IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 19, Issue 4, Ver. V. (Jul.-Aug. 2017), PP 13-18
www.iosrjournals.org

A Framework for Machine Learning based Multi Agent System

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Abstract: *Applications which can facilitate decision making are gaining importance. They can be found in domains like process control, air traffic control, inventory management, airline reservation etc. Developing applications for these domains have several flaws. First, they do not achieve the desired goal. Second, even if they do, their implementation and maintenance is very costly. Agent oriented system offers a qualitative change in this position. An agent learns from its environment, manipulates itself and coordinates with other agents in the system. Researchers have designed many agents but they were unable to solve complex dynamic applications of this kind. It is still an open problem for the researchers to let the agent learn and adapt as per requirements. In this paper, we addressed this issue. We have focused on design and development of multi agent system (MAS) which can reason and learn for environment. We have chosen Airline reservation as our case study.*

Keywords: *Multi agent System, Machine learning, Decision tree, Support vector machine, Multi layer perceptron, Radial basis function.*

Date of Submission: 26-07-2017 Date of acceptance: 05-08-2017

I. Introduction

World Wide Web is important source of information, but due to its dynamic and constantly changing behavior, users are not able to get the most relevant and updated information according to their requirements. Searching any information on internet is a time consuming process[1]. So, there is a need for a system which integrates and interprets this huge amount of heterogeneous information on the net. A multi agent system is a collection of intelligent agents that work in cooperation to achieve the desired goal. In agent based system, all agents have their internal states and goal, and they work autonomously to achieve the stated goal via communication to each other. Web services do not work autonomously; at each step there is a person who directs the system. Agents use the initial instructions given by client and then proceed to achieve the goal without human intervention, and report either success or failure. Combining these two technologies in one can lead to the development of more powerful applications.

II. Multi Agent System

Multi Agent System can be best characterized as a software technology that is able to model and implement individual and social behavior in distributed systems. It is a loosely coupled network, in which all problem solvers (agents) are interacting to each other to solve a given problem which cannot be solved by a single agent. It is a software technology which model and implements the individual and social behavior in distributed environment. It is characterized by cooperation, coordination, role assignment; negotiation and self organization. MAS are used for the distributed and open system. Several issues to be considered for development of multi agent system like: character of an agent, function to be performed, communication language, protocols, cooperation etc.

III. Machine Learning

Machine Learning

Prediction of future based on past experience is machine learning. It is the branch of science where system is programmed to automatically learn and improve with experience. Here learning means to recognize and understand the input data and make a wise decision when new input is presented to system. Machine learning plays a key role in wide range of applications such as pattern recognition, natural language processing, expert system, data mining and many more.
In machine learning, to evaluate an algorithm, we split the data set into two sets, one is the training set, on which we learn the behavior or properties of data and another is testing set, which is used to test these properties.

IV. Machine Learning In Mas

Multi agent system is an intelligent system. Intelligence implies a certain degree of autonomy which in turn requires the ability to make independent decisions. Thus agents have to be provided with the appropriate tool to make such decisions. In most dynamic applications programmer cannot possibly foresee all the situations that an agent might encounter and therefore the agent needs the ability to adapt to new environments. Two important factors that affects the efficiency of MAS is **agent heterogeneity** and **amount of communication** between agents, so to reduce the inherent complexity in MAS, machine learning is introduced in MAS. Competitive and cooperative are two broad categories of learning in Multi Agent System. In competitive learning, agents work in asynchronous fashion and the output of the best agent will be declared as final output. In cooperative learning, agents cooperates to each other and the final output is the aggregation of the result of individual agent [2] .Q-learning is one of the reinforcement learning which can be applied in Multi Agent Environment. By

introducing machine learning in MAS, we are increasing the efficiency of agents and also reducing the information overload. Overall system performance will get enhanced by combining these two approaches [3].

V. Related Work

They used a recommendation system based on tourism system, which was used multi agent approach, which recommends users with the list of tourist activities that the user can perform according to his preferences. This system captures the user profile dynamically and then generates the list of activities. It also generates the schedule of these activities [4, 5].

Multi agent system architecture should be comprised of all of the agent properties that make them rational like autonomy, social ability, pro-activeness and reactivity [6].In this paper they proposed a model which was based on Multi Agent System and used an algorithm to dynamically select optimal composition of web services. He suggested that encapsulation of web services with MAS enhanced the autonomy, reliability, robustness of the system [7].

Decision tree (DT) is widely used machine learning algorithm for pattern classification, when the training set is provided [8]. DT algorithms have several advantages like; to find out subset of attributes relevant for classification, from set of attributes and to find the association or relationship amongst the attribute. Iterative Dichotomizer 3(ID3) is one of the Decision tree algorithms.

Support vector machine is one of the learning algorithms which can be used to learn agents in multi agent environment for credit risk evaluation [9]. While using SVM, prerequisite assumptions are least needed. SVM nonlinearly transforms the input space into high dimensional feature space, and also maximizes the margin.

VI. Multi Agent System For Air-Reservation (MASAR)

Nowadays large amount of travel data is available on internet but it is very difficult to find out the relevant requested information. The advantage of going to a system based on intelligent agent technology is its speed in problem solving by reducing the search time. Based on the learning, intelligent agent provides useful travel tips to the customer. Basic features of the application will include the ability for a booking agent to perform the following:

- Book passengers on flights.
- Give passengers special needs or requests.
- Display information about flight and passengers.
- Display a seat layout map at appropriate times.

One of the most important features of the system is that it is not particular to any single airline company. So it gives best optimum offers to their customer.

A. Agents and their roles in Air-Reservation

Interface Agent: It is the first agent in the system which communicates both with Customer and other agents in the system. It provides GUI by which Customer communicates with our system. Customer fills the form and states his requirement in form. This request is then sent to Facilitator Agent for further processing. It helps the Customer in formation of queries and also display results generated by Travel Agents to Customer.

Facilitator Agent: It establishes communication between Customer and Travel Agents. All the Travel Agents are registered to Facilitator Agent. It is the manager who decides the Travel Agent to process Customer's query. It decomposes the task into set of subtasks and assigns these to various Travel Agents.

Travel Agents: These agents are built to facilitate all the request of the Customers. They are not directly communicate with the Customer but take the entire Customer's request from Facilitator Agent. It retrieves the requested information from wide range of travel database, processes the query using the available information and sends an optimum and relevant reply to Interface Agent.

Reservation Agent: From the information produced by Travel Agent, Customer selects only those in which he is really interested in and deletes the remaining. Now the Reservation Agent either book or cancel the reservation according to the Customer's preferences and finally it acknowledges this information to the Interface Agent.

B. Data collection and preparation

For Air Reservation, we collected the data from different sources and then organized them in the desired format. We explored many websites for the domains and identified the key features which were important in development of the featureset. We extracted the important features of the domains and prepared the featuresets as shown in Table 1.
These features enabled us to know the behavior of customers in case of air-reservation

C. Machine Learning Model: Design and Implementation

Here we used four machine learning algorithms: namely Decision Tree, Radial Basis Function, Multi Layer Perceptron and Support Vector Machine for training four different classifiers to be used by the MAS.

D. Training and Testing

We generated Total 3000 samples as the different values of features, for both the applications. In that 60% (2400 instances) samples were considered as training set and trained on different machine learning models and remaining 40% (600 instances) samples were used as cross validation and test data in both the applications.
In case of Air Reservation, the flyers were categorized in 3 categories. Table II shows these categories.

Table I

Feature No.	Feature	Value
F1	Category	1. Economy 2. Business
F2	Age Group	1. More than 60 years 2. Between 35 and 60 years 3. Between 20 and 35 years 4. Less than 20 years
F3	Customer Type	1. Frequent 2. New 3. Staff 4. Returning
F4	Tourist Loyalty	1. Good 2. Average 3. Bad
F5	Geographic Location	1. National 2. International
F6	Destination	1. If International than Country 2. If National than City
F7	Reservation Mode	1. End User 2. Travel Agents
F8	Airlines	1. Air India 2. Indigo 3. SpiceJet 4. Jet Airways 5. Go Air 6. Air Asia
F9	Flight Timing	1. Morning 2. Afternoon 3. Evening 4. Night

Feature set for Air-reservation

Table II

Cat ID	Category
C1	Frequent
C2	One Time
C3	Occasional

Categorization of Flyers

After training the classifiers for different values of the features as characteristics of customer, it gave us the type of customer as output according to his/her preferences in case of air-reservation.
By this way we developed intelligent agents as now it could display the filtered and relevant information according to the type of customer, from the huge amount of information available on World Wide Web.

VII. Evaluation Criteria For Performance Measure Of The Classifiers

For evaluation, we used 300 samples which were given to the classifiers for classification. These samples had already been classified by a human. Thus the results of the classifiers with manual classification were compared. We calculated the precision, recall and f-measure. For this we used four parameters, these were:

- **True Positive (TP) –** These were the cases in which both manual and classifier's classification gave the same positive results, i.e. if a manual classification considered a case to be of class C1 then classifier also adjudged it as C1.
- **True Negative (TN) –** These were the cases in which both manual and classifier's result gave the same negative result, i.e. they both did not gave the classification for them
- **False Positive (FP) –** These were the cases in which classifier gave a positive result while manual classification gave the negative result.
- **False Negative (FN) –** These were the cases in which classifier gave a negative result while manual classification gave the positive result.

  Based on these four values Precision, Recall and F-Measure where calculated as follows:
- **Precision-** It was calculated by dividing true positive by the sum of true positive and false positive. It is shown in equation 1.

$$Precision = \frac{TP}{TP + FP} \qquad (1) \qquad (5.1)$$

- **Recall**- It was calculated by dividing true positive by the sum of true positive and false negative. It is shown in equation 2.

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

- **F-Measure**: F-Measure is the harmonic mean of Precision and Recall. It is shown in equation 3.

$$F - Measure = \frac{2 * Precision * Recall}{Precision + Recall} \quad (3)$$

VIII. Results

In Air-reservation domain, decision classifier's accuracy was 94.33% as out of the 300 samples, it was able to correctly classify only 283 samples. The average precision, recall and f-measure values of this classifier were 0.7915, 0.7538 and 0.7721 respectively. Detailed class based results for this classifier is shown in Table III.

Table III.

Class	TP	FP	FN	Precision	Recall	F-Measure
C1	1	0	0.071811	1	0.933	0.965339
C2	0.985	0.026	0.045335	0.974283	0.956	0.965055
C3	0.983	0.017	0.055015	0.983	0.947	0.964664
C4	1	0	0.071811	1	0.933	0.965339
Average	**0.7936**	**0.0086**	**0.048794**	**0.7915**	**0.7538**	**0.7721**

Results of Decision Tree Classifier on Air Reservation Dataset

For Radial Basis Function Classifier, the accuracy of the classifier was 96% as out of the 300 samples, the classifier gave 283 correct results. The average precision, recall and f-measure values of this classifier were 0.7915, 0.7682 and 0.7795 respectively. Detailed class based results for this classifier is shown in table Table IV.

Table IV

Class	TP	FP	FN	Precision	Recall	F-Measure
C1	1	0	0.017294	1	0.983	0.991427
C2	0.985	0.026	0.022157	0.974283	0.978	0.976138
C3	0.983	0.017	0.070591	0.983	0.933	0.957348
C4	1	0	0.055966	1	0.947	0.972779
Average	**0.7936**	**0.0086**	**0.033202**	**0.7915**	**0.7682**	**0.7795**

Results of RBF Classifier on Air Reservation Dataset

For Multiple Layer Perceptron Classifier, the accuracy of the classifier was 99.33% as out of the 300 samples, the classifier gave 298 correct results. The average precision, recall and f-measure values of this classifier were 0.7915, 0.7952 and 0.7933 respectively. Detailed class based results for this classifier is shown in Table V.

Table V

Class	TP	FP	FN	Precision	Recall	F-Measure
C1	1	0	0	1	1	1
C2	0.985	0.026	0.010956	0.974283	0.989	0.981586
C3	0.983	0.017	0	0.983	1	0.991427
C4	1	0	0.013171	1	0.987	0.993457
Average	**0.7936**	**0.0086**	**0.004825**	**0.7915**	**0.7952**	**0.7933**

Results of MLP Classifier on Air Reservation Dataset

For Support Vector Machine Classifier, the accuracy of the classifier was 95.33% as out of the 300 samples, the classifier gave 286 correct results. The average precision, recall and f-measure values of this classifier were 0.7915, 0.7856 and 0.7884 respectively. Detailed class based results for this classifier is shown in Table VI.

Table VI

Class	TP	FP	FN	Precision	Recall	F-Measure
C1	1	0	0.017294	1	0.983	0.991427
C2	0.985	0.026	0.015	0.974283	0.985	0.979612
C3	0.983	0.017	0	0.983	1	0.991427
C4	1	0	0.041667	1	0.96	0.979592
Average	**0.7936**	**0.0086**	**0.014792**	**0.7915**	**0.7856**	**0.7884**

Results of SVM Classifier on Air Reservation Dataset

IX. Evaluation Of Multi Agent System

In our study, MLP was giving better results on Air-Reservation dataset. We used this classifier in the multi agent system. In order to verify, whether the classifier along with the MAS was giving good results or not, we evaluated the results with 100 manual results. These 100 results were done by the humans who analyzed the requirements of the users and then came to a judgment. Based on their judgment they provided the respective information.

We used Precision, Recall and F-Measure to calculate the performance of the MAS. For precision, we accounted the matches i.e. the number of time both human and MAS came to the same judgment which was divided by total judgments that the MAS gave. In case of tourism domain the MAS was able to give 87 judgments and in case of Air-Reservation, MAS was able to give 93 judgments. For recall, we accounted the matches which were divided by the total judgments made by the human. For F-Measure, we used the harmonic mean of precision and recall which is shown using equation 3. Computation of precision is shown in equation 4 and computation of recall is shown in equation 5.

$$Precision = \frac{correct\ judgments(Matches)}{Total\ judgements\ by\ MAS} \quad (4)$$

$$Recall = \frac{Correct\ Judgements\ (Matches)}{Total\ Judgements\ by\ human} \quad (5)$$

In case of air reservation, f-measure was 0.91. So accuracy was above 90%. The result of this is shown in Table VII.

Table VII

Domain	Precision	Recall	F-Measure
Air-Reservation	0.95	0.88	0.91

Evaluation Results of Multi Agent System

We did significance testing for verification of the results produced the evaluation. We have conducted a paired t-test at 95% confidence interval. This test was chosen because it is the most frequently used measure which can identify the significance i.e. the results are repeatable and are not produced as a matter of chance. The test was conducted at 95% confidence interval which tells us that in 95% cases the results were repeatable and did not happen as a matter of chance. This is done by finding the probability for the same. This value is termed as p-value. For 95% confidence interval, α-value (0.05) is the threshold. If the value of p is lesser than the value of α then we can safely conclude that the results are reliable and our null hypothesis holds and if it does not than our null hypothesis is rejected.

Table VIII shows the results of the paired t-test for decisions of humans and MAS for Air-Reservation. Here again, we observed positive value of t, i.e. the value of $p \leq \alpha$. This showed that the paired t-test was statistically reliable.

Table VIII

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
.73300	.44261	.01400	.70553	.76047	52.370	.999	.000

Paired t-test of Human and MAS for Air Reservation Domain

X. Conclusion

In this paper, we focused on design and development of multi agent system (MAS) which can reason and learn for environment. To achieve this goal machine learning classifiers –Decision tree, Support vector machine, Multi layer perceptron and Radial basis function were used. Performance of all these classifiers was also compared and among these the best classifier was used in the system.

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IOSR Journal of Computer Engineering (IOSR-JCE) is UGC approved Journal with Sl. No. 5019, Journal no. 49102.

*Archana Mangal. " A Framework for Machine Learning based Multi Agent System." IOSR Journal of Computer Engineering (IOSR-JCE) 19.4 (2017): 13-18.