Multi-Agent Coordination and Control System for Multi-Vehicle Agricultural Operations

Osman Ali [a,b], Bart Saint Germain [a], Jan Van Belle [a], Paul Valckenaers [a], Hendrik Van Brussel [a], Johan Van Noten [b]

[a] Department of Mechanical Engineering, Katholieke Universiteit Leuven, Belgium

[b] Flanders Mechatronics Technology Centre, Leuven, Belgium

{osman.ali, bart.saintgermain}@mech.kuleuven.be

ABSTRACT
A multi-agent coordination and control system is deployed for controlling multiple interacting agricultural vehicles involved in the crop harvesting process. Crops are gathered by combine harvesters. The harvested product is transferred to one or more tractors every time the combine harvester's storage capacity is reached (figure 1). Good cooperation between the combine harvesters and the tractors is important for successfully completing the harvesting process. The multi-agent system allows concurrent planning and execution of the process, aiming to increase efficiency of the vehicles and improve cooperation between them. The planning is performed by short-term operational forecasting. The system provides detailed instructions and guidance to the operators of the individual vehicles (combine harvesters and tractors) by means of a graphical user interface. The state updates from the agricultural vehicles are considered by the multi-agent system, which dynamically updates the control instructions. In this way the control instructions for the agriculture vehicles remain valid and effective throughout the process.

Categories and Subject Descriptors
I.2.9 [**Artificial Intelligence**]: Robotics-Operator interfaces

General Terms
Design, Management

Keywords
Operational planning and control, multi-vehicle coordination

1. INTRODUCTION
Nowadays, many different agricultural vehicles are used to perform seasonally changing tasks in agriculture (seeding, fertilizing, harvesting). In this particular application the crop harvesting process is considered, which is typically carried out by combine harvesters and tractors operating in a complementary manner to harvest the fields (figure 1).

Crops are gathered by combine harvesters by following specific patterns to harvest the field. The combine harvesters have a limited bin capacity and need to unload grain to the tractor trailer at regular intervals to continue the harvest operation. The efficiency of the crop harvesting process can be significantly improved by planning detailed operations and interactions for the agricultural vehicles [1]. However, the dynamics in the open and distributed operating environment of the crop process make the planning for efficient execution complex. Important information for planning, such as duration of operations, depends on the runtime performance of the vehicles and hence cannot be accurately determined in advance.

Figure 1. Crop harvesting with multiple agriculture vehicles

A multi-agent coordination and control system is deployed for planning and controlling the crop harvesting operations of the combine harvesters and the tractors. The system aims to increase efficiency of these vehicles and improve their cooperation during execution of the process. The multi-agent system is based on the PROSA holonic reference architecture [2]. PROSA denotes **p**roduct, **r**esource, **o**rder, **s**taff agent **a**rchitecture. The system is composed of components corresponding to the real world entities in the crop harvesting environment. Thus, these components reflect the resources (the agriculture vehicles, crop fields), the operations to be performed and the knowledge to perform the operations. The control instructions for the combine harvesters and the tractors are generated by means of short-term operational forecasting [3]. The operational planning continues throughout the execution of the process. The actual execution of the operations with the vehicles is monitored to detect variations or disturbances. This information is taken into account by the multi-agent system to adapt the planning accordingly. Thus, the planning remains valid and effective throughout the harvesting process. Notably by monitoring actual execution and determining deviations from the predicted operating conditions or vehicle

Cite as: Multi-agent coordination and control system for multi-vehicle agricultural operations, Osman Ali, Bart Saint Germain, Jan Van Belle, Paul Valckenaers and Hendrik Van Brussel, *Proc. of 9th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2010)*, van der Hoek, Kaminka, Lespérance, Luck and Sen (eds.), May, 10–14, 2010, Toronto, Canada, pp. 1621-1622

performance, it becomes possible to address some of the main disadvantages of known schedules for the operations of multiple coordinating vehicles. In practice it is found that deviations from predictions of operating conditions and vehicle performance can disrupt the planning and introduce inefficiencies in the operations of the vehicles. Particularly where some operations are dependent on other vehicles operations, the efficiency can be improved by adapting the planning in real time according to actual conditions and performance.

2. DEMONSTRATION SCENARIO

The multi-agent system will be used for controlling one combine harvester and one tractor involved in harvesting a (rectangular shaped) crop field. The system will generate control instructions for the vehicles through short-term operational forecasting. For example, based on the operating data from the combine harvester, the system can determine when and where exactly the combine harvester will require to unload the harvested product. This information can be further used to plan cooperation between the combine harvester and the tractor for the grain transfer operation. By forecasting the interactions between the combine harvester and the tractor, their individual operations can be optimized according to the prevailing circumstances.

The control instructions provide detailed guidance for the operations of the vehicles. These include for example, a representation of two dimensional tracks of the proposed movement of the combine harvester and the tractor and the indication of positions where the grain transfer between them should take place. The execution of the operations of the vehicles is controlled according to the control instructions. For this purpose, a graphical user interface (GUI) is developed to display the proposed track to the operator of the vehicles. Figure 2 shows a screen-shot of the GUI for the combine harvester. The display indicated the current position of the real-world combine harvester which corresponds to its actual coordinate position in the field. A virtual combine harvester following the planning (position evolution over time) is used to guide the operator of the real-world combine harvester.

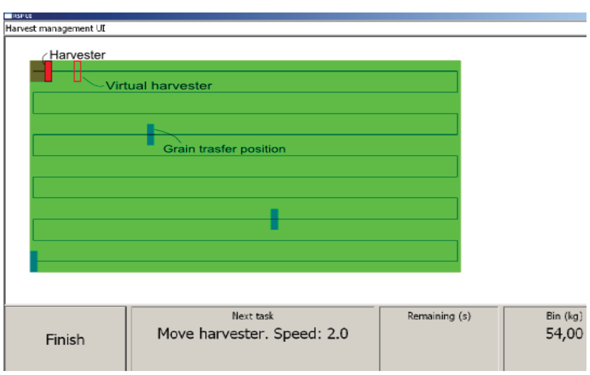

Figure 2. GUI for the combine harvester

These control instructions are updated regularly during execution according to changes in internal conditions (e.g. vehicle performance) or external conditions (e.g. crop density, field slope). This can be as a result of monitoring for example how much crop is harvested per square metre, or how fast the harvester moves, or what is the actual track taken by the harvester etc.

3. DEMONSTRATION SETUP

The multi-agent coordination and control system will be hosted on a computing platform. Two other computing platforms will be used to host the system components of the combine harvester and the tractor. These computing platforms will be equipped with suitable communication systems for the exchange information (Fig. 3 shows the demonstrator setup). The computing platforms of the agriculture vehicles will have GPS modules to provide position data of the vehicles on point by point basis.

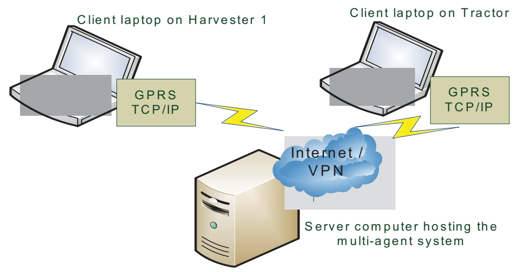

Figure 3. Demonstrator setup

The demonstration will include a walking test in which two persons (each carrying the computing platform of the combine harvester and the tractor respectively) will follow the movement instructions for the combine harvester and the tractor in the supposed area of the field. An available area will be used as the area of the field. The crop density for the assumed field will be simulated. The multi-agent system will take into account the data on the positions of the harvester and the tractor and will provide detailed operating instructions (routes and interactions) for these vehicles. The instructions will be displayed on the respective computing platforms of the vehicles. The dynamic and live aspects of the system can be demonstrated as follows:

- The person carrying the platform of a vehicle will try to follow the planned route of the vehicle with the specified speed. When the person will deviate from the planned route, this variation will be detected by the multi-agent system. The system will update the route for the vehicle in real time according to its recent state (position and speed).
- Variations in the crop density model of the field can be introduced at run-time through the GUI. Such variations will have an influence on the performance of the combine harvester. The performance variation will be detected by the by the multi-agent system, which will dynamically update the planning for coordination between the combine harvester and the tractor (i.e., interaction for the grain transfer operation).

REFERENCES

[1] Ali, O., Verlinden, B., VanOudheusden, D., 2009, Infield logistics planning for crop harvesting operations. Engineering Optimization, 41(2), 183-197.

[2] Van Brussel, H., Wyns, J., Valckenaers, P., Bongaerts, L., Peeters, P., 1998, Reference architecture for holonic manufacturing systems: PROSA. Computers in Industry, (37), 255-274.

[3] Holvoet, T., Valckenaers, P., 2006, Beliefs, desires and intentions through the environment. In AAMAS '06 proceedings. 1052-1054, New York, NY, USA, 2006. ACM Press.