Integrated CrackSense Solution

Executive summary

Fruit cracking is a highly variable disorder exacerbated by climate extremes, causing significant economic damage and up to 50% yield loss across multiple fruit crops. To address this challenge, the Integrated CrackSense Solution deploys smart farming tools that combine multi scale sensing technologies and machine learning models at the fruit, tree, and regional levels to accurately predict and monitor cracking risks. These predictive models are integrated into a Spatial Decision Support System (SDSS) web platform and supported by a public data repository, empowering stakeholders like farmers and policymakers to input field data, estimate risks, and optimize agricultural resource management.

Introduction

Fruit cracking, a peel disorder that reduces fruit quality and yield, occurs primarily during the pre-harvest stage and affects numerous fruit crops, both annual and multi-annuals, including citrus, pomegranate, tomato, paper, persimmon and grapes. Its incidence is highly variable and influenced by external factors such as climatic conditions and environmental variability, orchard management practices, such as, irrigation and mineral nutrition, as well as by endogenous factors, such as fruit size and shape, hormonal content and genetic makeup. In certain years, cracking rates rise sharply, and these increases are increasingly associated with climate-change-driven weather extremes. Economic damage of the disorder cross crops is significant, and in certain years more than 50% of yield loss might occur. Due to the chaotic characteristics of the phenomenon, fruit cracking is difficult to predict, thus limiting growers' ability to cope with it. CrackSense focuses on citrus, table grapes, sweet cherries and pomegranates in the following countries, France (sweet cherry, citrus), Germany (sweet cherry), Greece (pomegranate, table grape), Israel (citrus, pomegranate, table grapes) and Lithuania (sweet cherry).

CrackSense aims to tackle yield losses due to fruit cracking by providing the **Integrated CrackSense Solution** that will enable the use of smart farming tools to mitigate the effect of cracking on the yield and thus enable better management of farmers' resources. This will contribute to reducing the losses due to fruit cracking that will be directly added to the production value.

Methodology

The Integrated CrackSense Solution is composed of the following components:

I. **Upscaling sensing tools: cracking monitoring at the fruit-, tree- and plot level**

The integrated solution is based on a three-level cracking monitoring framework that employs a range of complementary sensing technologies. At the **fruit level**, cracking is detected through the integration of RGB, thermal, and LiDAR imaging, enabling the identification of cracks and their association with changes in fruit surface temperature and wetness. At the **tree level**, data acquired from UAV-mounted RGB, thermal, multispectral and LiDAR sensors are combined with ground-based monitoring systems to assess tree physiology and water status ("tree health"). Cracking incidence and yield are also monitored on a per-tree basis. At the **plot level**, the integration of UAV- and ground-based sensing data with local climatic information and spatial plot characteristics, such as topography, soil texture, and soil water status, enables the estimation of cracking risk across the orchard. Incorporating satellite-derived climatic data further extends monitoring and analysis to the regional scale. Overall, the integration of sensing technologies across the fruit, tree, and plot levels represents a progressive upscaling approach for comprehensive cracking assessment and prediction.

II. Modeling: fruit level, tree level, plot level, fruit-tree level

Cracking risk prediction is evaluated at several different levels. At the **fruit level**, close range data of fruits and tree canopy are processed with computer vision and deep learning algorithms to predict the risk of cracking before it is visible on the fruits, or to detect the level of cracking in later stages of the season. At the **tree level**, a number of sensing sources are combined in a hierarchical manner to predict the risk of cracking: (i) remote sensing and ground sensors features are extracted from the acquired data, and tree health status in estimated with machine learning models. For instance, citrus trees stem water potential is estimated using spectral and thermal reflectance indices, as well as dendrometers' measurements and local climatic conditions. (ii) the estimated tree health parameters in two specific growth stages are used to estimate the risk of cracking through other machine learning techniques. At the **regional level**, satellites are used to predict the risk of cracking using spatio-temporal data observed over the entire field, supported by ancillary farmers' meta data.

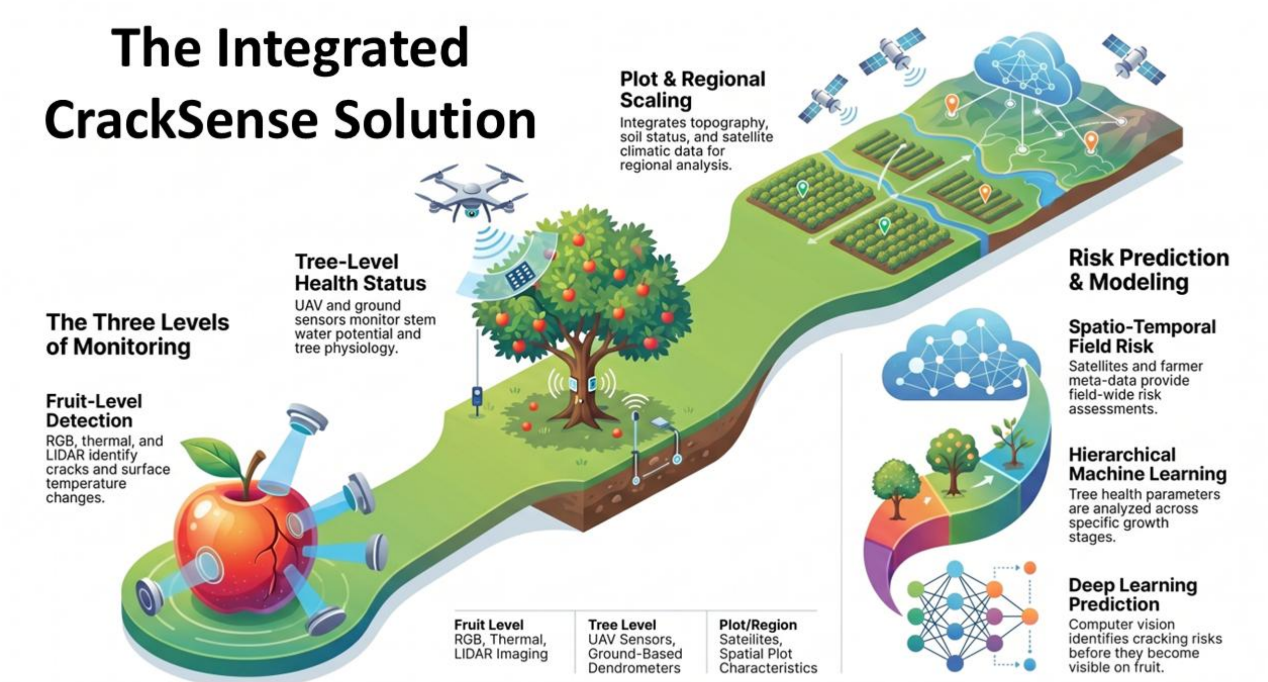

Figure 1: Sensing tools and modeling approaches of the Integrated CrackSense Solution

III. Publicly available databases

As part of CrackSense, a large and continuously expanding dataset is being collected at the fruit, tree, plot, and regional scales. To facilitate efficient data management and accessibility, a dedicated data repository has been developed, enabling users to easily access and download datasets according to various parameters, including crop type, country, and sensing technology. This repository is expected to become part of the European EU Partnership Agriculture of Data (AgData) initiative.

IV. SDSS generation

A Spatial Decision Support System (SDSS) was constructed, that integrates the developed models with spatio-temporal data obtained from OSINT Earth Observation Systems (EOS, e.g., Copernicus Sentinel).

V. SDSS implementation

The SDSS, that implements the Integrated CrackSense Solution, is made accessible to a wide range of stakeholders, like farmers, advisers, policy makers, extension. A Web platform has been created that enables the stakeholders to select a field, and provide all the information available for that field. The platform withdraws ancillary OSINT data and uses the developed models to estimate the risk of cracking.

Conclusion

The Integrated CrackSense Solution aims to provide smart farming tools to help farmers mitigate the effects of fruit cracking and better manage their resources, ultimately reducing yield losses. To achieve this, the project has implemented a Spatial Decision Support System (SDSS) via a web platform that allows stakeholders—such as farmers, advisers, and policymakers—to input field data and use predictive models to estimate the risk of fruit cracking.

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