# AUTONOMOUS PRECISION AGRICULTURAL DYNAMIC COMPLEX SYSTEM

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**Abstract :** *For the spade works in precision agriculture more often the robots are being used instead of men. Therefore there is need for unified standard to manage the robots, to create software level plans and communication environment modules. The new unified standard would be made on basis of agroXML updated standard. The Robotic Multiagent system robots work is depending on sustainable Software Multiagent system software plan. In the article Software Multiagents system and Robotic Multiagent system components and their cooperation ability and tasks are reviewed. Precision Agriculture Dynamic Complex System main task would be long term planning and communication management between Robotic Multiagent system and Software Multiagent system is reviewed. This would be an innovative solution to combine both Multiagent systems into one common system.*

**Keywords***:* Precision agriculture, multiagent system, complex system, schema.

## Introduction

In little more than a decade, precision agriculture has emerged from a concept to production-scale, multiple-task operations implemented on a field-by-field basis. As precision agriculture is developing new necessities to develop technologies arise. One on main issues is to hand over the precision agriculture decision making to software to analyze data quicker and more precisely and reach better result in shorter term. By using Multi agents' qualities such as autonomous deliberation, planning and communication, Robotic Multiagent system (RMAS) and Software Multiagent system (SMAS) may solve autonomously the delegated tasks with different methods that are reviewed in the articles and are presented by authors as a schema. The cooperation of both Multiagents would be promoted by the Precision Agriculture Dynamic Complex System (PADCS), which main task would be long term planning and communication management between RMAS and SMAS is reviewed. This would be an innovative solution to combine both Multiagents systems into on common system.

## Precision agricultural tools

Precision agriculture needs information as digital crop maps with underlining database in which stores attribute data in different layers, which consist of different crop information like weed management, precision water management, nutrient management, crop diseases management, parasites management and many more (Shrinivasan, 2006). Each of this information is stored at different layer. Layer can be used to for additional data storage, retrieval, queries execution for analyses. Analysis is used for decision making to increase crop productivity. This is done by precision agricultural dynamic complex system (PADCS) help which is in this paper is described as schema in results.

Global Positioning System (*GPS*) is used to get accuracy from trilateration process for agricultural machinery. Agricultural machinery (AM) catch the coded signal from several satellites and in AM built GPS unit receives that and recalculates latitude and longitude. With this technology agricultural machinery knows crop field dimensions accuracy from several centimeters to 3 m (Tiangang, 2004).

For data calculations, storage, manipulations, decision making is need for *computational device* like computers, microcontrollers and many different auxiliaries for systems demands and performance goal (Shrinivasan, 2006).

*Data* is important component of PADCS functionality it contains every necessary information about crop, AM (statuses, learning, financial calculations, environment, planning and many other information). Data in PADCS have many different standards and interpretations (binary, XML, different communication standards, Java, GIS, analog type and different other kinds) (Yoshida et al., 2008).

PADCS can work with *reference maps* (geographical are graphical representation), choropleth maps (illustrates attribute data values in colored polygons, line and points), isoline maps (illustrates data as contoured maps). All maps are viewed and made for GIS software (Chen et al., 2010). Maps are used for analyses and for decision making processes (Base, 2006).

PADCS use analog and digital *communication systems* to communicate between Multiagent systems and their agent components. These communication systems could be internet, wireless, sensor networks, GPS signaling, local communication systems as Bluetooth, GSM network and different new technologies. Basic communication language needs to be considered as improved agroXML language based standard (Doluschitz, 2009).

### Multiagent system

Multiagent system could be described as homogeneous system (property of a team of agents whose members are exactly the same both in the hardware and in the control software) and heterogeneous system (property of a team of agents whose members have a difference either in the hardware devices or in the software control procedures). In Multiagent - system must easily achieve robustness, in acceptable time period make deliberation processes and calculate the agents behavior plan as also provide the learning processes using historical information about Multiagents system behavior and influencing environment. (Pentjušs et al., 2011; Wooldridge, 2009).

RMAS system components could be stationary or mobile devices (agricultural machinery) and often made as homogeneous systems architecture. RMAS system uses reactive deliberations processes and has only execution and data mining functionality for soil fields.

SMAS system components could be software systems which are located on some server, computer or different calculating machine. On computer should be installed operation system like UNIX, Windows, Linux (Stallings, 2009) or similar, to provide necessary SMAS functionality.

All Multiagent systems (RMAS and SMAS) should have potential work on JAVA based environment (Bruegge, 2009).

### Precision agricultural dynamic complex system

Dynamic complex system involves numerous interacting agents whose aggregate behaviors are to be understood. Such aggregate activity is nonlinear, hence it cannot simply be derived from summation of individual components behavior.

Close relationships between RMAS and SMAS components in PADCS, may be the reason, when failure in one in these components can lead to cascading failures which may lead to catastrophic consequences on the PADCS system functionality. It can be difficult to determine the boundaries of a PADCS complex system. It works in stochastic dynamic continuous and open environment where boundaries are unlimited (difficult to determine boundaries).

PADCS is an open system, which continuously interacts with its environment. The historical records of a PADCS may be important for future changing, learning algorithms and deliberation processes. Because PADCS is dynamical system, it could change it functionality over time, and prior states may have an influence on present states (complex systems have a memory). The RMAS and SMAS components each of them are multi-agent systems where leader role takes PADCS. RMAS and SMAS are different kind of sophisticated system, which have very different goals and functioning systems (Complex systems may be nested). PADCS coupling rules, the dynamic network of a complex system small-world or scale-free networks, where can be found many local structured interactions and a smaller number of inter-area connections (dynamic network of multiplicity).

PADCS exhibit behaviors that are emergent, minor systems basic processes of behavioral outcomes and activities may be significantly affecting PADCS as whole (produces emergent behaviors). Small changes in PADCS, RMAS and SMAS system interaction may cause a large effect, a proportional effect, or even no effect at all. In linear systems, effect is always directly proportional to cause.

Relationships contain feedback loops (relationships are non-linear). Relationships contain negative (damping) and positive (amplifying) feedback loops in PADCS (Bar -Yam, 2003).

### Results and discussions

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 for coordination of vehicles movements, robotized field machinery, arable information data base, different type agents properties, knowledge, deliberation mechanisms, communications and decisions database, finances 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 (Shrinivasan, 2006). RMAS and SMAS technologies is PADCS system components, which allows for us to add more modules to this system as technologies grow and new researches would be found.

### Robotic multiagent system

RMAS *Information agent* - it should have functionality like: information collection from robotic agents, making deliberation process, learning, calculations of financial projections and providing access to SMAS interface. Information agent should have following concepts: (Fig.1 a).

1. Persistence - information agent must 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 information about environment agents, scheduling actions.
2. Social ability – makes interaction with environmental agents collecting requirements, needs, dimensions, and deciding of decisions for actions of robotic agents. Information agent provides an interface for other agents with internal RMAS and external services of PADCS.

3. Activeness - information agent don't demonstrate activeness behavior. It is a stationary located agent in environment.
4. Reactivity - information agent acts like governor agent for other agent types by taking requests and providing all necessary deliberation processes. Have no mobility opportunities.

*Environmental agent* – is spatial agent, where is stored crop area processing actions, spatial information, results of financial projects and statuses. It should act like information manager from robotic agent and information agent. Environmental agent tries to coordinate conflicting processes between different robotic agents, get and operate with rules that restrict possible settings for environment parameters and provide data about environmental agent environment formation. Environmental agent should have following concepts: (Fig.1 a).

1. Persistence - environmental agent must have 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 crop field data and require raw information via sensors. Acquired data and selections, requirement and identity environmental agent sends to information agent, but information agents send them to environmental agent as calculation results.
3. Activeness - environmental agent goal - directed behavior goal is to make crop field information calculations and raw obtained data storage.
4. Reactivity - environmental agent collects environment formation and results of financial projection data via Robotic agents and information agent calculations results, responds to changes that occur in it by sending massages robotic agents.

*Robotic agent* - it is autonomous agricultural machine, which makes crop field cultivation, via sensors acquires crop field information, and provide with it environmental agent and then it gets information agent. Robotic agents operate with information agents made decisions of future robotic agent’s behavior. Robotic agent should have following concepts: (Fig.1 a).

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 crop field environmental information and provides with that 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 crop field cultivation processes. It is mobile agricultural autonomous machine.
4. Reactivity - robotic agent perceives current environment via environmental agent and takes a respond to environmental change using information agent calculating obtained raw crop field environmental data.

## Software multiagent system

*Applications* (Fig. 1 c) are important models in SMAS. GIS agent is used for attribute data collection, visual representation and analyses. With Multiagent - system approach and deliberation algorithms for calculating equilibriums for individual SMAS agents there should be following concepts (Fig 1 c):

1. Data interpretation – GIS data interpretation is made through data storage systems like local SQL database or public accessible database of stored farmer’s crop land data. Information could be like different GIS useable maps and different type of models for prediction and background processes for data integration from publically accessible data storage places.
2. Data collections – GPS systems provides positioning information for crop field and crop field dimensions. Through RMAS information agent with PADCS systems approval information pass to SMAS GIS agent where it verify that. Sensing technologies like remote sensing systems (aerial photo, Satellite imagery), proximal sensing (in field soil sensors, in field crop sensors) are used to get real time information for RMAS environmental agents planning and deliberation process as attribute data. Local database information which use background processes for data collection also provides with some real time necessary information. For data collection process can be used different communication technologies like wireless, Ethernet, sensor networks, Bluetooth communication between Robotic agents, GSM network for bigger crop fields.

*GIS* (Fig. 1 c) system is used to get accuracy on crop field treatment and different type analyses and financial benefits calculations. For RMAS environmental agent GIS provided information is very important for deliberation and planning processes, which controls robotic agents reactive behavior for crop land treatment should have following concepts (Fig 1 c):

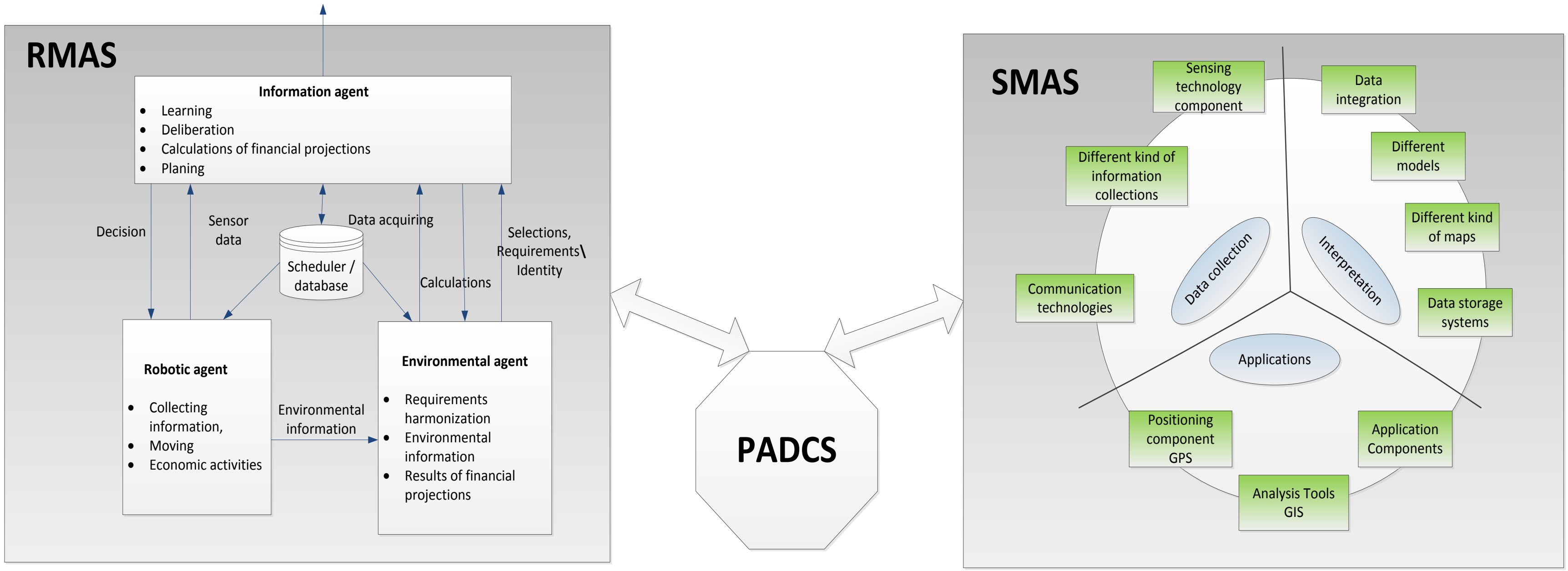
1. Data interpretation – GPS data interpretation is made through RMAS robotic agents who pass this data to RMAS environmental agents. Data is stored in database and provides SMAS GIS agent with that, if PADCS system approves that. Can be used local positioning systems on crop field as GPS system. Data is interpreted by SMAS GIS agent as different maps, models. GIS systems data main goal is to make an accuracy of analyses, deliberation, planning and financial calculation processes.

2. Data collections – GPS systems which use RMAS robotic agents to calculate positioning on crop field and crop field dimensions. Through RMAS information agent with PADCS systems approval information pass to SMAS GIS agent where it verify that.

*Application components* (Fig. 1 c) is used to store specified information about crop field data or even make additional deliberation or planning or calculation processes, data storage or new improvement models functionality verification and they should have following concepts (Fig 1 c):

1. Data interpretation – is necessary only for RMAS and PADCS. Graphical interpretation is not necessary. Can be used data storage system, computational software, different tools and improvement technologies what can appear on future.
2. Data collections – Application components can use wide range of communication technologies to communicate with other agents provide new data or make additional calculations with new type data increasing PADCS system efficiency.

PADCS (Fig. 1 b) is complex system collaborates with two Multiagent systems RMAS and SMAS. It provides interface between them two and has main goal is to control between these two Multiagent systems information flow and make comparison on both deliberation, planning and goal – based behavior to increase efficiency of crop field treatment and getting better financial aspects. Makes interface between complex system and human to inform status what is happening in PADCS. Human have opportunity to make changes in plans and PADCS tries to implement these changes in system activity.




a) b) c)

Figure 1. **Precision Agricultural Dynamic Complex System**

## Conclusions

PADCS schema must be used for further research in agent's simulation tools, on decision making mechanisms creation, on RMAS prototype, SMAS prototype, XML communication based system , on learning mechanism creation, on preferences learning and decision making in conflict resolutions.

Implementing PADCS in real farm makes agriculture process as autonomous process, where robots can do their duty without human interactions, planning, deliberation, calculations and analyses is made by PADCS. Only human system interaction is made by human interface where it can find out PADCS status, plans and change each model goal-based behavior changing PADCS plans.

Deliberation, planning and calculation algorithms must be researched and tested on PADCS system, to increase its efficiency and time consumption in these processes.

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