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Pronofrut: IT-assisted Stereology for Monitoring Orchards for Precision Horticulture

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Pronofrut™ is a crop monitoring service developed for the fruit, winery and horticultural industries which incorporates a stereological sampling methodology supported by Information technologies to optimise sampling, data collection and processing. Originally developed with yield estimation as the primary objective, it has evolved to provide tools and techniques for providing key information required to implementing precision management of orchard and horticultural crops. Such information includes georeferenced maps of plant characteristics and fruit loading, early detection of infection by botrytis and other molds, evaluation of labour quality, evaluation of the distribution of fruit quality and maturity, and yield estimation.

Although commercial fruit trees are genetically uniform, because both the root stock and the scion/cultivar are of clonal origin, due to variations in many orchard conditions there may be large variations in tree yield, providing a challenge for accurate estimation. Early forecasting of crop yield is important for market planning and for growers and exporters to plan labor, bins, storage and purchase of packing materials. Modern orchard management for high value production, such as fruit for export and quality wines, involves the manipulation of individual tree canopies and even individual fruit. Thus, the ability to conduct rapid, timely evaluations of the quality of tasks such as pruning and thinning of trees and fruit is also fundamental for delivering quality and costs and correcting errors early on.

The general procedure is:

1. A high resolution, georeferenced image of the orchard is derived from images obtained using an unmanned aerial vehicle (UAV) equipped with specialized cameras. Alternatively, maps may be obtained using optical sensing from ground-based vehicles.

2. OrchardMapper software uses image analysis of the orchard images to detect individual plants and their characteristics, and quantify the spatial variability of the plantation as derived from visible features in images. This information is input to an algorithm that selects the sample trees, with selection designs depending on the objective of the sampling, and also provides a prediction of the contribution to estimation error from the tree sample.
3. Manual fruit counts and size (diameter, volume or mass) measurements are made on small samples of fruit selected systematically uniformly at random (a fractionator design) across the plantation. Low counts are important to reduce human errors in counting. The selection of samples are made following unbiased sampling and counting rules. A smartphone app (Pronofrut Sampler) is used to guide sampling indicating to the user the exact position of the sample, and also to input data and, at the end of a survey, upload the data to a server for processing. The application saves a position and timestamp for each sample, permitting the creation of maps of the orchard.
4. The sample counts and measurements are used to estimate yield and distributions of quality parameters and a semi-empirical variance model is used to predict the error of the yield estimate.
5. If the variance model predicts an error that exceeds the target precision (typically less than 10% at field scale), a supplemental sample may be taken as guided by the app.

Steps 1–2 are optional, but provide a way to optimize tree sample selection and reduce the cost of the survey.

We present Pronofrut with a special emphasis on the IT assisted aspects, namely the OrchardMapper software for individual plant detection from images, the selection of tree samples and variance prediction, and the Sampler application for in-field manual counting and sampling.

We will also present results of yield forecasts carried out at the commercial scale for several species, including comparisons of the true error with the model-predicted error, where the ‘true error’ is derived as the difference between the estimated yield and the yield reported by the packing house.