Progress Report: Fish Metrics Estimation Pipeline

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1 Project Overview

The goal of this project is to develop an end-to-end AI-based pipeline that can detect individual fish in video footage, estimate their length and weight, and eventually provide insights into their behavior and freshness post-harvest. The project adopts a modular development methodology, leveraging object detection models, computer vision, and regression techniques, with future provisions for integrating object tracking and visual freshness assessment.

2 Timeline of Development

May 1, 2025 – Initial Planning and Literature Review

- Outlined the key deliverables: Length Estimation, Weight Estimation, Behavior Analysis, Freshness Prediction.
- Decided on a modular and incremental development strategy.
- Conducted an extensive literature review of prior approaches in:
  - Vision-based fish detection and measurement
  - Regression models for weight estimation
  - Visual cues for freshness classification

May 17, 2025 – Stage 1: Fish Detection with YOLO Models

- Annotated fish in video frames using RoboFlow.
- Trained YOLOv12s and YOLOv8 object detection models for single-species detection (White Leg Shrimp).
- Incorporated basic pre-processing, augmentation, and validation workflows.

Model Performance Comparison:

Model	mAP@50	Precision	Recall
YOLOv12	82.6%	77.1%	83.8%
YOLOv8	79.4%	74.0%	85.6%

Table 1: Detection Model Evaluation

May 28, 2025 – Initial Length Estimation Logic

- Developed ArUco marker-based length estimation to convert bounding box sizes to real-world metrics.
- Performance issues noted due to:
  - Poor lighting and video clarity
  - Tank wall reflections and motion blur
- Recommended hardware improvements: stable camera mount, black tank background, uniform lighting.

June 10, 2025 – Automated Dataset Generation and Regression Trials

- Attempted automated fish frame collection via motion detection and YOLO inference.
- Data quality remained a bottleneck:
  - Tank reflections affected ArUco detection
  - Frame skipping occasionally led to lost detections
  - Tracking logic was not yet integrated
- Created initial dataset correlating measured lengths to provided weights.
- Trained linear and polynomial regression models.

Weight Estimation Models

- **Linear Regression (Degree 1):**

$$\text{Weight} = 1.072 \cdot \text{Length} - 0.031 \cdot \text{Width} + 0.0026$$

  $\text{MSE} = 0.00083, \quad R^2 = 0.99926$

- **Polynomial Regression (Degree 2):**

$$\text{Weight} = 0.0129 + 1.0643 \cdot \text{Length} + 0.00008 \cdot \text{Length}^2$$

  $\text{MSE} = 0.00085, \quad R^2 = 0.99925$

June 30, 2025 – Model Integration and Pipeline Finalization

- Integrated all components into `FishEstimatorWithWeight_Modified.py`:
  - Object detection
  - ArUco marker-based length scaling
  - Weight estimation using polynomial regression
- Added compression pipeline: frame skipping, JPEG compression, CRF-controlled H.264 encoding.
- Annotated output with overlays: bounding boxes, dimensions, weights, and summary statistics.
- Validation was hindered due to cascading inaccuracies in detection and scaling.

3 Proposed Workflow and Recommendations

1. Fish Detection

- Upgrade video capture to use stable, mounted cameras and uniform lighting.
- Continue training with YOLOv12 or explore anchor-free detectors like RT-DETR.

2. Length and Width Estimation

- Replace bounding box heuristics with keypoint-based skeletal or contour detection.
- Improve ArUco marker placement and visibility.

3. Weight Estimation

- Collect a richer dataset with true weight labels.
- Incorporate multivariate regression (e.g., including fish girth or contour length).

4. Behavior Analysis (Planned)

- Use object tracking (SORT, ByteTrack) for persistent fish IDs.
- Extract temporal patterns and mobility clusters to infer stress, crowding, etc.

5. Freshness Prediction (Planned)

- Correlate visual signs (e.g., eye clouding, body stiffness) with known post-harvest timelines.
- Requires collection of controlled freshness-labeled video data.

4 Challenges and Risks

- **Low Video Quality:** Most severe bottleneck. Affects detection accuracy and ArUco visibility.
- **Lack of Tracking:** Frame-based estimates prevent aggregation or temporal analysis.
- **Training Data Quality:** RoboFlow auto-annotations need manual verification.
- **Storage Constraints:** Need centralized (preferably cloud) storage for datasets, logs, and model checkpoints.

5 Conclusion

Substantial progress has been made in the foundational stages of the Fish Metrics Estimation Pipeline. Despite limited video quality and annotation challenges, a complete MVP has been developed integrating detection, measurement, and regression-based estimation. Moving forward, integration of tracking, better input data, and behavior modeling will elevate the system from a per-frame pipeline to a full real-time analytics tool.

Additional Notes:

- Detailed implementation is documented in `Code_Report.pdf`
- Source code and checkpoints are housed in the `Build/`, `Detection-Model-Training/`, and `Weight-Estimation-LR_model/` directories.
- Future project extensions can directly plug into the modular pipeline architecture established here.