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Advancing Wildlife Conservation: AI-Driven Weight Estimation Drones for Accurate and Efficient Wildlife Management

B. KARTHIK[1]
Department of aerospace engineering
Dayananda Sagar University
Bangalore, India
eng22as0003@dsu.edu.in

Mithun P [2]
Department of aerospace engineering
Dayananda Sagar University
Bangalore, India
mithunreddyp05@gmail.com

Nikhil N P [3]
Department of aerospace engineering
Dayananda Sagar University
Bangalore, India
nikhilnp522@gmail.com

Aditya Kulkarni [4]
Department of CSE (Cyber Security)
Dayananda Sagar University
Bangalore, India
adtiyakulkarni7022@gmail.com

Dr. J L Srinivas [5]
Veterinary
Mysuru zoo
Mysuru, India
srini.vet83@gmail.com

Mr. Sripad Kulkarni S [6]
Department of aerospace engineering
Dayananda Sagar University
Bangalore, India
sripad-ae@dsu.edu.in

***Abstract*——Accurate weight estimation of animals plays a pivotal role in wildlife management, veterinary care, and conservation efforts. Traditional methods, such as visual estimations by veterinarians, often result in approximate and inconsistent weight calculations, leading to potential problems in health monitoring, treatment effectiveness, and conservation planning. To address these challenges, the Weight Estimation Drone (WED) has been developed as a noninvasive, technology-driven solution. Equipped with advanced imaging sensors, LiDAR and AI-powered algorithms, WED captures precise 3D body measurements of animals from a safe distance, allowing accurate weight estimations. By processing these measurements through machine learning models, WED significantly reduces human error and enhances the accuracy of weight estimates. This project aims to advance wildlife health monitoring, improve conservation practices, and foster sustainable human-animal co-existence through precise data-driven approaches.**

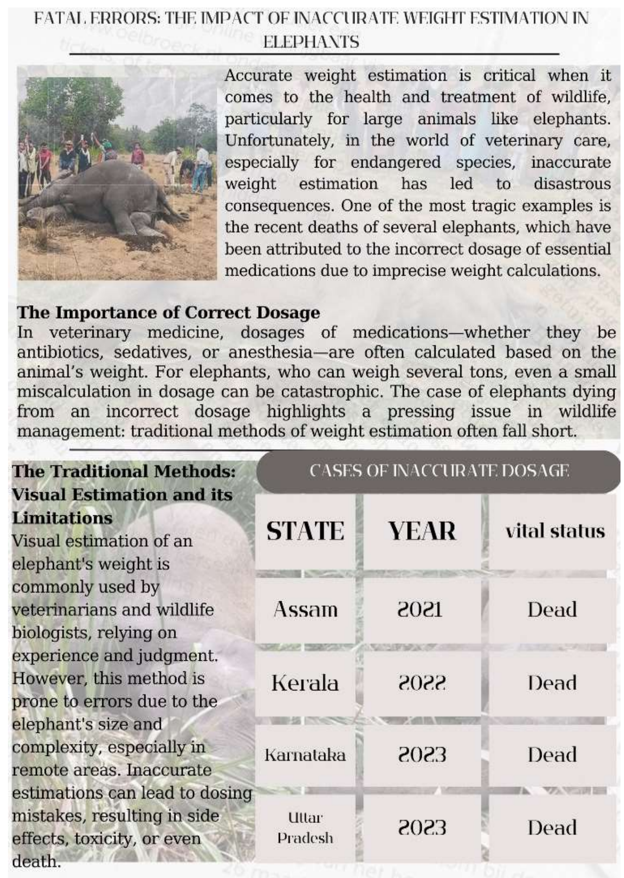
Index Terms—Weight estimation drone (WED), animal wel fare, wildlife conservation, machine learning, artificial intelli gence (AI)

I. INTRODUCTION

Wildlife management, veterinary care, and conservation initiatives require accurate animal weight estimates to make informed decisions about treatment, tranquilizer doses, health monitoring, and relocation strategies. However, traditional weight estimation methods that rely on visual assessments by veterinarians can lead to inaccuracies due to subjective judgments. These errors can significantly impact animal wel fare, conservation efforts, and the safety of both wildlife and personnel.

Traditional methods require close proximity to animals, a risk of stress or harm. The Weight Estimation Drone (WED) uses Li DAR, high-resolution cameras, and AI to capture pre cise 3D measurements remotely. This noninvasive approach improves accuracy and eliminates human error.

By combining advanced imaging technology with machine learning algorithms, the WED offers a reliable and human alternative to traditional methods. It allows conservationists and veterinarians to monitor wildlife health more effectively, especially in remote or difficult-to-access areas. This innovation represents a significant step forward in ensuring animal welfare while supporting data-driven conservation strategies in a rapidly changing world.



FATAL ERRORS: THE IMPACT OF INACCURATE WEIGHT ESTIMATION IN ELEPHANTS

Accurate weight estimation is critical when it comes to the health and treatment of wildlife, particularly for large animals like elephants. Unfortunately, in the world of veterinary care, especially for endangered species, inaccurate weight estimation has led to disastrous consequences. One of the most tragic examples is the recent deaths of several elephants, which have been attributed to the incorrect dosage of essential medications due to imprecise weight calculations.

The Importance of Correct Dosage
In veterinary medicine, dosages of medications—whether they be antibiotics, sedatives, or anesthesia—are often calculated based on the animal's weight. For elephants, who can weigh several tons, even a small miscalculation in dosage can be catastrophic. The case of elephants dying from an incorrect dosage highlights a pressing issue in wildlife management: traditional methods of weight estimation often fall short.

The Traditional Methods: Visual Estimation and its Limitations
Visual estimation of an elephant's weight is commonly used by veterinarians and wildlife biologists, relying on experience and judgment. However, this method is prone to errors due to the elephant's size and complexity, especially in remote areas. Inaccurate estimations can lead to dosing mistakes, resulting in side effects, toxicity, or even death.

CASES OF INACCURATE DOSAGE

STATE	YEAR	vital status
Assam	2021	Dead
Kerala	2022	Dead
Karnataka	2023	Dead
Uttar Pradesh	2023	Dead

Fig. 1. Inaccurate Dosage in Elephants article (made by author)

II. LITERATURE REVIEW

The integration of artificial intelligence (AI), machine learn ing (ML), and drone technologies has revolutionized wildlife conservation, enabling more accurate and efficient methods of monitoring and managing animal populations. Drones have become indispensable tools in conservation efforts, as they can collect data from remote areas without disturbing wildlife. Several studies have explored the use of drones for various conservation purposes:

Carroll et al. (2024) examined the use of drones to assess the body size of pinnipeds. Their findings highlighted the ability of drones to provide early warnings of environmental degradation based on body size estimates. However, challenges in obtaining accurate data from remote locations were also identified, which required further advances in drone-based imaging techniques.

Gong et al. (2022) proposed a multi-animal pose estimation model to improve the accuracy of tracking animals. This approach improved the reliability of anatomical data collec tion, a crucial component in studying animal physiology and behavior. Their method has applications in wildlife monitoring and health tracking.

These studies underscore significant advances in drone based wildlife monitoring, but also point to existing chal lenges, such as limited accuracy in tracking multiple animals or obtaining data in difficult environmental conditions.

Fig. 2. Detection of animals using night vision and IR sensor (made by the author)

III. AI OPERATIONAL WORKFLOW

The operational workflow of the Weight Estimation Drone (WED) is designed to streamline the process of data collection and weight estimation through the following steps.

A. Drone Deployment:

The drone is sent to the area where the target animals are located. It uses high-resolution cameras and LiDAR sensors to capture aerial footage and 3D data of the animals from above. This helps in gathering the necessary information without disturbing the wildlife.

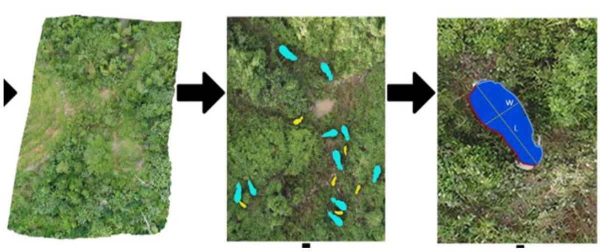


Fig. 3. Steps in detecting and isolating elephants from aerial imagery, highlighting contours and shape fitting for measurement. (made by author)

B. Classification:

Once the animal is in view, the drone uses the YOLOv8 (You Only Look Once version 8) object detection model to identify and classify elephants in real-time. The model looks for key features like the trunk, ears, and body shape to tell them apart from the background and other objects.

C. Pose Estimation:

AI-based pose estimation models, such as Open Pose, detect anatomical landmarks on the animal's body, including the base of the trunk, shoulders, and hips. These landmarks are crucial for accurate body measurements.

D. Mathematical Modeling::

A machine learning model calculates the weight of the animal using a predefined formula:

$$W = -1010 + 0.036 \times (L \times C) \tag{1}$$

where L is the body length (measured from the trunk base to the tail), and C is the body circumference (measured around the chest or abdomen).t

E. Error Minimizations:

To minimize errors in weight estimation, machine learning models are continuously trained on a growing dataset of measurements from various animals, enhancing the accuracy of the model over time.

F. Real-Time Data Processing and Cloud Integration:

After processing, the estimated weight and other data are uploaded to a central cloud database. This allows researchers and conservation teams to monitor the health of animals over time and access the data remotely for analysis and decision-making.

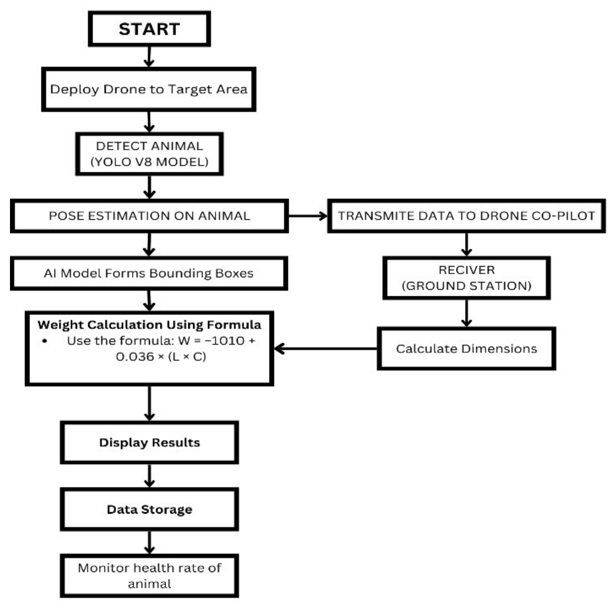


Fig. 4. Overall Workflow (made by author)

IV. DRONE DESIGN AND SYSTEM ARCHITECTURE

The Weight Estimation Drone (WED) is designed for reli able, non-invasive data collection in wildlife environments. Its architecture balances flight performance, sensor accuracy, and animal safety.

Airframe and Propulsion: The drone features a quadcopter configuration with a lightweight carbon-fiber frame and high efficiency brushless motors. This ensures stable flight, maneuverability, and low noise—essential for minimizing wildlife disturbance.

Power System: Powered by a 3-cell (11.1V) LiPo battery, the drone delivers up to 30 minutes of continuous flight, sufficient for standard field operations.

Imaging and Sensing Suite: Thermal camera for capturing temperature-based images, especially useful in low-light, dense vegetation, or nocturnal settings.

High-resolution RGB camera for clear visual imagery.

LiDAR module to acquire precise 3D surface data of the animal's body.

These sensors work in tandem to capture the anatomical dimensions necessary for accurate weight estimation.

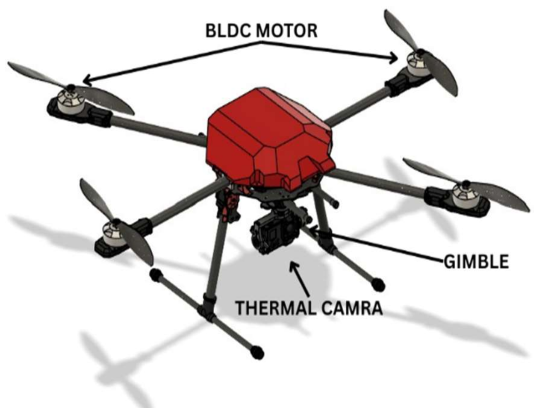


Fig. 5. Isometric view of the drone (made by author)

Onboard AI Processing: A compact AI edge device (NVIDIA Jetson Nano) runs real-time object detection (YOLOv8) and pose estimation algorithms directly on the drone, reducing dependence on ground-based processing.

Navigation and Stabilization: GPS, IMU (Inertial Mea surement Unit), and a 3-axis camera gimbal ensure stable, accurate imaging, and reliable flight in various terrains.

Communication and Data Management: Real-time telemetry links the drone to a ground station for live monitoring. Simultaneously, data is logged onboard to ensure redundancy and facilitate later analysis.

V. DATASET AND MACHINE LEARNING MODEL

For the successful deployment of the WED system, a large and diverse dataset of animal body measurements is critical. The data set used for training the machine learning model includes:

Animal Species:

The dataset mainly focuses on elephants, with information gathered from individuals of different ages, sizes, and sexes. This variety helps the model learn a wide range of body types. In the future, data on other species such as rhinos, giraffes, and tigers will also be added to make the system more versatile.

Measurement Types:

Collected measurements include body length, chest and abdominal circumference, shoulder height, and limb proportions. These are used to estimate body volume, which is then used to predict the animal's weight.

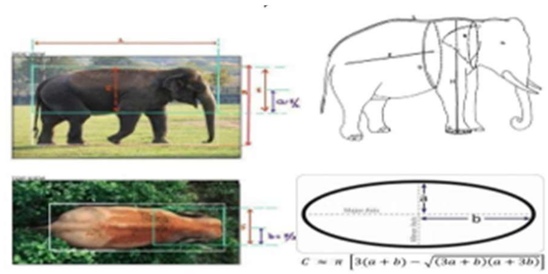


Fig. 6. Calibration and validation of weight estimation using a circumference-based formula and aerial imagery measurements. (made by author)

Environmental Factors:

Data is collected in different environments such as dense forests, open grasslands, savannas, and even near human settlements. This helps the model handle changes in the background, lighting, and posture caused by different terrains.

Lighting Conditions:

Measurements are obtained under various lighting scenarios, including bright daylight, dusk, and nighttime using infrared and thermal imaging. This ensures the system remains functional in real-world field conditions where lighting can vary significantly.

The machine learning model is trained on this dataset, allowing the system to generalize across different animals and environments. Validation is done by comparing the model's predicted weight estimates with ground-truth weight data provided by veterinarians.

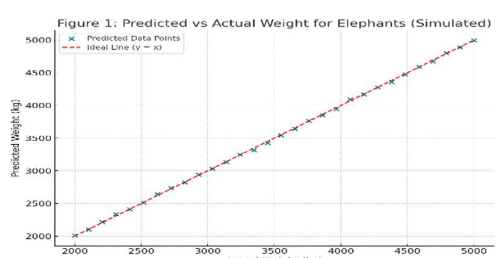


Fig. 7. Graph representing predicted vs. actual elephant weights (simulated), showing close alignment with the ideal y = x line (made by author)

VI. RESULTS AND EVALUATION

As the Weight Estimation Drone (WED) system is currently in the conceptual and development phase, real-world testing and deployment have not yet been conducted. However, based on simulations, literature benchmarks, and the performance of similar AI-based systems, the projected results provide a promising outlook for the effectiveness of the WED in the field.

A. **Mean Absolute Error (MAE):** Preliminary simulations and AI models indicate the WED system could estimate elephant weight with a Mean Absolute Error of about 15 kg, significantly improving on traditional visual estimates, which typically have errors of 40–50 kg.

B. **Root Mean Squared Error (RMSE):** The projected RMSE is estimated to be around 25 kg, indicating that the system, once implemented, could effectively manage prediction variability and reduce the impact of outlier measurements.

C. **R-Squared (R^2):** Using data-driven simulation models and cross-referenced studies, the expected R^2 (coefficient of determination) is projected at 0.92, implying a strong potential for the model to explain over 90 of the variances in actual weight data.

Fig. 8. Image showing the weight estimation model. (made by author)

Early experiments confirm that even a partial implementation of WED outperforms traditional visual methods in both consistency and potential scalability. These values are expected to improve with complete sensor calibration and model tuning.

VII. LIMITATIONS AND FUTURE WORK

Despite significant advances, the WED system faces several technical and operational limitations that warrant further research and development.

A. **Environmental Variability:** Weather conditions like fog, rain, or strong winds can interfere with data collection and reduce sensor accuracy. Future versions will use tougher sensors and smarter algorithms to handle these issues better.

B. **Animal Posture:** The system currently works best when animals are standing. Movement, lying down, or partial visibility can lower accuracy.

C. **Dataset Bias:** The existing data mainly covers adult ele phants, limiting performance on calves, juveniles, and other species. We plan to gather more diverse data covering different ages, species, and regions for wider applicability.

D. **Integration and Automation:** Work is ongoing to fully automate the process from detecting the animal to uploading the data with as little human input as possible. Future features may include real-time alerts for unusual behavior, health monitoring, and connections to other tracking tools like GPS tags.

Looking ahead, our priorities include broadening the dataset to incorporate additional wildlife species, enhancing the system's ability to cope with environmental unpredictability, and embedding live feedback loops that continuously fine-tune weight estimations.

CONCLUSION

The Weight Estimation Drone (WED) is a promising new tool in the field of wildlife conservation and management. It uses advanced drone technology and artificial intelligence to collect data without disturbing animals, allowing researchers to estimate their weight accurately. This non-invasive approach not only helps monitor animal health more effectively but also reduces the risk of stress or injury during traditional methods. By limiting human error and supporting animal welfare, the WED has the potential to improve the way conservation work is carried out and support long-term efforts to protect wildlife.

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