AI & SUSTAINABILITY IN VET EDUCATION

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Title of WP: WP3 – AI-SAVES@ProjectHub

Activity Reference: AI Waste Classifier – Mobile Robot with LED and Path Navigation

Logo:

POLITEKNIKA TXORIERRI

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1. **Project Title:**

   AI Waste Classifier – Mobile Robot with LED and Path Navigation

2. **Project Category:**

   Artificial Intelligence • Computer Vision • Robotics • Sustainability

3. **Project Description:**

   This project uses a Raspberry Pi 5, a Pi Camera and a 2WD robot kit with an L298N motor driver to recognize three types of materials and move the robot along different paths depending on the detected material.

   Instead of a pre-trained AI model, the system performs real-time material classification using computer vision techniques (OpenCV), based on:

   - Brightness (V channel in HSV)
   - Colour saturation (S channel in HSV)
   - Edge density (Canny edge detection)

   The system classifies materials as:

   - Paper
   - Plastic
   - Metal

   Shows the live camera image and the predicted material name on the screen.

   Turns on a different LED for each material (for example: Green, Yellow, Red).

   Makes the robot perform a different movement circuit:

   - Material 1 (Paper)
     → Turn left 90° and then go forward 30 cm
   - Material 2 (Plastic)
     → Go forward 30 cm
   - Material 3 (Metal)
     → Turn right 90° and then go forward 30 cm

   The robot uses a 2WD chassis with L298N motor driver and is powered from a 12V battery and a 12V→5V buck converter for the Raspberry Pi.

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4. **Keywords:**

   AI, Raspberry Pi 5, OpenCV, Computer Vision, Mobile Robot, L298N, 2WD, LEDs, Sustainability

5. **Target Audience:**

   - Vocational students (beginners in Python and robotics)
   - Teachers who want a simple AI + robotics project
   - Workshops about recycling and sustainability

6. **Project Objectives:**

   - Implement a real-time material classifier using computer vision techniques.
   - Analyze camera images using colour and edge features.
   - Control LEDs and DC motors using Python and lgpio.
   - Make the robot execute different movement paths depending on the detected material.
   - Understand how AI-inspired vision techniques can support recycling and sustainability.

7. **Project Timeline:**

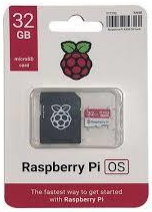
Task	Estimated Hours	Description
Introduction & AI + recycling	1 hours	Explain idea and goals
Computer vision basics	2 hours	Colour, brightness, edges
Raspberry Pi setup	2 hours	OS, libraries, camera test
LEDs & L298N wiring	3 hours	Connect LEDs, motors, test scripts

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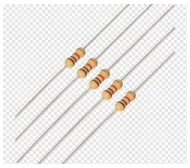
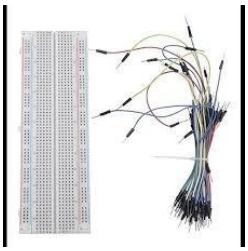
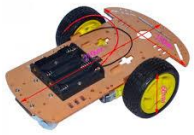
Task	Estimated Hours	Description
Vision-based classification	4 hours	HSV + edge detection
AI + robot integration	5 hours	Classify + LEDs + robot paths
Testing & tuning (distance/turn)	3 hours	Adjust times for 30 cm & 90°
Total	**20 hours**	

8. Materials required

Raspberry Pi 5 (4GB/8GB)	
Raspberry Pi Camera (V3)	
MicroSD 32 GB with Raspberry Pi OS	

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3 LEDs (Red, Green, Yellow) + 3× 220–330 Ω resistors	 
Breadboard + jumper wires	
2WD robot chassis with: • 2x DC motors • Wheels • Battery holder / base	
L298N dual H-bridge motor driver	
12V → 5V buck converter (min. 3A, better 5A)	

9. Resources Provided:

- Example datasets and Teachable Machine templates for object classification.
- Python scripts for motor control and image processing.
- Wiring diagrams and Raspberry Pi setup guides.
- Evaluation rubric and report template.

10. Tools and Technologies Used:

- Hardware: Raspberry Pi 5, Pi Camera, L298N, 2x DC motors, 2WD chassis, LEDs, resistors, 12V battery, buck converter.
- Software: Raspberry Pi OS, Python 3, OpenCV, Picamera2, lgpio, Flask (for video streaming), NumPy.

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- Online tool: Google Teachable Machine (Image Project)

11. Step-by-Step Implementation Plan:

1. **Phase A – Vision-based detection**
   - Capture live camera frames using Picamera2.
   - Convert images to HSV colour space.
   - Analyze:
     - Mean brightness (V channel)
     - Mean saturation (S channel)
     - Edge density (Canny)
   - Define thresholds to classify:
     - Paper
     - Plastic
     - Metal

2. **Phase B – Hardware wiring**

   - Camera: connect Pi Camera to CSI port and test with camera_test.py.

   - LEDs:

     - Connect anode of each LED to GPIO via resistor.

     - Example:

       - Red → GPIO 16

       - Green → GPIO 19

       - Yellow → GPIO 26

     - Connect all cathodes to GND.

   - L298N + Motors (simple wiring):

     - Connect both motors to the OUT1/OUT2 and OUT3/OUT4 terminals.

     - Connect 12V battery to L298N +12V and GND.

     - Put the ENA and ENB jumpers in place → always enabled (full speed).

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- Connect L298N inputs to Raspberry Pi GPIO (BCM):
  - IN1 → GPIO 20 (left motor, forward)
  - IN2 → GPIO 21 (left motor, backward)
  - IN3 → GPIO 12 (right motor, forward)
  - IN4 → GPIO 13 (right motor, backward)
- VERY IMPORTANT: Connect GND of L298N to GND of Raspberry Pi.

- Power:
  - 12V battery → L298N +12V (motors)
  - 12V battery → buck converter → 5V → USB-C to Raspberry Pi 5

3. **Phase C – Software setup**

- Install libraries (many may already be installed):

  sudo apt install python3-opencv python3-picamera2

  pip install tflite-runtime gpiozero lgpio numpy
- Test camera: python3 camera_test.py
- Test LEDs: python3 led_test.py
- Test motors: python3 motor_test.py

4. **Phase D – Full integration (AI + LEDs +Robot)**

- Run classify_robot.py:
  - The robot shows the camera live.
  - It prints and draws the material name.
  - It turns on the correct LED.

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- Each time a material is detected (with a small pause), the robot:
    - For paper: turn left ~90° + forward ~30 cm
    - For plastic: forward ~30 cm
    - For metal: turn right ~90° + forward ~30 cm

- The distances and angles are controlled by time constants (seconds). Students can tune these times by trial and error on their own robot.
- The system waits for several consecutive frames with the same classification before taking a decision (stability check).
- Each material triggers:
    - A specific LED
    - A single movement sequence.
- The robot provides live video streaming via browser: http://IP:8080/video

12. Evaluation Criteria:

- **Dataset quality (25%):** Variety, lighting, number of samples.
- **Hardware setup (20%):** Safe & correct GPIO wiring.
- **AI integration (30%):** Stable real-time detection & LED reaction.
- **Creativity & presentation (15%):** Explanation, diagrams, sustainability.
- **Vision logic understanding (10%):** Correct explanation of how color and edges are used to classify materials.

13. Languages Available:

English

14. Contributors:

- **Miren Arrien (Project Lead)** – Lead educator responsible for project development and coordination.
- **Enaitz Elejalde (Technical Expert)** – Provided expertise in IOT.
- **Aitor Rey (Technical Expert)** – Provided expertise in IOT.
- **Jokin Goioaga (Technical Expert)** – Provided expertise in IOT.

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15. Feedback and Continuous Improvement:

After each phase of the project, students and teachers should briefly review both the AI system and the robot behaviour:

- Phase Reviews
  - Model training: Check if the AI correctly identifies paper, plastic, and metal.
  - Wiring: Verify LEDs, motors, and the L298N driver are connected safely and work correctly.
  - Movement tests: Confirm the robot turns close to 90° and moves roughly 30 cm.
  - Full integration: Ensure the robot reacts correctly to each material (LED + movement).

- Final Reflection
  Students evaluate:
  - How accurate the AI model was?
  - How reliable the robot movement was?
  - What challenges appeared during integration?

- Improvement Suggestions
  Students propose simple upgrades such as:
  - Adjusting vision thresholds (brightness, saturation, edge density)
  - Improving lighting conditions for more stable detection
  - Fine-tuning movement timing (better 90° turns / 30 cm travel)
  - Adding sensors for obstacle detection
  - Combining vision rules with simple machine learning models
  - Adding a display, sound feedback or web-based monitoring

- Future Use
  The results and suggestions help improve future lessons combining AI, robotics, and sustainability.

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