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# Sensor prototype development for automated monitoring of integument damage of laying hens using artificial intelligence models

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# Background + Scientific problem

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- Monitoring welfare manually is time-consuming, highly subjective and stressful
- Automatic and contactless AI technologies are not available for laying hens due to various application constraints on real-farm conditions
- The majority of existing models have been developed under artificial settings
- **Therefore, the objective was to develop an AI-driven sensor prototype with a corresponding camera model that should be able to monitor specific indicators associated with integument damage of individual laying hens** → *Pilot study with proof of concept*



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# Material and Methods

- **Manual assessment**:conducted in a commercial (free range organic) laying hen farm in Mecklenburg-Western Pomerenia, Germany, 3000 hens per herd

- Data collection period > 30 weeks
- n = 50 hens randomly collected

- Parameters: Feather damage, skin injuries, inflammation

- Body areas: Comb, neck, back, tail, abdomen



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# Material and Methods

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**Scoring system using a four-level scale:**

**0** = no damage
**1** = moderate damage
**2** = distinct, major damage
**3** = severe damage

– derived from KTBL + MTool® (→ gold standard)

– useful for scientific experiments + herd management

**Manual assessment data had a crucial role in the conceptual prototype development:**

–Reference data for the AI-Model (→ ground truth data)

–Target positions for the camera model



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# Material and Methods


- **Placement** in the litter area (<20 Lux)
- **Steel ring** with access ramps on both sides
- **Central glass platform** serving as the recording area
- **Camera unit** consisting of full-HD USB Webcameras:
  - 2x Logitech Brio 300 + 2x Logitech c920s Pro
  - Automated script for recordings 7:30 am to 7:30 pm
- **Metal housing** protected the control and power management systems (→ Raspberry pi + SSD drive)
- **A mobile internet** connection enabled remote access for parameter and system adjustments



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# Main Results

Source: A.Gruen

**Score 0** – no visible damage

**Score 2** – major damage

**Score 3** – severe damage



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# Main Results (from manual assessment)

| Age of hens (weeks) | Damage type (%) | | |
|---|---|---|---|
| | Feather damage | Skin injuries | Inflammation |
| 70 | 58 | 8 | 17 |
| 75 | 53 | 12 | 9 |
| 80 | 46 | 18 | 9 |
| 90 | 42 | 19 | 11 |
| 95 | 55 | 22 | 12 |
| 100 | 53 | 23 | 12 |

- **Feather damage** was the main damage type during the assessment period

| Age of hens (weeks) | Number of affected hens with Score ≥1 | Score (%) | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 70 | 42 | 8 | 10 | 32 | 0 |
| 80 | 46 | 8 | 18 | 54 | 21 |
| 90 | 48 | 4 | 30 | 52 | 14 |
| 100 | 45 | 8 | 12 | 56 | 22 |

- The **abdomen** was identified amongst the most affected body parts



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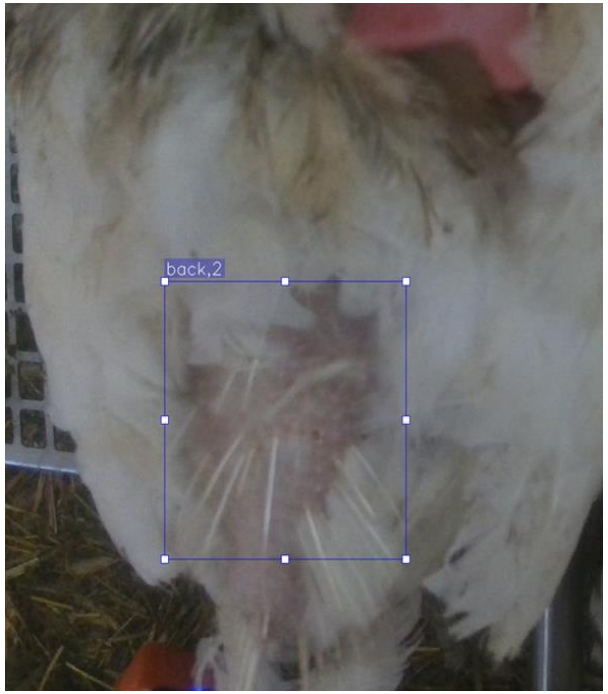
# Main Results

- Image collection from video recordings: **Topview** – neck to tail
- **Annotation with a customized tool**: [Body part] - [Damage type] – [Severity]

Source: A.Gruen


**Score 1** – minor visible damage




**Score 2** – major damage


**Score 3** – severe damage



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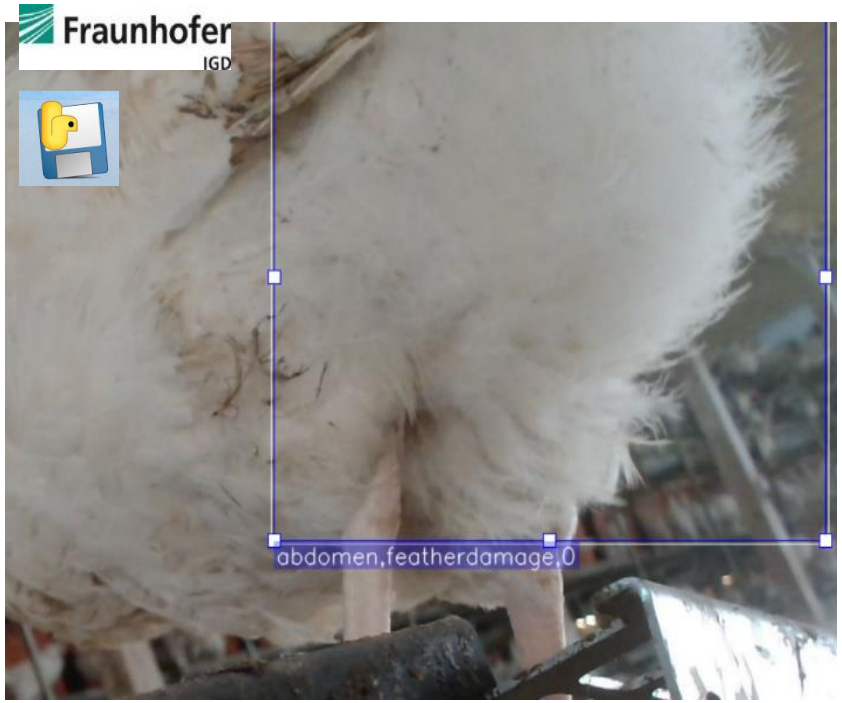
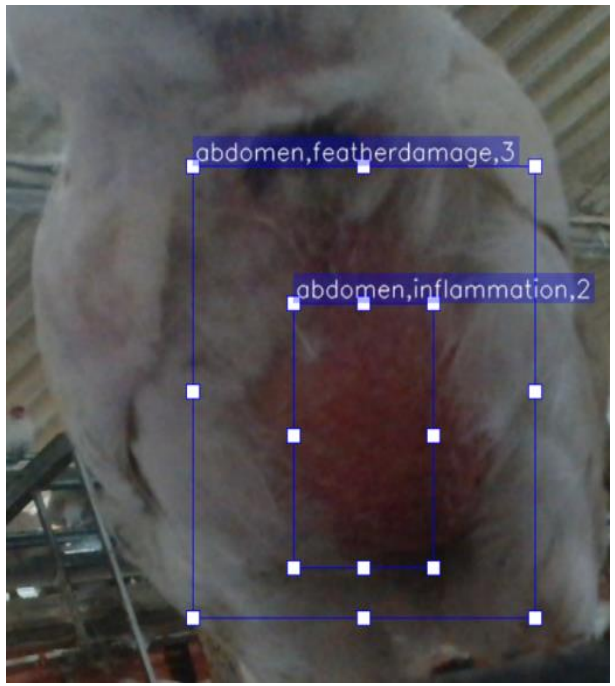
# Main Results

- Image collection from video recordings: **Sideview-** Abdomen
- **Annotation with a customized tool**: [Body part] - [Damage type] – [Severity]








Source: A.Gruen

**Score 0** – no visible damage

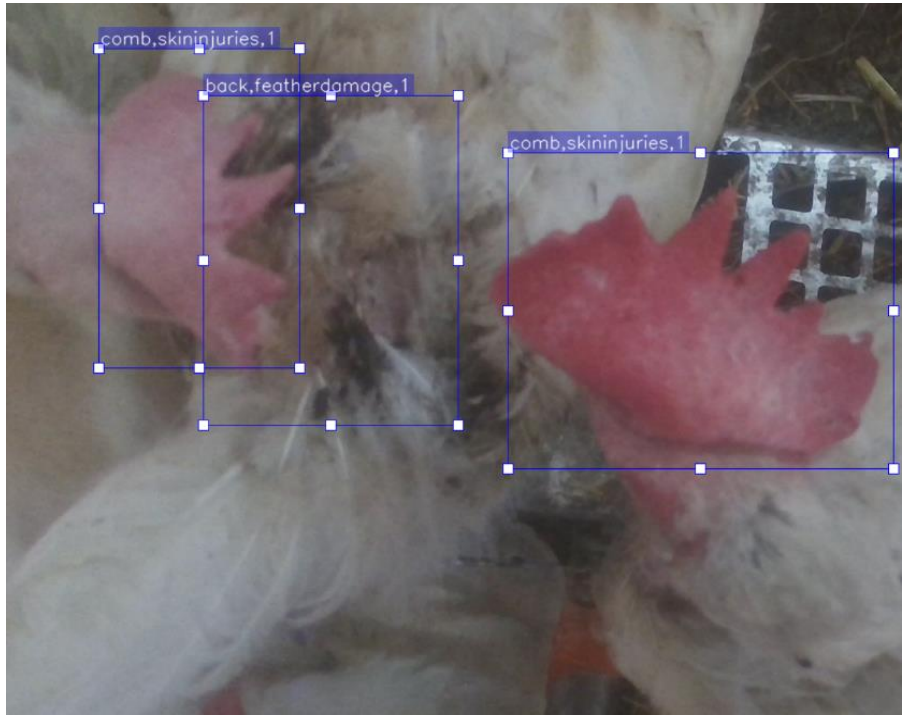
**Score 1** – minor visible damage

**Score 3** – major damage

# Main Results

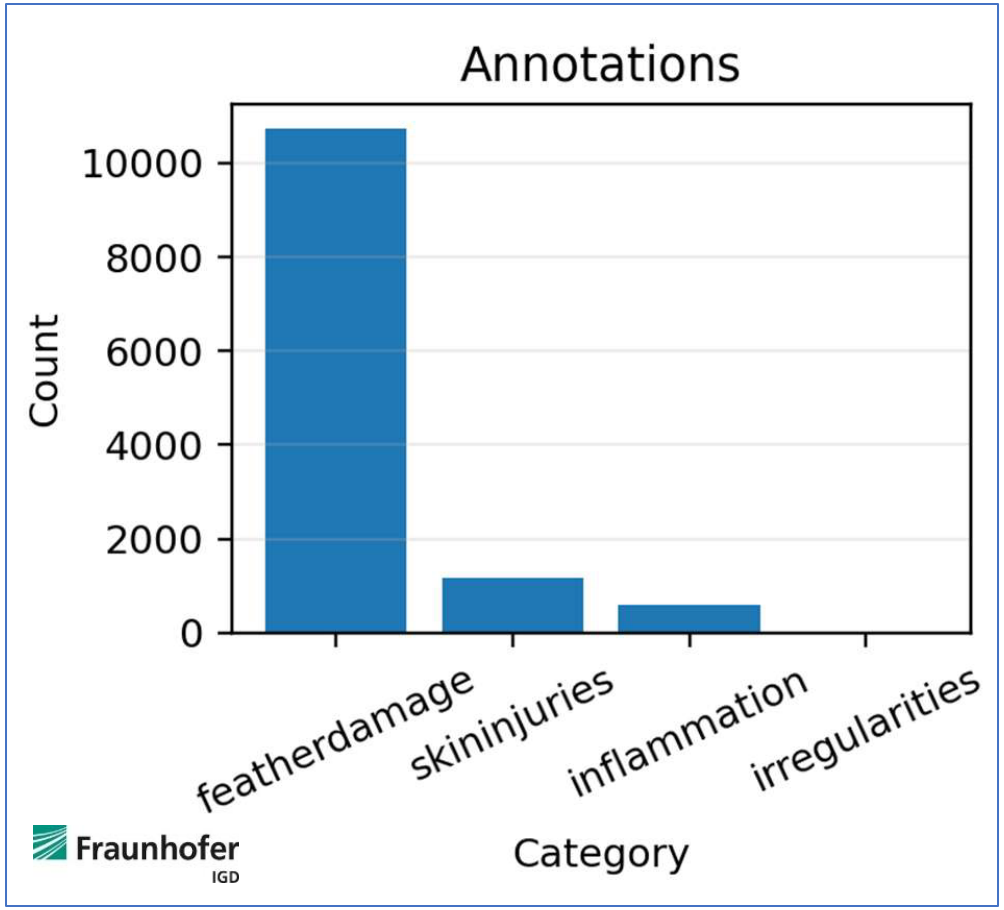
- The initial prototype was provided by Novu.track GmbH mainly used in commercial broiler farms
- The **new conceptual approach** led to major modifications for monitoring laying hens
- Hens used the prototype primarily for grooming and resting → **continuous, stress-free data collection**
- **570 videos** per day and per camera (.mp4)
- **Data annotation**: Customized tool
- **BBoxAnnotator:**

  [Damage type] – [Severity class] – [anatomic location]
- Next step: combining deep learning and large language models (LLM) within a Python-based interface



# Main Results

- Preliminary data analysis completed
- Total unique image/frames: 5.475
- Total non-zero annotations: 12.533
- Strongly imbalanced data set → Risk of bias:
  - Damage type: feather damage
  - Severity: score 2
  - Body part: tail
- Substantial variation in the visual scaling of the bounding boxes → use of multi-scale augmentation




- 1st approach: Binary Model [2: 0/1]
- Next step: Multiclass Model [4: 0-3]



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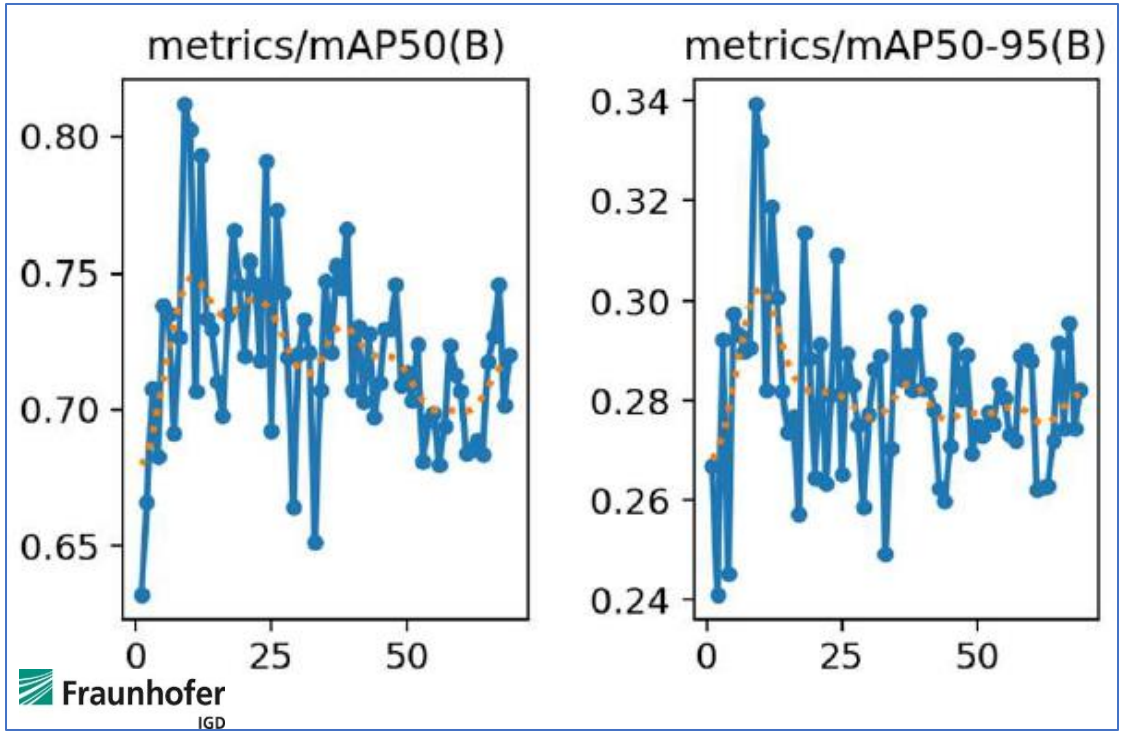
# Main Results

- Comparison of binary **feather damage performance** using four popular models (Ultralytics):
  - YOLO26n
  - YOLO11n
  - YOLO12n
  - RT-DETR-l

- **YOLO26n** appears to be the strongest performer

- **Best Metrics:**

| | |
|---|---|
| mAP50 | (0,812) |
| F1 | (0,776) |



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# Challenges

- **Modifying scoring criterias** for systematic annotation

- **Resolution and image quality**:
  - adequate for feather assessment → multiclass model
  - acceptable for comb and inflammated areas → binary model
  - insufficient for injury detection → technical boundry

- **Imbalanced dataset:**
  - Uneven representation across categories

- **Progression of damage:**
  - over a complete production cycle with a long timeline
  - Necessity for more studies during specific, critical time periods


# Discussion

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- Standards for AI-based individual animal identification are currently lacking (Ajibola et al. 2024) → this prototype could fill such a gap
- In contrast to the laboratory-based "*Stressed Chicken Score*" (Schlegel et al. 2024), the model allows data collection for pain and welfare related parameters in a typical barn environment.
- Some **integument-specific target markers**, particularly feather damage, could be assessed automatically in a real-farm environment as requested in a potential national animal welfare monitoring program
- A **differentiated assessment of damage patterns** is essential for taking targeted measures that potentially improve the welfare of the laying hens
- For flexible application in other breeds, age groups or housing environments, more training and validation is required → AI optimization



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# Conclusion

- Results confirmed the acceptance of the prototype
- Stress-free, contactless data collection was achievable
- Target positions for a camera model assessing welfare related indicators were determined
- Classification parameters for image analysis could be established
- The model enabled data analysis for a commercial real-farm environment
- However, it needs further AI-optimization particularly due to imbalanced data sets
- Manufacturing a new prototype will be the next intertwining step including an early warning system with a user-friendly interface for end-users

# Acknowlegements and Contacts

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Collaboration Partners:

Novu.track GmbH

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- **YOLOv12**

Tian, Y., Ye, Q., & Doermann, D. (2025). *YOLOv12: Attention-Centric Real-Time Object Detectors*. arXiv:2502.12524.

- **YOLO26**

Jocher, G., Qiu, J., Liu, M., Lyu, S., Akyon, F. C., & Kalfaoglu, M. E. (2026). *Ultralytics YOLO26: Unified Real-Time End-to-End Vision Models*. arXiv:2606.03748.

- **RT-DETR-L**

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# Additional Material

| Manual assessment: | SUM* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age (in weeks) | **70** | **75** | **80** | **85** | **90** | **95** | **100** | **101** |
| Anatomical target areas | 15.10.2025 | 21.11.2025 | 18.12.2025 | 28.02.2026 | 04.03.2026 | 08.04.2026 | 13.05.2026 | 20.05.2026 |
| **Feather damage** | | | | | | | | |
| Neck | 40 | 50 | 51 | n.e. | 40 | 50 | 45 | 53 |
| Back | 75 | 84 | 101 | n.e. | 78 | 90 | 101 | 104 |
| Tail | 78 | 85 | 90 | n.e. | 77 | 82 | 98 | 99 |
| Abdomen | 74 | 85 | 93 | n.e. | 88 | 105 | 88 | 96 |
| **Skin injuries** | | | | | | | | |
| Comb | n.e. | n.e. | n.e. | n.e. | n.e. | 100 | 88 | 93 |
| Neck | 2 | 2 | 7 | n.e. | 7 | 1 | n.e. | n.e. |
| Back | 13 | 33 | 52 | n.e. | 40 | 31 | 45 | 44 |
| Tail | 8 | 13 | 34 | n.e. | 38 | 24 | 16 | 21 |
| Abdomen | 12 | 20 | 38 | n.e. | 41 | 26 | 15 | 32 |
| **Inflammation** | | | | | | | | |
| Back | 6 | 0 | 1 | n.e. | 2 | 0 | 7 | 8 |
| Tail | 13 | 6 | 9 | n.e. | 17 | 11 | 30 | 35 |
| Abdomen | 57 | 43 | 57 | n.e. | 58 | 51 | 54 | 58 |

- n = 50 laying hens
- Score of all hens are summarized for each assessment day
- Max. $\Sigma$ for each indicator= 150



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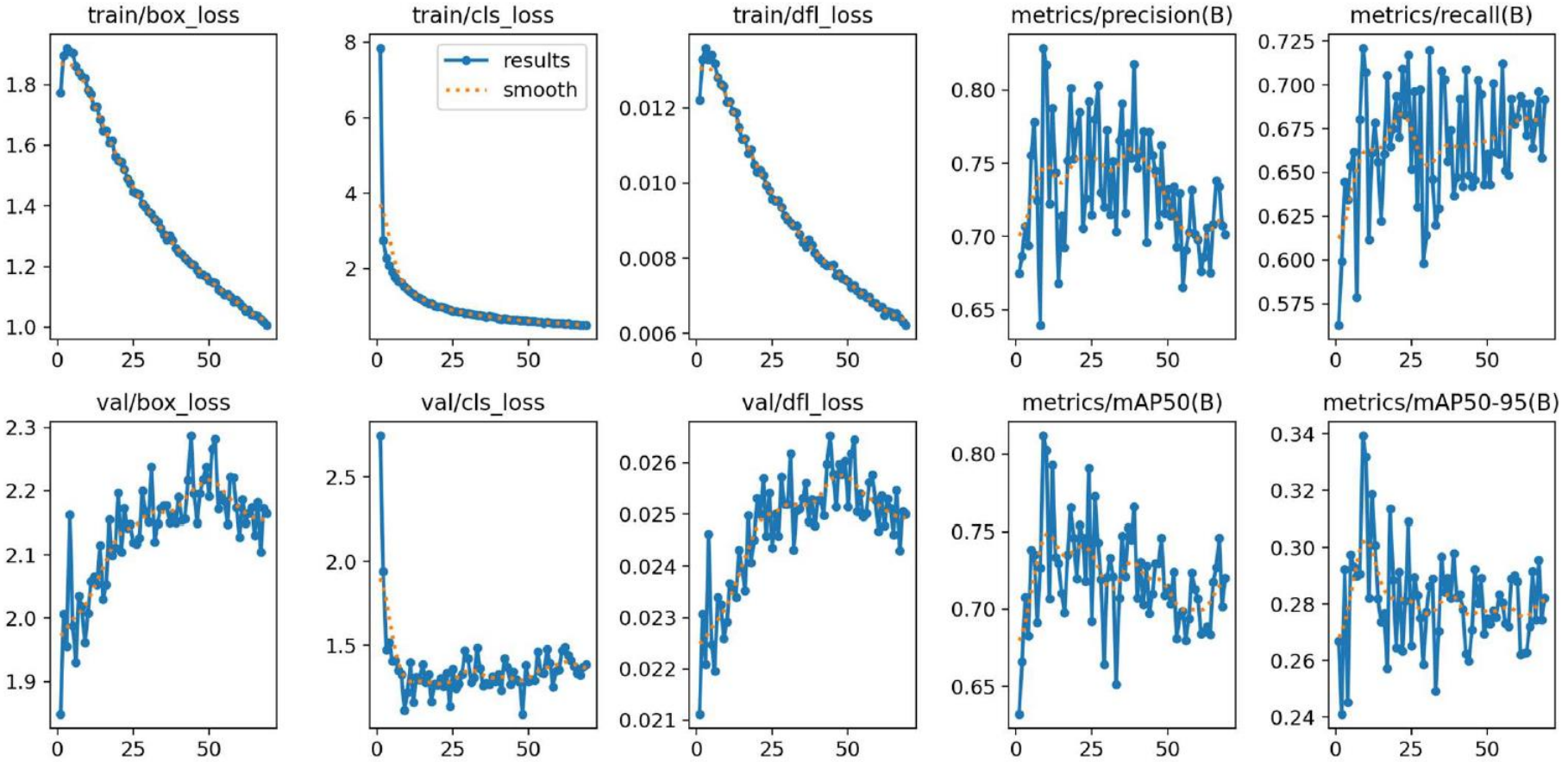
# Additional Material




- Preliminary metrics for the first binary model for feather damage