A Novell Mushroom Cultivation Mechanization Architecture by Using Multi-Agent and parallelism Systems

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Abstract- To increase efficiency, speed, accuracy and to decrease cost, the recent approaches in developing decision support systems for agriculture, and more generally for environmental problems management, tend to adopt a “systemic” approach. This paper presents a new methodology for mechanization of mushroom cultivation which can be applied to other agricultural products. We are using a multi-agent system to parallelize most of mechanization steps which can considerably increase the speed and efficiency of cultivation or production. This system consists of six agents, namely, Monitoring of environmental condition, Preparation of Compost, Day counter, Temperature regulator, Sprinkler and Harvest. The paper provides a review on the studies on mechanization with multi-agent and the other methods, the multi-agent model, functionality of each agent, the overall efficiency of this methodology and compares it with some other existing works.

Keywords- Agriculture; Mushroom Cultivation; Mechanization; Agent; Multi-Agent System; Parallelism

I. INTRODUCTION

Much research has been done in many countries to investigate impact of mechanization on the quality of agriculture [1]. For example, the median harvesting extremity is 182% in 18 agricultural regions of West Bengal that is 33.8% greater than the country’s average. Cultivate mechanization increases the production of different crops because of better quality of processes and accuracy [2]. Also, agricultural mechanization development in some countries such as China has shown the crucial importance in advancement and enhancing agricultural production level [3].

Multi-agent system is composed of a set of computer procedures where several agents share the same source, limited or not, and communicate with each other. The formalism used for the hardware agents is derived from the well-known beliefs, desires, and intentions (BDI) architecture that are described extensively in the technical literature [4, 5]. In the beliefs, desires, and intentions architecture each agent maintains a set of beliefs, a set of desires, and a set of intentions. The set of beliefs indicates what the agent currently believes to be true concerning its environment. It is a localized view which states that where an agent believes to be true may or may not in fact be true[6]. Agents are autonomous and social computational entities that can perceive the information concerning their environment through sensors and affect the environment in an appropriate manner using some form of actuators [7]. Agents are frequently used in many applications including some with real-time requirements such as communication systems [8], database searching and retrieval, control systems applications, and sensor fusion applications [9].

Agents are frequently used in many applications including some with real-time requirements such as examine population environment interactions [10], economy [11] and community resource management for Aceria-based agriculture [12].

So far different hardware and software methodologies are developed for mechanization of some agriculture products. Some of them are: Agricultural Automation by use of Automatic systems and sensors [13], NEPER: a multiple strategy wheat expert system [14], TROPOS: a multi-agent system for integrated protection in agriculture [15], the sharing of water between different users: multi-agent system to improve the negotiation [16]. Considering these methodologies, in order to increase efficiency and speed, accuracy and to decrease cost, we have developed a multi-agent system for mushroom cultivation mechanization which improves this process considerably by increasing performance, maximizing speed and minimizing the cost of production.

Growing a mushroom from spore to harvest takes lots of work and at least 10 weeks of time. The mushroom starts in a laboratory where the spores are germinated and form the thread-like fibers called mycelium. Tiny pieces of these fibers are placed on millet seeds and then incubated. Next, the mushroom mycelium is delivered to a mushroom farm. Here, it is cast by hand into an eight-inch deep bed of pasteurized compost. The heat and the humidity in the mushroom house, called a double, are carefully controlled. Computers are often used to help monitor and regulate the growing conditions in the doubles. After about two or three weeks, the compost is covered by the mushroom mycelium. At this time, peat moss is layered over the mycelium. Suddenly, the room temperature is dropped to 60 degrees and the humidity is raised to 95 percent. The mushroom mycelium then all pull together and start to grow up. In another two to three weeks, the mushrooms are fully-grown above the
peat moss and ready to be picked. You can see environmental factors with their values in Table 1 [17].

<table>
<thead>
<tr>
<th>Factors</th>
<th>Value</th>
<th>Impact of changes in values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>20-30°C</td>
<td>Minimal Influence</td>
</tr>
<tr>
<td>Humidity</td>
<td>80-90%</td>
<td>Exhaustion in tissues, shrink and Color change</td>
</tr>
<tr>
<td>Concentration of carbon dioxide</td>
<td>15-18%</td>
<td>Preparation of appropriate conditions for micro-organism</td>
</tr>
<tr>
<td>Solid PH</td>
<td>5.5 - 6.5</td>
<td>Rancidity</td>
</tr>
<tr>
<td>Sunlight</td>
<td>3000 lux</td>
<td>Color change</td>
</tr>
</tbody>
</table>

The rest of this paper is organized as follows. Section 2 discusses related works on multi-agent systems in agriculture. Section 3 presents our proposed multi-agent model. Implementation and results are discussed in Section 4 and finally Section 5 concludes the paper.

II. RELATED WORKS

This section provides an overview on some mechanization methodologies for agriculture products.

A. Agricultural Automation by Use of Automatic Systems and Sensors

In [13], some reasons have been described as to why a number of prototype automation systems, which were developed in the 20th century, have not yet proceeded to commercialization. Some barriers that have deterred this are identified, and to overcome these barriers, it is suggested that future researches focus on this issue. Examples of these automations are:

- Fututech — an Australian system to automate certain abattoir operations
- MAGALI — a French system for robotic harvesting of citrus fruit
- SM — an Australian system for robotic shearing of sheep
- A British system for robotic harvesting of mushrooms

Some barriers that have prevented or retarded the exploitation of computer-controlled machines in agriculture are discussed as follow. The development of automated agricultural machines has been affected by a number of barriers specific to this application area. The seasonality of many agricultural products is one barrier. A machine dedicated to automating a particular seasonal task is likely to be idle for much of the year. This loss of productivity may increase the machine’s anticipated payback time in such a way that an investment in the machine is unjustifiable using commonly accepted accounting methods such as discounted cash flow. Anticipated developments in telecommunications technology are expected to have a major impact upon the development of agricultural automation in the 21st century. This will allow video imagery to be economically transmitted in real time from a driverless agricultural vehicle to a base station on the property or elsewhere, so that the operation of such vehicles can be remotely monitored. Moreover, when on-board sensors indicate that a vehicle is encountering exceptional conditions, it can be remotely guided or stopped from the base station until automated operation may be safely resumed. Sensor systems are developed so that the maturity of plants can be recognized reliably. Robots will become capable of harvesting fruits and vegetables individually according to their size and ripeness. This would eliminate the need for subsequent grading and would allow foods to be packaged immediately after they are picked.

B. NEPER: A Multiple Strategy Wheat Expert System

We have faced many problems using the first generation expert systems methodology, which is mainly based on acquiring rules and using rule base system shells. Therefore, Edress et al. 2003 [14] decided to investigate the usage of second-generation expert systems methodologies and tools to develop the NEPER wheat expert system using the generic task methodology. This paper presents a methodology for developing a strategic Expert System for wheat crop production, which has been developed using a multiple design approach. NEPER wheat strategic expert system consists of six agents: namely, variety selection, land preparation, sowing, irrigation, fertilization, and harvest. Each subsystem has its own database. You can see more details below:

- **Variety Selection agent**: Identification of the appropriate varieties for a specific site based on various parameters such as the soil type, soil salinity, drought, etc and forwarding the output to planting and harvest agents.
- **Land preparation**: recommendation on how to prepare soil for wheat cultivation such as soil tillage, maintaining drainage system, getting rid of previous crops and summer weeds, and others based on the outputs of other subsystems (variety selection, land preparation) as inputs. The output of this agent is used by planting agent.
- **Planting agent**: Determination of the appropriate planting date, planting methods and seed rate based on the inputs.
- **Irrigation subsystem**: schedule plan for irrigation quantity, intervals, and irrigation time, taking into consideration soil

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type, soil salinity, water quality, rain, temperature, for each specific site.

- **Fertilization subsystem**: fertilization regime in terms of fertilizer name, dose, and application time, according to the soil fertility, previous crops, water quality, planting type, etc.

- **Harvest subsystem**: recommendation about the appropriate harvest date and harvest machinery used.

**C. Tropos: Designing a Multi-Agent System for Integrated Protection in Agriculture**

Ref. [15] focuses on design issues faced during the development of a decision support systems (DSS) regarding the use of technicians of the advisory service performing pest management according to an Integrated Production (IP) approach. The Tropos methodology is an agent-oriented software development methodology [16] based on two key ideas, namely: (i) the use of knowledge level concepts, such as actor, goal, plan and dependency among actors, along the whole software development process, and (ii) the critical role assigned to the preliminary phase of requirements analysis aimed at understanding the environment in which the system-to-be will operate. The proposed system in [15] consists of four actors (agents):

- **Procedure actor**: follows IP production protocol and collects orchards data for Advisor agent.

- **Local Government actor**: finds a Plant Disease Expert, sets up IP production protocol and issues the desired certification to the Procedure.

- **Plant Disease Expert actor**: provides IP for Advisor and Local Government, runs disease models on the basis of information extracted from the seasonal data and chooses an effective disease model for Advisor.

- **Advisor actor**: chooses IP protocol based on the provided IP by Planet Disease Expert for Procedure and manages disease crisis which may occur in case of unforeseen events.

**D. The Sharing of Water Among Different Users: Multi-Agent System to Improve the Negotiation**

Water sharing has become an important problem for French farming. A lot of negotiations take place among farmers, water suppliers, public services and environments to allocate water resources among users. For helping these negotiations, Bars et al. 2002 [18] have presented an Agent-Based modeling (ABM) by showing the consequences of water allocation rules toward respect of different criteria like economic, ethical, environmental. The model developed takes into account two types of agents (Table 2): cognitive and reactive. Cognitive agents [19, 20] obtained their knowledge from environment and their information memory makes a decision action, but reactive agents [21] are more active and their structures are only composed of knowledge and communication modules. You can observe the type of these agents in Table 2.

<table>
<thead>
<tr>
<th>Agents</th>
<th>Type</th>
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<tbody>
<tr>
<td>Farmers</td>
<td>Cognitive</td>
</tr>
<tr>
<td>Water supplier</td>
<td>Cognitive</td>
</tr>
<tr>
<td>Information supplier</td>
<td>Reactive</td>
</tr>
<tr>
<td>Crops</td>
<td>Reactive</td>
</tr>
<tr>
<td>Climate</td>
<td>Reactive</td>
</tr>
</tbody>
</table>

- **Farmer agent**: it determines its cropping plan and its global water needs and then it sends them to the water supplier agent. Also, it will receive the amount of water allocated.

- **Water supplier agent**: it receives a set of water requests, adds them up and proposes a water amount to each farmer agent.

- **Information Supplier agent**: it synthesizes each farmer agent with global information about highest, average and lowest revenues and crops yields and sends them to each farmer agent to decide whether or not to invest in more irrigation capacities.

- **Crop agent**: it determines the crop yields which are related to rainfall and water allocation and sends them to farmer agent.

- **Climate agent**: it calculates the water consumed depending on the climate of the year for water supplier agent.

**III. THE PROPOSED MULTI-AGENT SYSTEM**

In this paper we have proposed a multi-agent system for mechanization of mushroom cultivation. Each agent in the system performs a part of mechanization process and all together provides a serial-parallel model which speeds up the overall process considerably. The processes of mushroom cultivation are shown in Figure 1. Based on these processes we define the following agents for our multi-agent system:

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A. Environmental Condition Monitoring Agent

This agent receives information from the environment by sensors periodically and if these readings are out of the specified range or pass the thresholds (Table 1), then this agent will issue an appropriate alarm. For example, if the temperature is lower
or higher than defined thresholds, it turns on the heaters until the temperature reaches the desired state. The sensors can sense the amount of CO\textsubscript{2}, humidity, sun light and temperature in the cultivation area. The appropriate ranges for CO\textsubscript{2} is between 15 to 18 percent, humidity is 80 to 90 percent, sun light about 3000 lux and temperature 20 to 30 degrees centigrade.

B. Preparation of Compost Agent

This agent controls the compost status, e.g. its width, height and weight. If each of these parameters is not in the specified ranges, then an alarm or error message will be issued. While a sterile substrate free from all competitive micro-organisms is the ideal medium for cultivating edible mushrooms, systems involving such strict hygiene are generally too costly and impractical to operate on a large scale. Substrates for cultivating edible mushrooms normally require varying degrees of pre-treatment in order to promote growth of the mushroom mycelium to the practical exclusion of other micro-organisms. The substrate must be rich in essential nutrients in forms which are readily available to the mushroom, and be free of toxic substances which inhibit growth of the spawn. Moisture content, pH and good gaseous exchange between the substrate and the surrounding environment are important physical factors to consider. Compost is a pot with 12-18 kg weight, 105 m height and 1-1.5 m width. The pots enter the room and then, they are measured by sensors. The task of compost provider agent is evaluation of pots physical parameters. If the parameters are not correct, this agent will issue an alarm and appropriate error message.

C. Day Counter Agent

After completing the preparation of compost and planting the seed phases, “Day counter” agent will be active and start counting the days. After twenty days, some photos will be taken from surface of compost by several cameras. Then some detection color algorithms apply on these pictures. With detection of white color on the surfaces, this phase will be completed. Otherwise, this agent will return the ID of the wrong pots and it will be filled with some forest soil and then the temperature regulator agent is called.

D. Temperature Regulator Agent

After the observation of the mycelium (white color), the room temperature drops to 60 degrees by this agent. Then, all the mushroom mycelium pulls together and starts to grow up. For this purpose, “Temperature regulator” agent calls the “Monitoring” agent and opens the air valves of the room to enter fresh air to the room.

E. Sprinkler Agent

This agent keeps moisture in the room at 80 percent level. It receives the humidity rate from the monitoring agent continuously and when it is necessary to increase this rate it sprays water into the composts to have enough moisture.

F. Harvester Agent

After a few days, operators dig the compost for a few inches (It helps the caps grow) and calls “Harvest” agent. This agent asks “Monitoring” agent to adjust the humidity at 85 percent level and the sunlight on 3000 lux with turning on enough light.

IV. COMMUNICATION BETWEEN AGENTS

The agent model is shown in Figure 2. In this model, we have two main agents to collect environmental parameters: MA1, and MA2. Among various existing MAC protocols, we have used time division multiple access (TDMA) protocol for media access because there is a constant number of nodes between sensors and MA1-2. TDMA divides the channel into individual time slots, which are then grouped into frames. In each time slot, only one node can transmit. TDMA is intrinsically energy-efficient. A sensor node can turn off its radio during all time slots in a frame. Moreover, when the number of nodes in a cluster changes, it is difficult for a TDMA protocol to dynamically change its frame length and time slot assignment [22]. We can see the state diagram of sensors nodes in Figure 3.

![Fig. 2 The proposed multi-agent model for mushroom cultivation mechanization](image-url)

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As we said, after a few days, operators deep the compost for a few inches and calls MA6. This agent asks the MA1 to adjust the humidity and sunlight of the hall. They can communicate with each other through some signals. The state diagram of MA1 is shown in Figure 4. For adjusting the humidity and sunlight, MA1 sends a signal to MA5 (Figure 5). Also the state diagram of MA5 is shown in Figure 5 as a sample for MA2 to MA6.

V. IMPLEMENTATION AND PERFORMANCE EVALUATION

This system can reduce pollution and increase safety. For mushroom cultivation, environment must be oxygen-free. Existence of people in the salon may cause pollution of the compost and environment and change the temperature. On the other hand, working in an oxygen-free environment can harm workers. This system prevents people entrance and pollution of the compost and provides an accurate cultivation with a high efficiency and high amount of crop.

Moreover, we have divided the cultivation processes among agents defined in pervious section. We provide the maximum parallelism in the model to have the maximum speed of operation for these processes. The proposed multi-agent model for the serial model and mushroom cultivation mechanization are shown in Figure 1 and Figure 2.

We have implemented the proposed multi-agent system and the serial model using C# to compare the speed and performance of our model for this mechanization process with serial model. The serial run time is obtained by calculating the total run time of all functions specified in Figure 6. Based on the results shown in Table 3, we can see our proposed multi-agent system could parallelize most of tasks by agents, speed up the mushroom cultivation control process up to 4.87 times on a quad core processor system.
VI. CONCLUSION

To increase efficiency and speed, accuracy and to decrease cost, the recent approaches in developing decision support systems for agriculture, and more generally for environmental problems management, tend to adopt a "systemic" approach. So, we have tried to figure out an optimized way in mushroom cultivation. For this purpose, we have introduced a multi-agent system with several agents where the agents can if possible, perform their tasks in parallel and synchronous with each other, interact with each other and decide automatically. There are some software agents which are described briefly in Section 4. The result of implementation shows this methodology provides a considerable speedup in the control mechanism of mushroom cultivation process. The presented methodology provides an infrastructure to increase the speedup of cultivation control process and can be applied to most of agriculture products. Also, in mushroom cultivation, pollution is an important factor that has more effects in the growth of the mushrooms. With using sensors, reduce people entrance and remote monitoring, we could decrease pollution and increase the amounts of the crops.

REFERENCES


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