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Review Paper

Evaluation of the Performance of Intelligent Spray Networks Based On Fuzzy Logic

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Abstract

Considering the ever increasing advances in technology, especially in the field of IT, It is felt necessary to approach more correctly the question of using pesticides at the suitable time and in a scientific way; because it is observed that, due to lack of necessary knowledge in deciding the type, the amount, or the application time of pesticides, using pesticides not only does not solve problems but causes irreparable environmental and economic damages as well. Therefore, in this article we tackle the default implementation and mechanization of the process of controlling pests, one of the methods of which is the use of intelligent spray using the fuzzy logic. In this method, based on the prevailing conditions in the field, it is divided into several parts so as to protect the environment, to economize in the use of pesticides, and to avoid spraying the parts of the field that are not infested with pests; and sensors sensitive to the pests present are used so that fuzzy logic can be employed to decide what types of pesticides and how much of them are to be used.

Keywords: Multi-agent systems, fuzzy logic, wireless sensor network.

Introduction

Pests are organisms that feed on different parts of plants. They compete with man to obtain the food they need to survive, damage the crops and products man produces, and disrupt his agricultural activities. Therefore, identifying and controlling pests is very important; and to this end, we have used fuzzy logic to eliminate some of the existing problems (in controlling pests) and to speed up the identification and the control of pests.

Every fuzzy model consists of the three parts of the input indices, the fuzzy rules (fuzzy deductive engine), and the output indices. Different methods are employed to describe the input and output indices and the way the rules are combined to make the deductions. In this article, we have used a model based on the min_max fuzzy deduction system and the long range form of wireless communications, which is one of the most important intelligent transportation systems, in order to show the capabilities of fuzzy logic in evaluating the performance of spray networks; and taking into account the similar studies carried out on intelligent irrigation systems in which internet automation equipment and connections to web were used , and considering the fact the internet can be used to manage irrigation from anywhere on earth, the information identified by sensors is processed through the web site and changed by the input tank into intelligent commands which can be carried out on the field as operational commands by using controllers and celluloid taps.

In a similar study, three irrigation control systems equipped with a fuzzy controller (FLC), and ON/OFF controllers with and without the use of hysteresis were studied to control the intelligent greenhouse irrigation system. The fuzzy control systems showed greater capability compared with the other systems in reducing water use, in lowering energy consumption, in decreasing the tear and wear of the parts of the control system, in preventing water stress in the soil and in the plants. Fuzzy control systems are very cheap as well, and hence the use of this type of control system is very useful in all agricultural activities.

In another article on evaluating the performance of Marun irrigation networks by using fuzzy logic, a model was prepared based on the Mamdani minimum maximum deduction system and the method of defuzzification of the center of gravity. This model was used to evaluate the performance of the Marun irrigation network from the overall management point of view.

The Goals of the Study: i. Designing a fuzzy logic algorithm to control pests, ii. Stopping the senseless use of pesticides, iii. Evaluating the fuzzy logic algorithm

Identifying pests and Pesticides

Pests: Pests are organisms that feed on different organs of plants, compete with man in obtaining the food they need, and damage the crops and products produced by man.

Identifying Pests: We have to realize that not all insects are pests and that some insects are beneficial and destroy pests. Therefore, these beneficial insects (biological pesticides) must be protected.

It is better that the loss caused by each insect pest species be determined, that the producer be given the opportunity to understand the pests and to be given the necessary information about the dangers posed by the pests, and that the producer search for the most suitable method of controlling pests.

Types of Pests: First Class Pests: These pests are dangerous; and if they are not controlled, they will completely damage the crops, and there will be nothing left to harvest.

Second Class Pests: These pests usually do not cause extensive damage, except at certain times and under specific conditions when there is an outbreak of these pests (aphids are an example).

Third Class Pests: These are inherently pests and can cause damage, but under normal conditions their damage is not economically significant. The agents studied in our method are the aphids.

Features of Class Two Pests (Aphids): i. Aphids feed on buds, flowers, and the underside of the lower leaves of ornamental plants. ii. Aphids on different plants are usually yellow, green, red, or black. iii. Aphids have two forms: the winged (alate) and the wingless (apterous). iv. Weather conditions during spring speed up the multiplication of aphids. v. Because of the mutations in their genes, aphids are vectors of viral diseases. vi. Some aphids spend their life cycle on one plant species (autoecious), while others spend part of their life cycle on one plant species and the rest on another one (heteroecious). vii. Aphids usually secrete a sticky and sweet substance called honeydew which attracts ants. Ants use their antennae to stimulate aphids to secrete honeydew and then feed on it. viii. Some ants make nests for (female) aphid colonies and keep the aphids as prisoners inside these nests, or carry the aphids to other places, especially onto plant roots, and in fact turn into exploiters of aphids. In return, ants often protect aphids from the attack and harm of their enemies. ix. The size of the population of aphids, and hence the damage they cause, depends on weather conditions, humidity, temperature, luminosity and light intensity, and the activity of parasites and predators (biological control).

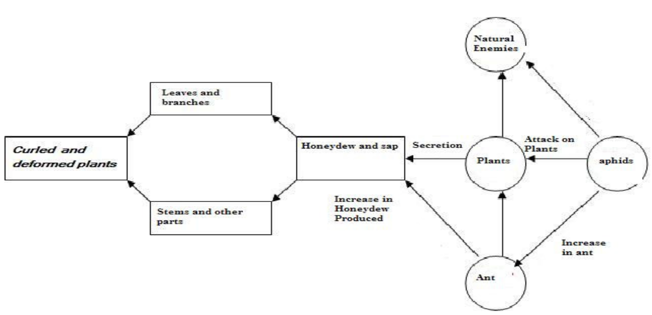

Figure-1
Diagram of the way aphids attack plants

In the diagram above ,enemy agents (red) are distinguished from friendly agents (blue), aphids attack plants, suck their sap, secrete honeydew on plant parts (branches, leaves, stems, the underside of plant parts, etc.). Aphids attack plants, drive away their natural enemies (ladybird beetles), and attract ants to the plants and their surroundings. Ants stimulate aphids to produce more honeydew

Multi-Agent Systems (MAS): A multi-agent system (MAS for short) is a network of independent and connected software agents used to solve problems beyond the knowledge of the individual agents. Multi-agent systems are systems which consist of independent components and which have the following features: i. Each agent, on its own, does not have the capability to solve the main problems. ii. There is no control over the whole system. iii. The data and information are distributed. iv. Calculations are performed asynchronously

In multi-agent systems, the agents must be able to find each other and to interact with each other. A multi-agent system includes a set of agents interacting with each other. The different agents have different "range of operations", but each agent is able to influence the other parts of the environment. There may be overlapping of the ranges of activities of the agents; and this will cause interdependence among the agents. Multi-agent systems can work under most conditions _ i.e., since they do not have a single decision-making brain and decision making is distributed among the agents, even if a number of the agents fail, the system will continue to operate. Moreover, these systems are a better choice than single-agent systems for large scale, and also for unknown, environments.

In this article: The environment: a sample agricultural field.

The friendly agents: the plants, the natural enemies, the wireless sensor network, the spray sensors, and the camera sensors.

The enemy agents: a second class pest (aphids): Of course, ants are also considered to somehow be an enemy agent, but since they have an indirect role in the attack on plants, and because they do not harm the plants, and due to the fact that this article is more focused on controlling aphids, we have almost disregarded ants as an agent.

The Plan of the Main Phase: As can be seen in this plan, the above mentioned field is divided into parts, and each part has separate sensors and independent sprayers to optimize both the control operations and the quantity of pesticides used. In this method, each sensor acts independently and, if it recognizes the pest in question, it sends a message to the control room. In the control room, on the basis of the sent data, and also based on pre-defined rules, and after taking all the mentioned exceptions into account, if it is deemed necessary, spraying is carried out. In order to spray, first a pulse is sent to each of the electric taps on the relevant tank, and then the correct quantity of the necessary pesticide is sprayed through the pump and the pipe network.

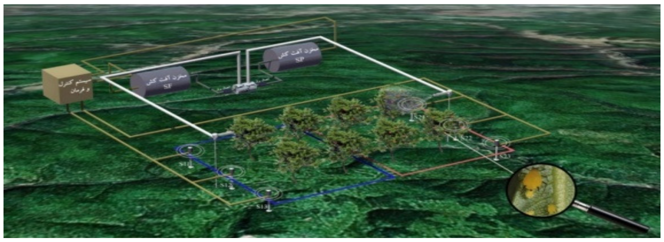

Figure-2

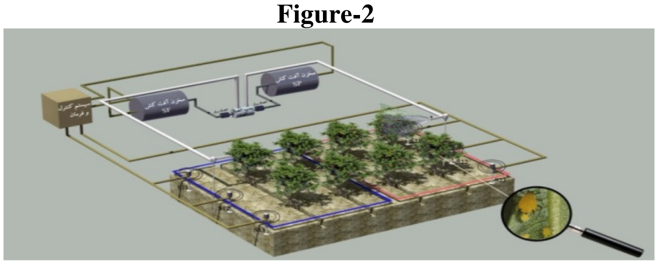

Figure-3

Fuzzy Logic: Fuzzy logic is a tool to show uncertainty and vagueness and to express the inherent uncertainty of problems. Its noteworthy feature is that it extends human reasoning and deduction capabilities to systems based on knowledge in the format of speech expressions and statements stated in the form of if –then rules. Fuzzy logic can be used to map input space onto output space; i. e., the input and a series of deduction rules are used to produce a suitable output. In this research, the max_min fuzzy logic is used to produce a smart output

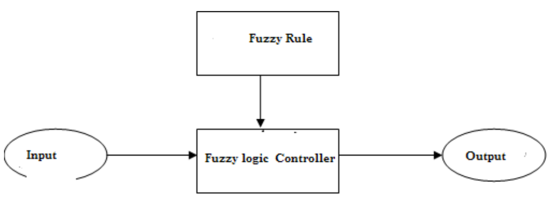

Figure-4

Control Parameters for the Identification of the Aphid Pest:

A1: sucking sap, secreting honeydew on the plants, weakening and killing plants, A2: gathering of ants around and on plants and departure of natural enemies, A3: reduction in plant photosynthesis, settling of dust on plants, weakening and death of plants

According to the formula, the population of the pest increases linearly on the basis of the control parameters: Y= C* Ai (i= 1, 2, 3…); and C is a constant. In fuzzy logic, for each defined control parameter (A1…A3) in the input table, a number between zero and one is considered as a criterion. These criteria are classified as low, medium, high, and very high in order to implement fuzzy logic. According to this classification, the input table will be as follows:

Table-1
Fuzzy Classification Ranges

Low	0-0.25
Medium	0.25-0.5
High	0.5-0.75
Very high	0.75-1

The General form of Fuzzy Rules: If {A1 is x1} and {A2 is x2} and {A3 is x3} then {action}, x1, x2 , x3 refer to criteria of the control parameters.

Therefore, based on this input table, the fuzzy rules, and the defined deduction rules, it will be concluded if a pest (enemy agent) has attacked the plants. If an attack has taken place, the best action (based on the input and on the fuzzy rules defined) is chosen from among the determined actions as the output for tackling the pest.

Table-2
The Fuzzy Input

Input	Fuzzy Classification	Degree or Criterion of Loss
A1	Medium	0.40
	High	0.75
A2	Medium	0.45
	Very high	0.8
A3	Medium	0.4
	High	0.7

Fuzzy Diagrams for the Inputs

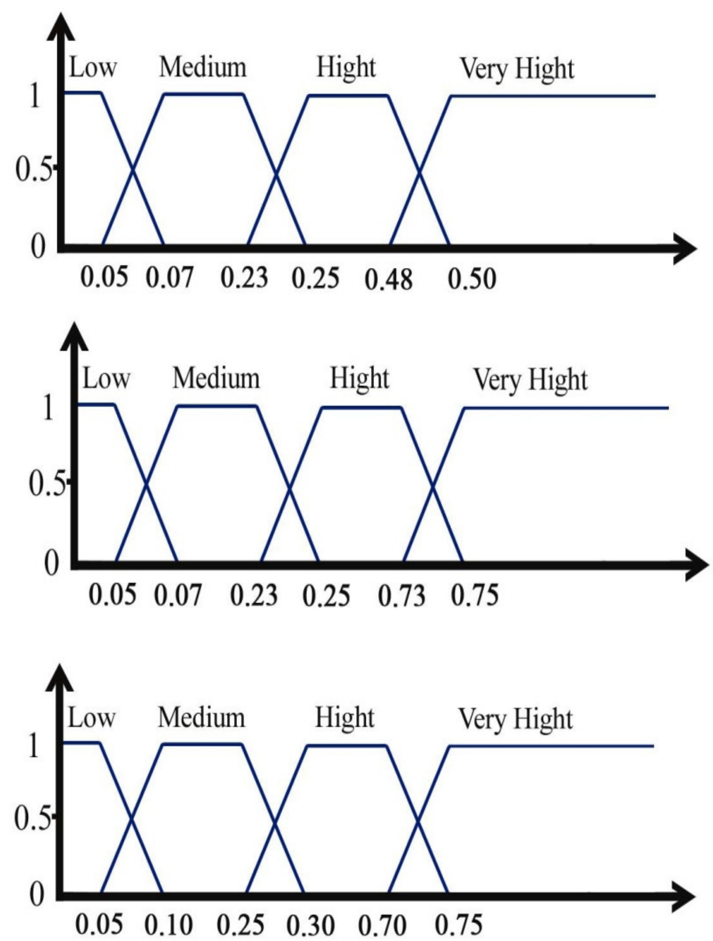

Figure-5

Action: Controlling aphids will only be successful if it starts as soon as the first aphid colony appears. Pesticides used to control aphids are mostly organic phosphate contact insecticides such as malathion, gusathion, diazinon and superacid sprayed at the rate of 1 to 1.5 grams of active ingredient per liter of water.

Penetrating insecticides, which are also called systemic insecticides, like phosphamidon, metasystox and similar insecticides, penetrate plant tissues and are substantially superior to contact insecticides, because besides killing aphids on the underside of leaves, and other places where the insecticide does not reach, they do not cause a lot of harm to beneficial parasites and predators of aphids. Systemic insecticides are also effective against plant mites, and their residual effect lasts from 10 to 20 days, depending on the growth of the plants and the type of the insecticide used. Spraying must be carried out when the leaves have sufficiently grown so that a greater amount of the active ingredient of the insecticide enters the plants.

Aphids can also be controlled by using biological agents (changes in weather conditions, humidity, temperature, luminosity and light intensity).

There are also non-chemical control methods, such as spraying the plants with water to wash aphids off the plants. Strong selective insecticides (which only kill aphids), such as Pirimor or Pirimicarb and Chess or Pimetrozin can also be used to control aphids.

However, in our study, only the following two insecticides were used for controlling aphids: i. Malathion (general insecticide), which is a contact organophosphate (SF), used at the rate of two liters per 1000 liters of water. ii. Pirimor or Pirimicarb , a selective insecticide that kills only aphids(SP) , used at the rate of 0.5-0.7 kilograms per 1000 liters of water. In this study, the max_min fuzzy logic was used to produce intelligent output. The IF……THEN rules are shown in table 3.

Table-3
The Fuzzy Output

Control Information			**Controlling Aphids(action)**	**max_min combination**
A1	**A2**	**A3**		**Min(0.40,0.45,0.40)=0.40**
Medium (0.40)	Medium (0.45)	medium (0.40)	SF	Min(0.40,0.45,0.70)=0.40
Medium (0.40)	Medium (0.45)	high (0.70)	SF	Min(0.40,0.80,0.40)=0.40
Medium (0.40)	Very high (0.80)	Medium (0.40)	SF	Min(0.40,0.80,0.70)=0.40
Medium (0.40)	Very high (0.80)	High (0.70)	SP	Min(0.75,0.45,0.40)=0.40
High (0.75)	Medium (0.45)	Medium (0.40)	SF	Min(0.75,0.45,0.70)=0.45
High (0.75)	Medium (0.45)	High (0.70)	SP	Min(0.75,0.80,0.40)=0.40
High (0.75)	Very high (0.80)	Medium (0.40)	SP	Min(0.75,0.80,0.70)=0.70
High (0.75)	Very high (0.800	High (0.70)	SP	SF: Max(0.40,0.40,0.40,0.40)=0.40 SP: Max(0.40,0.45,0.40,0.70)=0.70 0.70> 0.40 Therefore, the final decision is to expand action or use SP insecticide

Conclusion

In this study, it was shown how the capabilities of the fuzzy method can be used to evaluate the performance of intelligent spray networks. Based on two indices, Malathion (a general insecticide) of the organophosphate type with a contact action and Pirimor or Pirimicarb (a selective insecticide that kills only aphids) were considered in making the final decision. Results of the evaluation are presented in the fuzzy output table.

By employing this method, a combination of quantitative and qualitative indices, which is not possible in customary methods, has been used.

In this research, the fuzzy model of evaluation was employed to take advantage of the capabilities of fuzzy logic in evaluating the performance of spray networks; and an attempt was made to use this fuzzy model of evaluation and to employ the capabilities of this method to improve the speed of pest control operations through the use of intelligent agents without needing the physical presence of the farmer.

Moreover, one of the positive results of mechanizing processes is that there will be less interference on the part of the human work force, unpredictable mistakes will be reduced, costs and energy consumption will decrease, and productivity and efficiency will improve.

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