Lateral Legends 2.0

Drone for Garbage Detection and Waste Management System using Embedded Computing and Machine Learning

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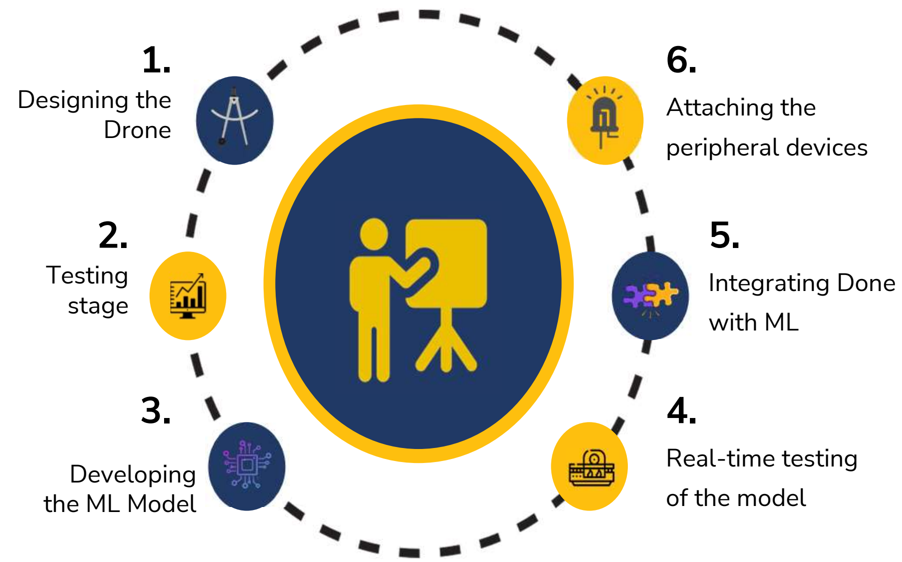
INTRODUCTION

- Drones are one of the fastest-rising technologies in today's world. Known for their flexibility in design, versatility in traversal, and relative ease of control, drones are an economically sound, secure, and more innovative option to traditional methods.
- For example, geographical mapping, delivery services, and mechanized warfare are fields that are being slowly captivated by drones.
- Another technology that has taken over the market is Machine Learning and Artificial Intelligence.
- With the ability to learn from data and generalize that knowledge well to real-world applications without the need for extensive rules, machine learning allows one to unlock a wide range of domains without the need for extensive resources.
- Our project combines these two technologies, i.e., autonomous drone and machine learning to combat an everyday problem that is apparent in every locality.



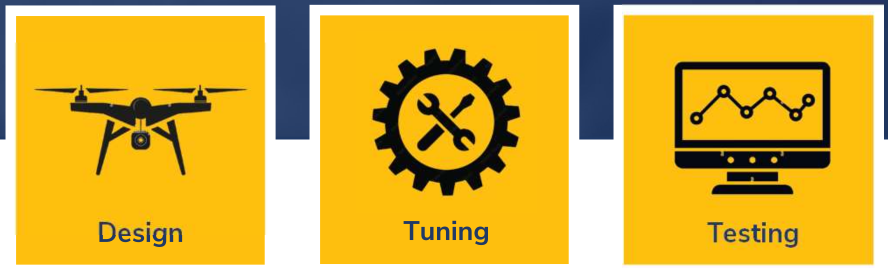
Aim & Solution

To design and manufacture an autonomous system using drone technology and machine learning algorithms, such that it can be used as a tool for waste management and other similar applications.

- A waste detection vision system mounted on an autonomous drone with a pre-planned route.
- When the system detects waste in a frame it saves the frame along with the GPS coordinates of where it was taken.

The solution to the problem statement has been devised while keeping in mind the sustainability of the product, cost of manufacturing, and simplicity of use. The solution aims to reduce the resources required to maintain the cleanliness of the local areas in an innovative manner.

DRONE IMPLEMENTATION



01 Design

The design phase is a blend of a delicate balance between **Aerodynamics, Propulsion System, Power Management,** and **Performance.** All these requirements are achieved by integration of good **R&D,** Choice of parts, and Calibrating the ultra-precise sensors.

02 Tuning

Drone manufacturing involves tuning and **configuring** various **sensors** and **communication modules** according to our requirements, in the best way possible. This process is mainly focused on **Integrating** different modules by matching their **Baud rate**.

03 Testing

The testing process involves a **comprehensive evaluation** of all the components, from motors and propellers to sensors and communication systems. This process points out all the mistakes that were made in the previous steps. The **Testing and debugging** procedure is crucial for this kind of Autonomous drone.

AUTONOMOUS
FLIGHT

Autonomous drones operate through a combination of telemetry and GPS modules. They rely on onboard sensors like cameras, lidar, and radar to perceive their surroundings. They perform a wide range of functions that are way more efficient than manual flights and some benefits include

- Pre planned missions
- Aero Surveillance
- Hassle free handling

Autonomous drones are the silent sentinels of progress, charting new horizons in the realm of possibilities.

This figure shows the real-time flight data and the parameters of various sensors

This figure shows an Autonomous flight path that is planned in the software for the drone to follow

MACHINE LEARNING MODEL – CONSTRAINTS AND REQUIREMENTS

A vanilla model that has been trained from scratch generalizes to real-world environments only if it has been trained with a large dataset and has a sufficient number of trainable parameters. However, certain constraints will limit the use of these aspects.

Efficiency

- Due to the power requirements of the motors of the drone, the computer that will process the ML model will be low-powered (5V)
- Thus the algorithm should be computationally efficient

Prior information encoded in model

- Since we lack a significantly large dataset, we need some prior information encoded in the model.
- Usually done by choosing a specific class of functions but we use a different approach

Low latency

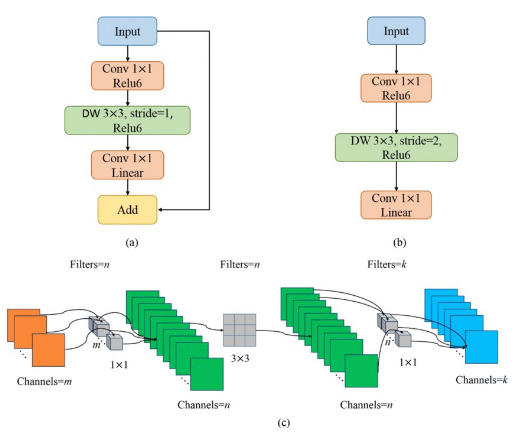
- Being a real-time application, our model needs to be fast. A high latency rate would mean the model would lag and miss some frames from the video stream.

MACHINE LEARNING MODEL – CHOOSING THE MODEL AND TRAINING TECHNIQUE

Given the need for high efficiency, low latency, and some prior information encoded in the network, we decide the model we want to train and the training technique we want to use.

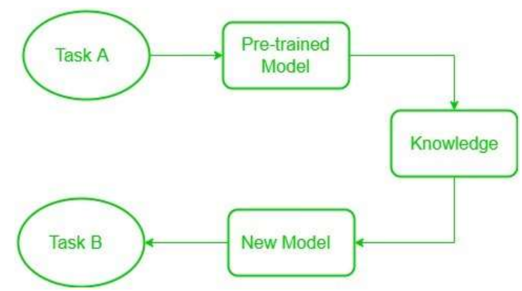
Base Model – MobilenetV2

- The MobilenetV2 is a convolutional neural network optimized for low-power devices like mobiles.
- It uses an operation called depth-wise convolutions instead of regular convolutions to reduce the time complexity of calculations.
- Being a popular network, trained versions of the model are publicly available.
- These models have been trained on benchmark datasets such as ImageNet



Training technique – Transfer Learning

- Transfer learning is a technique by which a pre-trained model is selectively re-trained on a different dataset for a different but similar task.
- In our case we use the MobilenetV2 trained on ImagNet for object classification and transfer learned it on a smaller dataset specific to our task.
- This technique allows our model to have some prior information, making it easier to train while maintaining high accuracy and robustness.



MACHINE LEARNING MODEL – DEPLOYMENT

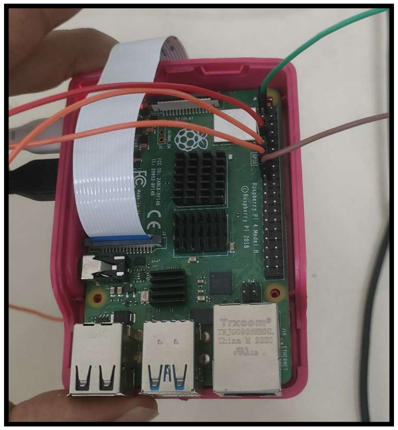
The model has been trained and optimized for edge devices. Now it is time for deployment. As deep learning frameworks like Tensorflow and PyTorch cannot be installed on embedded systems and edge, we use an alternative built specifically for these applications.

Framework – TensorFlow Lite

- TensorFlow Lite is a mobile library for deploying models on mobile, microcontrollers, and other edge devices.
- Models trained via TensorFlow can easily be converted into TensorFlow Lite-compatible versions and be used for inference.
- TensorFlow Lite offers a much lighter framework and is easy to interface with edge devices.

Hardware for Deployment – Raspberry Pi 4

- The Raspberry Pi 4 is a generic device that works on the Linux Operating system.
- It uses a 32-bit ARM-based processor along with a heat sink to prevent overheating.
- It has 27 GPIO pins to interface with sensors and devices, as well as a GPIO header to connect to the camera.
- It supports HDMI output, making it easy to work with.
- Using TensorFlow Lite, a serial pipeline is created on this device for real-time processing.



INTEGRATION AND BENEFITS

By integrating drones into the waste management system, municipalities, environmental agencies, and community stakeholders can enhance operational efficiency, optimize resource allocation, and mitigate environmental risks while fostering public participation and awareness in sustainable waste management practices.

Aerial Waste Surveillance:

- Drones equipped with cameras and sensors to conduct aerial surveillance of waste management facilities, landfills, and illegal dumping sites.
- Drones can fly over large areas quickly and capture high-resolution images and video footage, allowing waste management authorities to identify potential hotspots, monitor environmental hazards, and assess the effectiveness of waste disposal strategies.

Community Engagement and Education:

- Schools, universities, and environmental organizations can organize drone workshops, STEM programs, and outreach events to teach students and citizens about the importance of waste reduction, recycling, and sustainable practices.
- Drones can capture captivating aerial footage and interactive 3D models to illustrate the impact of waste on ecosystems, wildlife habitats, and public health.

Remote Waste Collection and Sorting:

- Drones with robotic arms and grippers to autonomously collect and sort recyclable materials from designated collection points.
- Drones can navigate through narrow spaces, inaccessible terrain, and hazardous environments to retrieve waste materials efficiently and safely.
- Integration with AI-powered computer vision algorithms can enable drones to identify and segregate different types of recyclables on the fly, streamlining the sorting process and maximizing resource recovery.

Wildlife Conservation:

- Drones can contribute to wildlife conservation efforts by monitoring wildlife habitats, tracking endangered species, and identifying threats to biodiversity.
- They can conduct aerial surveys of protected areas, wildlife reserves, and conservation sites to assess habitat quality, detect poaching activities, and monitor wildlife populations, aiding in the conservation.

INTEGRATION AND BENEFITS

Drone integration offers numerous benefits across industries, including increased efficiency, safety, and productivity, while enabling organizations to unlock new capabilities and insights for improved operational performance and competitive advantage. As technology continues to evolve, drones are poised to play an increasingly important role in shaping the future of industries such as agriculture, construction, infrastructure, public safety, and environmental monitoring.

Cost-Effectiveness:

- With todays world quipped with drone technology and its development, drone manufacturing is slowly becoming mainstream.
- By installing drone in waste management system we can reduce cost at various places.
- They require minimal manpower and resources compared to ground-based operations, resulting in lower operational expenses and increased efficiency.
- Drones offer a cost-effective alternative to traditional methods of data collection, inspection, and surveillance.

Sustainability and Scalability:

- Drone technology is scalable and can be integrated seamlessly with existing workflows, systems, and infrastructure.
- Drones offer environmentally friendly alternatives to traditional methods of data collection and transportation, reducing carbon emissions, noise pollution, and ecosystem disturbances associated with manned aircraft and ground vehicles.
- They can be powered by electric batteries or renewable energy sources, further minimizing their ecological footprint.
- Drones are easily adaptative.

Data Accuracy and Real-Time Monitoring

- Drones capture high-resolution images, videos, and sensor data with accuracy, enabling detailed analysis, modeling, and decision support. Advance technique can be employed to analyze and hence find results such as heatmaps and 3D models can also be generated.
- Drones equipped with live video streaming capabilities enable operators to monitor operations, track assets, and make informed decisions in real-time.
- Integration with data analytics software and AI algorithms allows for real time analysis, detection, and insights.

Safety and Flexibility :

- By replacing manned operations with drones, organizations can mitigate risks to human personnel involved in hazardous or high-risk tasks such as search and rescue operations, disaster response, and infrastructure inspections.
- Drones can operate in challenging environments and adverse weather conditions without endangering human lives.
- Drones can be set up to fly on their own, following specific routes and performing various tasks without constant human control. This makes them adaptable to different situations and allows them to do things like navigating through obstacles or capturing images from specific angles without much manual intervention.