

AR-ENHANCED CARBON FOOTPRINT TRACKING

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Abstract:

Carbon emissions from things we do every day, like driving, are a big part of climate change. But most people still have a hard time keeping track of and understanding their carbon footprint because the tools that are available now rely too much on manual data entry, which is slow, inconvenient, and often wrong. This project offers a contemporary and intuitive solution utilizing Augmented Reality (AR) and real-time object detection. The system automatically recognizes vehicles or modes of transportation when the device's camera is pointed at them. It then uses predefined environmental datasets to quickly estimate their CO₂ emissions. The AR-based interface makes the process more fun and interactive, so users don't have to type anything in by hand. It also helps users see their impact on the environment more clearly. The system not only estimates emissions, but it also looks at the calculated CO₂ percentage and gives the user simple, text-based suggestions for sustainable environment. This helps people not only learn about their current carbon footprint, but also how they can lower it in real life. Overall, the system is a smart, efficient, and easy way to keep track of transportation-related carbon footprints. It encourages people to be more aware of their daily choices that are good for the environment.

Keywords: Carbon Footprint, Augmented Reality, Real-Time Tracking, CO₂ Emissions, Sustainability, Environmental Awareness.

I. INTRODUCTION:

Rapid industrialization and the continuous growth of technology have significantly increased carbon dioxide (CO₂) emissions from transportation, energy consumption, manufacturing, and waste generation. These emissions are a major cause of climate change, global warming, and environmental imbalance, making effective carbon monitoring essential for sustainable development. Most traditional carbon tracking systems rely on manual data entry and fixed estimation techniques, where studies such as [1] highlight how this leads to inaccurate results and reduced user engagement. In addition, research like [2] explains that the absence of real-time tracking and interactive visualization makes it difficult for users to clearly understand their carbon footprint and take meaningful action. To address these challenges, the proposed AR-Enhanced Carbon Footprint Tracking system integrates Artificial Intelligence (AI), Augmented Reality (AR), and Computer Vision (CV) to provide a smarter and more interactive solution. The system uses the device camera along with advanced models like YOLO, as discussed in [3], and TensorFlow.js frameworks referenced in [4] to detect objects such as vehicles and estimate their CO₂ emissions using a structured environmental database. This approach, supported by findings in [5], enables users to receive instant visual feedback and improves overall awareness and engagement. The system is designed using a multi-layered architecture that includes frontend, backend, AI/ML, and database components, where architectural design principles in [6] ensure scalability and performance. It is implemented as a Progressive Web Application (PWA), with concepts similar to those presented in [7], allowing easy access across multiple devices without installation barriers. Additionally, the system

supports manual activity logging and provides interactive dashboards, which according to [8] and [9] help users monitor emission trends effectively. Prior research such as [10] also emphasizes the importance of intelligent systems in promoting sustainable decision-making.

II. RELATED WORK:

Recent research shows that machine learning models are widely used for carbon emission estimation, improving prediction accuracy across sectors [1]. However, these approaches are limited by insufficient data and inconsistent emission factors. The Green Algorithm provides a practical method to measure computational carbon footprint, though it is affected by hardware efficiency and runtime variations [2]. Studies on machine learning systems highlight energy consumption and design factors influencing emissions, but challenges in optimization and sustainable infrastructure remain [3]. Research on household emissions identifies major lifestyle-related sources, yet variability in user behaviour limits accurate tracking [4]. Marker-less augmented reality techniques improve flexibility and performance, but face hardware and environmental constraints [5]. Deep learning-based object detection enhances real-time environmental monitoring, although it requires high computational resources [6]. Edge computing improves response time by enabling local data processing, but is constrained by limited resources [7]. Integration of IoT with AI enhances monitoring, though it increases cost and reduces scalability [8]. Advances in AR visualization and sustainable computing improve user engagement, yet challenges like device compatibility and energy efficiency persist [9][10].

III. PROPOSED SYSTEM:

A. Overview of Proposed System:

The proposed system provides a real-time carbon footprint tracking solution using Augmented Reality and Artificial Intelligence. It detects transportation-related objects through a camera using an object detection model and estimates their CO₂ emissions based on a predefined dataset. The results are displayed instantly using AR overlays, making the process interactive and user-friendly. The system also includes a manual entry feature to record daily activities for continuous tracking. All collected data is stored and analysed to generate insights and trends. This approach improves accuracy, reduces manual effort, and promotes sustainable environmental practices.

B. System Architecture

The architecture consists of five core modules:

- User Interface and Interaction Module
- API Gateway and Authentication Module
- AI-Based Object Detection Module
- Carbon Emission Estimation Module
- Data Storage, Analytics, and Visualization Module

The system is designed using a multi-layered architecture consisting of the following components:

- **Frontend Layer:**

The frontend is developed using HTML, CSS, JavaScript, and Bootstrap. It provides a user-friendly interface for accessing the AR scanner, dashboard, and activity logging features.

- **Backend Layer:**

The backend is implemented using Django REST Framework, which handles API requests, user authentication, and communication between system components. Secure access is maintained using JWT-based authentication.

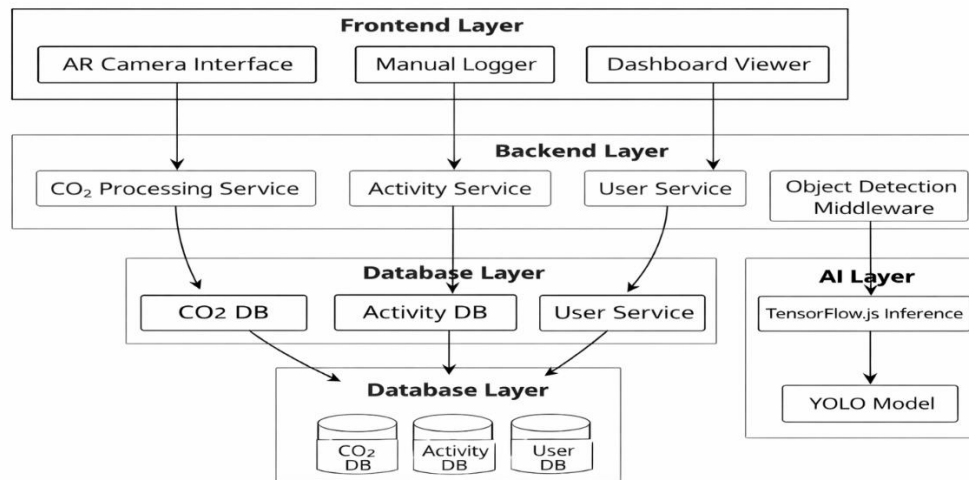


Fig. 1. System Architecture

Figure 1: System Architecture of AR-Enhanced Carbon Footprint Tracking System

- **AI/ML Layer:**

This layer performs real-time object detection using YOLO and processes data using TensorFlow.js. It identifies objects from the live camera feed and sends the detected class information for emission calculation.

- **Database Layer:**

The database stores user data, detected object records, carbon emission datasets, and activity logs. SQLite is used for development, while PostgreSQL is used for production.

These layers work together to enable real-time object detection, carbon emission estimation, data storage, and visualization in an efficient and scalable manner.

IV. IMPLEMENTATION:

A. User Module

The User Module manages registration, login authentication, and secure sessions using JWT. It enables profile updates and access to personalized dashboards, logs, and achievements, while ensuring that only authorized users can use the AR scanner and access stored emission data, thereby maintaining privacy and security.

B. AR Object Detection Module

The AR Object Detection Module enables real-time scanning through the device camera using WebRTC to capture live video. It processes the stream with YOLOv11 integrated with TensorFlow.js to detect transportation objects such as cars, motorcycles, and buses, and highlights them using AR overlays via the Canvas API. This module serves as the core component by providing instant and interactive object recognition.

C. Emission Calculation Module

Once an object is detected, the Emission Calculation Module estimates its carbon emission value by retrieving CO₂ factors from a structured dataset based on EPA and DEFRA guidelines. Using predefined formulas, it calculates the approximate emission level and displays the result in real time through the AR interface, providing immediate environmental feedback to users.

D. Manual Logging Module

The Manual Logging Module enables users to record daily activities when camera-based detection is not available. Users enter details such as travel distance, electricity usage, or household activities through structured forms, and the system converts them into CO₂ emission values using predefined rules. This ensures continuous carbon tracking without real-time scanning, enhancing system flexibility.

E. Database and Storage Module

The Database and Storage Module securely store and retrieves system data, including user credentials, detected object records, emission datasets, manual logs, and analytics results. SQLite is used in development, while PostgreSQL is used in production to ensure reliability, scalability, and performance. Structured data management supports efficient dashboard updates and smooth system operation.

F. Dashboard and Analytics Module

The Dashboard and Analytics Module visualize carbon emission data through interactive charts, graphs, and summary reports. It displays daily, weekly, and monthly statistics with comparisons and trend analysis. By showing how user activities affect overall carbon footprint, it promotes informed decisions and environmentally responsible behaviour.

V. ALGORITHM:

Proposed AR-Based Carbon Emission Estimation Workflow

INPUT: Real-time camera stream with optional user activity data

OUTPUT: Estimated carbon emissions displayed and stored for analysis

BEGIN

 INITIALIZE system and load object detection model

 LOAD emission dataset D // D: Emission Dataset

 WHILE system is active DO

 /* Real-Time Object Detection */

 CAPTURE frame F from video stream V // F: Frame, V: Video Stream

 PREPROCESS frame F for object detection

 DETECT objects in F using trained model

 FOR each detected object i DO

 IF confidence $P_i > T$ THEN // P_i : Confidence Score, T: Threshold

 IDENTIFY class label C_i // C_i : Object Class

 MAP C_i to emission factor E_{Fi} // E_{Fi} : Emission Factor

 COMPUTE $CO_{2i} = E_{Fi} \times U$ // CO_2 : Carbon Dioxide, U: Usage factor

 DISPLAY C_i and CO_{2i} using AR overlay // AR: Augmented Reality

 STORE (C_i , CO_{2i} , timestamp)

 END IF

 END FOR

 /* Manual Entry Module */

 IF user provides activity A THEN // A: User Activity (travel, electricity, etc.)

 MAP activity A to emission factor E_{Fj}

 COMPUTE $CO_{2j} = E_{Fj} \times A_j$ // A_j : Activity value

 STORE (A, CO_{2j} , timestamp)

 END IF

 /* Data Management and Analytics */

 UPDATE dashboard with stored emission data

 GENERATE emission trends and summaries

 PROVIDE suggestions based on emission levels

 END WHILE

 RETURN cumulative emission results

END

VI. RESULTS:

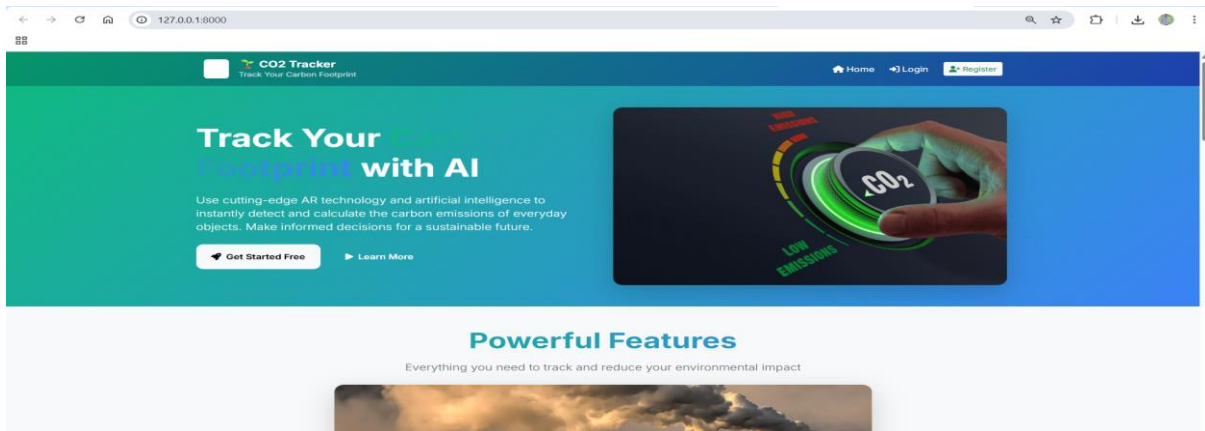


Figure 2: User Interface of the Proposed Carbon Footprint Tracking System

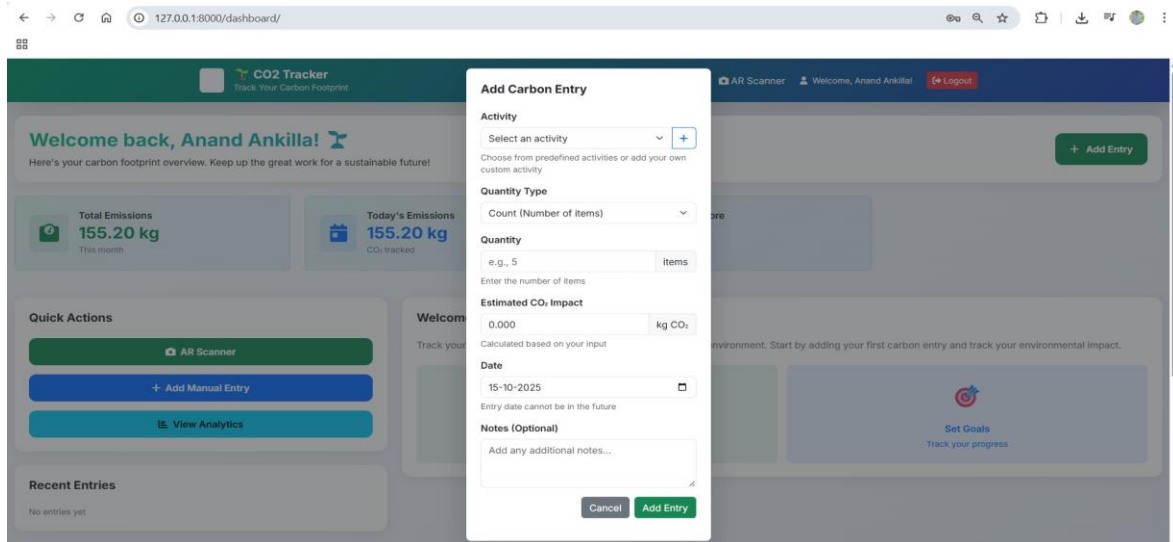


Figure 3: Manual Carbon Emission Entry Interface

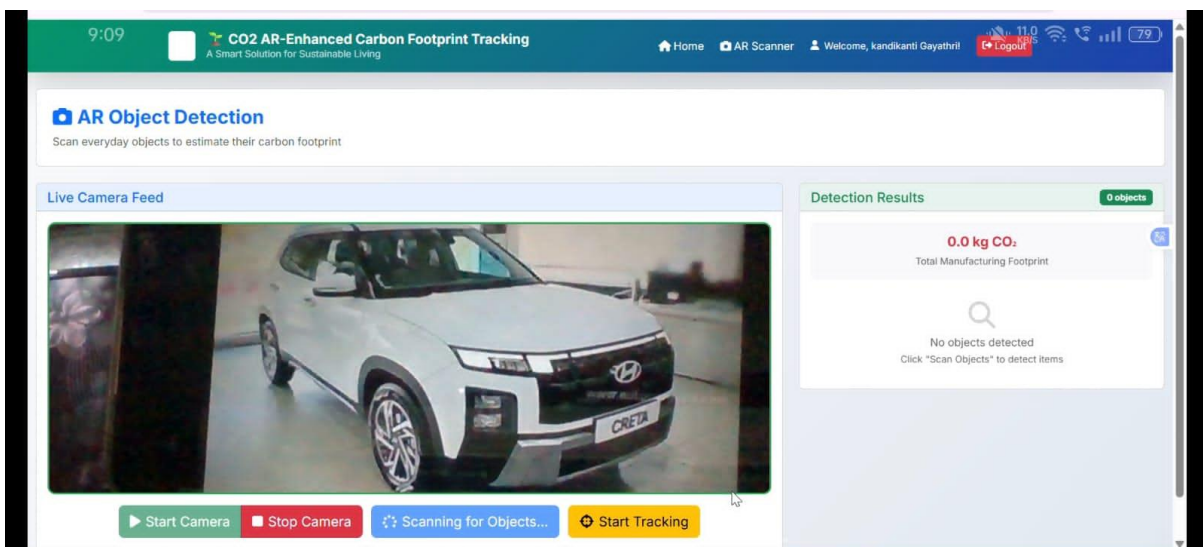


Figure 4: AR Scanner Interface for Object Detection and Emission Tracking

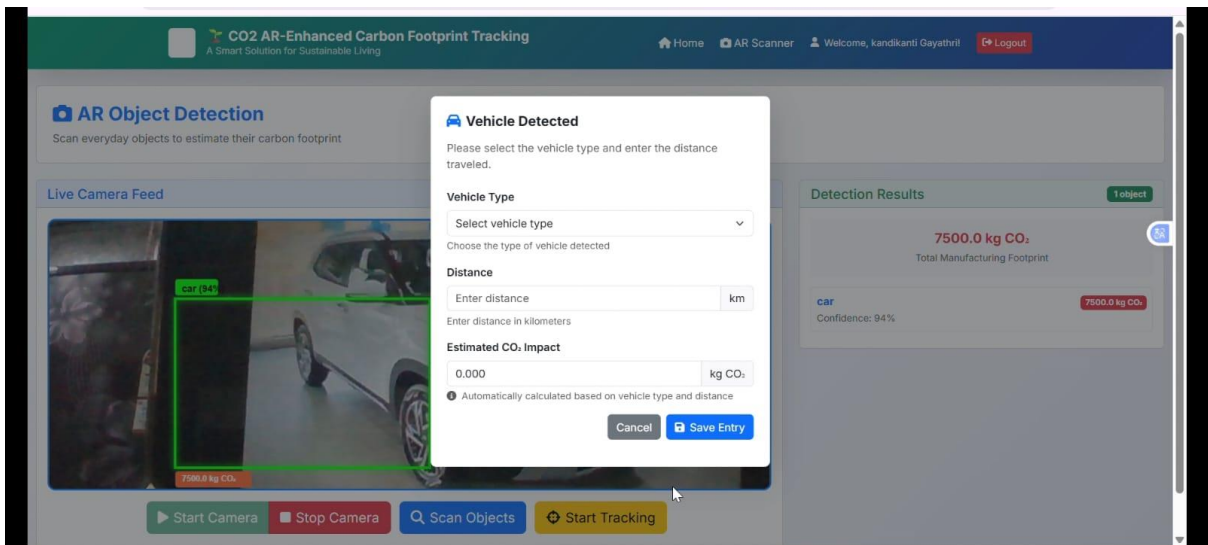


Figure 5: Real-Time Detection Result with CO₂ Estimation

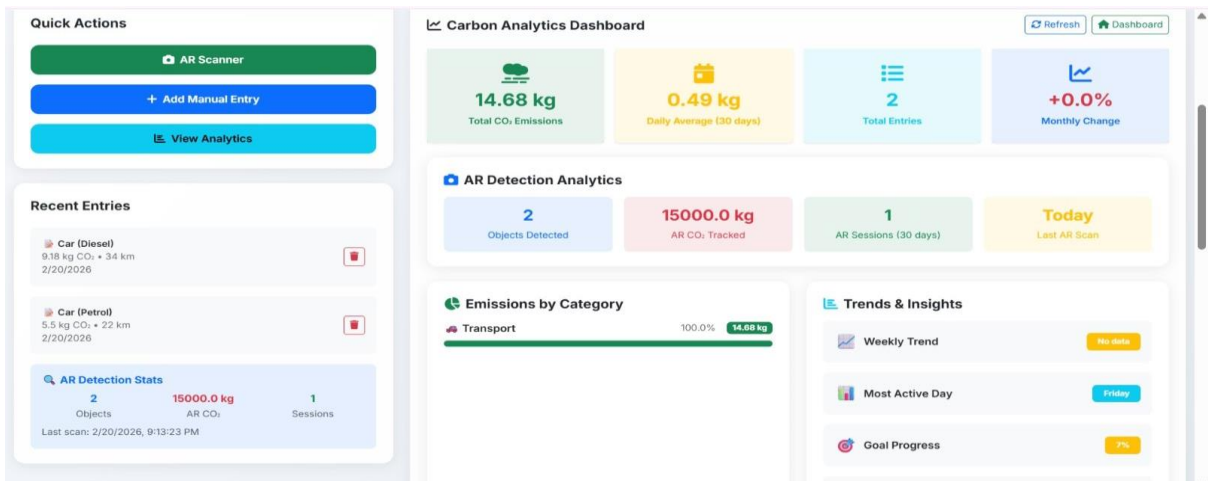


Figure 6: Carbon Analytics Dashboard

VII. CONCLUSION:

This research presents an innovative approach to carbon footprint tracking by transforming traditional manual methods into an instant and interactive experience. By integrating Augmented Reality (AR) with real-time object recognition, the proposed system enables users to easily visualize and understand their carbon emissions in a practical and engaging manner. Unlike conventional tools, the system provides immediate feedback and personalized insights, enhancing user awareness and participation. Overall, the project contributes a user-centred and technology-driven solution aimed at promoting sustainable behaviour and supporting global efforts toward environmental conservation.

REFERENCES:

- [1] L. Lanelongue, J. Grealey, and M. Inouye, "The Green Algorithms: Quantifying the Carbon Footprint of Computation," *Advanced Science*, vol. 8, no. 12, 2021.
- [2] D. Patterson, J. Gonzalez, Q. Le, et al., "Carbon Emissions and Large Neural Network Training," *arXiv preprint arXiv:2104.10350*, 2021.
- [3] G. Jocher et al., "YOLO: Ultralytics Object Detection and Segmentation," GitHub repository, 2023.
- [4] M. Abadi et al., "TensorFlow: Large-Scale Machine Learning on Heterogeneous Systems," 2016.

- [5] W. Shi, J. Cao, Q. Zhang, et al., “Edge Computing: Vision and Challenges,” *IEEE Internet of Things Journal*, vol. 3, no. 5, pp. 637–646, 2016.
- [6] R. Azuma, “A Survey of Augmented Reality,” *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 4, pp. 355–385, 1997.
- [7] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, “You Only Look Once: Unified, Real-Time Object Detection,” *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2016.
- [8] A. P. McAuley et al., “Augmented Reality for Environmental Monitoring: A Survey,” *Journal of Environmental Informatics*, vol. 41, no. 1, pp. 12–28, 2023.
- [9] J. Minx, G. Baiocchi, T. Wiedmann, et al., “Carbon Footprints of Cities and Other Human Settlements,” *Nature Climate Change*, vol. 3, pp. 524–528, 2013.
- [10] Y. Wang, X. Chen, and H. Liu, “Marker-less Augmented Reality Tracking Using Deep Learning Techniques,” *IEEE Access*, vol. 9, pp. 112233–112245, 2021.