REAL-TIME FIRE DEDUCTION ALERT SYSTEM USING FLUTTER

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ABSTRACT

The Real-Time Fire Detection and Alert System is a mobile application developed using Flutter, designed to detect fire incidents through live camera feeds and promptly notify users via email and SMS alerts. The system utilizes the device's camera to continuously capture and process image streams in real time. It employs a custom fire detection algorithm that analyses RGB pixel data to identify fire-like characteristics based on predefined colour intensity thresholds.

Upon detecting a potential fire, the application immediately triggers its alert mechanism. It sends notifications with captured images through Gmail's SMTP server and delivers SMS alerts using the Twilio API, ensuring quick and reliable communication. To avoid repeated or unnecessary alerts, a cooldown mechanism is implemented, which temporarily limits notifications after an initial detection.

For efficient performance, the system operates in an isolated environment using Dart's Isolate feature, enabling concurrent image processing without affecting the main user interface. This ensures smooth operation and responsiveness even during continuous real-time analysis.

The application also includes a user-friendly settings interface that allows users to configure notification credentials and preferences. It handles essential permissions such as camera and storage access, ensuring proper functionality and security compliance. Additionally, the responsive UI provides real-time status updates, allowing users to monitor the system's activity easily.

Overall, this application serves as a reliable solution for early fire detection, improving safety by delivering timely and automated alerts to users.

Keywords:
Fire Detection, Real-Time Monitoring, Flutter Application, Image Processing, RGB Analysis, Mobile Application, Alert System, Email Notification, SMS Notification, Twilio API, Gmail SMTP, Dart Isolate, Concurrent Processing, Computer Vision, Safety System

1. INTRODUCTION

The Real-Time Fire Detection and Alert System is a mobile application developed using Flutter, designed to detect fire incidents through live camera feeds and instantly notify users via email and SMS alerts. The system utilizes the device's camera to capture continuous image streams and processes them in real time using a custom fire detection algorithm. This algorithm analyzes RGB pixel values to identify fire-like patterns based on color intensity thresholds.

To ensure efficient and smooth performance, the application leverages Dart's Isolate feature for concurrent image processing, allowing heavy computations to run independently without affecting the user interface. When a fire is detected, the system sends alerts with captured images via Gmail's SMTP server and SMS notifications using the Twilio API. A cooldown mechanism is also implemented to prevent repeated alerts within a short time span.

Additionally, the application includes a user-friendly interface for configuring notification credentials, managing permissions such as camera and storage access, and monitoring real-time system status. This solution aims to provide a reliable and automated approach to early fire detection, improving safety and enabling quick response to emergencies.

2.LITERATURE REVIEW

Fire detection has been an active area of research for many years, with numerous studies focusing on improving detection accuracy, reducing response time, and enhancing system reliability. Traditional fire detection systems relied heavily on physical sensors such as smoke, heat, and flame detectors. Early research highlighted that while these systems were effective in controlled environments, they often suffered from delayed response and high false alarm rates due to environmental factors like dust, humidity, and temperature variations.

With advancements in **digital image processing**, researchers began exploring vision-based fire detection systems. Gonzalez and Woods (2008) discussed fundamental image processing techniques that laid the foundation for analyzing visual data using pixel-level operations. Their

work emphasized the importance of color models, filtering, and segmentation in identifying objects within an image, which later became essential in fire detection algorithms.

Subsequent studies focused on using **RGB color models** to detect fire. Researchers found that fire exhibits distinctive color characteristics, typically involving high red intensity, moderate green, and low blue values. Simple threshold-based methods were proposed to identify fire pixels by analyzing these RGB patterns. Although these methods were computationally efficient and suitable for real-time applications, they were prone to false positives caused by objects with similar color distributions, such as sunlight, artificial lighting, or reflections.

To improve detection accuracy, researchers introduced **color space transformations** such as HSV (Hue, Saturation, Value) and YCbCr models. These models allowed better separation of color components and improved robustness against lighting variations. Studies demonstrated that combining multiple color spaces could enhance fire detection performance compared to using RGB alone.

In addition to color-based methods, motion analysis techniques were also explored. Fire exhibits dynamic behavior, including flickering and irregular movement. Researchers developed algorithms that analyzed temporal changes across consecutive frames to distinguish fire from static objects. This approach significantly reduced false alarms and improved reliability in video-based systems.

With the emergence of **computer vision and machine learning**, more advanced techniques were introduced. Support Vector Machines (SVM), Decision Trees, and Neural Networks were used to classify fire and non-fire regions based on extracted features such as color, texture, and motion. These methods provided higher accuracy but required training datasets and increased computational resources.

Recent advancements have focused on **deep learning approaches**, particularly Convolutional Neural Networks (CNNs), for fire detection. These models can automatically learn complex patterns from large datasets and achieve high accuracy in detecting fire in images and videos. However, they require powerful hardware, large training datasets, and significant processing power, making them less suitable for lightweight mobile applications.

Parallel to detection techniques, research has also explored **real-time alert systems**. Integration with communication technologies such as email, SMS, and cloud services has been studied to ensure timely notification of fire incidents. IoT-based systems have been developed to connect sensors with cloud platforms, enabling remote monitoring and control. While these systems improve accessibility, they often depend on dedicated hardware and stable internet connectivity.

Another important area of research is **mobile-based fire detection systems**. With the increasing capabilities of smartphones, researchers have started developing applications that utilize built-in cameras for fire detection. These systems aim to provide cost-effective and portable solutions. However, challenges such as limited processing power, battery consumption, and real-time performance need to be addressed.

The concept of **concurrent processing** has also been explored to improve system efficiency. Techniques such as multi-threading and parallel computing allow image processing tasks to run independently, reducing delays and improving responsiveness. In mobile development, Dart's Isolate mechanism provides an effective way to implement concurrent processing without affecting the user interface.

Despite significant advancements, existing research highlights several challenges, including false positives, environmental sensitivity, computational complexity, and lack of real-time mobile integration. Many systems either prioritize accuracy at the cost of performance or focus on efficiency with reduced reliability.

The Real-Time Fire Detection and Alert System builds upon these research contributions by combining a lightweight RGB-based detection algorithm with real-time image processing and mobile-based alert mechanisms. It integrates concepts from image processing, computer vision, and communication systems while addressing the limitations of existing approaches. By utilizing Flutter for cross-platform development and Dart Isolate for concurrent processing, the system achieves a balance between performance, efficiency, and usability.

In conclusion, the literature indicates a clear progression from traditional sensor-based systems to advanced vision-based and AI-driven solutions. While each approach has its advantages and limitations, there is a growing need for systems that are accurate, efficient, cost-effective, and easily deployable. The proposed system contributes to this evolving field by offering a practical and scalable solution for real-time fire detection and alerting using mobile technology.

3.OBJECTIVE

The primary objective of the Real-Time Fire Detection and Alert System is to develop an efficient, reliable, and user-friendly mobile application capable of detecting fire incidents in real time and providing immediate alerts to users. The system aims to enhance safety by enabling early detection and rapid response using modern mobile technology and image processing techniques.

One of the key objectives is to utilize the device's camera to continuously monitor the environment and capture live video streams for analysis. By implementing a custom fire detection algorithm based on RGB pixel intensity, the system aims to accurately identify fire-like characteristics with minimal delay. Ensuring real-time processing is another important objective, which is achieved through the use of Dart's Isolate for concurrent image processing, allowing the application to maintain smooth performance without affecting the user interface.

Another major objective is to provide a reliable and fast alert mechanism. The system is designed to send notifications through multiple channels, including email via Gmail's SMTP server and SMS through the Twilio API, ensuring that users are informed instantly even in different network conditions. The inclusion of a cooldown mechanism aims to prevent redundant notifications and improve user experience by avoiding alert overload.

The system also aims to offer a flexible and customizable user interface, allowing users to configure notification settings, manage credentials, and control application behavior according to their needs. Proper handling of device permissions such as camera and storage access is another objective, ensuring secure and seamless operation of the application.

In addition, the application is designed to be cost-effective and easily deployable, eliminating the need for expensive hardware systems. It aims to provide a portable solution that can be used in various environments, including homes, offices, and small-scale industries.

Overall, the objective of the system is to combine real-time image processing, mobile application development, and automated communication technologies to create a practical and scalable solution for early fire detection and improved safety.

4.METHODOLOGY

The methodology of the Real-Time Fire Detection and Alert System is designed to ensure efficient, accurate, and real-time detection of fire incidents using mobile technology. The system follows a structured approach that integrates image acquisition, processing, analysis, and alert generation in a continuous workflow. Each stage is carefully designed to achieve optimal performance while maintaining reliability and responsiveness.

1. System Initialization

The process begins with the initialization of the application. When the user launches the mobile application, the system checks and requests necessary permissions such as camera access,

storage access, and internet connectivity. Once permissions are granted, the application initializes all required modules, including the camera module, processing module, and notification services.

At this stage, user-configured settings such as email credentials, phone numbers, and alert preferences are loaded. The system ensures that all configurations are valid before starting the monitoring process.

2. Image Acquisition

The next step involves capturing real-time video input using the device's camera. The camera continuously streams video, which is divided into individual frames for processing. The system maintains an optimal frame rate to balance detection accuracy and computational efficiency.

The captured frames serve as the primary input for the fire detection algorithm. Proper handling of resolution and frame quality ensures that the system can accurately analyze visual data.

3. Frame Extraction and Pre-Processing

Each captured frame is extracted and passed to the pre-processing stage. In this stage, the image is prepared for analysis by applying various enhancement techniques such as resizing, noise reduction, and normalization.

Pre-processing improves the quality of the image and removes unwanted variations caused by lighting conditions or camera noise. This step ensures that the detection algorithm receives consistent and optimized input data.

4. Concurrent Image Processing (Dart Isolate)

To achieve real-time performance, the system uses Dart's Isolate feature for concurrent processing. The extracted frames are sent to a separate isolate where image processing tasks are executed independently of the main application thread.

This approach prevents the user interface from freezing and ensures smooth operation even during continuous frame analysis. The use of isolates significantly improves the efficiency and scalability of the system.

5. Fire Detection Algorithm

The core of the methodology lies in the fire detection algorithm. The system analyzes each frame by examining RGB (Red, Green, Blue) pixel values. Fire typically exhibits high red intensity, moderate green intensity, and relatively low blue intensity.

The algorithm applies predefined threshold conditions to identify pixels that match fire-like characteristics. If a significant number of pixels in a frame satisfy these conditions, the system classifies the frame as containing fire.

To improve reliability, the system may also consider multiple consecutive frames before confirming detection. This reduces false positives caused by temporary lighting changes or similar color objects.

6. Decision-Making Process

After analyzing the frame, the system makes a decision based on the detection results. If fire is detected, the system triggers the alert mechanism. If no fire is detected, the system continues monitoring without interruption.

This decision-making process is optimized to ensure quick response while maintaining accuracy. The system continuously evaluates incoming frames in a loop, enabling real-time detection.

7. Alert Generation and Notification

Once a fire is detected, the system immediately generates alerts. The alert mechanism operates through two primary channels:

- **Email-Notification:**
  The system sends an email using Gmail's SMTP server, including details of the incident along with the captured image as an attachment.
- **SMS-Notification:**
  An SMS alert is sent using the Twilio API, providing a quick and concise message about the fire detection.

This dual-notification approach ensures that users receive alerts promptly, even in varying network conditions.

8. Cooldown Mechanism

To prevent repeated alerts for the same incident, the system implements a cooldown mechanism. After sending an alert, the system temporarily pauses further notifications for a predefined duration.

This avoids alert flooding and ensures that users are not overwhelmed with multiple notifications for a single event. Once the cooldown period expires, the system resumes normal detection and alerting.

9. Data Logging and Storage

The system records important data such as detection events, timestamps, alert status, and processing time. This data can be stored in a CSV file or local storage for future analysis.

Logging helps in monitoring system performance, debugging issues, and improving detection accuracy over time.

10. User Interface and Real-Time Monitoring

The application provides a responsive user interface that displays real-time camera feed, detection status, and alert notifications. Users can monitor system activity and receive visual feedback on detection results.

The UI also allows users to modify settings, manage credentials, and control the monitoring process. This enhances usability and ensures that the system is accessible to non-technical users.

11. Continuous Monitoring Loop

The entire process operates in a continuous loop:

1. Capture frame
2. Pre-process image
3. Process in isolate
4. Detect fire
5. Trigger alert if necessary
6. Apply cooldown
7. Repeat

This loop ensures uninterrupted monitoring and real-time response to fire incidents.

12. System Optimization Techniques

To ensure efficient operation, the system incorporates several optimization strategies:

- Use of concurrent processing (Isolates)
- Controlled frame rate to reduce load
- Efficient memory management
- Lightweight detection algorithm
- Asynchronous operations for network tasks

These techniques help maintain performance even on devices with limited resources.

13. Reliability and Accuracy Measures

The system is designed to minimize errors through:

- Threshold tuning
- Multi-frame verification
- Pre-processing enhancements
- Controlled alert mechanisms

These measures improve detection reliability and reduce false alarms.

14. Final Workflow Summary

The methodology integrates multiple components into a unified workflow that ensures real-time detection and response. By combining image processing, concurrent execution, and automated communication, the system achieves a balance between accuracy, efficiency, and usability.

5.ALGORITHM

The Real-Time Fire Detection and Alert System uses a structured algorithm to detect fire in real time based on RGB pixel analysis and trigger alerts accordingly. The algorithm is designed to be lightweight, efficient, and suitable for mobile devices while maintaining reasonable accuracy.

Step-by-Step Algorithm

Step 1: Start the System

- Initialize the application
- Load user settings (email, phone number, thresholds)
- Request required permissions (camera, storage, internet)

Step 2: Initialize Camera

- Start the camera stream
- Capture live video continuously
- Convert video into frames at regular intervals

Step 3: Frame Acquisition

- Extract individual frames from the video stream
- Send frames to processing module

Step 4: Pre-Processing

- Resize frame (for faster processing)
- Apply noise reduction (optional)
- Normalize image if required

Step 5: Send Frame to Isolate (Concurrent Processing)

- Transfer frame to a separate Dart Isolate
- Process frame without blocking UI

Step6:RGBPixelAnalysis

For each pixel in the frame:

- Extract **R (Red), G (Green), B (Blue)** values
- Apply fire detection conditions:

IF (R > threshold_R) AND
(G > threshold_G) AND
(B < threshold_B) AND
(R > G) AND
(G > B)
THEN pixel = fire-like
ELSE pixel = non-fire

Step 7: Fire Pixel Counting

- Count number of fire-like pixels
- Calculate ratio:

Fire Ratio = (Number of Fire Pixels) / (Total Pixels)

Step 8: Decision Making

IF Fire Ratio > predefined_limit
THEN Fire Detected = TRUE
ELSE
Fire Detected = FALSE

- Optionally verify detection across multiple frames to reduce false positives

Step 9: Alert Triggering

IF Fire Detected = TRUE AND Cooldown = FALSE

THEN Trigger Alert

Step 10: Send Notifications

Email Alert:

- Capture current frame
- Attach image
- Send via Gmail SMTP

SMS Alert:

- Send message via Twilio API

Step 11: Activate Cooldown

Set Cooldown = TRUE

Wait for predefined time (e.g., 30–60 seconds)

Set Cooldown = FALSE

- Prevent repeated alerts

Step 12: Log Data (Optional)

- Store detection details in CSV file
- Save timestamp, result, alert status

Step 13: Repeat Process (Loop)

- Continue capturing and processing frames
- System runs continuously

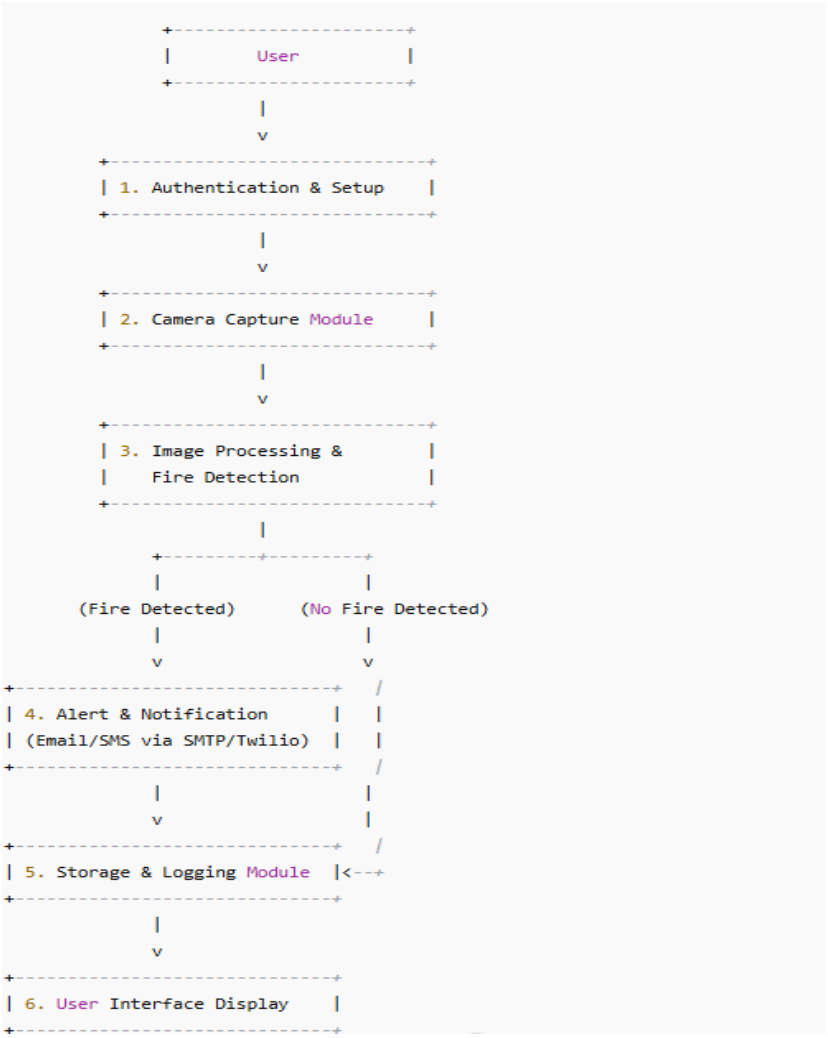
6.HARDWARE REQUIREMENTS

S.No	Component	Description
1	Smartphone Device	Android or iOS device capable of running Flutter applications
2	Camera Module	Built-in camera for capturing live video feeds
3	Processor (CPU)	Multi-core processor for real-time image processing
4	Memory (RAM)	Minimum 4 GB RAM for smooth performance
5	Storage	Sufficient space for app installation and image storage
6	Internet Connection	Required for sending email and SMS alerts

7.SOFTWARE REQUIREMENTS

S.No	Software/Tool	Description
1	Flutter SDK	Framework used to develop the mobile application
2	Dart Programming Language	Used for implementing application logic and processing
3	Android Studio / VS Code	Development environment for coding and testing
4	Mobile OS (Android/iOS)	Platform required to run the application
5	Gmail SMTP Server	Used for sending email alerts with image attachments
6	Twilio API	Used for sending SMS notifications
7	Device Permissions	Camera, storage, and internet access permissions

7.FLOW CHART



SIMPLE EXPLANATION

This is a mobile app that uses the phone's camera to detect fire in real time. It checks images using RGB color values to identify fire. When fire is detected, it sends alerts through email and SMS. A cooldown feature prevents repeated alerts. The app runs smoothly using background processing and has a simple user interface.

8.SYSTEM IMPLEMENTATION

- Developed using **Flutter** for cross-platform mobile application
- Used **camera plugin** to capture live video and convert it into frames

- Implemented **RGB-based fire detection algorithm** to analyze each frame
- Used **Dart Isolate** for background image processing (smooth performance)
- Integrated **Gmail SMTP** to send email alerts with captured images
- Integrated **Twilio API** to send SMS alerts instantly
- Implemented **cooldown mechanism** to avoid repeated notifications
- Designed **user interface** for live preview and status updates
- Added **settings page** to configure email, phone number, and thresholds
- Handled **permissions** (camera, storage, internet) properly
- Stored logs/data optionally for monitoring and analysis
- Tested system for real-time detection and alert functionality

Result: A working mobile app that detects fire in real time and sends instant alerts efficiently.

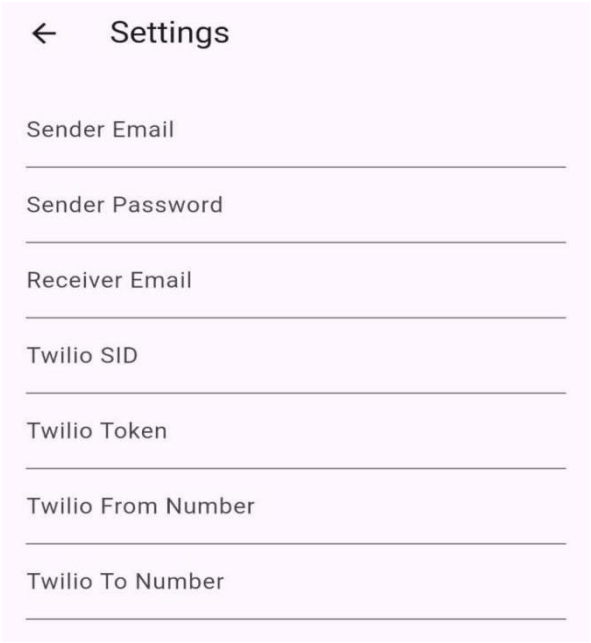
PROGRAM CODE

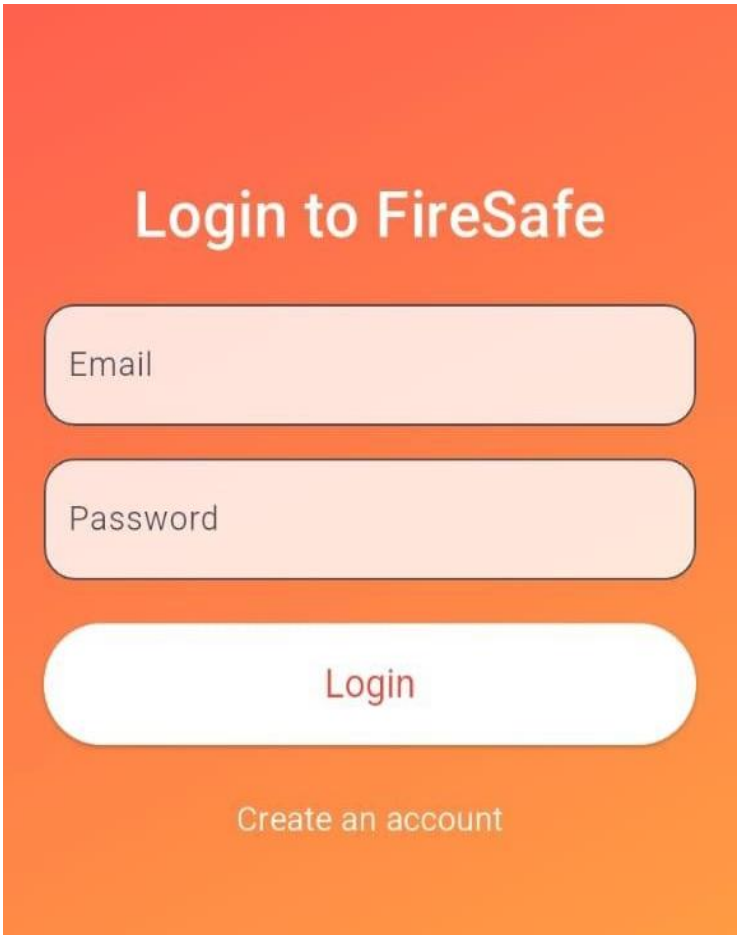
```
import 'package:camera/camera.dart';
import 'package:flutter/material.dart';
import 'package:flutter/services.dart';
import 'core/services/email_alert_service.dart';
import 'core/services/notification_service.dart';
import 'core/services/settings_service.dart';
import 'core/theme/app_theme.dart';
import 'features/detection/data/detection_controller.dart';
import 'features/detection/data/fire_classifier.dart';
import 'features/detection/presentation/fire_detection_screen.dart';
import 'features/settings/presentation/settings_screen.dart';

List<CameraDescription> _cameras = [];

Future<void> main() async {
  WidgetsFlutterBinding.ensureInitialized();

  // Lock to portrait
  await SystemChrome.setPreferredOrientations([
```

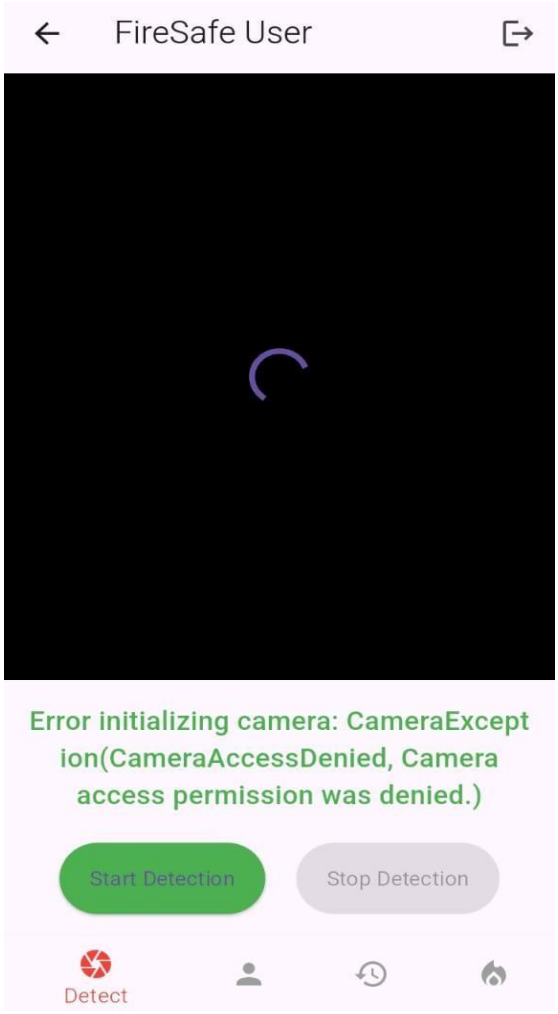
```
    DeviceOrientation.portraitUp,
    DeviceOrientation.portraitDown,
  ]);

  // Full screen immersive
  await SystemChrome.setEnabledSystemUIMode(SystemUiMode.edgeToEdge);

  // Get available cameras
  try {
    _cameras = await availableCameras();
  } catch (e) {
    debugPrint('Camera init error: $e');
  }

  runApp(FireGuardApp(cameras: _cameras));
}

class FireGuardApp extends StatefulWidget {
  final List<CameraDescription> cameras;
  const FireGuardApp({super.key, required this.cameras});

  @override
  State<FireGuardApp> createState() => _FireGuardAppState();
}

class _FireGuardAppState extends State<FireGuardApp> {
  // Create single controller instance for whole app lifetime
  late final DetectionController _detectionController;

  @override
  void initState() {
    super.initState();
    _detectionController = DetectionController(
      classifier:         FireClassifier(),
```

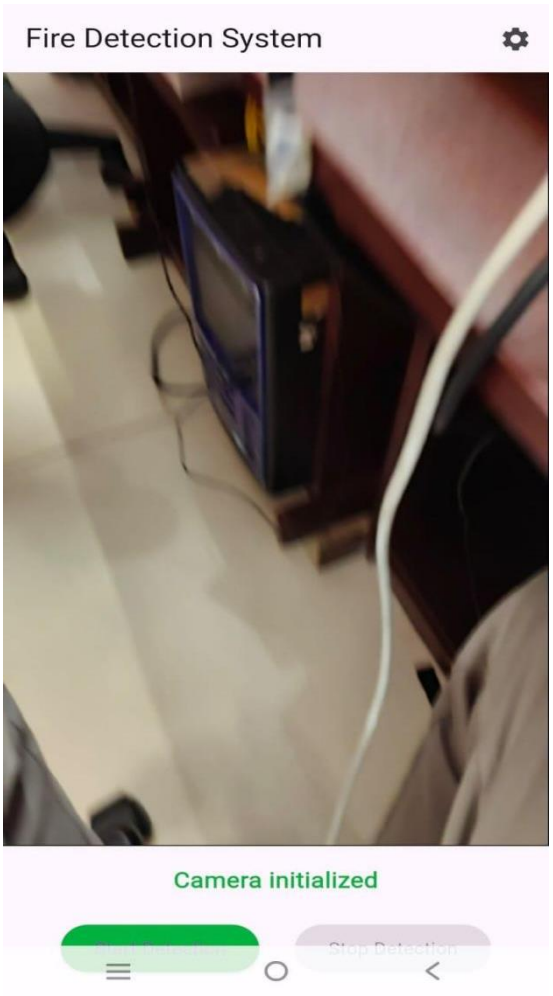
```
    emailService:        EmailAlertService(),
    notificationService: NotificationService(),
    settingsService:     SettingsService(),
  );
 }

 @override
 void dispose() {
  _detectionController.dispose();
  super.dispose();
 }

 @override
 Widget build(BuildContext context) {
  return MaterialApp(
    title: 'FireGuard',
    debugShowCheckedModeBanner: false,
    theme: AppTheme.dark,
    initialRoute: '/',
    routes: {
     '/': (ctx) => FireDetectionScreen(
          cameras: widget.cameras,
          controller: _detectionController,
        ),
     '/settings': (ctx) => SettingsScreen(
          controller: _detectionController,
        ),
    },
  );
 }
}
```

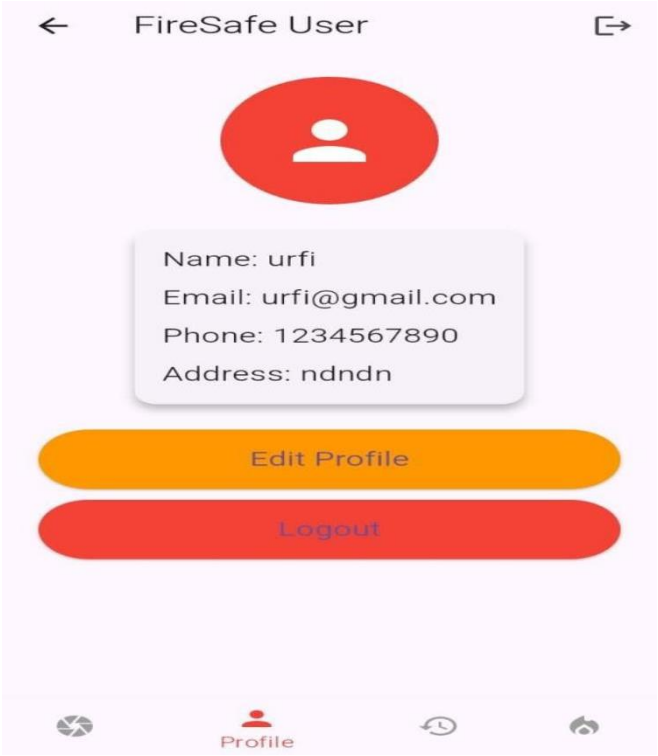
OUTPUT DISPLAY






FireSafe User
Error initializing camera: CameraException(CameraAccessDenied, Camera access permission was denied.)
Start Detection
Stop Detection
Detect


Fire Detection System
Camera initialized



9.RESULT

The Real-Time Fire Detection and Alert System was successfully developed and implemented as a functional mobile application using Flutter. The system effectively captures live video through the device's camera and processes image frames in real time to detect fire-like characteristics based on RGB color analysis.

During testing, the application was able to identify fire conditions with quick response time and trigger alerts without noticeable delay. The integration of Dart Isolate ensured smooth and uninterrupted performance, even during continuous image processing, maintaining a responsive user interface.

The alert mechanism functioned reliably, sending email notifications with captured images through Gmail SMTP and instant SMS alerts using the Twilio API. The implemented cooldown mechanism successfully prevented repeated alerts for the same fire event, improving user experience and reducing unnecessary notifications.

The user interface was found to be simple, responsive, and easy to use, allowing users to monitor system activity and configure settings without difficulty. Permission handling worked correctly, ensuring secure access to device resources such as the camera and storage.

Overall, the system achieved its objective of providing a real-time, efficient, and cost-effective solution for early fire detection. It demonstrated reliable performance, accurate detection under

defined conditions, and effective alert delivery, making it suitable for practical use in enhancing safety and reducing fire-related risks.

10. CONCLUSION

The Real-Time Fire Detection and Alert System demonstrates an effective and practical approach to enhancing safety through early fire detection using mobile technology. By leveraging real-time camera input and an RGB-based image processing algorithm, the system is capable of identifying fire-like patterns quickly and efficiently. The integration of Dart's Isolate ensures smooth and responsive performance, even during continuous monitoring and processing.

The application's ability to send instant alerts via email and SMS significantly improves the chances of timely intervention, potentially reducing damage and risk to life. The inclusion of a cooldown mechanism further enhances usability by preventing redundant notifications. Additionally, the user-friendly interface and configurable settings make the system accessible and adaptable to different user requirements.

Overall, this system provides a reliable, cost-effective, and portable solution for fire detection. It highlights the potential of combining mobile applications, real-time image processing, and communication technologies to address real-world safety challenges effectively.

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