



CPS: Synergy: Autonomous Vision-based Construction Project Monitoring

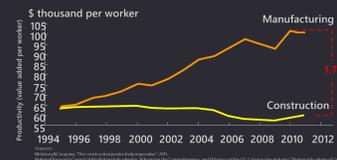
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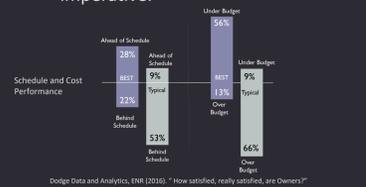
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Introduction

U.S. construction industry
\$1,153,175,000,000 +5-12% growth rate
Value of Construction Put in Place in the United States, 2016 Commercial and industrial building sectors



Improving efficiency of the US construction industry is a national imperative.

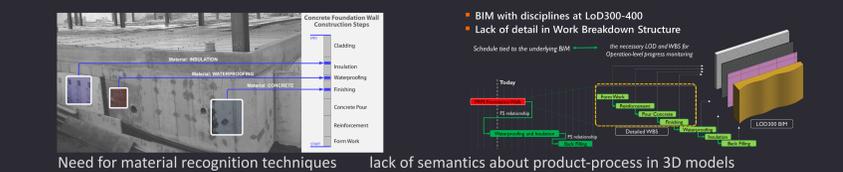


Why: Factors in poor productivity

- I. Inadequate communication
- II. Flawed performance management
- III. Poor short-term planning
- IV. Missed connections to actual progress
- V. Insufficient risk management



Limitations in current visual sensing methods



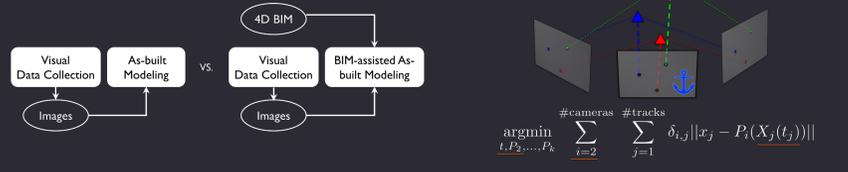
Project Objectives

Improve frequency, detail, and applicability of construction monitoring by automating collection, analysis, and reporting via camera-equipped UAVs and 3D building models, with following:

- Data Collection:** record videos for progress monitoring and place cameras for activity monitoring using aerial robots. Objectives: guarantee completeness of model capture, improve control mechanisms to enable camera placement and close observations, and coordinate recordings and camera placement with feedback from visual analysis.
- Progress Monitoring:** create 3D models of ongoing construction and compare to 3D plan models. Objectives: improve efficiency and reliability of image-based reconstruction, recognizing material properties and geometry, and provide confidence measures to pick informative camera viewpoints.
- Activity Monitoring:** annotate crew and equipment activities from a network of cameras and to inform their placement. Objectives: recognize worker/equipment trajectories and activities from videos, and characterize modes of error in object detection as the basis for choosing camera viewpoints.
- Reporting:** provide analytics that predict reliability of work plans based on current progress. Objectives: create reliability metrics for plans, formalize a classification mechanism to evaluate and generate both "sequencing" and "crew-balance chart" control alternatives for ongoing tasks and activities.

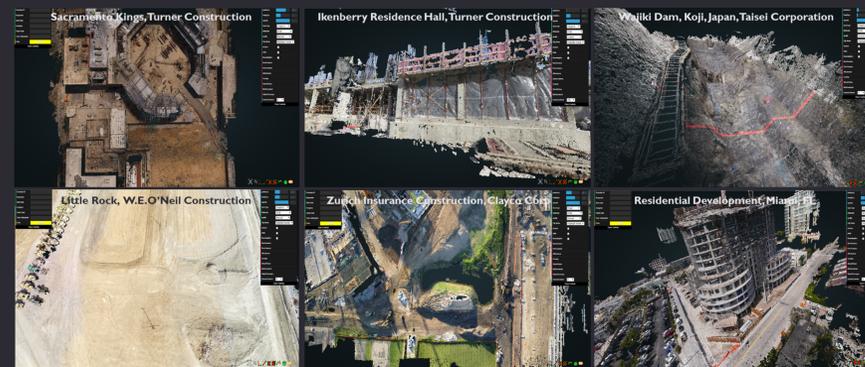
Project-Level Monitoring

Generate image-based point cloud models

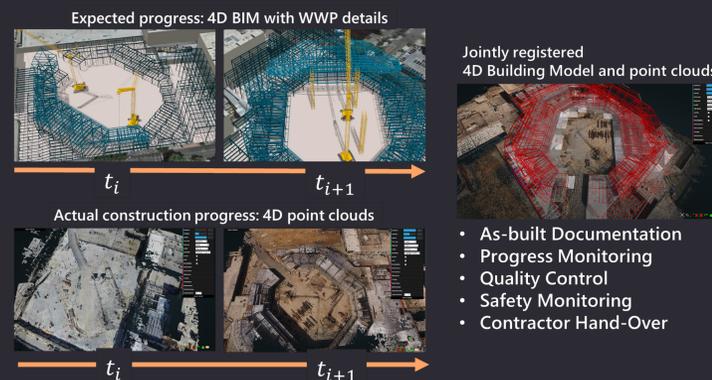


Pipeline of Structure from Motion + Dense Reconstruction

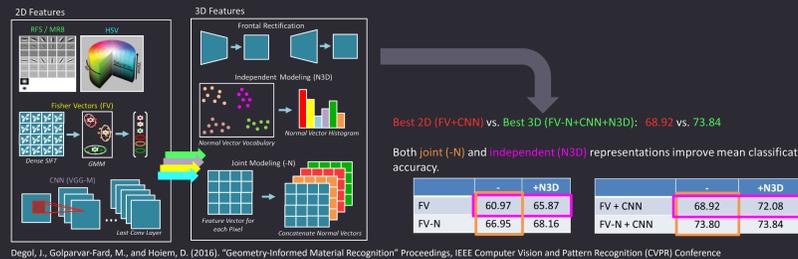
Using 3D building model to form a constraint-based Structure from Motion



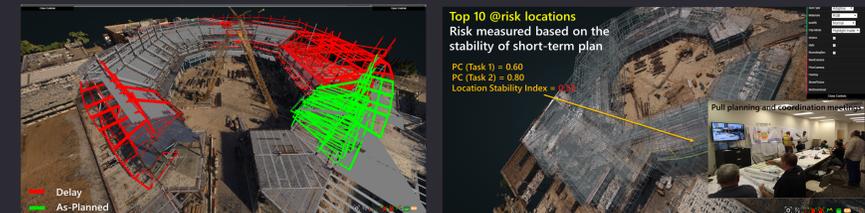
Alignment of as-built and as-planned models.



Geometry helps in Material Recognition – Knowledge of Materials helps with progress monitoring

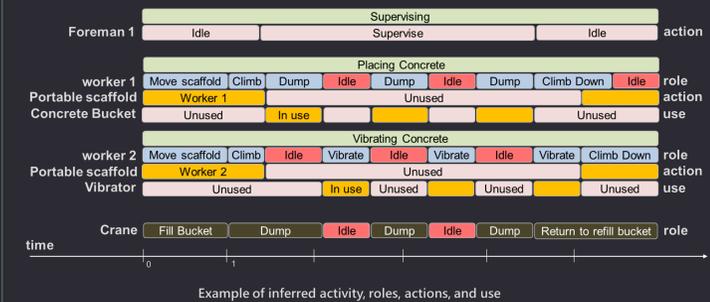


Visualize and communicate @risk locations based on plan reliability



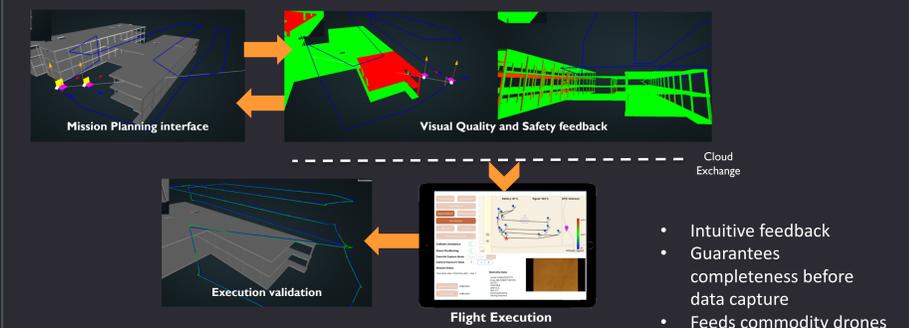
Task-Level Monitoring

Worker detection, tracking and activity analysis



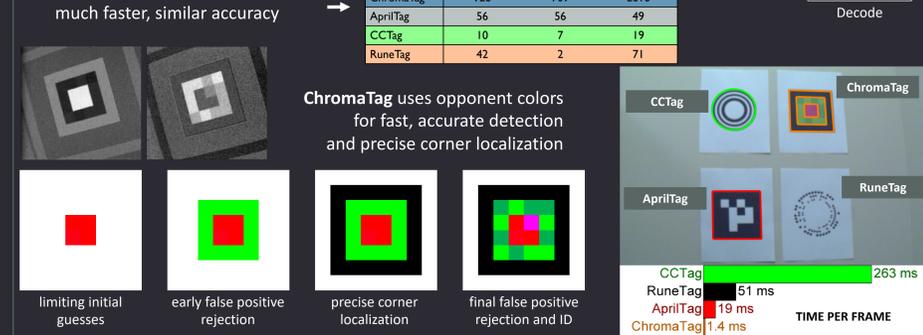
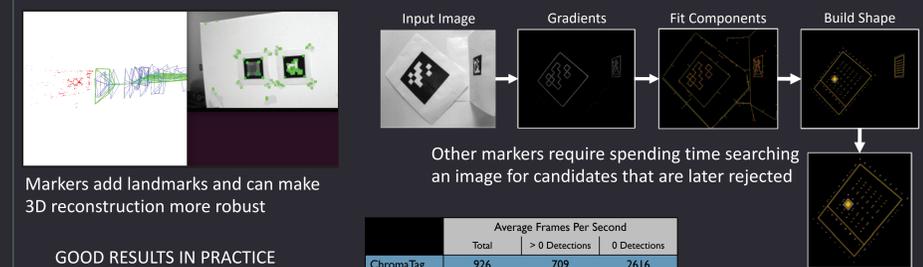
Goal-Driven 3D Visual Data Capture

- Use 4D BIM as a prior to optimize drone flight plan for aerial image capture
- Predict visual coverage (performance) and proximity to structure (safety)



Improving Performance

ChromaTag: a colored marker and a fast detection algorithm



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