Predicting Daily Milk Yield in Dairy Cattle Using Multi-View Behavioral Recognition and Visual Identification

María Alejandra Galicia Almaraz[1], Timilehin Ayanlade[2] and Soumik Sarkar[2]

1. Instituto Tecnológico Autónomo de México, Ciudad de México, México.
2. Iowa State University, Iowa, USA.

Background

Modern dairy farms face the dual challenge of increasing milk production while ensuring animal welfare and environmental sustainability.

Monitoring cow behavior is a key strategy for early detection of productivity-impacting health issues and understanding productivity drivers (Chun-hua et al., 2019).

Current monitoring systems often rely on wearable sensors, which, while effective, are costly, labor-intensive, and difficult to scale.

These limitations have driven interest in non-invasive alternatives capable of tracking behavior and welfare indicators across multiple animals simultaneously.

Objectives

- To develop a non-invasive computer vision system capable of detecting, classifying, and identifying individual cows from multi-view images for comprehensive daily behavior analysis.
- To accurately predict milk yield based on behavioral and environmental data.

Methodology

Dataset

MmCows, an open-source, large-scale multimodal repository comprising 15 days of video footage from 16 dairy cows (Vu H. et al., 2024).

Two experimental settings were considered:

- Phase 1: Single-view images from one camera, extracted every 100 seconds.
- Phase 2: Composite frames integrating four synchronized cameras arranged in a 2×2 grid, with one image extracted every 3 seconds (capturing ~45 seconds of real time).

Image Processing

Each frame was analyzed through a three-stage vision pipeline:

1. **Cow Detection – YOLOv8**

- Identifies all visible cows in each frame.
- Generates bounding boxes (see Fig.1 and Fig.2) and detection confidence scores.

Fig1. Detection example – Phase 1

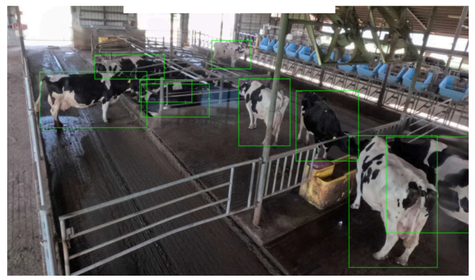
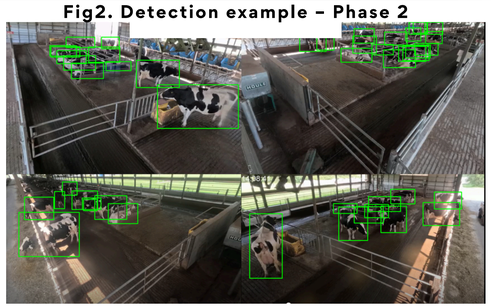


Fig2. Detection example – Phase 2



2.Behavior Classification – ResNet18

- Receives cropped images of each detected cow.
- Classifies behavior into one of seven categories:

0: Walking, 1: Standing, 2: Feeding (head up), 3: Feeding (head down), 4: Licking, 5: Drinking, 6: Lying

3.Individual Identification – EfficientNet (Dual Models)

- Two models were trained: one for lying cows and one for active cows.
- Each predicts the unique ID (cow_id) of the animal (see Fig. 3 and Fig. 4).
- Only high-confidence predictions (≥ 0.60) were retained; others were labeled as unknown (cow_id = -1).

Fig 3. Identification without filtering - Phase 1

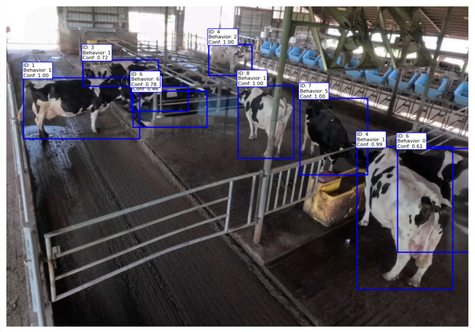
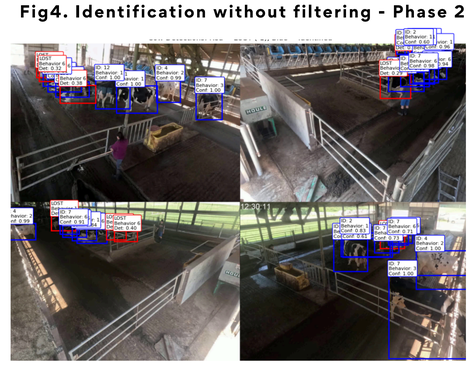


Fig4. Identification without filtering - Phase 2



Behavior Aggregation and Predictive Modeling

- For each image, the cow_id, behavior_id, confidence score, source of detection (direct, reassigned, unknown), and timestamp were recorded.
- Daily behavior data were aggregated and normalized per cow.
- Three experimental scenarios were tested to predict milk yield using Random Forest and XGBoost regressors:
  1. Behavioral data only
  2. Behavior + previous-day milk yield
  3. Behavior + previous-day milk yield + environmental variables (temperature, humidity, THI)

Results & Conclusions

Table 1. Phase 1 – RF & XGBoost

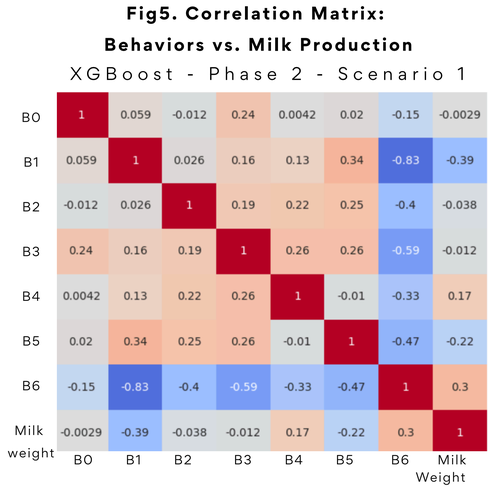
	Random Forest			XGBoost		
Scenarios	1	2	3	1	2	3
MSE	33.66	6.96	6.64	34.74	8.53	8.93
R^2	0.16	0.78	0.79	0.13	0.73	0.72

Table 2. Phase 2 – RF & XGBoost

	Random Forest			XGBoost		
Scenarios	1	2	3	1	2	3
MSE	20.45	7.7	8.55	17.06	12.73	8.68
R^2	0.38	0.75	0.75	0.48	0.64	0.73

- Incorporating previous-day milk yield markedly improved prediction accuracy, especially in the Scenario 3 in Phase 1 with Random Forest (see Table 1 and Table 2).
- Adding weather variables provided moderate gains.

Fig5. Correlation Matrix: Behaviors vs. Milk Production



- Lying behavior was among the most predictive for milk yield, supporting previous research.
- However, lying cows were the hardest to identify in single-view images, reducing their impact in Phase 1 models.
- Multi-view imaging with smart reassignment improved cow ID accuracy and model robustness, which shows the importance of reliable identification for behavior-based prediction.
- This study supports the potential of non-invasive, computer vision-based monitoring systems to inform more precise and welfare-oriented dairy management. Nonetheless, improving cow re-identification accuracy remains a key area for future research and development.

References

Vu, H., Prabhune, O., Raskar, U., Panditharatne, D., Chung, H., Choi, C., & Kim, Y. (2024). MmCows: A multimodal dataset for dairy cattle monitoring. Advances in Neural Information Processing Systems (NeurIPS) Track on Datasets and Benchmarks.

Chun-hua, S., Jian-jun, G., Xin-sheng, S., Xin-yu, Y., Juan-juan, Z., Chao, W., Dian-rui, Q., Ya-nan, W., Man, F., & Yu-hong, G. (2019). Correlation between behavior and milk yield of dairy cows. International Journal of Agriculture and Biology, *21*(1), 93–98. https://doi.org/10.17957/IJAB/15.0867