Using gaussian process metamodels for sensitivity analysis of an individual-based model of a pig fattening unit

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Objective
To define and implement an appropriate sensitivity analysis approach for an individual-based model

Model description
a pig fattening unit model able to
i) Simulate individual performance of pigs (variability) X with farmer’s practices
ii) Evaluate the effects of these practices on technical, economic and environmental performance.
  • Dynamic (daily time step)
  • Stochastic (animal profiles, mortality)
  • Mechanistic
  • Discrete-event model (agenda of events)
  • ~10 min per simulation

Sensitivity analysis
• 14 inputs tested (5 integers, 9 real numbers)
• 10 outputs studied (technical and environmental results)

Two steps approach (due to calculation time)

i) One gaussian process metamodel per output (using 100 simulations)
ii) Extended Fourier Amplitude Sensitivity Test (eFAST) method (N=1500 scenarios for each trajectory: 21000 simulations per metamodel)

→ ~200 time faster using gaussian process metamodels than using our model itself (2 h vs. 2.5 weeks of calculation)

Fig. A: Coefficients of variation of the model's studied outputs (using the 100 simulations for the metamodels)
• Variations of phosphorus excretion: 85% due to phosphorus intake
• Variations of nitrogen excretion: 84% due to nitrogen intake
• Variations of percentage of pigs in optimal slaughter weight range: 38% due to cleaning period, 18% due to minimum number of pigs per delivery to slaughterhouse, 14% due to quantity of feed intake, 8% due to the number of places per pen

Fig. B: Average sensitivity indices of the inputs investigated, among all the outputs
• Feed intake explains 37% of the variation
• Duration of cleaning period explains 31% of the variation
• Phosphorus and Nitrogen intake explain each 11% of the variation
• Minimum number of pigs per delivery explains 10% of the variation
• The other inputs explain each less than 5% of the variation

Conclusion
The sensitivity analysis allowed us to
i) Validate the model behaviour by expertise
ii) Identify the most sensitive inputs (>30% of sensitivity explained, feed intake, cleaning period) and the less sensitive inputs which can be set for routine use (<5% of sensitivity explained, number of places per pen, number of pen per room, delivery tolerance, size of extra-room, amino acid intake, mortality rate, rate of pigs per room, maximum time fatten in extra-room, area allocated per pig)

→ Perspective: These results will be confirmed by a second sensitivity analysis including newly implemented economic and environmental (calculated by Life Cycle Assessment) results.