the period under study [13]. The incident, however, does not appear to affect the stability of the Greek government (A_{12}=0.60), the support of which to the Greek-Cypriot army appears to be considerable (A_9=0.70), as it been the case. The support to the Turkish forces on the island is very strong (A_8=0.88), a development sustained by the strength of the Turkish forces (A_{11}=0.66). Finally, the international influence has contributed to the crisis (A_{15}=-0.85) negatively, given that, at least indirectly, it encouraged Turkish aggressiveness by opposing the purchase of the S-300 system.

At this stage we requested the model to consider a 50% reduction of the intensity on the island, aiming at evaluating the extent to which it can reflect the climate prevailing on the island with the tension cooling down after December 1998. The model has indeed reached the intensity-reduction target by attaining equilibrium at A_1=0.37 (Table 26 and Figure 17). The role of the international influence, once it took initiatives, climbed from A_{15}=-0.85 to A_{15}=0.74 indicating reluctance to approve of the Turkish threats and actions in Cyprus that used to support a climate of tension, while its pressure on the Cypriot side contributed to the same direction considerably. The latter is introduced in the model through the weight w40=0.27 (Table 25) which links the international influence C15, to the peace talks C6. The negative weight w39=-0.50 that links C15 with C4 (solution to the Cyprus issue), implies a decrease of the international support to the solution of the problem, something which reflects the shift of emphasis placed during the crisis period from solving the Cyprus problem to resolving the S-300 crisis.

The reluctance of the Greek side to provide active military support to the installation of the S-300 on the island is reflected in the relevant zero activation level (A_{10}=0.0), unlike that of the Cypriot National Guard, the activation level of which had reached A_9=0.8 revealing its adherence to the S-300 project. The Cypriot government itself does not seem to be confident enough concerning its decision to install the missiles, since its activation level drops to A_7=-0.53, given the disagreement which took place between the military and the politicians over the issue. Finally, special attention should be drawn to w25 that links the stability of the Greek government (C12) to the Greek support to the Cyprus issue (C5), the weight linking the two assuming the impressive value of 0.99. This underlines the unanimity and confidence of the Greek side concerning the influence exercised upon Cyprus.

7. Conclusions.

Following the presentation and construction of a FCM and a CNFCM model describing the Cyprus political issue, we have introduced a hybrid model based on Genetically Evolved Certainty Neuron Fuzzy Cognitive Maps (GECNFCMs) designed to facilitate political decision-making in the face of crises. The Genetic Algorithm of this model was used to find the optimal weight matrix that satisfies a predetermined activation level for a certain concept. The decision-maker is thus able to consider hypothetical scenarios by defining the target activation level of a concept in focus and to study the resulting weight values and activation levels once the model has reached equilibrium and the target has been met. The five scenarios simulated in this context were as follows: The first involved an environment of escalating intensity on the island (C1), the second simulated the consequences in cases of decreased and increased solution possibilities respectively, while the third investigated the case of increased/decreased Turkish threats (C3). The fourth scenario dealt with variations of the international influence (C15) while the fifth was involved with the reduction of the support to the Turkish forces in Cyprus (C8). The results of these scenaria were quite encouraging: The GECNFCM reached the targetted activation level in equilibrium state in nearly all cases, allowing the decision-maker to forecast the dynamics of a given situation and to measure the variables determining the final state.

The hybrid system was then tested to face an actual crisis, namely that which was caused following the installation of the S-300 missiles on the island. The hybrid system simulated this political situation successfully and produced results which were very descriptive of the actual events that lead to the defusion of the crisis. Thus, the validation process proved that the hybrid system proposed can be a reliable tool in the hands of political analysts and decision-makers aiming at managing a crisis or solving intricate political problems.

Finally, concerning some drawbacks of the method in cases in which the model exhibits limit cycle or chaotic behavior, future research will focus on attempting to define the range of values for the elements of the weight matrix that drive the model to this type of behavior.

Captions for figures

Figure 1. The mathematical model of a single artificial neuron

Figure 2. The evolution procedure in pseudocode

Figure 3. The Cyprus issue CNFCM model

Figure 4. Stabilization of the model in equilibrium

Figure 5. Scenario 1: Equilibrium for w12=0.7

Figure 6. Scenario 2: Limit cycle and equilibrium for w9=0.0

Figure 7. Scenario 3.Chaotic behavior for w9=-0.6

Figure 8. Equilibrium for target A_1=0.95

Figure 9. Equilibrium for target A_4=-0.9

Figure 10. Equilibrium for target A_4=-0.2

Figure 11. Equilibrium for target A_3 =0.9

Figure 12. Equilibrium for target A_3=-05

Figure 13. Equilibrium for target A_{15}=-1

Figure 14. Limit cycles for target A_{15} =-0.4

Figure 15. Equilibrium for target A_8 =-0.2

Figure 16. S-300 crisis: CNFCM equilibrium

Figure 17. S-300 crisis: GECNFCM equilibrium

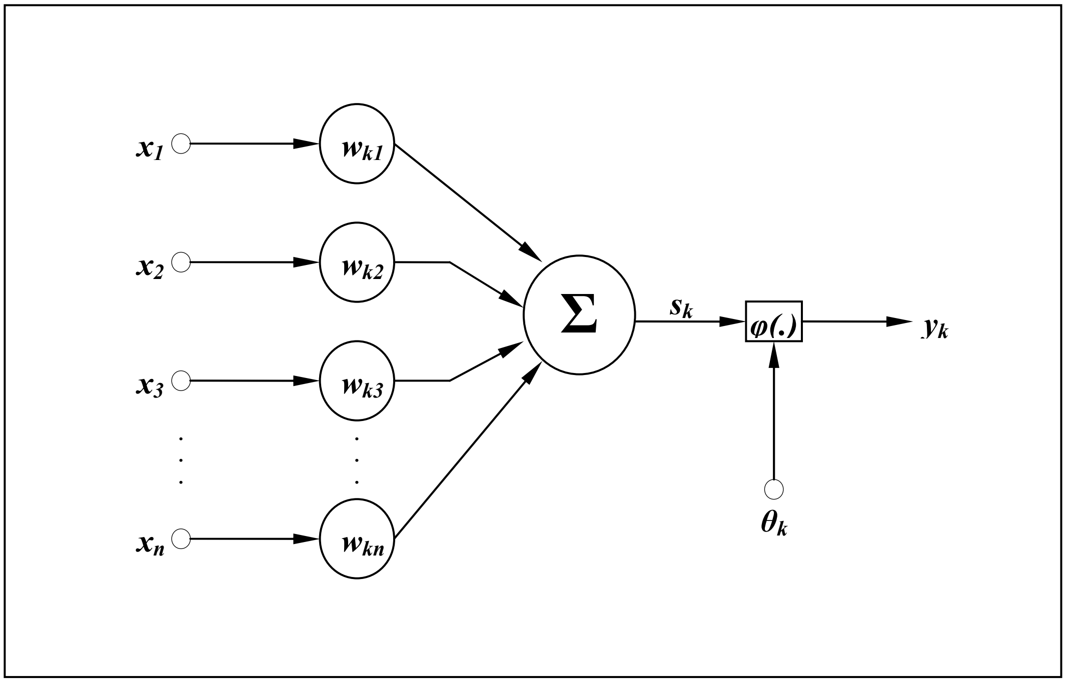
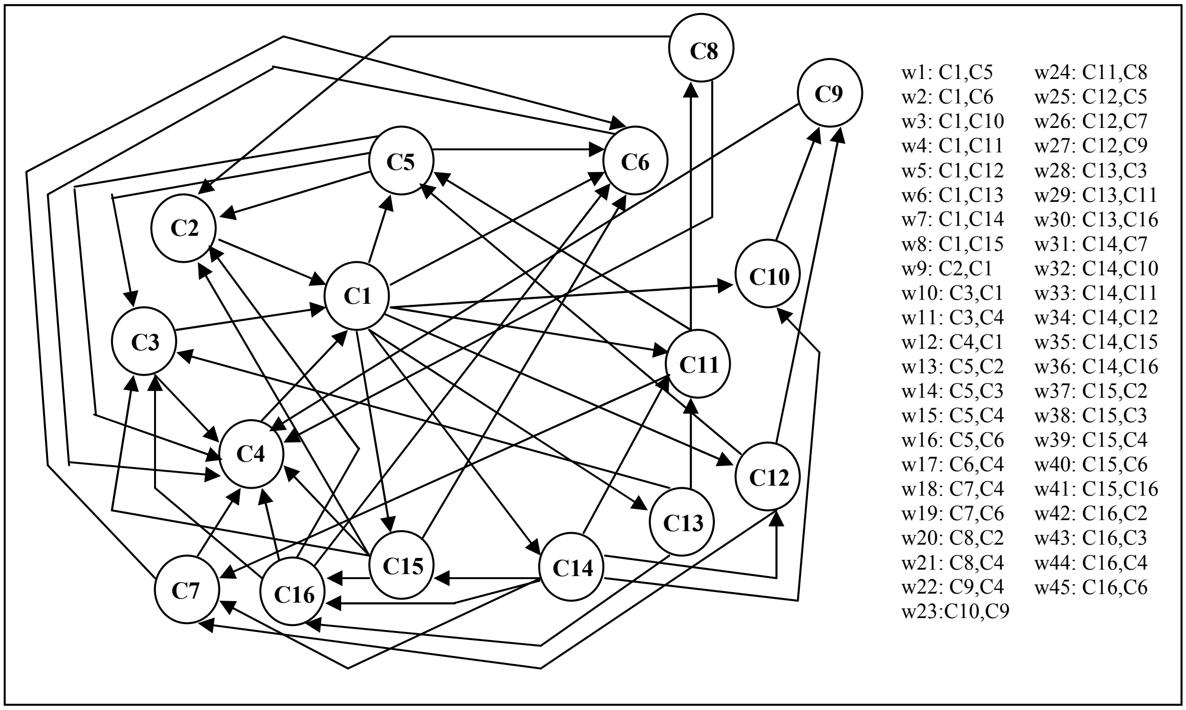


Figure 1

```
Procedure evolution program
   begin t ← 0 ;
      Initialize P(t) ;
      Evaluate P(t) ;
      while not (termination condition) do
         begin
            t ← t+1 ;
            select P(t) from P(t-1) ;
            alter P(t) ;
            evaluate P(t)
         end
   end
```

Figure 2


C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
w1: C1,C5
w2: C1,C6
w3: C1,C10
w4: C1,C11
w5: C1,C12
w6: C1,C13
w7: C1,C14
w8: C1,C15
w9: C2,C1
w10: C3,C1
w11: C3,C4
w12: C4,C1
w13: C5,C2
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w15: C5,C4
w16: C5,C6
w17: C6,C4
w18: C7,C4
w19: C7,C6
w20: C8,C2
w21: C8,C4
w22: C9,C4
w23:C10,C9
w24: C11,C8
w25: C12,C5
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w27: C12,C9
w28: C13,C3
w29: C13,C11
w30: C13,C16
w31: C14,C7
w32: C14,C10
w33: C14,C11
w34: C14,C12
w35: C14,C15
w36: C14,C16
w37: C15,C2
w38: C15,C3
w39: C15,C4
w40: C15,C6
w41: C15,C16
w42: C16,C2
w43: C16,C3
w44: C16,C4
w45: C16,C6

Figure 3

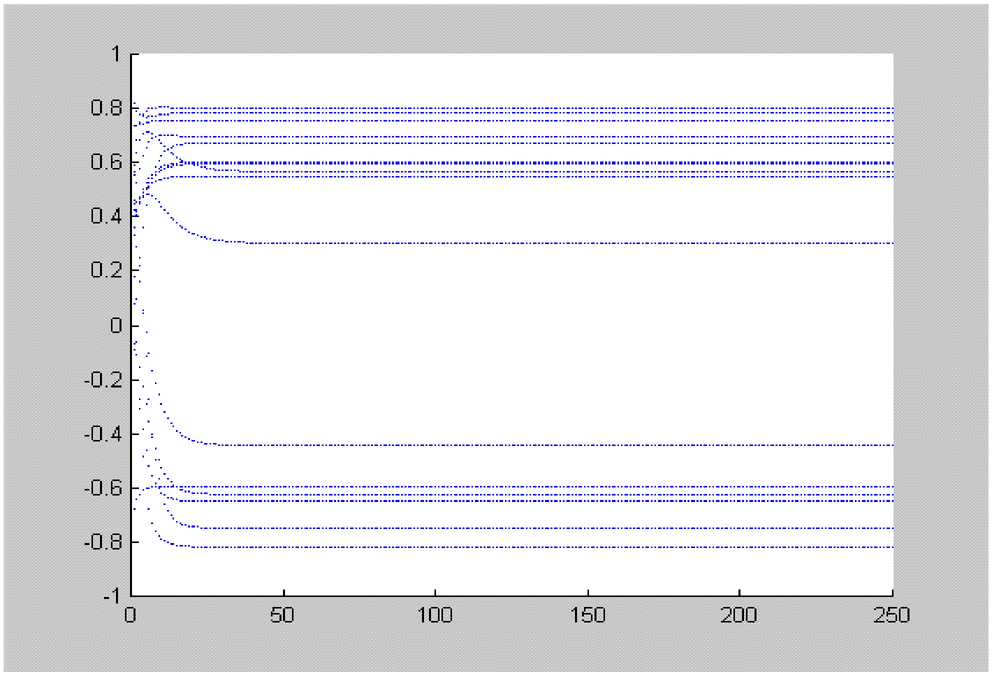

Figure 4

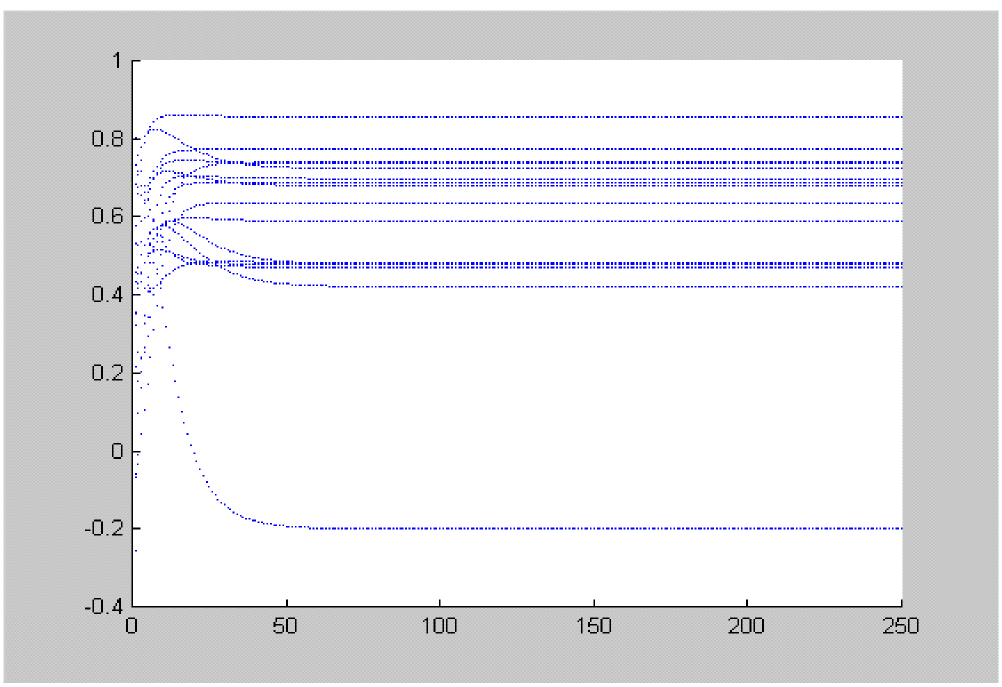

Figure 5

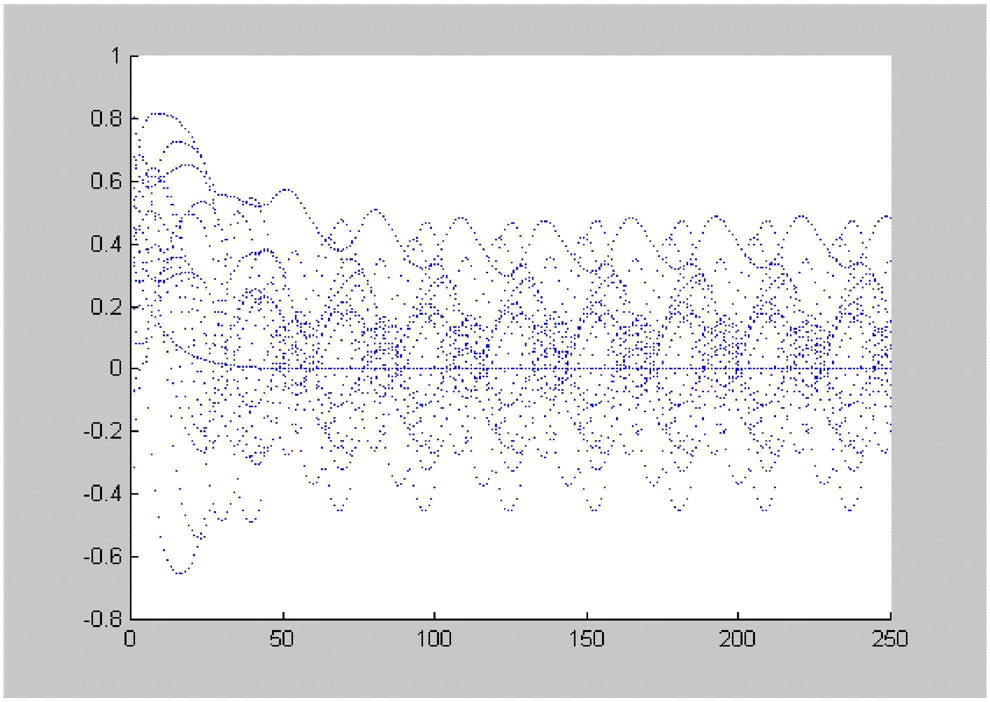

Figure 6

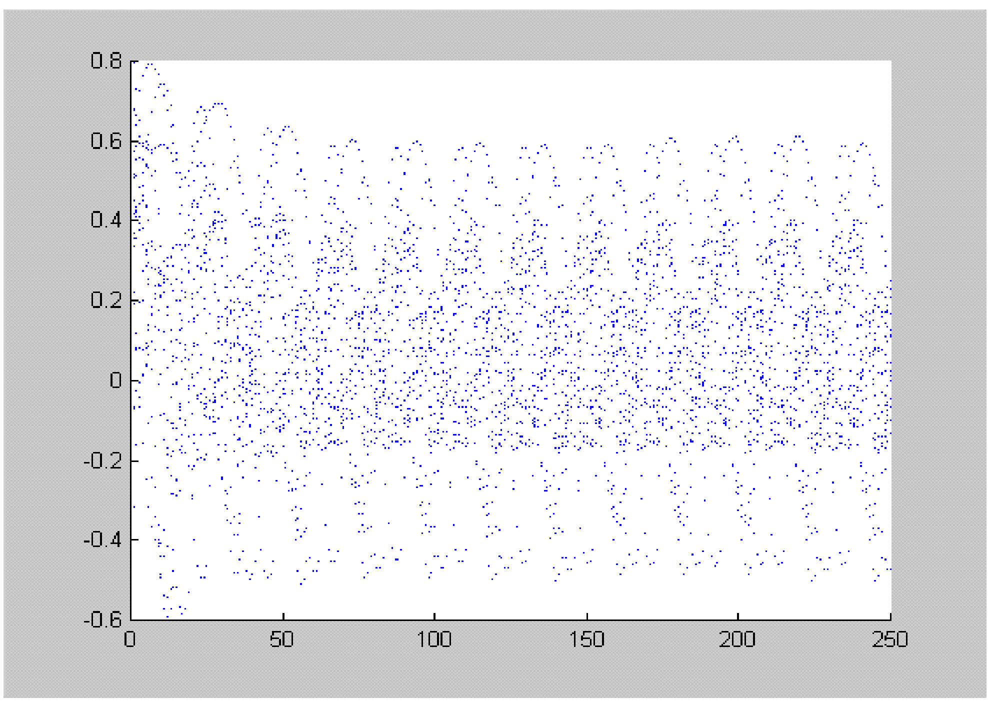

Figure 7

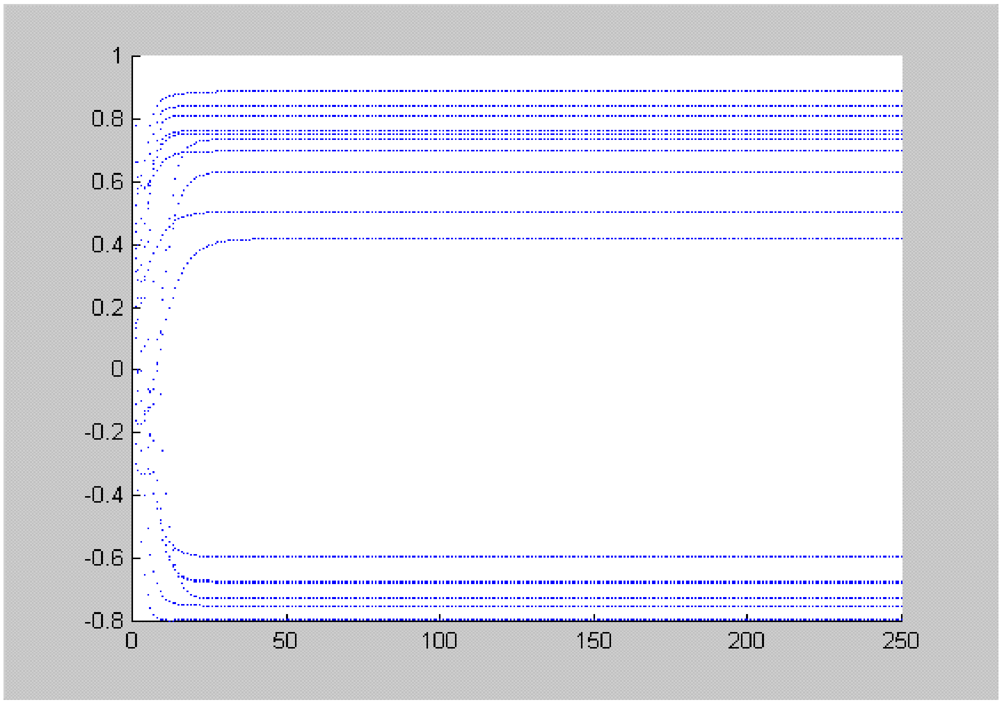

Figure 8

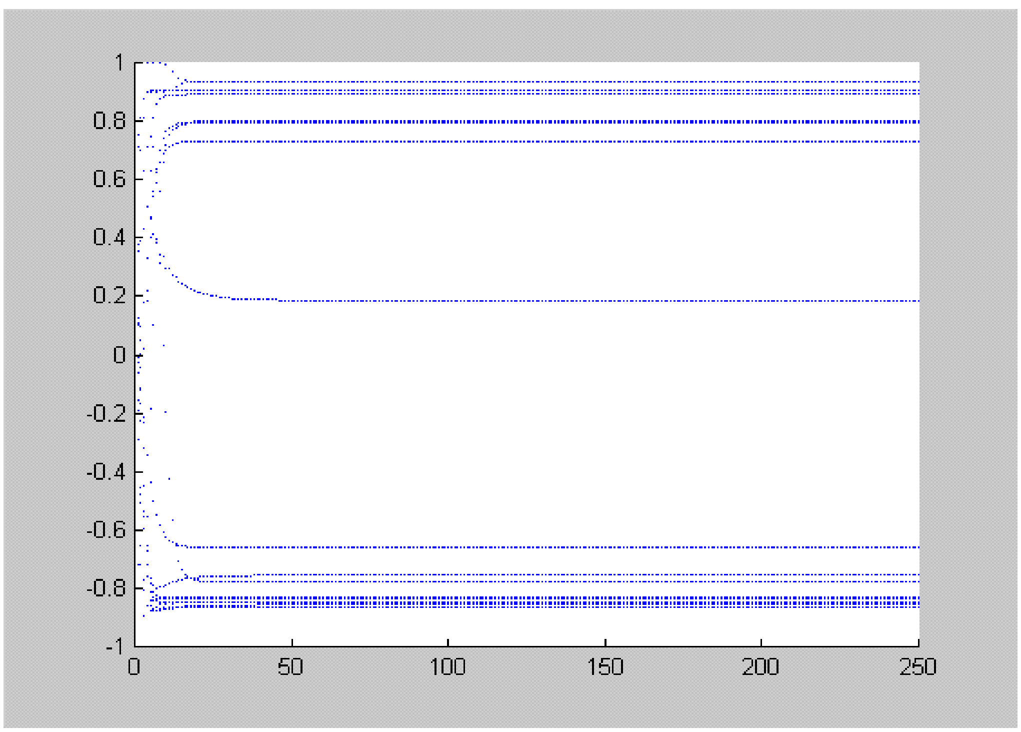

Figure 9

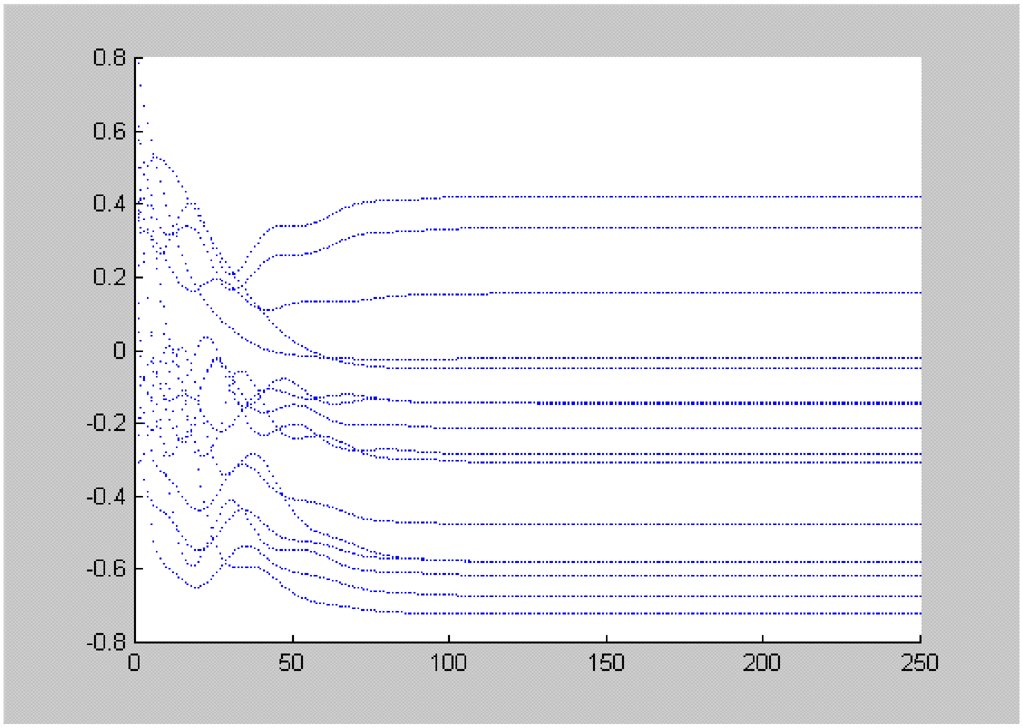

Figure 10

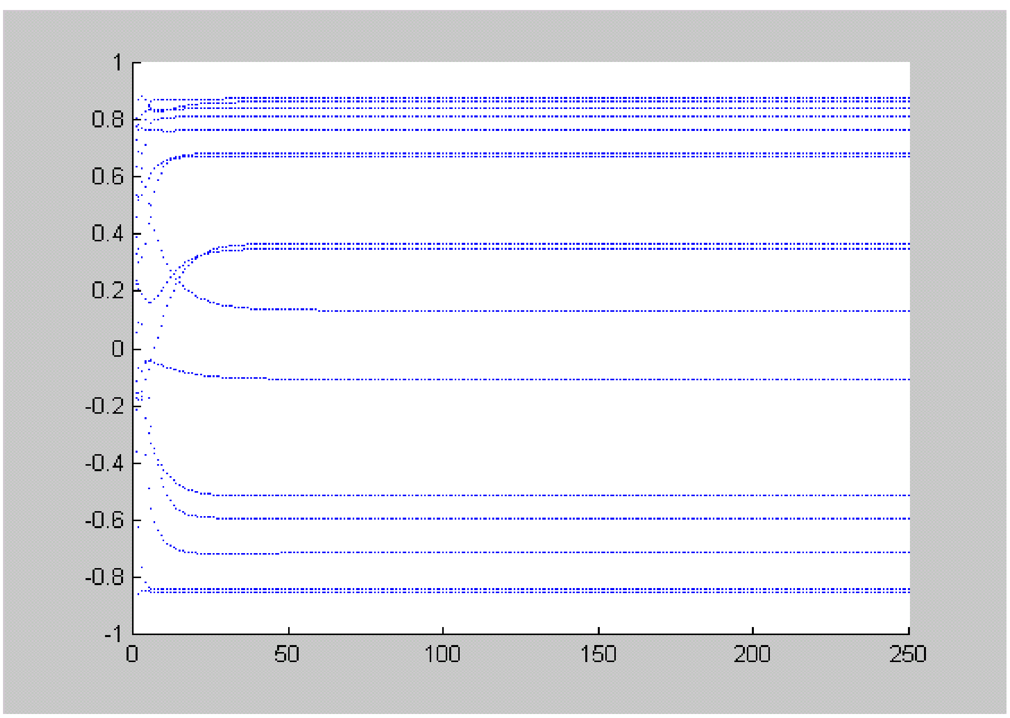

Figure 11

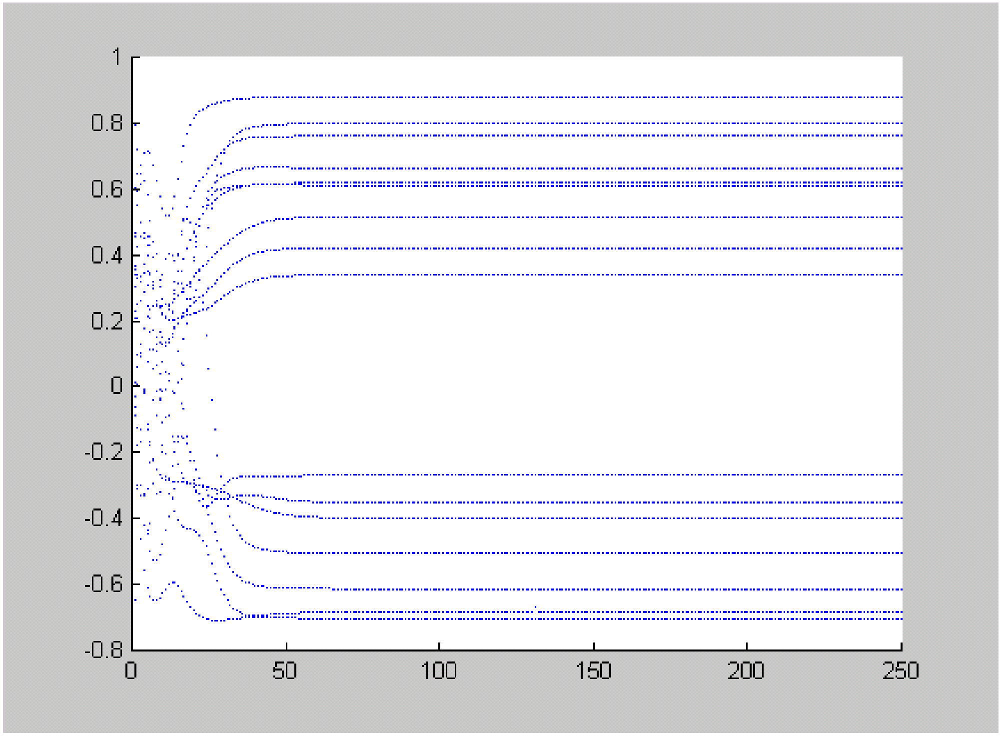

Figure 12

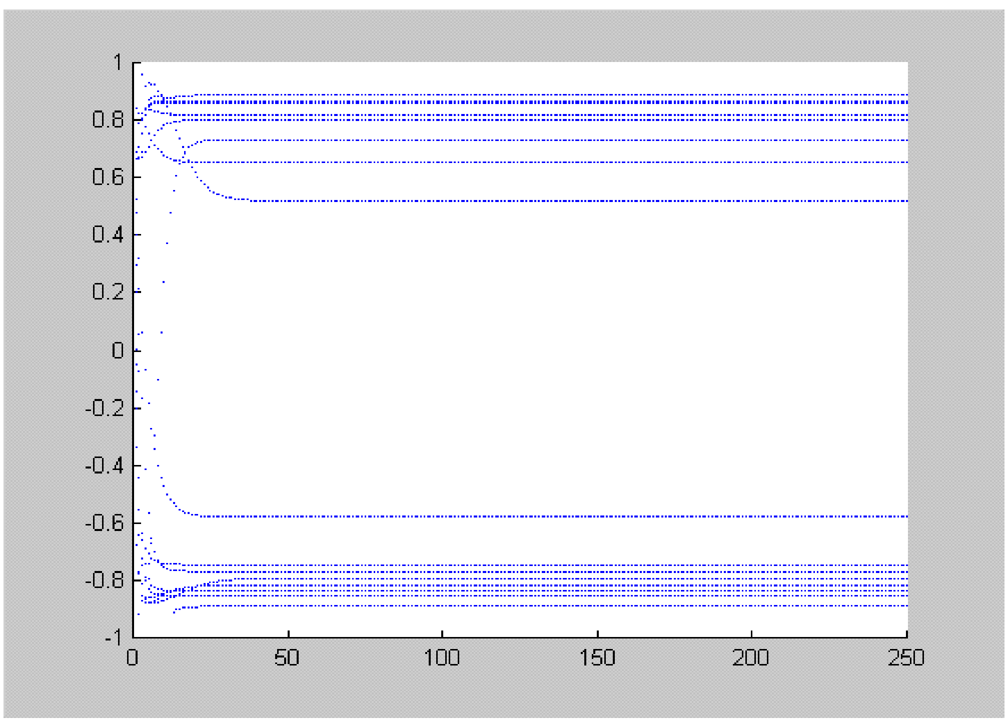

Figure 13

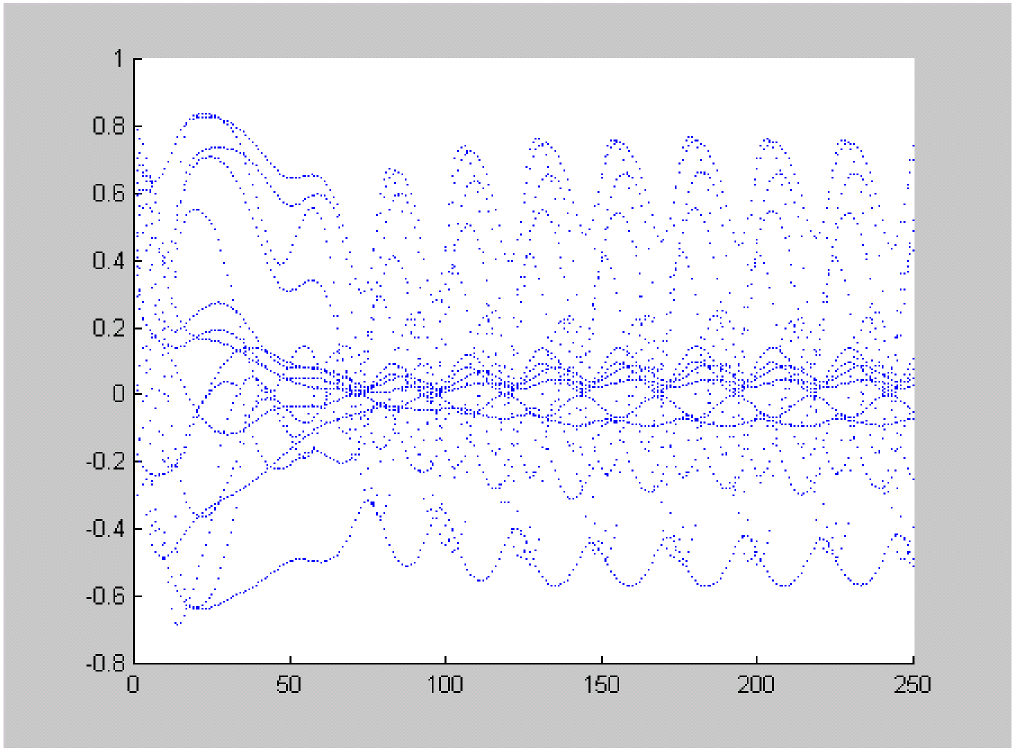

Figure 14

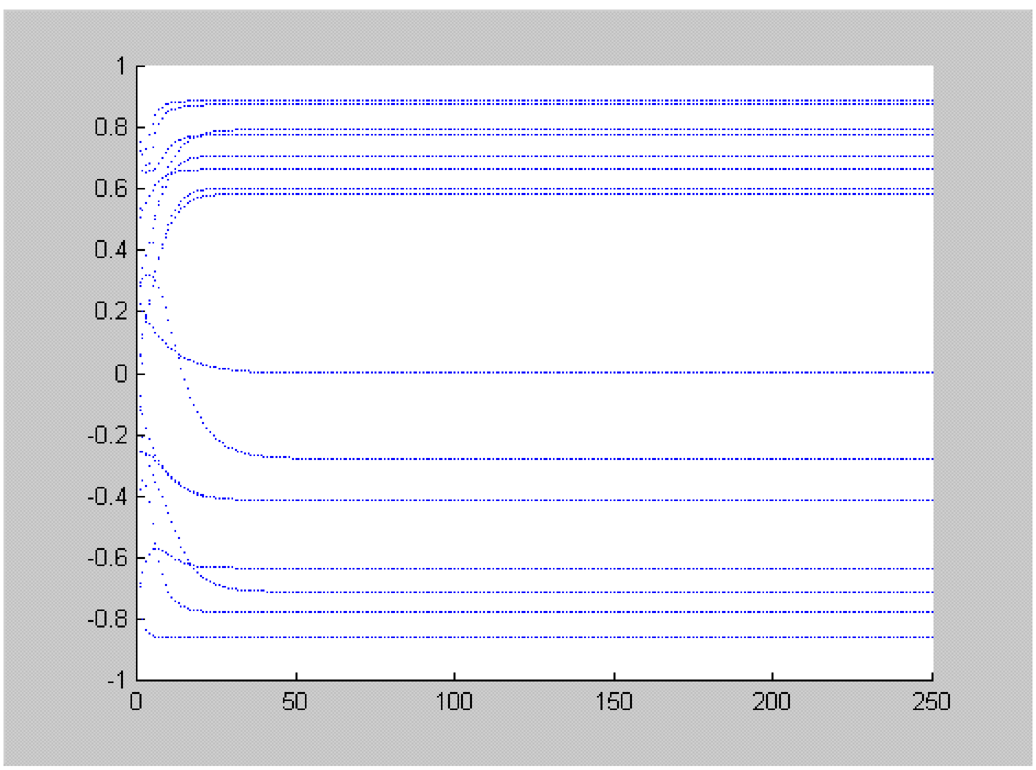

Figure 15

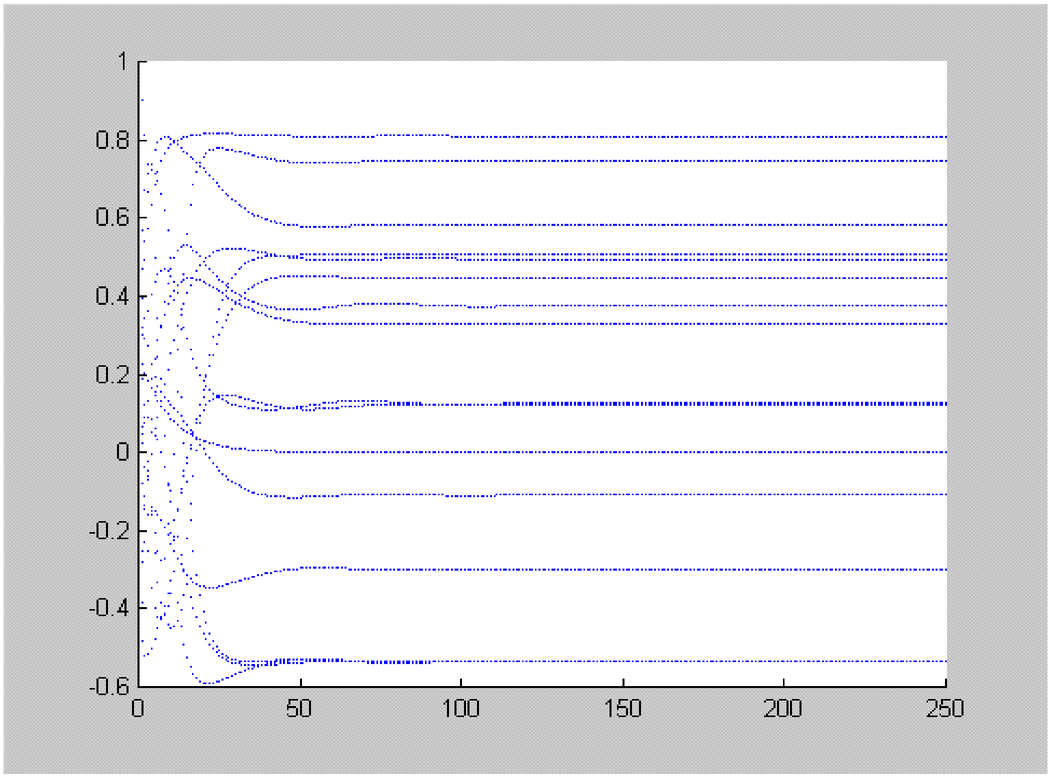

Figure 16

List of Tables

Table 1. Description of the concepts in the Cyprus issue model

C1	Instability /Intensity in Cyprus	C9	Support to the Greek-Cypriot Army
C2	Turkish Forces Actions in Cyprus	C10	Reinforcement of the Greek Army
C3	Turkish Threats	C11	Reinforcement of the Turkish Army
C4	Solution of the Cyprus Problem	C12	Stability of the Greek Government
C5	Greek Political Support	C13	Stability of the Turkish Government
C6	UN talks on the Cyprus Problem	C14	EU/NATO Economic, Military and Political Support
C7	Stability of the Cyprus Government	C15	International Influence
C8	Support to the Turkish Forces	C16	Turkish-Cypriot Reactions

Table 2. Normalized weight matrix

w1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**
0.10	0.29	0.03	0.32	-0.06	0.10	-0.16	0.13	0.21	0.21	-0.23
w12	**w13**	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**
-0.21	0.34	0.29	0.06	0.10	0.13	0.23	0.26	0.34	-0.19	0.26
w23	**w24**	**w25**	**w26**	**w27**	**w28**	**w30**	**w31**	**w32**	**w33**	**w34**
0.23	0.19	0.19	0.06	0.10	0.10	0.10	0.19	0.13	0.23	0.16
w35	**w36**	**w37**	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**
0.16	0.13	-0.23	-0.19	0.23	0.26	0.19	0.13	0.13	-0.03	-0.03

Table 3. Examples of cycles starting and ending at concept C1

C1	w1	+	C5	w13	+	C2	w9	+	C1			
C1	w1	+	C5	w14	+	C3	w10	+	C1			
C1	w2	+	C6	w17	+	C4	w12	-	C1			
C1	w1	+	C5	w15	+	C4	w12	-	C1			
C1	w1	+	C5	w16	+	C6	w17	+	C4	w12	-	C1
C1	w1	+	C5	w14	+	C3	w11	-	C4	w12	-	C1
C1	w3	-	C10	w23	+	C9	w22	+	C4	w12	-	C1
C1	w4	+	C11	w24	+	C8	w21	-	C4	w12	-	C1
C1	w4	+	C11	w24	+	C8	w20	+	C2	w9	+	C1
C1	w5	-	C12	w25	+	C5	w13	+	C2	w9	+	C1
C1	w5	-	C12	w25	+	C5	w14	+	C3	w10	+	C1
C1	w5	-	C12	w26	+	C7	w18	+	C4	w12	-	C1

Table 4. Activation levels (A_i) calculated by the Cyprus issue CNFCM model

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
0.69	0.59	0.75	-0.59	0.79	-0.44	-0.74	0.78
C9	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
-0.65	-0.62	0.60	0.30	0.67	0.56	-0.81	0.54

Table 5. Scenario 1: Calculated activation levels (A_i) for w12=0.7

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
0.67	0.58	-0.19	0.69	0.72	0.48	0.77	0.46
C9	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
0.68	0.63	0.47	0.73	0.48	0.85	0.73	0.42

Table 6. Scenario 2: Final activation levels (A_i) for w9=0

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
-0.11	0.00	0.17	0.07	-0.19	0.06	0.15	-0.09
C9	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
0.15	0.07	0.02	0.14	0.12	0.48	0.34	-0.05

Table 7. Increased instability (A_1=0.95): GECNFCM optimal weight matrix

w1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**	**w12**
0.89	0.90	0.98	-0.03	-0.19	-0.21	0.02	-0.15	-0.75	-0.53	0.18	0.81
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
0.05	-0.33	0.91	0.42	0.89	0.39	0.28	0.73	0.11	-0.59	-0.24	0.88
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
-0.76	-0.68	-0.37	-0.28	-0.40	0.32	-0.78	0.07	-0.84	-0.78	-0.69	0.35
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.52	-0.49	0.71	-0.01	-0.50	-0.02	0.07	0.34	-0.004			

Table 8. Increased instability (A_1=0.95): Activation levels calculated with GECNFCM's optimal weights

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
0.88	-0.75	-0.59	0.76	0.84	0.75	0.69	-0.67	-0.67	0.41	-0.72	-0.79	0.73	0.63	0.81	0.50

Table 9. Solving the Cyprus problem: GECNFCM optimal weight matrix for targeted A_4=-0.9

w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12
0.43	-0.85	-0.98	0.98	-0.04	-0.82	0.63	-0.98	-0.81	-0.61	-0.70	-0.93
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.23	-0.94	-0.44	-0.90	0.76	-0.79	-0.73	0.33	0.55	0.30	-0.81	-0.43
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
0.57	-0.41	-0.58	-0.28	0.55	0.90	-0.40	0.39	-0.64	-0.96	-0.20	-0.76
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.09	-0.21	0.81	0.63	0.20	0.99	-0.76	0.01	-0.22			

Table 10. Solving the Cyprus problem: GECNFCM activation levels for targeted A_4=-0.9

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
0.93	-0.84	0.18	-0.86	0.89	-0.83	0.90	-0.84	-0.66	0.79	0.73	0.79	-0.75	-0.77	-0.83	-0.85

Table 11. Solving the Cyprus problem: GECNFCM weight matrix for targeted A_4=-0.2

w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12
-0.81	0.27	0.76	0.27	-0.86	0.15	-0.09	0.96	0.75	-0.57	0.95	0.52
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
0.58	-0.15	0.41	-0.70	-0.64	-0.60	-0.52	0.33	-0.40	-0.93	-0.89	0.62
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
-0.10	-0.12	-0.79	0.69	0.53	-0.91	0.55	0.57	0.25	0.02	0.65	0.68
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
0.01	0.45	0.57	-0.62	-0.60	-0.12	-0.01	0.52	0.37			

Table 12. Solving the Cyprus problem: GECNFCM final activation levels for targeted A_4=-0.2

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
-0.14	-0.28	-0.30	-0.21	-0.61	0.33	-0.14	-0.02	0.42	-0.57	-0.04	-0.47	-0.58	-0.72	-0.27	0.15

Table 13. Rise of Turkish threats: GECNFCM optimal weight matrix for targeted A_3=0.9

W1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**	**w12**
-0.05	0.84	0.75	-0.78	0.31	-0.69	0.86	0.02	0.78	0.39	0.64	0.63
W13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.23	-0.32	0.26	0.49	0.31	-0.40	0.52	0.45	0.02	-0.22	-0.12	-0.88
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
-0.27	-0.15	0.03	-0.84	-0.85	0.01	-0.74	-0.42	-0.83	0.37	0.40	0.61
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.69	0.52	0.68	0.22	0.35	-0.16	-1.00	-0.54	-0.47			

Table 14. Rise of Turkish threats: GECNFCM activation levels for targeted A_3=0.9

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
0.86	0.84	0.87	0.81	0.34	0.67	0.13	0.76	-0.59	0.36	-0.84	-0.51	-0.10	-0.71	0.68	–0.85

Table 15. Reduction of Turkish threats: GECNFCM optimal weight matrix for targeted A_3=-0.5

w1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**	**w12**
0.95	-0.74	0.88	0.05	0.95	0.41	-0.44	-0.29	-0.35	0.65	0.83	-0.52
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.54	-0.86	-0.67	0.75	-0.13	-0.03	-0.42	-0.31	-0.53	-0.18	0.45	0.38
W25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
-0.76	-0.45	0.23	-0.37	0.48	0.34	-0.58	0.16	-0.69	-0.80	-0.60	0.71
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
0.15	-0.56	-0.68	0.03	0.55	-0.08	0.25	-0.14	-0.54			

Table 16. Reduction of Turkish threats: GECNFCM activation levels for targeted A_3=-0.5

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
0.79	-0.61	-0.26	-0.70	0.87	0.34	-0.39	0.76	0.42	0.51	0.61	-0.68	0.60	-0.50	0.66	0.35

Table 17. Reduction of International Influence: GECNFCM optimal weight matrix for targeted A_{15}=-1

W1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12
0.61	0.13	-0.45	0.45	-0.10	-0.13	-0.23	-0.83	-0.45	1.00	0.20	-0.39
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
0.67	-0.13	0.63	-0.97	0.22	-0.40	-0.31	0.43	-0.75	0.92	0.71	0.82
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
-0.30	0.44	-0.20	0.65	0.30	-0.93	0.89	0.20	-0.05	-0.62	-0.84	0.01
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
0.56	-0.85	0.49	-0.08	0.69	-0.84	-0.81	0.15	-0.84			

Table 18. Reduction of International Influence: GECNFCM activation levels for targeted A_{15}=-1

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
0.88	-0.76	0.85	-0.74	-0.81	-0.58	0.80	0.65	-0.85	-0.83	0.81	0.86	0.51	-0.79	-0.89	0.73

Table 19. Increase of International Influence: GECNFCM optimal weight matrix for targeted A_{15}=-0.4

w1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**	**w12**
0.22	0.95	0.27	0.94	0.73	-0.86	-0.15	-0.04	0.66	-0.52	0.09	0.25
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.90	0.44	-0.24	0.91	-0.15	-0.21	0.05	0.15	-0.36	0.11	-0.40	-0.43
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
0.47	0.75	0.17	0.56	-0.30	0.84	0.39	0.33	0.01	0.05	-0.23	-0,42
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.36	-0.51	-0.45	0.51	-0.26	0.34	0.69	-0.69	0.56			

Table 20. Increase of International Influence: GECNFCM activation levels for targeted A_{15}=-0.4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
-0.39	-0.51	0.42	-0.25	0.74	0.07	0.10	0.02	-0.05	0.05	-0.07	0.51	0.69	-0.48	-0.05	0.48

Table 21. Reduction of support to Turkish Forces in Cyprus: GECNFCM activation levels for targeted A_8=-0.2

w1	**w2**	**w3**	**w4**	**w5**	**w6**	**w7**	**w8**	**w9**	**w10**	**w11**	**w12**
0.62	0.28	-0.72	-0.82	0.36	0.33	-0.60	-0.83	-0.98	0.14	0.01	0.73
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.79	-0.21	0.57	0.08	0.20	-0.12	0.10	-0.05	0.50	-0.50	0.33	0.11
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
0.99	0.50	-0.29	0.86	0.86	0.93	-0.69	-0.13	0.46	0.76	0.64	0,46
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.06	0.34	0.01	0.17	-0.49	0.50	0.70	-0.98	-0.50			

Table 22. Reduction of support to Turkish Forces in Cyprus: GECNFCM activation levels for targeted A_8=-0.2

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
-0.29	0.17	0.61	-0.13	-0.43	-0.40	0.51	0.21	-0.34	0.48	0.30	-0.53	0.50	-0.89	-0.01	0.72

Table 23: S-300 crisis weight values defined by the experts

w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12
0.0	-0.1	0.0	0.0	0.0	-0.4	0.0	0.0	0.8	0.1	-0.3	-0.4
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
0.0	0.1	0.1	0.1	0.2	0.0	0.1	0.1	-0.8	-0.1	0.2	0.2
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
0.0	0.1	0.0	0.25	-0.3	0.1	0.2	0.0	0.0	0.1	0.1	0.0
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.5	-0.3	0.3	0.9	-0.3	0.3	0.1	0.4	0.1			

Table 24: S-300 crisis: CNFCM calculated activation levels

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
0.79	0.87	0.77	-0.77	-0.41	-0.63	-0.41	0.88	0.70	0.00	0.66	0.60	-0.71	0.58	-0.85	-0.27

Table 25: Settling the S-300 crisis: GECNFCM optimal weight matrix for targeted A_I=0.4

w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12
0.10	0.60	-0.65	0.13	0.25	-0.24	-0.21	0.48	0.59	-0.70	-0.49	0.81
w13	**w14**	**w15**	**w16**	**w17**	**w18**	**w19**	**w20**	**w21**	**w22**	**w23**	**w24**
-0.63	-0.67	0.88	-0.41	-0.77	0.79	0.89	0.38	-0.53	-0.04	0.22	-0.32
w25	**w26**	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**
0.99	-0.20	0.80	0.88	-0.52	0.01	0.05	-0.47	-0.62	-0.67	0.88	0.55
w37	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**	**w44**	**w45**			
-0.73	-0.14	-0.50	0.27	-0.41	-0.13	-0.09	-0.41	-0.37			

Table 26. Settling the S-300 crisis: Final activation levels for targeted A_I=0.4

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
0.37	-0.53	-0.10	-0.29	0.44	0.49	-0.53	-0.53	0.80	0.00	0.50	0.58	0.12	0.32	0.74	0.12

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