Agent Negotiations for Improving Quality of Solutions from Multiple Perspectives

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Abstract **-Most of the real world problems can be solved using more than one method which may return slightly different solutions. For instance, statistical techniques, artificial neural networks, fuzzy logic and genetic algorithm can model the same real world problem subject to own strengths and weaknesses. However, it is evident that human beings can modify/improve solutions generated in the individual capacity through negotiations among the individuals. This concept has been employed in the Multi Agent Systems (MAS) technology which can model complex real world problems to achieve quality solutions beyond the individual capacity. In this work, MAS has been used to ensemble weather forecasting results individually generated by Artificial Neural Network (ANN) and Genetic Algorithms (GA) through negotiation among solutions. It considers ANN and GA as two agents. It has selected this application domain to demonstrate the concept since weather forecasting is important for many sectors such as agriculture, fisheries and transportation. Our MAS solution forecasts the rainfall for next twenty four hours with the use of set of present weather conditions as inputs for ANN and GA agents. The defined two agents are used to operate on an ANN and GA solutions that start negotiation & deliberation to produce a more rational forecasting. The experiment concludes that even when solutions by ANN Agent and GA Agent shows a disparity at the beginning, they reach to commonly agreeable solution through the negotiation in the multi agent solution with a 65% of success.**

1. Introduction

A rational problem solving strategy has a great importance in any domain such as Science, Engineering, Biology, Commerce and Arts. Most of problems in these domains can be solved using more than one method which may return slightly different solutions. The common approach has been used a single technology or method to solve a particular problem. Yet, these technologies have their own strengths and weaknesses unique to them which directly affect the qualities of the final result. By using multiple technologies to solve a single problem, the limitations of the individual technologies can be controlled while enabling maximum use of their strengths in to the final solution. This concept has been employed in the MAS technology which can model complex real world problems to achieve quality solutions beyond the individual capacity. In order to show the concept, the multi agent negotiations based multiple perspective approach was used in the weather forecasting domain since an accurate weather forecasting mechanism is an essential requirement in any country. Any accurate weather forecast can lead to the mitigation of risks associated with sectors like Agriculture, Transport, Fishing, etc. Governments and other organizations also use weather forecast reports to protect life and properties [1].

Recently weather forecasting model development efforts have been made to obtain better forecast models by using ANN, Fuzzy Logic (FL) and GA kind of none algorithmic problem solving techniques available in the field of Artificial Intelligence. Different types of ANNs have been proposed to forecast weather results. Back Propagation Neural Network (BPNN) and Radial Basis Function Neural Network (RBFNN) has been used to efficiently generate forecast results [2], but final outcomes were biased to the trained data set and the false positive rate was around thirty percent. ANN approach also can be used for real time weather forecasting [3] by using data from all combinations of atmospheric conditions to train the network for limiting the biasness of the results. An ensemble of ANN techniques like Multi-layered Perception Network (MLPN), Elman Recurrent Neural Network (ERNN), Radial Basis Function Network (RBFN) and Hopfield Model (HFM) has produced accurate forecast results [4]. The problem of less accuracy in forecast reports has been addressed using Dynamic Weighted Time Delay Neural Networks (DWTDNN). Its main focus has been to forecast both temperature and rainfall [5] by treating weather forecasting as an unbiased time series forecasting problem. GA based forecasting approach have also been used for weather forecasting in order to filter out sets of historical data for K-Nearest Neighbour (K-NN) model. K-NN model then classify the weather report in an appropriate way to generate accurate results [6], but this method is a time and resource consuming method. Further, GA has been used to populate mathematical models to predict the rainfall over India that best describe the temporal variations of the seasonal rainfall and therefore enables the forecasting of the future rainfall [7]. Although there are number of mathematical models that can be created using this method, only the

particular region will be represented in the models. Therefore forecasts for other regions may not be accurate. Combined FL and K-NN are also used to predict weather conditions [8]. K-NN is used to filter the fuzzy membership functions. Richness of the training dataset determines the quality of the results generated from the fuzzy logic system. Although there are number of non algorithmic forecasting models available, false positive rate of forecast reports seems to be considerably high.

In order to solve the false positive rate of the forecast results problem, multi agent negotiation based ensemble of multiple perspective approach was proposed through this work. Meteorological experts and related staff can be considered as the users of the proposed system. After giving present weather conditions such as Maximum temperature, Minimum temperature, Relative humidity day time and Relative humidity night time, Rainfall as inputs to the system, the rainfall forecast for next twenty four hours will be produced. Two agents were assigned to generate rainfall forecasting reports independently by using ANN and GA based forecasting models. In order to release the conflicts among agents, the negotiation and deliberation process is used. Java Agent Development Environment (JADE) is used to develop the Multi agent negotiations architecture. The ANN and GA toolkits available in MATLAB are used to develop weather forecasting models. The historical weather data set related to the Colombo city was taken from department of meteorology Sri Lanka. It includes the weather data from 1st of October 2011 to 30th of November 2011. This data were used to train and develop the ANN and GA based forecasting models. Further, part of the dataset was used to test the system. Finally, in order to show that the proposed concept is functional, the negotiated rainfall forecast results have been plotted which shows that they reach a commonly agreeable solution through negotiation. This system has a set of capabilities such as the ability to work with incomplete and noisy data. It uses both data and expert knowledge to produce results. Only disadvantage is that it takes considerable amount of time to produce results due to negotiation process.

The rest of the report has been organized as follows. Section 2 reports on critical and organized analytical reviews on set of works in the weather forecasting domain. Section 3 reports on the relevant technologies. Section 4 depicts an approach to multi agent negations for weather forecasting. Section 5 gives the design of the negotiation model. Section 6 demonstrates the implementation of the negotiation model. Section 7 discusses the evaluation and Section 8 gives the conclusion and further work.

2. Existing Weather Forecasting Models

When considering the domain of weather forecasting, various types of ANNs, GA based models and FL based combined models have been widely used to come up with better forecasts. Thus it is evident that a single problem can be solved using different technologies. Examples of these models are presented throughout this section.

A. Artificial Neural Network Based Models

Tiruvenkadam & Subhajini, [2] proposed and developed an artificial neural network (ANN) based weather forecasting system by highlighting the strengths of ANN like non algorithmic problem solving techniques with indications of their simplicity and robustness features. This study has been used in the Back Propagation Neural Network (BPNN) and Radial Basis Function Neural network (RBFNN) to generate weather forecasts. As training data they have used a sample real dataset of a particular area from a metrological department. The factors temperature, air pressure, humidity, cloudiness, precipitation, wind direction and wind speed of weather forecasting are used from meteorological experts to train the models. Finally they have come up with a rainfall prediction system. Through the study, the performance of BPN and RBF is also compared and stated that RBF is much accurate and efficient. By looking at the solution it can be seen that the final results are depend on the trained data set and it generates more biased results to the trained data set. When looking at the available statistics, false positive rate of forecasting were around thirty present.

Hung et al, [3] have presented a real time rain fall prediction system by using set of ANN techniques while improving the performance of forecasting. Study was based on the Bangkok City, Thailand and the entire research was based on collected weather data from seventy five locations in the city around the predicting point for four years of time. Entire data set had been used for developing ANN model and authors have found that the model based on feed forward ANN model using hyperbolic tangent transfer function achieved the best rainfall prediction than other models. Work has used a combination of parameters such as relative humidity, air pressure, wet bulb temperature and cloudiness etc to form the model from surrounded data collection stations and allow producing the rain fall reports in real time manner. The authors have used different copies of ANN model to train them using different datasets (from rainy and none rainy periods) to achieve unbiased forecasting results. Finally the author has produced six types of rainfall prediction reports ranging from one hour to six hours ahead. Among them according to the author one hour to three hour results were more accurate than others. Final results were generated using a single output from the model and there was a probability to generate false positive results due to the independency in decision making of the model.

Maqsood et al, [4] proposed somewhat different approach for next twenty four hour weather forecasting by using ANN and associated technologies. Their approach consists of an ensemble

of seven different neural network models. Each ANN model uses separate technologies (Multi-layered perception network (MLPN), Elman recurrent neural network (ERNN), radial basis function network (RBFN), Hopfield model (HFM), predictive models and regression techniques) to perform the prediction and final prediction report comes as a collective answer from all the models. In assembling process, they have proposed a weighted assembling method depending on the ANN model's error rate. Each model has been separately trained with a common data set, which includes Temperature, Wind speed and Humidity. Once an independent forecast was generated from each model, all the outputs go through a module called average results generator. Finally the entire system produced an average forecast report for a specific time. By looking at the approach, it can be seen that the final result comes just as an average value. Rather doing this way to get the final result, if it is possible to go to negotiation based process among each model to conclude the final answer, it would have been more rational and of less false positive results.

S. Santhosh and Sheref, [9] has proposed a neural network based algorithm for predicting the temperature. According to the authors, the major problems of weather predictions are the error involved in the measurement of initial conditions in atmosphere and incomplete understanding of the atmospheric process. Due to above problems the traditional weather forecast results become less accurate. In order to solve such problems they have proposed a temperature prediction system using Back Propagation Neural network. This network contains three layers called input layer, hidden layer and output layer. For training of the system they have used a real time weather dataset that contains about two hundred entries. According to the approach it is a simple and efficient method for making any data related predictions but they have concluded that BPN as the better method available to make this kind of predictions, without testing other available Neural Network models.

James N,K.Liu and Raymond S.T.Lee [10] has proposed a methodology to short term rain fall forecasting in a relatively small region using a Back Propagation Neural Network model. Data sets from eleven weather stations were used for training the model. Six hourly data of dry bulb and wet bulb temperatures, rain fall, mean sea level pressure, relative humidity, wind direction and wind speed were used from selected weather stations to train the model. In order to solve the incomplete data problem, linear function interpolation with nearby value mechanism has been used. The proposed method has included a GA with Elitism mechanism for selecting the high fit data to train the ANN from transformed data set. Fuzzy based classified rainfall parameters were used as the expected output from neural network when training the model using BPN mechanism. Finally the model has been tested by using three data sets. They are Set A: Weather data from single station at Hong Kong, Set B: Weather data from multiple stations at Hong Kong, Set C: Time series weather data from multiple stations. Then linear correlation and average classification method is used for analyzing the model and according to the outcome of them, authors have concluded that the multiple station model is more accurately when predicting the rainfall over other models. According to the work done, the accuracy of model depends on richness of the data set that is used for model training.

L.L LAI et al [5] proposed an intelligent weather forecasting model. Normal difficulty in simulating the meteorological phenomena and the corresponding characteristic of weather forecasting has been addressed in the work. By using complex differential equations and computational algorithms it is difficult due to none linear nature of atmosphere when forecast the conditions. Through this work authors have proposed a methodology to forecast short term temperature and rainfall. In order to do so they have proposed Dynamic Weighted Time Delay Neural Network (DWTDNN) with suitable data preprocessing mechanisms. Authors have also mentioned the strengths of ANN technology to forecast on various areas such as short term load forecasting, agriculture risk management. Due to difficulty in capturing time related dynamics of time series events authors have mentioned that the existing multi layer neural networks were not suitable for weather forecasting like time series predictions. DWTDNNs are kind of dynamic neural networks which maintain a short term memory mechanism to store dynamic data. In order to train the proposed network they use pre processed data from fourteen meteorological centers around shanghai. According to their test results, the proposed system has given that approximate weather results. Although it gives approximate results, there are improvements to be placed in the architecture because still the false positive rate can be seen in the final results as shown in drafts.

B. Genetic Algorithm Based Models

Yuen Keith, [4] proposed an approach to rain fall prediction system by using hybridized genetic algorithm (GA) and K-nearest neighbour (K-NN) classifier based on a set of weather data. Normally it is difficult to perform a classification on huge amount of data to get proper predictions on rain fall, but through this work, the author has used a genetic algorithm with a fitness function to select highly fit data for the rain fall classification process based on K-NN algorithm. Further the author has done a set of experiments and proved that the accuracy of the heavy rainfall prediction processes. According to the work done by the author, the approach is suitable only for heavy rain fall forecasting and time taken to generate high fit data is considerable.

C. M. Kishtawal et al [8] have proposed a genetic algorithm based rainfall forecasting model. Through the study they have assessed the feasibility of a

nonlinear technique based on a genetic algorithm for the prediction of summer rainfall over India. The Genetic algorithm has been used to populate mathematical models to predict the rainfall. The genetic algorithm finds the equations that best describe the temporal variations of the seasonal rainfall over India, and therefore enables the forecasting of future rainfall. The forecast equation developed in this study uses the monthly mean rainfall during June, July, and August for the past years over five rainfall homogeneous zones of India to predict the seasonal rainfall over the Indian landmass. They have applied the GA to find the equation that best fits the rainfall data in one part of the dataset called the training set. The predictability skill of the solution equation then has been validated using a separate dataset. Authors have attempted to pick an equation in such a way that the difference between the fitted and the actual values of the time series does not exceed a threshold at any instance, in addition to the fact that such equation should achieve the maximum possible fitness strength. The major advantage of using genetic algorithm versus other nonlinear forecasting techniques such as neural networks is that GA produces a model as an equation for rainfall forecasting. It is to be noted that due to the limitation on the population of candidate equations, or the number of operators allowed in an equation, it is difficult to obtain the most appropriate expression at the end of the initial evolution process. Although there are number of mathematical models that can be created using this method only a particular region will be represented in the models. Therefore forecasts for other regions may not be accurate.

Juan Peralta et al [11] have introduced the comparative method for time series forecasting. This is important for displaying the manner in which the past continuous conditions affect the future conditions. Authors have used the concept of evolving neural network to forecast the weather like conditions. They have comparatively used two neural network evolving methods to develop the system, where one was carried out with a genetic algorithm and the other with an estimation of distribution algorithms. The main objective of this study is to; take an attempt to improve the accuracy of final forecasting results. The genetic algorithm based model has been used to define best neural network model. This process has been involved to define the best fit neural network properties such as number of hidden layers, activation functions etc... Authors have used five types of time series data for experiment setup and finally have concluded the Strength of GA based forecasting model.

C. Fuzzy Logic Based Combined Models

K. Hansen & Denis Riordan, [8] have proposed a FL based weather forecasting system for an airport area. According to the problem they have addressed, it is a small area prediction within small time periods when compared to the traditional weather forecasting problems. They have proposed a fuzzy logic and K-NN combined method to solve their problem. They have used K-NN algorithm to produce, fuzzy membership functions required to form a FL model from thirty six years of collected data set. Here they have worked with traditional weather prediction experts to tune the FL system to produce accurate results. Finally by testing this system with existing systems, and it is showed that the accuracy of their system. By looking at their work they have addressed the problem of retrieving required fuzzy membership functions for the fuzzy logic model and implementation of FL system.

Raymond Lee and James Liu, [12] have proposed an intelligent weather forecasting system. Main objectives of their work was to reduce the computation power require to generate weather forecast results compared to traditional methods and generate forecast results within short periods of time for relatively small regions. In order to achieve these objectives they have used Intelligent Java Agent Development Environment (iJADE) to develop Fuzzy Neuro based intelligent agents for automatic weather information gathering and filtering and for time series weather prediction. The iJADE provides an intelligent layer which supports to develop intelligent capabilities other than communication and mobility in JADE and IBM Aglets. According to the proposed system it contains five major components as follows. User Requirement Definition Scheme for collection of specification of the expected report. The Weather Reporting Scheme is for handling final reports. Data collection scheme is used as a set of mobile agents to visit remote weather stations and collect weather data. Variable selection and Transformation scheme selects appropriate weather data to train and test the system. Fuzzy Neuro Training and Prediction Scheme are used for training and making predictions according to the data sets from a variable selection scheme. When looking at the test result provided by authors it can be concluded that the proposed method is better than the single station prediction model.

Predictions in Financial, Production, Climatology, Traffic control etc can be taken as time series prediction problems. There are mathematical models available to make predictions for those areas. However those models require an accurate set of initial input values for models. Otherwise small errors in initial input values lead to inaccurate predictions. Practically having an initial input values is impossible. In order to overcome the above problem Luis et al, [13] have proposed the Adaptive Network-based Fuzzy Inference System (ANFIS) and a Genetic Algorithm based two approaches with comparisons of each other. As the data set for construct the two models they have used microscopic traffic of an automobile through a succession of two hundred and nine traffic light positions. Dataset was used in fuzzy model training purpose and construction of fuzzy membership functions in ANFIS model. GA model is also used on the same

dataset to generate the set of rules associated with predictions. Only the highest fit rules were chosen for use. Finally authors have compared both models and stated that the ANFIS model works better for predictions compared to GA model. Error rate, time consumption and processing were lower in the ANFIS model compared to GA model.

Through the literature survey discussed above, the three major Artificial intelligence approaches (ANN, GA, FL) were widely used by authors to solve the problems in weather forecasting. Among those approaches more than eighty percent of researches have been conducted using ANN and limited amount of researches have been conducted using GA, and FL. High false positive rate of reports, being biased to the trained dataset, taking more time to produce results (cannot be used for real time predictions) and models are not generalized to the areas are the identified problems of the three technologies through the survey. By analyzing above problems, high false positive rates of the forecast results can be considered as the major problem; because wrong weather forecast results may make the civilian's day to day life style unstable and sometimes it can lead to huge financial losses in any country. Next section discusses the essence of ANN, GA and multi agent negotiations technology relevant to the weather forecasting domain.

3. Overview of Technologies Adapted

Through the literature survey, it was identified that the false positive rate of weather forecasting is a major problem. In order to produce a solution, essences of relevant technologies are discussed through this chapter with the justification of choice of a particular technology.

A. Artificial Neural Networks

The nature of the weather data available, they are incomplete, noisy and there is no theory to model the dataset and need generalization ability to predict weather results. According to the literature available [14], feed forward neural network model with a back propagation training algorithm is suitable to model weather forecasting models. When considering the domain of weather foresting, we can train a back propagation neural network by using historical data on weather conditions to predict future conditions. The trained neural network will be able to predict future weather conditions with the generalization ability.

B. Genetic Algorithm

When considering the problem of weather forecasting, we can set weather parameters such as Temperature, Relative humidity, Rainfall, Wind speed as genes to produce a chromosome in a genetic algorithm. Then by using fitness function and constraints on each gene in the chromosome with genetic algorithm we can produce high fit chromosomes as the forecasts for each parameter. Although the process takes more time to produce results it can generate adaptable results [15].

C. Multi Agent Negotiations for weather forecasting

In this work, planning to use the generic negotiation framework [16] to release the conflicts among ANN and GA based forecasting agents. There is a well defined protocol for agents to negotiate. One agent can be either ANN or GA based agent and calls out rainfall for next twenty four hours. The other party will respond to the proposal indicating whether it is acceptable or if not it will propose new rainfall forecast to the other party. This process goes on several times and both agents will populate the space of potential agreements (possible results). By using those potentially agreed forecast results; agents find the best result as the rainfall forecast. This best result finding process has been included in the negotiation protocol. Since this generic framework can be use differently to develop various negotiation applications, it has been used in an adaptable manner to solve the weather forecasting problem.

The next section discuss the main hypothesis of the project with explanations of how the selected technologies are used to solve the problem as inputs, process, outputs, users and features points of view.

4. An Approach to Using MAS Negotiations for Weather Forecasting

In order to produce a solution for the problem of false positive rate, rest of the work planning to propose an approach for rainfall forecasting using technologies mentioned in the previous section.

Our main hypothesis is the false positive rates problem in weather forecast reports which can be solve by using agent technology in the manner of multi agent negotiation among multiple perspectives.

The meteorological experts are considered as the users of the system. Proposed system uses minimum temperature, maximum temperature, relative humidity day time, relative humidity night time and rainfall for forecasting rainfall for next twenty four hours. The rainfall forecast report is generated separately from multiple perspectives such as ANN, GA associated agents. Most of the times these two agents will produce slightly different rainfall results for the same input and the ANN and GA forecasting models are not much accurate independently. In this situation the two agents identify their conflict. Then they start negotiation and deliberation process to share the findings of each agent for releasing the conflicts. In the negotiation both agents independently tries to reduce the disparity in results among each other and conclude the final results. This conclusion derives as the pair of results from ANN and GA where they have minimum difference.

The request, resource, message, ontology based multi agent negotiations architecture has been implemented through the work. The JADE framework used to develop the MAS. The main agents available in the system are GUI agent for interaction with the external users, ANN agent for forecast rainfall using artificial neural networks, and GA agent for forecast rainfall using genetic algorithm. In order for agents to operate, ontology is implemented in MATLAB. Additional knowledge for agents to operate developed as the Java rules available in a Java object. Finally, all the modules work together to form the multi agent negotiations based forecasting model.

Proposed system uses multiple technologies to forecast the rainfall. System has set of capabilities such as ability to work with incomplete and noisy data, produce results using limited data. It used both data and expert knowledge to produce results.

Since two different perspectives contribute for producing a single answer by using same environmental data set, it is expected to be a more rational rainfall forecast reports. Proposed request, resource, message space, ontology based multi agent system design presented in the next chapter.

5. Design of MAS Negotiations Based Weather Forecasting Model

This section elaborates the approach that was stated in previous chapter. The MAS based on the request, resource; message space and ontology architecture used to show the available agents in the system. Figure 1, Shows the interaction among each module.

A. Design of User Interface and User Interface Agent

This is the request Agent available in the system. It manages the user interface for users to interact with the system. At the starting of the GUI agent, the UI will be initialized and the ANN and GA based agents started. The GUI and GUI agent collectively support to gather inputs such as temperature, relative humidity and rainfall data in to the system. Then create the forecast request message and send the request to the ANN and GA based agents. It also supports displaying negotiation messages among resource agents with negotiated rainfall forecast related details.

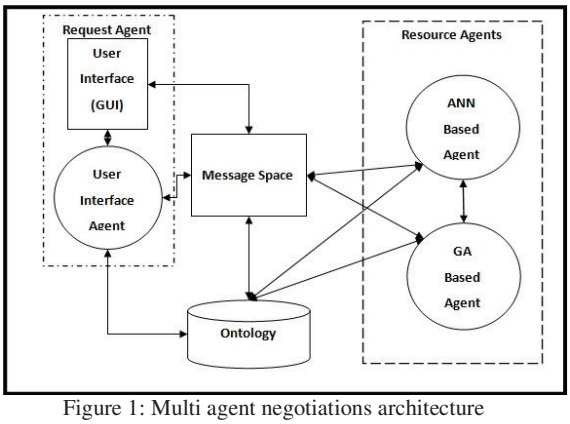

Figure 1: Multi agent negotiations architecture

B. Message Space

Message space is the place where all the agents write their important messages and read required details for the negotiation purpose. Information included in message space are input data such as temperature, humidity and rainfall and forecast results of each agent and other negotiation related messages of resource agents. Using message space all the agents are able to have awareness about current states of the counterpart agent. The agents in the system read the required messages from the message space when necessary.

C. ANN and GA Based Agents

The ANN and GA agents' uses current weather conditions in producing rainfall forecast for next twenty four hours. Once they receive a request for weather forecast from GUI agent, they query the ANN and GA models available in the ontology to produce initial rainfall forecast. Once the forecasts are available they update the message space by informing their current forecast results separately. Here after they pay attention to the counterpart agent's forecast results for same input conditions. Once the forecast of counterpart agent is available, it compares it with its own result. If there is a mismatch between results then that agent identifies the conflict and uses their negotiation knowledge available to start the negotiation process. The negotiation process continues until an agreement reaches or specified number of negotiation attempts reach. However ANN agent uses theoretical and heuristic foundation to conduct the negotiation while GA agent uses random search mechanism.

D. Ontology

The ontology maintains knowledge related to agents in the system. It helps to reduce the size of each agent by maintaining ANN and GA based forecasting models and negotiation related knowledge. ANN and GA based knowledge can be dynamically changed while the agents are in operation. Negotiation related knowledge is stored as rules in the ontology and this rule based knowledge does not change dynamically. All the agents have an

ability to access their knowledge and dynamically make suitable changes on it.

1) Ontology Related to ANN

By default, a trained back propagation neural network is available in the ontology. ANN agent uses trained back propagation neural network model as the default model and it uses to generate forecast results at the beginning. Within the rest of negotiations, forecasting model is changed by the ANN agent for achieving more GA agent intensive forecast results. After the initial forecast, the dynamically changed forecasting model will be online trained by the ANN agent. In order to change the ANN forecasting models, the error goal, the learning rate and number of epochs should be changed by the ANN agent.

2) Ontology Related to GA

The GA based forecasting model is available in the ontology. This generates forecasting according to the forecast requests. When the negotiation goes on, this model generates more ANN agent intensive results to minimize the conflict among agents. For that, it continuously changes the crossover and mutation rate kind of GA options. When compared with the ANN forecasting model, the GA model is capable of producing not only the rainfall forecast but also temperature and relative humidity kind of other conditions for next twenty four hours simultaneously.

3) Rule Based Knowledge

The ANN agent maintains the negotiation knowledge as rules. These rules support to make suitable changes in ANN forecasting model to release conflicts among resource agents. These rules formatted as IF, THEN and ELSE manner.

Through this section design of the request, resource, message space, and ontology based multi agent negotiations architecture; their functions and interactions to produce rational forecast reports were discussed and Implementations of these modules will be discussed within the next section.

6. Implementation of MAS Negotiations Based Weather forecasting Model

The design has been implemented using software technologies such as Java technology, Java Agent Development Environment (JADE) and MATLAB tools.

A. Implementation of User Interface and GUI Agent

The UI was developed by using Java UI development components. This interface closely works with GUI Agent. This agent was implemented by extending the agent class available in JADE [17] libraries. Within the setup method of the GUI agent, UI will be called to start the interface and it initializes the agent platform controller. Once the platform controller is initialized, it then starts up the resource agents such as ANN and GA agents. The cyclic behavior class available in JADE [17] has been used to develop the mechanism which processes the incoming messages. This mechanism retrieves the messages and updates the GUI periodically.

B. Implementation of Message Space

Message space has a XML file which resides in the ontology. All the agents can access available nodes of XML file in the ontology by using document builder library in Java. Parameters such as Maximum Temperature (MaxT), Minimum Temperature (MinT), and Relative Humidity Day time (RHD), Relative Humidity Night time (RHN), Rainfall (RF), Rainfall forecast from ANN agent (RFTNN) and Rainfall forecast from GA agent (RFTGA) are stored in message space.

C. ANN and GA Based Agents

These agents were developed by extending the agent class available in JADE development library [17]. Each agent has two main types of behaviors. One for reading the receiving messages (ReadMessges) and the other for read the ontology (ReadOntology). The first behavior was developed by extending the CyclicBehaviour class available in JADE and latter was developed by extending the OneShotBehavior class available in JADE. The behaviors for reading ontology differ from agent to agent. Differences of resource agents depend on the functioning of these behaviors. The agents continuously read their own message queue to classify newly received messages from other agents. The current development contains two types of classifications namely REQUEST and INFORM. REQUESTs are for the received agent to do something such as generate a new forecast result using the forecasting models available in the ontology. INFORMs are for the received agent to get to know about something such as current results of others. According to the forecast results they decide to go for negotiations or conclude the final forecast.

The ANN agent and GA agent changes the properties of their own forecasting models to come up with the counterpart agent acceptable forecast result. In order to change the properties of the forecasting models in the ontology, the “eval” function which is available in matlabcontrolls library [18] was used within the agents. The ANN properties are the learning rate, error goal and number of epochs. GA agent changes its crossover and mutation options to come up with more agreeable forecasts.

D. Implementation of the Ontology

Implementation of the Ontology was based on MATLAB tools, XML and Java technologies. Separate MATLAB based forecasting modules are available for resource agents to use. A XML file maintains the message space related information inside the ontology. A java object holds the rule based knowledge for ANN agent to operate on negotiations.

1) Implementation of ANN Model

Implementations of ANN model was based on the Neural Network tool kit available in MATLAB [19]. Initially, a feed forward neural network with back propagation learning algorithm has used to forecast the rainfall. The implemented model contains five input neurons for input data such as maximum temperature, minimum temperature, relative humidity day time, relative humidity night time and rainfall. There are ten neurons available in the hidden layer and one neuron available in output layer which gives rainfall forecast as output. The log-sigmoid (logsig) transfer function was used as the activation function of the hidden layer. The linear transfer function (purelin) is used in the output layer. The resilient back propagation algorithm (trainrp) was used as the back propagation training algorithm [20]. Figure 2 shows the architecture of the ANN model.

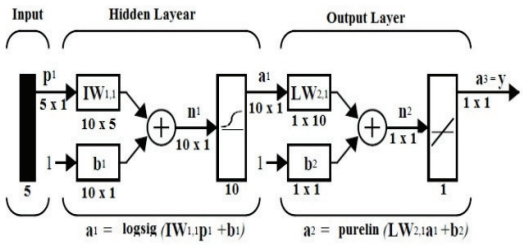

Figure 2: Architecture of the ANN model

2) Implementation of GA Model

GA tool kit available in MATLAB was used for develop the GA model. In order to support the negotiation process, the GA model is dynamically changed by the GA agent. The GA model contains a chromosome with six genes. The Figure 3 shows the chromosome structure.

MaxTF	MinTF	RHDF	RHNF	RFF	RFFDT

Figure 3: Structure of the chromosome in GA model.

The first five genes give the forecasts for the next twenty four hour conditions such as Maximum temperature forecast (MaxTF), Minimum temperature forecast (MinTF), Relative humidity day time forecast (RHDF), Relative humidity night time forecast (RHNF), Rainfall forecast (RFF) and the final gene gives the rainfall forecast of the day after tomorrow (RFFDT). The GA model consists of a mutable fitness function that has been designed heuristically and gene level constraints have been decided using available weather data set.

3) Implementation of Rule Based Knowledge

The ANN agent maintains a set of rules for negotiation purposes. In order to release the conflicts among ANN and GA agents, ANN agent uses available rules to change its own ontology (ANN forecasting model). These rules are encapsulated in to a java class. The rule outputs are based on the amount of difference between ANN and GA forecasting results. As shown in the examples following rules can be considered.

RULE 1:
IF number of epochs equals epochs has used in training THEN
Number of epochs equals epochs used in training plus Hundred
Update the current parameters
ENDIF

When the training process terminates due to number of epochs exceeded, it does not guarantee the proper convergence of the ANN model. In order to properly train the network it may need more epochs. So by increasing the number of epochs, we can expect a more converged network.

RULE 2:
If ANNForecast grater then GAForecast THEN
IF learning rate less than 0.08 THEN
Learning rate should increase by 0.01
ELSE
Learning rate equals 0.05
ENDIF

The RULE 2 is based on the back propagation algorithm [20]. When the ANN forecast is greater than GA forecast, in order to release the conflict, ANN forecast must decrease. According to the back propagation algorithm, increasing the learning rate causes to decrease the final answer of the used ANN model. This property has been used in this rule.

RULE 3:
If ANNForecast less then GAForecast THEN
IF learning rate greater than 0.01 THEN
Learning rate should decrease by 0.01
ELSE
Learning rate equals 0.05
ENDIF

The RULE 3 is based on the back propagation algorithm [20]. If the ANN forecast is less than GA forecast, in order to release the conflict among ANN and GA, ANN forecast must be increased. According to the back propagation algorithm, decreasing the learning rate causes to increasing the final answer of the used ANN model. This property has been used in this rule.

Next section uses implemented prototype for testing of project achievements against the project objectives.

7. Evaluation

This section is about testing of project achievements against the project objectives. It uses the implemented prototype MAS model as the major tool for demonstrating and testing the concept. The evaluation strategy has been designed to explain the level of achievements in objectives.

The weather forecasting models (ANN, GA) were trained using historical weather data sets based on Colombo city from 1st of October 2011 to 18th of November 2011. Twelve days of weather data from

19th November 2011 to 30th November 2011 has been allocated for testing purposes.

Rainfall forecast for 20th November, were generated on 19th November by issuing weather conditions of the 19th November. Then the database was updated (data used to train the ANN model) on 20th November by using 19th November measured conditions and 20th November measured rainfall. Now database was then ready to forecast rainfall for 21st November by using the 20th November weather measurements. This process was conducted until the rainfall forecast of 30th November. Day by day the setup was updated to have up to date data for training the ANN model.

In order to forecast the amount of rainfall for next twenty four hours, number of negotiation attempts has been constrained to ten. In this experiment it selects the best forecast result on a daily basis. The negotiated rainfall forecast results of ANN and GA agents have been plotted for showing the negotiation process among ANN and GA agents and behavior of disparity between each other. The reports on collected results presented in Figure 4 and selected best forecast results for each day available in the Figure 5.

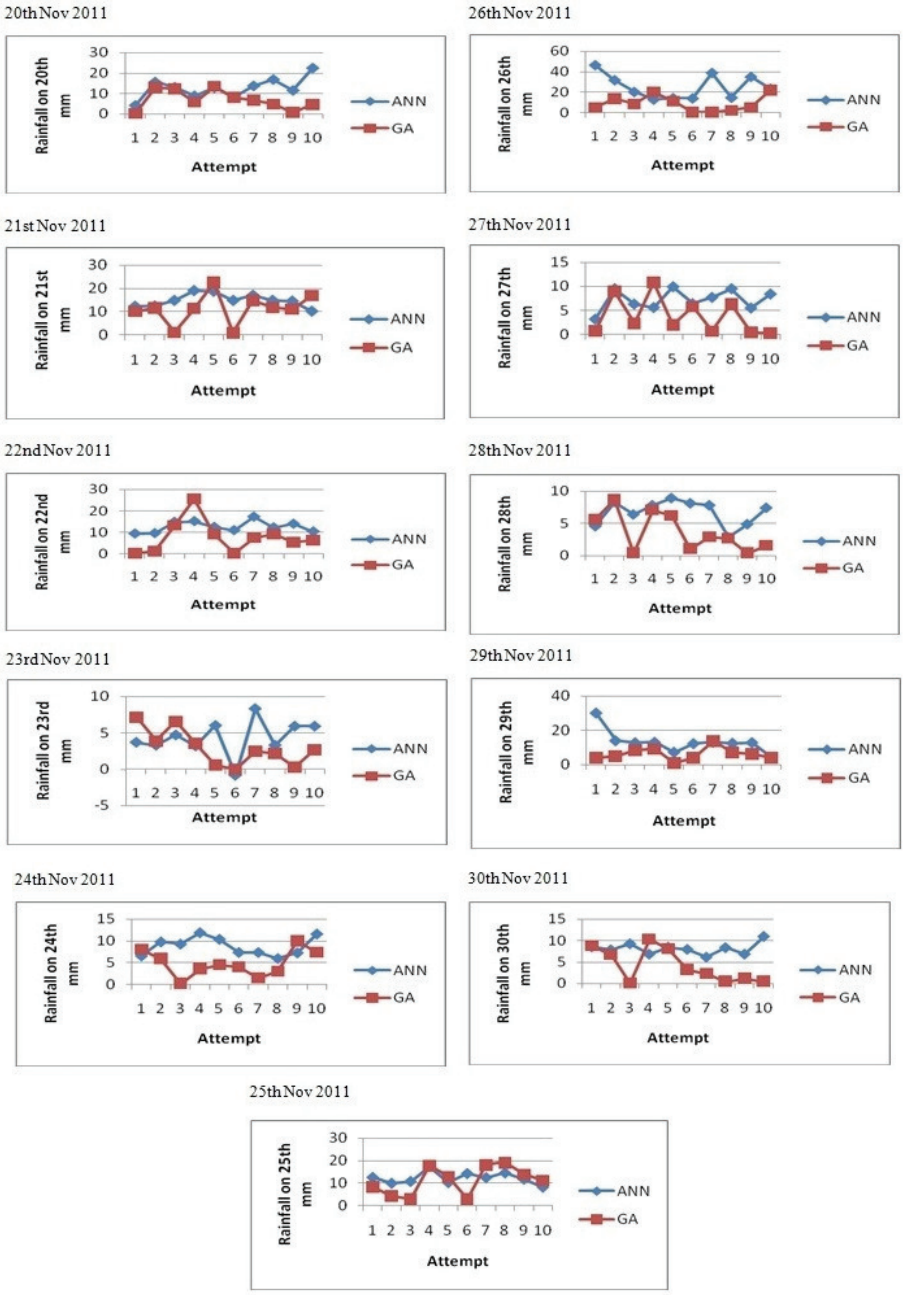

Figure 4: Experimental results with ten negotiation attempts

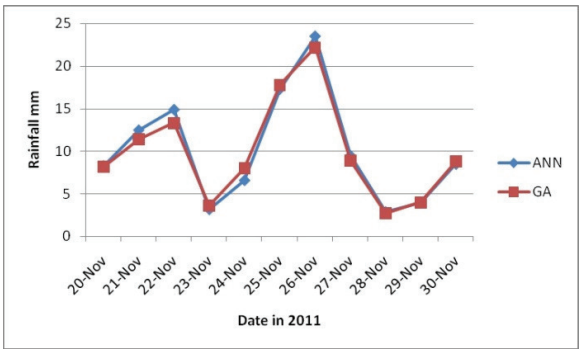

Figure 5: Summary of experimental results with ten negotiation attempts

According to Figure 5 the mean square error of results between ANN and GA solutions was 0.76. The results obtained from the evaluation will be interpreted to analyze the strength of the proposed solution in the next section.

8. Conclusion

This section focuses on the interpretation of the results that were taken from the evaluation. Finally, the section discusses about potential further work which will be worth doing as the continuation of the project.

According to the experimental results that were mentioned in the previous chapter, it shows the gradual reduction of disparity of forecast results between ANN and GA agents. Further it shows that when the number of negotiation attempts increases, the disparity between two agents reduces. The experiments conclude when solutions by ANN agent and GA agent shows a disparity at the beginning, but reach to commonly agreeable solution through the negotiation in the multi agent solution with around 65% of success.

Through this work a MAS negotiations based multiple perspective approach to real world problem solving was discussed. The weather forecasting domain was used as the application area to show the proposed concept. There are two soft computing approaches (ANN and GA). They have been employed to produce results within the agent negotiation environment. By increasing the number of forecasting technologies, it can be guaranteed to have more rational and quality results. The statistical weather forecasting approach called Analog weather forecasting approach and a decision tree based forecasting model can be proposed to use in separate agents as further work. By enabling MAS negotiation among more approaches or technologies, it can guarantee the accurate results beyond the capabilities of each individual agent.

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