Infrastructure Inspection with Robots and 3D Reconstruction Methods: A Comparative Study of Computer Vision Algorithms

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Introduction

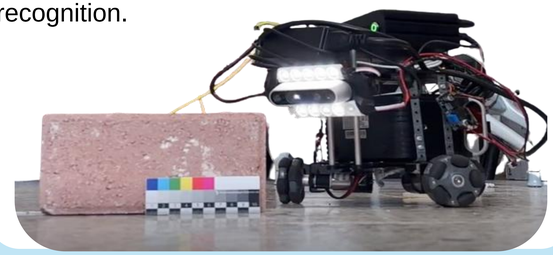
Rationale

- The objective is to benchmark the defect representation accuracy of modern 3D reconstruction methods, as a way to evaluate the feasibility of the methods to be used as a complementary tool for surface inspection in industrial and civil infrastructure.
- The focus is on detecting small scale and fine defects (e.g. cracks, scuffs, edge chips) with high accuracy.

Proposed Approach

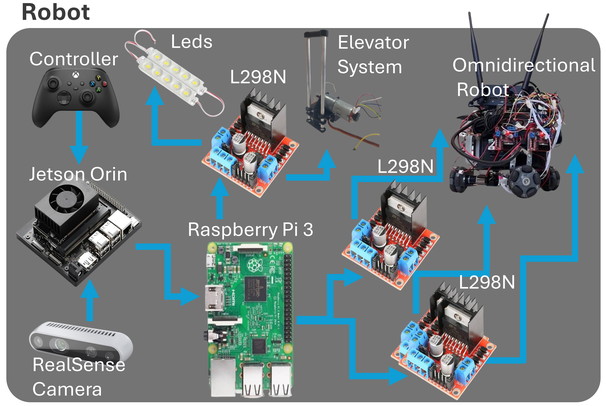
- 3D Reconstruction using a single RGB Camera and a Mobile Robot.
- A benchmark of photogrammetry methods and defect detection methods based on Computer Vision (CV).
- Photogrammetry methods: Structure-from-Motion with Meshing based on AliceVision framework [1], and 3D Gaussian Splatting [2] which preserves radiance field characteristics for scene optimization while avoiding computations in empty areas.
- Defect detection methods: Classical CV* (e.g. Canny edge detection, contour detection, etc.) and Modern CV (e.g. Class-Activation Map (CAM**) based on CNNs)

* Classical CV: Gaussian Blur filter [3] for removing noise and traditional Canny edge detection algorithm [4] and Dilate [5] to thicken edges.
** CAM [6] identifies the image regions that a CNN considers most discriminative for category recognition.



Methodology

System Configuration

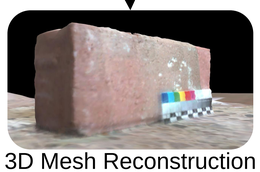


* Arrows represent data flows.

Inspection Sample

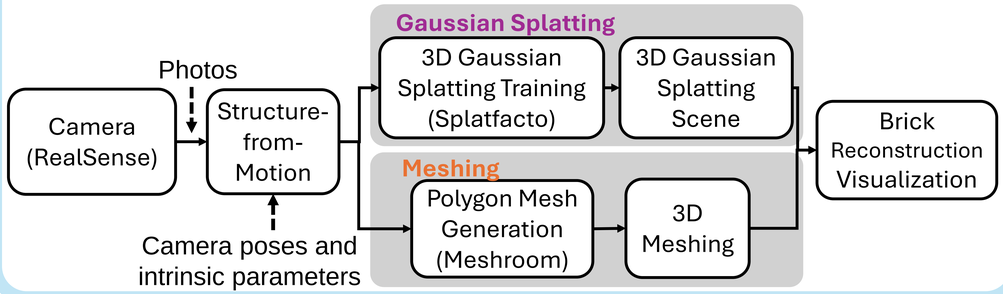
3D Gaussian Splatting Reconstruction

Real Object



3D Mesh Reconstruction

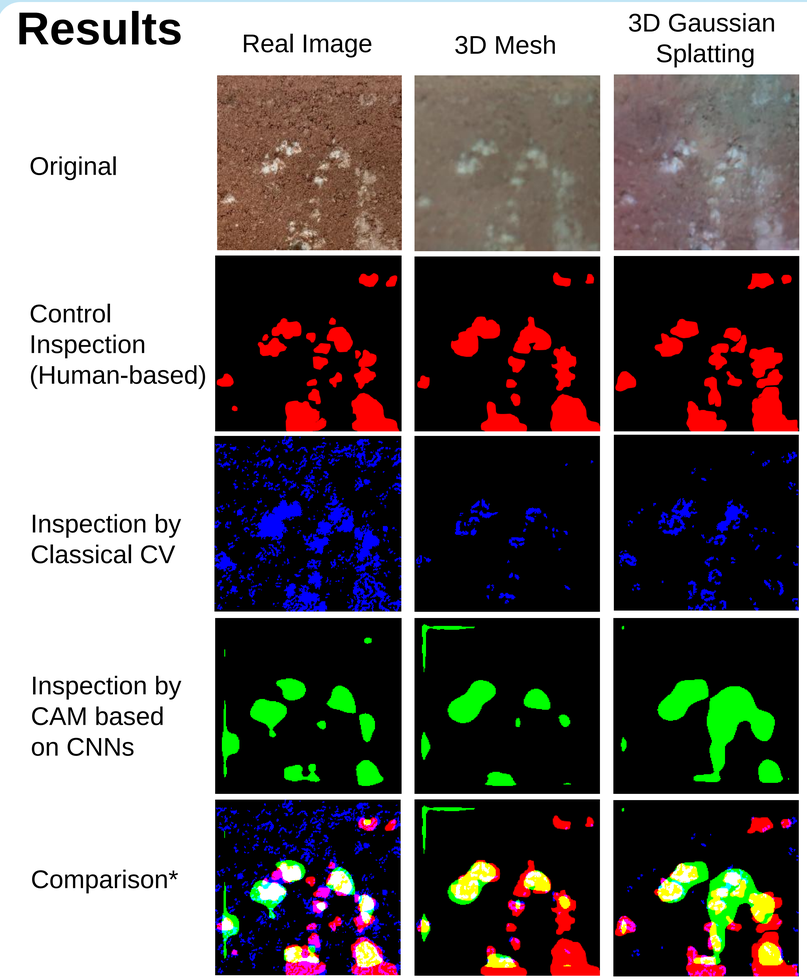
3D Reconstruction Pipeline



Conclusions

- In the results, it is observed that Classical CV can detect defects at a smaller scale. However, we can also observe several instances of false positives. On the other hand, MAP can detect clusters of multiple defects similar to the Control Inspection. Nevertheless, it may miss small details.
- Moreover, Gaussian Splatting proves to be a highly promising reconstruction method for conducting inspections on a virtual reconstruction of an asset of interest, as both Classical and Modern CV algorithms correctly detect relevant pixels compared to Control Inspection.
- Future work will evaluate the defect detection methods based on the ISO 10110-7 and related standards. Additionally, the scanning process with the robot will be improved to enhance the 3D reconstruction accuracy. Finally, robotic navigation systems will be integrated to perform inspections in real complex environments [7] [8].

Results



* Legend:

- Control Inspection + Classical CV + CAM
- Control Inspection + CAM
- Control Inspection + Classical CV
- Classical CV + CAM
- Control Inspection
- Classical CV
- CAM

References

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