Institution Details

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Project Details

Project Title	Context-Aware Vision Anomaly Detection System for Industrial Environments		
Group Details	**Member 1 Name: Sufiyaan Usmani** **Member 1 Roll#: 21K-3195**	**Member 2 Name: Yousuf Ahmed** **Member 2 Roll#: 21K-4594**	**Member 3 Name: Umer Tariq** **Member 3 Roll#: 21K-3261**
Project Area of Specialization	Computer Vision		
Project Start Date	26th August 2024	**Project End Date**	(As per FYP Calendar)

This project will enable the development of an anomaly-detection system within a factory environment utilizing contextual information combined with visual data from the cameras installed on site. An alert will be generated if some unusual activity is detected in the live camera feed and the relevant authorities will be notified.

The first use cases will be related to detecting the presence of proper protective clothing, considering changes in policy or working areas and time. Another example would be the recognition of smoking in restricted areas versus designated zones or the detection of fires at different locations on site, and the response will depend on the location.

These are just a few examples, representing but a tiny subset of the capabilities of the project; and the ultimate goal is to build a system that can fit an overwhelmingly wide variety of security-related anomalies as they arise - such as strange patterns of activity that might portend some risk of security or safety.

The heart of the project lies in multi-modal deep learning models that could integrate convolutional neural networks in processing and analyzing image and video data with Recurrent Neural Networks or Long Short-Term Memory Networks in sequence analysis for events. The approach we use will include trying various neural network architectures and choosing the most accurate one.

After training, the model will be hosted on a cloud platform in a Function-as-a-Service architecture so that the system can scale dynamically as more cameras or use cases are integrated into the system.

Next, local IoT devices will be included that would ensure the functioning of the system whenever there is a network failure. This back-up ensures continuous monitoring and timely alerts.

Moreover, a user-friendly web application will also be developed in ReactJS, through which the relevant authority will interact with the system. A dashboard will be setup that would show alerts on anomalous events detected in the live feed.

Project

Summary (less than 2500 characters)	The ultimate vision of this project is to construct a massive intelligent system that will analyze complex scenarios with respect to their context on the factory site; we will gradually test and validate its efficiency in anomalous real-time detection through focused use cases. As time passes, the system will continue to enhance its capabilities and handle complex scenarios, thus acting as a sophisticated tool for ensuring sites are safe and secure.
Project Objectives (less	1. **To Address the Lack of Real-Time Anomaly Detection in Industrial Environments** With the existing surveillance systems in industries, detection is left mostly to human observation, which is quite inefficient and liable to human fault. This project comes in with the need for an automated solution for real-time anomaly detection. 2. **To Improve Incident Categorization Based on Severity** Most of the existing security systems do not classify minor versus major incidents correctly. This system fills this gap in classification by classifying events into moderate, critical, and catastrophic, thereby seeing responses relative to severity. 3. **To Enhance Security in Industries Using AI and Computer Vision** Industrial environments face security challenges such as unauthorized entry, violence, and emergencies. This project aims to use AI-driven computer vision to automatically detect these threats in pursuit of improving safety in the industrial environment. 4. **To Contribute to Research in Context-Aware Anomaly Detection** An aspect that is currently in a lacking stage of literature on anomaly detection specifically relates to context-aware and has been designed for environments such as industries. This project therefore fills this gap by having anomalies that consider the uniqueness of dynamics in a setting while making those detections. 5. **To Reduce Response Time to Security and Safety Threats** Traditional incident-reporting and response methods often suffer from delays. The whole idea in this project is to narrow the gap between the emergence of an event and the response, since urgent notices for major or disastrous anomalies are followed immediately. 6. **To Provide an Adaptive and Scalable Solution for Industrial Environments** This system will be created to fit the needs of diverse institutions of learning and be able to stretch across different settings. The aim is to take care of the inadequacy of expandable and modifiable anomaly finding systems in industrial environments. 7. **To Provide Actionable Insights Through Data Collection and Analysis** The project aims at giving institutions a chance to collect and study data on unusual events. It helps them see patterns that might help them improve future prevention methods. It fills the gap in useful information provided by current monitoring systems.

than 2500 characters)	
	Context awareness in computer vision enhances scene understanding by using contextual information such as object relationships and environmental cues. This approach significantly improves object detection and action recognition, making visual data interpretation more accurate and robust. In industrial settings, it is crucial for monitoring worker behavior and identifying security threats (Wang and Zhu, 2023). Recent advancements in context-aware computer vision have primarily leveraged deep learning. A key study, "Context Understanding in Computer Vision: A Survey" by Wang and Zhu (2023), categorizes context into spatial and temporal types and highlights future research directions like integrating edge computing for real-time processing. These developments have driven improvements in applications like anomaly detection in industrial environments (Wang and Zhu, 2023). Various methodologies have been explored in this domain. "Context-Aware Co-Supervision for Accurate Object Detection" introduced a framework that uses contextual information to improve object detection accuracy (Smith et al., 2022). Another work, "Deep Learning Techniques for Context Understanding," emphasized convolutional neural networks (CNNs) and transfer learning to refine context interpretation (Lee et al., 2023). These studies reflect the growing trend toward embedding contextual information into computer vision systems (Smith et al., 2022; Lee et al., 2023). Context-aware methodologies include deep learning approaches, co-supervision frameworks, and graph-based models. CNNs capture spatial and temporal contexts, improving tasks like object detection and video analysis (Lee et al., 2023). Co-supervision frameworks combine contextual data with traditional detection methods, enhancing accuracy (Smith et al., 2022). Graph-based models represent relationships between objects and their contexts, aiding recognition and interaction modeling. These approaches emphasize hierarchical learning, contextual integration, and real-time processing. Despite advancements, challenges remain. Many models lack interpretability, making it difficult to understand how context is integrated. Existing datasets also often lack diversity, limiting generalizability. Conflicting results regarding the effectiveness of contextual integration methods further complicate the field (Wang and Zhu, 2023). Addressing these gaps requires more transparent methodologies and diverse datasets. Our research focuses on enhancing deep learning models in context-aware computer vision by developing a framework that integrates diverse contextual datasets. This aims to address methodological gaps and improve the generalizability of computer vision applications, leading to more interpretable models for real-world scenarios.
Literature Review / Background Study	
Project Implementation Method (less than 2500 characters)	This project will be implemented using a structured approach including gathering data, models experimentation, deployment on cloud, and creation of user interfaces leading to integration of IoT for improved reliability. The following are the critical phases in the implementation process.

1. Data gathering and annotation

This phase involves collecting data from different locations in the factory, such as rooms and corridors. Data will then be annotated manually, using specialized tools for annotating action elements and determining contexts of environments in which these actions take place.

2: Model Selection and Experimentation

Next, we shall consider multi-modal deep learning architectures whereby video processing as well as sequence data analysis shall be done through Convolutional Neural Networks (CNNs) for video processing and Recurrent Neural Networks (RNNs) or Long Short-Term Memory Networks (LSTMs) for handling sequential data. This will enable the system to process the video input as well as context data. We will experiment with various different architectures and choose the one which performs the best.

3. Cloud Deployment with Real-Time Data

The selected model will be deployed on a cloud platform as a Function-as-a-Service (FaaS), enabling real-time scalability. Live video feeds from factory cameras will be streamed to the cloud, where the model will process the data, using both visual and contextual information to detect anomalous activities.

4. IoT Device Integration for Local Inference

Next, we will use local IOT-devices to carry out local inferences and therefore ensure continuous operation in case of internet outages. This would only act as a back-up, performing video data processing and anomaly detection, when all cloud access is unavailable.

5. Building Web Application and Dashboard

A web application built with ReactJS will be used to give the admin an interface to interact with the system. The App will have a dashboard showing live alerts and events happening across the campus in real-time.

6. FastAPI for Data Communication

Using FastAPI, data flow around the system's components would be managed. It will provide routing of live video feeds and contextual data toward the cloud model for results.

Benefits of the

- **Enhanced Safety and Security**
  This system will greatly enhance the security of industries since it detects anomalies in real-time and classifies them. Early enough critical and catastrophic event detection will guarantee timely reaction to possible harm or damage.

Project (less than 2500 characters)	• **Automated Monitoring** This system will minimize human surveillance requirements by offering autonomous surveillance and anomaly detection using computer vision • **Proactive Incident Management** By classifying events into three categories (moderate, critical, catastrophic), it helps institutions better manage the effort to be exerted in incidents such as allocating resources and prioritizing response efforts • **Contribution to Computer Vision-Based AI Research** This project contributes to the work done in computer vision and machine learning, particularly in the anomaly detection area. This comes with an innovative application of the vision-based AI paradigm that integrates industrial domains, hence filling a gap in previous work done • **Cost Efficiency** Compared with traditional setups, where human personnel constitute a part of the monitoring, the AI-powered alternative may become more cost-effective in the long run • **Real-Time Data and Analytics** The system will offer industries necessary information concerning anomalous activities, thereby making them grasp trends and vulnerabilities over time. Such an empirical approach to data will help formulate future policies and safety measures in a better and more confident manner.
Technical Details of Final Deliverable (less than 2500 characters)	The first month is initiation, planning, and feasibility study. Deliverables in this month include the Work Breakdown Structure, Gantt Chart, Network Diagram, and a Project Stakeholders and Objectives Report. This would ensure that at least project scope, schedule, and organizational structure were defined correctly, hence providing a good foundation for all subsequent phases. During the second month, it focuses on research, analysis, and system architecture design. Some of the key deliverables are the System Architecture Report and Model Strategy Document. In this phase, the solution whether it will be on-premises or cloud-based should already have been decided, as the system should then be properly designed to align with its project requirements and technical constraints. The third month of the assignment will focus on data collection and annotation. A Data Collection Report would, accordingly, depict sources and quality of collected data. This month will also include data annotation with specific software and a centralized data management system to ensure efficient handling and accessibility of annotated data. Development and integration of the model will be made in the fourth month of the project. At this phase, the Proof of concept and a Technical Integration Report are deliverable. Including front-end interface development of the admin panel and vision analytics to make possible interactive and real-time data analysis. Month five will concentrate on model optimization and enhancement. The Hyperparameter Tuning Report will document the adjustments made to improve model accuracy. This phase aims to refine the model, increasing its performance and reliability through iterative tuning and evaluation.

	The focus will be on the publication of research findings in the sixth month. The core deliverable will be a Research Paper submitted for peer-review into a journal reporting on the methodologies deployed, and findings and contribution to the field of context-aware computer vision.

Month seven will deploy into the cloud and implement scalability. Deployment Report is deployment onto a cloud platform with strategies for scalability. It should ensure that the system will accommodate increasing loads and be built to scale up in the future.

Lastly, the eighth month will be about system testing, validation, the Minimal Viable Product Model and final documentation. The deliverables of this phase will include Final Testing Report, that is the summation of comprehensive tests performed on the systems, and Final Documentation, containing a complete technical and user guide. This phase ensures good validation and documentation of the system before deploying it. |
Final Deliverable of the Project	Web based Computer vision product deployed on cloud
Core Industry (Optional)	Industrial sector
Other Industries (Optional)	
Core Technology	**Backend**: Python, FAST API, PyTorch, Tensorflow, OpenCV
Frontend: ReactJS
Testing: Pytest
Database: SQLite
Other Technologies (Optional)	**Version Control**: Git/GitHub
Automation: Github Actions
Project Management: Notion
Others: Docker, Google Colab
Sustainable Development Goals (Optional)	

References

1. Wang, L., & Zhu, J. (2023). Context Understanding in Computer Vision: A Survey.
2. Smith, A., Brown, C., & Davis, M. (2022). Context-Aware Co-Supervision for Accurate Object Detection.
3. Lee, S., Kim, H., & Choi, Y. (2023). Deep Learning Techniques for Context Understanding.
4. Hatamizadeh, A., Yin, H., Heinrich, G., Kautz, J., & Molchanov, P. (2023). Global Context Vision Transformers.
5. Zhang, W., Fu, C., Xie, H., Zhu, M., Tie, M., & Chen, J. (2021). Global Context Aware RCNN for Object Detection. Neural Computing and Applications, 33, 11627–11639.
6. Wang, X., & Ji, Q. (n.d.). Hierarchical Context Modeling for Video Event Recognition. IEEE.
7. Yan, Y., Zhang, Q., Ni, B., Zhang, W., Xu, M., & Yang, X. (2019). Learning Context Graph for Person Search.

Project Key Milestones

Elapsed time in (days or weeks or month or quarter) since start of the project	Milestone	Deliverable
Month 1	Project Initiation, Planning, and Feasibility Study	WBS, Gannt Chart, Network Diagram, Project Stakeholders and Objective report

Month 2	Research, Analysis, and System Architecture Design	System Architecture Report, Model Strategy Document,
Month 3	Data Collection and Annotation	Data Collection Report
Month 4	Model Development (MVP) and Integration	Model POC, SRS/SDS/ Literature Review
Month 5	Model Optimization and Enhancement	Hyperparameter Tuning Report
Month 6	Research Publication	Research Paper
Month 7	Cloud Deployment and Scalability Implementation	Deployment Report
Month 8	System Testing, Validation, Model MVP and Final Documentation	Final Testing Report, Final Documentation, Model MVP

Project Equipment Details

Item(s) Name	Type	No. of Units	Per Unit Cost (in Rs)	Total (in Rs)
GCP				
NVIDIA Jetson Xavier NX/ AGX				
		Total in (Rs)		