IMPROVING PRECISION AGRICULTURE METHODS WITH MULTIAGENT SYSTEMS IN LATVIAN AGRICULTURAL FIELD

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Abstract. Latvia is located in Baltic region with its own specific climate conditions and also its agricultural fields differ from other European countries. Latvian fields are small and have many tiny forest lands, which is a negative factor for agricultural land management. But even in such situation precision agricultural methods can be applied. This paper is monographic review of precision agriculture methods application with main direction of possible usage of multiagent systems. Application of multiagent systems in precision agriculture has not been widely discussed yet in Latvia region. Multiagent systems usage in precision agriculture field offers many opportunities: it can decrease machinery weight and dimensions, can increase one type machinery count on the field etc. When multiagents are used it is possible to redistribute whole big agricultural task into smaller parts for it faster completion, upgrade precision agriculture machinery function from automatic to autonomous job performance. One main function of multiagent sytem is to monitor all agricultural fields by using subfield areas, where farmer can identify specific parameters of each area and implement management practices according to the area needs. These many agent systems are viewed like multirobot system with own decision making, real time planning and autonomous work performance. Additional feature is that each unit is independent, but it is collaborating with other units on the field to reach the total aim of the task. Unit's collaboration can be reached without human assistance.

Keywords: precision agriculture, multiagents, robot systems.

Introduction

Precision Agriculture (PA) is based on detailed information on the status of agricultural object. Object can be as individual crop or as field area (a subfield). These subfields may be a grid of squares that arbitrarily divide the field, or they may be a series of homogenous areas that have been determined to be significantly different from the surrounding areas. By collecting and analyzing data from that subfield area, the farmer can make decision based on information from just that area, decision that might not be appropriate for other areas of field [1].

Such agricultural processes like crop protection, field watering, fertilization needs frequent updates in data. Sensors and continuous data acquiring plays an important role in preserving environment by reducing pesticide usage and maximizing quality. Today when it is possible to use information technologies such as Global Positioning System (GPS), Geographic Information System (GIS), remote sensing, intelligent devices, computers and other tools all needed tasks could be done by automatic machines or robots and human role is only to monitor them.

Agent in precision agriculture is understood like computational process, something between computer program and a robot, which can be considered as autonomous since it is callable of adapting in case of environmental changes. Intelligent agents are used in various complex systems like biology, artificial intelligence (AI), computer networking, robotic systems, computer games, and military defense systems, transportation logistics, GIS and many other fields. Precision agriculture complex systems which are based on multi-agents technology can be divided in two different multi-agents based technology types: homogeneous robot multi-agents system (RMAS) [2; 3] and heterogeneous software multi-agents system (SMAS) [4]. Each subsystem has communication technology between agents, deliberation mechanism, data acquiring from influencing environment and other collaborative agents, decision making mechanisms, learning technologies, goal – based behavior ability. This paper aim is to describe RMAS in more specific detailed parts.

Latvian region has its own specific climate conditions. That's why many precision agricultural methods, which are suitable for Europe, often are not so good for Latvia. Main feature of Latvia is that agricultural fields are small and has many tiny forest lands, which is a negative factor for agricultural land management. In this case usage of big agricultural machines is not very effective way and use of smart, small robotized vehicles can improve quality and effectiveness of land management. In such situation precision agricultural methods in interaction with robot agents or robot systems can be applied.

Materials and methods

The agro equipment has always been an important vector for the development of agriculture. For several years, we have been witnessed to an irremediable increase in the size of agricultural machines. If this "first way", encouraged by farm machinery industry, is synonymous of high outputs, a lot of disadvantages can nevertheless be identified in term of soil compaction, high fuel consumption, difficulty to control large width implements on irregular soils. A "second way" has recently been proposed by several research laboratories, based on light weight robots for small scale farming at the plant level. This approach is well suited to high added value product such as market gardening or flower production. However for crops like cereals smart robot machines even in swarm working configuration would certainly not be able to assume harvest operations in large production areas [5].

Precision agriculture can be considered as a three-phase cycle (Fig. 1). The first phase is data collection. It also compares the measurement of parameters characterizing the agricultural object. Data collection is the process of determining objects to be mapped and collecting data about those objects. Examples of data typically collected in PA are yield mapping, soil sampling and crop scouting [1].

The second phase is the data interpretation or data analysis. Data analysis is the process of organizing, manipulating, querying and summarizing. Raw data can be a large amount of numbers and extremely hard to understand by itself. Using specific tools can help to summarize and identify relationships between variables that the farmer can use to make a decision [1]. This step is very hard to automate, that means that farmer still have to personally make the decision.

The third phase is the application. It involves the adjustment of important parameters and making the needed actions [6]. This phase also can be called as data utilization, since it is at this point that a decision is made and put into practice [1].

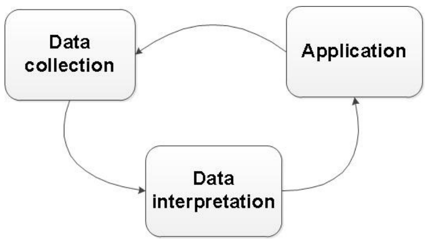

Fig. 1. **Three-phase cycle in PA**

Tasks for robot teams could be classified with different complexity, depending on task structure and robot team cooperation type. Tasks can be starting from main operations – searching for objects [7], or environmental monitoring without deep communication [8], till high level communication and synchronization, as example could be cooperative transfer of objects [9], cooperative monitoring of environmental variables [10; 11] and football playing [12-15].

There are many researches about robot cooperation, but still this field is not yet fully discovered [16]. The main focus of robot cooperation researches is about tasks - material handling and transportation of objects.

Robotized vehicles must act and operate in concern to achieve the main task goal. The robots communication isn't explicit, and the control is based on the interactions among them and the object. Others researches used so called decentralized controllers, which were based on the dynamical relations between the robots and the object to coordinate the robots, for example, [17]. Complex dynamical models [18], force sensing [19] and homogeneous robots could be used instead [20].

Sensors, programming module, motion module, interaction module, which working results are based on data from different software computational and calculation modules, improve the essential requirements of autonomous performance by homogeneous robot teams. Nowadays there are required many competing situations for different robots to achieve fault tolerance through sufficient separation in case of failures of sense, plan or act modules. Cooperative robot systems are actual research fields for recent years. Usage of multiple robots executing specific tasks has some advantages over single robot solutions. Such advantages are: robot design simplicity, increased fault tolerance, better performance and spatiotemporally distributed sensing. Another major research field is to investigate the cooperation strategies between homogeneous robots, and heterogeneous robots team. There is a presumption that in the next decade's robotization will rapidly advance and need for new autonomous heterogeneous robotic collaboration and communication technologies will occur in various intelligent, stochastic, dynamical changing environments fields.

Agent term in precision agriculture is understand like computational process, something between computer program and a robot, which can be considered as autonomous since it is callable of adapting in case when environment changes.

Multi-agent system has no formal definition, only an agreement on the most common features like multiple agents acting in one environment, all agents have same type of input, agent actions affect some part or even all common environments state of all agents or communication process between agents, in some cases even between agents and the environment. On the other hand an agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives [21].

Precision agriculture consists of several different computational processes like GIS – geographic information system, different types of digital maps, many statistics based on collected digital maps data, GPS – Global Positioning System for coordination of vehicles movements, Robotized field machinery, arable information data base, different type agents properties, knowledge, deliberation mechanisms, communications and decisions database, currency calculation block, mobile homogeneous agents refueling, raw materials storage base. These computational processes together forms autonomous precision agricultural complex system based on multi-agents technology [1; 22].

Precision agricultural complex system based on multi-agents technology is divided in two different multi-agents based technology types: homogeneous robot multi-agents system (RMAS), heterogeneous software multi-agents system (SMAS) [23]. Each subsystem has communication technology between agents, deliberation mechanism, data acquiring from environment and other collaborative agents, decision making mechanisms, learning technologies, goal–based behavior ability.

RMAS is similar as Multi Robot System [2; 3], where RMAS is described as homogeneous (property of a team of robots whose members are exactly the same both in the hardware and in the control software) system instead of heterogeneous (property of a team of robots whose members have a difference either in the hardware devices or in the software control procedures) system. In RMAS system can be easily achieve robustness because all robots are same and fault tolerance is granted in this way. An adaptation is weakly ensured, because there is no differentiation among the robots. There are three way architectures: behavior based architecture (BBA) [24], Sense-Model-Plan-Act architecture (SMPAA) [25], hybrid architecture (HA) [26]. SMPAA architecture is used on realizing high level deliberative behavior, but for RMAS it can't be used because the operation execution requires a large amount of time. BA and HA are quite common used to realize robotic teams, especially when reaction time of robotic team is very important in dynamically changing environment. For robotic teams has been created some testbeds like:

1. Foraging for RMAS is one of the governor criteria in choosing RMAS architecture, because of robots tasks like rescue and search operations, toxic waste cleaning, mine cleaning [23; 27; 28]. Different methods to cope the problems like interference, where communication and knowledge sharing are involved in this task.
2. Multi target observation for RMAS. In this testbed are being tested problems like surveillance, recognition, security, communication, sensor fusion, cooperation and coordination and still those are open research fields.
3. In box pushing testbed is tested difficulties like task allocation, robustness and communication. Under exploration and flocking is researched flocking, formation maintenance, map building problems, where tasks can be reached with exploration formation or flocking.
4. Soccer testbed testing is based on RMAS cooperation which is fundamental for effective accomplishment of task. There are five different leagues with different environment, agent types, environmental observation rules and knowledge, RMAS architecture, information gathering, decision making, centralization or distribution properties.

These testbeds are examples for what kind of different problems must be solved, what requirements must be fulfilling to make fully operational robotic team system called RMAS.

As robots become more autonomous and sophisticated, they are increasingly being used for more complex and demanding tasks.

Results and discussion

RMAS should consist of three types of agents with different ability functions: information agent, environmental agent, robotic agent. All these three types of agents together make a fully functional RMAS with deliberation, decision – making, collaboration, learning, goal – based behavior abilities.

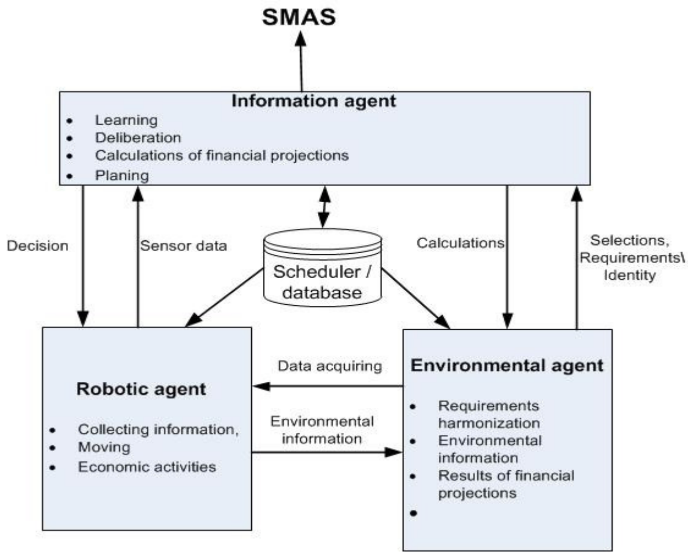

Fig. 2. **RMAS architecture**

Information agent – it should have functions like: information collection from all other robotic agents, making deliberation process, learning, calculations of financial projections and providing access to SMAS interface. Information agent should have following concepts: (Fig. 2).

1. Persistence – information agent have its own threads and schedules. It can start and shut down them having no impact on other types of agents. Have access to scheduler / database where stored whole information about all environment agents, scheduling actions.
2. Social ability – information agent interacts with environmental agents collecting requirements, needs, dimensions, and deciding of decisions for actions of robotic agents. Information agent provides an interface with internal and external services.
3. Activeness – information agent don't demonstrate activeness behavior. It is a stationary located agent.
4. Reactivity – information agent acts like chief to other environmental and robotic agents by taking requests and providing all necessary deliberation process. Could have no mobility opportunities.

Environmental agent – is spatial agent, where is stored agricultural land area processing actions, spatial information, results of financial projects and status. It should act like information collector from robotic agent and information agent. Environmental agent might harmonize conflicting preferences between different robotic agents, collect rules that restrict possible settings for environment parameters and provide data about environmental agent operating environment formation. Environmental agent should have following concepts: (Fig. 2).

1. Persistence – information agent has its own threads and schedules. It can start and shut down them having no impact on other types of agents.
2. Social ability – environmental agent interacts with robotic agent to acquire stored agricultural land data and require raw information from environment via sensors. Acquired data and selections, requirement and identity environmental agent sends information agent, but information agents sends environmental agent calculation results.
3. Activeness – environmental agent goal-directed behavior goal is to make necessary agricultural land information calculations and raw obtained data storage.

4. Reactivity – environmental agent collects all environment formation and results of financial projection data via Robotic agents and information agent calculations results, responds to changes that occur in it by informing robotic agents.

Robotic agent – it is autonomous agricultural machine, which makes agricultural land cultivation, via sensors acquires necessary information about agricultural land, and provide with that kind of information proper environmental agent and information agent. Robotic agents operate with information agents made decisions of future robotic agents behavior, observe the ambient environment. Robotic agent should have following concepts: (Fig.2).

1. Persistence - robotic agent has its own threads and schedules, and them can start and shut down by self or information agent based on made planning and deliberation calculations.
2. Social ability - robotic agent collects agricultural land environmental information and provides them to environment agent and information agent. Robotic agent acquires environment formation via sensors. Robotic agents goal based behavior is calculated and controlled by information agent.
3. Activeness - Robotic agent has reactive behavior for agricultural land cultivations. It is agricultural autonomous machine with mobility option.
4. Reactivity - robotic agent perceives current environment via environmental agent and takes a respond to environmental change using information agent calculating obtained raw agricultural land environmental data

Conclusion

Researching the existing robotic teams it was found out that the provided RMAS architecture could be good for Latvian agricultural lands cultivation, but it is needed to practically test this architecture.

The robotic team's researched testbeds should be considered as standards for RMAS architecture developing robotic teams for Latvian agricultural lands cultivation

Paper research shows that RMAS advantage is tackle complex systems by agent's interactions, decision – making, planning, and negotiating with each other to find a best system behavior or action to dispose difficulties.

RMAS schema must be used for further research in agent's simulation tools, on decision making mechanisms creation, on RMAS prototype creation, on learning mechanism creation, on preferences learning and decision making in conflict resolutions, on MCS prototype interaction with real execution equipment. In each research stage will acquire necessary information to continue next stage of researches.

Implementing RMAS system in practice would decrease agriculture machines weight, thereby decreasing costs and substitute human in cultivation work control.

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