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Distributed decision support system for airport ground handling management using WSN and MAS ☆

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ABSTRACT

The economic situation in the air transportation industry claims for new business models supported by accurate management processes, which need constant feedback of the real status of the environment. The objective of this work is to achieve an updated/real decision support systems (DSS) to allocate resources in an airport even when disturbances occur by combining artificial intelligent techniques with visibility technologies. This work proposes the combined use of Multi-agent systems (MAS) along with Wireless Sensor Networks (WSN) to provide the required information on the status of the resources and the environment. The MAS is based on a double layer of decision-taking levels and on a Markov reward function whereas the WSN is based on a Zigbee network of Radio Frequency Identification (RFID) readers with active tags as end nodes, which are carried by the physical resources. The proposed distributed DSS has been tested at Ciudad Real Central Airport in Spain.

1. Introduction

The world economic crisis has forced airlines to modify the way in which they are operating: improving productivity and reducing costs. Modern airports can be extremely complex organizations, which often involve governmental organizations, private companies, airlines, aircraft operations and airport operators (Ashford et al., 1998). New ideas like common use are emphasizing cost reduction to improve productivity. The concept of "Common Use Model" indicates that airport operators can gain centralized control over facilities and technologies, increase passenger-processing options and acquire shared use efficiencies as they move from exclusive use toward common use. Airport common usable space is defined as the space in which any airline may operate and as space that is not specifically dedicated to any single airline. In this model, all airline usable airport space is available to be used by any airline. The goal of the full "Common Use Model" is to minimize the amount of time any given airline resource is not in use, as well as to maximize the full use of the airport (Belliotti, 2008). Airports benefit from increased utilization of existing resources. In a full common use airport, airlines are assigned with no preferences given to any individual airline, similar to the air traffic control process. To manage resources properly, computer software and systems are put in place to perform complex calculations, monitor usage and provide status reporting.

In the "Common Use Model", the ground handling (GH) companies are the key point because of their central role. The GH companies have to provide service to different types of incoming flights, airlines, passenger, cargo services, etc., while working in a dynamic and safety restricted shared environment. These companies need to reduce costs and offer accurate results to the service contract with the airlines to avoid been charged for delays. In most of cases, GH companies are directly hired by airlines in a rigid contract to assist with supplies. The way to reduce costs is to optimize the resources attending the incoming flights. The optimization is focused on the reduction of the number of resources and the time to assist a flight to increase productivity.

New control systems are steadily increasing their complexity due to pressing requirements for productivity and flexibility. This complexity becomes especially poignant when dealing with typically big plants, airports or centers for logistics; where the usual control is too rigid and hard to manage, maintain and update (Thorne et al., 2007). This control is based on continual planning algorithms (DesJardins et al., 1999), which presents three specific information deficiencies in distributed shop floor operations (Brenner and Nebel, 2009). Three requirements that are especially relevant to provide decision support in high volatile industrial environments are:

- *The usage of the resources*: it is not easy to know when a resource is available or busy. The information feedback of the state of the resources is complex with a high dependency on the surrounding environment.
- *The expected duration of the processes:* considered as a single task each process has different lengths depending on the

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external and internal conditions. The process cannot be completely defined as a mathematical static function or by a template as the real situation is in constant change.

- *The coordination of the involved elements in a task or process*: it is not easy to define the rules of negotiation in a collaborative environment and to reflect the strategic policies in every single operational decision.

For a modern system however, finding an adequate response to a broad range of possible new situations must be business-as-usual and this should apply even while the system is being modified/updated (Garcia et al., 2003). Thus, distributed control becomes standard practice as it allows a division of the problem in smaller and more affordable ones. In this case, the control system relies on a negotiation process to take decisions that affect more than one of its parts (Durfee, 1996). The need for an improvement in the connection between the real environment and the information systems is essential (Sandholm, 1999); Enterprise Resource Planning (ERPs), expert systems or other new information/management systems have given place to new architectures, which need constant feedback of information on the real environment.

This research also proposes the use of a WSN for acquiring tracking information on resources using RFID tags attached to mobile resources that are used at ground handling operations (Sung et al., 2007). This new visibility framework based on RFID is a powerful tool to help distributed continual planning because of the continuous information feedback about the resources it provides. Following these ideas, the new control system (Fig. 1) needs to integrate heterogeneous information coming from the manufacturing/logistics environment through elements such as sensors (RFID or Barcode) or actuators (PLC, Robots or simple actuators) as well as from more complex information systems as ERP, WMS or even expert systems.

Once the information has been captured from high volatile environments, it is necessary to take short-term and even online decisions whenever deviations or disturbances from the plan arise (Schönberger and Kopfer, 2007). These assignment tasks are closely related to the processes of review, control, planning, updating of information and 24-h-data availability. The current scheduling/planning operations, usually centralized at a control department, are based on software tools with a great lack of field communication. To adapt these tools, new ideas and concepts coming from those used at the development of Intelligent Manufacturing Systems (IMS) can be applied in distributed planning and decision making (Abramovici and Filos, 2009). The current trend is to manage the information using new concepts as alignment, agile manufacturing, or interoperability. Most of these are being implemented through new artificial intelligent techniques such as Bayesian networks (Jensen, 1996), multiagent systems (Bussman et al., 2004), Neural networks (Yu et al., 2009) or Fuzzy systems (Lee et al., 2008), which define expert DSS capable of adapting to disturbances.

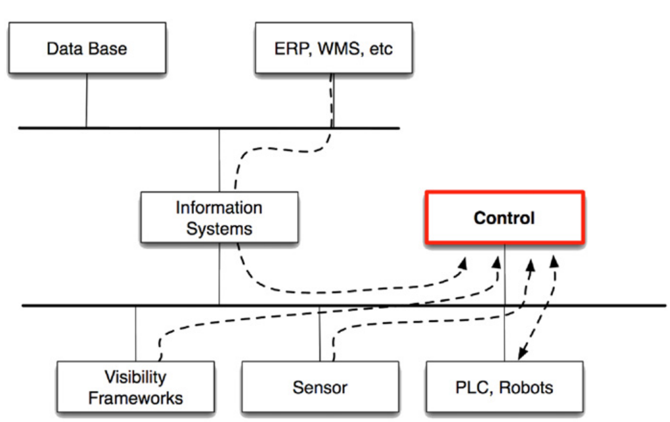

Fig. 1. Current information flow in the control systems.

The key contribution of the research is therefore the robust combination of MAS, DSS and WSN by taking advantages of all their individual features. The proposed combined framework is being implemented at the Ciudad Real Central Airport in Spain. This is a small airport and its demand is based on low cost companies and cargo operations. The airport wants to improve the productivity of ground handling resources by reducing delays, overloads and overstaff. This will reduce costs, following the path set by low cost companies. In the case at hand, software and hardware had to be developed from scratch and particularized to this airport. Thus, the first step was to develop a pre-validation environment that was presented as a demo show at the airport. This made possible the testing of the proposed MAS and the combination of ICTs before the deployment of the complete system.

2. WSN TO improve the visibility in high volatile environments

The first important stage towards making sound decisions is to gather the appropriate information. Even more so whenever the decision support system is to efficiently operate in real time conditions. Following the three requirements presented in the previous section; this DSS uses a combination of the technologies RFID and Zigbee to track the resources at an airport, a factory or a logistics center. The identified resources can be vehicles, products, pallets, machinery and employees. The idea is based on having a WSN capable to cover big distances and track resources on specific zones through the use of all the capabilities of RFID, especially those about identification, and not just to primarily activate/deactivate the WSN modules (Medagliani et al., 2010).

The analyzed technologies of communication between readers were WIFI, WIMAX and Zigbee. The reasons for selecting Zigbee were its characteristics of acceptable distances, auto routing capability, low consumption and a sufficient bandwidth. Zigbee is a specification of a set of high-level protocols for wireless communication, for use with low-power digital radios, based on IEEE 802.15.4 Wireless Personal Area Network (WPAN). These applications require secure communication with low data transmission rates and maximization of battery life, following the current technological developments and trends (Ansari et al., 2009). Its main features are the low consumption, the mesh network topology and its easy integration (nodes can be manufactured with very little electronics). Zigbee network topologies allow three alternatives: star, tree and mesh. For the situation in hand, the mesh topology is particularly interesting, allowing to maintain the communications even in the event of failure in one or more of the Zigbee nodes; as new routes can be recalculated by the coordinator node. In the tested Zigbee system, the communication module can cover around 400 m with a rate of 250 kb/s, performing a large number of identifications per second between nodes. In this option, the bottleneck is the read speed of the RFID reader because of the implemented anti-collision protocol. RFID is the technology of choice for product identification, which has a multi-level standard: the Electronic Product Code (EPC).

In the case of airports, information has to be shared in real time between ground handling companies, airlines, airport suppliers and air traffic control. From the point of view of ground handling, the use of the EPC standard provides a transparent way to share the information of this WSN among the agents involved, which is a key factor to be addressed in multi-company industrial environments. Using WSN based on Zigbee with RFID reader nodes, the identification process can cover big distances and, at the same