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### ► **To cite this version:**

Subhasish Basak, Julien Bect, Laurent Guillier, Fanny Tenenhaus-Aziza, Janushan Christy, et al.. Quantitative risk assessment and optimization of process intervention parameters for French raw milk soft cheese. IDF World Dairy Summit 2022, Sep 2022, New Delhi, India. . <hal-04017197>

**HAL Id: hal-04017197**

**<https://centralesupelec.hal.science/hal-04017197v1>**

Submitted on 7 Mar 2023

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# QUANTITATIVE RISK ASSESSMENT AND OPTIMIZATION OF PROCESS

## INTERVENTION PARAMETERS FOR FRENCH RAW MILK SOFT CHEESE.

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### Context

This study is a part of the European project **ArtiSane-Food** that aims at controlling food-borne pathogens in artisanal fermented food of meat and dairy, origin produced in the Mediterranean region. As a participating country one of the main objective for France is to allow the continuation of the production of raw milk soft cheeses, which is today potentially at risk due to future European regulations. At the French national level this project is in collaboration with ANSES, CNIEL, CentraleSupélec - Université Paris-Saclay and organizations from the dairy industry.

### Problem Statement

The primary goal is to establish efficient intervention strategies, in order to “economically” reduce the risk of **Haemolytic Uremic Syndrome (HUS)** caused by **Shiga-Toxin producing Escherichia coli (STEC)** present in raw-milk soft cheese.

Intervention strategies in cheese making:

#### • Pre-harvest milk sorting:

STEC and *E. coli* strains follow same fecal route!

– A bulk tank of milk is tested with probability  $p_{\text{test}}^{\text{milk}}$

– Farms with *E. coli* conc.  $> I^{\text{sort}}$  are rejected

–  $C_{\text{pre}}$ : Cost of testing and rejecting bulk tank milk

#### • Post-harvest cheese sampling:

– A batch of cheese is tested with probability  $p_{\text{test}}^{\text{cheese}}$

– From a single batch  $n_{\text{sample}}$  cheeses are tested for presence of STEC

–  $C_{\text{post}}$ : Cost of testing and rejecting cheese batches

The aim is to find the **optimal** values of the process intervention parameters  $\{p_{\text{test}}^{\text{milk}}, I^{\text{sort}}, p_{\text{test}}^{\text{cheese}}, n_{\text{sample}}\}$ , that minimize the risk of HUS and the costs ( $C_{\text{pre}}$  and  $C_{\text{post}}$ ).

### Quantitative Risk Assessment (QRA)

QRA based on model proposed by ?

#### • Farm module + Pre-harvest step

STEC conc.  $Y_{\text{milk}}^{\text{STEC}}$  in farm milk is computed

$$Y_{\text{milk}}^{\text{STEC}} = Y_{\text{milk}}^{\text{EC}} \cdot (Y_{\text{feces}}^{\text{STEC}} / Y_{\text{feces}}^{\text{EC}})$$

#### • Cheese module

Evolution of STEC is modeled with ODEs

$$\frac{dy}{dt} = \mu^{\text{max}}(t) \cdot y(t) \cdot \left(1 - \frac{y(t)}{y^{\text{max}}}\right)$$

STEC cells form colonies (clusters) inside cheese

– No. of colonies (Poisson):  $N^{\text{colony}}$

– Size of colonies (LogNormal):  $Y^{\text{colony}}$

#### • Consumer module

Batch risk is computed using a dose-response model:

$$\Gamma = \sum_s N_s^{\text{colony}} \cdot Y_s^{\text{colony}}$$

$$R^{\text{batch}} = \sum_{\text{age}} g_{\text{age}} \int_{\Gamma} P[\text{HUS}|\gamma, \text{age}] \cdot p(\gamma) d\gamma$$

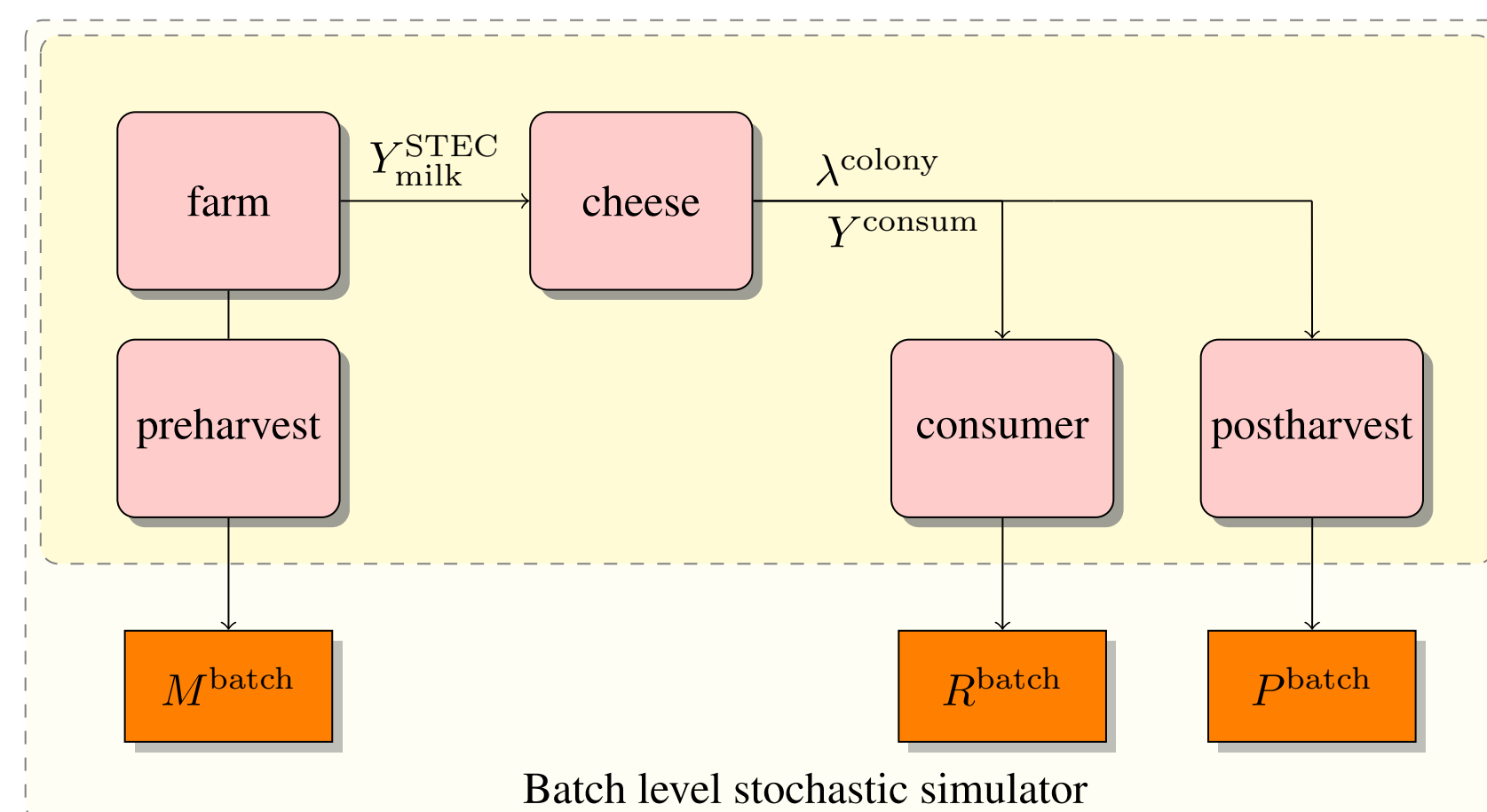
averaging over consumer age

#### • Post-harvest module

Proportion of rejected batches  $P^{\text{batch}}$  is computed

$$P^{\text{batch}} = P[\Gamma > 0] = 1 - \exp(-K \cdot n_{\text{sample}})$$

### Quantities of Interest (QoI)



Several batches are simulated to estimate

$$\bullet R_{\text{avg}} = \mathbb{E}[R^{\text{batch}} \cdot (1 - P^{\text{batch}} \cdot p_{\text{test}}^{\text{cheese}})]$$

$$\bullet P_{\text{avg}} = \mathbb{E}[P^{\text{batch}} \cdot p_{\text{test}}^{\text{cheese}}]$$

$$\bullet M_{\text{avg}} = \mathbb{E}[M^{\text{batch}}]$$

QoIs are

$$\bullet \text{Relative risk: } f_1 = \frac{R_{\text{avg}}}{(1 - P_{\text{avg}}) \cdot K_1}, (K_1: \text{baseline risk})$$

$$\bullet \text{Intervention cost: } f_2 = C_{\text{pre}}(M_{\text{avg}}) + C_{\text{post}}(P_{\text{avg}})$$

### Bi-objective optimization

We consider the bi-objective optimization problem

$$\min_{x \in \mathbb{X}} f(x)$$

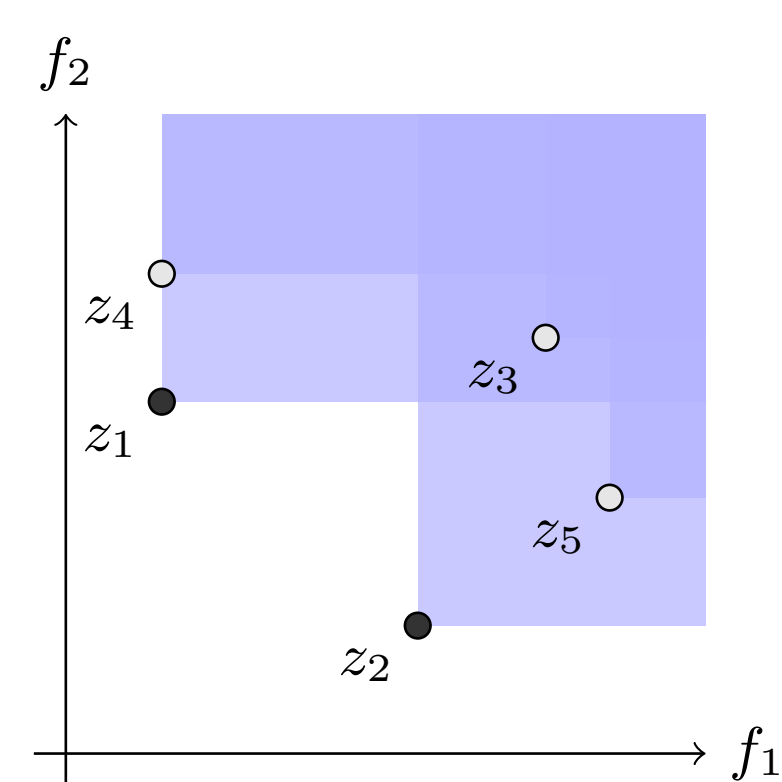
where,  $f = (f_1, f_2)$

• Not necessarily has a unique solution  $x^{\text{opt}} \in \mathbb{X}$ , in presence of conflicting objectives

• The solution set  $\mathcal{P}$  consists of **Pareto optimal** points

$$\mathcal{P} = \{x \in \mathbb{X} : \nexists x' \in \mathbb{X}, f(x') \prec f(x)\}$$

where  $f' \prec f \implies f'_i \leq f_i, \forall i$ , with at least one of the inequalities being strict



Pareto optimal points  $z_1$  and  $z_2$

• In stochastic setting, we assume additive noise: for  $x_i \in \mathbb{X}$ , we observe  $Z_i = f(x_i) + \varepsilon_i, \varepsilon_i \sim \mathcal{N}(0, \Sigma)$

• The problem boils down to estimating  $\mathcal{P}$

### PALS

Optimization of the QRA simulator

• It is **stochastic** and computationally **expensive**

• Gradient based optimization is not feasible

• Thus we reside on Bayesian approaches

**Pareto Active Learning for Stochastic simulators** proposed by ? and extended by ?.

• It uses Gaussian process regression for approximating the simulator function

• Estimates  $\mathcal{P}$  by classifying each point in  $\mathbb{X}$  as **Pareto optimal**, **Non-Pareto optimal** and **Unclassified**

### Experimental results

• Minimizing  $f$  over the input space  $\mathbb{X}$

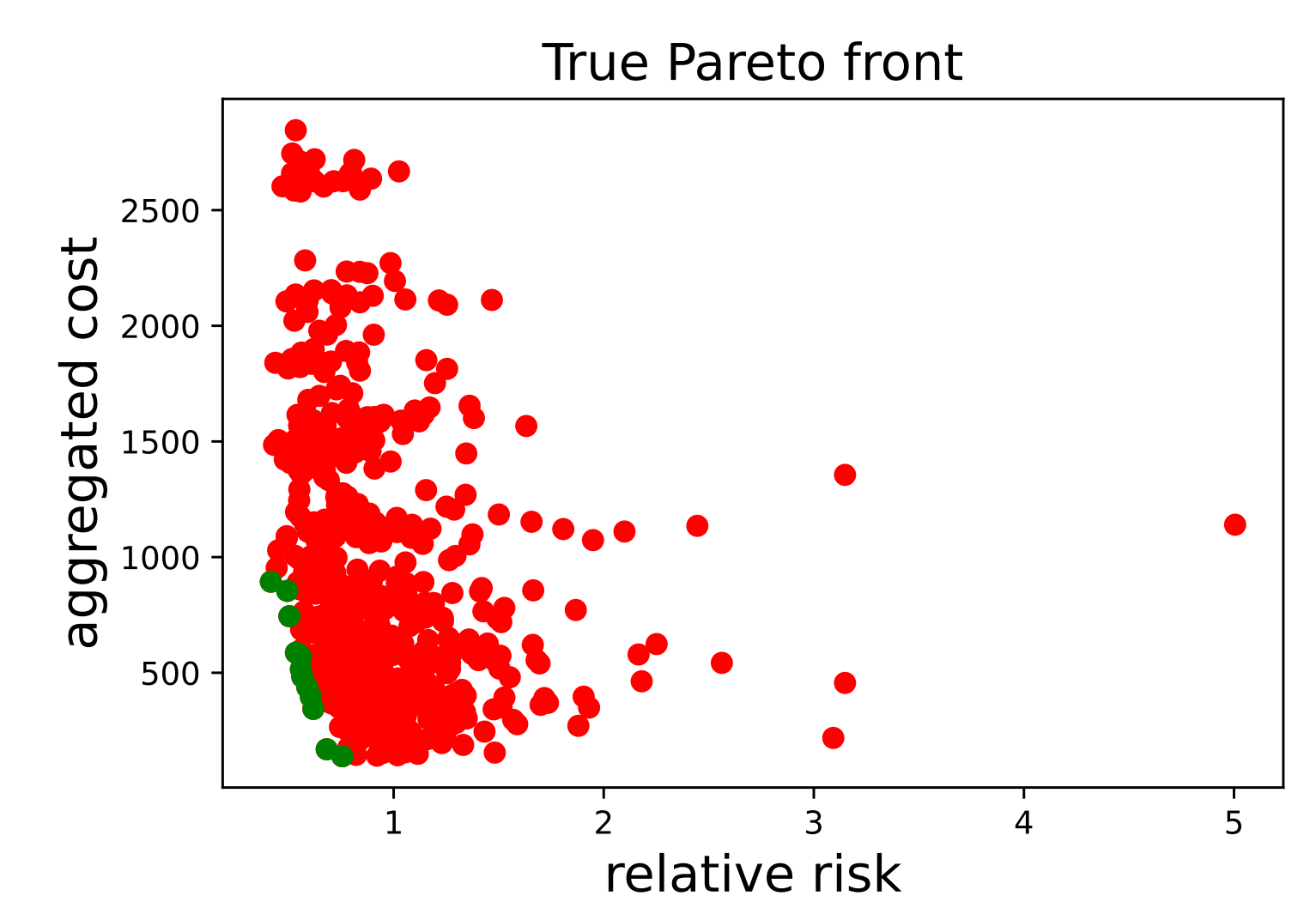
–  $n_{\text{sample}} \in \{5, 10, 20, 30, 50\}$

–  $I^{\text{sort}} \in \{10, 20, 30, 40, 50\}$

–  $p_{\text{test}}^{\text{milk}} \in \{1/10, 1/20, 1/30, 1/40, 1/50\}$

–  $p_{\text{test}}^{\text{cheese}} \in \{0.1, 0.2, 0.3, 0.4, 0.5\}$

• **True Pareto front**: estimated using 5000 samples for each of  $5 \times 5 \times 5 \times 5 = 625$  input points

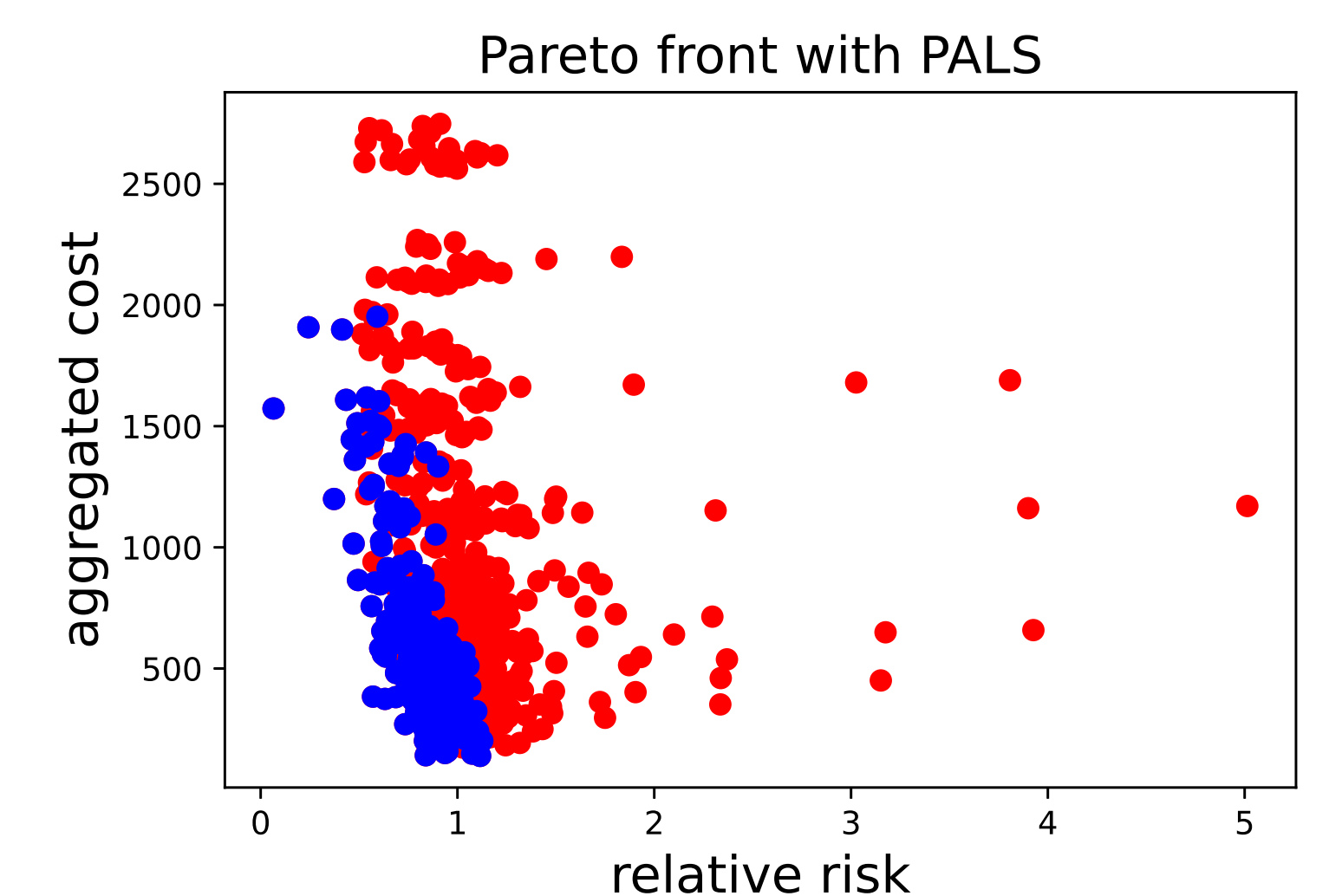


– Pareto optimal (green) and dominated points (red)

• **Pareto front estimated using PALS**

– Initial design size = 60, evaluation budget = 40

– batch size per iteration = 300



• With PALS using significantly less ( $100 \times 300$ ) evaluations, the user can provide the following insights

– Most of the dominated (red) points are well classified

– The points corresponding to  $\mathcal{P}$  remain unclassified (blue)

### References

F. Perrin, F. Tenenhaus-Aziza, V. Michel, S. Miszczycha, N. Bel, and M. Sanaa. Quantitative risk assessment of haemolytic and uremic syndrome linked to O157:H7 and non-O157:H7 shiga-toxin producing escherichia coli strains in raw milk soft cheeses. *Risk Analysis*, 35(1):109–128, 2014.

M. Zuluaga, G. Sergent, A. Krause, and M. Püschel. Active learning for multi-objective optimization. In *Proceedings of the 30th International Conference on Machine Learning*, pages 462–470. PMLR, 2013.

B. Barracosa, J. Bect, H. Dutrieux Baraffe, J. Morin, J. Fournel, and E. Vazquez. Extension of the Pareto Active Learning method to multi-objective optimization for stochastic simulators. In *SIAM Conference on Computational Science and Engineering (CSE21)*, Mar 2021.

This work is part of the **ArtiSaneFood** project (grant number : ANR-18-PRIM-0015) which is part of the **PRIMA** program supported by the **European Union**.