AI & SUSTAINABILITY IN VET EDUCATION

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Title of WP: WP3 – AI-SAVES@ProjectHub

Activity Reference: 3.2 – Project template for AI-SAVES@ProjectHub

Logo:

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AI-SAVES@PROJECTHUB PROJECT SUBMISSION TEMPLATE

This template provides a structured format for submitting projects to the **AI-SAVES@ProjectHub**. Each section should be completed thoroughly to ensure consistency and provide all necessary information for project evaluation and sharing within the hub.

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1. Project Title:

Automated System for Identification and Separation of Waste

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2. Project Category:

This project is fundamentally centered on leveraging artificial intelligence as a powerful tool for learning. Therefore, its primary category is:

- AI for Education

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3. Project Description:

This project addresses the growing need for sustainable waste management by developing an automated system for identifying and classifying recyclable materials using computer vision and artificial intelligence. The solution comprises two main components: a full-stack web application (WasteVisionWeb) that allows users to upload images for real-time classification, and a comprehensive educational repository (WasteVision-AI) designed to facilitate the training and development of AI models. The primary goal is to promote a circular economy and environmental education by providing a practical, scalable, and accessible tool for use in educational and community settings.

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4. Keywords:

- Recycling
- Sustainability
- Environmental Education
- Computer Vision
- Artificial Intelligence (YOLOv8)

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5. Target Audience:

The primary audience includes:

- Educators
- Students

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6. Project Objectives:

As outlined in the project report, the specific objectives are:

- To develop an artificial intelligence model capable of accurately identifying and classifying different types of recyclable materials (e.g., plastic, glass, paper, metal, biodegradable).
- To integrate the AI system into a physical prototype, consisting of a camera and a microcontroller (Raspberry Pi), to enable automated waste sorting.
- To develop educational materials that encourage the adoption of the technology in school and community environments, promoting awareness of environmental issues and sustainability.

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7. Project Timeline:

The project was developed iteratively over three sprints between February and June 2025.

- **Start Date:** February 16, 2025
- **End Date:** June 30, 2025
- **Key Milestones:**
    - **Sprint 1 (16/02/2025 – 22/03/2025):** Focused on system architecture definition, initial development of the waste classification model, and database implementation.
    - **Sprint 2 (23/03/2025 – 26/04/2025):** Centered on integrating the AI model with hardware (Raspberry Pi) and developing the user interface for real-time result display.

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- **Sprint 3 (27/04/2025 – 30/06/2025):** Involved system optimization, implementation of reporting modules, and the creation of environmental education content.

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8. Resources Provided:

WasteVision-AI Educational Repository: A complete Python-based repository for training, validating, and deploying the YOLOv8 waste detection model. Includes setup scripts, interactive training forms, and detailed documentation.

WasteVisionWeb Application: A full-stack web application (React frontend, .NET backend) for user management and real-time waste classification, containerized with Docker for easy deployment.

Hardware Specifications: Detailed configuration for the physical prototype, including the Raspberry Pi 5, camera module, and necessary software setup.

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9. Tools and Technologies Used:

AI & Machine Learning: Python, YOLOv8n, Ultralytics, PyTorch, NCNN (for ARM optimization), Roboflow API.

Backend: C# .NET 8, ASP.NET Core.

Frontend: React, TypeScript, Axios.

Database: MySQL.

Infrastructure & DevOps: Docker.

Authentication: Keycloak.

Hardware: Raspberry Pi 5, Raspberry Pi Camera Module v3.

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10. Step-by-Step Implementation Plan:

This project is designed for replication in educational settings. A user can replicate the project by following these steps:

1. **Set up the Educational Repository:** Clone the WasteVision-AI repository from GitHub and run the automated setup script (setup.bat / setup.sh) to create the virtual environment and install dependencies.

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2. **Prepare Data:** Use or expand the provided "Garbage Classification" dataset.
3. **Train the AI Model:** Use the interactive GUI provided in the repository to configure hyperparameters (epochs, batch size, etc.) and train the YOLOv8 model on the dataset.
4. **Deploy to Edge Hardware:** Export the trained model to an optimized format (e.g., NCNN) and deploy it on a Raspberry Pi 5 using the provided Python scripts for real-time inference via the camera feed.
5. **Deploy the Web Application:** Use the provided docker-compose.yml file to build and run all services of the WasteVisionWeb application (frontend, backend, database, Keycloak) in a containerized environment.
6. **Interact and Evaluate:** Use the web application to create an account, upload images for classification, and review the detailed results and historical data on the user dashboard.

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11. Evaluation Criteria:

The project's success was measured using a combination of quantitative metrics and qualitative assessments:

- **Model Performance Metrics:** The model's performance was rigorously evaluated using standard metrics, including learning curves for training/validation loss (box_loss, cls_loss), Precision, Recall, and mean Average Precision (mAP). The final model achieved a robust mAP@0.5 of 0.546.
- **Confusion Matrix Analysis:** A detailed analysis of the confusion matrix was performed to identify class-specific performance, highlighting strong performance for classes like Glass (0.74) and Metal (0.67) and identifying areas for improvement (e.g., Paper).
- **Real-Time Hardware Validation:** The successful deployment and execution of the optimized model on the Raspberry Pi 5, achieving real-time object detection, served as a key validation of the project's viability and portability.
- **Functional Application Testing:** The WasteVisionWeb application was validated through end-to-end testing (using Cypress) and a final evaluation of the user interface, confirming that the dashboard, scanner, and user profile functionalities are intuitive, cohese, and meet all functional requirements.

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12. Languages Available:

Portuguese: The primary language for academic and descriptive documentation.

English: The language used for the application's user interface, all source code, and technical comments.

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13. Contributors:

Afonso Guilherme Vieira da Silva Oliveira: Lead Developer / Student.plea

Joaquim Filipe Peixoto dos Santos: ISEP Advisor.

Goreti Marreiros: ISEP Co-advisor.

Ana Lúcia S. Machado: External Supervisor.

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17. Feedback and Continuous Improvement:

Continuous improvement is a core principle of this project. Feedback is gathered through rigorous performance analysis, which directly informs a clear roadmap for future enhancements. Key areas for development include:

- **Dataset Expansion:** Enriching the dataset with more examples of underperforming categories (e.g., "paper") to boost classification accuracy.
- **Performance Optimization:** Further optimizing the local fallback model using tools like TensorRT to accelerate inference speed on edge hardware.
- **User Experience Enhancement:** Re-architecting the image classification process to be asynchronous, allowing for a non-blocking user experience.
- **Advanced Analytics:** Expanding the administrative dashboard with more sophisticated data visualizations and analytics features.

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Submission Notes:

Please ensure that all required documents and resources are attached to your submission. The AI-SAVES@ProjectHub review team will evaluate the submission based on the provided information. Once approved, the project will be published on the hub, and partners will be notified.

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