**Project Title:** *AI-Powered Sustainability Project*

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**1. Project Summary**

Sustainability is a growing global priority, and AI offers powerful tools to tackle environmental challenges. Search algorithms, game strategies like Minimax, and constraint satisfaction problems help simulate complex systems and model sustainable decision-making. Supervised machine learning can predict environmental trends, guiding proactive actions. Generative AI tools like ChatGPT and DALL·E further support sustainability by creating educational and engaging content. This project combines these AI methods to build interactive tools that promote awareness and action toward a sustainable future.

**2. Trash Picking**

**Overview:**

Sustainability-themed puzzle game where players control a garbage truck tasked with collecting all trash scattered across a grid-based neighborhood. The primary objective is to collect all trash and return to the dumpster using the least amount of fuel.

**Implementation Observations:**

AI uses two algorithms:

* The A\* algorithm finds the most efficient path by combining the actual movement cost with a heuristic (Manhattan distance) to the nearest trash or the dumpster.

A screenshot of a video game

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* The Random Search AI was at first a Greedy Search, it was meant to move toward the nearest piece of trash based solely on the same Heuristic, but Greedy Search sometimes followed a random path leading to inefficient routes.

A screenshot of a video game

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**Technical Insights:**

Algorithm Performance

**Conclusion & Future Work:**

Key Findings:

* A\* algorithm consistently finds efficient paths, balancing fuel consumption and trash collection.
* AI's performance relies heavily on the Manhattan distance heuristic.

Future Development:

* Refining Greedy algorithm to work properly
* Create bigger complex map for added difficulty
* Coming up with a more accurate heuristic

**3. Plant The Tree First!!!**

**Overview:**

"Plant The Tree First" is an educational game designed to promote sustainability awareness through a competitive tree-planting simulation. The game features two players navigating a grid-based environment to plant trees in designated drop zones while avoiding obstacles.

**Implementation Observations:**

Human vs Human Mode

* Functioned perfectly with balanced gameplay
* Winning probability depends entirely on player strategy

Human vs AI Mode

* Difficulty
  + Easy (Depth 3): Able to find nearby drop zones, Slower response time, less optimal pathfinding
  + Medium (Depth 6): Well-balanced performance, responded efficiently, consistently outperformed human players, Optimal difficulty level
  + A screenshot of a video game

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    AI-generated content may be incorrect.Hard (Depth 9): Surprisingly less efficient than Medium, obstacles (houses) interfered with decision-making, occasionally made random moves due to complexity

A screenshot of a video game

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* Minimax AI (Player 2) consistently outperformed random-move AI (Player 1) across all difficulty levels
* Demonstrated the effectiveness of the Minimax algorithm over random movement
* Validated the AI implementation's correctness

**Technical Insights:**

Algorithm Performance

Minimax with Alpha-Beta Pruning proved effective but showed limitations:

* Performance peaked at medium difficulty (depth 6)
* Higher depths didn't necessarily translate to better performance due to: Increased computational complexity, Obstacle interference in path evaluation, and Time constraints affecting quality

**Conclusion & Future Work:**

Key Findings:

* Medium difficulty (depth 6) provides optimal challenge
* Hard mode requires algorithmic refinement
* AI vs AI mode validates Minimax superiority

Future Development: Implementing Iterative deep learning and integrate more educational content on sustainability

**4. ML Models**

During the machine learning portion of our project, we explored three distinct modeling tasks.

**Logistic Regression: Predicting Recycling Rates**

We began by using logistic regression to predict whether a country recycled 25% or more of its total waste. Our input features were:

* Year
* Total weight of trash collected

We gathered data from 38 OECD countries. One striking observation was the outlier status of the United States, which produced more than three times the trash of the next highest country. This skewed the dataset significantly.

Despite multiple attempts at tuning the model, it consistently predicted that nearly all countries recycled more than 25% of their waste — an optimistic but inaccurate conclusion. This result likely stemmed from poor feature separability and the overwhelming influence of outliers.

A graph with numbers and dots

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A screenshot of a computer screen

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**Multiclass Logistic Regression: Predicting Air Quality**

Next, we shifted our focus to predicting air quality levels in cities using the following environmental features:

* Dew point
* Humidity
* Pressure
* Temperature
* Wind speed

Using multiclass logistic regression, we found that:

* Humidity was the most influential predictor of air quality.
* Dew point and temperature also had moderate predictive power.
* Pressure and wind speed had little to no impact, likely due to their minimal variability or lack of direct relevance.

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**K-Means Clustering: Land Use and Political Rights**

Lastly, we applied k-means clustering (k = 7) to group countries based on:

* Arable land (% of total land)
* Urban land area (km²)
* Political rights (Freedom House Index)

The clustering results were modest. Most countries fell into a single large cluster, likely due to the global scarcity of large urban areas. However, outliers like China, the U.S., and India stood far apart from the rest.

These outliers significantly influenced the model, suggesting that an alternative method such as DBSCAN may have been more appropriate. DBSCAN could better handle the noise and density variation, mitigating the impact of extreme values.

A graph with purple dots

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**Compare with AI generated models**

**Logistic Regression: Predicting Recycling Rates**

A graph of a scatter plot of recycling data

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The scatter plot for both manual and AI generated models are the same

A screenshot of a computer screen

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* **Values**: The specific values for precision, recall, f1-score, and support differ between the two matrices, indicating variations in model performance.
  + **Manual**: Shows higher precision for class 0 and higher recall for class 1, suggesting the model is better at identifying class 1 but may have more false positives for class 0.
  + **AIGen**: Shows more balanced precision and recall values for both classes, indicating a different balance between false positives and false negatives.
* **Accuracy**: **Manual** has an accuracy of 0.54, while **AIGen** has an accuracy of 0.44, reflecting differences in overall model performance.
* **Macro and Weighted Averages**: The macro and weighted averages differ, providing insights into how the model performs across all classes.

**Multiclass Logistic Regression: Predicting Air Quality**

**A screenshot of a computer screen

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* **Values**: The specific values for precision, recall, f1-score, and support differ between the two images.
  + **Manual:** Shows higher precision for class 2 and more balanced metrics for class 4.
  + **AIGen:** Shows higher precision for class 1 and higher recall for class 2.
* **Macro and Weighted Averages:** **Manual** includes macro and weighted averages, while **AIGen** does not specify these metrics.
* **Support:** The support values differ, indicating different sample sizes for each class in the two images.

**K-Means Clustering: Land Use and Political Rights**

* **Values:**
  + **Arable Land**:
    - **Manual**: Varying values, clustered near the y-axis.
    - **AIGen**: Percentage of total land, clustered near the lower x-axis.
  + **Urban Land**:
    - **Manual**: Low values.
    - **AIGen**: Area in km², with outliers.
* **Clustering:**
  + **Manual**: No clustering.
  + **AIGen**: K-Means clustering.

**A chart with different colored dots

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**5. GenAI Trivia + Visuals + Reflection**

**Trivia Game**

* Overview:

The GenAI Trivia Game is an AI-developed interactive trivia game focused on Generative AI and its applications. It offers two game modes: a standard mode with no timer and a timer challenge mode, where players must answer questions within a set time limit.

* What We Did:
  + Developed an AI-generated trivia game with multiple-choice sustainability.
  + Generated the set of questions and answers from the provided set of words using AI.
  + Implemented **two game modes**:
    - **No Timer Mode**: Players can take their time to answer questions.
    - **Timer Challenge Mode**: Players must answer questions within a limited time to increase the challenge.

**Futuristic Green Cities Visuals:**

* Overview:

The GenAI Visual is an AI-developed gallery focused on Generative AI and its applications. It offers photos of futuristic cities when applying sustainability policies into modern city development plans.

* What We Did:
  + Developed an AI-generated photos of the future green cities.
  + The cities have features such as eco-buildings, water reuse systems, solar architecture

**Reflection**

* Trivia Game:
  + Developing the GenAI Trivia Game highlighted both the potential and limitations of AI. Challenges included lack of precision in question generation, resulting in vague or overly generic questions, and the need for trial-and-error prompting to refine the content. Trial-and-error prompting also happens during generating the game, there was a need to specify and adjust the prompt for AI to create the game with the exact features needed. Despite these issues, the game remains an engaging educational tool.
* Futuristic Green Cities Visuals:
  + The Future Green Cities Gallery showcased AI-generated visuals of sustainable cities powered by renewable energy. While visually impressive, the gallery struggled with context awareness, often lacking the specificity needed to create realistic, functional representations. The AI’s output was sometimes overly generic and biased, not fully capturing the complexities of integrating AI into urban sustainability. However, the visuals sparked creativity and imagination about AI’s role in the future.

**6. Conclusion**

**Major accomplishments:**

* **Successful Integration of AI Techniques:**The project effectively combined various AI methods, including search algorithms, game strategies, supervised machine learning, and generative AI tools.
* **Development of Educational Tools:**The creation of interactive games like “Trash Picking”, "Plant The Tree First!!!" and the GenAI Trivia Game provided engaging ways to educate users about sustainability.
* **Supervised ML Models:**Explored different machine learning models to predict sustainability-related outcomes. This included evaluating models using metrics like F1 score, accuracy, and confusion matrix, and visualizing clusters and predictions.
* **AI-Generated Insights and Comparisons:**The project included research on generative AI, comparing AI-generated insights to real-world data**.**

**Key learnings:**

* **Algorithm Performance:**The project demonstrated the effectiveness of algorithms like Minimax with Alpha-Beta Pruning, particularly at medium difficulty levels. It also revealed the need for refinement at higher difficulty levels to improve decision-making accuracy.
* **Machine Learning Insights:**Exploring different machine learning models for predicting sustainability-related outcomes underscored the importance of selecting appropriate evaluation metrics. The use of F1 score, accuracy, and confusion matrix provided a deeper understanding of model performance and areas for improvement.
* **Generative AI Potential:**While generative AI tools like ChatGPT and DALL·E can create engaging content, they also require careful prompting and refinement to ensure accuracy and relevance.

**Potential improvements:**

* **Algorithm Refinement:**Further refinement of algorithms, especially for higher difficulty levels in games, could enhance performance and decision-making accuracy.
* **Enhanced Data Handling:**Implementing alternative (more advanced) clustering methods could better manage outliers and improve the robustness of the models.
* **Expanded Educational Content:**Integrating more detailed and context-specific educational content into your games and visuals could provide deeper insights into sustainability practices.
* **Iterative Deep Learning:**Exploring iterative deep learning techniques could offer more sophisticated predictions and simulations, enhancing the project's overall impact.