ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1687

IMPROVE Floodeye: Integrated Mobile System for Predictive Routing and Optimized Vehicle Navigation Using Ensemble Algorithm

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Publication Date: 2025/08/05

Abstract: The increasing frequency of urban flooding necessitates effective solutions for real-time navigation and predictive routing. This study presents IMPROVE Floodeye, an integrated mobile system designed to optimize vehicle navigation using internet of things IOT and ensemble algorithm. The system collects and analyzes real-time flood data from various sources, including weather reports, sensors, and user-generated inputs. By leveraging an ensemble algorithm that combines machine learning models, it predicts flood-prone areas and recommends alternative routes to ensure safe and efficient travel. The mobile application provides users with dynamic updates, visual flood maps, and adaptive route suggestions. Evaluation results demonstrate the system's accuracy in flood prediction and routing optimization compared to conventional navigation systems. The implementation of IMPROVE Floodeye offers a scalable and intelligent solution for urban flood management, enhancing commuter safety and reducing travel time. Based on the findings on the Floodeye system, the following recommendations are proposed to enhance its effectiveness, sustainability, and scalability. These include the integration of various types of sensors to more accurately measure flood levels and rainfall intensity, and the expansion of the routing scheme to cover a wider geographic area for improved data coverage. Additionally, incorporating community-based reporting can boost situational awareness and the reliability of flood monitoring. Collaborating with local government units (LGUs) is essential to support system deployment, integrate data with disaster response protocols, and foster public trust and adoption. Lastly, conducting long-term system evaluations is crucial for guiding future improvements and ensuring the continued sustainability of the project.

Keywords: *Internet of Things, Flood Prediction, Vehicle Navigation, Ensemble Algorithm, Mobile System, Predictive Routing, Real-time Data Analysis.*

How to Cite: Brent V. Dita (2025) IMPROVE Floodeye: Integrated Mobile System for Predictive Routing and Optimized Vehicle Navigation Using Ensemble Algorithm. *International Journal of Innovative Science and Research Technology*, 10(7), 2912-2917. https://doi.org/10.38124/ijisrt/25jul1687

I. INTRODUCTION

Flooding has long been a significant concern in the Philippines, particularly in low-lying areas such as Sta. Cruz, Laguna. The municipality is highly vulnerable to flooding due to its proximity to Laguna de Bay, frequent typhoons, and heavy rainfall, which often result in road closures, traffic congestion, and public safety hazards (David et al., 2020). Inadequate drainage systems and rapid urbanization have further exacerbated the issue, making real-time flood monitoring and efficient transportation management crucial for the community (Alconis & Capuno, 2021).

With the increasing severity and unpredictability of floods due to climate change, intelligent navigation systems have become a necessity (Santos et al., 2022). Traditional flood monitoring and navigation solutions rely heavily on manual reporting and static flood maps, which are often outdated and ineffective in dynamic weather conditions (Lopez & Tuazon, 2019). To address this challenge, the development of a Floodeye: Integrated Mobile System for Predictive Routing and Optimized Vehicle Navigation with an Ensemble Algorithm is proposed. This system aims to enhance real-time flood monitoring, provide adaptive route recommendations, and optimize vehicle navigation in flood-prone areas.

The Floodeye system integrates geospatial data, machine learning models, and ensemble algorithms to analyze flood risks and suggest the safest and most efficient routes for commuters, emergency responders, and logistics providers. By utilizing an ensemble algorithm, the system combines multiple predictive models, such as Decision Trees, Random Forest, and Neural Networks, to enhance the accuracy of flood

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forecasting and route optimization (Garcia & De Guzman, 2023; Yusof et al., 2020). The mobile application component provides real-time updates, route suggestions, and flood alerts, ensuring that users can make informed travel decisions.

The implementation of this system in Sta. Cruz, Laguna is expected to significantly reduce the impact of flooding on mobility and safety. It will assist local government units (LGUs), disaster response teams, and the general public in mitigating the risks associated with sudden floods (Cruz & Ramos, 2021). The study aligns with smart city initiatives and contributes to the broader goal of leveraging artificial intelligence (AI) and Internet of Things (IoT) technologies for sustainable urban planning and disaster resilience (UN-Habitat, 2022; Dela Cruz & Navarro, 2024).

By conducting this research, the study seeks to improve urban flood management, enhance disaster preparedness, and optimize transportation efficiency in Sta. Cruz, Laguna. The insights and technological advancements derived from this project may also be extended to other flood-prone areas, ultimately contributing to a more resilient and adaptive infrastructure across the country (Marquez et al., 2025).

➢ *This Study Aims to Develop and Implement IMPROVE Floodeye:*

Integrated Mobile System for Predictive Routing and Optimized Vehicle Navigation with an Ensemble Algorithm in Sta. Cruz, Laguna. Specifically, it seeks to:

- To develop a solar powered wireless sensor network, incorporated with a rain gauge sensor for determining the amount of rain pouring, water level sensor for monitoring the height of the flood and camera to capture the actual footage on the area.
- To develop a mobile application that gives the best route, manages and disseminates all the information from the wireless sensor network, and gives the actual footage of the area where the device is located
- Implement an ensemble algorithm for flood prediction and route optimization by combining multiple machine learning models to improve forecasting accuracy and enhance travel efficiency.
- Evaluate the system's effectiveness and accuracy through real-world testing and simulations in flood-prone areas of Sta. Cruz, Laguna.

II. RELATED LITERATURE

This section presents an overview of recent research activities where data from flood hazards, artificial intelligence, internet of things and other new technologies has been used for knowledge and analysis.

Based on the study of Nguyen, Le, et al. (2020) titled "Flood forecasting and early warning systems using machine learning and IoT technologies", which explored the integration of sensor-based data collection and machine learning algorithms for real-time flood monitoring and prediction. Their system employed water level sensors, rainfall gauges, and image capture devices to gather environmental data, which was then transmitted via a wireless network to a centralized server. The study compared several machine learning models, including Random Forest, Support Vector Machine (SVM), and Long Short-Term Memory (LSTM) networks, to determine the most accurate prediction model for flood levels. Results showed that LSTM provided the highest accuracy in forecasting flood trends. This aligns with the proposed project's approach of deploying sensor-equipped devices and testing multiple machine learning algorithms to optimize flood height prediction, as well as its integration with mobile applications for real-time user access and route planning based on flood conditions.

According to the study by Jain, Kothyari, and Raju (2021) titled "IoT-based real-time flood monitoring and alert system using sensor networks," the researchers designed a flood detection system incorporating ultrasonic sensors to measure water levels, a rain gauge for precipitation data, and a GSM-based alert system. The system was powered by solar panels and included a mobile interface for real-time updates. The authors emphasized the effectiveness of using multiple sensors for reliable flood monitoring and early warning. Their findings showed improved response times and accurate flood detection in semi-urban areas. This supports the proposed project's integration of float sensors, tipping bucket rain gauges, solar-powered units, and mobile interfaces for real-time visualization of flood data and alerts.

Pham, Hoang, et al. (2022) in their work "Application of machine learning algorithms in flood prediction based on IoT sensor data," investigated the performance of several machine learning models such as Decision Trees, Random Forests, and Artificial Neural Networks on real-time sensor data collected from flood-prone regions in Vietnam. Their study found that Random Forest outperformed other models in terms of prediction accuracy, especially when combined with sensor inputs such as water height, rainfall intensity, and environmental images. The researchers also highlighted the importance of model testing and validation to select the most suitable algorithm for specific geographic contexts. This aligns closely with your project's goal of testing different ML algorithms to determine the most accurate method for predicting flood heights.

III. METHODOLOGY

The Floodeye: Integrated Mobile System for Predictive Routing and Optimized Vehicle Navigation with Ensemble Algorithm is a smart flood monitoring and navigation system designed to enhance disaster resilience and improve urban mobility in Sta. Cruz, Laguna. The system leverages real-time flood data, geospatial analysis, and artificial intelligence (AI)-driven predictive modeling to provide safe and efficient routing solutions for commuters, emergency responders, and logistics providers during flood events.

The development of the FloodEye Device includes a independent power source which is solar powered system which includes solar panel, battery and charge controller. The Microcontroller used in the device is the Raspberry Pi to process the data from different inputs like camera, float sensor and precipitation sensor and sends the data to the Firebase

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Database. It is a cloud-based database solutions provided by Firebase, a platform developed by Google for building and managing mobile and web applications

At the core of Floodeye System is an ensemble algorithm (voting ensemble) being develop/ tested using Azure Machine learning platform. This algorithm integrates multiple machine learning models—such as Random Forest, Decision Trees, and Neural Networks—to enhance the accuracy of flood forecasting and route optimization. The system gathers data from IoT-based flood sensors (floodeye), and send the data to the firebase database where the data are being stored and access through the mobile application develop using Apache Cordova a mobile development platform with Hypertext Markup Language, Cascading Style Sheets, and JavaScript. This platform is used in making mobile applications allows users to receive flood alerts, adaptive navigation suggestions, and traffic updates, empowering them to make informed travel decisions.

The proponent used the HERE We Go Maps and Navigation in routing application. The Here We Go Maps can integrate recommendation platform that san provide better routing. It can also add waypoints that is needed in making different routes on the application to be made. Also, the mapping services for this platform is free.

Through real-world implementation and testing, Floodeye will be evaluated based on its functionality, reliability, usability, efficiency, portability and maintainability. The evaluators are divided in three categories, the ICT experts, and disaster related agency and from ordinary citizen from the area. The project ultimately seeks to establish a cost-effective and scalable flood navigation system, which can be adopted by other flood-prone municipalities, contributing to a more resilient and technology-driven urban infrastructure.

IV. RESULTS AND DISCUSSION

The proposed project will have three FloodEye device deploy in different places/route that has the capability to capture the image of the area, can detect the height of flood using float sensor and rain rate using tipping bucket sensor. The unit will be power by solar panel and lithium battery controlled by a solar charge controller. The project will be incorporated with a mobile application wherein the user can see the condition of the area using the images taken by the camera and the reading of the sensors. There is also a prediction of flood height using machine learning algorithm, different algorithms will be tested to see the best algorithm that fits the prediction service and a routing services that is based on the flood height of the area.

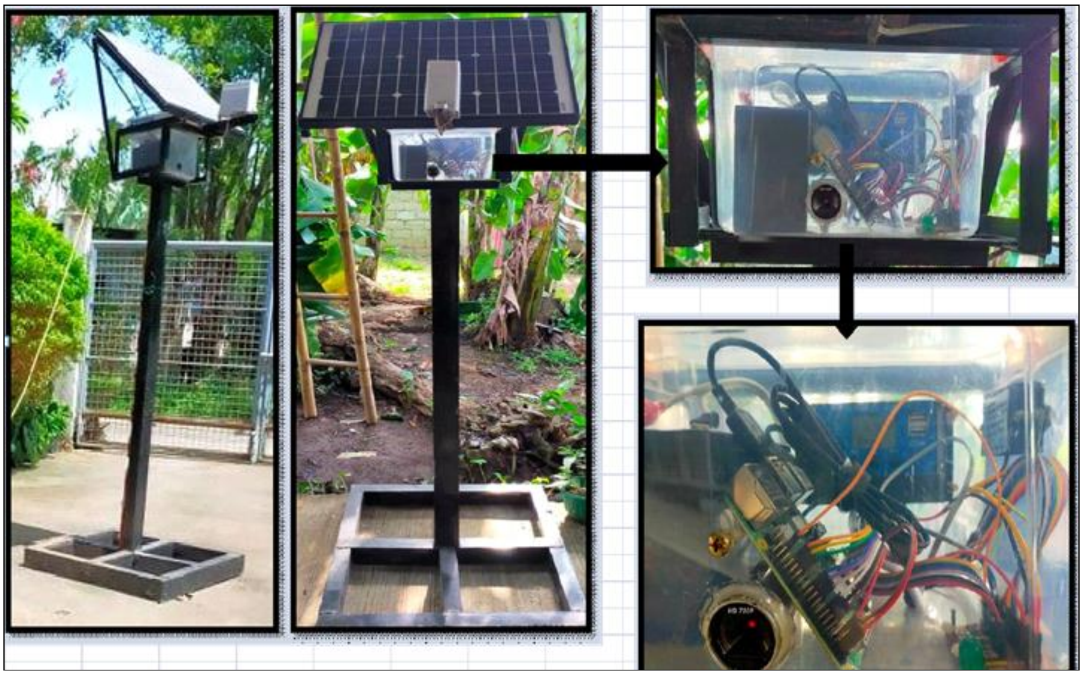

Fig 1. Floodeye Device

Figure 1 shows floodeye device. The Frame of the Microcontroller Unit is made of Metal. It has a square base that holds the whole unit. It also has a vertical bar that holds the float sensors and the top part of the frame holds the microcontroller (R Pi), the precipitation sensor, camera, battery, charge controller and the solar panel.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1687

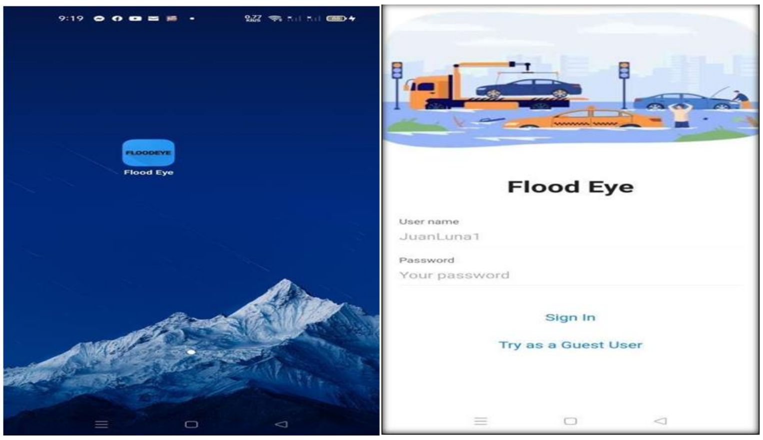

Fig 2-a Icon of Mobile Application Fig 2-b Login Window

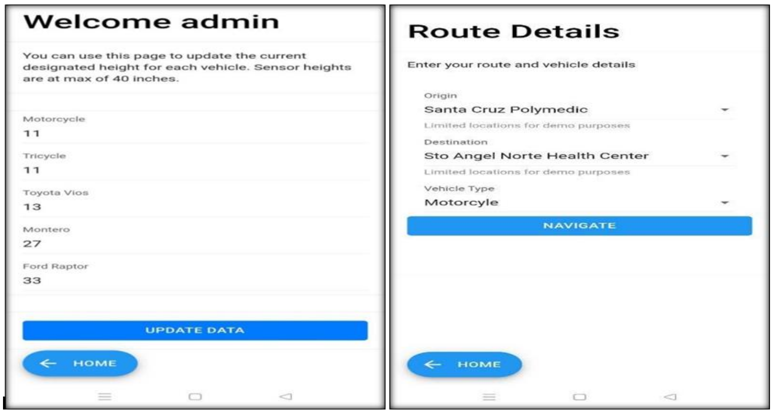

Fig 2-c Admin Window Fig 2-d Guest User Window

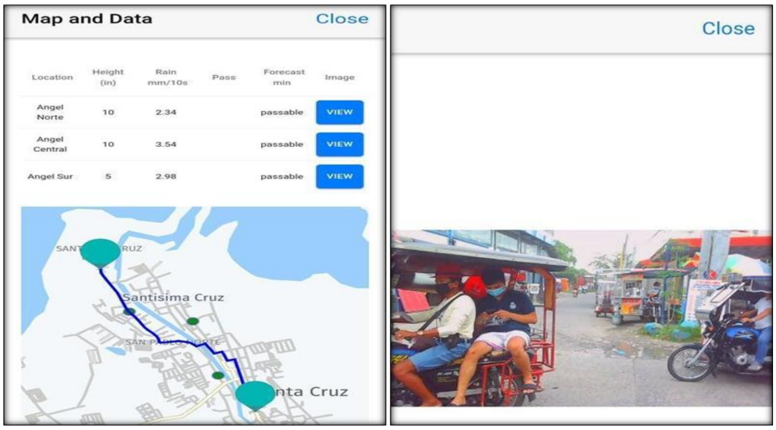

Fig 2-e Map And Data Window Fig 2-f Image Window

Fig 2. Floodeye Mobile Application user interface

Figure 2 shows the user interface of the mobile application after installing on the phone. In figure 2-a show the icon after installing the application on the mobile phone, figure 2-b show the log in window where the use will choose whether to try as guest or admin. If the user corectly encoded the username and password he will go to the admin window shows in figure 2-c where the user can change the maximum wading depth of the vehicle, which is the deepest water it can safely drive through without risking damage. In figure 2-d whos the Guest user window where the user will set the origin, destination and vehicle to be use by the user. After clicking the navigate button the user will go to the Map and Data window where the user will see the different locations and the different data from the floodeye device like the flood height, rate of precipitation. This window also show if road where the device is located is passable or not. On the lower part of the window the user can see the map that give route based on the condtion of the flood. The three green circle are the locatoin where the floodeye device is located. Lastly if the user click the view button, the image button will appear. This window will give an image where the floodeye device is located to see the actual situation on the area.

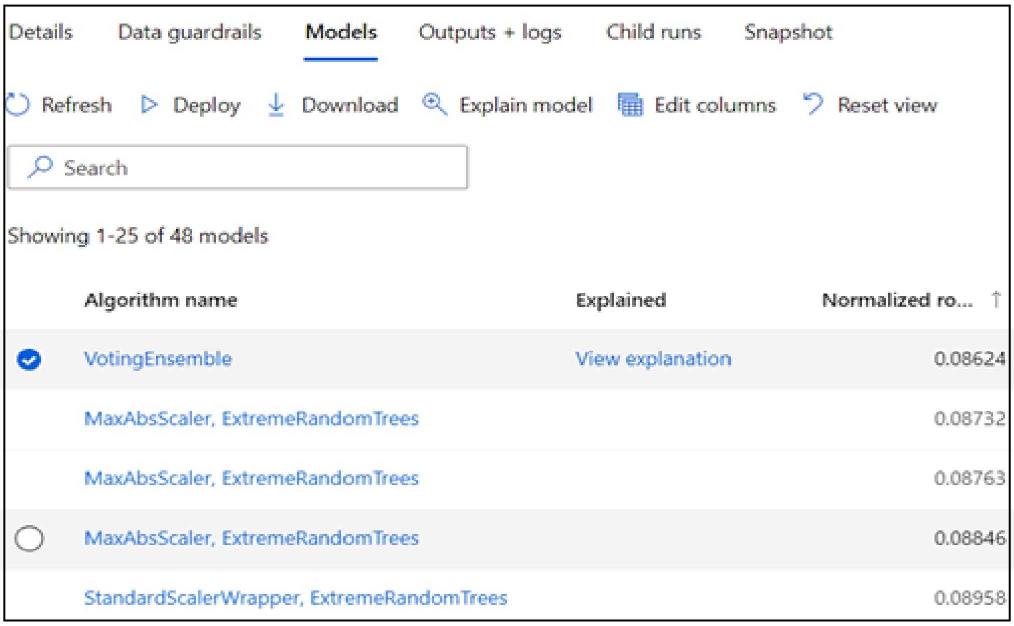

Fig 3 Screenshot of Azure ML user interface

Figure 3 shows the test results for Azure machine learning using different algorithms. Based on the results, the algorithm to be used in predicting the flood height was determined which has the lowest NRMSE (Normalize Root Mean Square Error). From the figure above, VotingEnsemble have the lowest NRMSE with a value of 0.08624 that makes them gives the best value in prediction.

Table 1 Summary of Evaluation

Criteria	Respondents Rating			Overall Rating
Criteria	Disaster Agency	ICTS expert	CivicSociety	
Functionality	4.6	4.8	4	4.51
Reliability	4.5	4.5	4.5	
Usability	4.8	4.8	4.8	
Efficiency	4	4	4	
Portability	4.6	4.8	4.2	
Maintainability	4.8	4.8	4.8	
Average Rating per respondent category	4.55	4.61	4.38	

Table 1 shows the summary of evaluation conducted by the proponent. The ICTS experts have the highest evaluation point the is 4.55, next is disaster agencythat have 4.61 and the lowest if from the group of civic society that is 4.38, and the overall rating is 4.51. This concludes that all respondents are very satisfied with the system performance.

RECOMMENDATIONS

Based on the findings on the floodeye system, several actionable recommendations are outlined to ensure the effectiveness, sustainability, and scalability of the project:

- Utilize various types of sensors to accurately measure flood levels and rainfall intensity.
- Implement the routing scheme across a broader geographic area to enhance data coverage and system effectiveness.
- Incorporate Community-Based Reporting to improve situational awareness and enhance the accuracy of flood monitoring.
- Collaborate with Local Government Units (LGUs) to support system deployment, ensure data integration with local disaster response protocols, and enhance public trust and adoption.
- Conduct Long-Term System Evaluation to guide future improvements and ensure sustainability.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1687

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