Towards Improving Agriculture Sustainability through Multifactorial Machine Learning

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Abstract

Wine farms have to adapt their activities to achieve sustainable development goals. Our objective is to contribute to this adaptation by developing machine learning models to predict phenology and pest risk with the aim of reducing the application of phytosanitary treatments.

Introduction

The Internet of Things, the cloud, Big Data technologies and Machine Learning (ML) are digitizing farm management [1]. These technologies transform the data captured in the fields into information and knowledge in real time. Information and knowledge can guide the decisions necessary to manage farms, adapting them to the characteristics of a specific campaign, geographical regions, field, area of the field, and to the characteristics of a specified field. Precision Agriculture is the term coined by the community to refer to the last cases [1].

Farmers' practices are guided by two determinants: the vegetative state of the plants, which is their phenology, and the risk of suffering a pest. Phenology and pests are influenced by the same climatic factors [2]. Being able to predict the phenological state and the current risk level of suffering a pest within a time horizon can help farmers to optimize their tasks and the applied phytosanitary treatments.

There are several statistical-based models of phenology and pests working right for a specific variety in a specific area [2]. However, they do not generalize well to other scenarios. Besides, they cannot be used in real time and they cannot easily be adapted to include new variables or more data.

Our purpose is to demonstrate that multi-source machine learning models are able to predict the phenological state and pest risk levels with a time horizon enough to be useful for farmers (at least two weeks in advance). We will consider several data sources (field observations, climatic station networks, weather forecasts, and satellite hyperspectral images) and analyse their possibilities aiming to obtain general models and a methodology for adapting them to other species and/or areas.

Background

In [3], we performed a deep analysis of the current state of the art of phenology, phenology models, the use of of hyperspectral images, and the application of ML to predict phenology and pest.

It is known that several factors influence the phenological development. However, most of the models developed during the last 3 centuries only consider the temperature and, sometimes, solar radiation as the main determinants of the phenological and the pest evolution [2]. To create general prediction models, a long-term multi-scale phenology monitoring is needed for interpreting the mechanism behind an observation is needed [2].

Several studies highlighted the application of Big Data and ML for determining the phenology of plants and the life-cycle of pests that can affect them. Big Data can be applied to capture the data from sensor networks, and combine and transform them for feeding ML algorithms. Deep Learning algorithms have shown their validity for extracting the behavioural patterns of complex processes with the combination of multi-sourced data; they have demonstrated their validity when time-series data are used and when processing images is required.

Human-captured data and remote sensor data can be used to determine the phenological state of plants. Thus, the new models can take advantage of hiper-spectral images captured by drones, aircrafts or satellites. These images are observations of big geographical areas obtained with a regular frequency. They can be stored and reviewed when desired.

The bands of hiper-spectral images can be combined to obtain different *vegetal indexes*, which are indicators of features of the green cover of the plants, which can be related with the phenological state or the presence of pest affecting the leaves.

Goals and Approach

Our goal is to propose a methodology for the development of intelligent phenology and pest models of woody crops (peach trees —*Prunus persicae*— and grapevines —*Vitis vinífera*—). We will use ML with the objective to anticipate in a decisive time the phenological evolution of the species under analysis and of a subset of pests that can affect them.

The models will allow users to determine if a phytosanitary treatment should be applied with the purpose of mitigating the pests. So, these models will contribute to reduce the environmental impact of the farm and to increase its economic efficiency. We will use existing biological knowledge (i.e., using physical and biological models) for determining the parameters to be considered.

In order to archive this general goal, we first need to perform a study of the state of the art of the methodologies, technology and ML algorithms for determining the phenological evolution of plants and for predicting the pests that can affect them. Then, we will identify the available data sources, their suitability, and the methodologies for processing data and the ML models that can be applied. Finally, we will develop new ML models for predicting the phenology of the varieties under study and of the pests that can affect them.

Current Status and Next Steps

So far, we have performed an extensive review of the state of the art covering the agronomist and data science approaches for creating phenology and pest predictions models [3]. We identified the data sources to be considered, their well-known problems, and the most commonly-used ML algorithms and their purpose. As a conclusion, we have started to sketch the methodology of our work.

Currently, we are creating phenology models using human and (climatic) sensor observations. We started to train Random Forests (RF) and Artificial Neuronal Networks (ANN) models. Once we validate these models, we will create the pest models and finally we will add satellite images.

Conclusions

Our research aims to contribute to farming sustainability, in particular in the context of cropping grapevines. However, as phenology is a good indicator of climate change, this work can have other applications. If we are able to obtain general models, we will be also contributing to the sustainable development of other economic activities in rural areas, such as tourism for bird or flower observation.

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