Multi - Agent Based Artificial Intelligent Process Control

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Abstract
The agent technology is the fundamental cell of the distributed intelligence that provides many different solutions to commonly known problems faced in many fields. The Artificial intelligence (AI) is one of the key technologies that can be built by using all (AI) implementation technology currently known and it can compute regardless of its current location's. The current situation of a power station Refinery in Iraq is that agents deviation are monitored and controlled by manual activities. In this paper, a system which combines two (AI) technologies has been proposed for monitoring and controlling automatically the agents in the power station Refinery. The main goal of the proposed system is the flow control of the multi - agents and their distributed problem solving using tow (AI) technologies combinations. The system consist of two parts , the first is the " Fuzzy ARTMAP " Neural Network as a multi - agent data fusion classifying system. The Neural Network classify the agents performance deviations of the Process from the desired standard level. The second is the Genie part as a multi - agent control system. This part is based on the Bucked - Brigade and the genetic algorithm as a control system for the performance controlling of the process deviations classified by the Neural Network. Results shows that the proposed system improved the performance of power station with low cost and less effort reducing the manual activities. The system concept can be used for other different fields .

Keywords
Fuzzy ARTMAP neural network , Genetic Algorithms , Learning classifier systems , Bucket Brigade algorithm , Power station , Process control .

I. Introduction

The term of agent is defined as anything that can be viewed as perceiving its environment through sensors & acting upon its environment through the effectors [1]. The primary feature of agent technology is the agent's ability to communicate with each other enabling each agent of uniting their efforts to become a collective of working individuals who are aware of each other's goals. Intelligent agents have some sort of decision - making model which will give the agent primitive level of intelligence. The intelligence is usually based on reasoning theory , knowledge based system , fuzzy logic , genetic algorithms , Artificial neural networks or some combination of these. Basically an agent is considered to be intelligent if it has the ability of perceives its environment and the capability of reasoning its perception , solve problems and determine the actions depending on its environment and the tasks which were they are given to it by its user [2]. The term ARTMAP is a class of neural network architecture that performs incremental supervised learning recognition to the input vectors. The first ARTMAP system was used to classify inputs by the set of features (also called pattern or vector) they possess of binary values representing the presence of absence of each possible feature [3]. A new system , which is more general is called the fuzzy ARTMAP was developed to classify the inputs by a fuzzy set of features, or patterns of fuzzy memberships values between 0 or 1 indicating the extent to which each feature is presented [4, 5]. A verity of fuzzy ARTMAP on a cluster of workstations learns the required tasks fast and has the capability for on - line learning was implemented. It has the ability to provide the learning structure that can allows the explaining of the answers that the neural network produces [6]. Learning using the classifier systems is one of the ways of using evolutionary methodology for machine learning application. These systems are a class of rule - based , message processing systems. Rules are known as classifiers because they are mainly used to classify messages in to general sets. Learning in classifier system was achieved by using the Bucket - Brigade and the genetic algorithm [7-9]. The Bucket Brigade allocates strength (credit) to the classifiers according to their usefulness in attaining system goals. The genetic algorithm is used to search for new plausible classifiers. This paper present, a Fuzzy ARTMAP neural network model which is proposed to classify the process performance of the multi - agent's behaviors in Al - Daura Refinery power station. It is based according to agent's behavior and its standard level (S.L.). The data fusion from the environment are classified in to three classes , class (S) when the data fusion from the agents are within the (S.L.) , class (H) when the data fusion from the agents are higher than the (S.L.) and class (L) when the data fusion from the agent are under the (S.L.) [9]. This " Fuzzy ARTMAP " system is combining with the second part , the Genie part [10]. The Genie part is used to learn the behavior of the multi - agents deviation data fusion by using the learning classifier systems as an agent control system .

II. Al - Daura Refinery Station Multi - agent Process

In Al - Daura Refinery station , a boiler has been selected as a prototype for this research. It has a performance of 310 KW. Its continuous operating rate for steam is 142 ton/hr at a temperature and pressure of 260 °c and 20 bar at full load [9]. The boiler is a device for generating a steam , which are used for the production of power at Al - Daura Refinery. The performance of the boiler will directly affect the whole power system. Table 1 illustrates the multi agent process of the boiler hardware.

III. The Agent Configuration Management

The behavioral of the agents are combined to give an overall configuration system for the complete product lifecycle. This system has been developed to support earlier work on change propagation in an integrated design environment where the behavioral agents define the rules for co - operation and change management also it has the knowledge about the design entities and their relationships. The first aspect of the configuration management scheme is the labeling of the design model and hence the process of change is represented within our labeling scheme as referring to table (1). The multi - agents are labeled as shown in table (2).

Table 1: illustrates the Boiler control system items.

No.	ITEMS	UNITS	TAGS (AGENTS)	Standard Level
1.	Steam Drum Level	mm	LRCA-1355	+50 to +200
2.	Boiler Feed Water Flow	Ton/ hr	FRC-1357	70 to 110
3.	Boiler Feed Water Pressure	Bar	PI-1360	33 to 40
4.	Boiler Feed Water Temperature	°C	TR-1352	115 to 125
5.	Boiler Feed Water Level	mm	LIC-1351	+100 to +200
6.	Main Steam Flow	Ton/ hr	FR-1356	50 to 110
7.	Main Steam Temperature	°C	TRCA-1353	260 to 280
8.	Main Steam Pressure	Bar	PICA-1361	19 to 20
9.	Fuel Oil Pressure	Bar	PIA-1356	6.8 to 15
10.	Fuel Oil Flow	m³ /hr	FRC-1351	3 to 7.5
11.	Oil/Steam Diff. Pressure	Bar	PDICA-1354	1.5 to 3
12.	Fuel Oil Temperature	°C	TAR-1351	90 to 110
13.	Low Pressure Steam	Ton/ hr	PI-1351	1 to 3

Table 2: The Labeled Agents

No.	AGENTS	LABLE	No.	AGENTS	LABLE
1.	LRCA-1355	A	8.	PICA-1361	H
2.	FRC-1357	B	9.	PIA-1356	I
3.	PI-1360	C	10.	FRC-1351	J
4.	TR-1352	D	11.	PDICA-1354	K
5.	LIC-1351	E	12.	TAR-1351	M
6.	FR-1356	F	13.	PI-1351	Q
7.	TRCA-1353	G			

The agents behavioral are the representation of each design discipline in the agent structure which contains the rules about the co - operation and negotiation with other agents and uses these to control the final output. The rules for controlling these agents depend on the relationships between them. Fig. 1 describe the relationship between these agents.

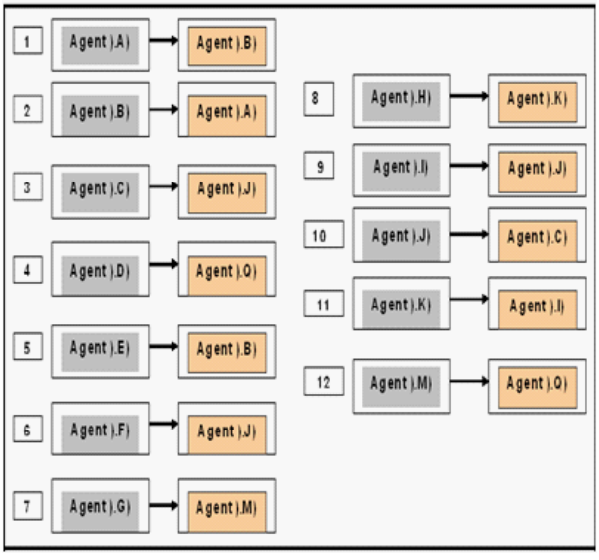

Fig. 1: The Relationship between the Agents.

IV. The Fuzzy "ARTMAP" Algorithm

The Fuzzy ARTMAP Algorithm is used for each agent in the boiler as a classifying system [9]. Fig. 2 shows the architecture of the fuzzy ARTMAP for each agent. The exploration of the network variations begin by varying the baseline vigilance. The selection of the proposed Fuzzy ARTMAP decision thresholds for the output class is divided to three classes as the following [9] :

A) (L) class : which means that the data fusion received from the environment is less than the desired standard level .
B) (H) class : which means that the data fusion received from the environment is higher than the desired standard level .
C) (S) class : which means that the data fusion received from the environment is at the standard level (the desired situation) then it will switch out to the environment and will not enter to the second part of controlling systems.

V. The Project Methodology

The control system of an agent can be implemented by a network of different learning classifier system (LCS). The issue of the architecture by which we mean the problem of designing the network that best fit some predefined class of behaviors.
Flat architecture is proposed as a distributed architecture design including three interacting LCS , connecting to the agent's sensors in which each LCS system is trained with a different reinforcement program , taking in account the characteristics of the task that the considered LCS has to learn as shown in fig 3. The idea is that distinct LCS implement different basic response that making up a behavior pattern regarding the way in which the agent is built up from the action proposed by the LCS , this action are realized in parallel by different effectors.

A. Learning Classifier

The three proposed learning classifier systems (LCS) are used as an overall control system , to switch between the behaviors after the analysis of the environmental message is received from the environment. The agent control system is consisting of three (LCS - Switches) :

1 – Learning classifier System – One
The (LCS-SW1) is used to learn the control of agent (A) , agent (B) , agent (C) and agent (D).

2 – Learning classifier System – Two
The (LCS-SW2) is used to learn the control of agent (E) , agent (F) , agent (G) and agent (H) .

3– Learning classifier System – Three
The (LCS-SW3) is used to learn the control of the agent (I) , agent (J) , agent (K) and agent (M) .

B. The LCS1 , LCS2 , LCS3 Performance

The performance system is the heart of the agent control and the matching procedures are the heart of the performance system consisting of a message list and classifiers. There is only single message in the message list that is used to match against a condition part of all classifiers and there is no other message to be received in the current cycle until the system produces an action .
Therefore the evolutionary learning is used for searching in the rule space. The genetic algorithm searches for possibly new useful rules by its genetic operations. The fitness function used direct to search the rule strength [10] .

C. Coding (LCS1, LCS2, LCS3) Conditions

The length of message , which (LCS1, LCS2, LCS3) is received 3 bits environment message mapping it to eight states from 0 to 7 of three bits only.

The form and meaning of the three bits in the input message of LCS1 is used to learn the behavior of controlling the relating agent (A) , agent (B) , agent (C) and agent (D) within their standard level (S.L.) as shown in table (3). The same Procedure conditions are followed for LCS2 and LCS3.

Table 3: Form and meaning of the (LCS1) Conditions.

The Message	Its meaning
000	If (A) is less than the (S.L.) of 50.
001	If (A) is higher than the (S.L.) of 200.
010	If (B) is less than the (S.L.) of 70.
011	If (B) is higher than the (S.L.) of 110.
100	If (C) is less than the (S.L.) of 33.
101	If (C) is higher than the (S.L.) of 40.
110	If (D) is less than the (S.L.) of 115.
111	If (D) is higher than the (S.L.) of 125.

Table 4: Form and meaning of the (LCS3) Action.

Message	Its meaning
000	Increase (B) to (S.L.) of higher than 70 & less than 110.
001	Decrease (B) to (S.L.) of less than 110 & higher than 70.
010	Increase (A) to (S.L.) of higher than 50 & less than 200.
011	Decrease (A) to (S.L.) of less than 200 & higher than 50.
100	Increase (J) to (S.L.) of higher than 3 & less than 7.5.
101	Decrease (J) to (S.L.) of less than 7.5 & higher than 3.
110	Increase (Q) to (S.L.) of higher than 1 & less than 3.
111	Decrease (Q) to (S.L.) of less than 3 & higher than 1.

D. Coding (LCS1, LCS2, LCS3) Actions

Each classifier within LCS1 , LCS2 , LCS3 consists of the condition part of (3 bit) representing the situation of the agents in the environment and from action part of (3 bit) representing the action to be done in the environment. For example the representation of the rule " If agent (A) is less than the (S.L.) of 50 " to be sensed from the environment the action to be taken is " Increase agent (B) to the (S.L.) of higher than 70 and less than 110 " , Actions of LCS1 , have the form and meaning as in table 3 and table 4. The same Procedure actions are followed for LCS2 and LCS3 .

VI. The (LCS1, LCS2, LCS3) Algorithm

The algorithm of the basic execution cycle of the proposed learning classifier system is illustrated in fig. 4.

VII. The (LCS1, LCS2, LCS3) Blockdigram

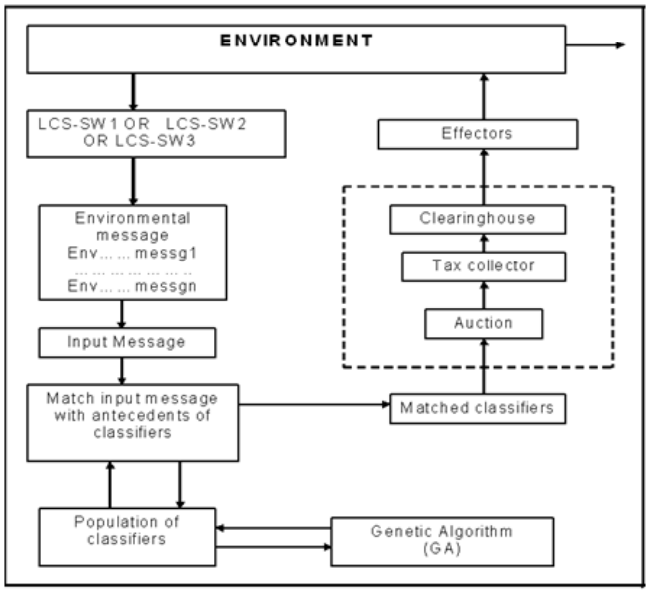

Fig. 5: illustrate the blockdigram of the learning mode architecture

VIII. The Proposed System Flowchart

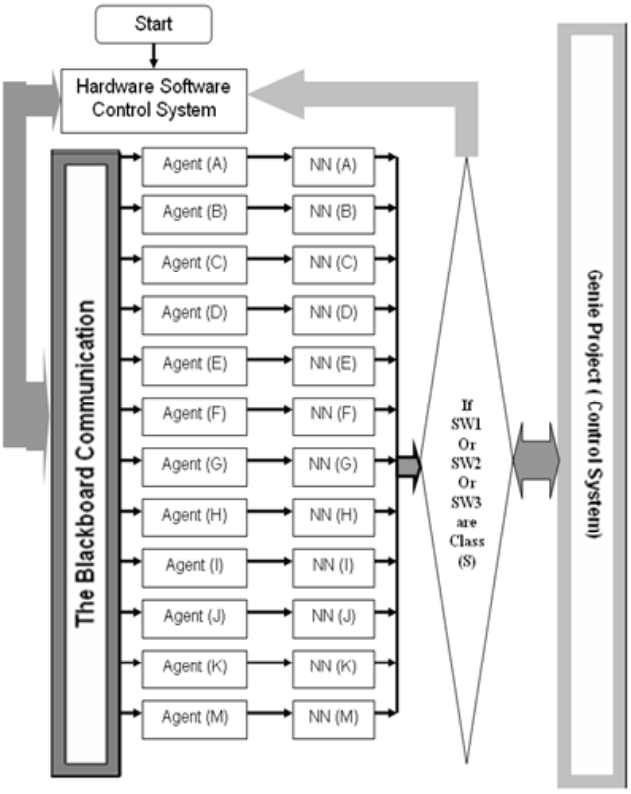

Fig. 6 : illustrates the flowchart of the proposed system.

IX. The System Implementation

The proposed system is designed to train the fuzzy ARTMAP neural network for each agent. The training data were extracted from the boiler position in Al - Daura Refinery station in which the data are taken according to the practical situation and according to its procedures the training data must be trained previously .

The Fuzzy ARTMAP Neural Network are applied for each agent in a separately manner. According to each agent standard level. If the data fusion were within the range or between the standard level (S. L.) then the system will switch out of the genie part but

if the data were out of range which means higher or lower than the (S.L.) then the system will switch to the gene part .

The executing of the genetic algorithm based machine learning responds by presenting the initial report as display in fig. (7) that illustrate the input of the parameters , which is used for LCS1, LCS2 and LCS3 respectively. It consists of (48) classifiers taking all the possible probabilities. The condition part of each classifier consists of (3) bits while the action part is (3) bits. The initial strength value used is (10) for the classifiers and all the classifiers have the same strength at the beginning. The amount of reward that is provided is (10) to be reward for the good action and zero for the bad action for the three LCS .

3	10.00	0.00	0.00	□	001:[001]
4	10.00	0.00	0.00	□	#1#:[010]
5	10.00	0.00	0.00	□	0#0:[100]
6	10.00	0.00	0.00	□	010:[010]
7	10.00	0.00	0.00	□	0#0:[000]
8	10.00	0.00	0.00	□	#01:[001]
9	10.00	0.00	0.00	□	##1:[001]
10	10.00	0.00	0.00	□	#01:[001]
11	10.00	0.00	0.00	□	0#1:[001]
12	10.00	0.00	0.00	□	#0#:[000]
13	10.00	0.00	0.00	□	111:[111]
14	10.00	0.00	0.00	□	111:[111]
15	10.00	0.00	0.00	□	01#:[010]
16	10.00	0.00	0.00	□	0#1:[001]
17	10.00	0.00	0.00	□	11#:[110]
18	10.00	0.00	0.00	□	##0:[000]
19	10.00	0.00	0.00	□	100:[100]
20	10.00	0.00	0.00	□	#01:[001]
21	10.00	0.00	0.00	□	010:[010]
22	10.00	0.00	0.00	□	010:[010]
23	10.00	0.00	0.00	□	100:[100]
24	10.00	0.00	0.00	□	#1#:[010]
25	10.00	0.00	0.00	□	#00:[000]
26	10.00	0.00	0.00	□	011:[011]
27	10.00	0.00	0.00	□	0#1:[001]
28	10.00	0.00	0.00	□	#11:[011]
29	10.00	0.00	0.00	□	#00:[000]
30	10.00	0.00	0.00	□	01#:[010]
31	10.00	0.00	0.00	□	#01:[001]
32	10.00	0.00	0.00	□	111:[111]
33	10.00	0.00	0.00	□	0#1:[001]
34	10.00	0.00	0.00	□	#1#:[010]
35	10.00	0.00	0.00	□	1#1:[101]
36	10.00	0.00	0.00	□	#1#:[010]
37	10.00	0.00	0.00	□	0##:[000]
38	10.00	0.00	0.00	□	10#:[100]
39	10.00	0.00	0.00	□	0##:[000]
40	10.00	0.00	0.00	□	000:[000]
41	10.00	0.00	0.00	□	1#0:[100]
42	10.00	0.00	0.00	□	#01:[001]
43	10.00	0.00	0.00	□	0#0:[000]
44	10.00	0.00	0.00	□	#11:[011]
45	10.00	0.00	0.00	□	##0:[000]
46	10.00	0.00	0.00	□	#11:[011]
47	10.00	0.00	0.00	□	1#0:[100]
48	10.00	0.00	0.00	□	#00:[000]

Fig. 7: The Initial Report for the Basic Learning Classifier System

The genie part have been applied for each of LCS1 , LCS2 and LCS3. The operation is run for each group of the agents in a separately manner. According to the experiment by applying the extracted data from power station position.

The environmental messages appear from the first group of LCS-SW1 which are consisting from agent (A) , agent (B) , agent (C) and agent (D). The LCS-SW1 is switched this message towards the LCS1 .

The LCS1 received the message form (111) as shown in fig. (8). This message is transferred to the performance system were matching process is preformed on this message with the condition part of all the classifiers. The numbers of matching classifiers appears were (3,4,5,6,7, 6, 13, 16, 17, 25, 28, 31, 45, 48).

The winner classifier number is (17) which has the highest strength value equal to (126.00) therefore the action of this winner will be sent to the environment by the system effectors to control the related agent .

The environmental message (111) sense that agent (D) is higher than the (S.L.) of (3) then the action that is done by the effectors is to decrease the related agent (Q) to the (S.L.) of less than (3) and higher than (1) .

There is no environmental message received from LCS-SW2 therefore the system will switch out of the gene part.

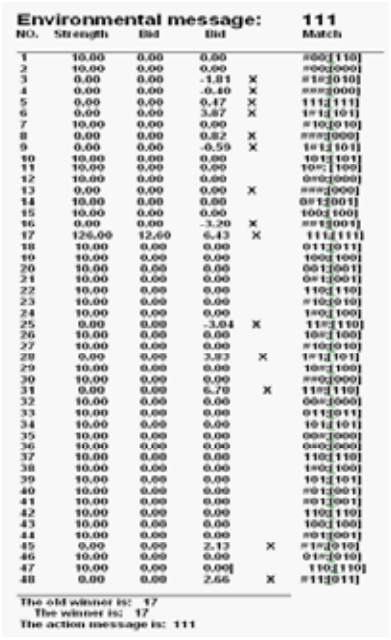

Fig. 8: The Result Report of the Learning Classifier System.

An environmental message appears from the third group of LCS-SW3 which is consisting from agent (I) , agent (J) , agent (K) and agent (M). The LCS-SW3 is switched this message towards the LCS3 .

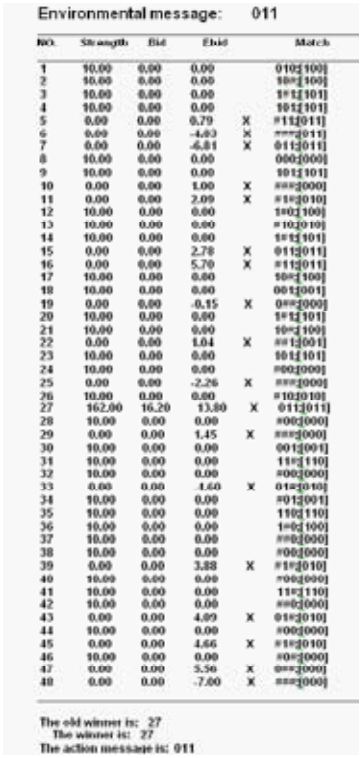

Fig. 9: The Result Report of the Learning Classifier System

The LCS3 received the message form (011) as shown in fig. (9). This message is transferred to the performance system were matching process is preformed on this message with the condition part of all the classifiers. The numbers of matching classifiers appears are (5-7, 10, 11, 15, 16, 19, 22, 25, 27, 29, 33, 39, 43, 45, 47, 48). The winner classifier number is (27) which has the highest strength value equal to (162.00).

Therefore the action of this winner will be sent to the environment by the system effectors to control the related agent. The environmental message (011) sense that agent (J) is higher than the (S.L.) of (17.5) then the action that is performed by the effectors is to decrease the related agent (C) to the (S.L.) of less than (40) and higher than (33) .

X. Conclusions

This paper present the " Fuzzy ARTMAP " neural network as an on – line fast learning mechanism for multi - agent data fusion classifying system. It can be provided with low computing costs for learning strategy. According to the experiments the data fusion from the multi - agent of the process performance has been classified accurately to three classes , class (S) when the data fusion is within the standard level (S.L.) , class (H) when the data fusion are higher than the standard level (S.L.) and class (L) when the data fusion are under the standard level (S.L.). within few seconds , less efforts and low cost. The effectiveness of using the dynamic fuzzy ARTMAP is confirmed by the simulation results in which three typical levels has been present.

The Genie Part is a feasible tool to built robust simulated control system. This choice is efficient to achieve high performance for a variety of Agent behavior control system for data fusion for other different fields. The experiments presents shows that the combination of the " Fuzzy ARTMAP " neural network and the genie part results in improving the performance of the power station automatically within low cost reducing the manual activities.

XI. Acknowledgements

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