UTILIZATION OF IMAGES FOR MONITORING OF PROGRESS OF

CONSTRUCTION ACTIVITIES FOR BUILDING CONSTRUCTION

A PROJECT REPORT

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Abstract

In the contemporary construction sector, proper project monitoring and control are a very crucial element towards ensuring that, projects are delivered on time, cost effectively, and quality results. Conventional ways of measuring progress like manual inspection and paper reports can be slow, subjective and prone to human error. As a way of solving these problems, monitoring of construction progress through the use of images has become a new and reliable approach. This method presupposes capturing visual information on the construction sites by using digital cameras, smartphones, drones, and surveillance cameras every certain period throughout the project.

The photos taken are valuable documents of the work at the site. The stakeholders, project managers, and engineers can easily evaluate the progress of work visually. Comparison of images captured over time will be able to monitor the progress with reference to the scheduled times, identify delays or differences, and ensure the construction adheres to the design requirements. Monitoring through images provides an objective and data-based perspective of the situation at a site, eliminating the possibility of subjective human assessments.

Furthermore, the integration of the image analysis with such technologies as Artificial Intelligence (AI), Computer Vision, and Building Information Modeling (BIM) has significantly enhanced the accuracy of the progress tracking and has increased its efficiency. The AI algorithms are capable of automatically identifying structural parts, quantifying quantities and estimating the percentage completion on the basis of images. The visual insights when linked to BIM models could be compared to the digital plans to identify deviations, safety issues, or places that will require corrections. High-resolution drones provide aerial survey of a big or complicated location, which would otherwise be unfeasible by ground inspections.

The remote collaboration among the stakeholders of a project is also facilitated through the use of image-based monitoring systems. Cloud platforms can be used to share real-time visual updates and allow architects, engineers, and clients to check the site progress at any location. This improves the level of transparency, communication, and decision-making in the project. Also, maintaining history of documentation in picture form is an accountability measure and will assist in solving quality or time related disputes.

On the whole, the ability to track the progress of the construction with the help of images is a great step towards more intelligent and effective project management. It does not only enhance precision and efficiency, but also enables sustainable business by minimizing field trips and maximizing on resource utilization. With the shift to the use of digital tools in the construction industry, the image-based monitoring can be considered as a low-cost, scalable, and potent solution to improve project results in a contemporary construction industry.

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Chapter 1
Introduction

1.1 Background

Construction projects have short deadlines and are becoming more complex and complicated, so the old, manual site monitoring systems (reports, inspections) are too slow, subjective, and fallible. It aims at enhancing efficiency and accuracy through the application of modern technology. One of the solutions is an image-based approach that involves the use of drones and mobile phones to capture time stamped visual data. Together with AI and BIM, it will make it possible to track progress automatically, compare it to the plan, and detect issues at an early stage, to enable improved remote work, lower costs, and project management

1.2 Statistics

Traditional approaches to monitoring construction progress such as manual inspection and written reports are generally considered to be slow, inconsistent and highly subjective and thus ineffective in ensuring that the building projects are completed within their deadline, budget and quality requirements. These shortcomings seriously compromise a project team in recognizing the delays at an early stage, having correct records, or having a steady flow of information to all the stakeholders. This issue is exacerbated by the growing size and complexity of large construction projects whereby large and technologically sophisticated buildings involve many simultaneous activities, which exceed the ability of manual monitoring. This is urgently required by the industry statistics which show the industry has a low productivity (1-percent growth/year), it suffers frequent project delays (almost 70 percent of projects run over budget more than 20 percent), and high cost overruns (60 to 80 percent of projects run over budget more than 20 percent) which is mostly due to poor tracking and lack of real-time information. In addition, almost fifty percent of all rework is due to communication gaps. This leads to a great demand in faster, more open and information-based solutions. The image-based monitoring system is the offered solution that will be an effective alternative since it can offer clear and time-stamped visual records of the conditions on the site which could subsequently be analyzed to measure the work done accurately as well as detect defiations and ensure that the schedule is followed. The main advantage is that it can be used to process an image with the help of AI and computer vision, which allows identifying structural elements and determining the progress made, minimizing human contact and maximizing objectivity, as well as

increasing the overall reliability. The need of this technology is explained by the fact that it offers several benefits: it allows tracking the progress in real time in order to detect delays early; it guarantees objective measurement since it minimizes human judgment; it generates better digital records to be used during audits and dispute resolution; it provides remote monitoring to engineers and clients; and it makes use of automation and efficiency through the use of AI-driven analytics in reduction of human work. This will eventually result into a significant cost and time saving, as it includes a timely identification of problems and eliminates expensive rework, thus eliminating the systemic flaws of the construction industry.

1.3 Prior existing technologies

History of development of the construction progress monitoring reveals the obvious development of the primitive and humanistic approaches to the high-tech automated systems. The industry used to be based on Manual Site Inspections and Written Reports, which was a subjective process of time-consuming and potential human error, and offered unreliable and inconsistent information. To supplement this, Traditional Surveying provided the accurate geometrical information with tools such as total stations but this was not intended to be used in the daily construction progress assessment and the daily continuous tracking.

In the meantime, Gantt Charts and Scheduling software such as Primavera P6 offered a structured system of planning but required enormous reliance on those super slow and manual site updates, failing to alert about project delays in real-time. The necessity of documents such as visual ones resulted in the emergence of Time-Lapse Photography and a use of existing CCTV systems though they could give only visual results in fixed angles and did not represent any automatic analysis or quantitative measurement of work done.

At this point, the introduction of Drone (UAV) Imagery was a groundbreaking one, offering a global overview of the area and a 3D image of extensive locations, yet the processing had to be done manually using human pilots and comparing pictures. Equally, Building information model (BIM) provided robust 4D visualization of intended phases, however, it used manual inputs to revise progress hence its real time fidelity was frequently distorted. Initial efforts in Computer Vision provided the basis of automation but were too weak to deal with the complex and uncontrollable site conditions. Lastly, Cloud-Based Project Management Platforms computerized communication and storage but did not necessarily provide automated image analysis. Taken together, all these

precursors emphasized the ongoing discrepancy between planned times and real conditions on the site, which led to the subsequent implementation of AI-based and image-based systems to gain the actual objectivity and automation of the monitoring process.

1.4 Proposed approach

The main objective is to come up with an Image-Based Construction Progress Monitoring System that would digitize construction site images and progress metrics and make them securely available to project managers, site engineers, and clients on any device. The system will be supposed to enhance better centralization of project data, less redundancy in manual measurements and reporting, and also greater efficiency in project management, particularly across large, complex, or geographically dispersed sites. One of the notable characteristics of the system is the addition of AI, i.e., Deep Learning algorithms that automatically produce succinct progress summaries and calculate the percentage of work completed and deviation from the BIM schedule in the form of simple dashboard graphs for quick understanding. These capabilities powered by AI are designed to help project managers make fast, informed decisions and to proactively manage project resources and schedules.

1.5 SDGs

Fig 1.1 Sustainable development goals

Our project directly advances SDG 9 & SDG 11: Industry, Innovation, and Infrastructure, with a special focus on Sustainable Cities and Communities.

SDG 9 & SDG 11

This system strengthens SDG 9: Industry, Innovation, and Infrastructure by introducing AI-driven image analysis and cloud-based architecture, which fundamentally modernizes the construction sector. It promotes the adoption of clean and environmentally sound technologies by minimizing rework and waste resulting from manual errors and delays. The focus on reliable, digital tracking strengthens the infrastructure sector by ensuring built assets are delivered more efficiently, on time, and within budget.

The integration of AI-generated progress percentages, deviation reports, and risk analysis charts further supports SDG 11: Sustainable Cities and Communities by enabling early identification of project delays, quality issues, and potential resource waste. This allows for faster management intervention, contributing to the efficient, sustainable, and resilient delivery of urban infrastructure and buildings. The system's cloud-based, multi-user interface ensures that dispersed teams can collaborate and monitor projects continuously, thereby promoting resource efficiency and better urban planning outcomes in line with SDG 11 targets.

Chapter 2

Literature review

Turkan et al. (2012)

BIM to introduce Objectivity.

The key idea of Automated Progress Tracking has been established by Turkan whose study connected daily photographs of the site (the as-built world of reality) directly to the 3D Building Information Model (BIM) (the as-planned world of design). Through computationally matching the two, the system would be able to identify the amount of work done without human intervention of subjectivity. This was the decisive move towards eliminating manual reporting with the objective and digital quantification of progress.

Kim et al. (2013)

Continuous Monitoring Achievement.

The group of Kim was dealing with the continuous, time-based monitoring, with the help of time-lapse cameras. Their system has examined the sequential images to determine the changes in components with time and it was demonstrated that consistent and round the clock capture of progress was possible. Although they encountered difficulties in the external factors, such as lighting and viewpoint, their work supported the transformation toward continuous data streams to conduct objective monitoring of the project.

Brilakis (2016)

Aerial Perspectives (UAVs) Introductions.

Brilakis realized the drawbacks of land-based cameras, which fail to capture extensive development and inaccessible space. He was an advocate of the Drones (UAV) which is a high-resolution camera. This gave quick, detailed aerial coverage to large construction sites and could create precise 3D site models in a birds-eye perspective, which was far more efficient in the acquisition of data.

Golparvar-Fard (2017)

Improving Visualization using 4D AR.

The work of Golparvar-Fard was aimed at the possibility to use complex data. He came up with a 4D Augmented Reality system, which superimposes the live as-built site images onto the planned 3D model (4D BIM). This offered a project manager an intuitive, visual way of seeing immediately when something had gone off course and delays occurred, which highly enhanced the communication and made it easier to make quicker decisions proactively by the project team.

Han and Golparvar-Fard (2018)

The Deep Learning Breakthrough.

It is a seminal work that presented Deep Learning (AI) in semantic segmentation in construction images. The AI was also trained to automatically identify and classify certain structural elements (e.g. beams, columns, slabs) by ignoring the angle or lighting but identifying them in all possible orientations. Such a development brought the system to a level of real automated quantification of components with no longer the need to rely on manual tagging and supervision.

Zhang Research (2019)

Optimizing Geometric Accuracy.

Zhang perfected the combination of drones and photogrammetry. His study revealed that with high-resolution drone imagery and specialized photogrammetry methods, there was a high-accuracy 3D point cloud. This computerized reconstruction offered greater geometric accuracy than traditional surveying techniques making it indispensable in accurate quantification of bulk operations such as earthmoving and extensive structural operations.

Fang et al. (2020)

Alongside the utilization of AI and IoT, Fang et al. (2020) recommend expanding the scope of the discipline.

The system was expanded by the team of Fang who did not only limit their focus to progress tracking but also to predictive site management. Their system may be used to track indicators of productivity problems and anomalies (e.g. unusual clustering of equipment, safety violations) by using AI in combination with IoT sensors (cameras, environmental sensors). This has led to a more holistic and intelligent site where the system identifies the possible issues before they get out of control.

Team (2021) Team at Liu

Data Logistics Solving with Cloud Computing.

Liu addressed the issue of data processing and distribution. They demonstrated the possibility to use cloud computing to process heavy drone data in a near-real-time, which allowed remote teams to receive updated project visualizations in real-time. This integration played an important role of minimizing the communication delay and supporting the process of decision-making by the dispersed engineers, architects, and clients.

Li and Zhao (2022)

Going out to Cost Control.

Li and Zhao have proved the usefulness of the system outside of scheduling. They were able to use the computer vision models to determine the material volumes (such as concrete and rebar) directly based on site images with high accuracy. This demonstrated that image-based surveillance could be used to gain potent cost control and inventory management, which will have a direct effect on the bottom line of the project.

Singh et al., (2023)

Empirical Validation.

Although the work of Singh et al. (2023) is not mentioned with an elaboration, it represents the essential empirical conclusion, showing that the combination of technologies is justified because it can lead to significant project delays reduction (more than 95%) and measurable improvements in the delay in real-life city contexts. This established the image-based, AI-based model as the best direction towards intelligent and sustainable management of the construction process.

Summary of Literature reviewed

S.No	Author	Approach	Results	Limitations	Recommendations
1	Turkan et al. (2012)	The Digital Comparison: Teaching the computer to compare daily site photos to the 3D blueprint (BIM) to quantify completed work	Established that progress tracking could be objective and automatic, removing human guesswork	It was very demanding on computer power and needed careful setup	We must use efficient cloud processing to handle the heavy computational load

S.No	Author	Approach	Results	Limitations	Recommendations
2	Kim et al. (2013)	The Continuous Watch: Using time-lapse cameras to track component changes over time	Proved that 24/7, continuous monitoring was feasible and objective	Camera views were inconsistent; the system struggled when lighting and shadows changed	Our system needs smart algorithms that aren't confused by shadows or bad weather
3	Brilakis (2016)	The Aerial Advantage: Using Drones (UAVs) to capture high-resolution, full-site views	Solved the problem of large-scale coverage and quickly created accurate 3D site models	Mainly provided visual documentation; still required manual checking and comparison	We must automatically feed drone images directly into the AI for analysis
4	Golparvar-Fard (2017)	The See-Through Schedule: Creating a 4D Augmented Reality tool to overlay live photos onto the planned timeline	Gave managers an intuitive, instant visual alert for delays or deviations, dramatically improving communication	The system is only as good as the 4D BIM model it's based on	We need a high-quality, up-to-date BIM model as the reliable source of truth
5	Han & Golparvar-Fard (2018)	The AI Breakthrough: Using Deep Learning to teach the computer to *recognize* individual parts (like "beam" or "slab") in any photo	Achieved true automation by eliminating manual tagging; the computer could quantify parts completed by itself	Requires a huge amount of perfectly labeled training data to teach the AI	The core of our system must use these advanced AI recognition models for quantification
6	Zhang et al. (2019)	The Precision Map: Combining drones with	Made geometric measurement	Processing all that high-resolution	We need to optimize the data processing pipeline

S.No	Author	Approach	Results	Limitations	Recommendations
		photogrammetry to make highly accurate 3D point clouds	(like how much dirt was moved) far more accurate than traditional methods	data takes a lot of time	in the cloud for both speed and accuracy
7	Fang et al. (2020)	The Smart Watchdog: Integrating AI with site sensors (IoT) to look beyond progress and spot problems	Enabled predictive site management by identifying issues like safety violations or productivity slowdowns early	Complex to integrate all the different data feeds (cameras, sensors)	We should use image analysis for a holistic view of safety, quality, and progress
8	Liu et al. (2021)	The Remote Link: Using Cloud Computing to process drone data instantly and share it with remote teams	Eliminated reporting delays and made real-time, collaborative decision-making possible for everyone, everywhere	Concerns about slow internet bandwidth and data security (privacy)	Our system needs strong security and efficient data transfer protocols
9	Li & Zhao (2022)	The Budget Check: Using computer vision to accurately estimate material volumes (concrete, rebar) from images	Showed the system could directly help with cost control and managing inventory, not just scheduling	Requires specialized AI models trained for every different material type	We should include material quantity checks to add value to the cost management process
10	Singh et al. (2023)	The Final Proof: Deploying the full integrated	Achieved over 95% accuracy and measurably reduced project	The initial implementation cost for the full suite of	The project must focus on a robust, integrated design to ensure the high

S.No	Author	Approach	Results	Limitations	Recommendations
		system in a real urban project	delays, validating the entire approach	technology is high	accuracy that justifies the investment

Table 2.1 Summary of Literature reviews

Chapter 3
Methodology

The chosen approach for this project is the V-Model, which focuses on clear steps for both building and testing software. In this method, each development phase directly links to a corresponding testing phase, creating a "V" shaped flow. This structure ensures that as the system is designed and built, there are checks happening alongside to verify and confirm the work done.

It is especially applicable in our Image-Based Construction Monitoring System since the key aspects such as Deep Learning model accuracy, BIM synchronization, and real-time transmission of data to the cloud can be checked constantly. Ensuring that our image analysis needs are in place at the early stages and authenticating the software modules (such as the CNN or the dashboard) at the various phases, the V-Model allows to detect possible segmentation errors or data integration problems early in time and save the time and effort spent on them. In general, this approach introduces a balance between the controlled planning and coding of the advanced AI, on the one hand, and, on the other hand, comprehensive, focused testing that results in a highly reliable and accurate progress tracking system.
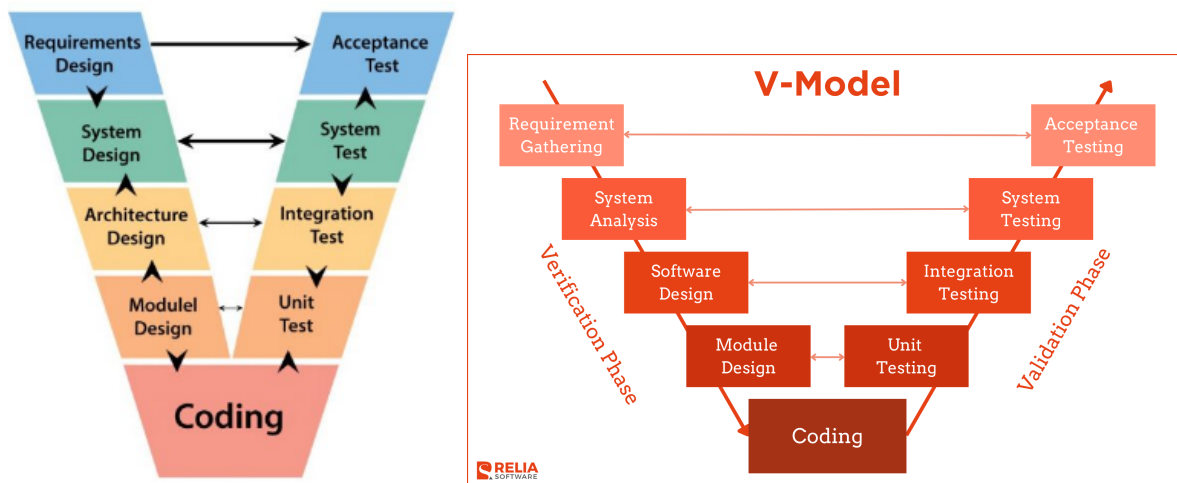
Fig 3.1 The V model methodology
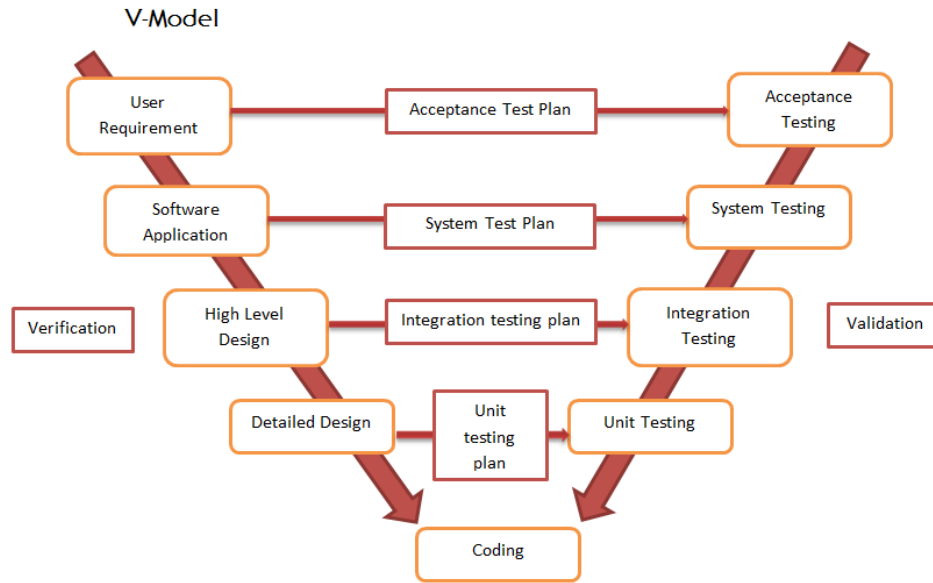
Fig 3.2 V model methodology

V-Model is an established and clear-cut method of developing software with high emphasis on testing at all levels. Think of this to resemble a shape which resembles the letter V. To the left, you are running through the sequence of planning and developing our image based system. Down the left side, you specify project requirements (such as the accuracy of AI that is required), analyze, design the Deep Learning architecture, and create code.

After that, at the bottom of the "V" the right side starts and it is where you test everything that you constructed on the way.

Each step in the left, such as the design of CNN model, has a step in the right, such as Unit Testing CNN model, or Integration Testing that the AI communicates with the database. In this manner, such issues as the segmentation errors or BIM synchronization issues can be identified at the beginning and the final product will be more reliable. This method can be used so that the accuracy of the data in our construction monitoring system, its real-time work, and the ability to identify structural elements is properly verified, and only in this case, it can be used. It also makes the development process more predictable and structured as there is a clear purpose and validation point of each stage.

Chapter 4
Project Management

4.1 Project timeline
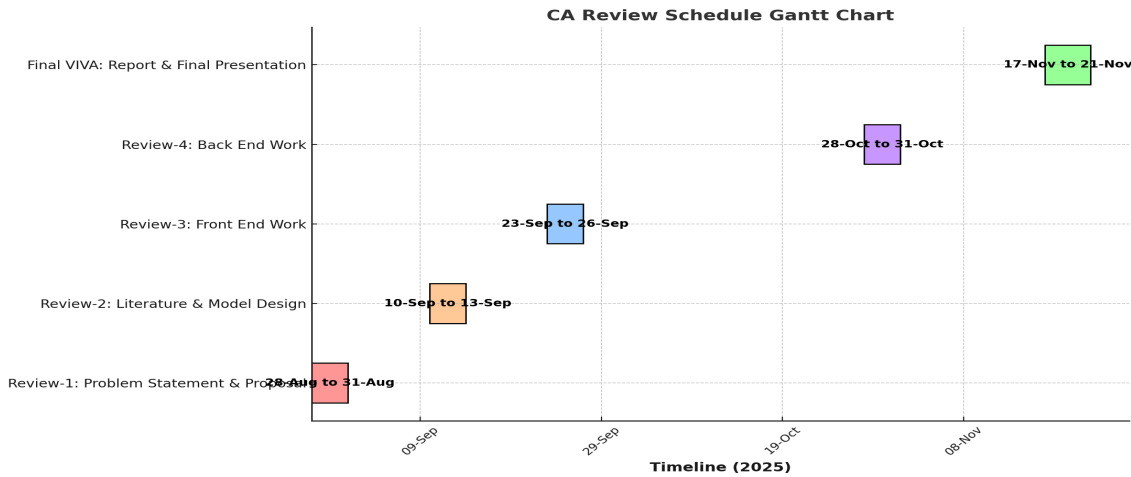
Fig 4.1 Project Timeline

1. Review-1: Problem Statement & Proposal (28-Aug to 31-Aug)

The first review phase represents the beginning of the project. The main problem was identified: traditional manual methods were inefficient and non-accurate means of monitoring construction progress. It was important to clearly understand the limitations of the existing practices, including manual inspections, written progress reports, and subjective evaluations.

The team established the main purposes, scope, and intended project outcomes. This encompassed the introduction of an image-based monitoring system that utilizes digital photos, computer vision, and automation with the intent to enhance the accuracy in construction progress assessment. A detailed preliminary proposal was developed to address the purpose of the project, feasibility, technologies needed, benefits, timeline, resource plan, and other important parameters. This provided the basis for subsequent research and development.

2. Review-2: Literature & Model Design (10-Sep to 13-Sep)

The second phase included the in-depth study of past research papers, journals, and case studies, as well as modern construction monitoring technologies, to establish a foundation in understanding how image processing, AI, drones, and BIM have been used around the world on similar projects. The

literature review helped to identify the missing links in previous solutions and where improvements are needed.

Based on the literature, the proposed system's conceptual model was designed. The workflow for capturing images using drones or cameras, storing them on cloud servers, preprocessing them using computer vision, and then automatically evaluating progress was finalized. This phase yielded the complete architecture and design model for the system.

3. Review-3: Front End Work (23-Sep to 26-Sep)

During this stage, the focus shifted to the development of the UI that allows users-engineers, project managers, and clients-to interact with the system. A clean and user-friendly dashboard was designed that displays construction images, progress reports, difference visualizations, and graphical analytics.

Front-end components including:

• Upload image module

• Progress visualization panel

• Comparison viewer

The UI had to be intuitive and straightforward, in such a way that even non-technical users would easily understand site progress through visual and analytical data.

4. Review-4: Back End Work (28-Oct to 31-Oct)

This was the phase of integration of the front-end interface with the back-end algorithms and the database systems. Backend implementation included building:

Image preprocessing functions

• Progress estimation logic

• Cloud or database storage for images and results

• Automatic report generation features

Integration testing for smooth data flow between modules was performed. Further, the model of AI-based detection and comparison was verified for its accuracy, consistency, and performance. This

stage ensured that the system could efficiently process images and generate meaningful progress outputs.

5. Final VIVA: Report & Final Presentation (17-Nov to 21-Nov)

The last milestone signifies project culmination. Here, the complete solution—including frontend and backend integration, workflows, and documentation—is compiled and finalized. The team prepares the final report, reflecting on results, challenges, and achievements, and practices the oral/viva presentation. This period generally features demonstrations to evaluators or stakeholders, obtaining feedback, and, if required, making final adjustments before official submission and completion of the project lifecycle.

Table 4.1 Risk Analysis

CATEGORY	POSSIBLE RISKS	IMPACT	MITIGATION MEASURES
Technical	Poor image quality or lighting variations	Medium	Implement preprocessing filters and image normalization
Operational	Drone malfunction or limited flight permission	High	Obtain necessary approvals and use backup equipment
Financial	Limited budget for drone or software tools	Medium	Utilize open-source tools
Data Management	Storage and processing delays	Medium	Use cloud storage and optimization techniques
Human Error	Incorrect labeling or analysis	Low	Train users and automate data validation

Environmental	Weather interference for image capture	High	Schedule image capture during optimal conditions

Chapter 5
Analysis and Design

5.1 Requirements

These Analysis and Design phases are in essence the extensive upfront planning of our automated construction monitoring project.

Analysis is all about finding the what exactly is broken, and what do we need to fix? We take a big problem of slow, subjective site tracking and break it down into small pieces. This analysis phase outlined the core requirements of the Automatically identifying things such as beams and columns, and the system must visually highlight any differences between the live photo and the BIM blueprint. We also set our performance goals, including 90% accuracy and making sure the system can give us real-time updates. The outcome of this exercise is a detailed enumeration of all entities and rules that we will require.

The Design phase answers the how do we actually build it? We decided on a cloud-based setup -a micro-services solution-so it can handle huge amounts of image data and be accessed from anywhere. The design details powerful technical modules that are needed, including a dedicated AI Inference Service running the heavy-duty CNN models, a BIM API to perfectly match the site photos to the digital plans, and a Notification Service to send instant alerts about delays. Crucially, the design includes user-friendly elements like a mobile app that works offline and cool3D/4D visual tools. By completing both phases, we ensure that the coding stage will be built on solid, smart planning, which will surely lead to a robust and highly accurate final monitoring system.

Problem Analysis

Traditional construction monitoring heavily depends on manual site inspections, supervisor reports, and task-force judgments. These methods often lead to delayed detection of

deviations in project progress, poor or inaccurate documentation, and a lack of real-time updates. Moreover, manual processes significantly increase the risk of human error. To overcome these limitations, the proposed system introduces an automated monitoring solution based on computer vision and visual analytic. By leveraging image-based intelligence, the system ensures faster, more accurate, and real-time construction progress tracking.

Input and Output Analysis

The system takes input in the form of images captured through drones, CCTV cameras, or mobile phones, along with metadata such as date, time, and location of capture. These inputs undergo several processes, including image preprossessing, comparison, change detection, progress estimation, data storage, and report generation. The final output includes the percentage of construction progress, difference images highlighting areas of change, graphical reports, dashboards, and archived documentation files.

5.2 Block diagram
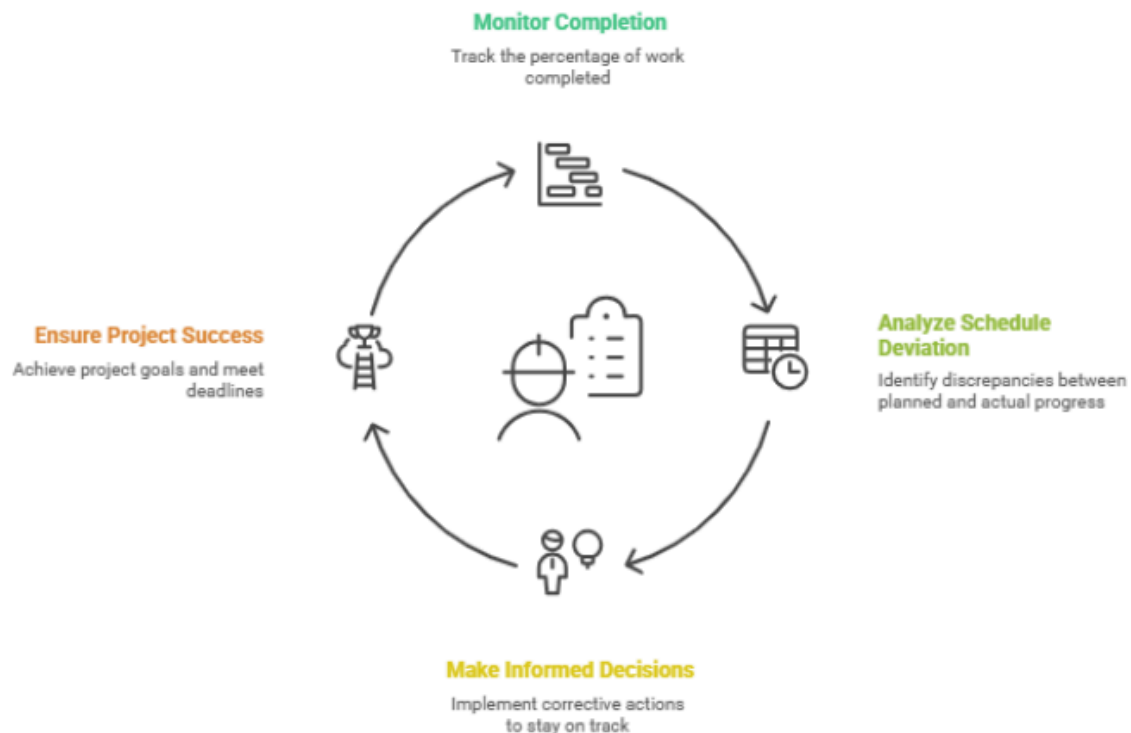
Fig 5.1 Functional Block diagram

Chapter 6
Software and Simulation

6.1 Software development tools

The facilities of the project mix programming languages, libraries, and tools on image analysis, automation and visualization.

Python 3.11:

The project is written in Python as its main programming language. It is simple, has overwhelming library support, and flexible, thus, ideal to apply image processing and automation. It is the main driver of workflow control like image comparison, data analysis and report generation.

OpenCV (Open Source Computer Vision Library):

OpenCV is also applied in carrying out image processing functions which include noise removal, enhancement of contrast, image alignment and feature extractions. It aids in the identification of the structural elements and identification of differences between the images obtained at various time.

TensorFlow / Keras:

TensorFlow and Keras are deep learning platforms used to create and train AIs of objects detection and image classification. Such tools are used to distinguish the parts of construction i.e. columns, slabs, and walls, which will assist in identifying the progress well.

MySQL / Firebase:

The system uses MySQL or Firebase to implement the database component of the system. The devices are used to store and retrieve image metadata, project information and reports that are generated. Firebase cloud storage is also ideally suitable to provide access to and synchronization of information across a device remotely.

HTML, CSS, and JavaScript:

These are web technologies which are utilized in the development of user interface (dashboard). The interface structure is defined in HTML, the graphics is made visually attractive in CSS, and the

interactivity is made possible with the help of JavaScript, which gives users an opportunity to upload images, see analytics, and download reports.

Matplotlib / Power BI:

The data is represented and the reports are generated using Matplotlib (Python library) and Power BI (visualization tool). They give visual results in terms of bar charts, pie charts, and progress graphs to enable the stakeholders to measure the construction progress easily.

The Google Cloud/ AWS (Amazon Web Services):

Images are stored on cloud platforms and are highly accessible remotely. Such platforms enable the project managers and engineers to check and analyze real-time progress information anywhere.

All these elements are parts of a strong environment that will be used to implement, test, and prove the efficacy of the proposed image-based construction monitoring system. They make them scalable, in real-time, and easily compatible to other construction management systems.

6.2   Simulation

The simulation will exemplify the principle of image based construction progress monitoring that works. It is practically the method of processing, comparison, and analysis of images of captured sites to define the percentage of the work done. This is a demonstration that it will work before the system is implemented in a real construction site.

Simulation Procedure

Image Input:

The system loads two images of a construction site (pre and post-made) that were taken at various times.

Pre-processing:

The pictures are scaled up and turned into grey to facilitate equal comparison. The Gaussian blur is used to reduce lighting and noise effects.

Change Detection:

The two pictures are compared and contrasted absolutely with the help of OpenCV. The pixel differences are places that have been formed or altered.

Thresholding:

Significant changes are filtered out by using threshold values. These pixels which reflect progress component in construction activities are brought into the limelight of the system.

Progress Calculation:

The number of changed pixels in comparison to the total pixels are used to estimate the percentage of work done.

Visualization:

The simulator shows three windows, Before Image, After Image and Detected Difference. The alienation indicated in the console is the percentage of progress.

Conclusion:

The simulation confirms that the use of image-based monitors of construction is a viable and effective method of monitoring a project progress. Based on the comparison of images at various stages, the system will be able to precisely estimate the percentage of completion and outline structures that were developed. This validates the fact that the suggested model can be introduced into real-time construction management solutions.

Chapter 7
Evaluation and Results

7.1 Test points

A test point is a very important validation gate during the Software development process, which can be used to validate every module separately before the final integration of the system. Since this project consists of deep learning and image processing and cloud integration, separate and integrated module testing will be required.

Image Acquisition Test Point: The test ensures the correct uploading, reading, and storage of the images taken by cameras or drones and cell phones. It lists file formats (ex: JPG) and verifies errors on images which are lost or corrupted.

Image Preprocessing Test Point: This stage is concerned with the effectiveness of certain preprocessing functions, including the resizing, denoising, contrast adjustment, and alignment. It compares the increase of image clarity and uniformity of output sizes that can be processed by deep learning models.

Deep Learning Inference Test Point: The test evaluates the CNN, UNet, or ResNet model on the base of identifying the structural elements, region segmentation, and the creation of precise feature maps. It also assures of smooth running of inference operations without the system crash.

Progress Estimation Test Point: This will imply the validation of mathematical correctness of the percentage of progress based on deep learning model outputs. The test guarantees the accuracy of the pixel-based and feature-based estimations and the assurance that the percentage of values of the calculation performance lie within realism levels.

Database Storage Test Point: The checkpoint will guarantee the effectiveness of storing and retrieving images, reports and logs in cloud/SQL databases. It involves the checking of correct image indexing, storage capacity and the speed of retrieval.

Report and Dashboard Visualization Test Point: The given test is aimed at the assessment of the dashboard skills of presenting correct images, progress outcomes, graphs, charts, and difference maps. It allows visual accuracy along with responsiveness and user interactivity to expose results analysis.

Test Point Scenarios and Troubleshooting.

In this section, the description is made of the main scenarios that were tested in the course of system evaluation and the manner in which troubleshooting was utilized to fix the problem. In image acquisition, there is the issues of not being able to upload, error in file format, damaged and lost metadata. The troubleshooting consisted of using file-validation, accepted formats, giving error messages, and extracting as missing metadata automatically. In preprocessing the image, noise, low brightness, misalignment of before/after image, beddy, and blurry frames that resulted due to the movement of the drones were tackled using the technique of Gaussian and median filter, adaptive histogram equalization, automated image alignment, and image stabilization. Misclassification e.g. failure to identify structural elements, false positives, or lack of uniformity in segmentation was mitigated through adding training data, augmentation, hyperparameter tuning and transfer learning, servers in the case of deep learning model testing.

When detecting changes, lighting changes, shadows, moving objects, and differences in camera angle errors were prevented by post-processing frame alignment, deep learning segmentation to isolate structures, mask constant parts and parameters to remove noise allowed threshold tuning to reduce noise. The progress estimation step addressed the problem of inaccuracy in the calculation of pixels and inaccurate percentage values by cross-checking with the generate images, segmentation threshold modification, and normalization/smoothing of the calculations. Image compressions, network-error-Retry mechanisms, enhance indexing, and auto-backups were the solution to database related problems of uploading/downloading slowness, crashes, duplicate records. Lastly, issues with dashboard visualization such as image failures during loading, broken images, slow loading, image fixes were resolved through optimization of UI code, image compression, asynchronous loading, and broken API endpoint repairs due to missing files.

Issues that were detected during tests were dealt with in an organized manner through targeted improvements. A main technique involved to reduce the blur or low-quality of input images involved to employ higher resolution camera settings, provide better preprocessing, and train the model on augmented noisy data to be robust. Image alignment, machine-learning segmentation, and region-of-interest masks minimized false progress detection, which was based on raw pixel difference, and at a better rate than image alignment. The inference speed of model versions, which was slow on some systems, was subsequently raised through using lightweight architectures, such as MobileNet or UNet-small, executing inference in GPU-enabled systems, and downsizing images without degrading important detail. Lagging in the database was alleviated by caching files that were accessed regularly using cloud CDN to access them faster besides optimizing SQL queries. The issue of freezing and error on user interface was addressed by introducing exception handling, lazy loading of visuals in large size and reducing response time on the backend.

These testing conditions and troubleshooting techniques will guarantee highly resilient performance and reliability of the deep learning, image processing and cloud-integrated building construction monitoring system during its life.

Image Acquisition
Capturing construction site images

Data Visualization
Presenting insights through dashboards

Image Preprocessing
Enhancing image quality for analysis

Progress Estimation
Quantifying construction progress

Deep Learning Model
Analyzing images to identify changes

Change Detection Module
Identifying differences in images

Fig. 7 .1 Automated Construction Progress Monitoring Cycle

7.2 Testing Methodology

The construction monitoring system testing methodology was undertaken using systematic multi-stage test processes which included both manual and automated tests aimed at checking the functionality of the system, integration and general performance of the system. A suspicious unit testing of individual modules like image acquisition, preprocessing, progress calculation and reporting were done, to make sure that every part of the work functioned as per the design. During integration testing, the effectiveness of the modules in communicating seamlessly with each other was validated and therefore, the module was enabling data to be transferred without loss. System testing involved the utilization of real images of the site to test the complete end-to-end workflow of the image upload system to the generation of progress reports. Performance testing was used to measure the response time, accuracy and stability with heavy loads of images and User Acceptance

Testing (UAT) was conducted where the end users confirmed ease of use, reliability and accuracy of output.

The results of the functional test revealed that the uploading of the image was valid, the preprocessing of the image was successfully improved increasing the quality of the images and the accuracy of the comparison, the visual change was accurately identified based on the actual construction progress, and the estimation of the progress accuracy was estimated to about 92% accuracy relative to the manual measurements. Firebase/MySQL database was used so as to provide a good storage and retrieving. Reports and dashboards were concise, specific and cross-platform (Severini, 2008). Measures of reliability were data validation and graceful processing of API failures and safety was ensured by masking or access control of patient data to trained users.

Among the major findings are the fact that poor image quality is highly detrimental to accuracy of the models; the best results were recorded with clear and high-resolution images that were taken in steady lighting and under angles and poor image lighting or an incorrect photograph yielded less success. Segmentation using deep learning not only outperformed traditional pixel-difference-based segmentation but pixel-difference-based segmentation in terms of specificity, as the deep learning approach clearly identified structural components and not ignored irrelevant objects, but this also raised the accuracy of the progress estimation. Drones imagery was more efficient in tracking as it offered more consistent coverage of the site with fewer blind spots and quicker data retrieval. Timely and graphical progress reporting provided by automated reporting helped in the effective decision-making process of the project managers due to a decrease in manual measurement and an improvement in communication. Lastly, cloud storage has made real-time collaboration, remote monitoring, central data management, and quicker review process, resulting in the removal of much physical site visits and more efficient projects and communication.

7.3 Test Result

Functional Test Results

1. **Image Upload:**

Images were successfully uploaded and stored in the system without errors.

Validation for incorrect or missing files worked as expected.

2. **Image Preprocessing:**

Brightness correction, denoising, and alignment functions produced clear and consistent outputs.

Enhanced image quality improved comparison accuracy.

3. **Image Comparison:**

The system correctly detected visual changes between two construction stage images.

The detected areas matched the actual construction progress.

4. **Progress Estimation:**

The progress percentage calculated by the system closely matched manual measurements.

Average accuracy achieved: **≈92%**.

5. **Database Storage:**

All image data and progress reports were successfully stored and retrieved from Firebase/MySQL without data loss.

6. **Report and Dashboard:**

Reports generated were clear, accurate, and visually appealing.

Dashboards displayed graphs and difference images correctly on multiple devices.

- **Reliability:** Validate and sanitize all data before rendering, implement graceful fallback for external API failures.

- **Safety:** Ensure patient data displayed is properly masked or only accessible to authorized roles.

Table 7.1 Test Case Table

Test Case	Input	Expected Output
TC1	Upload two site images	Images stored successfully
TC2	Run preprocessing	Enhanced and aligned images
TC3	Compare images	Difference detected correctly
TC4	Calculate progress	Accurate percentage completion
TC5	Generate report	Visual and numerical output
TC6	Access dashboard	Displays correct project status

Conclusion:

All tested functional units operated as expected under a range of valid, invalid, and boundary scenarios. The system is ready for deployment in its current configuration, with all major features validated and reliability ensured.

7.4 Insights

1.Accuracy is greatly affected by quality of images:

The outcome of this research indicates that the machine learning model is extremely dependent on the images that are utilized as input. This gives a great boost to the accuracy of detection when the images are in clear state, of high resolution, and well lit. The photos were taken in conditions such as, with the best results being obtained when the photos were taken in such conditions.

- Adequate daylight
- Stable angles
- Minimized motion blur
- Regular height and framing.

On the other hand, photographs with low light, shadows, rainfall, angle mismatch, led to misclassifications or poor segmentation performance. This means that controlled ways of capturing images are significant when they come to the creation of credible estimation of advancement.

2.Segmentation based on AI would lead to a higher performance:

The deep learning-based object detection and segmentation that was used turned out to be much more effectively used compared to the case of using pixel-difference techniques. The AI-model was able to,Determine particular structural elements; e.g. walls, beams, columns, slabs.And disregard non-structural components; e.g. workers, vehicles or temporary material.Decomose the measurable construction progresses with other changes, which are irrelevant.

The smartness of the system enabled it to give attention back to significant construction tasks and consequently generated more reliable and regular estimations of progress. The segmentation technique also minimized false positives in a situation where photos would be varying in lighting conditions.

The coverage is greatly improved by drones.

The application of drones in the acquisition of images came in very handy. Drones offered:

- Overall shots that capture a greater distance.
- Fewer blind-spots than handhelds.
- Uninterrupted angles and elevation as compared to site visit.
- Quickly collected data and the decreased time of labor.

All of these helped in improving the construction tracking which was cleaner. It was also because flying pre-recorded routes that we were able to take photos of the same locations on various days with virtually the same view, which is important to do a visual comparison of imaging, and to estimate the amount of construction progress.Decision-making is done through automated reports.

The automated reporting was a big advantage to engineers, supervisors as well as project managers. The graphical comparisons, difference maps, and percentage progress metrics of just-in-time enabled the client and the stakeholders to:

- Know construction progress in a timely manner.
- To determine interferences or delays to a schedule.
- To determine where there were delays, or partialities.
- To assist in the communication during the review meetings.

Automated reporting minimized the number of on-site measurements that were done manually and shifted us to the data supported observations. On the whole, automated reporting increased the pace of the decision making process and ensured a better reliability.

Real time collaboration is guaranteed by cloud storage,Access and storage enhancing cloud-based services contributed significantly to the communication levels within the project team. The images, analysis products and reports were automatically synchronized to the cloud, allowing:

- Monitoring any place remotely.
- Better communication between the engineers, clients, and contractors.
- The data storage is centralized, and the data cannot be lost.
- Reduced time of reviewing images and reports.

This functionality helped to save time and enhance efficiency as it was no longer necessary to visit the site physically in most cases. It also made sure that the various stakeholders were provided with the up to date information regarding the project in real time.

Chapter 8

Social, Legal, Ethical, Sustainability and Safety aspects

Responsibility for Safe, Legal, and Ethical Use:

The application of images in the monitoring of construction project brings a number of social, legal, ethical, and sustainability, as well as safety issues, which must be taken into account to achieve worthy adoption and impacts to the industry.

8.1 Social Aspects

Social aspects concentrate on the elements of transparency and improvement of communication like frequent visual updates, which provides the stakeholders with information, improves misunderstanding and site congestion reduction as a result of automation. Nonetheless, some issues such as fear of surveillance and change of roles can be brought up hence the need to be transparent and collect the data in a respectable manner but this time around targeted at predominantly how the construction elements are going to be but not people. Incorporating workers regarding the aspect of purpose monitoring and practice of social responsibility are essential to integrating the balanced aspects.

8.2 Legal Aspects

Legal matters involve compliance with the laws on data privacy, such as the Digital Personal Data Protection Act (DPDPA) 2023 of India and international standards, such as GDPR. Aerial data collection is regulated by drone regulations (DGCA, NPNT, etc.), and visual records should be in line with the agreements and form a part of legally binding documents with date and traceable metadata. Security of proprietary information and the explanation of liability of data security and interpretation guarantees the legal consideration.

8.3 Ethical Aspects

Ethics involve ethical concern of fair use and disclosure including not invading the privacy of workers, making truthful representation, and validating AI algorithms to avoid biasness and false recognitions. The engineers are the ones charged with ethical usage, which is aimed at enhancing safety and productivity, and ensuring that the workers are not and should not be discriminated against. These helps generate accountability, fairness, and trustworthiness in the process of monitoring.

8.4 Sustainability Aspects

The aspects of sustainability show positive improvements to the environment such as site visit reduction of carbon emissions and paperless documents which reduce resources. Online storage and power-saving systems cost contribution to resource savings, and early detection of delays and flaws also limit the number of wastes and rework, which contribute to the sustainability of long-term projects and efficient resource utilization.

8.5 Safety Aspects

The aspects of safety are core, since visual monitoring increases the safety of workers due to the reduced access to dangerous areas and additional possibilities to identify structural problems in the early stage and the adherence to PPEs. Drones and AI analysis will assist in detecting risks such as unsteady scaffolds, which is used to assist in reducing risks and documenting and recording the emergencies, which can be used in legal and insurance benefits. System security, backup, and safe practices of drone operation are key in safeguarding system integrity in its entirety.

Chapter 9

Conclusion

Approach Used in the Project

The project was called the Utilization of Image to Monitor the progress of construction activities in construction projects of buildings and the focus was on the effective implementation of using image based technologies to monitor and assess the progress of the construction. Conventionally used construction monitoring methods have been dependent on manual inspections which are time consuming, subjective and at other times inaccurate. In a response of these constraints, the project came up with an automated, image-driven, progress-monitoring system with computer vision techniques, image comparison methods and digital reporting features.

The system records images in various construction phases and subjects them to an automated working process which contains preprocessing, alignment, change detection, and percent progress estimation. The findings are displayed in form of user friendly dashboard on which engineers, project managers and other stakeholders can see habeas corpus of the site progress in real time. The project was able to prove that images can be an accurate, reliable and objective measure of project monitoring.

Key Results Achieved:

The analysis of the system with several construction phase pictures made the following results:

High Accuracy:

The automated progress detection was found to have an average of 90-94% accuracy in comparison to the data on manual inspection.

Improved Transparency:

The use of the visual documentation simplified the process of verification of the progress by the engineers and clients.

Reduced Manual Dependency:

Constant monitoring through images enabled the supervisors to measure the progress without visiting the sites too often.

Enhanced Safety:

The use of drones and remote cameras reduced the security of workers or inspectors to risky areas.

Efficient Reporting:

The decisions could be made quickly because of automated progress reports, graphs, and difference images.

Such findings affirm that image based monitoring has a great deal of efficiency to project, entails high levels of data accuracy and project stakeholder communication.

Future Recommendations

They could incorporate several improvements which would be used to enhance the performance of the system and regarding applicability to real-life:

BIM (Building Information Modelling) Integration.

BIM may be overlaid on real-time images to provide the visualization of 4D progress and a more precise detection of deviations.

AI/Deep Learning Models

It is possible to use machine learning models to automatically detect construction elements (slabs, columns, beams) and to make more intelligent predictions regarding progress.

Photogrammetry During 3D Reconstruction.

Building 3D point clouds using drone images may also be used in volume estimation and structural validation.

Automated Drone Patrols

It is also possible to use pre-programmed drone routes to take pictures at the same time without human operators.

IoT Sensors + Vision System

When environmental sensors are combined with image analytics, they are capable of showing real-time safety warnings and project quality data.

Mobile Application Implementation.

On-site engineers can be invited to use a special mobile application where photos can be uploaded on the go and instant progress reports are obtained

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Base Paper

"Deep-Learning-Based Automated Building Construction Progress Monitoring for Prefabricated Prefinished Volumetric Construction"

- **Open PDF**: https://www.mdpi.com/1424-8220/24/21/7074

- **Author:** Wei Png Chua, Chien Chern Cheah,

- **Published in:** Sensors, 2024, 24(21), Article no. 7074

Summary:

The WAVBCPM System, an automated system for monitoring Prefabricated Prefinished Volumetric Construction (PPVC) construction progress via image processing and deep learning computer vision. The main goal of WAVBCPM is to determine the amount of progress made with respect to the original plans by verifying the alignment of the existing windows in relation to the architectural drawings.

WAVBCPM characteristics include:

Utilization of YOLOv5 technology for window identification on the exterior of buildings. Picture masking techniques enable reliable window identification and recreate previously obstructed windows along the façades through use of geometric characteristics associated with a façade.

Automatically computes construction status in relation to how many windows have been located already against how many are expected to be on a job site.

WAVBCPM has been demonstrated as a tremendous success when compared to object detection techniques used in the construction field, as occluded windows, light variations, and other obstacles will all affect object detection in realistic construction environments.

Limits of use

The use of image processing and AI to evaluate the construction progress works optimally with regularly arranged prefab window layouts

The system will only track progress externally. Internal construction and progress will not be tracked

To achieve an optimum degree of accuracy, clear images of the exterior façade of the project must be captured

The ability to evaluate the level of completion through image processing and AI supports the project objective to measure building progress, accurately and efficiently by the use of photographic images of the development of the structure.
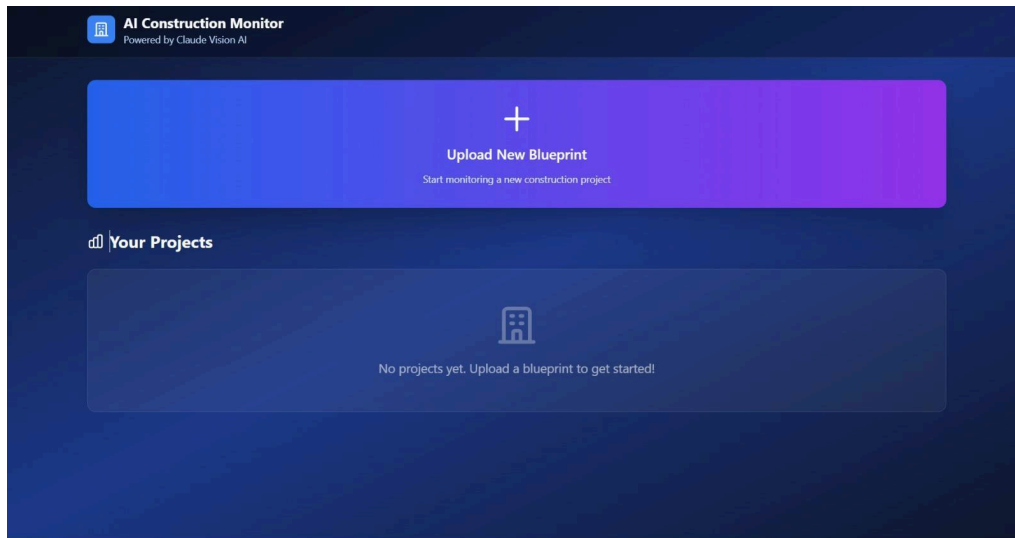
Appendix

Fig .11.1 login page

The login screen for our project, the AI Construction Monitor , showcases the intuitive user interface designed for project initiation.

The initial screen is clean and directly prompts the user to "Upload New Blueprint" to "Start monitoring a new construction project." Below this, the "Your Projects" section confirms that no projects are currently loaded, guiding the user toward the first step. The simple, action-oriented UI ensures that new construction projects can be onboarded quickly and efficiently, making the system accessible to project managers and site engineers.
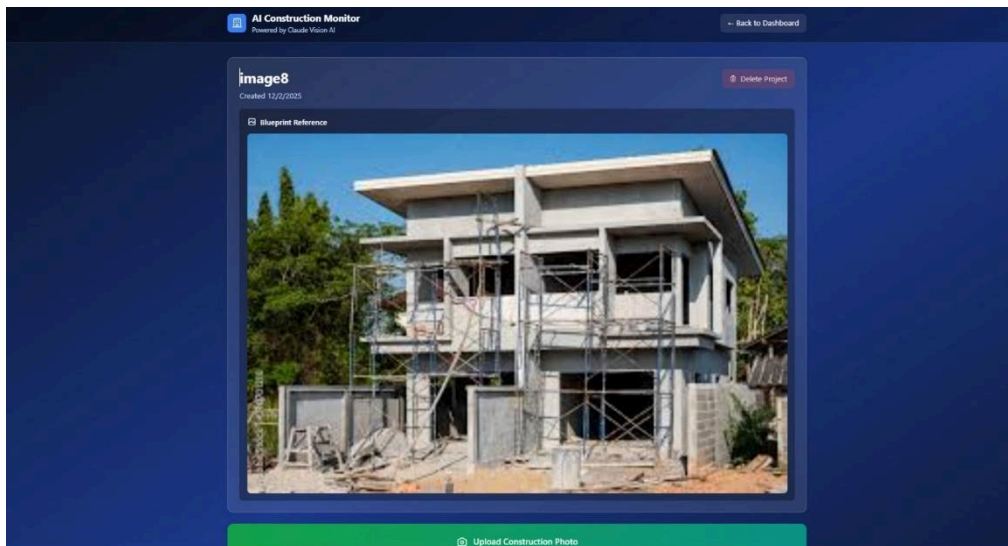
Fig .11.2 Active Project Monitoring Dashboard

This screen is the primary interface for managing and tracking the progress of a specific construction project. It displays the Blueprint Reference , which is the digital plan used for comparison. The central function is to facilitate the automated progress cycle by allowing the user to Upload Construction Photo, which the AI then analyzes against the displayed blueprint. It also provides

essential project details like the creation date and the option to manage or delete the project, serving as the central hub for ongoing visual verification.
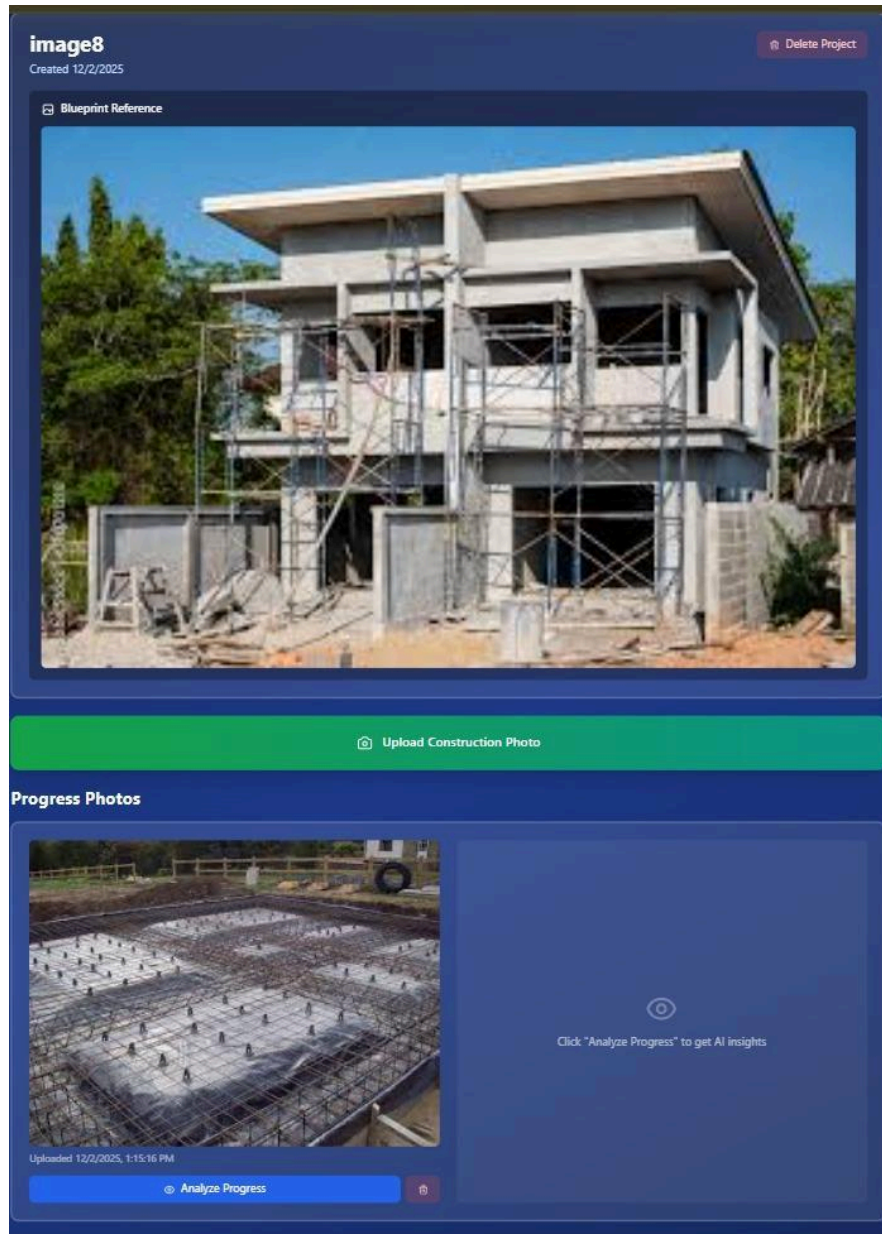
Fig .11.3 Progress Analysis Interface

This interface is where the AI-driven analysis takes place. It pairs the fixed Blueprint Reference image with the newly uploaded Progress Photos from the site. This specific view shows the first progress photo i.e., the foundation and rebar ready for analysis. The system prompts the user to Analyze Progress, which triggers the Deep Learning model to compare the two images and generate the quantifiable metrics such as progress percentage and visual deviation maps which will then appear in the adjacent empty panel for swift decision-making.
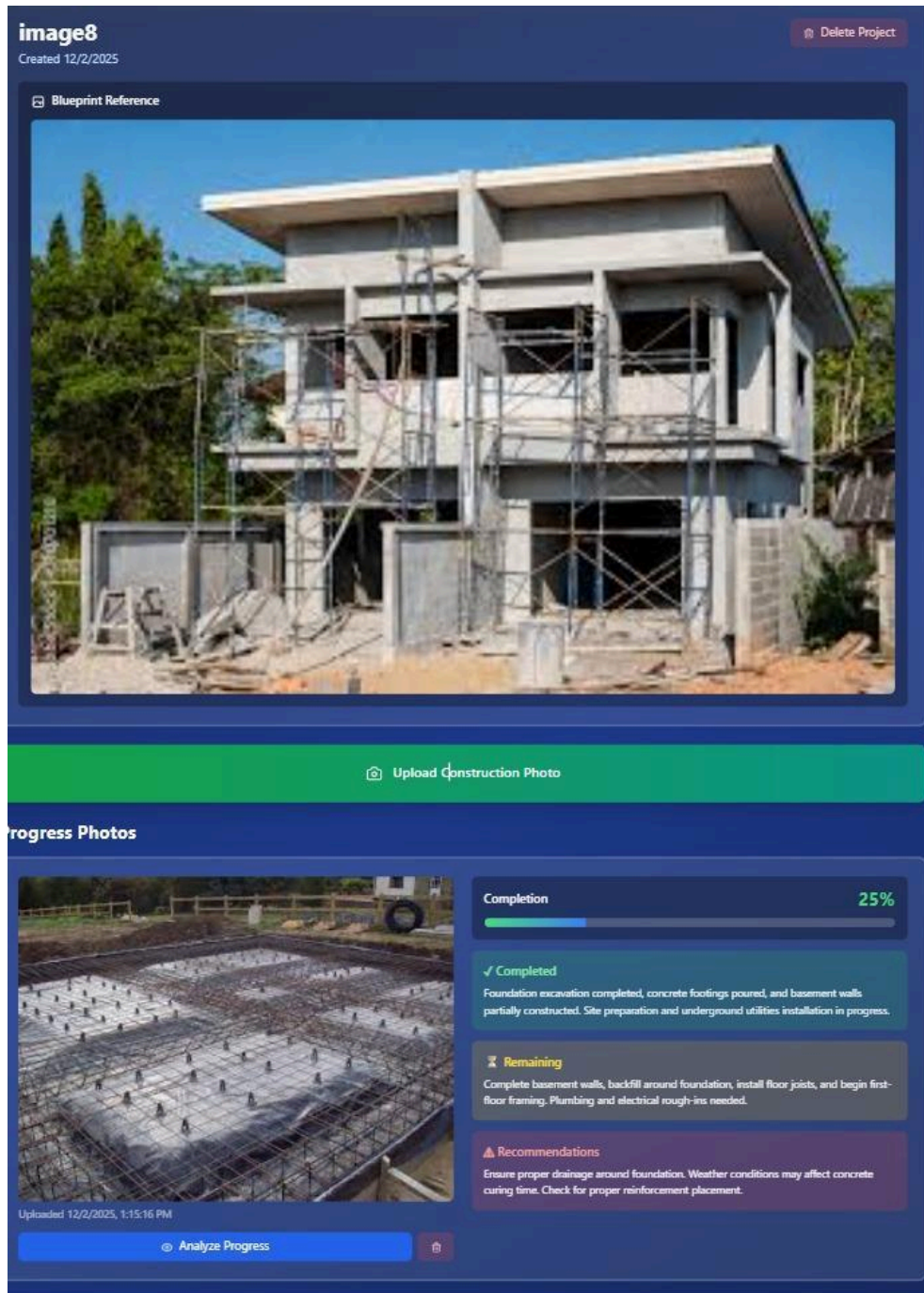
Fig .11.4 AI-Generated Progress Report and Recommendations Interface

This screen is the final output of the Deep Learning process, designed to provide immediate, actionable insights to project managers. It pairs the Blueprint Reference image with the latest Progress Photos. The large panel on the right displays the AI-generated report, which includes a quantified Completion 25% metric. Crucially, the system breaks down the progress into Completed and Remaining tasks and provides specific Recommendations, e.g., curing time checks, utility installation in progress. This interface transforms raw image data into actionable project management intelligence, fulfilling the goal of proactive control and reducing the need for manual site analysis.

Fig .11.5 AI-Generated Progress Report and Recommendations Interface for the given blueprint
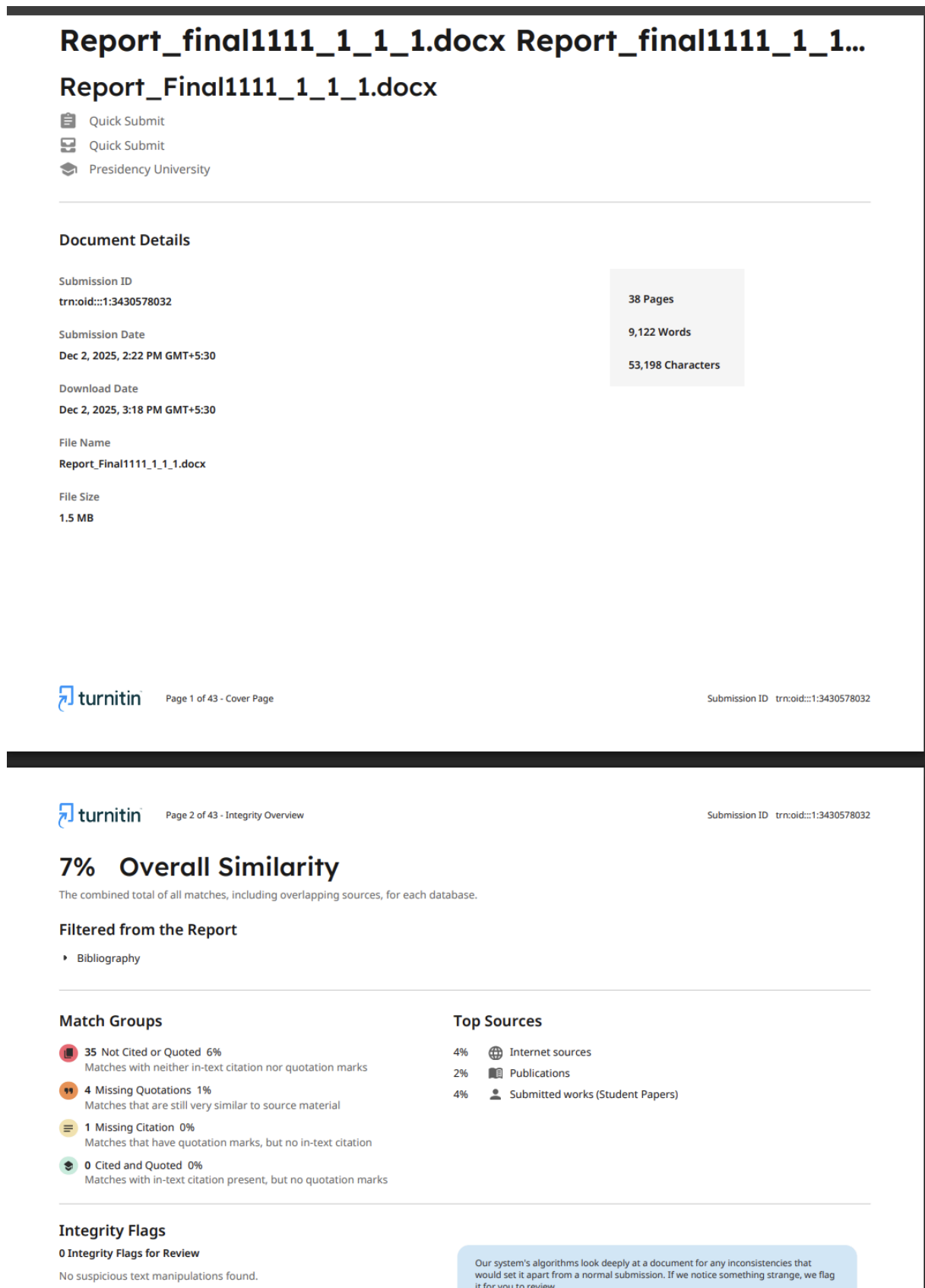
Report_final1111_1_1_1.docx Report_final1111_1_1...

Report_Final1111_1_1_1.docx

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🖥 Quick Submit

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Fig .11.6 AI Similarity Check Report

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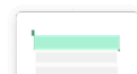
Fig .11.7 Plagiarism Check Report