Management of Technology Capstone Fall 2023

Final Report

Advancing Construction Management: Image Processing in BIM Integration & Machine Learning

Aarjav Ajmera
Dibo Shentu
Weiming Zheng
Akash Tomar
Wanyi Zhang
Victor Wang

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Abstract

To transform construction management procedures, this report investigates the convergence of image processing, machine learning (ML), and building information modeling (BIM) integration. In recent times, there have been notable developments in the construction sector, with digital technologies becoming crucial in enhancing productivity and streamlining decision-making procedures. This study focuses on using image processing, BIM, and machine learning to work together to address important difficulties in construction project management.

To extract useful information from visual data, including photos and films taken on building sites, image processing techniques are used. Afterward, these visual insights are smoothly incorporated into the BIM framework, giving the project a comprehensive and dynamic representation. BIM facilitates cooperation and improves stakeholder communication by acting as a central repository for all project data. The combined data is analyzed using machine learning algorithms, which allow for risk assessment, predictive modeling, and process improvement in the building industry. ML models can foresee possible problems, find trends in past project data, and suggest the best course of action for executing projects. Construction managers can deploy resources effectively, make well-informed decisions, and proactively reduce risks thanks to this predictive capability.

The report looks into how this integrated method is used in the real world to manage construction projects, taking quality assurance, cost control, and project timeliness into account. Case examples show how the combination of image processing, BIM, and ML improves overall efficiency, streamlines operations, and improves project visibility.

Introduction

NYC DDC has begun to capture 3D images of its various projects, including (1) existing conditions of interior and exteriors of public buildings (e.g., images of cracks) and (2) construction operations on infrastructure projects (e.g., aerial drone images of construction site). Ultimately, NYC DDC would like to apply machine learning techniques to interior building images and exterior building images, as an early potential example of an end-use of new technology, to identify building components, such as switches, doors, windows and existing quality conditions, to enable NYC DDC to estimate quantity take offs, which is a project cost estimation method. Another example of a potential end use of technology would be to apply machine learning to infrastructure operations to identify workers (with and without personal protective equipment) and construction machinery would enable NYC DDC to supplement safety inspection reporting.

At this point, NYC DDC is just beginning its investigations of new and emerging technologies—various image capture types and machine learning techniques—based on what it is collecting and exploring "proof of concept" ideas with technology vendors with whom it currently is working, all of which is a fraction of what is available and what the agency does. NYC DDC does not have a "master plan" (a) to investigate all possible technologies and techniques (b) in the context of all that it does in design and construction in a manner that (c) helps the agency to plan for the management of developing technologies and techniques. NYC DDC does not have a plan for its management of future technology to apply to what the agency does.

Problem Statement

The first goal of this project is to initially analyze the public building and infrastructure project images to extract items of interest for agency functions, with the goal of providing a strategic technological roadmap as to how the agency can incorporate new technology to existing site safety inspection practices.

Since the agency's initial efforts to date represents a series of small steps to assess technologies to be applied (that represent a fraction of what is available or will be available) to a subset of practices (that represent a fraction of what the agency does), the second goal of the project is to develop (a) develop a general understanding of the standard design and construction process of a large owner of assets, (b) investigate and assess the full menu of image capture types and machine learning techniques available in the market by vendor that can assist with the various parts of the standard design and construction process, (c) create a master plan for the management of future technology to be applied during the standard design and construction process of a large owner of physical assets, using NYC DDC as the case study owner.

The agency has made NYC DDC image data from its projects available to the team for this project to assist with the initial analysis described above. The goal of this project is to build a roadmap and an MVP as to how NYC DDC can leverage the application of technology for crack detection, PPE detection and BIM Modelling.

Literature Review

This report delves into a thorough examination aimed at bolstering construction management by seamlessly integrating image processing, machine learning (ML), and Building Information Modeling (BIM). Its primary focus lies in exploring the practical application of these cutting-edge technologies across various facets of construction management. These encompass the detection of cracks and personal protective equipment (PPE), the utilization of drones, and the pivotal role played by BIM in the realm of construction. Moreover, the report delves into the real-world implementation of these technologies in actual construction projects, taking into account crucial aspects such as quality assurance, cost control, and adherence to project timelines. Additionally, it delves into the intricate process of merging image processing with BIM and machine learning, providing a detailed roadmap and offering valuable recommendations to the New York City Department of Design and Construction (NYC DDC) on how best to incorporate these revolutionary technologies into their existing workflows. Overall, this comprehensive report serves as an indispensable guide for those seeking to leverage advanced technologies within the domain of construction management, with the ultimate goal of enhancing efficiency, elevating safety standards, and facilitating informed decision-making within the industry.

Crack Detection

An effective method to automatically detect and categorize the existence of cracks in photos is to combine machine learning with image processing for crack identification. There are a few essential phases in the process, and using resources like the Custom Vision website can make it easier to put this solution into practice.

Image Collection: Compile a dataset of pictures that illustrate the situations that your model must be able to identify. This covers both cracked and non-cracked photos. To guarantee that the model performs properly under different settings and for different kinds of cracks, a varied collection of photos is necessary.

Labeling: Indicate whether or not each image in your collection has fractures by manually labeling each one. In supervised learning, when the algorithm picks up knowledge from labeled instances, this stage is essential. The model can better comprehend the characteristics of cracked and non-cracked areas when the labels are properly applied.

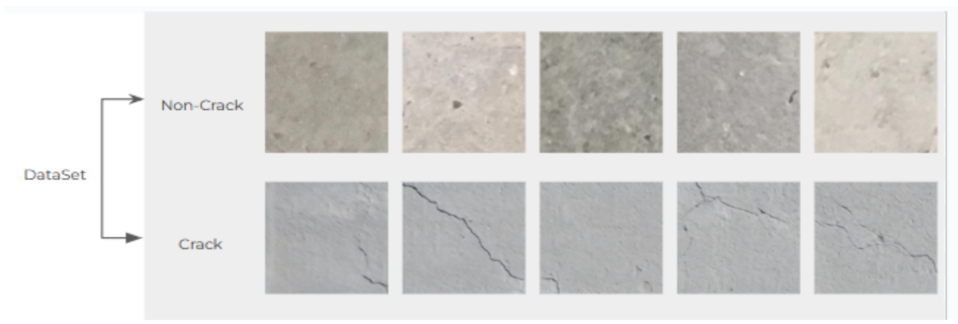
Data Upload: Provide annotated dataset to any appropriate machine learning model training platform, such as the Custom Vision website. The system learns patterns from these photos to generate predictions on new, unknown data, using this dataset as the training set.

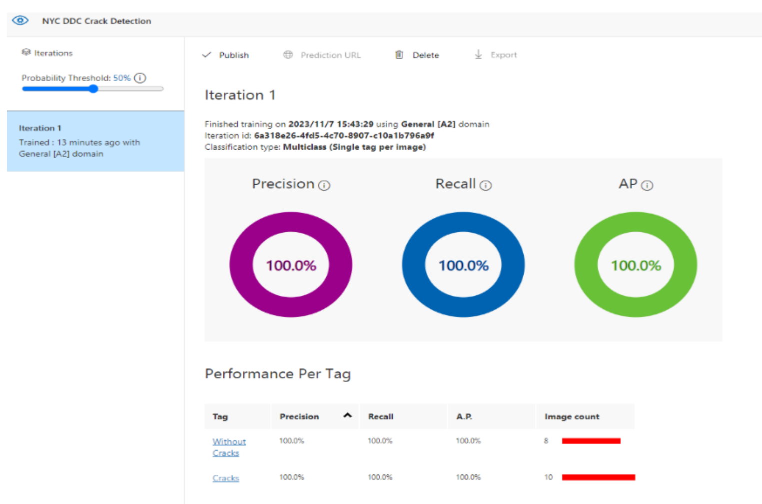
Model Training: Go to the Custom Vision website and click the "Train" option to start the training process. The supplied photos and their labels are used by the algorithm to modify its parameters during training. Until the model achieves an accuracy level that satisfies the predetermined standards, this iterative process is carried out.

Evaluation: Using a different collection of never-before-seen photos, assess the model's performance after training. To evaluate the efficacy of the model, metrics including accuracy, precision, recall, and F1 score are frequently employed. These measurements shed light on the model's ability to discriminate between areas that are cracked and those that are not.

Iterative Improvement: You might need to hone and enhance the model if its performance isn't up to par. This might entail expanding the collection with more tagged photos, particularly those that illustrate difficult situations. To create a strong and reliable fracture detection model, an ongoing process of training, assessing, and refining is essential.

Deployment: The model can be used for practical applications if it reaches an acceptable level of performance. This entails incorporating the trained model into programs or systems that can detect flaws in photos by automatically analyzing them.



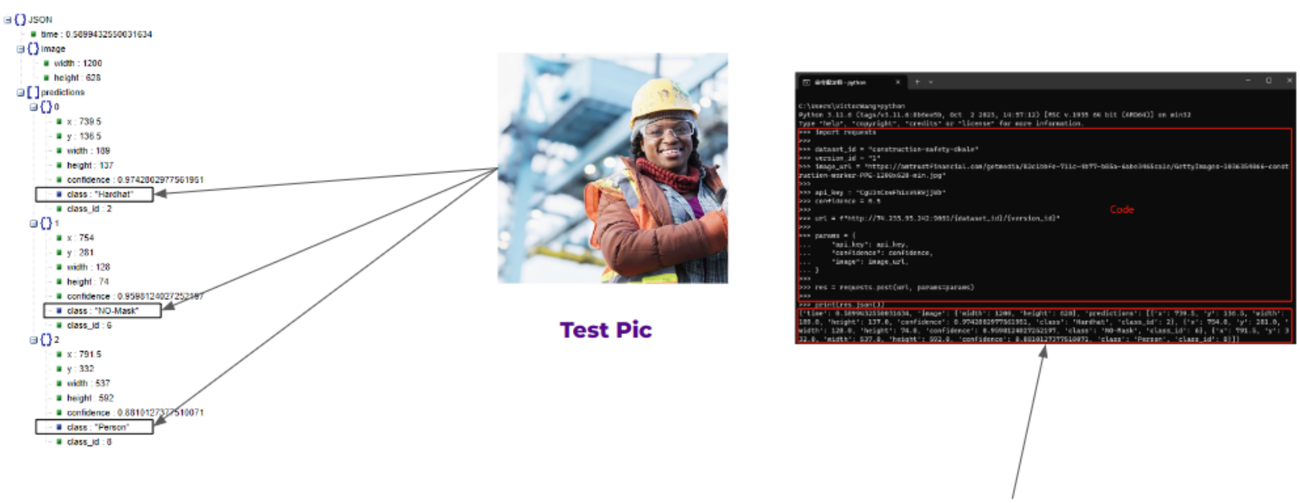


PPE Detection

Equipped with PPE Detection: A system to determine whether people in a work site are appropriately wearing personal protective equipment can be developed by utilizing machine learning and image processing. To determine whether workers are wearing safety helmets, safety glasses, and reflective undershirts, pictures or video recordings must be analyzed. A collection of labeled photos, where each image is paired with details about personal protective equipment (PPE) worn by humans, can be used to train machine learning algorithms. After that, the system can forecast in real time, improving safety compliance by guaranteeing that employees follow PPE regulations.

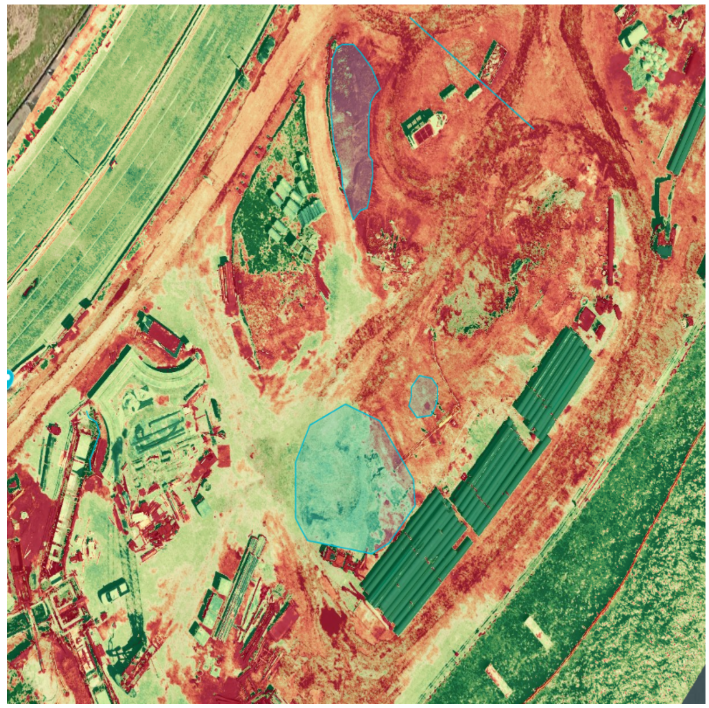
Machine Safety Inspection: To evaluate the safety state of machines, image processing, and machine learning can be used. To ascertain whether a machine is off and whether any combustible or explosive items are nearby, this entails analyzing pictures or visual data. It is possible to train machine learning models to identify the visual cues that indicate the health of the machine and possible dangers. If dangerous conditions are found, the system can notify supervisors or operators, which helps to promote a proactive approach to machine safety.

Safety of Construction Equipment: In a similar vein, the safety of construction cranes and other pieces of equipment may be assessed using image processing and machine learning. Images or video streams can be analyzed by the system to find any abnormalities or malfunctioning indicators that could jeopardize user safety. The system can categorize the safety state of equipment by using machine learning algorithms that can be trained on a dataset of photos that depict both safe and unsafe conditions. Preventive maintenance measures can be implemented in response to early detection of safety hazards, which lowers the likelihood of accidents on building sites.

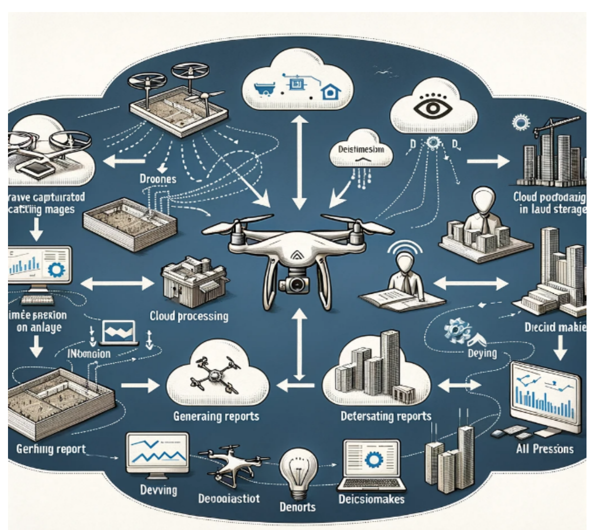


Results to Json

Drones



Using drone technology into construction processes is a versatile way to improve accuracy and efficiency at different phases of a project. Drones simplify site surveying and mapping by offering thorough aerial views that make it easier to create detailed topographic maps, identify possible problems, and support strategic site logistics planning. Drones are also essential for progress monitoring since they take pictures of construction sites and match them with BIM data. This makes it possible to track construction progress in real-time and see any deviations from the original plans right away. This guarantees an anticipatory reaction to possible obstacles, enhancing project schedules and resource distribution.



The construction sector is witnessing a dramatic synergy with the integration of drones and Building Information Modeling (BIM) software. Drones interface with BIM software to create a dynamic 3D model that superimposes real-time data collected from the construction site to provide an accurate and complete picture of the project. Real-time project monitoring is made possible by the visual insights that drones and BIM provide, which promotes communication between clients, engineers, contractors, and architects.

What is Building Information Modelling (BIM)?

BIM is a process that involves the creation and management of digital models of a facility's physical and functional characteristics. These models can be used for design, construction, and operation throughout the entire lifecycle of a structure. Building Information Modeling (BIM) is a transformative technology and process in the construction industry that involves creating and using intelligent 3D models to inform and communicate project decisions. BIM goes beyond traditional 2D drawings, allowing stakeholders to collaborate, visualize, and analyze various aspects.

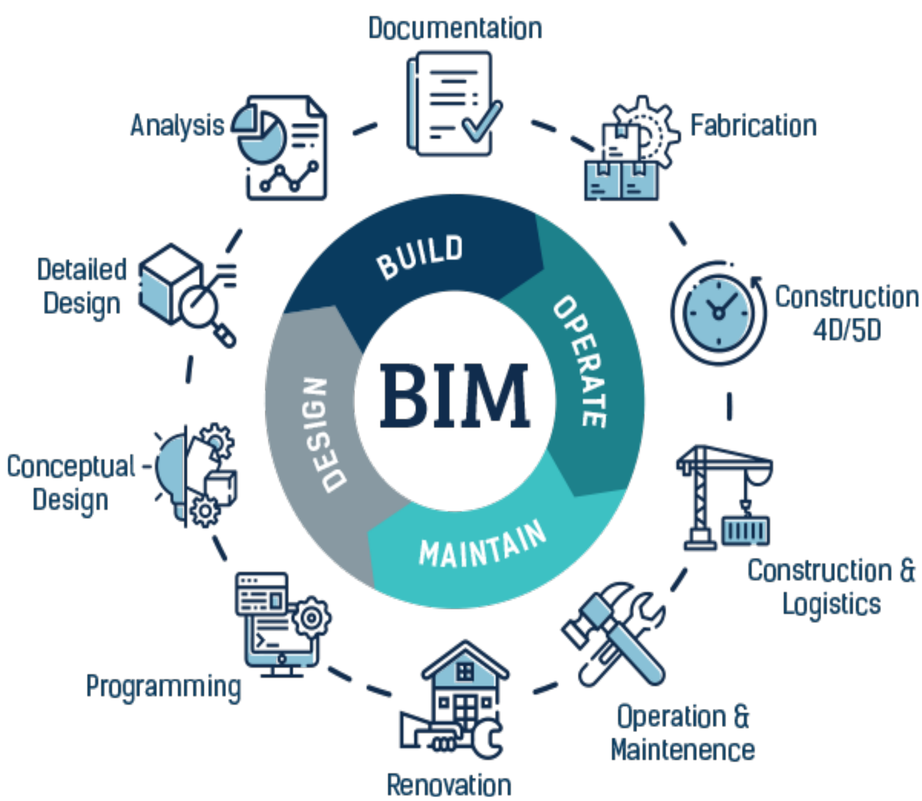


Image capturing Previous, Current, and Post Stages in BIM

Previous Stages include:

Site Analysis and Planning:

- Images taken before construction can help document the initial state of the site, providing valuable information for site analysis and planning.
- Identify existing structures, topography, vegetation, and any potential challenges or constraints.

Pre-Construction Documentation:

- Establish a baseline for existing conditions, aiding in pre-construction documentation useful for regulatory compliance and historical reference.

Current Stages include:

Progress Monitoring:

- Regularly captured images during construction provide a visual timeline of the project's progress.

Issue Identification:

- Images can be used to document and communicate issues or challenges encountered during construction.

Quality Control:

- Photographs can serve as a quality control tool, helping to identify deviations from plans or specifications.

Safety Documentation:

- Capture images to document safety protocols, potential hazards, and adherence to safety regulations.

Post Stages include:

As-Built Documentation:

- Post-construction images can be used to create accurate as-built documentation including any modifications or deviations from the original plans.

Facility Management:

- Images assist facility managers in understanding the building's layout, systems, and condition after completion.
- Useful for maintenance planning, identifying areas that may need attention, and guiding future renovations.

Historical Record:

- As time passes, post-construction images become a historical record of the project's evolution.
- Useful for reference in case of future renovations or expansions.

Roadmap to add images in BIM across project phases.

INCEPTION

Select BIM Software

- Choose a BIM software that supports visual integration and is widely accepted in the industry.
- Ensure compatibility with collaborative features for multi-disciplinary use.

Create a BIM Execution Plan (BEP)

- Develop a BIM Execution Plan outlining how BIM will be implemented throughout the project.
- Specify standards, protocols, and workflows for adding pictures.

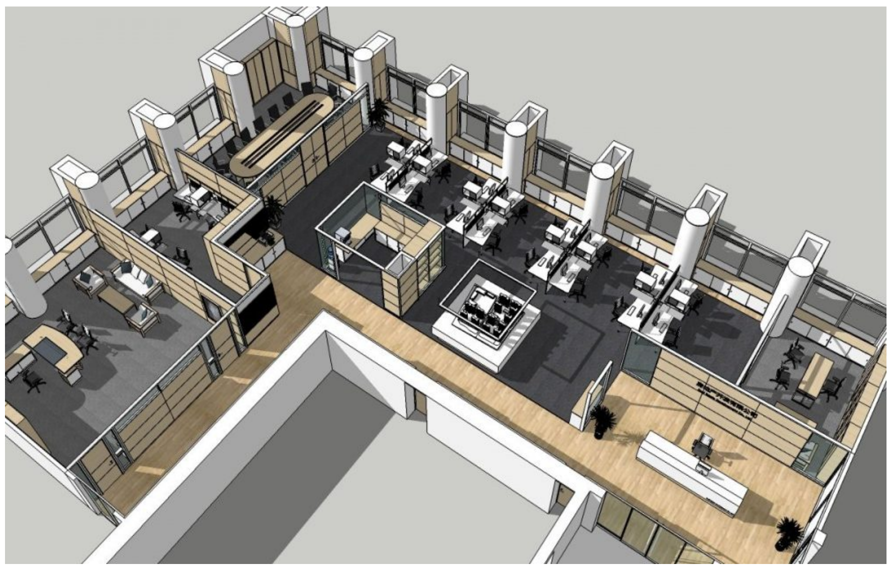
DESIGN PHASE

Model Development:

- Develop a detailed BIM model capturing architectural, structural, and MEP elements.

Conceptual Visualization:

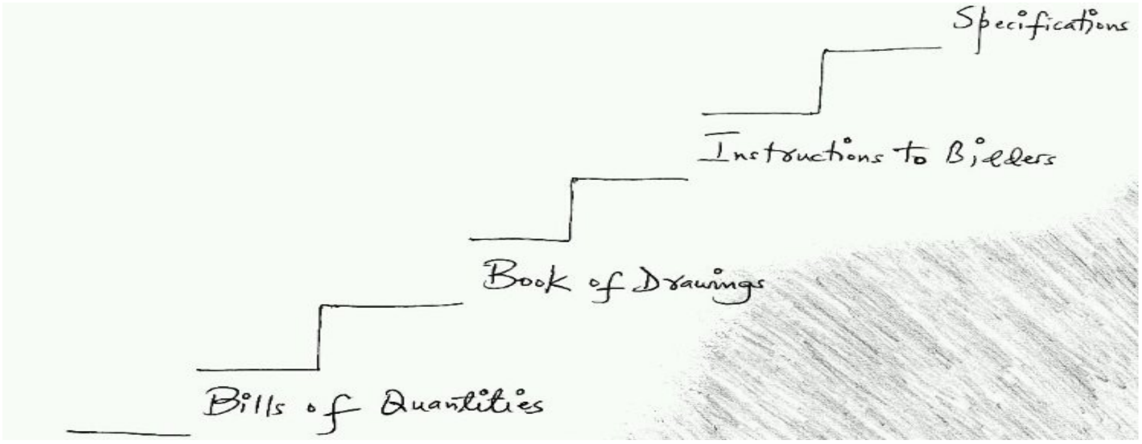
- Integrate concept sketches and preliminary design images.
- Attach images to relevant elements to convey design intent.



BID PHASE

Visual Context for Bidders:

- Add images providing context about the project site, surroundings, and neighboring structures.
- Visualize construction methodologies and logistics for better bidder understanding.



CONSTRUCTION PHASE

Construction Progress:

- Incorporate construction progress photos, site images, and documentation.
- Attach images to construction elements like walls, columns, or site components.

Logistical Considerations:

- Add images showing logistical considerations, storage areas, laydown yards, and staging zones.
- Provide visual references for construction planning.

POST-COMPLETION PHASE

As-Built Documentation

- Integrate images documenting as-built conditions.
- Attach pictures to elements reflecting the final state of the project.

Maintenance Visuals

- Add images related to equipment, maintenance procedures, and facility management.
- Attach images to elements requiring ongoing maintenance.

Level of Detail (LOD)

Introduction to LOD in BIM: A comprehensive explanation of LOD, its importance in BIM, and how it facilitates effective management and visualization of construction projects.

Detailed Analysis of LOD Stages: A deeper dive into each LOD stage, particularly LOD 400 and 500, emphasizing how image integration enhances the accuracy and utility of BIM models at these stages.

Technical Considerations and Implementation Strategies: Discussing the technical aspects of integrating high-resolution images in BIM, including standardization of image formats, data management, and the challenges and solutions in image integration.

Case Studies and Applications: Illustrating the practical application of image-integrated BIM at different LOD stages with real-world examples or case studies.

Conclusion and Future Directions: Summarizing the key points and discussing future trends or potential advancements in the field of image integration in BIM.

Conclusion

In conclusion, this detailed and comprehensive report serves as a testament to the transformative power of digital technologies in the field of construction. It highlights the critical integration of image processing, machine learning, and Building Information Modeling, showcasing how these technologies are revolutionizing construction management. Through thorough analysis and practical examples, it underscores the immense importance of adopting these technologies in construction projects for enhancing operational efficiency, ensuring safety, and improving decision-making processes. The report also provides a roadmap and strategic recommendations specifically tailored for the NYC Department of Design and Construction, paving the way for technological adoption in their operations and setting a precedent for the industry as a whole. By embracing these digital advancements, the department not only takes a significant step towards future advancements and sustainable practices but also becomes a beacon for others in the industry to follow. Therefore, this report stands as a crucial milestone in the journey towards a technologically-driven construction sector, shaping the future and promoting sustainable practices in the field.

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