DecisionAI: A Framework to Automate the Decision Making Process

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***Abstract*—accurate decision making is the key to make a business profitable. Decision support systems are used to make the decision making process accurate and easy. Even though there are many business specific decision support systems they cannot be used for general purpose decision making or outside their domain. DecisionAI provides a framework which can be used in any decision making domain with similar decision types. DecisionAI provides a good solution to many decision making problems in the industry allowing detailed analysis of data with the integrated intelligence.**

Keywords-Neural networks, Optimization, linear programming, decision, framework

I. INTRODUCTION

Accurate Decision Making is a key aspect of a successful business organization. The revenue and the profit of a business organization overly depend on the decisions that the management of the business organization makes. Hence most of the business organizations incur a lot of cost and time to fine-tune their decision making process.

Today in most of the business organizations decision making is carried out by the top management. Hence these decisions tend to be affected by the individual thinking process of the person who makes the decision.

With the exponential growth of IT, most of the business organizations have the ability to keep a large amount of data related to their business domain. Processing these data in an accurate and efficient manner is very important when it comes to decision making. But manual processing of data is a nightmare as humans need to put a lot of effort into data analyzing. Even if we put a lot of effort, the accuracy of the results generated by manual processing is quite doubtful.

Decision support software has been introduced as a solution to the above mentioned problems, where the software processes data and produces decisions in the corresponding business domain.

Most of the available decision support systems are business domain dependent where we can use them for a particular domain. The system proposed by this paper is a decision making framework which can be applied into multiple business domains with similar decision types.

II. Related Work

Currently there are many systems available to automate the decision making process. Most of the systems are decision support systems, built focusing their specific domain like clinical decision support, supply chain management, industrial process management, stock trading etc. Each of these systems highly depends upon the data specific to their domain.

- Decision Support Based on Integration of Fuzzy Clusering and MOP[1]
- Modeling one Human Decision Maker with a Multi-Agent System[2]

are two such systems.

Building a decision making system highly depends upon the domain the system is supposed to be implemented. That is, the decision criteria change according to the business environment.

The main technology/technologies which are to be used too depend on the problem domain. For example, for problems which can be approximated to mathematical functions, we can use statistical models (i.e.: regression analysis). For such systems, neuro-fuzzy techniques are not very suitable as statistical models would give more precise results. But for systems which are of a dynamic nature, statistical models cannot be used. Also as these domain dependent technologies are optimized for that particular domain, the model cannot be used for another domain. That is, for example, the technology that performs well in travel decision making will not give the same performance when it comes to clinical decision support. This is mainly because of domain specific data and their properties. So it is very hard to use a domain specific decision support system in a different domain.

III. PROPOSED SYSTEM

Main features of the proposed decision making framework are as follows.

- Ability to plug in the framework to a domain specific database and obtain decisions
- Add features to the data where necessary
- Integrated intelligence to analyze data and give the required decision.
- Add the effects of the irregular events that happen in the particular area.
- Optimization to cater constrains combined with decisions.
- Ability to analyze proposed decision
- View the effect of the decision with real time data available

The figure 1 below shows the overall modular architecture of decisionAI. Each module is responsible of performing a specific task. The decision making process starts with the language module and goes up to presenting to the user from presentation module..

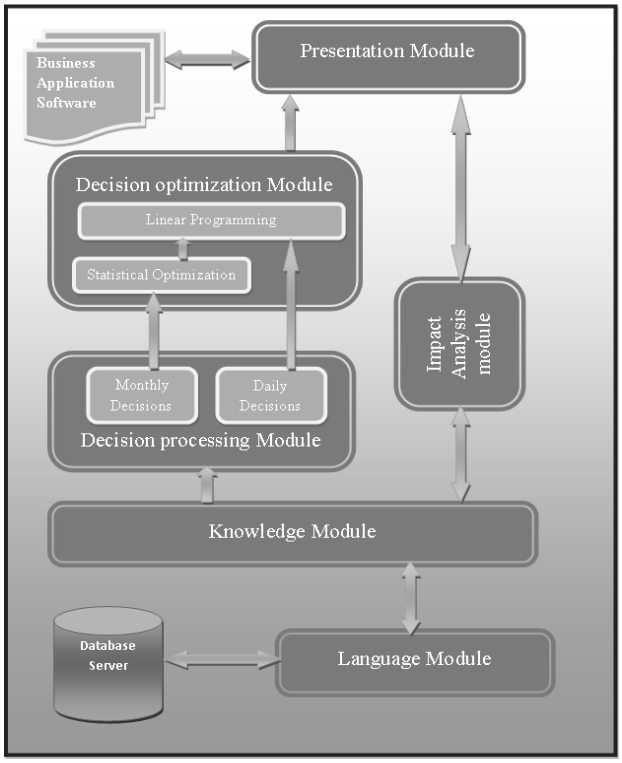


Figure 1. Modular Architecture of DecisionAI

A) *Language Module*

Language module is the module responsible for providing all the data needed by other modules. It works as the interface between the system and the domain data. It caters to any domain in which the system is capable of supporting decisions. The user is needed only to provide configuration information to the module which will help the module to extract domain data as necessary to be provided to upper modules. This module facilitates the user to add features of the data set easily. In the framework implementation, the language module has the functions of extracting domain data, processing domain data into system database and providing connection to the system's database. The configuration file is the basis of catering different decision types and different domains. The user needs to specify the configurations according to the domain information. It provides a model which will allow different domain information to be provided into the system so that the system can identify that information as necessary for decision making. Language module makes the framework plug and play to any database in any domain.

B) *Knowledge Module*

Knowledge module is responsible for mainly three functions. That is processing of daily basis data, pre processing data needed for the neural network and managing the events regarding decisions. Processing of daily data is done for decisions where the data is available on a daily basis but the decision is required on a monthly basis. Feeding data to the neural networks and managing events are done by the knowledge module.

C) *Decision Processing Module*

This is the core module of the system where all the data analysis and decision processing is done. Building a decision making system highly depends upon the domain and the system it is supposed to be implemented on. That is the decision criteria changes according to the business environment. A technology that performs well in travel decision making will not give the same performance when it comes to clinical decision support. This is mainly because of domain specific data and their properties.

Since we are building a framework which is intended to be used in any domain with similar decision types, the technology used to produce decisions should be a general one which is not dependent upon data. Considering this fact we first surveyed technologies which can be used in processing decisions and the technologies widely used in decision support systems.

Through basic background research on decision making systems we came across a set of AI technologies widely used in decision making systems. Almost all the decision making systems were based on these technologies or their derivatives.

1. *Artificial Neural Networks*

Neural networks can be used in several ways in decision making. For our problem, we are focusing more on:

- training a neural network to fit a function
- training a neural network to recognize patterns
- training a neural network to cluster data

The features of the ANN have proved itself over various other methods in decision making. One such domain is the Stock market [3][4], which is quite similar to our system. A stock market has many input parameters and its environment and the inputs change frequently. So the decisions must be made within a very short time and has to be precise where the ultimate goal is to earn more profit.

2. *Neuro Fuzzy Systems*

Fuzzy logic can provide results between absolute true and absolute false. So that, the outputs are only approximates, based on degrees of truth, rather than precise once. In simple words, fuzzy logic systems can be used when it is impossible to give an exact answer. Fuzzy logic uses "truth degrees" as a mathematical model of the vagueness phenomenon [5].
Rules are stated in "If - Then" format. More often in the format of: IF variable IS property THEN action. The designer can decide what should be the outputs depending on the inputs, according to the needs and the knowledge [5][6].

But using fuzzy logic alone, it is difficult to get good performance due to implementation difficulties. Finding membership functions and appropriate rules is quite tiring and impossible [7] to do manually with a large data volume involved in this specific problem. The next approach is to use learning algorithms together with fuzzy logic achieving performance in both fuzzy logic and learning algorithms

In this application we have used the ANFIS fuzzy logic toolbox in MATLAB implementing Takagi Sugeno fuzzy inference system. ANFIS uses back propagation learning to determine the input membership functions parameters and the least mean square method to determine the consequent parameters. There are five hidden layers where the first layer is responsible for mapping inputs to a membership function [7].

3. *Decision Trees*

In the context of decision making, decision trees can be used for classification and prediction of features or parameters that are directly associated with a decision. The knowledge that the decision-maker has about the world is encoded into a decision tree where each node is an alternative that represents a possible state of the world. The decision agent assesses alternatives (utility computation), apply dominance search that leads either to the choice of an action or a selection of alternatives to be further explored [8].
The decision is built based on complex information processing mechanisms, and deals with various forms of knowledge representations such as features, criteria, rules etc. The model they have proposed is based on psychological facts which will focus on the heuristics a decision maker would use in the decision process. This property is an important one as all the parameters which the decision is based on will not affect the decision in the same way. A human decision maker will easily identify which parameters will affect the decision most and which affects least.
So when we automate this decision maker, we should be able to provide this capability to our system. The selective attention mechanism they have used is an appropriate way to implement this capability. The anchoring mechanism also would be useful to our system as sometimes we would have to provide a value of a parameter which will not be continuous into the information process.

4. *Rule based (Expert systems)*

Expert systems use a knowledge base of human expertise for problem solving, or clarify uncertainties where normally one or more human experts would need to be consulted. Expert systems are most common in a specific problem domain. Every expert system consists of two principal parts: the knowledge base; and the reasoning or inference engine. The knowledge base of expert systems contains both factual and heuristic knowledge [9].
One widely used representation is the production rule or simply rule. A rule consists of an IF part and a THEN part. The "IF" part lists a set of conditions in some logical combination. The piece of knowledge represented by the production rule is relevant to the line of reasoning being developed if the IF part of the rule is satisfied; consequently, the THEN part can be concluded, or its problem-solving action taken. Expert systems whose knowledge is represented in rule form are called rule-based systems.

From the above mentioned technologies we omitted rule based systems and Fuzzy logic systems since they are directly dependent on the domain they work. Also with large volumes of data and dynamically changing business domains it is very hard to maintain a particular rule set providing correct decisions.

To compare the other three techniques and come up with a suitable technology, we used a hotel data set which consisted of 2850 records for 91 hotels. While modeling the data set, we considered the weather patterns, tourist seasons, and the holidays as the features of the dataset. After modeling, each of technologies were analyzed using correlation coefficient, Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE).

TABLE 1. EVALUATION OF DECISION MAKING TECHNOLOGIES

Model	Correlation	Mean Absolute Error	Root Mean Squared Error
Neural Networks	0.968	1.618	2.031
Decision Trees	0.5874	13.3593	20.8826
Neuro – Fuzzy systems	0.6133	11.0473	17.547

Based on these results, we concluded that Artificial Neural Networks, with Feed Forward Architecture and Back Propagation learning algorithm is the best technology to implement our system. And as we keep adding new features to the data set (improving the model), the results were getting finer.

Once we selected ANN as the decision processing technology the next step was to find how many hidden layers were required, number of neurons etc.
From the analysis we found out that the optimal results were given by the network with two hidden neurons. When building the model, we developed the decision processing module such that the network could be trained by the user when new data was available. Since we are developing a framework, we didn't hard code any neural network property like no neurons in the layers. These parameters were selected

after analyzing different architectures according to the given data. This approach provides the flexibility to use this framework independent of data.

Two main decision types are produced in the decision processing module. We selected these two categories after analyzing many domains like tour operator decision making, stock management decision making, bank decision making etc.
First one is using daily data to predict how the daily values will be for next month and finally output an optimal value for the month considering costs and profits involved. A statistical optimization is used for this purpose.

The next is to consider the daily data and make it monthly values and then produce a prediction for the next month directly. Both of these predictions are done using neural networks.

D) Optimization module

Even though the decision processing module predicts the decisions there may be situation where the user cannot afford all the decisions due to cost constraints and constraints from other parties involved in the business. Optimization module is used to handle those kinds of scenarios and adjust decisions according to the constraints. After analyzing techniques like genetic algorithms [10], statistical optimization and linear programming [11], linear programming was used as the optimization technique considering easy modeling, adding new constraints and results obtained. Linear programming model is used in optimization where the objective function is to maximize profit.

E) Presentation Module

The presentation module is responsible for all the user interfaces. Its main objective is to present the made decisions to the user and since the system has to prove its decision, this module also have facilities to present the impact of the applied decisions in a graphical way. Thus the user will be aware of the consequences of the decisions applied.

Presentation module includes some aspects of data visualization. We use different graphs like historical data graphs, how business is handling in the moment graphs, profit and loss graphs due to decisions in order to provide the user a clear view of how the business is operating.

F) Impact Analysis Module

The impact analysis module is responsible for allowing the user analyze the generated decisions from the system. In a situation where the user feels he needs to change the decisions proposed by the system, the user has the ability to compare his decision with the proposed decision and analyze profit etc. The analysis can be conducted changing the predicted value and changing the price of a unit. When price is changed considering the price elasticity we calculate the demand change and do the analysis and give the profit which can be obtained under that unit price.

G) Irregular Event Management

Irregular event is an event occurring in a particular area which cannot be found using past data patterns. For instance when there is a cricket match in a particular area the demand for hotels increases in that area. This demand increase cannot be found using past data but this should be included in the decision of how the hotel rooms should be reserved in that particular area. The main purpose of event management is to add the effect of irregular events to the decisions.

The user can add events defining the commencing date, ending date and also the cities which would be affected from that event. The user can also specify the demand of those events country wise or city wise. After predicting the prediction attribute value, the module alters those predicted values according to the demands set by the user considering in which cities the event will occur. The user needs to specify the city column name and country column name in configurations which should be considered when altering predicted value for each decision type.

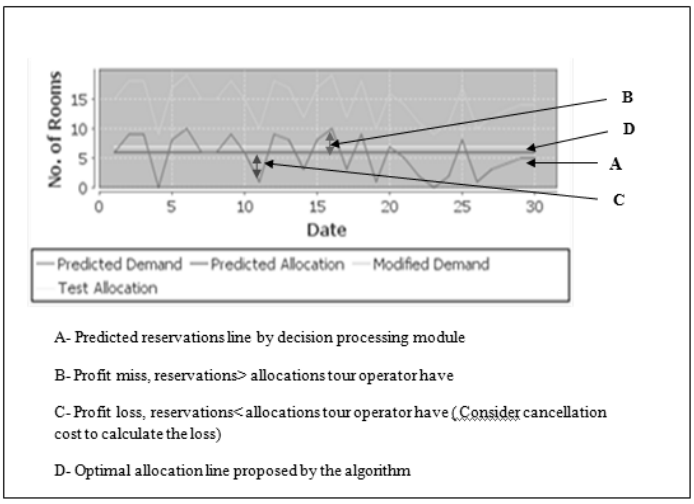
IV. Validation of Framework using Tour Operator Inventory Management Decisions

In order to validate the framework we did a domain specific integration of the framework. We chose tour operator inventory management as our domain. A tour operator typically combines tour and travel components to create a holiday. A tour operator has to take three main inventory management decisions,

- Hotel room inventory
- Car hire inventory
- Flight inventory

The present solution used by tour operators for inventory management is to take yearly average of the reservations, monthly average as the inventory level for the next month. This is a very basic approach to predict the inventory management which doesn't do any detailed data analysis.

We customized our framework to produce decisions of these three types considering the available past data, constraints and events occurring in a particular area.
Hotel inventory decisions were generated daily decision model where we predict the daily reservation pattern for the next month. Then we conduct a statistical optimization as follows considering the profit from a hotel room, reservation cancellation cost.



A- Predicted reservations line by decision processing module

B- Profit miss, reservations> allocations tour operator have

C- Profit loss, reservations< allocations tour operator have (Consider cancellation cost to calculate the loss)

D- Optimal allocation line proposed by the algorithm

Figure 2. Optimization of predicted daily reservations for hotel room inventory

Car hire inventory and flight booking inventory decisions were produced using monthly decision model where the number of car hire bookings for the next month and number of flight bookings for the next month is calculated.

Once the decision processing is done the linear programming modeling for optimization is done as follows.

Objective function:

$$Hotel\ room\ profit = \Sigma\ C_i X_i$$

$$= \Sigma\ Profit\ from\ a\ room\ in\ a\ particular\ hotel * predicted\ no\ of\ rooms\ in\ that\ hotel$$

Constraints:

$$Max\ cost\ the\ user\ can\ afford \leq \Sigma\ cost\ per\ hotel\ room * predicted\ no\ of\ rooms\ in\ that\ hotel$$

$$Max\ rooms\ from\ hotel\ 1 \leq predicted\ no\ of\ rooms\ from\ hotel\ 1$$

.....

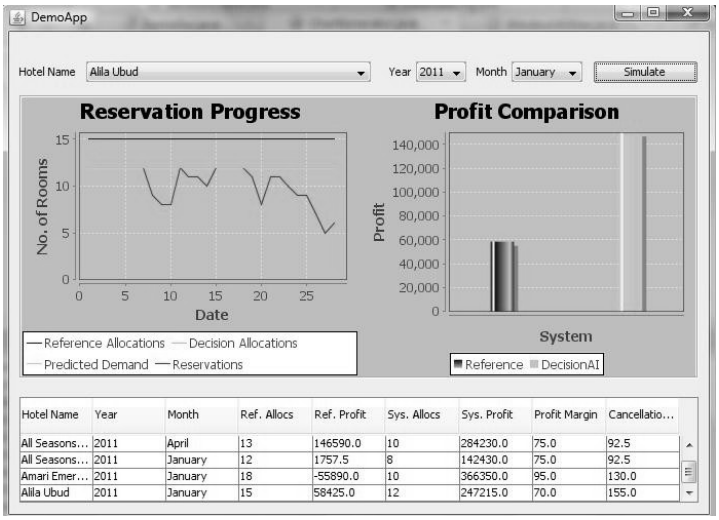
$$Max\ rooms\ from\ hotel\ n \leq predicted\ no\ of\ rooms\ from\ hotel\ n$$

Figure 3. Linear programming modeling of hotel room inventory decisions

After optimization the effect of irregular events are added to the decision considering the user given demand increase because of that event.

In order to do a comparison between the decisions we propose and the industry's current approach we did a simulation of the current approach using the yearly average as the inventory level.

Figure 4 depicts the results of the profit comparison between two different hotels. From the results it is clear that our decision making framework is performing much better than the industry's current approach.



Hotel Name	Year	Month	Ref. Allocs	Ref. Profit	Sys. Allocs	Sys. Profit	Profit Margin	Cancellatio...
All Seasons...	2011	April	13	146590.0	10	284230.0	75.0	92.5
All Seasons...	2011	January	12	1757.5	8	142430.0	75.0	92.5
Amari Emer...	2011	January	18	-55890.0	10	366350.0	95.0	130.0
Alila Ubud	2011	January	15	58425.0	12	247215.0	70.0	155.0

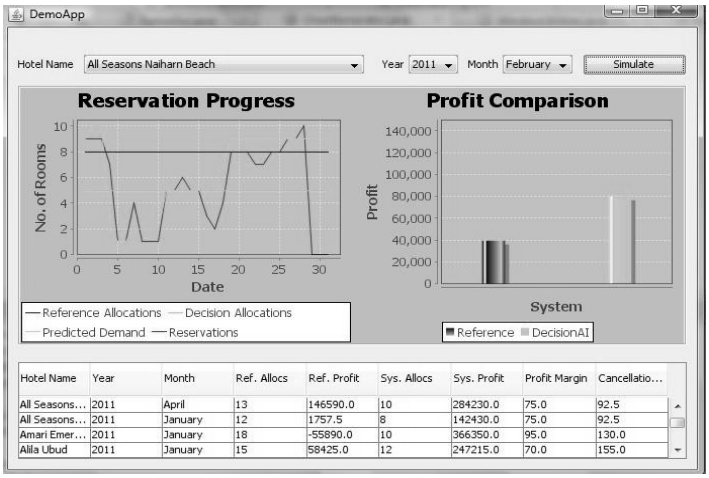


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Figure 4. Profit comparison of industry current approach and our system for two hotels

V. Strengths and Limitations

There are many industries where they do not use any proper data analysis before making the decisions. This system is well suited for that kind of business domain. Since the user has to do a minimal involvement in the training of the system unlike other decision support systems where the user has to define rules and all the other parameters before making a decision, this system is very user friendly and can be plugged and played very easily. Providing user the ability to analyze the decisions and change the framework accordingly is very flexible and user can understand the decisions very easily.

But it is not possible to define each and every decision type generally used in different industries. We have only defined two decision models monthly and daily considering the most general cases. There are many decisions which can be modeled using this framework. And also in order to train the network and get an accurate decision considerable amount of past data is required. So this cannot be used with newly established organizations where we cannot find data. The network is producing really good results when there is a decent set of features which really affects the decisions. Since this is a framework it is not possible for us to define features for data. The user should have knowledge of the features that are affecting decisions.

VI. Conclusion

DecisionAI provides a decision making framework which can be applied to different business domains with similar decision types. Even though there are many domain specific decision support systems a general system which can be used in any domain is missing. The framework is easily plug and play and configurable because of its modular architecture. The framework produce decisions using neural networks to analyze data then optimize these decisions considering constraints involved in decision making and finally add effect of irregular events and present the decisions to the user. Once the decision making is completed the user can analyze the decisions and do alternations as necessary.

The framework validation is done using tour operator as the decision making domain and it has been proved that the framework is performing really well than the industry's current decision criteria.

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