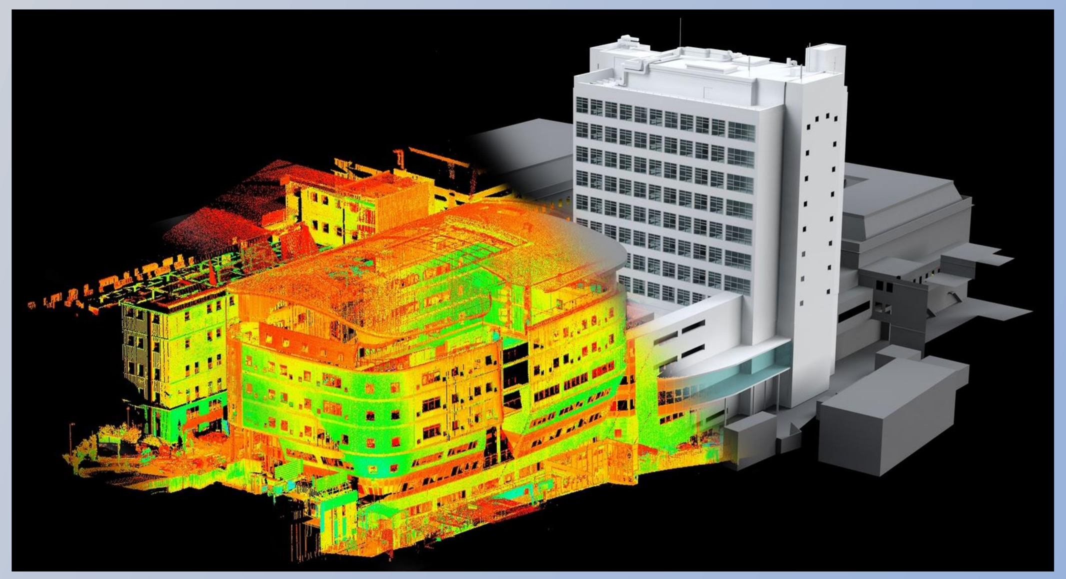
Dynamic Programming for 3D Imaging Planning in Dynamic Construction Environments

Student: Cheng Zhang, Supervisor: Pingbo Tang

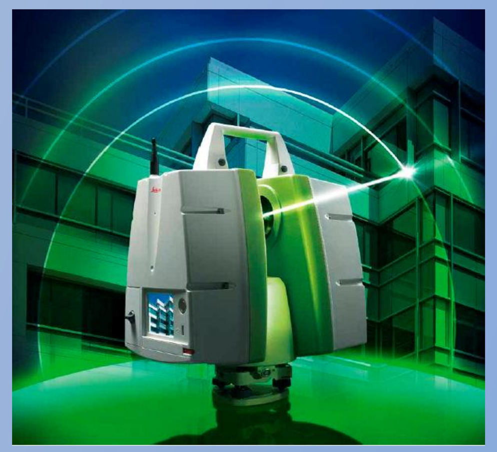
Introduction and Motivation

- In construction field, construction engineers need real-time geometries of the site for reducing spatial conflicts between construction activities, timely updates of construction progress, and reliable construction quality control.



- Advanced imaging technologies, such as laser scanning, can improve the geometric data quality while reducing the data collection time.

- However, manual imagery data collection often result in missing or low-quality data in cluttered job sites.

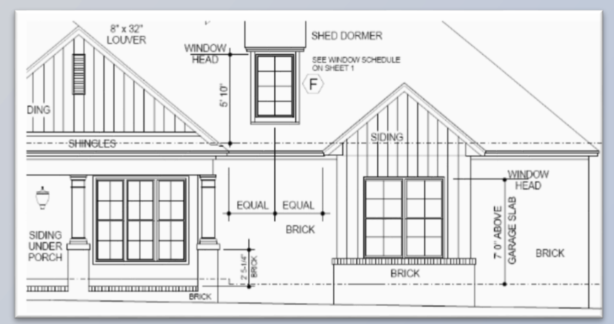


- Automatic 3D imaging planning methods, on the other hand, encounter exponentially large search space of plans of taking 3D images. It is thus important to establish new computational models for achieving rapid 3D imaging planning.

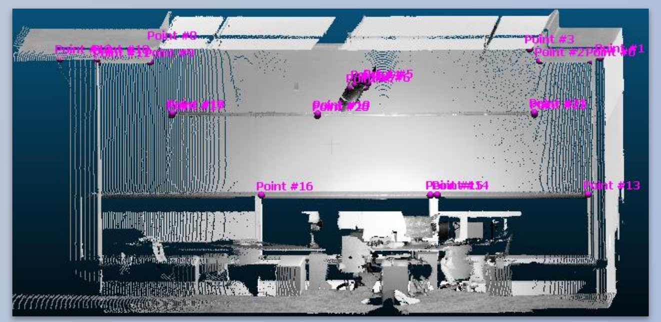
Overview of the Approach

This dynamic programming approach uses a “divide and conquer” concept.

1. Acquire information of feature points



(from design plan)

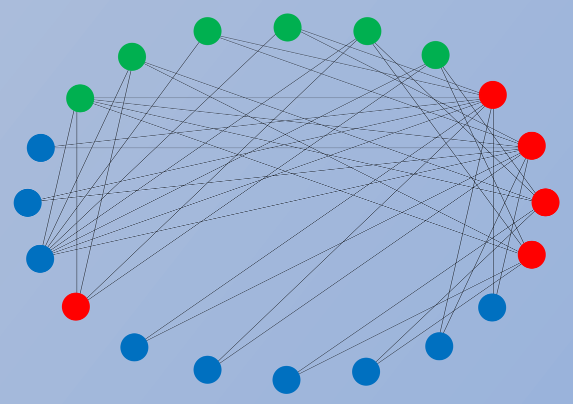


(from rough scan)

(from photograph)

2. Clustering the feature points into groups according to visibility

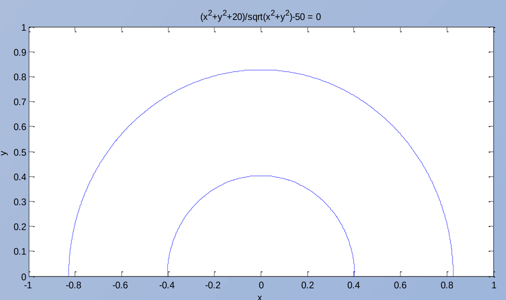
- Analyze which any 2 feature points can be scanned from a single scan position (visibility confliction analysis).
- Clustering points into groups that has no visibility conflict with each other.
- Each group indicates a necessary scan position; requiring minimum number of scanner positions
- Problem can be transferred to a typical vertex coloring problem in graph theory.



Color = 3
At least 3 scans are needed

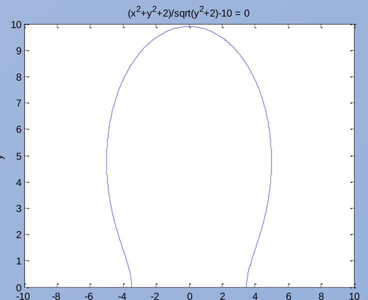
3. Deriving feasible area of each feature point to satisfy data quality requirements.

- Both horizontal and vertical level of detail (LOD) requirement should be met.



Feasible Area of Vertical LOD Requirement

+



Feasible Area of Horizontal LOD Requirement

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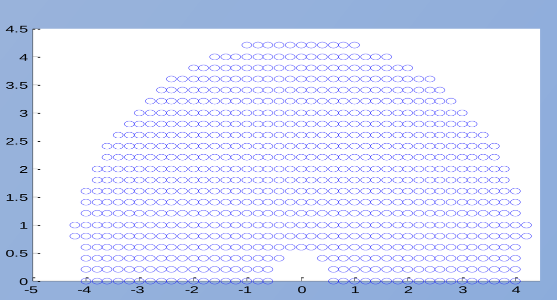
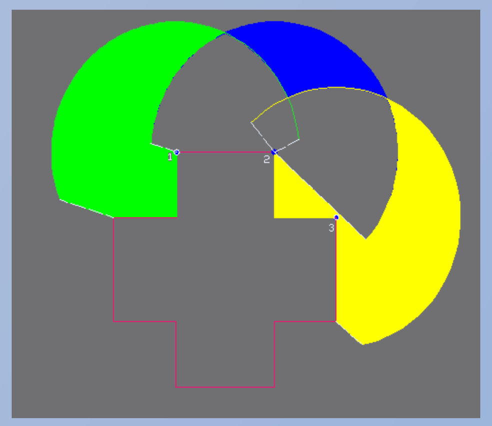


Discrete Feasible Area of A Feature Point

4. Finding optimal configuration space to minimize the scanning time for each group.



Feasible Area Generation

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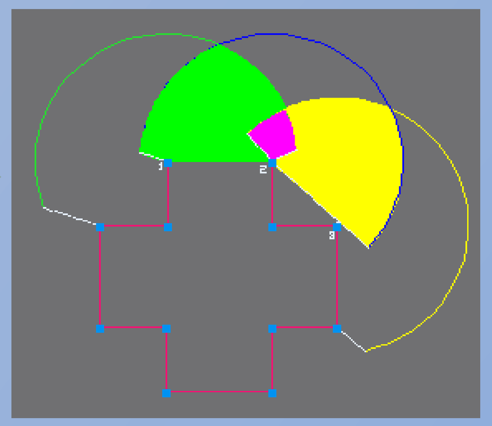

Feasible Area Intersection

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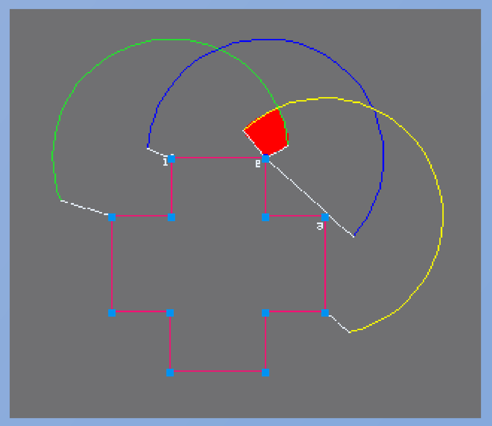
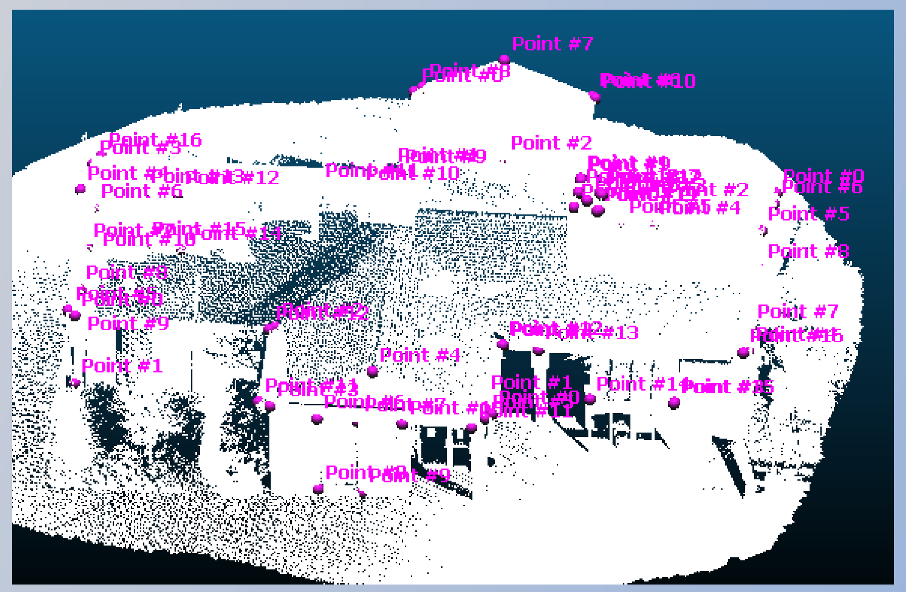


Localization

Case Study & Results

Scan planning of a parking service:

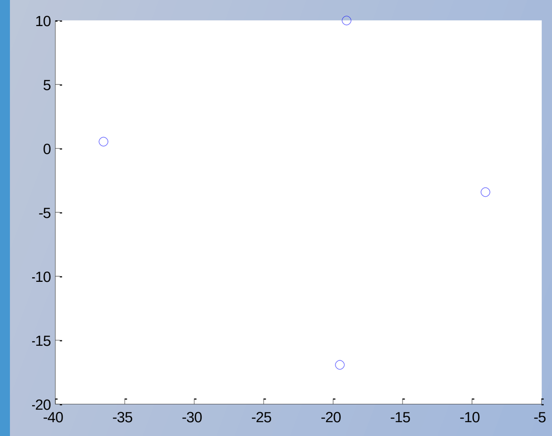
- Semi-automatic feature point information collection



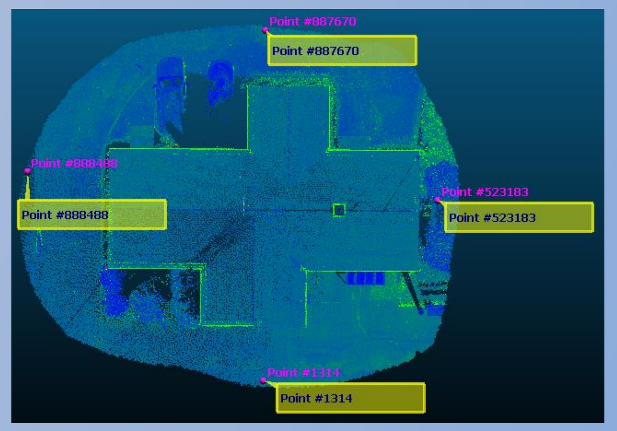
- Result (configuration space):

Minimum scan position needed: 4 scans.

Scan No.1:	Position (-19,10);	Resolution: 0.036°
Scan No.2:	Position (-19.5,-17);	Resolution: 0.036°
Scan No.3:	Position (-9,-3);	Resolution: 0.036°
Scan No.4:	Position (-36.5,0.5);	Resolution: 0.036°



(MatLab)



(CloudCompare)

Practical Implications

- The laser scan planning algorithm will generate both scanning position information as well as resolution of imaging at those positions.
- Future efforts will develop algorithms that generate 3D imaging plans involving other configuration parameters (e.g., noise level).
- The dynamic programming approach can improve the computational efficiency of 3D imaging planning while producing results with the same quality as the conventional scan planning methods.