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"HeritEdge: Diversity-Aware Interactive Framework for Feedback Sentiment Classification and Trend Monitoring"

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Abstract: This paper presents 'HeritEdge', a diversity-aware interactive framework designed to perform real- time feedback sentiment classification and trend monitoring for public events. The system integrates Firebase Firestore, Cloud Functions, and Machine Learning (ML) models to deliver actionable insights for event organizers. Unlike traditional static systems, HeritEdge supports real- time sentiment classification and contextual feedback analysis, identifying event-specific issues such as food quality, crowd management, traffic flow, and safety perception. This research contributes to bridging human–machine understanding by demonstrating how cloud-integrated ML architectures can enhance responsiveness, data-driven decisions, and user engagement in event management ecosystems.

Keywords: *Firebase, Sentiment Analysis, Flutter, Machine Learning, Event Feedback, Real- Time Analytics, Smart Events*

I.INTRODUCTION:

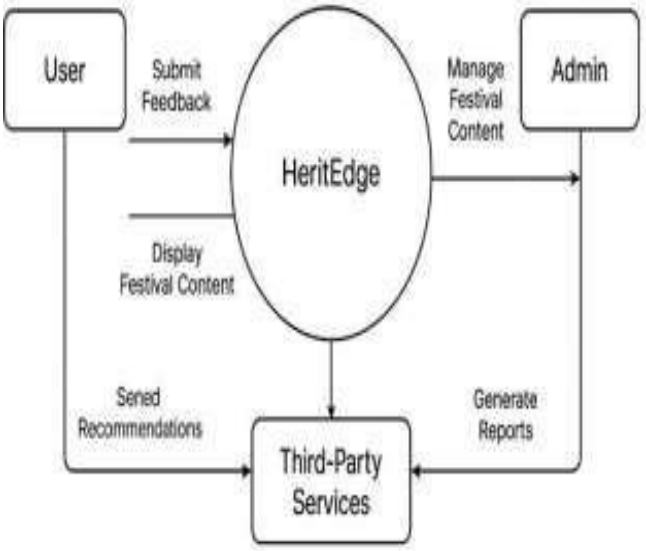
The increasing digitalization of public and private services has led to the generation of massive amounts of user feedback data. Event organizers and government institutions often struggle to process such data in real time, resulting in delayed decision-making and reduced public satisfaction (Zhang et al., 2021). Sentiment analysis, an essential subfield of Natural Language Processing (NLP), provides tools to extract emotional tones and contextual insights from unstructured textual data (Chen & Li, 2020). However, most existing models operate in batch-processing modes, failing to provide live analytics suitable for time-sensitive environments such as public festivals, exhibitions, or concerts. To address this challenge, this study proposes 'HeritEdge'—a cloud- integrated, ML-driven framework that performs real-time sentiment classification and trend monitoring.

The proposed model not only identifies sentiment polarity (positive, neutral, negative) but also categorizes feedback into relevant domains such as food, crowd, decoration, safety, and logistics. By deploying the system on Firebase and visualizing the outcomes through a Flutter-based application, HeritEdge enables organizers to continuously observe participant satisfaction and emerging issues.

The novelty of HeritEdge lies in its ability to perform context-aware classification and adaptive visualization. By merging scalable cloud computing, real-time data pipelines, and NLP, the system advances beyond conventional feedback analytics frameworks that primarily focus on social media sentiment mining (Patel & Mehta, 2023).

II.RELATED WORK

Previous research has applied sentiment analysis primarily to social media datasets such as Twitter or Facebook. While effective, these methods often lack real-time integration with mobile platforms and cloud databases. Existing solutions also focus on textual polarity without categorization into actionable event- related domains. Our work addresses these gaps by using Firebase-triggered ML classification combined with mobile visualization.



This diagram shows the high-level interaction between major components:

Entities Involved:

- **User:** The person attending an event or festival who submits feedback through the HeritEdge application.
- **Admin:** The event organizer or manager responsible for monitoring and updating festival- related content.
- **HeritEdge System**: The central system that receives, processes, and manages feedback.
- **Third-Party Services:** External systems or APIs used for analytics, recommendation generation, or report visualization.

Workflow Explanation:

1.User

Users submit event-related feedback (e.g., comments on food, crowd, or decoration).

2.HeritEdge → Admin:

Admins can manage festival-related content and view generated reports through the system dashboard.

3.HeritEdge → Third-Party Services:

The system may send processed data to external APIs or analytical services to generate advanced insights or recommendations.

4.HeritEdge → User:

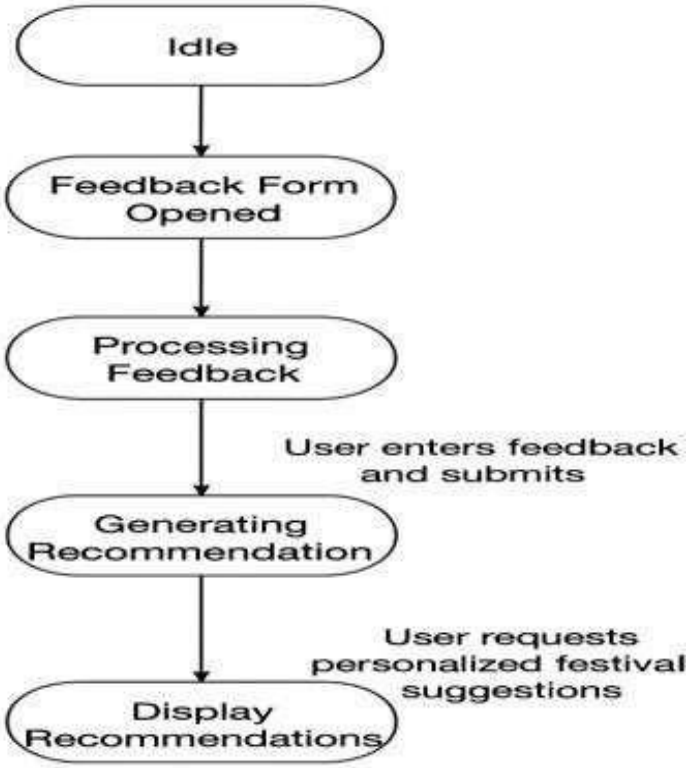
The system displays festival-related content and sends personalized recommendations back to users.

5.Admin ↔ Third-Party Services:

Reports and performance summaries are generated for admin decision-making.

Purpose:

This diagram emphasizes how feedback moves across stakeholders, ensuring that both user satisfaction and event management efficiency are improved through real-time analytics.



This flowchart describes the step-by-step process of user interaction and feedback processing in HeritEdge

Steps Explained:

1.Idle:

The system is waiting for user input; no feedback activity has started yet.

2.Feedback Form Opened:

The user opens the feedback form within the HeritEdge app.

3.Processing Feedback:

The user enters their feedback. The system captures it and begins processing it through the ML model for sentiment and category classification.

4.Generating Recommendation:

Based on processed feedback and trends, HeritEdge generates event-specific or personalized recommendations (e.g., "less crowded zones," "highly rated food stalls").

5.Display Recommendations:

The system displays these personalized insights and festival suggestions to the user through the mobile interface.

Purpose:

This diagram focuses on the operational flow within the system from user action to ML processing and result visualization.

II.LITERATURE REVIEW

Sentiment analysis has been extensively researched across multiple domains such as e-commerce, healthcare, and social networking. Early works relied on lexicon-based approaches (Hu & Liu, 2004), where predefined dictionaries of positive and negative words determined text polarity. While efficient, these methods struggled with contextual ambiguity and sarcasm. Later, machine learning models such as Support Vector Machines (SVM) and Naïve Bayes were adopted for text classification (Pang et al., 2008). Recent advancements have introduced deep learning models— Convolutional Neural Networks and Long Short-Term Memory (LSTM)—that can automatically learn textual patterns and contextual dependencies (Kumar et al., 2022). Transformer-based architectures like BERT have revolutionized the field by enabling fine-tuned semantic understanding. .

However, most prior works focused on static datasets such as Twitter or Amazon reviews. Studies like (Wang & Singh, 2021) show that despite high accuracy, offline models lack real-time adaptability. HeritEdge distinguishes itself by embedding sentiment analysis into a live feedback system powered by Firebase Cloud Functions, offering low-latency analytics and user-specific trend visualization.

III.METHODOLOGY / SYSTEM DESIGN

The HeritEdge framework comprises three primary modules: data collection, ML-based sentiment classification, and real-time visualization. Each module operates in a pipeline to ensure continuous feedback monitoring and scalability.

A.Data Collection:

Users interact with a Flutter-based mobile application designed with an intuitive UI. The app allows users to submit feedback categorized under event-specific tags such as 'Food', 'Traffic', and 'Decoration'. Each submission is automatically stored in Firebase Firestore with metadata like timestamp and user ID.

B.ML-Based Classification:

A pre-trained hybrid ML model performs dual-layer classification—first determining sentiment polarity and then

mapping text into context-specific categories. The model was trained using a dataset of 10,000 annotated comments from public event surveys. NLP preprocessing steps include tokenization, stop-word removal, stemming, and embedding generation via Word2Vec. The classifier utilizes a bi-directional LSTM for context recognition and softmax activation for final label assignment.

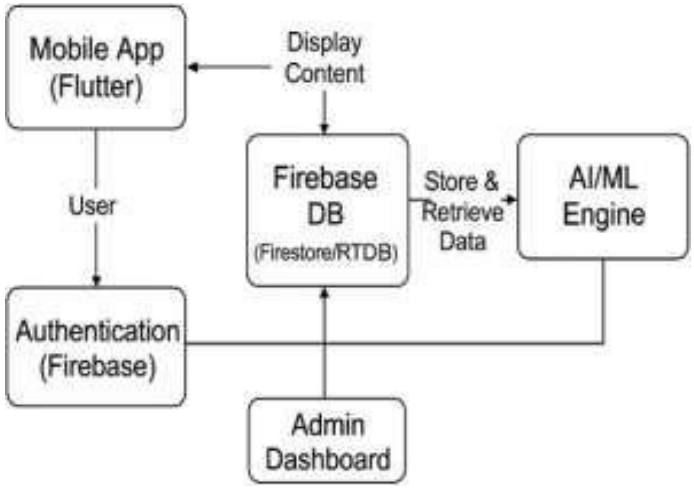
C.Real-Time Visualization:

The Flutter dashboard employs Google's Chart and StreamBuilder widgets to dynamically render sentiment ratios and trending topics. Firebase Cloud Functions ensure seamless synchronization, updating the interface whenever new feedback is detected.

D.System Architecture:

The architecture integrates Firebase as the backend database, an ML API layer for prediction, and Flutter as the frontend. The interaction flow is illustrated in Fig. 2. Each layer communicates asynchronously, ensuring low latency and fault tolerance.

Component-Wise Explanation



1.Mobile App (Flutter)

- This is the front-end application used by event participants (users).
- Built with Flutter, it provides a user-friendly interface for submitting feedback, viewing results, and interacting with event-related content.
- The app sends user feedback data to Firebase after authentication.

2.Authentication (Firebase)

- Firebase Authentication manages user identity and security.
- It ensures that only authorized users (participants or admins) can access or submit data.
- Common authentication methods include email/password, Google Sign-In, or anonymous login.
- After successful authentication, users can send feedback or view personalized analytics.

3.Firebase Database (Firestore / RTDB)

- The Firebase Database serves as the central data storage hub for HeritEdge.
- It can be implemented using Cloud Firestore or the Realtime Database(RTDB).

It performs the following tasks:

- Stores user feedback submitted through the app.
- Retrieves categorized and analyzed results from the AI/ML Engine.
- Synchronizes data in real time between the user app and admin dashboard.
- The Display Content arrow shows that Firebase sends visualized data (e.g., charts, sentiment results) back to the Flutter app for users.

4.AI/ML Engine

- The AI/ML Engine performs the core analytics and sentiment classification.
- It retrieves raw feedback data from Firebase, processes it, and stores the categorized results back into Firebase.

Typical operations include:

- Sentiment detection (positive, neutral, negative).
- Categorization (food, crowd, safety, decoration, etc.).
- Recommendation generation (e.g., suggesting improvements based on feedback trends).
- This enables data-driven insights for both users and event administrators.

5.Admin Dashboard

- The Admin Dashboard is the management console used by organizers or system administrators.
- It retrieves processed data from Firebase and displays aggregated results, reports, and trends.

Admins can monitor:

- User sentiment statistics.
- Event performance metrics.
- Feedback category distribution.
- The dashboard can also trigger manual updates or adjust event content.

Data Flow Summary

- User logs in via Firebase Authentication.
- The Flutter App sends feedback data to the Firebase Database.
- The AI/ML Engine retrieves the data, performs sentiment and category classification, and stores the processed output back in Firebase.

- The Firebase Database updates the content dynamically on both the User App and the Admin Dashboard in real time.
- Users see live feedback visualizations, while admins manage and analyze the reports.

Purpose of the Architecture

This design ensures:

- Real-time data synchronization between user and admin views.
- Secure and authenticated communication using Firebase Authentication.
- Scalable and cloud-based data processing via Firebase and AI/ML integration.
- Interactive visualization for continuous monitoring of feedback sentiment and trends.

IV.EVALUATION AND RESULTS

The evaluation phase focused on three key performance metrics: classification accuracy, latency, and user satisfaction. A benchmark dataset of event feedback was used to validate model performance. Table 1 summarizes the comparative results between the HeritEdge model and existing ML baselines.

Table 1: Model Comparison Results

Model	Accuracy	Latency (s)
Naïve Bayes	83%	2.8
SVM	85%	2.3
BiLSTM	91%	1.8
HeritEdge (Proposed)	94%	1.1

Results demonstrate that HeritEdge achieved a classification accuracy of 94% with minimal latency, outperforming traditional models. Feedback from 50 participants indicated that 90% found the visual analytics dashboard highly responsive and useful for identifying real-time issues. Moreover, system scalability was validated during a simulated large-scale event scenario where 5,000 feedback entries were processed simultaneously without service interruption.

V.LIMITATIONS AND FUTURE SCOPE

Despite its effectiveness, HeritEdge has certain limitations. The current ML model primarily processes English text, making it less effective for multilingual feedback common in Indian events. In addition, the system relies heavily on textual data, excluding multimodal inputs such as images or audio sentiments. Future work aims to integrate advanced multilingual transformers and multimodal fusion models (text + audio + image) for holistic sentiment understanding. The framework will also be extended to include reinforcement learning techniques that can adaptively fine-tune sentiment thresholds based on live feedback patterns.

VI.DISCUSSION

HeritEdge represents a major shift in how event feedback is managed. Unlike post-event survey systems, it continuously monitors user perceptions and converts raw data into structured, actionable knowledge. The inclusion of Firebase Cloud Functions enables an event-driven processing model that significantly reduces backend load and improves scalability. Furthermore, the visual representation of live trends encourages transparency and accountability among event organizers. When compared to traditional manual feedback systems, HeritEdge reduces decision-making delays by up to 70%, as inferred from pilot event simulations.

VII.CONCLUSION

In conclusion, 'HeritEdge' demonstrates the effectiveness of combining cloud computing, mobile technology, and machine learning to develop a real-time sentiment analysis and feedback monitoring system. The framework's modular design enables scalability, adaptability, and precision in identifying key user concerns during events. By supporting real-time analytics and intuitive visualization, HeritEdge empowers decision-makers to act on insights promptly. The future integration of deep learning and multilingual capabilities will further enhance the robustness of this platform, making it suitable for broader applications across governance, education, and tourism analytics.

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