MONITORING FISH SIZE BY STEREO IMAGING AND PREDICTING GROWTH WITH DES + MACHINE LEARNING

A framework for Aquaculture Digital Twins

From Knowledge to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal Program

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Data Science

1 Why a tank-specific Digital Twin?

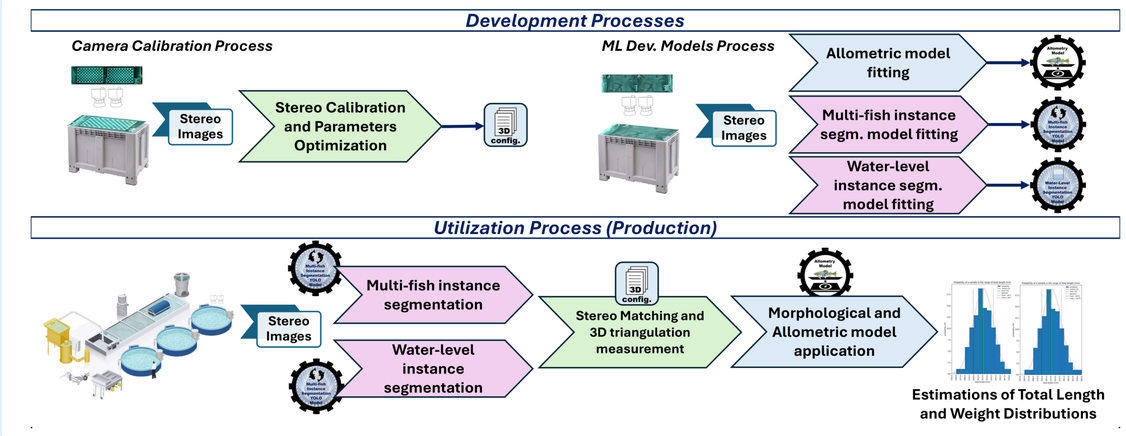
Weight dispersion is challenging in tanks of aquaculture of European seabass (*D. labrax*) and rainbow trout (*O. mykiss*) that are key farmed species in Portugal.

- It drives competition, aggression, poor feed efficiency, and unpredictable harvests.
- Corrective grading is laborious and stressful. Tanks differ in rearing parameters.
- Digital Twins, virtual models synchronized with physical data, predict future states.

This work develops their two kernels: observation and forecasting.

2 Observation kernel

Above-water stereo vision and environmental sensors [1]



Development and production pipelines: stereo images to length and weight distributions [1].

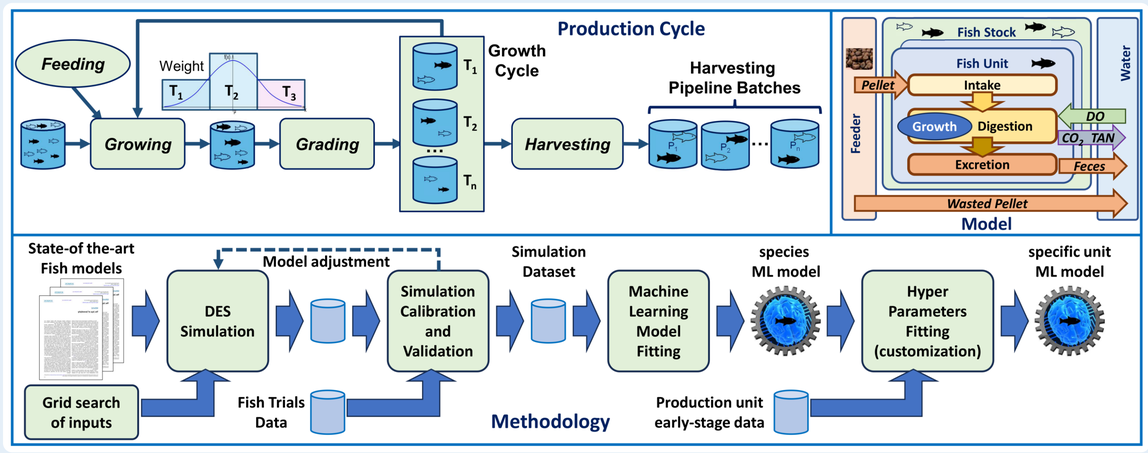
- **Optimized calibration:** validation error < 3.3%; fish length error <4.2%.
- **Refraction** corrected in two vertical planes; YOLOv11x segments the water line in border.
- **Multi-fish YOLOv11x contours** and a 33-point descriptor drive stereo matching, triangulation, and morphological filtering.
- **Reciprocal KNN stereo matching** through polar descriptor vector.
- **Gradient Boosting** allometry converts length and width to weight.

2.3% | 1.2%	6.9% | 4.9%	97.2%
median length MAPE seabass | trout	median weight MAPE seabass | trout	mask mAP50 segmentation

100-day seabass and 71-day trout trials; turbidity reached the 200 NTU sensor limit.

3 Forecasting kernel

Discrete Event System (DES) and Machine Learning [2]



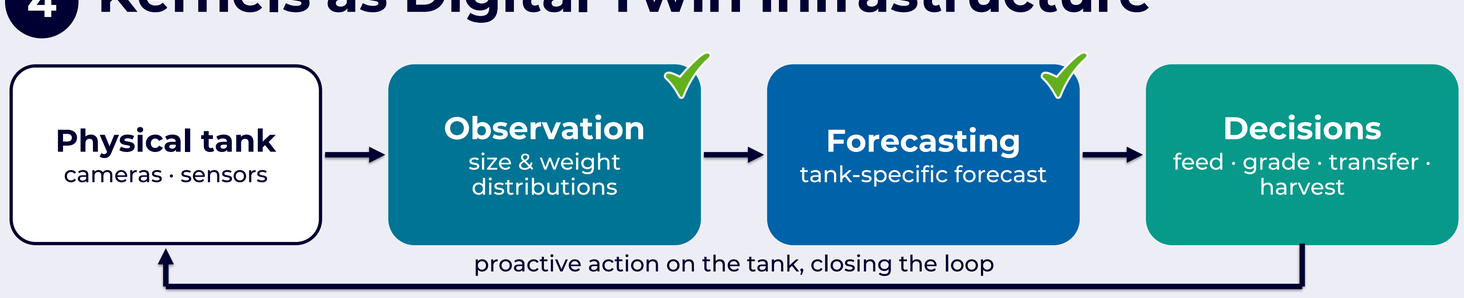
Production cycle, feed–fish–water model, and DES-to-ML methodology [2].

- **DES** simulates individual feed intake, growth, dominance, and metabolism, plus water chemistry.
- **Random Forest surrogates,** trained on 11,029 simulated days, reproduce the DES outputs with $R^2 > 0.996$.
- **Tank-specific hyperparameters** are fitted to the sampled weight distributions.
- **Rapid what-if evaluation** of feeding, grading, and harvesting scenarios.

1.1%	8.1%	20,000×
final mean weight MAPE	final weight SD MAPE	RF model faster than the DES

Validated on 21 European seabass tanks from two feeding trials.

4 Kernels as Digital Twin infrastructure



Each kernel was validated independently; full autonomous integration is the next step.

5 Impact

≈6%	Welfare
estimated economic gain	no handling for routine biomass sampling
Footprint	**SDG 12 · 14**
lower environmental impact	responsible production; life below water

Conclusion Non-invasive, population-level state estimation linked to tank-specific predictive modeling provides both computational kernels of a Precision Fish Farming Digital Twin, supporting proactive feeding, grading, transfer, and harvest decisions.

[1] L.C. Navarro et al. High-accuracy, non-invasive fish biometrics via above-water stereo vision for biomass and weight dispersion estimation. Computers and Electronics in Agriculture, under review (2026).
[2] L.C. Navarro et al. Predicting weight dispersion in seabass aquaculture using Discrete Event System simulation and Machine Learning modeling. Aquaculture Reports 38 (2024) 102315. https/doi.org/10.1016/j.aqrep.2024.102315

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