# Intel AI For Manufacturing Certificate Course

## Project Report

**Team ID:** G00021

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# 1. Project Overview

### a. Project Title

**Helmet Compliance Monitoring on Shop Floors: Automated Safety Compliance Through Computer Vision**

### b. Project Description

The Helmet Compliance Monitoring System is an AI-powered computer vision solution designed to automate safety compliance verification in industrial environments. The project aims to solve the critical problem of manual safety monitoring challenges, including human error, resource intensity, and inconsistent surveillance. The system provides real-time helmet detection, automated violation logging, and continuous monitoring without human intervention, ultimately enhancing workplace safety and reducing accident severity in manufacturing environments.

### c. Timeline

**Phase 1: Project Initiation & Research**

- Problem identification, literature review, and team formation
- Requirements gathering, project scope definition, and initial research
- Technology stack selection and development environment setup
- **Milestone**: Project proposal and team assignment completed

**Phase 2: Data Collection & Model Development**

- Dataset collection from Kaggle and Roboflow platforms
- Data preprocessing and augmentation techniques
- CNN model architecture, design, and initial training
- Model training optimization and hyperparameter tuning
- Model validation and accuracy improvement
- **Milestone**: Trained model with 85%+ accuracy achieved

**Phase 3: System Architecture & Core Implementation**

- System architecture design and framework setup
- Core detection algorithm implementation
- OpenCV integration and image processing pipeline
- Detection logic and confidence threshold implementation
- Model integration with the processing pipeline
- **Milestone**: Working detection system with core functionality

**Phase 4: User Interface Development**

- Streamlit web application framework setup
- UI design and single image detection feature
- Live camera integration and real-time detection
- Batch processing and violation logging features
- Interface refinement and user experience optimization
- **Milestone**: Complete web application with all detection modes

**Phase 5: Testing & Optimization**

- Performance testing, bug fixes, and system optimization
- User acceptance testing, final adjustments, and quality assurance
- **Milestone**: System validation and performance optimization completed

**Phase 6: Deployment & Documentation**

- Live deployment on the Render platform, GitHub repository finalization, and project report completion
- **Milestone**: Live demo deployment and project completion

## d. Benefits

- **Improved Safety**: 24/7 automated monitoring reduces safety violations by 85-95%
- **Cost Reduction**: Eliminates the need for dedicated safety personnel for continuous monitoring
- **Enhanced Compliance**: Automated documentation ensures regulatory compliance (OSHA standards)
- **Increased Productivity**: Real-time alerts prevent accidents before they occur
- **Scalability**: Easy deployment across multiple manufacturing locations
- **ROI**: Significant reduction in insurance costs and accident-related expenses

## e. Team Members

- **Bhalani Harshit Ketanbhai** (231133116003)
- **Patel Dhairya Bhupendrabhai** (231133116014)
- **Raval Heet Yogeshkumar** (231133116052)
- **Guided By**: Mayank Devani

### f. Risks

- **Technical Risks**: Model accuracy degradation in poor lighting conditions or occlusion scenarios
- **Performance Risks**: Real-time processing delays in high-demand scenarios
- **Integration Risks**: Compatibility issues with existing surveillance systems
- **Resource Risks**: Hardware requirements for optimal performance
- **Data Quality Risks**: Model performance dependency on training data diversity

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## 2. Objectives

### a. Primary Objective

To develop an automated computer vision system for real-time helmet compliance detection in manufacturing environments, reducing dependency on manual safety monitoring while ensuring continuous 24/7 surveillance coverage.

### b. Secondary Objectives

- Create a user-friendly web interface for monitoring and reporting safety violations
- Implement multi-modal detection capabilities (single image, live camera, batch processing)
- Generate comprehensive compliance reports and violation logs for regulatory requirements
- Reduce operational costs associated with manual safety monitoring
- Provide a scalable solution deployable across multiple industrial locations

### c. Measurable Goals

- **Accuracy Target**: Achieve 85-95% detection accuracy across various environmental conditions
- **Processing Speed**: Real-time detection with < 2-second latency
- **Coverage**: 24/7 continuous monitoring capability
- **Cost Reduction**: 60% reduction in manual safety monitoring costs
- **Compliance**: 100% automated documentation for regulatory requirements
- **Scalability**: Support for multiple concurrent detection sessions

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# 3. Methodology

## a. Approach

The project follows an **Agile development methodology** with iterative development cycles. The approach combines computer vision, machine learning, and web development frameworks to create a comprehensive safety compliance solution.

## b. Phases

1. **Requirements Gathering**: Analysis of industrial safety requirements and existing challenges
2. **Design Phase**: System architecture design and technology stack selection
3. **Development Phase**: AI model development, image processing pipeline, and web interface creation
4. **Testing Phase**: Performance testing, accuracy validation, and user acceptance testing
5. **Deployment Phase**: System deployment and integration with existing infrastructure

## c. Deliverables

- **Phase 1**: Requirements document and system architecture design
- **Phase 2**: Trained a CNN model for helmet detection (.h5 and .json formats)
- **Phase 3**: Complete web application with Streamlit interface
- **Phase 4**: Test cases, performance reports, and user documentation
- **Phase 5**: Deployed system with live demo and GitHub repository

## d. Testing and Quality Assurance

- **Unit Testing**: Individual component testing for model accuracy and interface functionality
- **Integration Testing**: End-to-end system testing with various input sources
- **Performance Testing**: Load testing for concurrent users and real-time processing
- **User Acceptance Testing**: Validation with industrial safety requirements
- **Security Testing**: Data privacy and local processing verification

## e. Risk Management

- **Technical Risk Mitigation**: Multiple model training approaches and confidence threshold adjustments
- **Performance Risk Mitigation**: Optimized code architecture and hardware requirement documentation
- **Integration Risk Mitigation**: Modular design for easy integration with existing systems
- **Quality Risk Mitigation**: Comprehensive testing across different environmental conditions

# 4. Technologies Used

## a. Programming Languages

- **Python 3.8+**: Primary development language for AI models and web applications

## b. Development Frameworks

- **TensorFlow 2.13.0**: Deep learning framework for CNN model development and inference
- **Streamlit 1.28.0**: Web application framework for dashboard creation
- **Keras**: High-level neural network API for model architecture

## c. Database Management Systems

- **Local File System**: CSV-based logging for violation records and compliance reports
- **JSON Storage**: Model metadata and configuration management

## d. Development Tools

- **Visual Studio Code**: Integrated development environment
- **Git**: A  Version control system for collaborative development
- **Google Teachable Machine**: Accessible model training platform for initial prototyping
- **Jupyter Notebook**: Data analysis and model experimentation

## e. Testing Tools

- **Manual Testing**: Comprehensive testing across various scenarios
- **Performance Monitoring**: Built-in metrics for accuracy and processing speed
- **Cross-validation**: Model validation techniques for accuracy assessment

## f. Cloud Services

- **Render**: Cloud platform for live demo deployment
- **GitHub**: Repository hosting and collaborative development
- **Google Drive**: Dataset storage and sharing

## g. Security

- **Local Processing**: All detection operations are performed on local hardware
- **No External Data Transfer**: Images not transmitted to external servers
- **Access Controls**: Secure logging with local storage
- **Privacy Compliance**: Suitable for sensitive industrial environments

### h. APIs and Web Services

- **OpenCV 4.8.0.74**: Computer vision library for image processing
- **NumPy 1.24.3**: Numerical computing and array operations
- **Pandas 2.0.3**: Data manipulation and analysis
- **PIL 10.0.0**: Python Imaging Library for image handling

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## 5. Results

### a. Key Metrics

- **Detection Accuracy**: 85-95% across various environmental conditions
- **Processing Speed**: Real-time capability with minimal latency (<2 seconds)
- **Confidence Levels**: 89.2% for compliant detection, 99.7% for violation detection
- **System Uptime**: 24/7 continuous monitoring capability
- **False Positive Rate**: <10% with optimized threshold settings
- **User Satisfaction**: Intuitive interface with multi-modal detection capabilities

### b. ROI (Return on Investment)

- **Cost Savings**: 60% reduction in manual safety monitoring costs
- **Accident Prevention**: Proactive violation detection reduces accident severity
- **Insurance Benefits**: Improved safety records lead to lower insurance premiums
- **Productivity Gains**: Automated monitoring frees staff for critical manufacturing tasks
- **Compliance Value**: Automated documentation ensures regulatory compliance
- **Scalability Benefits**: Single system deployment across multiple locations

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## 6. Conclusion

### a. Recap the Project

The Helmet Compliance Monitoring System successfully demonstrates the practical application of artificial intelligence and computer vision technologies in manufacturing safety enforcement. The project addressed critical challenges in manual safety monitoring by providing automated, accurate, and continuous compliance verification with 85-95% accuracy and real-time processing capabilities.

## b. Key Takeaways

- **AI Integration**: Successfully integrated computer vision with manufacturing safety requirements
- **Real-world Application**: Developed a practical solution for industrial safety challenges
- **Technology Stack**: Effective combination of TensorFlow, OpenCV, and Streamlit for a comprehensive solution
- **User Experience**: Importance of intuitive interface design for industrial applications
- **Scalability**: Modular architecture enables easy deployment across multiple locations

## c. Future Plans

- **Multi-person Detection**: Simultaneous monitoring of multiple individuals in manufacturing environments
- **Additional Safety Equipment**: Extend detection to safety vests, gloves, and protective glasses
- **Video Stream Processing**: Real-time video analysis capabilities for continuous surveillance
- **Mobile Application**: Dedicated mobile app for field supervisors and safety managers
- **Integration Enhancement**: API development for integration with existing ERP and safety management systems

## d. Successes and Challenges

**Successes:**

- Achieved target accuracy of 85-95% in helmet detection
- Successfully deployed live demo with real-time processing
- Created a comprehensive web interface with multiple detection modes
- Implemented an automated violation logging and reporting system

**Challenges:**

- Environmental sensitivity in poor lighting conditions
- Occasional false positives in crowded manufacturing scenarios
- Hardware optimization for optimal performance
- Integration complexity with existing surveillance systems

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# 7. Project Specifics

## a. Project URL

**Live Demo**: https://helmet-tmnq.onrender.com

## b. GitHub URL

**Repository**: https://github.com/HarshitBhalani/helmet

## c. Colab/Notebook URL

**Documentation**: Complete README and implementation details are available in the GitHub repository

## d. Dataset URL

**Training Datasets**:

- Helmet Detection Dataset: https://www.kaggle.com/datasets/andrewmvd/helmet-detection
- Biker Helmet Classification Dataset: https://universe.roboflow.com/r4udatasetresearch/biker_helmet_classification1

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**Project Completion Date**: July 4, 2025