Multiagent Architecture for Management of Milk Tankers in Dairy Industry

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Abstract: In the business sector there has been and always will be a demand for a single master mind or an expert which can look after the crucial business activities round the clock throughout a year. This is not possible for any single human being as the business activities are either controlled by more than one human in the form of a team or by a single human in a discontinuous manner. This introduces an inconsistency in the decision making process. There has always been search for artificial methods to perform the same task in a consistent manner. This research paper has explored the way how intelligent multiagent system can be used to look after such activities in real time. In this paper the architecture of MAS for the management of milk tankers for a milk processing company is discussed. It involves a combination of knowledge base deduction methods with multi agent techniques, working together to accomplish this task. The financial aspects of the project are not included in the scope of this research. [Aslam Muhammad, Ahmad Zargham, Martinez-Enriquez A. M., Multiagent Architecture for Management of Milk Tankers in Dairy Industry. Journal of American Science 2011;7(8):827-832] (ISSN: 1545-1003). http://www.americanscience.org.

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1. Introduction

The software agents have been introduced just a couple of decades ago and ever since they have become so popular that public entities as well as private companies have spent a considerable amount of effort, time and investment in researches related to development of software agents. A software agent is embedded in a specified environment in which it is capable of achieving certain tasks with some degree of autonomy, i.e. without constant human guidance or intervention [1].

The next step in the field of software agents was the introduction of Multiagent systems (MAS). A multi-agent system (MAS) consists of multiple software agents that can interact with each other as well as with the environment in which they are placed. MAS can be used to solve problems that are difficult for an individual agent. MAS have an automated approach which has made human life very easy. MAS have proven that they are capable of solving real world problems, examples of applications are: coordinated defense system, transportation, industrial supporting robots, logistics, air traffic control and so on. Communication among agents is the key feature in MAS and agents work as a team, collaborating with other, this is done by means of passing messages to one another [2].

This research reports how MAS can be utilized in the management of milk tankers carrying milk for processing in a dairy industry. Right allocation of milk volumes at the right time for processing in any dairy industry is the vital key for optimizing the company business. Usually large dairy companies have more than one processing plants in a country or region and collect milk from a wide area cross the region. Allocation of milk to different processing units is the most important step of milk processing, from the collection of milk to it transportation to the factory where it is processed and after processing the milk products are dispatched to the market.

Pakistan dairy sector was selected as a case study model for the implementation of this multiagent system. Agriculture is the largest sector of the Pakistani economy, contributing 23% to the GDP of the country and involving 42% of the total labor force. Livestock is the largest of the various agriculture sub sectors. Milk is the largest commodity from the livestock sector accounting for 51% of the total value of the sector. Pakistan is the Fifth largest producer of milk in the world with a total production of 28 billion liter of milk a year, from a total herd size of 27 million milk animals (buffaloes and cows). There is a consensus among the stakeholders and the development experts that Pakistan's Dairy Sector has immense potential for growth [3].

Many factors affect the allocation of volumes of milk to different operational units including the forecast of milk volumes expected to be received in the regions, the processing capacity of different units, any maintenance activity in progress in any area of the processing unit, the type of product having higher demand in a particular season etc. Milk distribution is predominately an art in which knowledge, experience, engineering and supply chain demand all play important roles. Often there is more than one option available which are technically and economically viable. In most of the present dairy industries milk allocation is made by experts on the basis of their extensive knowledge, past experience, and frequently 'intuition'. The development in the field of artificial intelligence and computer-based techniques in the recent years provide a way by which this process can at least be partially de-skilled.

This research paper aims at utilizing MAS to make decision in such a way that the outcomes of the decision making process are rational, consistent and correct. This is achieved through a combination of multi-agent system with a knowledge based system. Section 2 discusses the characteristics of the environment and agents involved in this multiagent architecture. It argues about the internal structure of individual intelligent agents. Section 3 shows how the multiagent architecture can be instrumented for real-world milk tanker management problems in a computationally and economically efficient way. Finally, in Section 4, the potentials and drawbacks of this system are discussed in order to come up with a set of conclusions respecting the applicability of multiagent technology to the milk distribution domain.

2. Related Work

Different related researches are present in following section:

2.1 Multiagent meta-model for strategic decision support

In this research the authors introduced a meta-model which generates multiagent system for strategic decision support. The system utilizes the new concepts of bargaining with learning to determine the cooperation between agents. Three essential functions form the original framework of the meta-model, provided with a technique of learning. System includes the search for typical plan of decisions while adapting to the problem and the search for the coalitions in the spatial and temporal dimensions. Overall the system allows an adaptation to all the types of strategic decision support [8].

2.2 Simulation and evaluation of urban bus-networks using a multiagent approach

The improvement in the service quality of public road demands analysis and planning tools. This need is mainly a result of evolution of the public road transportation systems. The existing range of road transportation simulation tools includes a variety of planning, training and demonstration tools. Out of these tools only a few cater the traveler behavior and public transportation specific vehicle operation. In this research, the authors introduce a bus-network simulation tools which include the above specificities. This toll also allows analyzing and evaluating a bus-network at diverse space and time scales. A multiagent approach is used to describe the global system operation as behaviors of numerous autonomous entities such as buses and travelers [9].

2.3 Milk-sense: a volatile sensing system recognizes spoilage bacteria and yeasts in milk

This research shows how an electronic nose unit containing 14 conducting polymer sensors can be used to detect the volatile profiles produced by uninoculated skimmed milk media or that inoculated with bacteria or yeasts when grown for time at some predefined temperature. It uses a discriminate function analyses (DFA) to separate unspoiled milk and that containing spoilage bacteria or yeasts. In this way the sensor array used behaves as a useful discriminator of microbial volatile profiles. This showed that it is possible to recognize, and differentiate, between species, the butanol and milk medium. Cross validation was made by using labeled individual replicates of treatments as unknowns demonstrated that it was possible to differentiate between (a) butanol controls; (b) unspoiled milk medium; (c) S. aureus; (d) K. lactis; (e) C. psuedotropicalis; and (f) B. cereus. The potential for using an electronic nose system for early detection of microbial spoilage of milk-based products is most certainly the method of future for detecting early milk spoilage [10].

3. Environment and agents in the system

The agents interact with the environment and as well as with the other agents present in the same environment. The architecture of the agents working in the environment is directly related with the complexity of the environment in which they operate.

3.1 Environment

The environment for the operation of agents in this study is inaccessible, in-deterministic, highly dynamic and continuous.

First of all inaccessible in the sense that the agent cannot possibly obtain complete up-to date information of the state of the environment because it is changing every moment. However complete up-to date information on the state of other agents is possible.

Any action which the agent takes will affect the environment, but up-to which extent it affects the environment and the achievement of goal for which the action the taken is not sure making it an in-determinant environment.

Like other situations the agent has partial control on the environment. For example the milk tankers were dispatched from the milk collecting centers and at the time of dispatch the collection center had calculated that it will reach the factory in 4 hours but it started to rain and the tankers got late. Form the collection center agent's point of view it did the right thing by postulating the time of arrival of tanker at the factory and communicating the factory agent about the arrival time. But in reality the schedule couldn't be met. Such kind of scenarios such as raining, road blocks etc. makes the environment dynamic.

The rate at which the environment is changing is relatively slow. Like the when it starts to rain the system agents have sufficient time to cater the raining affects and plan course of action well in time so that the system design purpose is met.

The environment carries a large numbers of percepts and the actions which can be taken against them are also numerous. To store these percepts and actions a large amount of storage data is required for each gent in the system which will exponentially raise the cost of the system. To make the system economical the environment is treated as a continuous environment and agents are designed accordingly to cope with this environment to fulfill its goal

3.2 System agents

The agents working in the current environment include; milk tanker agent, milk collection agent, factory agent and business support agent. In addition to these agents an expert system also works in collaboration with these agents which determines the milk quality index in the tanker. Some of these agents do not have a 'learning by experience' module in them because the agents with reactive capability will serve the purpose well. In this way the learning module is not included in agent's architect and makes them simpler and fewer resources are required to realize these agents. The following section contains their functional and architectural details.

3.2.1 Milk tanker agent

The agent for a milk tanker is the simplest agent of the system. A functional or relational agent design serves the purpose of this agent completely. The tasks assigned to milk tanker agents include monitoring of physical and chemical properties of milk which include temperature, pH and acidity. After computing these parameters the agent communicates them to milk quality expert system. The expert system sets the tanker in priority in reception at the factory. The milk tanker agent also analyzes the rout path set by the tanker driver and estimates the time to reach the factory and communicates this time to factory agent so that it may know the time of arrival of milk tanker in factory. If the route changes due to rain or road blockage the driver updates the new route and again the milk tanker agent computes the time to reach the factory according to the new route and communicates again to the factory agent. Each taker is associated with a separate milk tanker agent having unique identity. This helps in establishing an effective communication channel among the agents.

3.2.2 Milk collection center agent

The milk collected at the milk collection centers across the country/regions. The milk collection center agent computes the total amount of milk received and its quality. Then accordingly distributes the amount of milk in tankers and allocates them to different factories. Besides from communication with milk tanker agents the milk collection agent also communicates with business support agent which gives instructions regarding the allocation of milk to different factories. It also gets updates of the status of factories from the business support agent.

3.2.3 Factory agents

This is the agent representing the recipient processing unit i.e. the factory. A factory contains different plants and each plant may contain more than one processing line. In this system an agent is associated with each line. This agent sends the conditions of the line such as any breakdown or maintenance plans to the plant agent. It also depicts the health and operational status of the line. After receiving this information from the line agents the plant agent analyze the data and sends a report to the factory agent about the condition down the line. In this way the plant agent in a way tells the factory agent that how much milk can be processed on each plant. The factory agent after analyzing the health of the system communicates with the other agent present outside the factory and bargains on the quantity of milk it requires to process. The hierarchy of the factory gents is shown in the fig below.

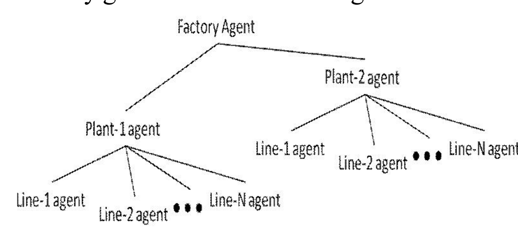

Figure 1. Hierarchy of the agents working inside a factory

2.2.4 Business support agent

This agent is like the supervisor of all the agents in the system. Its main responsibility, as clear from the name, is to support the company business. It controls the flow of information in the agent communication network and also has the additional role of resolving conflict among the agent in the system. It is fed with information such as the demand of different milk products in the markets and their sales trends in throughout the year. Using this information the agent postulates what product has the more priority and which should be made. Since it is also aware of the processing line types in different factories so it aides the milk collection center in distributing the milk to different factories. In case of any major breakdown on the line in any factory it reacts instantly and generates a new distribution plan to milk collection center agents.

3.3 Milk quality expert system

The condition of milk in a tanker is the most important parameter to determine the priority of processing of the milk volume. In addition different dairy products require different quality profiles. Some products require higher pH while others require lower pH value. Similarly fat and non-solid fats ratio is also different for different products. The milk tanker agents communicate the physical and chemical parameters of the milk within the tanker. Using these parameters milk quality profiles are computed by the milk quality. These profiles are matched with the product profiles and the best match is selected. Also this agent computes the rate at which the quality degrades within the tanker. Because the milk acts as a buffer solution but if due to action of micro bacteria the milk loses its buffer nature and spoils rapidly within a few hours. So it is very important to predict the quality and process it before anything goes wrong. Milk pH plays an important role in this regard.

Microbial milk spoilage can severely affect the quality of the finish product and hence the commercial success of dairy products due to undesirable off-odors, physical defects and secondary metabolite toxicity. Important spoilage species include some Gram-negative bacteria such as Pseudomonas uorescens, Pseudomonas fragi and some Gram-positive species such as Bacillus cereus and Staphylococcus aureus [5]. Additionally, acidic conditions in milk fermentation products such as yoghurt and sour milk may favor the growth of some yeasts which can also generate undesired off-odors, and loss of texture quality. By monitoring the microbial load these effects can be minimized and this is the job of milk quality expert system.

4. Proposed System Architecture

The knowledge required by the multiagent system to make decisions regarding the management of milk tankers includes the condition of milk in the tanker, the operational capacity of different units, seasonality impacts, maintenance and breakdown situations, market sales forecasts and business priorities. These inputs act as parameters for the system and using them concludes a decision. In this study the individual agents working in the environment gather some of these parameters through perceptions but any action cannot be taken until the information not shared among the agents. Even if the information is shared between the agents an effective action is not possible if the agents do not cooperate with one another.

In multiagent systems it is an important and interesting endeavor to study the development of cooperative behavior among agents. Through cooperation among different functional agents it is possible to achieve a task which would be impossible to accomplish with only one agent. [6].

The MAS used in this research utilizes the decentralized coordination model for communication i.e. there is no master supervisor or coordinator in the system. The agents communicate with one another and by means of barging reach a decision. The communication network of the agents is shown in the fig. 2.

The process starts at the milk collection center where milk is received from the field. Now the milk collection agent computes the total amount of milk stock and using the information sent by the business support agent distributes the milk to different factories. The business support agent has the information such as the seasonality impacts, sale forecasts, the situation updates in different factories. In Pakistan there are mostly three season of milk production which are the Flush Season: (Jan to April) during this season there is maximum production of milk in the country due to rain and availability of fodder. Second is the lean Season (April to July) minimum production of milk in the country due to high environmental temperature, less green fodder availability and natural reproduction cycle of animals. Last is the semi-flush season (Aug to Dec) in this season about 70-80 % milk production takes place in the country [7].

After the distribution plan has been generated by the milk collection agent it communicates it to different milk tanker agents about it. Each milk tanker agent is given a unique identity through which it is recognized in the communication channel. The tankers are filled with milk and dispatched to different factories. During their journey to the destined factory, they keep monitoring the physical and chemical properties of the milk in the tanker through various sensors and communicate these parameters to milk quality expert system.

The milk quality expert system determines the quality profiles of the milk within the milk tanker and updates the factory agent about it so that the factory agent can prepare for its receiving for the suitable product. The milk quality expert system also determine if there is a chance that if milk is going to spoil so that it's receiving priority is revised and is given higher priority.

Once the milk tanker has reached the factory it waits for its turn to deliver the milk to the factory. The factory agent then informs the respective plant agent about the arrival of the stock. Then the respective plant starts processing the milk. In case if any sudden breakdown occurs in the factory the factory agent instantly communicates with the business support agent and the other factory agents in the region for assistance. Now the bargaining starts within the factory agents under the super vision of the business support agent. If the situation does not get under controlled then the business support agent interferes in the bargaining process and imposes a decision on its own keeping the business objectives set earlier.

5. Case Study

An interesting scenario is presented in fig 3 below. The factory 1 receives milk from zones 1,2,3,4 and 5. This is shown by the green circle. Similarly for the factory 2 the crimson color circle covers partially zones 7 & 8 and complete zones 9 & 10. The zones 5 & 6 and some portions of zones 7& 8 are the intermediate zones and are in conflict between the two factories.

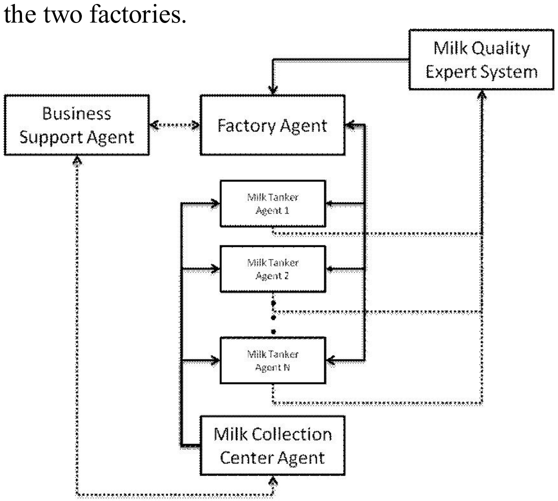

Figure2. The multiagent system architecture for the management of milk tankers in the dairy industry. The arrow heads indicate the direction of flow of information among different agents of the system.

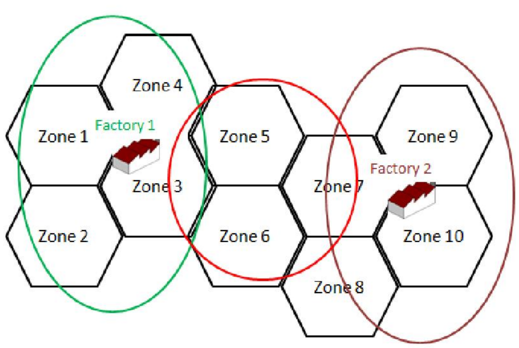

Figure 3. The green circle covers the zones covered by factory 1 while the crimson circle shows the zones covered by factory 3. The region encircled by the red intermediate circle indicates how conflict arises in these zones for allocation to both factories.

This conflict is resolved by the business support agent. This is achieved by using the facts and rules fed into the business support agent knowledge base. As discussed above the business support agent kames a decision keeping in view the business priorities, seasonality impacts, maintenance activities in progress in any factory and so on. In this way the milk collected from these zones goes to factory 1 and sometimes goes to factory 2. The system performance is monitored by the human user from time to time and there is the provision in the system to make small corrections. This is made possible by the fact that the same language of reasoning is used by both the system agents and human users. In this way it is possible for the user to calibrate the system from time to time. However most of the time the system runs autonomously yielding what would be termed as rational results. The overall performance of such a system adds valuable inputs to the company business.

6. Conclusion and Future Work

This paper presented a multiagent system approach for the management of milk tanker for a dairy industry. This work shows that the MAS techniques have an explicit effect on the existing conventional system. From the user's point of view, this system may be seen as an intelligent assistant capable to take useful decisions to support the business activity. This MAS mostly relies on the fact that the agents in the system apply reasoning procedures and use the bargaining to achieve the design objectives. The reasoning and bargaining of agents resemble those of the human operators making decision in the real world. In addition, the possibility for the business officials to access the knowledge bases and the ability to express this knowledge in understandable terms for the users make it feasible and easier to maintain and improve the knowledge base with their own experience and previous outcomes of the system when and where considered necessary. The use of a multi-agent system for routing of milk tankers benefits from the fact that with the passage of time the system gains experience and adds the newly gain knowledge in the existing data base for future decision making.

The beauty of MAS lies in the fact that it can incorporate any number of agents in its community. The greater the numbers of muti-functional agents the more complex problems are easily solved by it. In this research there is an opportunity for a route planner agent to assist the milk tanker driver (human user) in planning the shortest and economical path for the milk tanker transportation. After the milk tanker has been dispatched from the milk collection center a lot of factors can affect the itinerary of the milk tanker e.g. raining, road blockage or any breakdown in the tanker itself. Any route planner agent can be utilized for this purpose however it will require additional communication protocols in order to meet this system design objectives. The incursion of new agent, however, will affect the overall system performance which will require a complete impact analysis before actually engaging the agent in action.

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