Wildlife Species Detection using Night-Vision Camera Trap Media

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1. Abstract

Accurate identification of wildlife species is essential for ecological monitoring, particularly when using night-vision camera traps. These images often suffer from poor illumination and motion blur, making manual species classification challenging. In this study, we developed deep learning models using the YOLO (You Only Look Once) object detection framework to detect and classify six animal species from night-vision images.
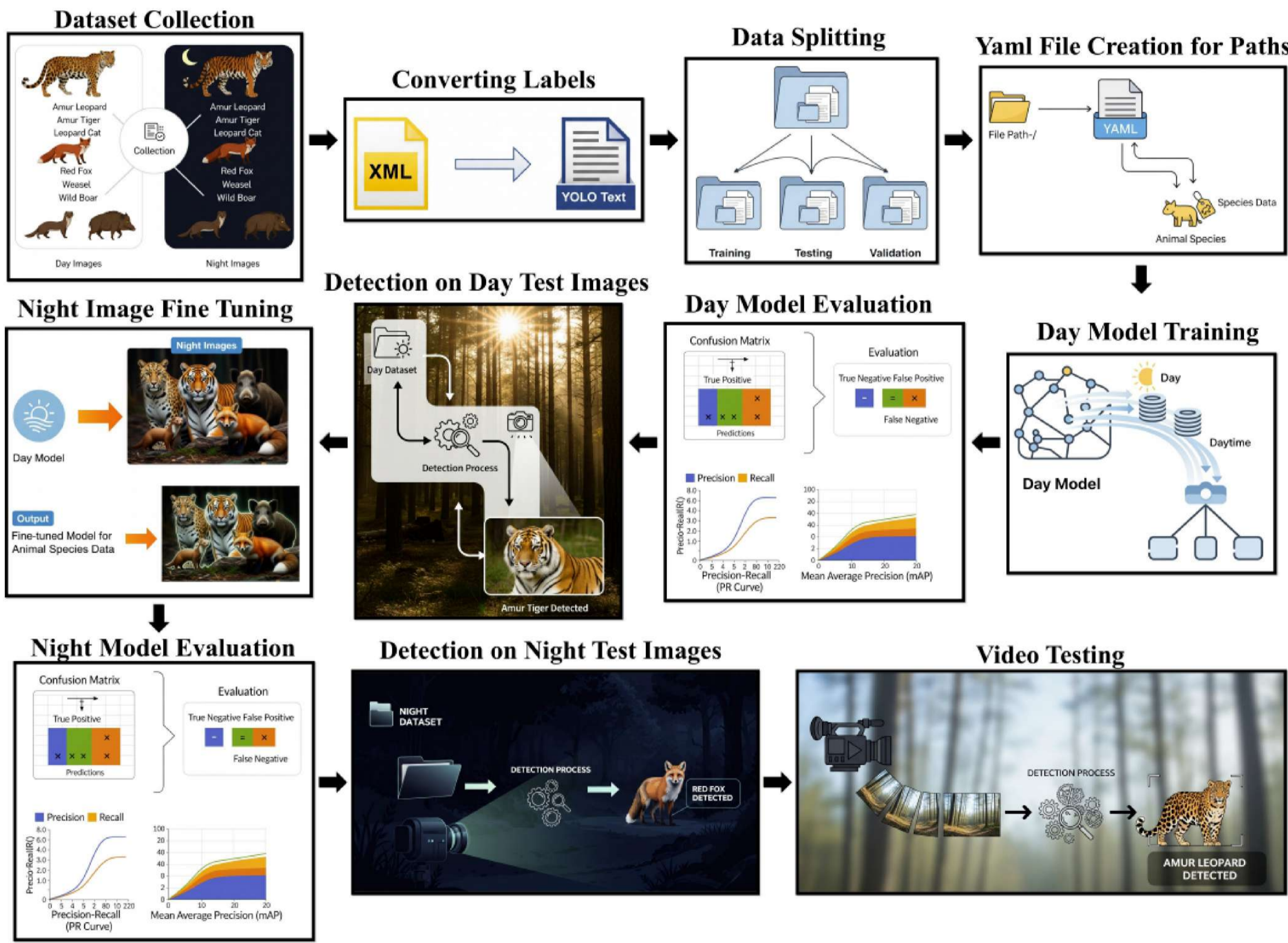
We evaluated two models, YOLOv11 and YOLOv12, and found that while both performed similarly in terms of confusion matrices and precision-recall curves, YOLOv11 achieved a better balance of precision (0.972), recall (0.971), mAP@0.5 (0.989), and mAP@0.5:0.95 (0.852). YOLOv11 showed more reliable performance during real-world inference, making it a consistent and robust choice for wildlife monitoring in low-light environments.

2. Dataset

The dataset consists of 4,200 day images and 3,000 night-vision camera trap images and video frames, evenly distributed across six species: Amur Leopard, Amur Tiger, Leopard Cat, Red Fox, Weasel, and Wild Boar. All images include bounding box annotations and represent challenging conditions such as low light, motion blur, and camouflage. For each species, the data was equally split into training (70%), validation (15%), and testing (15%) sets to ensure balanced learning and generalization.

3. Methodology

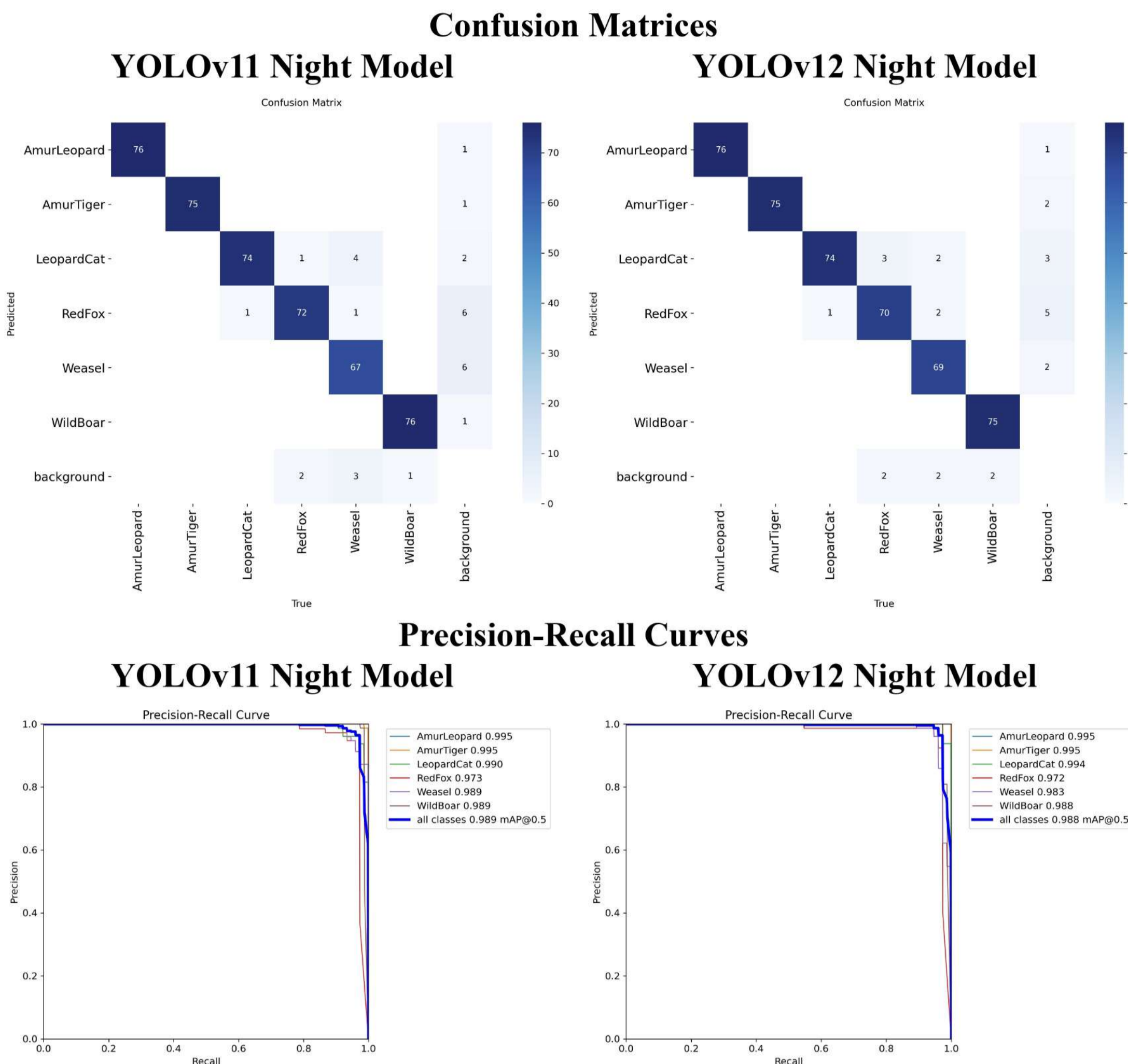Below is a detailed breakdown of the workflow followed during the project:

- **Dataset Preparation:** Collected day and night species images with annotations; converted XML labels to YOLO TXT format.
- **Data Split:** Splitted the dataset into train, validation, and test sets for each species, ensuring balanced representation across classes.
- **Config Setup:** Created YAML files defining paths, classes, and labels for training.
- **Day Model:** Trained YOLOv11 and YOLOv12 on day images; evaluated and tested on separate day data.
- **Night Fine-Tuning:** Fine-tuned the day model on night images; evaluated and tested on night data.
- **Video Inference:** Tested final model on wildlife videos to simulate real-world detection.

4. Night Model Evaluation Metrics

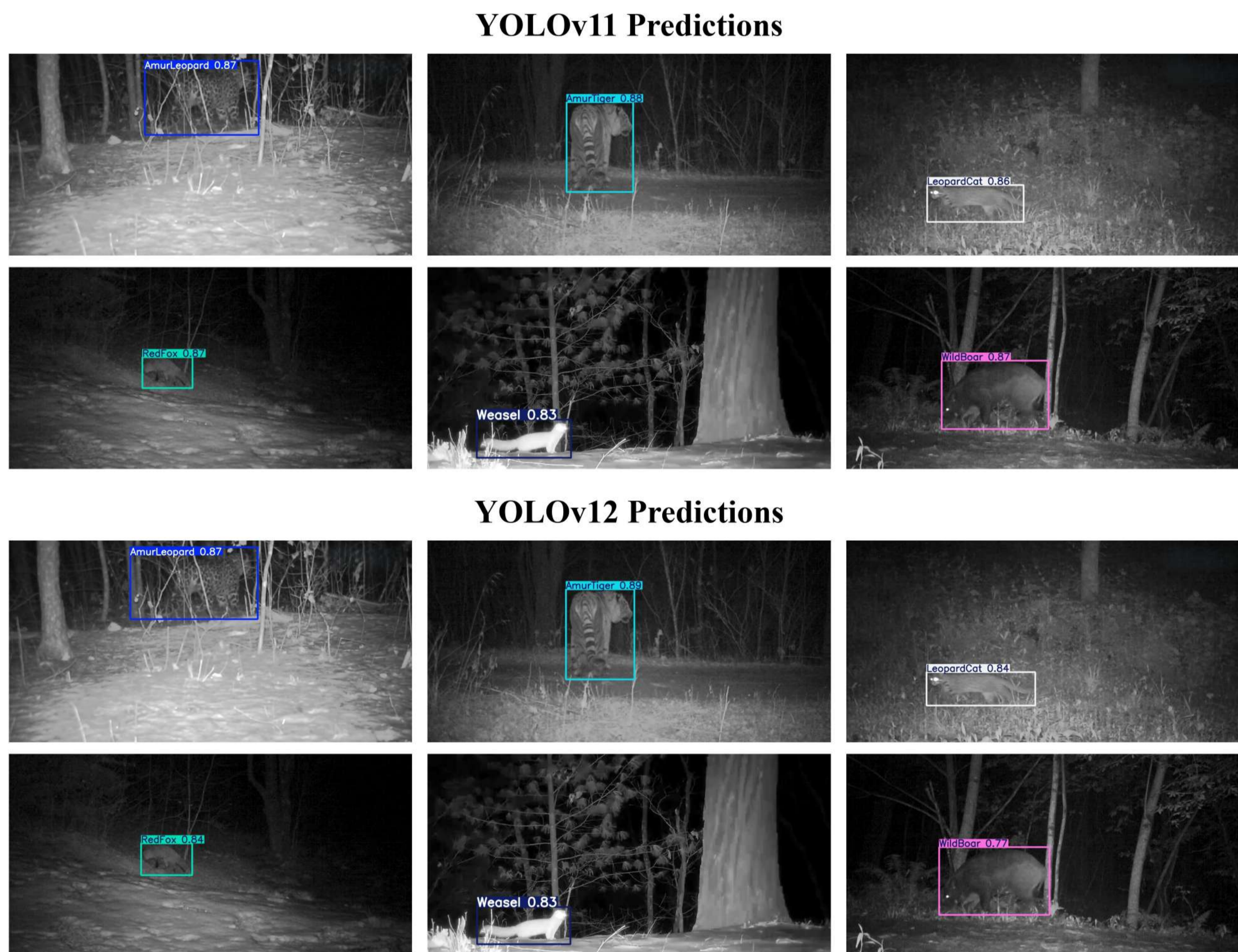| Species	YOLOv11				YOLOv12			
	Precision	Recall	mAP@0.5	mAP@0.5:0.95	Precision	Recall	mAP@0.5	mAP@0.5:0.95
All	0.972	0.971	0.989	0.852	0.990	0.962	0.988	0.854
Amur Leopard	0.985	1.000	0.995	0.883	0.993	1.000	0.995	0.886
Amur Tiger	0.984	1.000	0.995	0.881	0.998	1.000	0.995	0.891
Leopard Cat	0.936	0.978	0.990	0.864	0.977	0.973	0.994	0.879
Red Fox	0.932	0.960	0.973	0.817	0.986	0.942	0.972	0.797
Weasel	0.996	0.920	0.989	0.801	0.985	0.897	0.983	0.794
Wild Boar	1.000	0.970	0.989	0.865	1.000	0.963	0.988	0.879

Both YOLOv11 and YOLOv12 show similar overall performance in evaluation metrics. YOLOv12 has slightly higher precision and mAP@0.5:0.95, while YOLOv11 achieves better recall and a marginally higher mAP@0.5. YOLOv11 also maintains more balanced performance across species, highlighting its consistency.

5. Night Model Performance Graphs

Both YOLOv11 and YOLOv12 Night Models show comparable performance. While YOLOv12 achieves slightly fewer misclassifications in some categories, YOLOv11 maintains a well-balanced and consistent classification across all species. Overall, YOLOv11 demonstrates slightly more stable performance, making it a strong and reliable model for night-time species detection.

6. Results on Test Images

YOLOv11 matches or outperforms YOLOv12 in identifying most of the six species with a better confidence score. While both models perform equally well for Amur Leopard and Weasel, and YOLOv12 slightly edges ahead for Amur Tiger, YOLOv11 shows higher confidence for Leopard Cat, Red Fox, and Wild Boar. Overall, YOLOv11 demonstrates more consistent and reliable performance, making it the preferred choice for wildlife species identification.

7. Conclusion

- YOLOv11 and YOLOv12 show similar overall performance, but YOLOv11 achieves more balanced precision, recall, and mAP across all species.
- YOLOv11 demonstrates stronger consistency and robustness under night-time conditions and real-world test images.
- It also performs more reliably in video inference, detecting all species correctly, making YOLOv11 the preferred choice for wildlife identification.

8. Future Work

- Incorporate a feature to flag unfamiliar or untrained species as *"Unrecognized"*.
- Expand the dataset in size and diversity to enhance model robustness and generalization.
- Develop a real-time object detection web application deployable on a Raspberry Pi for field use.

9. References

1. Dataset: https://github.com/myyyyw/NTLNP
2. YOLO Documentation: https://docs.ultralytics.com/
3. Scott Leorna and Todd Brinkman. Human vs. machine: Detecting wildlife in camera trap images. *Ecological Informatics*, 72:101876, 2022.
4. Aslak Tøn, Ammar Ahmed, Ali Shariq Imran, Mohib Ullah, and R Muhammad Atif Azad. Metadata augmented deep neural networks for wild animal classification. *Ecological Informatics*, 83:102805, 2024.