Damaging Behavior Prediction in Precision Livestock Farming Using Multi-Sensor Data

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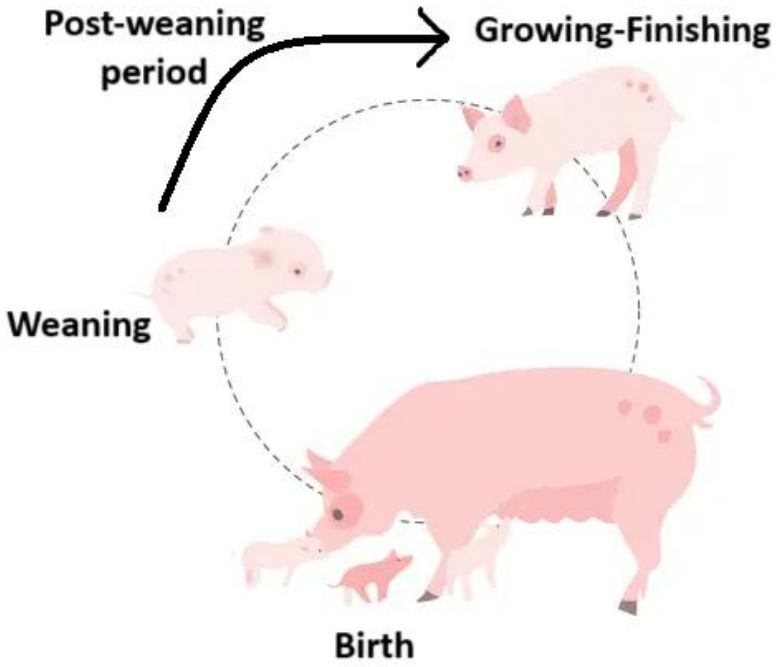
Current pig farming and its challenges

- **Challenges:** Physiological and environmental stressors that impact the health, welfare, and productivity of pigs.
    - Physiological: Nutritional stress, growth demands, etc.
    - Environmental: Climate control issues, overcrowding, etc.

Post-weaning phase

- The post-weaning phase is a critical period when piglets transition from mother's milk to solid food.



- Challenges include:
  - Nutritional stress
  - Social stress
  - Exposure to new pathogens

From stressors to welfare

Precision Livestock Farming

Biting behavior, such as tail or ear biting, is complex and influenced by multiple factors

Environmental sensors track ammonia, temperature, humidity, and CO2.

Precision Livestock Farming (PLF) uses sensors for real-time monitoring.

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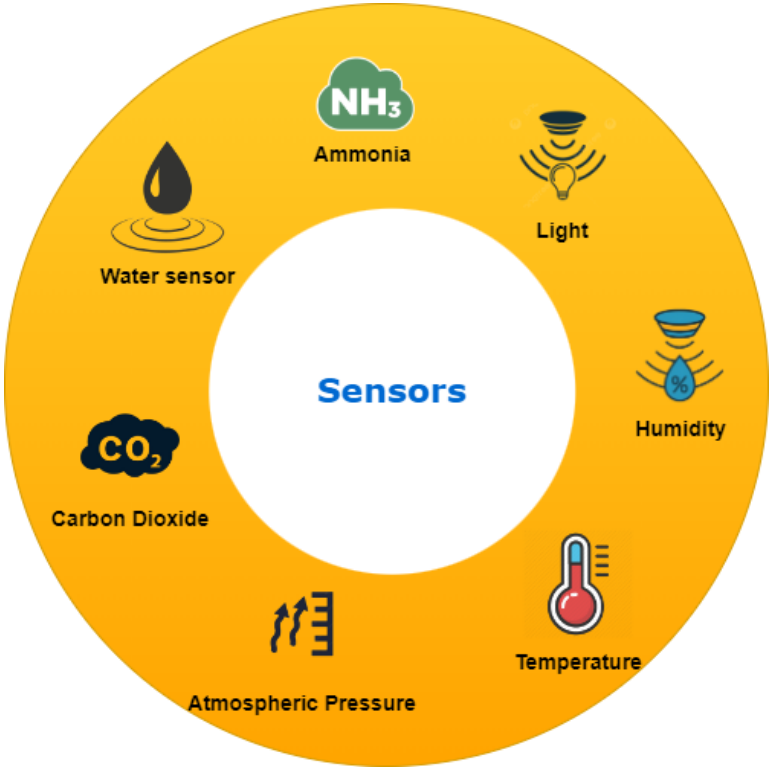
Utilizing Environmental Sensors

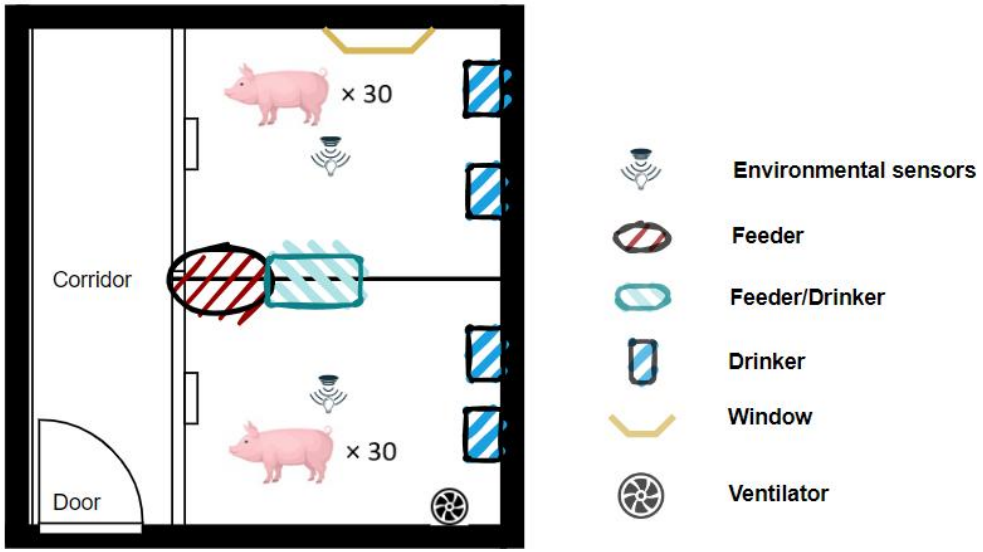
- Objective: Detect conditions that could lead to biting incidents.

- Early Warning System: Combine sensor data to alert farmers to potential risks.



Experimental Methodology

- **Study Context:** Conducted on a commercial pig farm in the Netherlands.
- **Setup:** 7 production cycles, 84 pens,
  - Each pen housing 30 piglets, in total 2520 piglets,
  - We monitored from post-weaning to ~25 kg.
- **Sensors Deployed:** Monitored environmental conditions on pen level



Layout of one room with two pens

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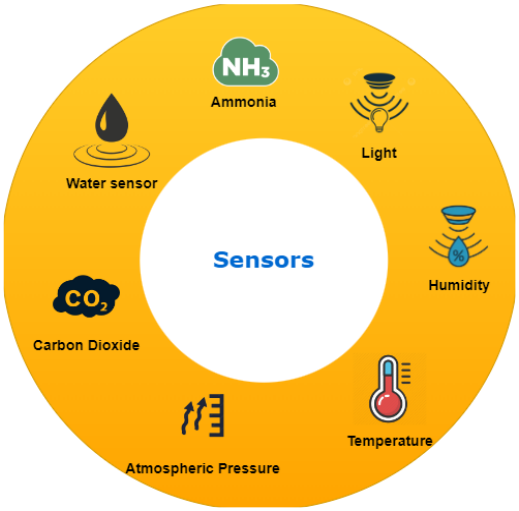
Raw Data Overview



Environmental Data: Continuous data collection on NH3, CO2, atmospheric pressure, temperature, humidity, light, and water intake.

Manual Data Collection: observations on tail and ear biting, used as gold standards for evaluating the early warning system.

Data Preparation & Labelling

- **Criteria for abnormal period if:**
  - >= 10% of piglets in the pen show damage
  - And >= 6% increase since last measurement

Target of early warning system = detecting Pre-abnormal period

Feature Engineering

- Extracting Key Features from Environmental Data

  Exposure time to:
  - Ammonia (NH3) Exposure (threshold: 20 ppm)
  - CO2 Levels (threshold: 3000 ppm)
  - Temperature Tracking (threshold: 31˚C)
  - Temperature-Humidity index (threshold 74)

Data Description

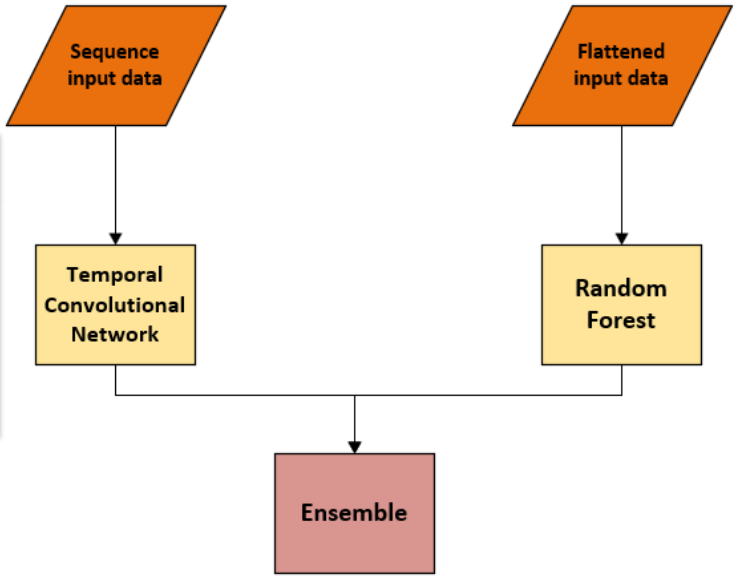
- **Sensors**: We used 13 features, including:
  - CO_2, NH_3, temperature, humidity, light, water intake, THI, exposure time to high levels of environmental factors etc.
- **Resolution**: Each day has 144 time points (e.g., 10-min intervals).
- **Pen-level data**: 84 pens from 7 rounds of data collection (2520 pigs).
- **Labels**:
  - 0 = normal
  - 1 = pre-abnormal / transition
- **Approach**: Binary classification between 0 (normal) and 1 (transition).

Prediction target: The pre-abnormal (transition) period — critical for early intervention.

Model Architecture

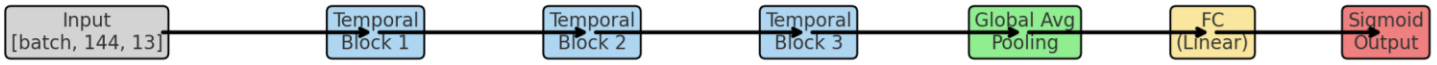
- **Hybrid Model: Temporal Convolutional Network (TCN) + Random Forest (RF) Ensemble**

Component	Role
TCN	Captures temporal dependencies
RF	Captures feature-level interactions
Ensemble	Combines both for improved performance



Temporal Convolutional Network (TCN)

- **Input**: Sequences of shape (144 time steps × 13 features)
- **Layers**:
  - Stacked Temporal Blocks with:
    - Dilated Conv1D layers (causal)
    - BatchNorm + ReLU + Dropout
    - Residual connections
  - Global Average Pooling
  - Final Linear layer → Output logit



Random Forest + Ensembling

RF input: Flattened features (144 * 13)

Ensemble:

- Average prediction from TCN and RF
- Final probability:

$$P_{final} = \frac{P_{TCN} + P_{RF}}{2}$$

Reason: Combines sequence-level and aggregate-level insights

Evaluation Strategy and Results

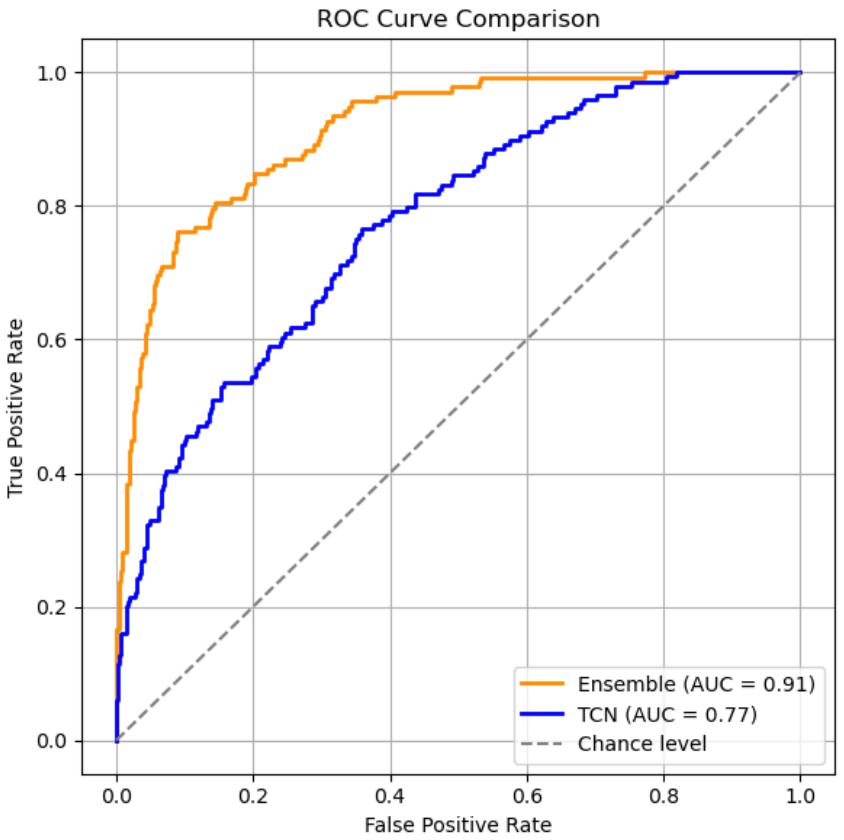
Cross-Validation:

- 5-fold stratified K-Fold for generalization

Loss Function:

- $BCEWithLogitsLoss$ with class weight to address imbalance

	TCN	Ensembled TCN + RF
Accuracy	0.65	0.855
F1 score	0.60	0.708
ROC AUC	0.77	0.911



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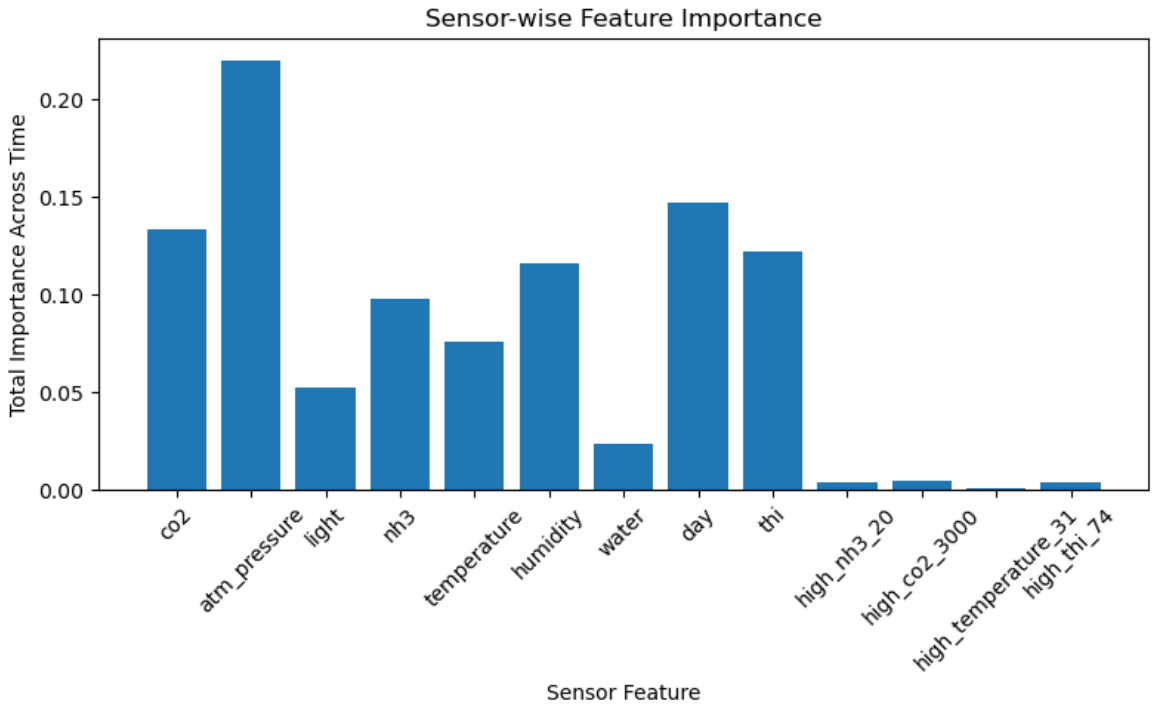
Feature Importance

- Random forest provides interpretable feature importances
- Highlights which sensor metrics contributed most to predicting transitions
- Atmospheric pressure, CO2, day of experiment and Temperature-humidity index were the most effective environmental factors



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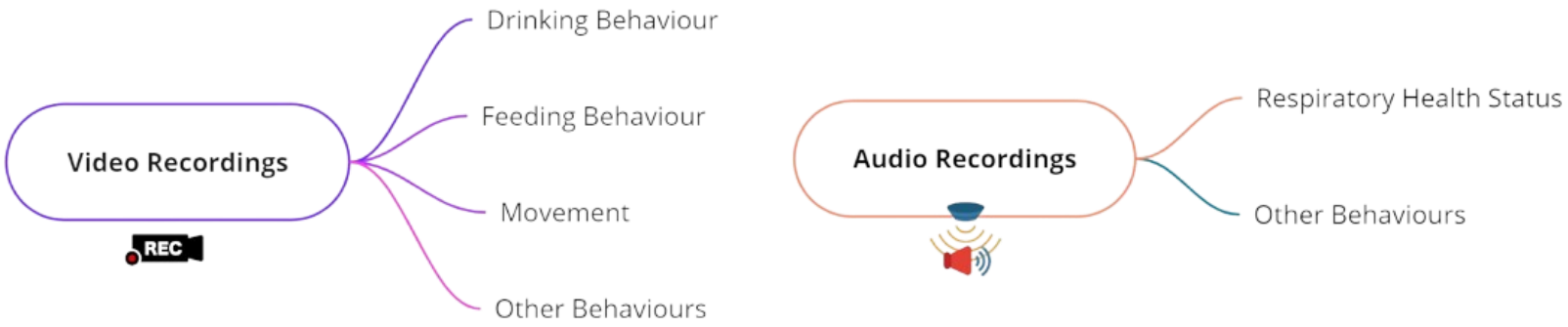
Key Insights

- **Environmental factors** alone may not be sufficient to predict biting behavior.
- We considered temporal-only features.
- There are still false negative predictions.

- These findings highlight the importance of **incorporating diverse** data sources.
- **Future analyses** will focus on adding behavioral data, from other sensors:
    - Video recordings
    - Respiratory health (coughing) sensors from SoundTalks

Next Steps

- Expand the dataset by including additional production cycles.
- Adding activity of the pens using optical flow methods
- Focus on collecting individual-level data using RFID tags, moving beyond group-level data.
- Integrate more behavioral data alongside environmental data.



- **Long-Term Goal:**
  - Implement the early warning system on a broader scale to enhance its practical utility in commercial pig farming.

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Conclusion

- Early detection of damaging behavior is critical for pig welfare.
- Environmental sensor data can predict pre-abnormal periods.
- Hybrid TCN + Random Forest model showed strong performance.
- CO_2, THI, and pressure were key predictors.
- Future work: integrate behavioral and individual-level data.
- Goal: a practical, real-time early warning system for farms.

Questions and Discussion

Thank you for your attention

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Conclusion

- **Enhancing Resilience**: Critical to improving pig welfare, especially in modern farming environments.
- **Sensor Fusion**: Offers a promising solution for developing effective early warning systems.
- **Ongoing Research**: Focused on refining predictive models, integrating diverse data sources, and enhancing accuracy to support better decision-making.

Model Architecture

- **Architecture**:
  - Several 1D convolution layers with dilation
  - Dropout + ReLU + residual connections
  - Final linear layer for binary output (sigmoid)

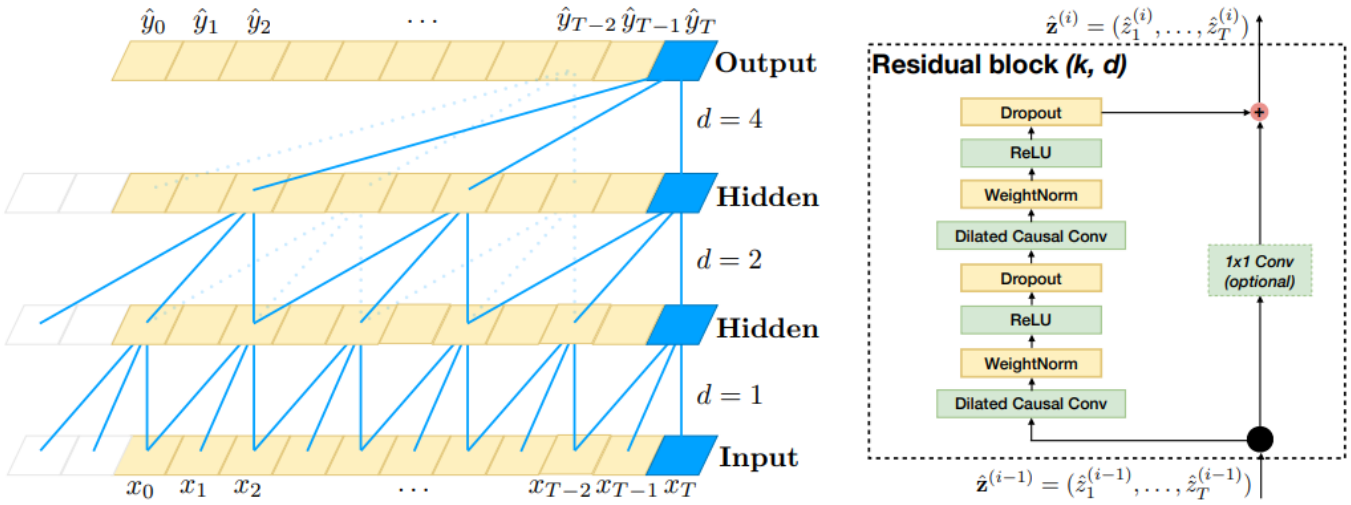

Figure from: Bai et al., An Empirical Evaluation of Generic Convolutional and Recurrent Networks for Sequence Modeling, 2018.

Complexity of Biting Behavior

Influenced by husbandry practices, diet, and environmental conditions.

Management strategies help, but not all challenges can be eradicated.

A comprehensive approach is necessary to address unpredictable factors.