VITIGEOSS Business Service: Task scheduling optimization in vineyards

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Abstract:
Context and purpose of the study – Agriculture plantations are complex systems whose performance critically depends on the execution of several types of tasks with precise timing and efficiency to respond to different external factors. This is particularly true for orchards like vineyards, which need to be strictly monitored and regulated, as they are sensitive to diverse types of pests, and climate conditions. In these environments, managing and optimally scheduling the available work force and resources is not trivial and is usually done by teams of senior managers based on their experience. In this regard, having a baseline schedule could help them in the decision process and improve their results, in terms of time and resources spent. To this aim we have developed the VITIGEOSS Business Service, a scheduling optimizer module of the VITIGEOSS platform, which offers support to vineyard managers in organizing their work forces and minimizing costs. The VITIGEOSS Business Service is designed to allow the user to easily configure the characteristics of any specific agronomy related process adapting its results. Moreover, it is an online service embedded in the VITIGEOSS web platform, so it can be accessed from any device.

Material and methods – The model developed during this research uses the AI based algorithms First Fit and Local Search to schedule the assignation of viticultural tasks to a set of working teams. The selection of the best scenario can be decided by three criteria: economic cost, environmental cost, or time of completion. The model has been tested using data from previous years from three use cases within the context of the VITIGEOSS project: soil cleaning in vertical vineyards in the Douro region in Portugal, shoot positioning to avoid disease propagation in the Campania region in Italy, and harvest scheduling including its planning in the Catalunya region in Spain.

Results – The application of VITIGEOSS Business Service to the use-cases described highlights the potentially critical impact of task schedule optimization. In the example of the scheduling of shoot positioning tasks, we observe a reduction of the time needed to finish the tasks of up 43% if the manager-defined priority is the time, which in turn leads to an increase of the overall economic cost of about 13%. On the other hand, when the priority is set to minimize the environmental impact of the tasks, results lead to an increase of 50% both in time and money to accomplish all the tasks. As can be observed, the results vary depending on what objectives are prioritized, enabling the simulation of workable scenarios to find the most convenient for each manager.

Keywords: optimization, task scheduling, management, economic cost, environmental cost.

1. Introduction

Field-related tasks such as vineyard management require a lot of planning and organization. Defining an optimal planning for a set of tasks can be challenging, especially if different criteria must be considered simultaneously. To keep track of their daily tasks and ensure that they are completed on time, vineyard managers typically spend many resources to define a course of action and plan a specific campaign. This represents not only a large time investment for the manager and the organization team but also a possible loss of profit if the planification is not optimized.

In this paper, we present the VITIGEOS Business Service, a task scheduler designed to tackle this problematic and facilitate, accelerate, and optimize the planification of tasks for vineyards. A task scheduler is a software tool that allows users to create and manage tasks, set deadlines, assign tasks to team members, and track progress. Our implementation is designed to be easy to use and gives vineyard managers an efficient way to manage their campaigns. The software provides a customizable input scenario and allows users to create tasks that are specific to their vineyard's needs. For example, users can create tasks representing pruning, irrigation, fertilization, pest control, and harvesting. Our task scheduler also manages different work teams and assign tasks to them, allowing team members to access the task list and visualize their calendar of action. In addition, one of the key features of the task scheduling optimization protocol that we developed is a flexible and customizable optimization score, which represents the criterion to evaluate the fitness of a particular solution. Our optimization scheme can be customized to balance different variables such as the time spent to finish the tasks and their economic and environmental cost, which is critical in obtaining personalized solutions that adapt to the demand of each manager.

In the next sections, a description of the planning setting and the optimization scheme is presented. This is followed by a use-case example to demonstrate the performance and versatility of the platform, showcasing its possible applicability to different scenarios.

2. Methods

2.1 Task organization scheme

To accommodate the scheduling optimization to different scenarios, the problem has been designed as a set of customizable tasks that have to be scheduled over a period of time and assigned to a particular work team. Each task can be defined individually to characterize the extension of the work it represents, the window of time when it should be done, which days the task can be performed, and which priority should be considered when scheduling this task: economic cost, environmental cost, or time cost (expressed as the end date of the task). The type of every task can be specified, and the maximum daily output of each type can be controlled. This is useful to manage tasks such as harvesting, where the daily capacity is limited by the cellars. The model also allows specifying if a particular task has been already preassigned to start on a specific day or to be done by a specific work team. Each work team can also be individually characterized by defining its throughput (the amount of work it can do per day), its work calendar, and its economic cost and environmental cost per worked day.

The solution of the scheduling algorithm consists of a set of task assignments, one for each task defined by the user. Each task assignment defines which work team will do a particular task, which day the work will begin, and which day it is expected to end. From each task assignment, there will be a resulting economic and environmental cost. The number of days that it takes to complete a task and the corresponding economic cost and environmental impact are calculated based on the work extension of the task and the characteristics of the work team assigned to it (throughput, daily economic cost, and daily environmental impact, respectively). The assignments are determined by taking into consideration the priority variable defined by the user for each task (time priority, economic priority, or environmental priority).

2.1 Optimization strategy

An optimal schedule is defined as the plan that minimizes a set of cost functions that depend on how the tasks are organized. We constructed three different cost functions (that we named Necessary score, Priority score and Secondary score, in order from higher importance to lower) that englobe the contributions of several constraints grouped by their relevance.

The Necessary score depends on requirements that must be fulfilled for a solution to be meaningful. It includes conditions such as:

- **Work team conflict:** Two work teams can't be assigned the same task.
- **Work team capacity:** A work team cannot be assigned a task that it is not able to perform.
- **Pre-assignments:** Tasks that have been pre-assigned by the user to start in a specific day or to a specific team can't be rescheduled by the algorithm.
- **Maximum daily output:** The daily output of a specific type of task can't overcome the limit specified by the user.

The Priority score contains the variables that must be optimized with priority:

- **Priority Economic cost:** Each task that has been characterized with ¨Economic priority¨ will add the economic cost of its execution to the Priority score.
- **Priority Environmental cost:** Each task that has been characterized with ¨Environmental priority¨ will add the economic cost of its execution to the Priority score.
- **Priority Time cost:** The number of days that it takes to finalize all the tasks with time priority is added to the Priority score.

The Secondary score contains the same elements of the Priority score, but for the properties that have not been marked as ¨Priority¨ by the user.

To minimize the score functions an optimization model has been built using the library Optaplanner[1], written in Java. To solve the problem, the model goes through various phases that use different optimization algorithms, including Great Deluge, Tabu Search and

Hill[2]. For a period of time determined by the user, the optimizer alternates among these options and at the end selects the best candidate found among all the solutions explored. The model is deployed using an API interface that communicates using input and output JSON files. It is embedded in a GUI interface in the VITIGEOSS platform (platform.vitigeoss.eu).

3. Results and discussion

In this section we present a set of results to showcase the performance of the model. The results presented herein are obtained from optimizing the scheduling of a set of shoot positioning tasks. The input dataset consists of 20 of such tasks to be organized over a period of 30 days. Each task represents performing shoot positioning on a particular parcel, and they have different work extensions depending on the size of the parcel. The tasks must be assigned to a set of 7 work teams, which have different throughputs and daily economic and environmental costs.
To illustrate the versatility of the model, we generated three different schedules by minimizing three different variables: total time spent, total economic cost and total environmental cost (Figure 1). This is equivalent to setting the priority of all the tasks to the time, economic and environmental cost respectively.

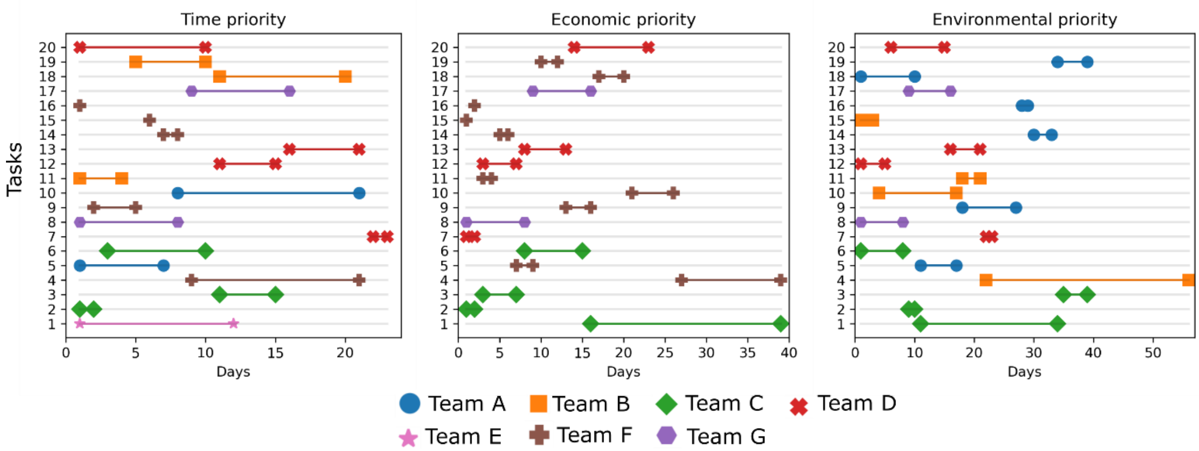

Figure 1: Three different scheduling examples of the 20 tasks. The days where a task will be performed is indicated by a colored line, with the first and last day highlighted. The color of the line indicates which work team has been assigned to each task. Each scheduling has been optimized to minimize a different property: time spent, economical cost and environmental cost, respectively.

We can observe how the algorithm spreads the tasks over all the work teams when the objective is to minimize the time spent doing the tasks (figure 1 left). Instead, the work teams A, B and E are not employed when the objective is to minimize the economic cost, as they are the least economically efficient work teams. When the objective is to minimize the environmental impact, work teams E and F are not used, as they represent mechanized (CO2 emitting) groups.

The overall impact of having different schedules is shown in figure 2, where the total time spent, and the overall economic and environmental costs are compared. We observe a reduction of the time needed to finish the tasks of up 43% (from 39 to 23 days) if the manager-defined priority is the time, which in turn leads to an increase of the overall economic cost of about 13%. On the other hand, when the priority is set to minimize the environmental cost of the tasks, results lead to an increase of 50% both in time and money to accomplish all the tasks.

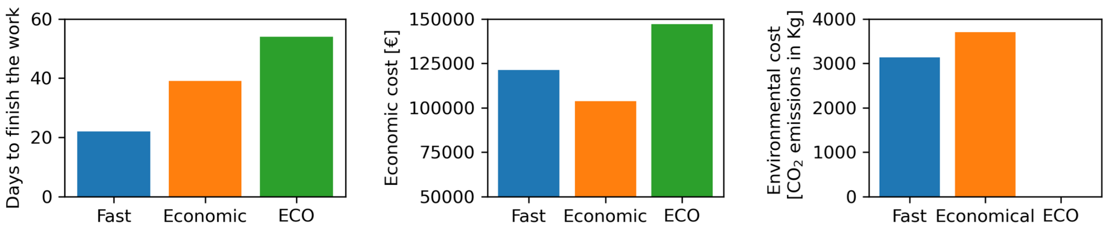

Figure 2: Costs associated with the three schedules generated by prioritizing time (blue), economic cost (orange) or environmental impact (green). Each figure represents a different total cost: time to finish all the works (left), total economic cost (middle), total environmental impact (right).

4. Conclusions

In this article, we have introduced the VITIGEOSS Business Service, a service to define and optimize scheduling problems specifically designed for vineyard-related tasks. Thanks to its versatility, our software allows the user to personalize the problem and its solution according to the needs adapting it to a wide variety of scenarios. We believe that our task scheduler can help vineyard managers improve their productivity and reduce the economic and environmental costs of their daily operations. By using this software, vineyard managers can quickly obtain a working schedule for tasks of any magnitude that are optimized according to their needs.

5. Acknowledgments

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