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Making reliable growth stages predictions thanks to the Choquet integral

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Abstract

A key issue in agriculture is maximizing crop efficiency while respecting natural environment and farms sustainability. We put our interest on an application of smart farming, proposing a generic way to identify the parameters of a growth stage prediction model. We propose an approach based on a parametric model for data aggregation thanks to the Choquet integral. The case study concerns an implemented prototype that, for a given culture and several input sources, provides farmers with better predictions of the growth stages. The experimental results are very encouraging, the predicted day remaining stable despite presence of noise and local errors.

Keywords: Choquet Integral, Decision Model, Parameters Identification, Smart Farming.

Introduction

Smart farming aims at improving agriculture production by using artificial intelligence and smart devices and, in continuity, farming optimization aims at supporting autonomous decision-making to maximize crop yield. In this context, the question of predicting the future days of growth stages (Kang, F., 2013) transition of a plant is still a challenge, as existing automated predictions are not accurate nor reliable enough to be effectively used in the farming process. Such predictions should be based on various available sources of information, that deliver in practice more or less accurate and reliable information (Pollet Y., Dantan J., & Baazaoui H., 2022). Predictions sources may be empirical « Degree Days » calculation (De Alwis S., Hou Z., Zhang Y., Na M.H., Ofoghi B., & Sajjanhar A., 2022), vegetation indexes processed from satellite images, interpolation from statistical tables, etc. The most general case is with n sources of prediction with limited reliability and accuracy; we here consider the case of 3 input sources (figure 1).

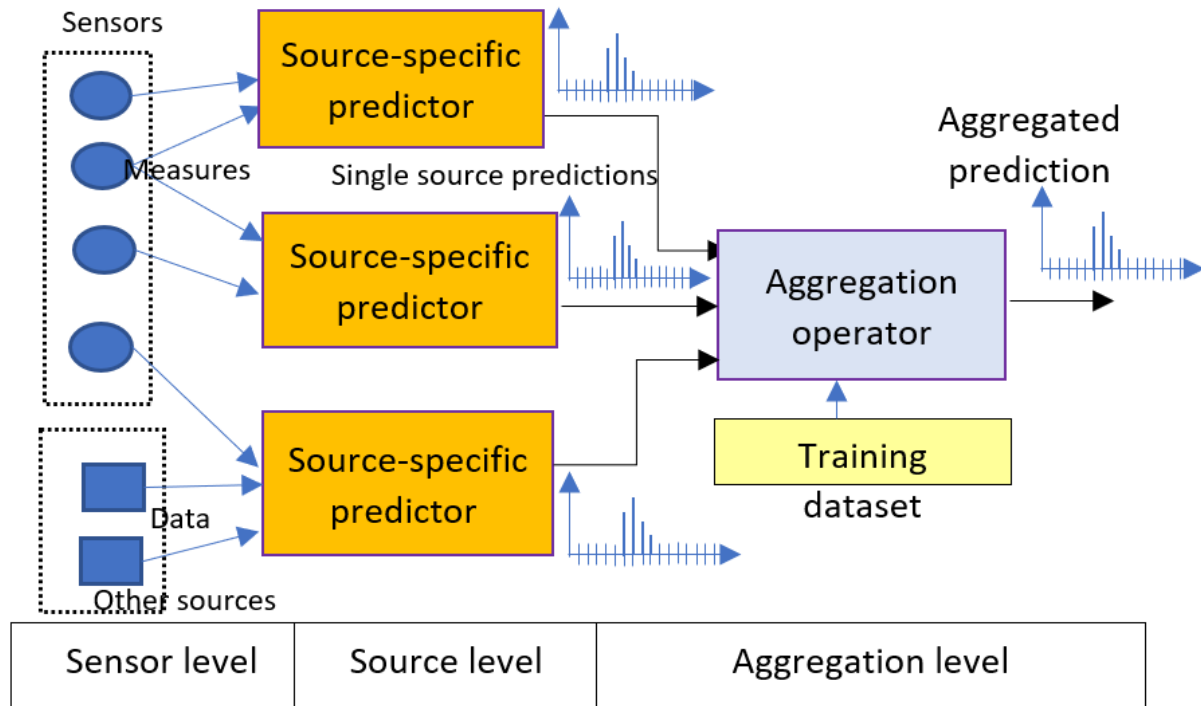


Figure 1. Functional schema of growth stages prediction, from (Pollet Y., Dantan J., & Baazaoui H., 2022).

Methodology

Multi-criteria decisions require use of aggregation functions, such as fuzzy integrals, among those the Choquet integral (Sugeno, M., 1974), which is defined from a fuzzy measure representing not only the relative importance of the various criteria but also the possible interactions between them (Grabisch, M., & Labreuche, C., 2008).

Our approach consists in identifying the parameters of a Choquet-based decision model using a training dataset including data delivered by available sources. We propose an algorithm adapted from the classical gradient descent and providing a robust solution, and a quality index to objectively evaluate the reliability of the made prediction in each case.

Results

The implemented prototype enables, for a given culture and three input sources, predicting growth stages. Data are parametrized with the day of maximum confidence, sources accuracy and noise. Figure 2 illustrates one simulation run for a given parameter set:

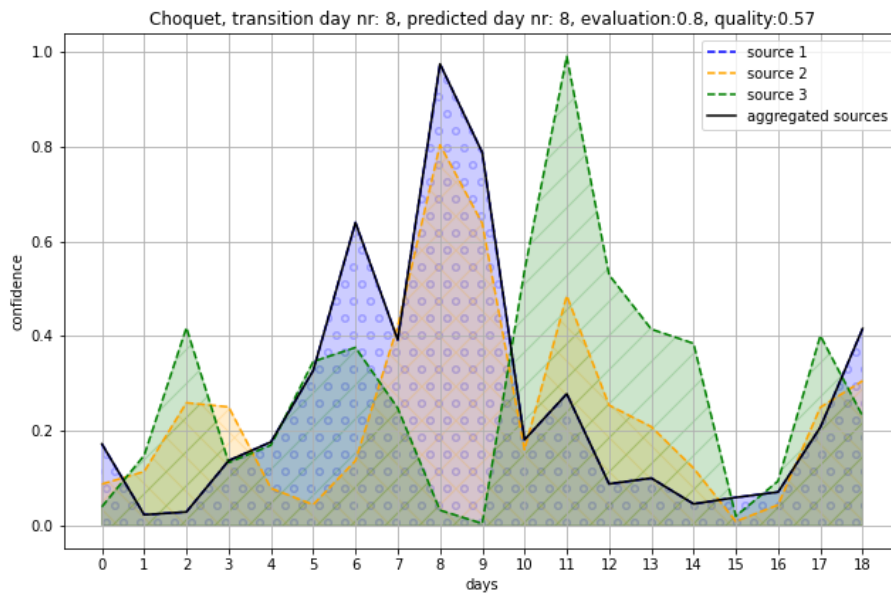


Figure 2. Simulation result with biased/noisy data

Table 1 provides aggregated results with 50 simulations.

Table 1. Experimental results

Average quality				Right day prediction ratio			
Source 1	Source 2	Source 3	Model	Source 1	Source 2	Source 3	Model
0.48	0.45	0.44	0.48	0.36	0.16	0.26	0.36

Average prediction quality - good even for noisy sources - as well as right day ratios are systematically superior to those of separately considered input sources. It tends to validate both the interest of our approach and a certain robustness of the algorithm.

Conclusion

In this paper, we proposed a generic way to identify the parameters of a growth stage prediction model by aggregating multiple sources. We provided a Choquet-based decision model associated a parameter identification approach. The experimental results are very encouraging, the predicted days being stable despite the variation of the noise attached to inputs.

An extension of our work concerns an algebraic approach enabling to reduce the dimension of the problem, and so reduce the number of Choquet parameters to be identified, enabling so to consider larger source sets with less calculations.

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