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► **To cite this version:**

Mateus Vilela Souza, Bruno Bachelet, Thiago F. Noronha, Loïc Yon, Christophe Duhamel. Online Scheduling with Time Windows of Agricultural Robots. 22ème congrès de la société française de Recherche Opérationnelle et d'Aide à la Décision (ROADEF), Apr 2021, Mulhouse, France. hal-03221259

**HAL Id: hal-03221259**

**<https://hal.science/hal-03221259v1>**

Submitted on 7 May 2021

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# Online Scheduling with Time Windows of Agricultural Robots

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**Keywords :** *online scheduling, time window, autonomous robot, energy management.*

## 1 Introduction

The advances in agricultural robotics [3] bring autonomous robots to work in farms. Farm Management Information Systems (FMIS) are sophisticated and complex systems to support production management in farms [4]. They need to integrate software for the scheduling of a fleet of such robots. As agricultural systems are by nature subject to unpredictable events, it seems necessary to provide a solution for online scheduling. After the description of the problem, which is to schedule tasks for the robots in order to fulfill demands for agricultural activities, we propose an online approach based on solving a Mixed Integer Linear Programming (MILP) problem at each step, meaning each time the FMIS is requested to adjust or complete the schedule.

## 2 Problem Description

We consider a farm composed of many plots (fields) and a warehouse. Robots are deployed on plots to perform some agricultural tasks and they go back to the warehouse for refilling (recharging battery or refueling), changing equipment (robots can change tool to perform different kinds of task), or parking when not in use. The fleet of robots is heterogeneous and the quantity of each kind of robot is limited. There are also several kinds of equipment (which quantities are also limited), and not any equipment can be set on any robot. A compatible coupling of a kind of robot with a kind of equipment is called here a configuration. Only a subset of configurations can be used to perform a given task on a plot.

The farm operators will emit demands for tasks. A demand is expressed as a task to perform on a given plot, in a time window with a preferred completion date and a priority. We consider the demands to be sent on the fly, as many agriculture activities depend on many unpredictable events (meteorological, detection of disease, state of maturity of plants, failure of robots...). The scheduling problem studied here is to decide which robot with which equipment (i.e. which configuration) to assign to a given demand with the hard constraint of being in its time window and the closest to its preferred completion date.

To make such decision, many data are required. First, the performance of the configurations must be estimated on any plot for any task (mainly the total time and the amount of energy needed to perform the whole task). These estimations can be provided by some measures on site or by a simulator [2]. They can also be adjusted by the FMIS from past activities. Secondly, the times to install and uninstall an equipment on a robot (which depend both on the kinds of robot and equipment), and the time and energy needed by a configuration to travel between locations can be estimated quite easily and can also be adjusted by the FMIS.

### 3 An Online Approach

The online approach proposed here is first based on solving the following MILP problem. The input data are a set of demands that have to be considered, the date of availability of each robot (meaning when it will be parked at the warehouse, free of any equipment and fully recharged, thus ready for the next mission). The problem is to decide what is the next route for each robot. A route is a mission for the robot: it leaves the warehouse fully recharged and set up with an equipment; it goes from plot to plot to perform the same task to fulfill several demands, and ultimately returns to the warehouse. This MILP problem, called here *Prize-Collecting Online Robot Scheduling* (PC-ORS), is based on the prize-collecting concept (e.g. [1]) and builds the routes by maximizing a sum of prize functions on demands.

A prize function  $P_i$  is defined for each demand  $D_i$  to be satisfied and depends on the scheduled completion date  $w_i$  for the demand: the closest  $w_i$  is to the preferred completion date, the higher is the prize (it is a piecewise linear function weighted by the priority set by the operator of the demand). Hence, the objective function is to maximize  $\sum q_i P_i(w_i)$  where  $q_i$  is another weight controlled by the online heuristic to adjust the prize function  $P_i$ , in order to favor some demands based on some criteria not integrated directly into PC-ORS, such as the criticality (i.e. the urgency to treat a demand), and so to avoid as much as possible decisions that could prevent demands to be satisfied.

The general idea of the online heuristic is that each time a robot goes back to the warehouse, it has to be fully recharged and its next route is computed by solving PC-ORS. Thus, if no unpredictable event occurs, the online heuristic is called every time a robot goes back to the warehouse. If an unpredictable event occurs, the FMIS analyses the situation and possibly communicates changes to our heuristic by adding new demands and updating the availability date of the robots. Then, when a robot goes back to the warehouse, the online scheduling is triggered with these new data.

### 4 Conclusion

We propose an online approach based on a MILP formulation to schedule the missions of autonomous robots for agricultural activities each time a robot goes back to the warehouse or when an unpredictable event occurs. First results show that the choice of the criteria rewarded by the prize functions impact the quality of the schedule, which needs further investigation.

*This work was sponsored by a public grant overseen by the French National Research Agency as part of the "Investissements d'Avenir" through the IDEX/I-SITE initiative CAP 20-25 (16-IDEX-0001).*

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