

Development of intelligent decision support system using fuzzy cognitive maps for migratory beekeepers

Ahmet ALBAYRAK¹, Fecir DURAN², Raif BAYIR^{3,*}

¹Department of Computer Programming, Karadeniz Technical University, Trabzon, Turkey

²Department of Computer Engineering, Faculty of Technology, Gazi University, Ankara, Turkey

³Department of Mechatronics Engineering, Faculty of Technology, Karabük University, Karabük, Turkey

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Abstract: This study presents the development of an intelligent information system using fuzzy cognitive maps that provides information to migratory beekeepers about the nectar flow and climate conditions in the regions they will visit. Beekeeping is an agricultural activity essentially focused on honey production. High honey yields in beekeeping can be achieved through migratory beekeeping. Migratory beekeepers complete the honey production season by carrying their hives to regions with high nectar flow. Beekeepers decide on the regions they will visit based on their previous experiences. In this study, a software-based system that provides information to the beekeepers about the honey yield in the regions they will visit has been developed. It is an intelligent information system developed using fuzzy cognitive maps that helps the beekeepers in choosing the region they will visit.

Key words: Fuzzy cognitive maps, intelligent information system, migratory beekeeping, honey bee

1. Introduction

Honey bees are creatures that directly or indirectly make substantial ecological contributions. Around the world, 35% of crop production for human food depends on pollination by insects, and 75% of this production is plant species of vital importance, especially for humans [1]. The economic value of pollination by insects around the world amounts to about €153 billion per annum [2]. Bees are among the most important pollinators. Honey bees are estimated to be effective in the pollination of 80% of agricultural crops in Europe [3]. Honey bee products such as honey, royal jelly, bee wax, bee pollen, bee venom, and propolis all hold a special place in the lives of people. Some products are used in the pharmaceutical industry, while others are used as nutrients due to the enzymes they contain [4]. Nectar-producing plants, used by honey bees to produce honey, vary from one region to another. Given its geographical location, climate conditions, and vegetation, Turkey holds a very convenient position for beekeeping activity [5]. With the spring months coming, the bloom period of plants with nectar and pollen production potential starts. The bloom period varies depending on the plant species, time, and altitude. Migratory beekeepers perform their beekeeping activities by following the bloom periods, based on their previous experiences. Migratory beekeeping is necessary for generating higher economic income in beekeeping [6].

Fuzzy cognitive map (FCM) is a method used for modelling complex systems through the use of existing knowledge and human experience. FCM is used to predict the behaviour of a system, to test the influence of

*Correspondence: rbayir@karabuk.edu.tr

parameters, and to analyse and simulate the system. FCM performs modelling using a connection matrix based on experience. The adaptation of the weight matrix is carried out through supervised learning, unsupervised learning, and hybrid learning. Among these learning models, the most preferred one in the literature is the nonlinear Hebbian learning algorithm. The second most preferred one is the genetic algorithm-based learning model [7]. In 2014, a decision support system with a user interface was developed for renewable energy resources in Greece. The system was used to plan local energy investments and define profitability rates [8]. FCM was also used in predicting the yield in cotton crop production in a precision agriculture application [9]. Besides these, FCM was also successfully used in predicting the yield of apple crops. After developing the weight matrix, the learning of the system was done with a nonlinear Hebbian algorithm [7]. FCM was also frequently used for medical diagnosis in the healthcare sector [10–12] as well as in the medical decision-making processes [13].

Intelligent information systems are systems where human behaviours considered “intelligent” are transferred to software tools by means of artificial intelligence techniques. Such systems help experts/decision makers use reasoning knowledge and inference methods. The other class includes agents, which are structured as softbots and knowbots. There is also a study on the design of a decision support system that gave advice to decision makers [14]. In the last 30 years, the loss of high-quality soil due to the use of fertilizers and pesticides has reached threatening dimensions. The soil nitrogen balance can be simulated by a knowledge base and an analytical modular part. The analytical part is built in a four-level structure consisting of eleven fuzzy systems. In this way, the recommended amount of fertilizer can be analysed and the soil quality can be preserved [15].

This study consists of the literature review given in the introduction as well as the following sections: selection of experts to work with the relevant stakeholders within the issue, the development of fuzzy cognitive map, implementation of the intelligent information system, testing, and conclusion.

2. Materials and methods

First, the subject of the study must be modelled conceptually to achieve success. Conceptual modelling is particularly preferred for environmental applications. Conceptual models can be used to explain relations, to test ideas and explore, and to control the inference and causality and identify information [16]. Conceptual models begin with gathering qualified information from stakeholders who have knowledge of the system operation and structure [17]. A methodological approach is used in the modelling process of this study. This approach consists of three basic steps. Step 1: Identifying stakeholders (institutes, agricultural development agencies, and academics). Step 2: With the selection of experts, identifying and determining the concepts and the nature of cause–effect relationships between these concepts. At this stage the conceptual map has been created. Step 3: The conceptual map created in the second step is applied and results are discussed.

As the first step in the methodology of the study, all stakeholders involved in the issue were considered in the selection of experts. Therefore, the agricultural credit cooperative of each province, which plans agricultural activities to make them sustainable and respectful to the environment and nature, was determined as the first stakeholder. The Beekeeping Research and Development Institute was chosen as the second stakeholder because of its academic studies on bee zoology, hive management, and efficiency. The last stakeholder consisted of beekeepers who do beekeeping as their only source of livelihood. These beekeepers are united within the Beekeepers Association. The second step of work started with experts chosen by these three stakeholders.

Honey production is the primary aim of beekeeping. However, it requires meeting various conditions inside and outside the hives. Factors that affect honey production can be counted as follows: number of bees in the colonies and their health condition; the number and intensity of nectar-producing plants in the region

where the colonies are located; the age and fertility of the queen bees in the colonies; adaptation of bees to the region in terms of racial and morphological features; whether agricultural spraying has been performed around the region and, if so, the intensity of spraying.

There are various factors that cause a decrease in the number of honey bees. Viral diseases, fungal diseases, and environmental factors are among these [18–21]. American and European foulbrood diseases are among the endemic diseases [22]. There are also various local epidemics in beekeeping in the literature, the causes of which have not yet been explained or solved [23]. Mass bee losses are also among these endemics. According to the results of a German bee-monitoring programme, there is a significant relationship between mite infestation and winter losses of colonies [24]. A study conducted in Greece can be counted as one of the best studies on the negative impacts of global warming and seasonal changes on bee colonies. In that study, Bacandritsos et al. researched sudden mass death of bees and found that there were 5 different viruses that caused these deaths. Temperature and humidity fluctuations were among the reasons for virus formation [25].

The lifespan of honey bees varies depending on different periods of the year. In order to ensure the continuity of the hive, the queen bees must lay eggs consistently. The egg-laying capacity of the queen must be sufficient in order to achieve the sufficient number of bees for honey production [26].

Achieving success in beekeeping depends on the use of honey bee ecotypes that are suitably adapted to the region. Due to climate conditions, Turkey hosts various honey bee ecotypes [27]. Another important factor affecting honey production is agricultural spraying. Agricultural spraying in the regions where beekeeping activities are performed affects the genetic structure of bees. Exposure to pesticides for a long time even corrupts the gene structure of bees [28]. Nectar-producing plants in the beekeeping regions and the amount of nectar they yield are extremely important for honey production. Honey bees use nectar and pollen to make honey as well as to feed the brood [29].

A study conducted in Turkey by the General Directorate of Forestry examined the amounts of pollen and nectar in honey samples of 100 g. Based on the amounts, a classification was developed, resulting in two categories: nectar production and pollen production [30,31]. In the report, the potential was labelled as “dominant” in cases where the amount of nectar or pollen available in 100 g of honey was equal or over 45 g. In the same way, it was labelled as “secondary” when the amount available was between 16 and 45 g, and as “minor” when the amount was between 3 and 15 g. The label “trace” was used for nectar or pollen amounts less than 3 g in 100 g of honey.

The team of experts from stakeholders were asked to rank pollen- and nectar-producing plants’ effects on honey production. In the survey, questions were asked consisting of five membership functions (Low, Little low, Medium, Little high, High) as in FCM. The values from each expert were reduced to a single value using weighted average method (the nectar or pollen that takes values in the interval $[-1, 1]$).

The effect of nectar-producing plants on honey production was 0.65, while that of pollen-producing plants was 0.35. Since it is the honey production we take into consideration, nectar and pollen potentials must be estimated separately for each plant species. In Eq. (1), N_i represents the nectar rate of a nectar-producing plant species, while N_{ic} represents the coefficient that measures the effect of nectar on honey production. Likewise, P_i represents the pollen rate of a plant species with pollen potential, while P_{ic} represents the constant that determines the effect of pollen on honey production. Eq. (1) estimates the nectar flow coefficient N_y . While calculating the coefficient, other factors were not taken into account.

$$Ny = \sum_{i=0}^{i=N} Ni \times Nic + Pi \times Pic \quad (1)$$

FCM is a combination of fuzzy logic and cognitive mapping [32]. FCM includes factors, i.e. concepts/nodes. These factors are important elements of the mapped system and they are linked. FCM also includes arcs that represent causal relationships between the factors. Direct arcs are labelled with fuzzy values in the interval $[0, 1]$ or $[-1, 1]$ and this represents the strength of impact between the concepts. The fuzzy part allows us to define the degree of causality of the link between the concepts of these diagrams [33]. Moreover, causality is inferred by positive (+) and negative (-) signs on each nodal link. Positive causality is represented with (+value), negative causality is represented with (-value), while 0 indicates that there is no causal interaction. FCM can model the link between the concepts in the problem space through the use of weight matrix. The problem can be transferred to a computer environment by computing the link between the concepts. The reason for using FCMs in this study is the requirement of user information and the need for digitizing experience-based information received from the experts. Favourable results can be obtained in FCM through learning the weight matrix. Therefore, nonlinear Hebbian learning was preferred.

In this study, while choosing the concepts for the FCM, factors that affect honey production were taken into account. The concepts were identified by experts selected from the stakeholders. Since no information was obtained about agricultural spraying, it was not included in the concepts. Because of the unauthorized use of pesticides by our agricultural producers, agricultural pesticide information has been regarded as invalid information and this information has not been included in the system. The cause-effect relationships between concepts were determined by experts. Furthermore, limit values for the concepts (membership functions) can be determined by experts. The operating principle of intelligent decision support system is given in Figure 1 as a block scheme. The weight matrix has taken the initial values from the survey results created by experts selected from the stakeholders. Users answer 12 questions about their bee colony at first. These answers are fuzzified by PHP functions running in the background. Meteorological data obtained from State Meteorology Directorate is also fuzzified.

The names of plants containing nectar or pollen, altitude range where it grows, flowering period, and density are saved to the mySql database. This information is fuzzified for FCM automatically when user selects the city they want to go to. FCM, which is developed using user data, nectar-pollen data, and meteorological data, runs with a nonlinear Hebbian learning algorithm until a specified stopping criterion is met. The stopping criterion was determined according to the difference in the error occurring in each iteration. Once the stopping criterion is met, the system shows the state vector to the user in an understandable manner. Membership functions representing the concepts are chosen based on the responses of experts. Membership functions for concepts are determined by types and by experts who will be formed in how many membership functions. Table 1 shows the concepts used in this study.

The state vector consists of the concepts given in Table 1. Experts have said that some of the concepts lack a unit and should be expressed with crisp values instead of membership functions. Limit values of the concepts represented by membership functions are given in Table 2. Membership functions of distribution are determined by the feedback received from trial and error and experts.

C1 and C2, concepts expressing nectar and pollen plants, are calculated according to Eq. (1). Because of the variation of nectar and pollen plants, the calculation results can be very different. C1 and C2 are given in percentiles (%) and so the value obtained from equation is converted into the range of percentiles. Crisp values are determined for C13, C14, and C16, which are not represented by a membership function. These crisp

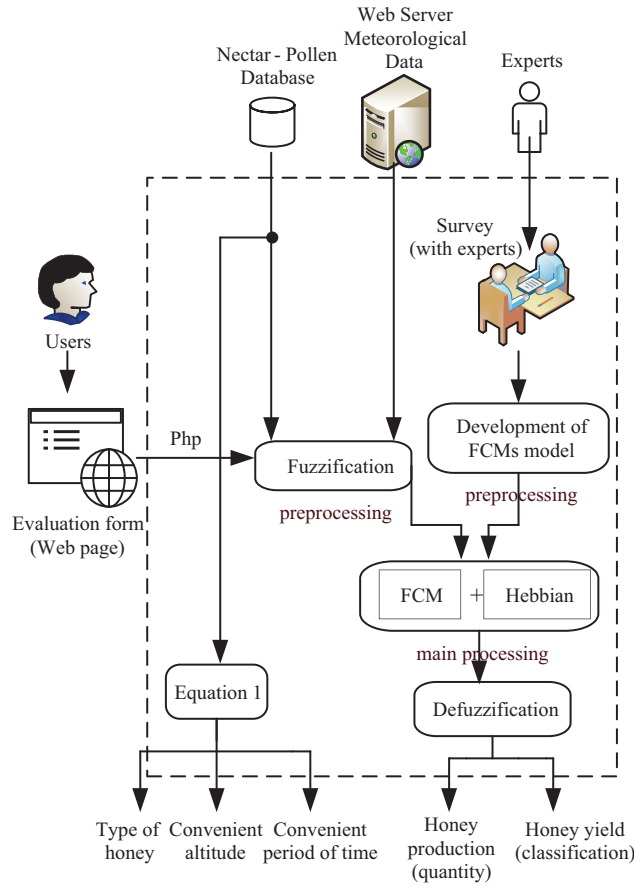


Figure 1. Block diagram.

values vary depending on the selected region. The crisp value for C13 is 1 if bee morphology and ecotype is selected properly. Otherwise the crisp value for concept C13 is 0.3. If the selection of the bee morphology is not appropriate for the region, bees cannot collect enough pollen or nectar from flowers. Moreover, bee ecotypes must be appropriate for the region. Likewise, if the correct bee race is selected, the crisp value of C14 is 1. Otherwise the crisp value for C14 is 0.2. It is not possible to produce intermediate values for these two concepts because these concepts define the basic requirements for beekeepers. Beehive type (C16) is assessed according to Eq. (2).

$$C16 = \begin{cases} 1 & \text{if } C16 = \textit{Thermo - Special Beehive} \\ 0.8 & \text{if } C16 = \textit{Modern Beehive} \\ 0.2 & \text{if } C16 = \textit{Primitive Beehive etc.} \end{cases} \quad (2)$$

In the FCM, the values of concepts are represented by the state vector (A_i) [34]. Since C3, C4, C5, and C6 include meteorological data, they were obtained from the state meteorological service. The data includes information from the last 50 years. C18 (honey production) constitutes the output of the information system. In the present study, the output was represented with 3 membership functions. Defined as low, medium, and high, these membership functions offer information to the user about the amount of honey to be produced. These membership functions were designed as 0–10, 10–20, and above 20. These concepts are also called output decision concepts [35]. Membership functions of concepts are determined according to experts' opinions. Trapezoidal

Table 1. Concepts of the fuzzy cognitive map.

Concepts	Number of Membership Function	Unit
C1: Nectar-producing plants	Three membership functions	%
C2: Pollen-producing plants	Three membership functions	%
C3 Average temperature	Three membership functions	°C
C4: Sunshine duration	Three membership functions	hour
C5: Number of rainy days	Three membership functions	day
C6: Average precipitation	Three membership functions	kg/m ²
C7: Population size of adult worker bees	Five membership functions	cm ² /colony
C8: Brood population size	Five membership functions	cm ² /colony
C9: Age of the queen bee	Three membership functions	month
C10: Egg-laying capacity of the queen bee	Five membership functions	%
C11: Viral diseases	Five membership functions	%
C12: Fungal diseases	Five membership functions	%
C13: Morphological characteristics and ecotypes of bees	Crisp Value	None
C14: Bee race	Crisp Value	None
C15: Beekeeper experience	Five membership functions	Year
C16: Hive type	Crisp Value	None
C17: Flight frequency of worker bees	Five membership functions	%
C18: Honey production	Three membership functions	kg/colony

Table 2. Limit values of the concepts.

	Nectar-producing plants (%)	Pollen-producing plants (%)	Average temperature (°C)	Sunshine duration (hours)	Number of rainy days (days)	Average precipitation (kg/m ²)	Honey production (kg/colony)	Age of the queen bee (months)
Low	0–30	0–30	0–10	0–3	0–15	0–30	0–10	0–12
Medium	30–60	25–50	10–20	3–6	15–25	30–60	10–20	12–36
High	60–100	50–100	>20	>6	>25	>60	>20	>36
	Population size of adult worker bees (cm ² /colony)	Brood population size (cm ² /colony)	Egg-laying capacity of the queen bee (%)	Viral diseases (%)	Fungal diseases (%)	Beekeeper experience (years)	Flight frequency of worker bees (%)	
Low	0–20	0–20	0–20	0–10	0–10	<3	0–10	
Little Low	20–30	20–30	20–35	10–20	10–20	3–5	10–20	
Medium	30–50	30–50	35–55	20–50	20–40	5–10	20–50	
Little High	50–70	50–70	55–75	50–75	40–60	10–15	50–70	
High	>70	>70	>75	>75	>60	>15	>70	

or triangular membership functions were used for different concepts. Figure 2 shows the membership functions created as a result of qualified information received from experts.

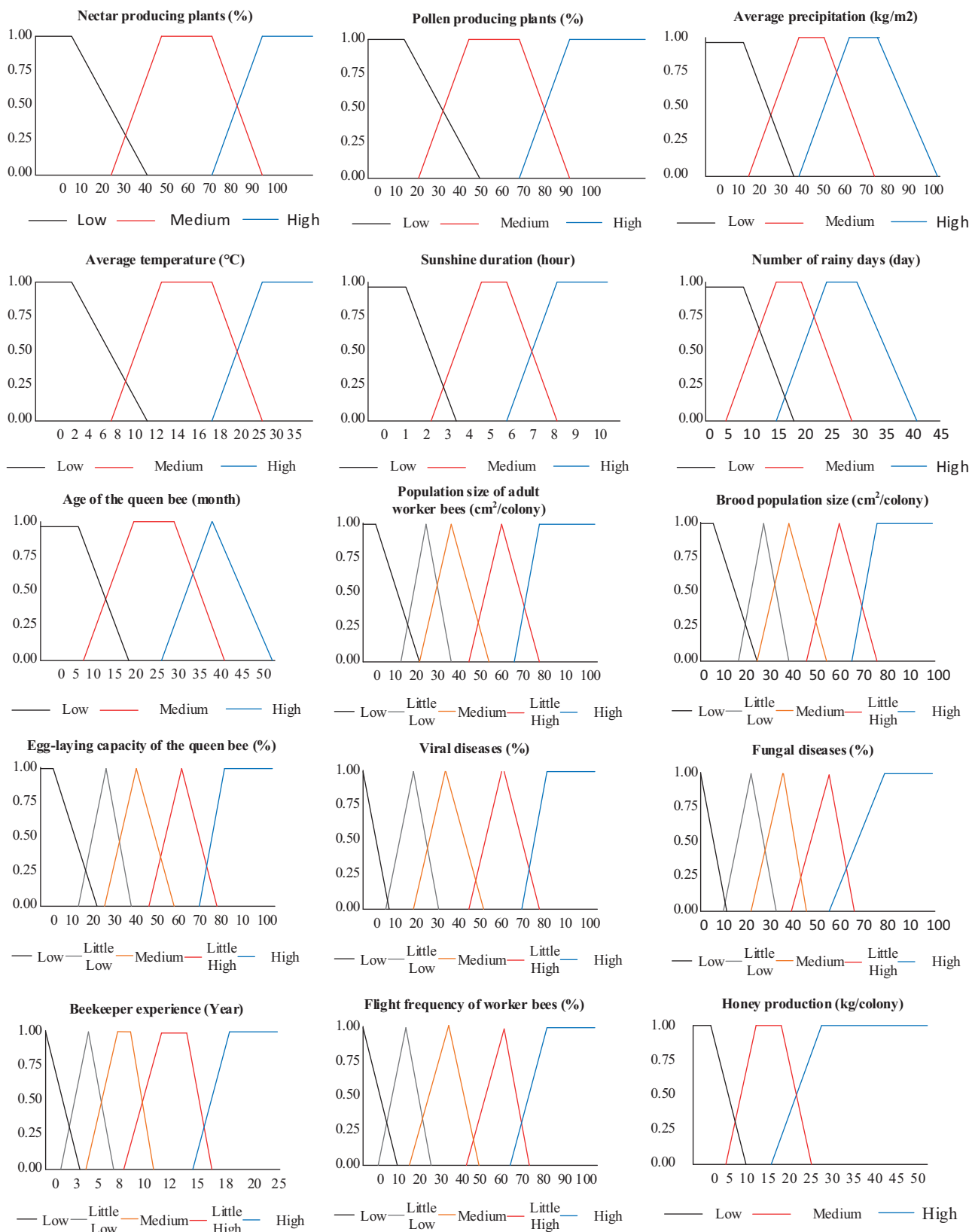


Figure 2. Determination of membership functions of concepts for cognitive map.

A weight matrix containing the relationships between concepts was created with 15 experts including 5 from each of the stakeholders. The effects of each concept on other concepts were examined while creating the weight matrix. In the survey carried out for this purpose, experts' opinions were represented with if-then rules. As a result of this survey, a weight matrix representing the causality relationships between the concepts was obtained (W_{ij}). In this way, a matrix of $W_{ij} = 18 \times 18$ was obtained. The link between the concepts is used to update the FCM's state vector. Updating was done by multiplying the state vector A_i by the values of related weight matrix W_{ij} . In addition, the calculation involves the sum of the previous value of the state vector. Eq. (3) shows the formulation:

$$A^{(k)} = f(A^{(k-1)} + \sum A^{(k-1)} \times W, \tag{3}$$

where $A^{(k-1)}$ is the previous value of state vector and W is the weight matrix. A threshold function is used for transferring the values obtained to the new state vector $A(k)$. Eq. (4) represents the threshold function. Since the state vector has positive values in the range $[0, 1]$, a sigmoid threshold function was used in this study.

$$W_{ji} = \frac{\int y^y \mu(y) dy}{\int y^y dy} \tag{4}$$

The threshold function guarantees that the values of state vector are in the range $[0, 1]$. Figure 3 shows the fuzzy cognitive map specially designed for the problem in this study. An improved FCM algorithm can be used for modelling with high uncertainty [9]. Eq. (5) represents the updating formulation for the improved state vector. In this study, Eq. (5) is used to update the state vector.

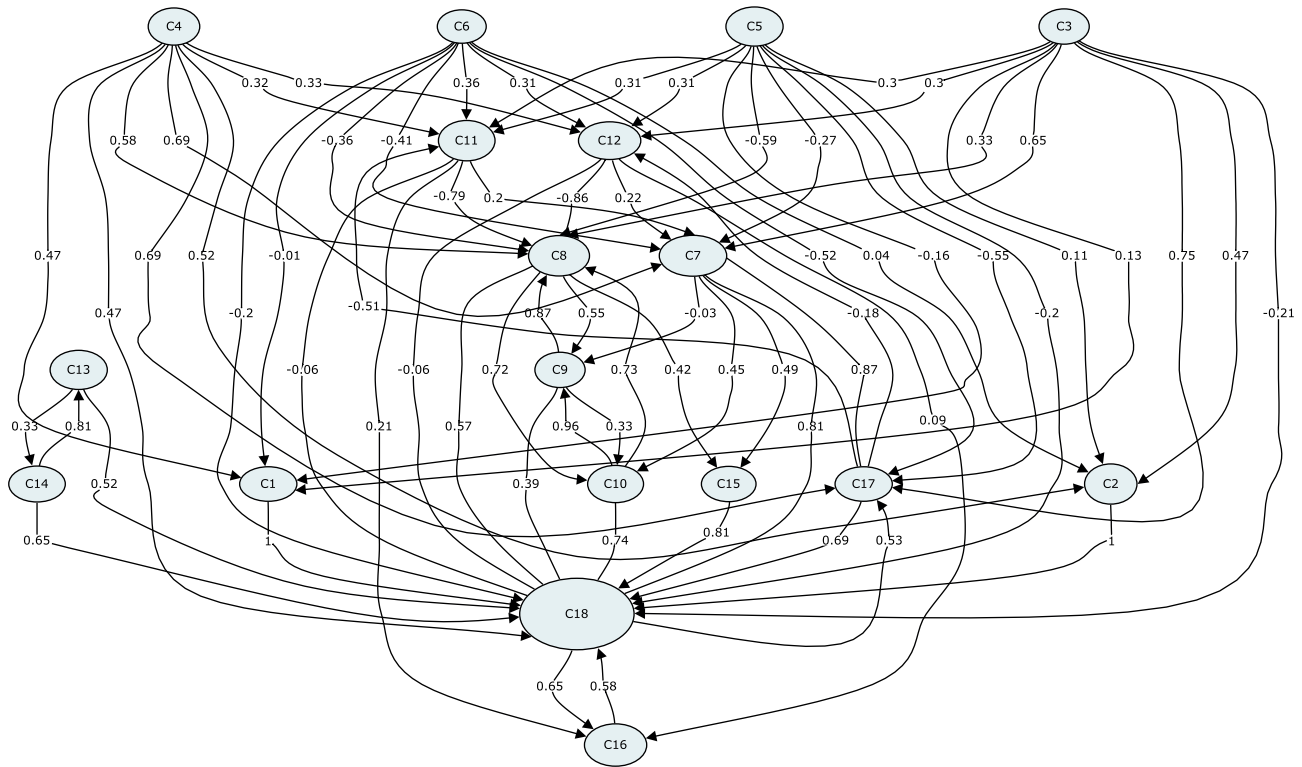


Figure 3. Fuzzy cognitive map.

$$A_i(k+1) = f((2A_i(k) - 1) + \sum_{j=1}^{j=N} (2A_j(k) - 1) \times W_{ji}) \quad (5)$$

where N is the number of concepts and k indicates the iteration step. The state vector is computed iteratively. The iteration stops when the state vector reaches a stable state. $A_k = A_{k-1}$ or $A_k - A_{k-1} \leq e$ is required to stop simulation. Here e indicates the acceptable error rate ($e = 0.001$). The weight matrix in the FCM representing the link between the concepts must be trained. The learning stops when the acceptable error rate is reached. In the present study, among the unsupervised learning approaches, a nonlinear Hebbian learning algorithm is used for the learning of the weight matrix. Immediately after updating the state vector, the weight matrix is updated through the use of the nonlinear Hebbian learning algorithm. In this algorithm, learning rule, learning parameter n_k , and weight decay parameter y are used. Eq. (6) shows the nonlinear Hebbian learning algorithm.

$$W_{ji}^{(k)} = yW_{ji}^{(k-1)} + n_k A_i^{(k-1)} \left(A_j^{(k-1)} - \left(W_{ji}^{(k-1)} \right) W_{ji}^{(k-1)} A_i^{(k-1)} \right) \quad (6)$$

The nonlinear Hebbian learning algorithm is calculated for all the values in the weight matrix with a value relation. Values that have no value–no relation remain 0, which is the initial value.

3. Experimental results

The intelligent information system was designed as a PHP-based website open to users who were granted permission. Users of the website are requested to provide information about the bees they have and to select a province where they would like to carry their hives (honeybeemonitoring.com/#sec3). Figure 4 shows a snapshot of the website.

Three different scenarios were used to test the information system. For the first scenario, the state vector is formed as follows: $A^0 = [0.179 \ 0.164 \ 0.457 \ 0.23 \ 0.532 \ 0.254 \ 0.125 \ 0.125 \ 0.25 \ 0.125 \ 0.875 \ 0.875 \ 0.5 \ 0.5 \ 0.125 \ 0.15 \ 0.125]$. For this scenario, disease is observed in the hives; the number of worker bees is small and their activity level is low; the number of broods is small; the queen bee is old and has low egg-laying capacity; the beekeeper has very little experience; the hive type is primitive, and the bee ecotype is not suitably adapted to the region. This selection is for Ankara Province. Ankara has a low average temperature (C3: 0.457) with a small number of sunny days (C4: 0.23) and a great number of rainy days (C5: 0.532). The meteorological data used in the information systems cover a period of 7 months. In order to obtain more accurate results from the system, and considering that beekeeping activities are not sustained during the whole year, such a limitation was used. It requires 11 iterations for the FCM with nonlinear Hebbian learning to reach the termination criterion. The final state vector is as follows: $A^{11} = [0.128 \ 0.199 \ 0.149 \ 0.262 \ 0.738 \ 0.816 \ 0.286 \ 0.114 \ 0.277 \ 0.168 \ 0.355 \ 0.758 \ 0.5 \ 0.5 \ 0.295 \ 0.123 \ 0.133]$. At this point, C18 (honey production) was 0.12. This means that honey production is at a very low level for the selected region and criteria. Figure 5 shows the values of the concepts over iterations.

For the second scenario, disease observed in the hives is at a low level; the number of worker bees and broods is average; the queen bee is middle-aged and has normal egg-laying capacity; the beekeeper is experienced; the hive type is modern and the bee ecotype is suitably adapted to the region. The initial state vector is as follows: $A^0 = [0.189 \ 0.264 \ 0.557 \ 0.23 \ 0.632 \ 0.254 \ 0.5 \ 0.5 \ 0.35 \ 0.5 \ 0.5 \ 0.5 \ 1 \ 1 \ 0.5 \ 0.75 \ 0.5]$. In this case, it requires 17 iterations for the decision support system to reach a stable state. The final state vector is $A^{17} = [0.759 \ 0.778 \ 0.879 \ 0.8 \ 0.105 \ 0.121 \ 0.796 \ 0.817 \ 0.755 \ 0.756 \ 0.461 \ 0.55 \ 0.531 \ 0.5 \ 0.602 \ 0.76 \ 0.85]$. C18 (honey

INTELLIGENT INFORMATION SYSTEM WITH FUZZY COGNITIVE MAPS

Choose the province: Ankara

What is the population size of adult worker bees?: Very small

What is the brood population size? (as surface area): Very small

How old is your queen bee?: Young

How much is the egg-laying capacity of the queen bee?: Very small

Is there any viral disease observed in the hive? To what extent?: No disease

Is there any fungal disease observed in the hive? To what extent?: No disease

Which race are your bees similar to in terms of morphological characteristics and ecotype?: Carniolan Bee

What is the race of your bees?: Carniolan Bee

How many years of experience do you have in beekeeping?(Year): Less than 1 year

Choose the hive type: Thermo Hive

What is the flight frequency of your worker bees?: Very Low

EVALUATE

Figure 4. Intelligent information system website.

production) was 0.635. This value indicates a season with a good level of honey production. Honey production per hive can reach up to 20 kg. Figure 6 shows the values of the concepts over iterations for this scenario.

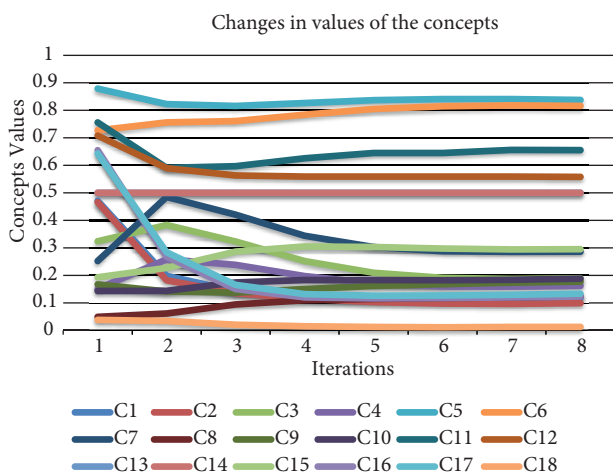


Figure 5. Changes in the concepts.

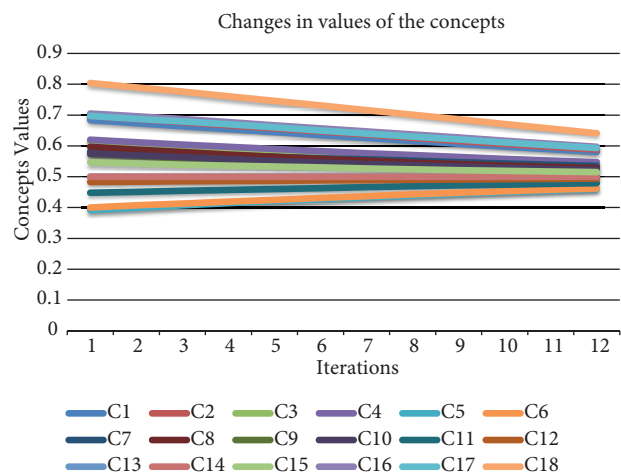


Figure 6. Changes in the concepts.

For the final scenario, the number of worker bees and broods is large; the flight frequency of worker bees is high; no disease is observed in the hive; the queen bee is young and has high egg-laying capacity; the beekeeper is highly experienced; the hive type is thermo (special hive), and the bee ecotype is suitably adapted to the region. The state vector for this situation is as follows: $A^0 = [0.179 \ 0.164 \ 0.557 \ 0.13 \ 0.732 \ 0.254 \ 0.875 \ 0.875 \ 0.7 \ 0.875 \ 0.125 \ 0.125 \ 1 \ 1 \ 0.875 \ 0.85 \ 0.875]$. It requires 44 iterations for the intelligent information system to reach a stable state. The final state vector after iterations is as follows: $A^{44} = [0.557 \ 0.408 \ 0.5 \ 0.514 \ 0.417 \ 0.477 \ 0.53 \ 0.52 \ 0.51 \ 0.51 \ 0.48 \ 0.49 \ 0.5 \ 0.5 \ 0.511 \ 0.59 \ 0.53 \ 0.13]$. C18 (honey production) was 0.86. Figure 7 shows the values of the concepts over iterations for this scenario. This value indicates a season with a very high level of honey production. Honey production per hive can reach more than 20 kg.

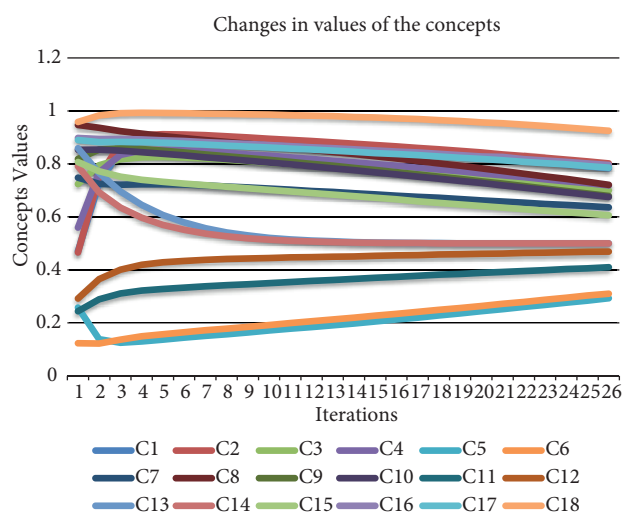


Figure 7. Changes in the concepts.

The intelligent information system was developed especially to help migratory beekeepers. Although the information system has a single output (C18 = honey production), it will be able to provide more detailed information about the region. Placing the hives at proper altitudes during the bloom periods will increase honey yield. Therefore, detailed information is given about the regions planned to be visited based on bloom periods and altitudes.

Another output of the information system is related to the honey type obtained in the regions. Honey is produced from the nectar-producing plants in the region where the hives are placed. Honey type depends upon the nectar potential of the plants. Five different types of honey are produced in Turkey [36]. These are chestnut honey, thyme flower honey, highland honey, pine honey, and citrus flower honey. This study provides information about the type of honey to be produced based on the data retrieved from the database about the nectar- and pollen-producing potentials of plants in the selected region.

4. Discussion and conclusion

The intelligent information system provides users with output information, such as the potential amount of honey to be produced, with the current bee colonies in the selected region, the type of honey, honey yield potential of the region (good, bad etc.), and optimum time and altitude for beekeeping in the selected region. It is continually updated with meteorological data during the operating period. With this feature, this study can be defined as a sustainable agricultural application.

In future work, geographical information systems will be included as a module to ensure more stable and real-time operation. Moreover, new wireless sensor networks will be established with sample beehives placed in certain locations in Turkey to get real-time data. With these networks, beehive parameters such as weight, temperature, humidity, amount of carbon dioxide, and the number of incoming and outgoing bees will be collected continuously. Thus, accuracy of the system will increase. Cloud-based web automation is considered as a choice to improve the software. The web automation will be designed as a framework to create a more flexible, dynamic, and scalable system.

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References

- [1] Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T. Importance of pollinators in changing landscapes for world crops. *The Roy Soc A* 2007; 274: 303-313.
- [2] Gallai N, Salles JM, Settele J, Vaissiere BE. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecol Econ* 2009; 68: 810-821.
- [3] Breeze TD, Bailey AP, Balcombe KG, Potts SG. Pollination services in the UK: how important are honeybees? *Agr Ecosyst Environ* 2011; 142: 137-143.
- [4] Sudarsan R, Thompson C, Kevan GP, Eberl JH. Flow currents and ventilation in Langstroth beehives due to brood thermoregulation efforts of honeybees. *J Theor Biol* 2012; 295: 168-193.
- [5] Davis PH. *Flora of Turkey and East Aegean Islands*. Edinburgh, UK: Edinburgh University Press, 1985.
- [6] Gösterit A, Kekecoglu M, Cıklı Y. Comparison of some performance traits of yiğilca local honey bee with caucasian and anatolian crosses. *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi* 7: 107-114.
- [7] Papageorgiou EI, Aggelopoluo KD, Gemtos TA, Nanos GD. Yield prediction in apples using fuzzy cognitive map learning approach. *Comput Electron Agr* 2013; 91: 19-29.
- [8] Kyriakarakos G, Patlitzianas K, Damasiotis M, Papastefanakis D. A fuzzy cognitive maps decision support system for renewables local planning. *Renew Sust Energ Rev* 2014; 39: 209-222.
- [9] Papageorgiou EI, Markinos AT, Gemtos TA. Fuzzy cognitive map based approach for predicting yield in cotton crop production as a basis for decision support system in precision agriculture application. *Appl Soft Comput* 2011; 11: 3643-3657.
- [10] John RI, Innocent PR. Modeling uncertainty in clinical diagnosis using fuzzy logic. *IEEE T Syst Man Cybern Part B* 2005; 35: 1340-1350.
- [11] Papageorgiou EI, Spyridonos P, Ravazoula P, Stylios CD, Groumpos PP, Nikiforidis G. Advanced soft computing diagnosis method for tumor grading. *Artif Int Med* 2006; 36: 59-70.
- [12] Papageorgiou EI, Spyridonos P, Glotsos D, Stylios CD, Groumpos PP, Nikiforidis G. Brain tumor characterization using the soft computing technique of fuzzy cognitive maps. *Appl Soft Comput* 2008; 8: 820-828.
- [13] Papageorgiou EI, Stylios C, Groumpos P. An integrated two-level hierarchical system for decision making in radiation therapy based on fuzzy cognitive maps. *IEEE T Biomed Eng* 2003; 50: 1326-1339.
- [14] Beemer BA, Gregg DG. *Advisory Systems to Support Decision Making, International Handbooks Information System*. Berlin, Germany: Springer, 2008.
- [15] Papadopoulos A, Kalivas D, Hatzichristos T. Decision support system for nitrogen fertilization using fuzzy theory. *Comput Electron Agr* 2011; 78: 130-139.

- [16] Argent MR, Sojda SR, Guipponi C, McIntosh B, Voinov AA, Maier H. Best practices for conceptual modelling in environmental planning and management. *Environ Modell Softw* 2016; 80: 113-121.
- [17] Mourhir A, Rachidi T, Papageorgiou EI, Karim M, Alaoui FS. A cognitive map framework to support integrated environmental assessment. *Environ Modell Softw* 2016; 77: 81-94.
- [18] Rosenkranz P, Aumeier P, Ziegelmann B. Biology and control of *Varroa destructor*. *J Invertebre Patho* 2010; 103: 96-119.
- [19] Vanengelsdorp D, Hayes J Jr, Underwood RM, Pettis J. A survey of honey bee colony losses in the U.S., fall 2007 to spring 2008. *PLoS ONE* 2008; 3: e4071.
- [20] Fries I. *Nosema ceranae* in European honey bees (*Apis mellifera*). *J Invertebre Patho* 2010; 103: 73-79.
- [21] Genersch E. American Foulbrood in honeybees and its causative agent *Paenibacillus larvae*. *J Invertebe Patho* 2010; 103: 10-19.
- [22] Pernal S. Statement on honey bees losses in Canada, final revision. Canadian Association of Professional Apiculturists, 2008.
- [23] Underwood R, Vanengelsdorp D. Colony collapse disorder: Have we seen this before? *Bee Culture* 2007; 35: 13-18.
- [24] Association of the German Bee Research Institutes (AGBRI). Monitoring projekt Völkerverluste Untersuchung jahre 2004–2008.
- [25] Bacandritsos N, Granato A, Budge G, Papanastasiou I, Roinioti E, Caldon M, Falcaro C, Gallina A, Mutinelli F. Sudden deaths and colony population decline in Greek honey bee colonies. *J Invertebre Patho* 2010; 105: 335-340.
- [26] Southwick EE. Metabolic energy of intact honeybee colonies. *Comput Biochem Phys Part A Phys* 1982; 71: 277-281.
- [27] Yücel B, Kösoğlu M. Comparisons of Muğla ecotype and Italian cross honey bees for some performances in Aegean Region (Turkey). *Kafkas Univ Vet Fak* 2011; 17: 1025-1029.
- [28] Schmehl RD, Teal PEA, Frazier JL, Grozinger CM. Genomic analysis of the interaction between pesticide exposure and nutrition in honey bees (*Apis mellifera*). *J Insect Phys* 2014; 71: 177-190.
- [29] McLellan AR. Honeybee colony weight as an index of honey production and nectar flow: a critical evaluation. *J Appl Ecol* 1977; 14: 401-408.
- [30] General Directorate of Forestry (GDF). Prominent pollen and nectar producing plant species in Turkey: Bloom periods, pollen or nectar capacities and the provinces in which they grow. Ankara, Turkey, 2012.
- [31] Sorkun K. Türkiye'nin Nektarlı Bitkileri Polenleri ve Balları. Ankara, Turkey: Palme Press, 2007.
- [32] Kosko B. Fuzzy cognitive maps. *Int Man-Machine Studies* 1986; 24: 65-75.
- [33] Papageorgiou EI. A review of fuzzy cognitive maps research during the last decade. *IEEE T Fuzzy Syst* 2013; 21: 66-79.
- [34] Kannappan A, Tamilarasi A, Papageorgiou EI. Analyzing the performance of fuzzy cognitive maps with non-linear hebbian learning algorithm in predicting autistic disorder. *Expert Syst Appl* 2011; 38: 1282-1292.
- [35] Papageorgiou EI, Poczeta K, Lapidou C. Application of fuzzy cognitive maps to water demand. *IEEE Int Conf Fuzzy (FUZZ-IEEE)*; 2–5 August 2015; İstanbul, Turkey. pp. 1-8.
- [36] Küçük M, Kolaylı S, Karaoğlu Ş, Ulusoy E, Baltacı C, Candan F. Biological activities and chemical composition of three honeys of different types from Anatolia. *Food Chem* 2007; 100: 526-534.