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R E P O R T

for LOT 01 – Task 1

Develop a system for monitoring forest areas and early forest fire detection and development of filters for better visibility of forest fires during the night (IoT Technology)

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15.07.2023 Skopje

This report has been generated in accordance with the service contract for European external actions No. 07-39/3 dated 15.02.2023. The project titled "Modern tools for wildfire' and floods' risk punctual forecast and monitoring and innovative techniques for citizens' safeguard awareness and preparedness" has been the foundation for the completion of the tasks outlined within this report. Reference: PREVEN-T – CN2 – SO2.4 – SC049/TD3

This report serves as comprehensive documentation of the successful completion of Task 1.

Introduction: Overview of Contracted Tasks

The escalating threat of forest fires necessitates the implementation of robust monitoring and early detection systems. This report provides an exhaustive account of the development of a sophisticated Streamlit application, purpose-built for the continual monitoring of forested regions and the prompt detection of potential fire outbreaks. The system integrates advanced computer vision techniques, cutting-edge object detection models, high-performance servers, real-time cameras, and a strategic data management approach, all meticulously designed to ensure effective day and night forest fire detection.

The scope of this contracted project encompassed the development of a comprehensive Information System for early forest fire detection and warning capabilities, along with establishing seamless connectivity between the P2 laboratory and the information center of P3.

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This collaborative initiative aimed to harness advanced technologies, fostering cooperation between P2 and P3 to achieve a set of well-defined objectives.

This task centered around the creation and deployment of a sophisticated information system for monitoring forested regions and detecting forest fires in their nascent stages. The task entailed a series of intricately connected sub-objectives, each contributing to the realization of a robust and efficient early warning system.

- Development of IS plans and procedures,
- Development of a model system for monitoring architecture,
- Installation of the equipment,
- Installation of needed software,
- Implementing measures for information security and business continuity,
- Testing of the model and ensuring full capacity effectiveness,
- Surveillance, monitoring and control of recordings and alarms.

In essence, this task exemplifies a meticulously structured approach to developing an early forest fire detection and warning system. By aligning diverse sub-objectives, the task embodies the collaborative efforts of P2 and P3 to create a cutting-edge solution that merges technology, strategic planning, and environmental responsibility to protect forested ecosystems and promote community safety.

1. Development of IS Plans and Procedures and Model System for Monitoring Architecture

The development of the Streamlit application for forest area monitoring and early fire detection necessitates a systematic approach, beginning with the formulation of comprehensive

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Information Systems (IS) plans and procedures, followed by the intricate design of a model system for monitoring architecture.

1.1 Formulation of Information Systems Plans and Procedures:

1.1.1 Project Scope and Objectives:

The initiation of the project involved a detailed analysis of its scope and objectives. This phase aimed to delineate the geographic extent of the forest area to be monitored, the targeted detection capabilities, and the desired level of automation in the notification process. Clear objectives were established, encompassing the creation of an efficient monitoring system that would enhance forest fire detection.

1.1.2 Resource Allocation and Timeline:

During this phase, a meticulous resource allocation plan was developed, outlining the equipment, and resources required for each development stage. Additionally, a well-defined timeline was established, detailing milestones, deadlines, and dependencies to ensure timely progress and completion.

1.1.3 Risk Management Strategy:

Identifying potential risks and devising strategies to mitigate them is crucial. The IS plans included a comprehensive risk assessment, identifying factors that could impede the project's progress or compromise its success. Mitigation measures were devised, ranging from technical contingencies to addressing possible regulatory hurdles.

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1.1.4 Collaboration and Communication Framework:

A cooperation framework has been established, which delimits stakeholders' roles, responsibilities, and communication channels, including the P3 – National Park Pelister, administrators, and end users. This facilitated streamlined interactions and efficient problem-solving.

1.2 Design of Model System for Monitoring Architecture:

1.2.1 Hardware Component Selection and Procurement:

A critical aspect of the model system's design was the selection of suitable hardware components. Detailed research and evaluation led to the acquisition of high-performance servers, optimized for real-time data processing and object detection. The servers were equipped with cutting-edge processors, ample memory, and redundant power supplies to ensure consistent performance and failover capabilities.

1.2.2 Camera Placement Strategy:

Strategically positioning cameras within the forest area was imperative for comprehensive monitoring. Site assessments and environmental considerations played a key role in camera placement, ensuring optimal coverage and minimizing blind spots. High-resolution cameras with low-light capabilities were selected to capture detailed images in varying lighting conditions.

1.2.3 Integration of Object Detection Algorithms:

The integration of object detection algorithms was central to the model system's capabilities. The YOLOv5 model, known for its speed and accuracy, was chosen for real-time fire detection. The

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model was trained using an extensive fire and smoke instances dataset to ensure its proficiency in differentiating between normal and anomalous conditions.

1.2.4 User Interface Development:

The user interface, developed using the Streamlit framework, was designed for intuitive interaction. This phase involved the creation of visually appealing displays that showcased live camera feeds, real-time object detection outcomes, and system notifications. User experience considerations guided the interface's design, ensuring usability and ease of navigation.

1.2.5 Redundancy and Failover Mechanisms:

To uphold the system's reliability, redundancy and failover mechanisms were meticulously integrated. The primary server assumed real-time processing responsibilities, while the secondary server stood ready for seamless takeover in case of primary server failure. This ensured uninterrupted monitoring and early detection capabilities.

1.2.6 Secure Data Transmission and Storage:

The model system's architecture incorporated secure data transmission protocols to ensure the privacy and integrity of captured images and video feeds. High-speed network connections and encryption mechanisms were implemented to safeguard data during transmission and storage.

1.2.7 Automated Notification Integration:

Automated email notification systems were seamlessly integrated into the model system. Triggered by the YOLOv5 model's detection of fire instances, the notification system promptly

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alerted stakeholders with concise descriptions of anomalies and links to real-time camera feeds for further analysis.

2. Development of a Model System for Monitoring Architecture

This phase involves a multidimensional approach that ensures the effective integration of hardware and software components, enabling seamless real-time monitoring and early fire detection.

2.1 Real-Time Data Processing and Object Detection:

The crux of this sub-objective resides in the system's capability to process real-time data and swiftly detect potential fire incidents. This achievement stemmed from the seamless integration of advanced object detection algorithms with the YOLOv5 model. The selection of YOLOv5 was driven by its unparalleled speed and accuracy, both of which were vital for prompt fire detection in dynamic environments.

The YOLOv5 model served as the linchpin of the system's early fire detection prowess. Leveraging the principles of You Only Look Once (YOLO), this model was meticulously integrated into the system's architecture to process video feeds in real time. It is important to note that the system's real-time capability corresponds to one frame per second, where each frame is treated as an individual data point.

Before integration, the YOLOv5 model underwent an exhaustive training process. A diverse and extensive dataset containing a plethora of fire and smoke instances was meticulously curated. Through iterative training cycles, the model was fine-tuned to recognize subtle

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differentiators between normal and fire-related visual cues. This meticulous training approach ensured that the model's predictions aligned accurately with ground truth data.

The YOLOv5 model's exceptional speed allowed it to process each frame within milliseconds, ensuring that potential fire incidents were promptly identified. Its accuracy, borne out of extensive training, enabled the system to differentiate between benign fluctuations and genuine fire occurrences. The model's efficiency was particularly crucial for nighttime fire detection, where visibility challenges necessitate rapid and precise anomaly recognition.

The real-time video streaming, operating at one frame per second, enabled the system to extract and send a single frame via email in the event of a potential fire detection. This approach ensured that stakeholders received a clear visual representation of the anomaly, aiding swift assessment and decision-making. The streamlined approach minimized email data usage while providing vital information in a concise format.

2.2. Data Streaming and Storage Infrastructure:

The sub-objective unfolded with the deployment of two distinct high-performance servers, each designated for specialized roles. The first server found its home in the information center within NP Pelister, endowed with the responsibility of processing video feeds from the cameras deployed in the forested area. This server's primary focus was to carry out real-time data analysis, anomaly detection, and alert triggering.

The second server was stationed in the laboratory within P2 – Military Academy „General Mihailo Apostolski" in Skopje, serving a dual purpose. Firstly, it functioned as a training ground for refining the YOLOv5 model and optimizing its accuracy over time. This iterative training process aimed to yield increasingly precise fire and smoke detection results. Secondly, the second server stood as a contingency measure, poised to take over seamlessly in

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case the first server encountered any operational issues. This backup mechanism guaranteed uninterrupted system performance and maintained the application's reliability.

2.3. Integration of Automated Notification Systems:

An integral aspect of the architecture was the integration of automated email notification systems. This component, triggered by the Streamlit application model for detecting fire or smoke incidents, introduced additional codes in the Python programming language script and ensured that stakeholders were immediately informed of potential fire incidents. The integration involved establishing a communication channel between the system and the designated e-mail addresses. The goal was to send an e-mail to the affected party from a separate Outlook account with a separate application password, including an attachment - a frame image and text with the probability as an accuracy variable. on the fire.

3. Installation of Equipment

The successful implementation of the Streamlit application for forest area monitoring and early fire detection hinges upon the precise installation of essential hardware components. This phase encompasses the strategic placement of high-performance servers, the meticulous setup of real-time cameras, and the integration of networking infrastructure to establish a seamless data transmission pipeline.

3.1. Installation of High-Performance Servers:

3.1.1. Server Location and Configuration:

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The high-performance servers, chosen for their computational prowess, were strategically positioned in an environment conducive to efficient data processing and system management. Physical considerations such as temperature control and ventilation were taken into account to maintain optimal operating conditions. The servers were meticulously configured, ensuring that their hardware specifications aligned with the project's computational requirements.

3.1.2. Software Deployment:

The installation of required software components was a critical step in optimizing server performance. The Streamlit application, designed to provide an intuitive user interface, was deployed on one of the servers. This involved the installation and configuration of software frameworks, libraries, and dependencies to enable seamless application execution.

3.2 Setup of Real-Time Cameras:

3.2.1 Strategic Camera Placement:

The installation and positioning of real-time cameras within the forest area were executed with precision. Comprehensive site assessments, conducted in collaboration with environmental experts, informed the strategic placement of cameras to ensure maximum coverage of the targeted region. Cameras were located to minimize potential blind spots and to capture critical areas susceptible to fire outbreaks.

3.2.2 Hardware Configuration and Calibration:

Each camera underwent meticulous calibration to optimize its performance under varying lighting conditions. Image settings such as exposure, focus, and white balance were adjusted to

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ensure that captured footage provided clear and detailed visuals, crucial for accurate fire detection. The cameras' connectivity to the servers was established, enabling the seamless transmission of live video feeds.

3.3 Networking Infrastructure Integration:

3.3.1 Network Connectivity Setup:

The establishment of a robust networking infrastructure was pivotal to enabling real-time data transmission between cameras and servers. High-speed network connections, including wired and wireless options, were deployed to facilitate seamless data transfer. Network security protocols were implemented to safeguard data during transmission, ensuring the privacy and integrity of captured visuals.

3.3.2 Data Transmission Optimization:

Efforts were dedicated to optimizing data transmission efficiency. Techniques such as data compression and bandwidth management were employed to ensure that live video feeds could be seamlessly streamed to the servers without undue latency. This optimization was crucial in maintaining the real-time nature of the monitoring system.

3.4 Integration of Power Backup and Redundancy:

3.4.1 Power Redundancy Mechanisms:

To mitigate the risk of power disruptions, redundancy mechanisms were integrated. Uninterruptible Power Supply (UPS) systems and backup generators were strategically

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positioned to provide a stable power supply to the servers and cameras. This ensured that the system could operate seamlessly even during power outages.

3.4.2 Failover Strategies:

Redundancy extended to server failover strategies. The secondary server, equipped with an identical configuration, stood ready to assume processing responsibilities in case of primary server failure. This failover mechanism minimized downtime and ensured continuous monitoring and early fire detection capabilities.

4. Installation of Needed Software

The successful deployment of the Streamlit application for forest area monitoring and early fire detection relies on the meticulous installation and configuration of essential software components. This phase encompasses the integration of the Streamlit framework, the seamless integration of the YOLOv5 object detection model, and the establishment of a robust software environment for efficient system operations.

4.1 Integration of Streamlit Framework:

4.1.1 Software Framework Selection:

The development phase initiated the selection of the appropriate software framework for building the user interface. The Streamlit framework was chosen due to its user-friendly nature, real-time interaction capabilities, and compatibility with the project's objectives. This decision was based

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on Streamlit's ability to streamline the creation of intuitive and responsive interfaces tailored to forest monitoring and fire detection needs.

4.1.2 Framework Installation and Setup:

The integration of the Streamlit framework started with its installation on one of the high-performance servers. This included installing the necessary libraries, dependencies, and support packages to create a seamless development and runtime environment. The framework was configured to work seamlessly with other software components, ensuring compatibility and optimal performance. This application was developed based on the Python programming language where different codes were inserted depending on the requirements.

4.1.3 Interface Design and Development:

The user interface design was meticulously planned to provide stakeholders with a comprehensive view of the monitored area and facilitate intuitive interactions. Elements such as live camera feeds, real-time object detection results, and system notifications were strategically placed to offer easy access and insights. The interface was developed using Streamlit's interactive widgets, ensuring an engaging and responsive user experience.

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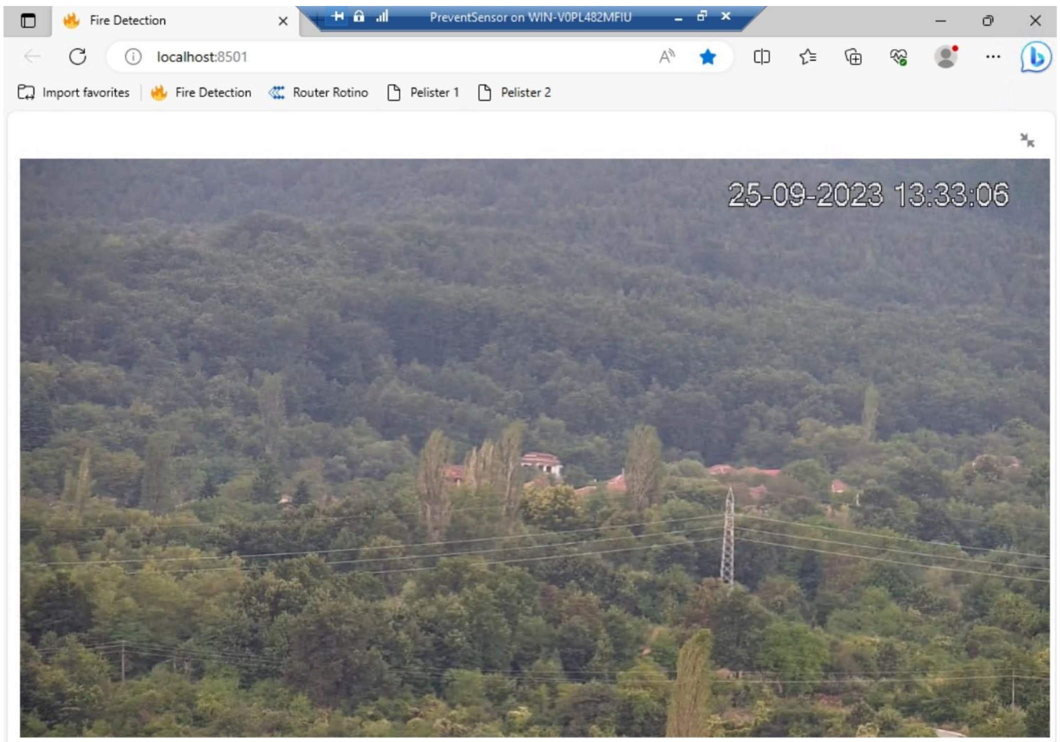

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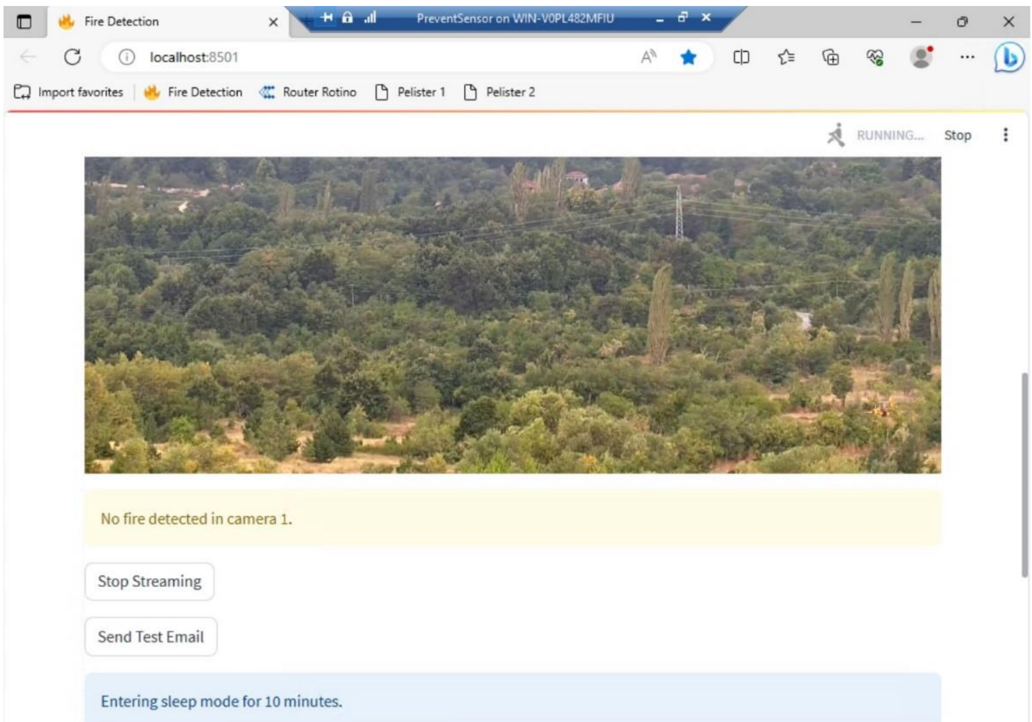

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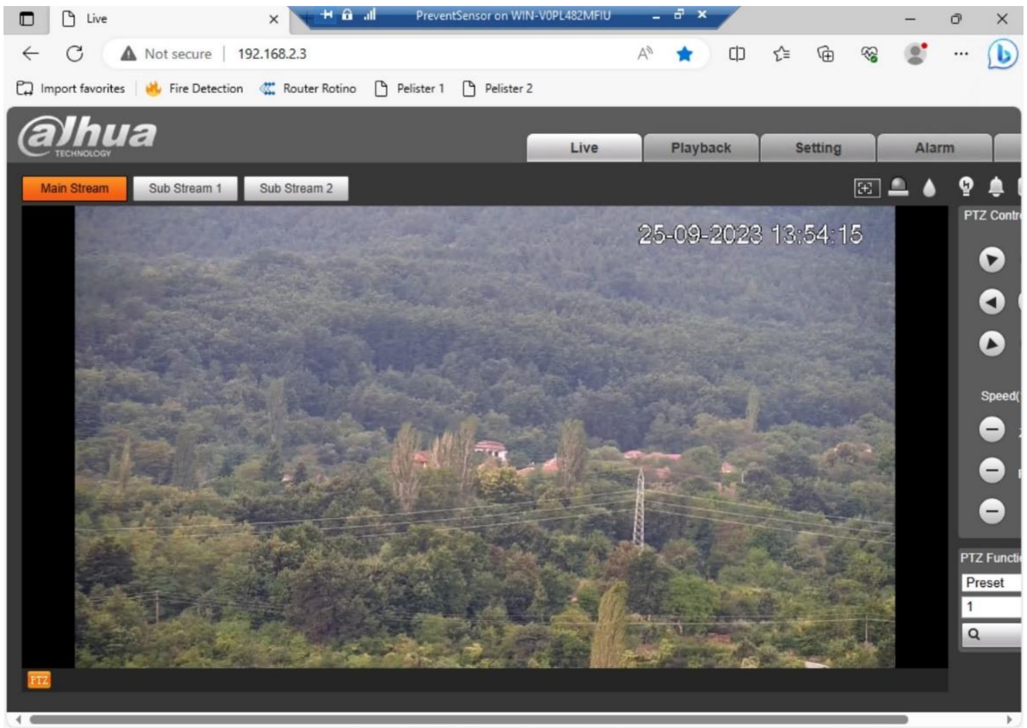

4.2 Integration of YOLOv5 Object Detection Model:

4.2.1 Model Integration Strategy:

The YOLOv5 object detection model was selected for its renowned speed and accuracy in identifying fire and smoke instances. The model integration involved optimizing the model's architecture, adapting it to real-time inferencing, and preparing it for seamless integration within the Streamlit application.

4.2.2 Model Training and Validation:

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Before integration, the YOLOv5 model was meticulously trained using an extensive dataset comprising fire and smoke instances. The model was trained iteratively, adjusting hyperparameters and fine-tuning its weights to maximize its accuracy in fire and smoke detection. Rigorous validation was conducted to ensure that the model's predictions aligned with ground truth data. First, a model was trained with over 20,000 fire and smoke images as well as nighttime fire and smoke images. 40% of the total number of images were for potential fires in daytime conditions, 40% were for nighttime conditions, and the remaining 20% of the images were without objects - fire in the image. After training the model, it was added to the Streamlit application script, providing real-time fire detection.

The application is made in such a way that it streams the videos from the cameras for 3 minutes and pauses for 10 minutes, to reduce the consumption of the Internet. At a maximum of 30 minutes, it sends an email to the stakeholders, also to reduce Internet consumption.

4.2.3 Model Integration and Optimization:

The trained YOLOv5 model was integrated into the Streamlit application's codebase. This required careful modification and optimization to ensure the model's compatibility with the application's runtime environment. Model loading, inferencing, and results visualization were meticulously implemented to ensure seamless and accurate fire detection within the interface.

4.3 Creation of Robust Software Environment:

4.3.1 Software Dependency Management:

A critical aspect of the software installation phase was the management of software dependencies. Libraries, packages, and frameworks used within the application were

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meticulously documented and managed to prevent conflicts and ensure smooth interactions among software components.

4.3.2 Testing and Debugging:

Extensive testing and debugging were conducted to validate the integration of software components. Rigorous testing scenarios were devised to assess the responsiveness of the user interface, the accuracy of object detection, and the system's ability to handle various usage patterns and scenarios.

5. Implementation of Measures for Information Security and Business Continuity

The development of the Streamlit application for forest area monitoring and early fire detection is underpinned by stringent measures to ensure information security and business continuity. This phase encompasses a comprehensive approach to safeguarding data integrity, mitigating risks, and establishing protocols to ensure uninterrupted system operations.

To protect against unauthorized access, robust access control mechanisms were implemented. User authentication protocols were established, requiring authorized personnel to provide valid credentials before accessing the system. Role-based access was enforced, ensuring that users had appropriate privileges based on their responsibilities.

Data security was fortified through encryption strategies. Both data at rest and data in transit were subjected to encryption, rendering sensitive information unintelligible to unauthorized parties. Encryption algorithms and protocols adhered to industry best practices, guaranteeing the confidentiality and integrity of critical system components.

5.1 Business Continuity Measures:

5.1.1. Redundancy and Failover Strategies: Redundancy mechanisms were meticulously integrated to guarantee continuous system operations. The failover capability of servers, previously detailed in the hardware installation phase, played a crucial role in minimizing downtime. In addition, automated failover tests were conducted periodically to validate the readiness of the secondary server.

5.1.2. Data Backup and Restoration: Data backup and restoration procedures were defined to safeguard critical system information. Regular backups of configuration settings, application data, and user records were performed. These backups were securely stored off-site to ensure their availability in case of data loss or corruption.

6. Testing and Ensuring Full Capacity Effectiveness

The robustness and effectiveness of the Streamlit application for forest area monitoring and early fire detection hinge on rigorous testing and validation. This phase encompasses comprehensive testing scenarios, performance evaluations, and optimization measures to ensure the system operates seamlessly, accurately detects fire incidents, and delivers timely alerts to stakeholders.

6.1 Testing Scenarios and Use Cases

6.1.1 Scenario Design and Validation:

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A diverse range of testing scenarios were meticulously designed to assess the system's capabilities under various conditions. Scenarios included daytime and nighttime monitoring, simulated fire incidents, different weather conditions, and varying levels of smoke concentration. These scenarios were crafted to emulate real-world situations, allowing for thorough validation of the system's performance.

6.1.2 Edge Cases and Anomalies:

Edge cases and anomalies were deliberately introduced during testing to evaluate the system's ability to handle unexpected situations. These included obscured camera views due to vegetation, variations in camera angles, and false positives triggered by non-fire elements that could resemble smoke.

6.1.3 User Interaction Testing:

User interactions with the application were subjected to testing to ensure that the interface was intuitive and responsive. Testers simulated user actions such as accessing camera feeds, viewing detection results, and initiating communication via email alerts.

6.2. Performance Evaluation:

6.2.1. Real-Time Processing Speed:

The system's real-time processing speed was evaluated to ensure that object detection using the YOLOv5 model met the desired standards. Performance metrics, such as frames per second (FPS) and inference time, were measured under different load conditions to guarantee the system's responsiveness.

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6.2.2. Detection Accuracy and Precision:

The accuracy and precision of the object detection model were rigorously assessed using ground truth data. Detection results were compared against actual fire and smoke instances to determine false positive and false negative rates. Adjustments to model parameters were made to enhance accuracy as necessary.

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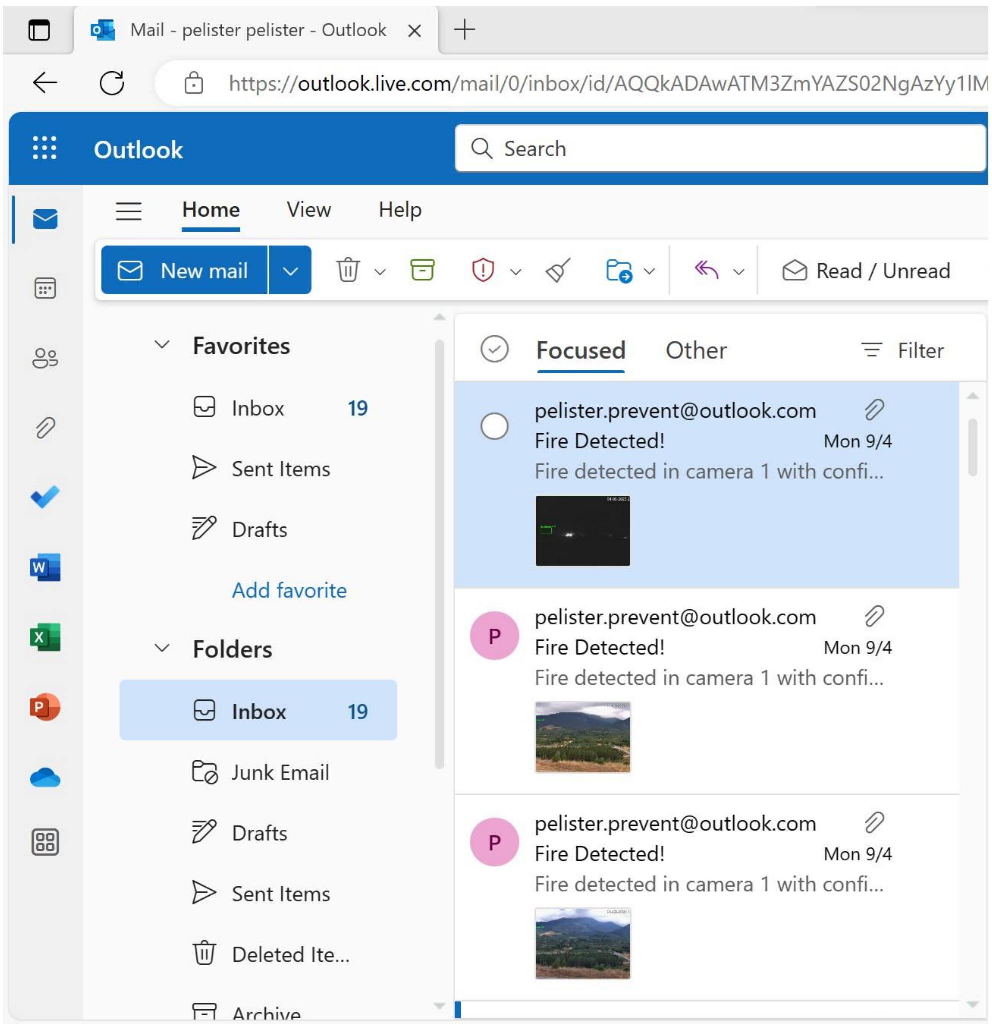

6.2.3. Email Alert Latency:

The timing and delivery of automated email alerts were evaluated to ensure timely communication of potential fire incidents. Latency measurements were taken from the detection trigger to the moment stakeholders received notifications, with optimizations made to minimize delays.

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6.3. User Acceptance Testing

6.3.1. Stakeholder Involvement:

Stakeholders were engaged in user acceptance testing to ensure that the application met their expectations and addressed their requirements. Feedback and suggestions from stakeholders were collected and integrated into the final system to enhance user satisfaction.

6.3.2. Usability and Accessibility Evaluation:

The usability and accessibility of the user interface were evaluated by stakeholders with varying technical backgrounds. Interface clarity, ease of navigation, and accessibility features were assessed to ensure that the system catered to a diverse user base.

6.3.3. Final Performance Benchmarking:

Upon incorporating refinements based on testing outcomes, final performance benchmarking was conducted. This encompassed a holistic assessment of the system's accuracy, speed, responsiveness, and reliability under real-world conditions.

7. Surveillance, Monitoring, and Control of Recordings and Alarms

The system continually monitors the forested area, providing stakeholders with uninterrupted access to live camera feeds. This enables ongoing surveillance and the rapid identification of any changes or anomalies that require attention.

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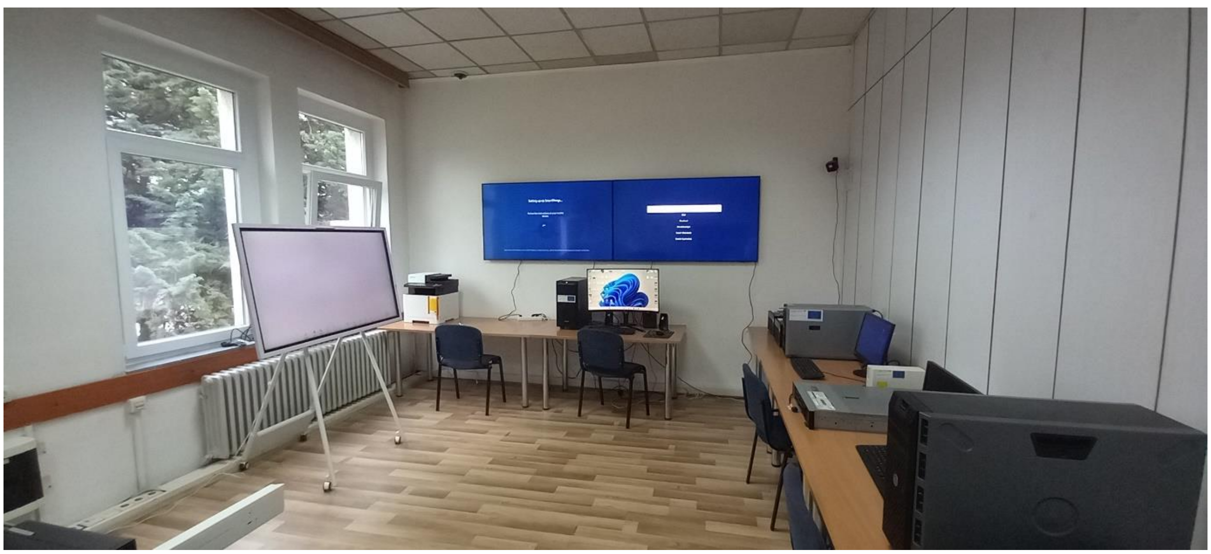
7.1. Alarm History and Data Logging:

The system maintains an alarm history and comprehensive data logs of detected anomalies, responses, and user interactions. This data is instrumental in post-incident analysis, system refinement, and accountability.

7.2. Remote Control and Configuration:

Adminiatrator has remote control over the system's configuration, allowing them to adjust parameters, update detection thresholds, and optimize system behavior based on evolving needs and conditions.



The surveillance, monitoring, and control phase exemplifies the application's operational essence. By providing real-time video streams, automating alarm triggers, enabling timely email notifications, and offering stakeholder interaction, the system empowers informed decision-making and efficient response to potential fire incidents.

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Conclusion:

The successful development of the Streamlit application for monitoring forest areas and early fire detection has been accomplished through the collective efforts, support, and collaboration of various stakeholders. The project's fruition is a significant stride toward effective environmental preservation and disaster mitigation. It showcases the integration of meticulous planning, strategic hardware deployment, software integration, and rigorous testing, culminating in a sophisticated system designed to safeguard forested regions from the devastating impact of wildfires.

The development process was guided by the implementation of Information Systems plans and procedures, which ensured a structured and organized approach to project execution. Crucial to this success was the model system for monitoring architecture, a foundation meticulously crafted in collaboration with P3 end-users. This architecture seamlessly integrated high-performance servers, real-time cameras, and cutting-edge YOLOv5 object detection algorithms. The premises within the information center, made available through collaborative efforts, served as an integral part of the system's infrastructure. Additionally, the expertise of expert from P3 played a pivotal role in shaping the system's architecture, optimizing its effectiveness, and ensuring seamless connectivity.

The installation of essential software components, including the integration of the Streamlit framework and the YOLOv5 model, further underscored the system's efficiency and responsiveness. The establishment of continuous surveillance, monitoring, and control mechanisms further solidified the system's effectiveness. These mechanisms, guided by

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collaborative efforts and expert insights, empower stakeholders to respond promptly and effectively to potential fire outbreaks.

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