QuickSketch
Building 3D Representations in Unknown Environments using Crowdsourcing

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GM

3D Maps

2D maps

- latitude, longitude

3D maps

- depth information
  - context awareness
  - path planning
  - obstacle avoidance
  - positioning

Collecting 3D Maps

3D sensors

- stereo camera
- LiDAR
- radar

Radar

Stereo camera

Car equipped with LiDAR

LiDAR

3

Problem: Rapid Map Construction

Disaster/wars change layout/geography

How can we *RAPIDLY* collect 3D maps of unknown environments?

- *AFTER* disaster/war *BEFORE* rescue/operation

BEFORE **AFTER**   **BEFORE** **AFTER**
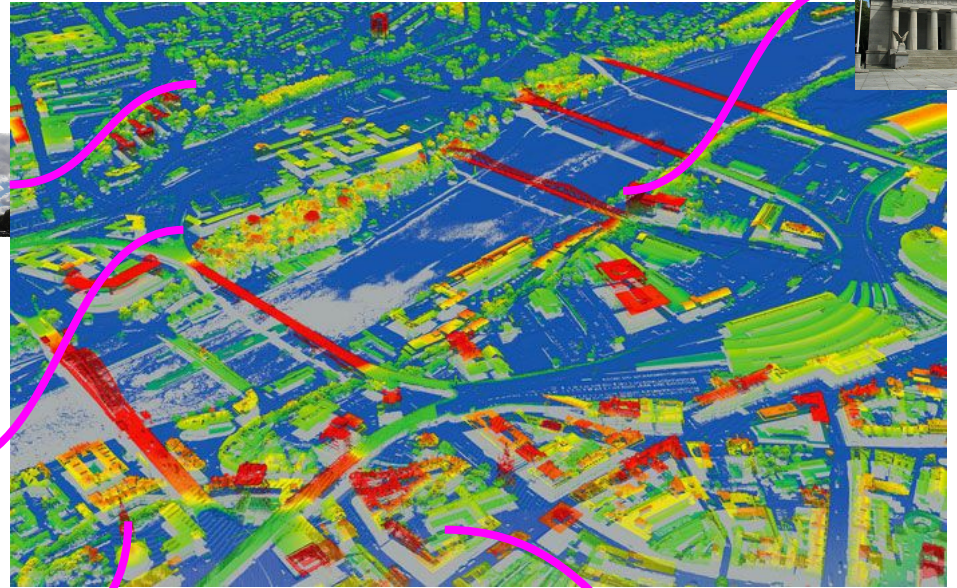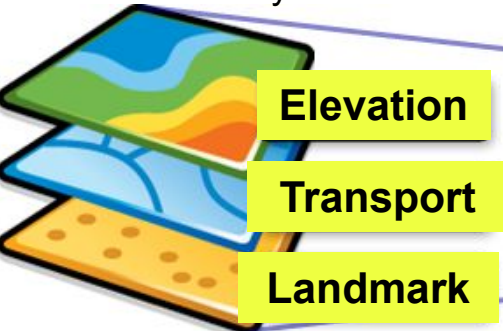
Problem: Augmenting Landmarks in 3D Maps

Landmarks

Use cases:

- Disaster relief
- War zones

Layers of 2D maps

Elevation

Transport

Landmark

Aerial LiDAR 3D map

https://aecmag.com/technology-mainmenu-35/1144-news-3d-aerial-laser-maps-provide-context-for-bim-projects

5
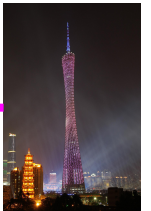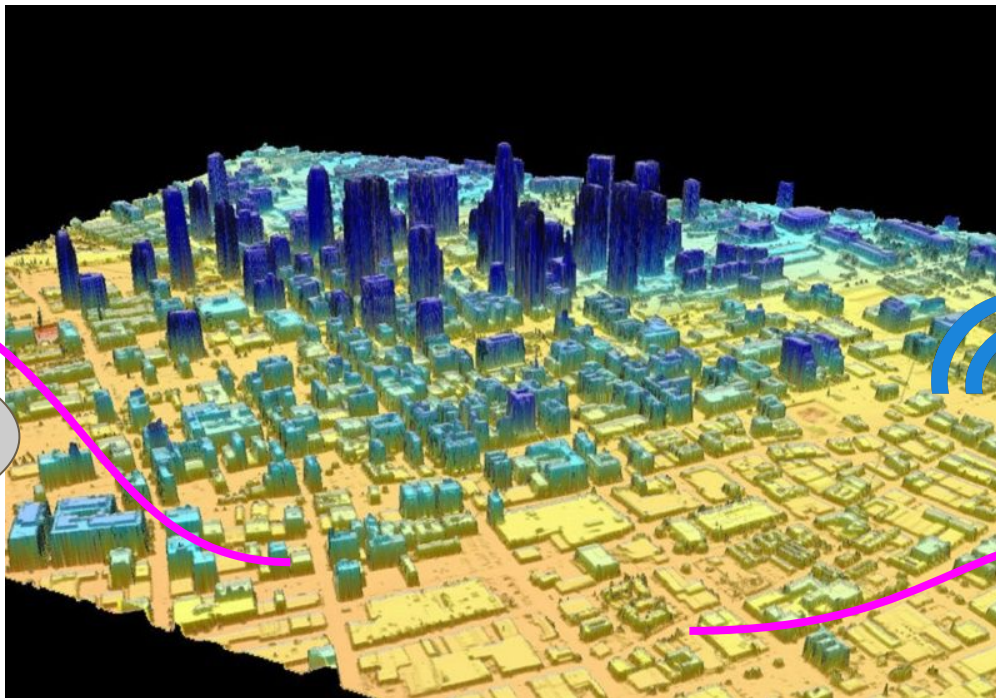
Problem: Visual Contextualization in 3D Maps

- Contextualizing visual intelligence
  - Find out *where* a given picture was taken

https://i-hls.com/wp-content/uploads/2016/04/lidar.jpg

Challenges

Map collection

- ***rapidly*** collect 3D sensor data
- ***rapidly*** construct 3D map

Landmarks

- 3D landmark detection

Visual intelligence

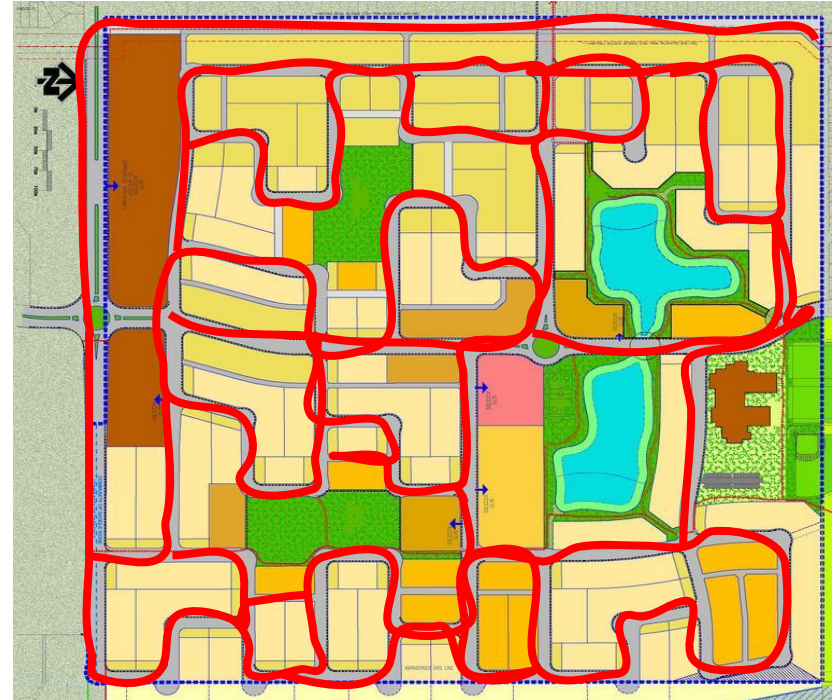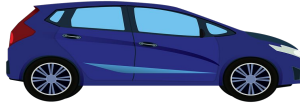- ***rapid*** contextualization

Challenges-Map Collection

Entire traversal of environment

Long time for map collection

Challenges - Landmarks

Accurately detect common landmarks
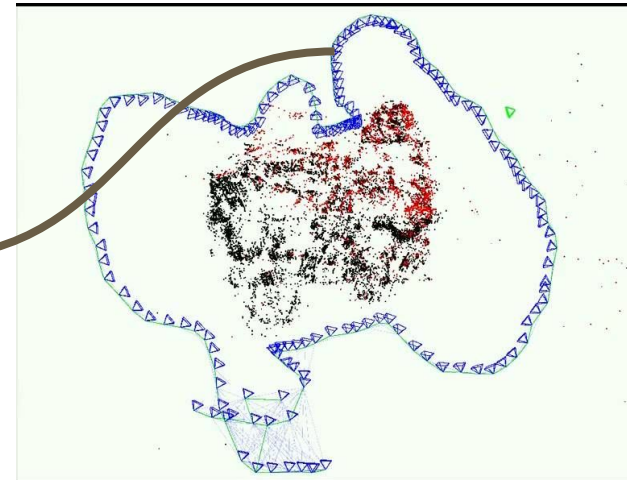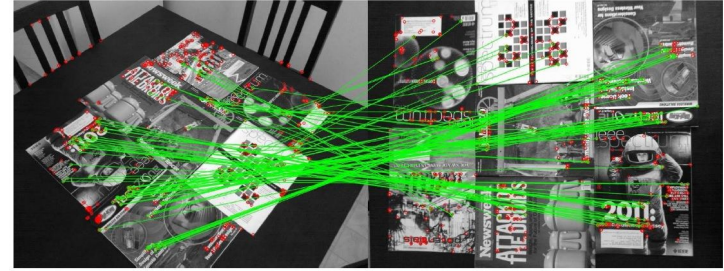
Annotate and position landmarks on 3D map

Annotating landmarks

Challenges - *Rapid* Contextualization

Rapidly position photos in large 3D maps

Avoid brute force feature matching with all map frames

Feature matching

3D map from stereo camera

QuickSketch Contributions

Crowdsourced 3D map collection

- accurately stitch map segments

Annotate and position landmarks

- 2D object detector
- 2D to 3D transformation

Rapidly contextualize visual intelligence

- guided search along landmarks

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Rapidly contextualize visual intelligence
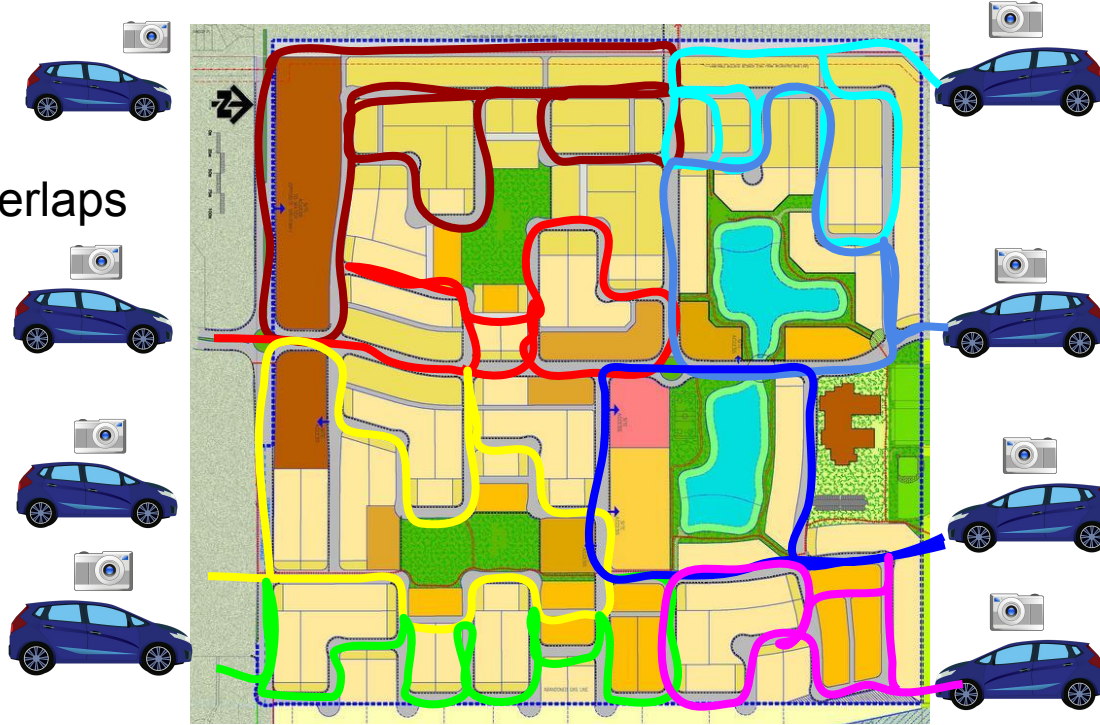
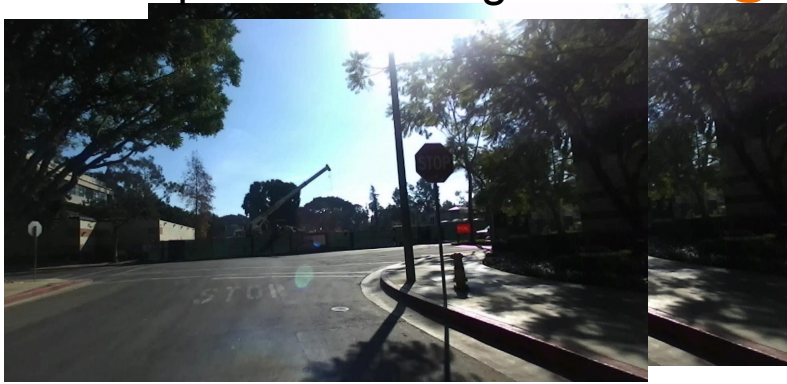- guided search along landmarks

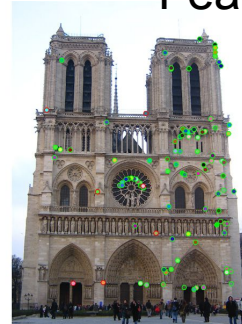# Crowdsourcing map collection

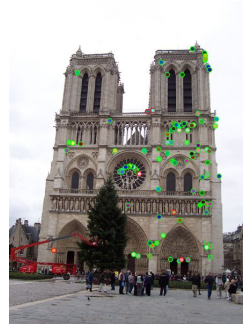Recruit multiple vehicles

Traverse regions with minimum overlaps
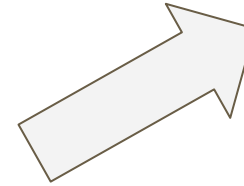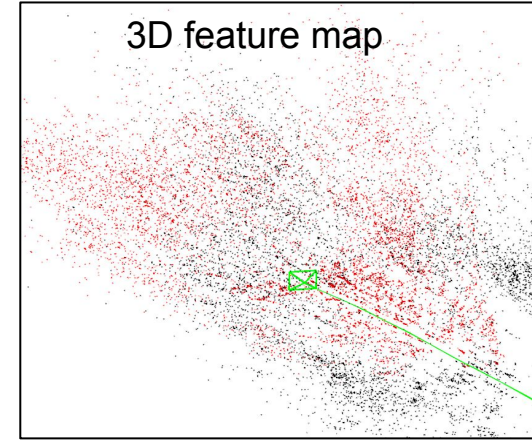
Reduce map collection time

Background - 3D Maps

Input stereo image

3D feature map

Feature extraction & depth estimation

SLAM MODE | KFs: 18, MPs: 2143, Matches: 357

Feature matching

- https://www.mathworks.com/discovery/image-registration.html
- https://www.cc.gatech.edu/~hays/compvision/results/proj2/html/gan9/index.html

14
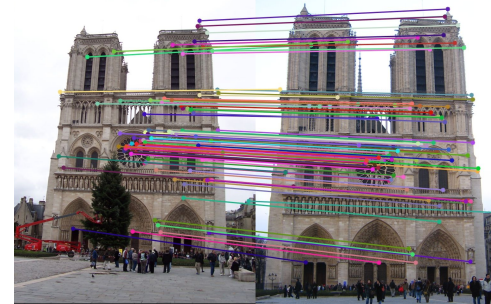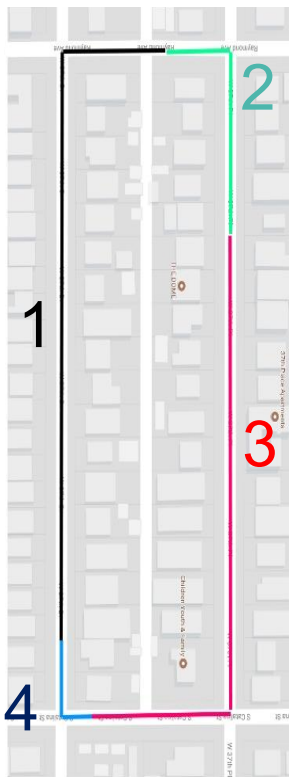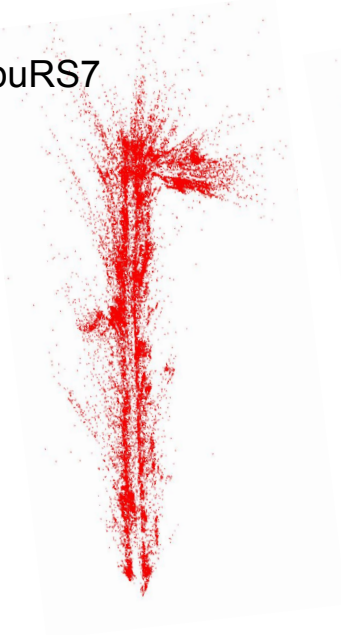
Background - 3D Maps
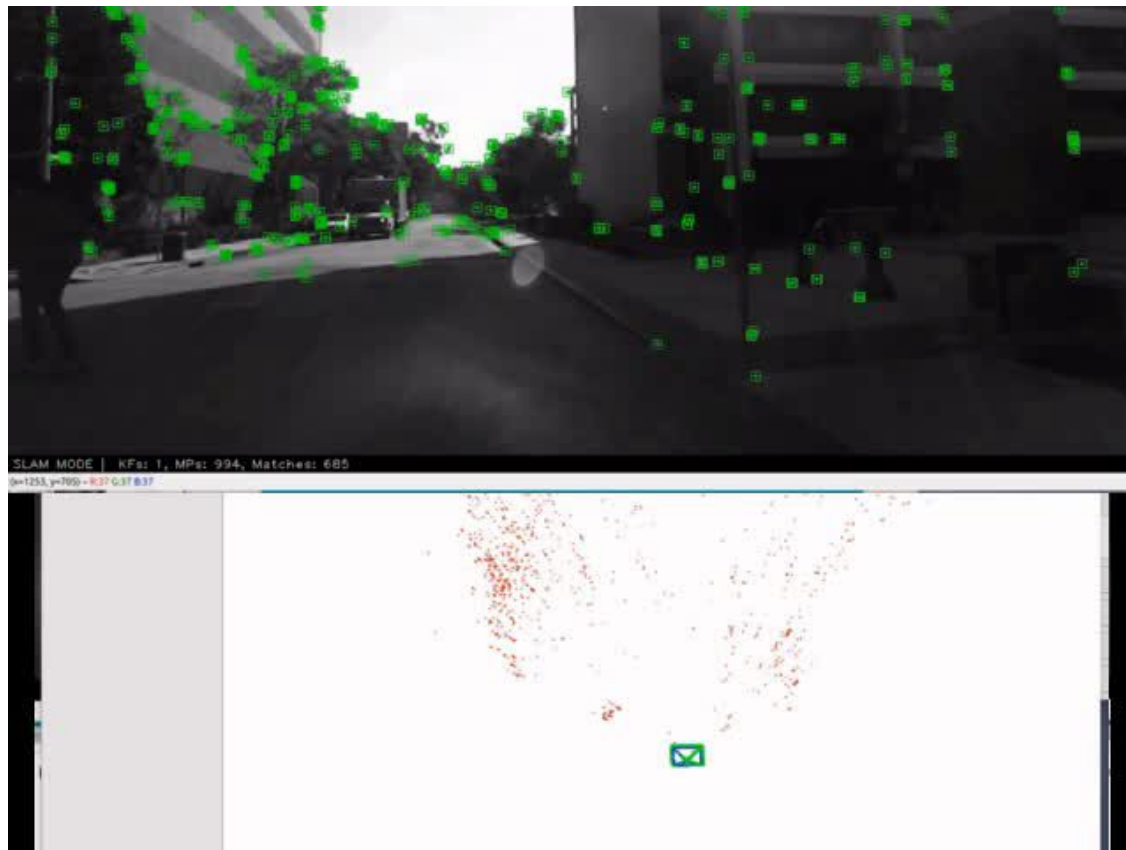
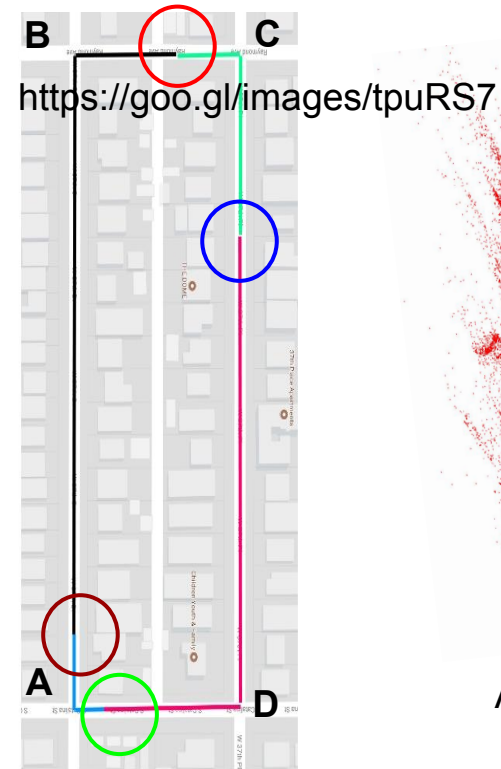# Stitching
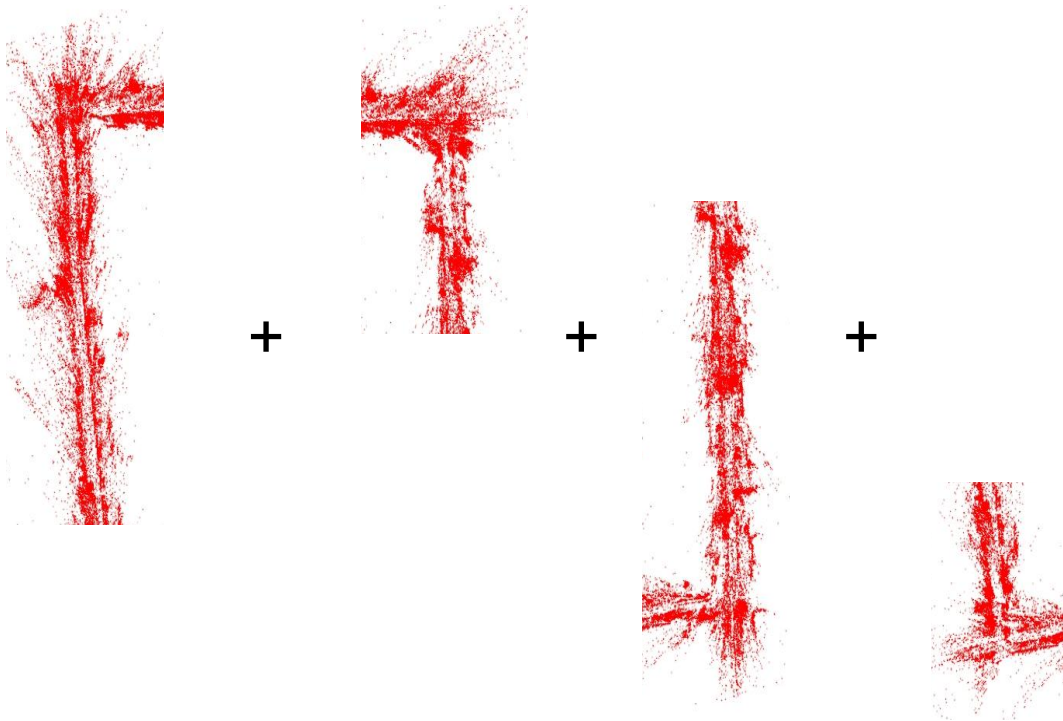
3D maps from different vehicles

QuickSketch - Stitching
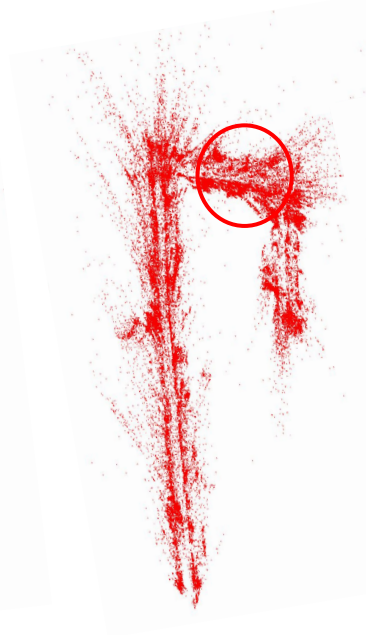
https://goo.gl/images/tpuRS7
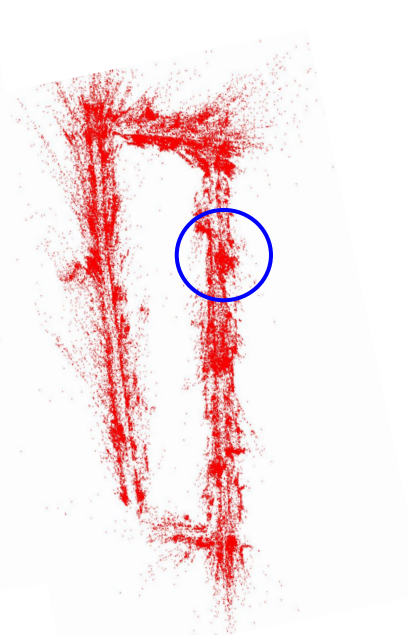
AB

ABC

ABCD

ABCDA

QuickSketch Contributions

Crowdsourced 3D map collection

- accurately stitch map segments

Annotate and position landmarks

- 2D object detector
- 2D to 3D transformation

Rapidly contextualize visual intelligence

- guided search along landmarks

QuickSketch - Annotation

2D object detector

stop sign

2D pixel to 3D voxels

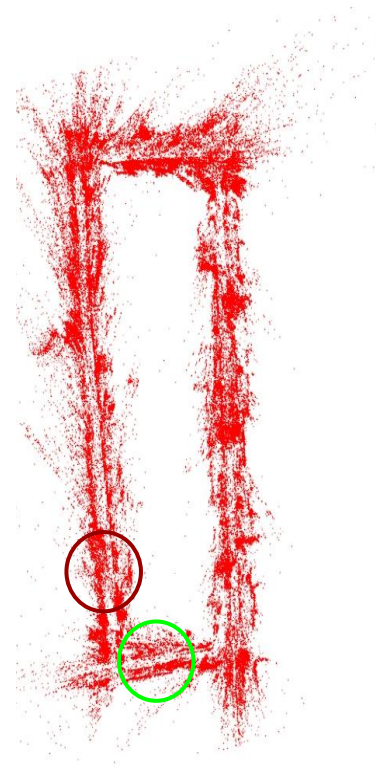3D transformation to map coordinates

{
    3D voxels,
    visual descriptors
}

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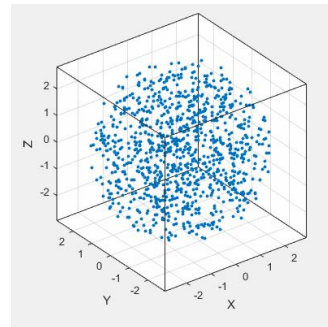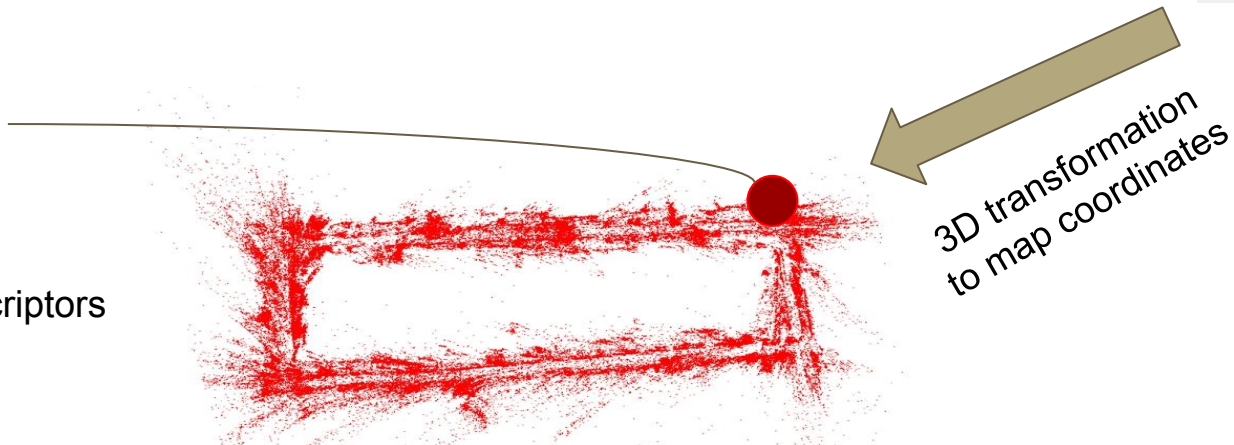Rapidly contextualize visual intelligence

-   guided search along landmarks

QuickSketch - Contextualizing Visual Intelligence

Input image

2D object detector
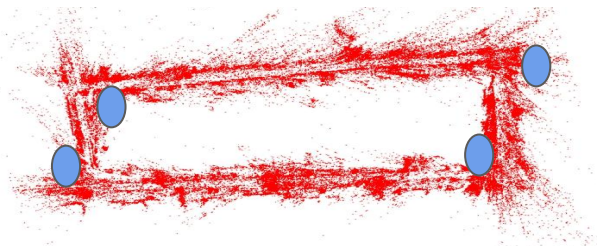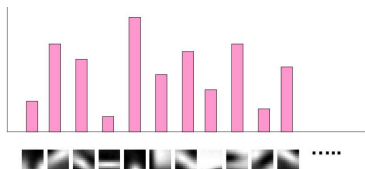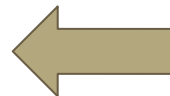
Annotated image

stop sign

Guided search along landmarks

Feature matching

3D position

Bag of visual words

QuickSketch - Design
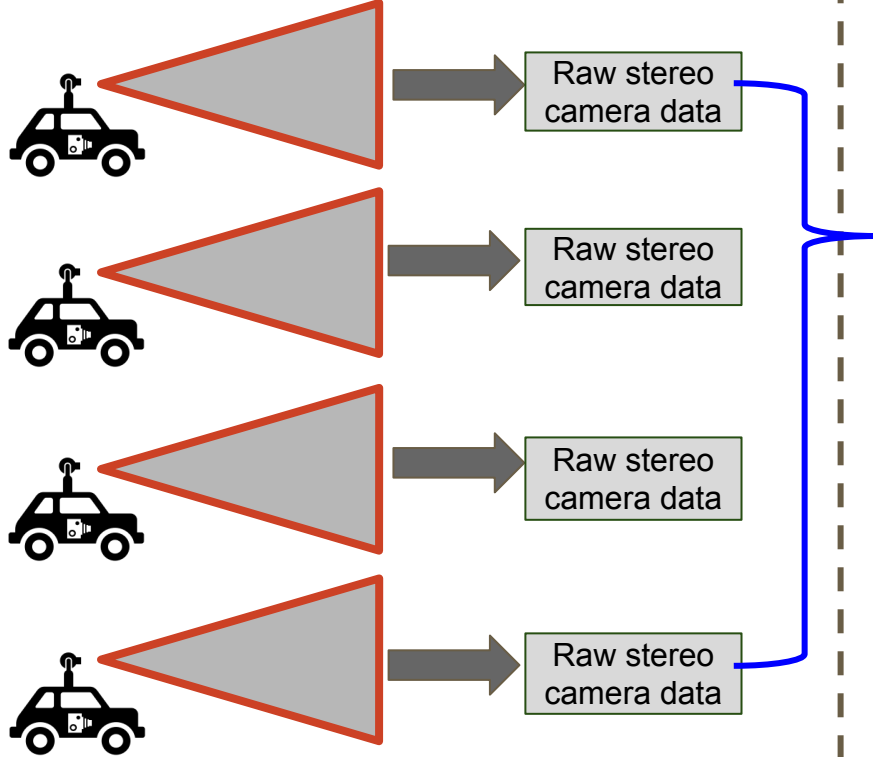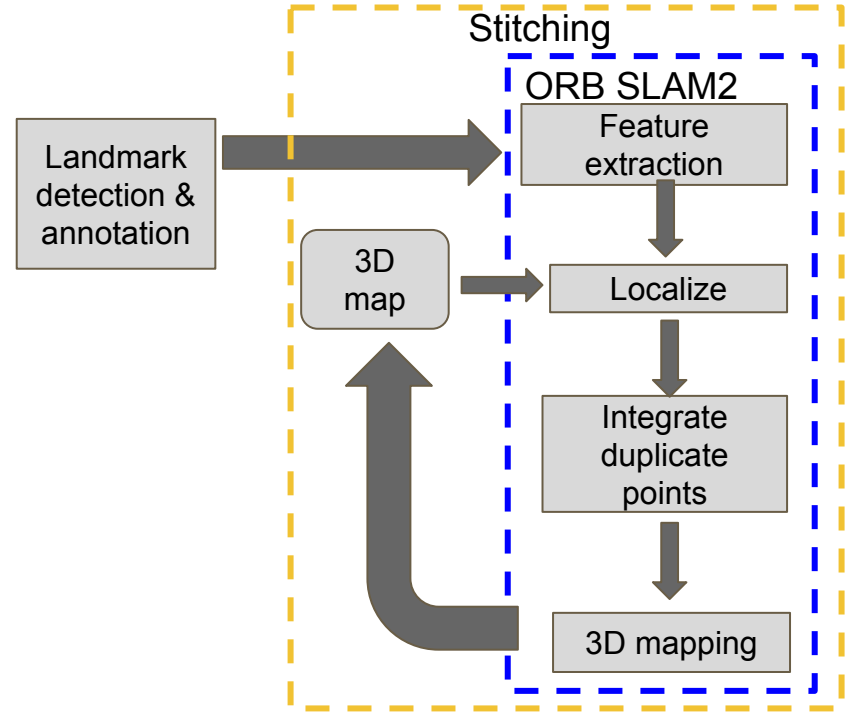
Evaluation

Stitching accuracy

Landmark annotation

Visual contextualization
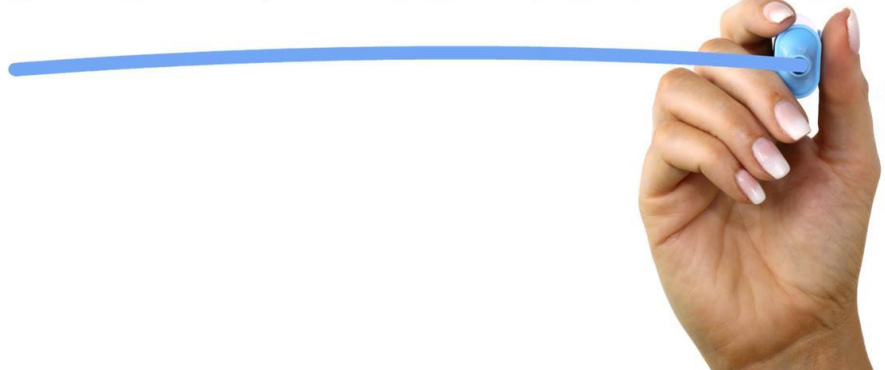
QuickSketch in Action
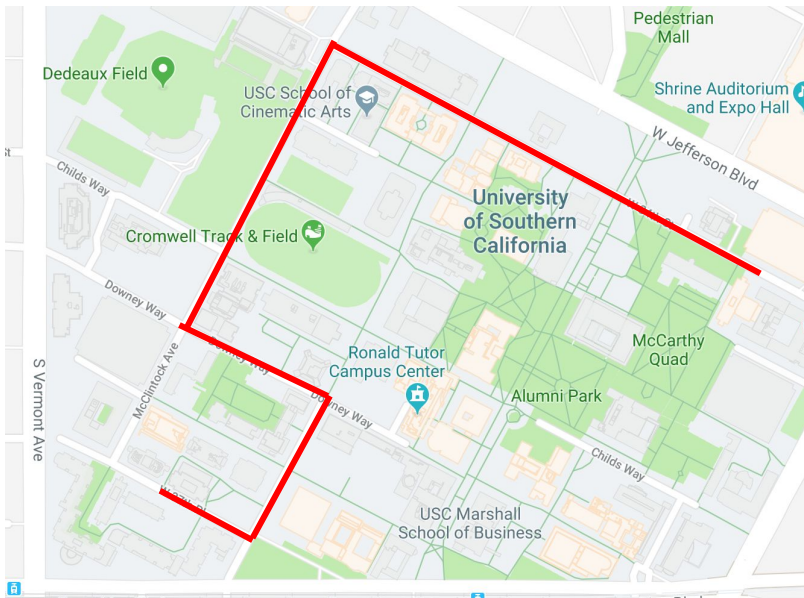
Evaluation - Stitching Accuracy

Mapping error:

Difference between estimated and actual position of stop sign

With loop closure

Without loop closure

ID	Distance (m)	Loop	Mapping Error (m)
1st stop sign	260	closed	0.31
1st stop sign	260	open	0.85
2nd stop sign	650	closed	3.81
2nd stop sign	650	open	48.0

**QuickSketch -
short length map segments
+
loop closure**

short, closed loop map segments for sub-meter error

Contextualizing Speed

Input image
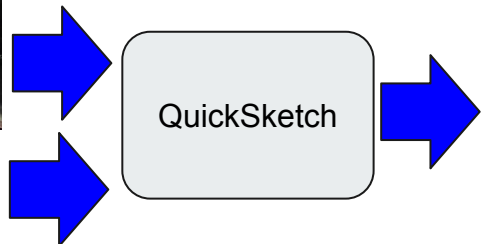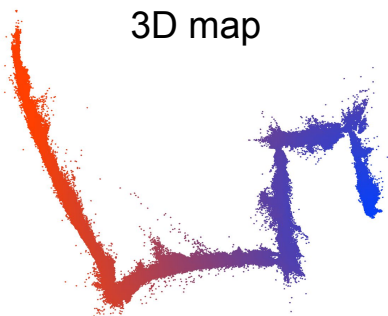
3D map

QuickSketch

Localization time:
- *time required to position a photo in the 3D map*

- 3D map of campus

- **ORB-SLAM2 - 5.51 seconds**
- **QuickSketch - 0.5 seconds**

order of magnitude faster contextualization

Positioning accuracy

Input image

3D map

QuickSketch

?
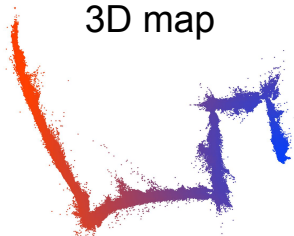
Positional accuracy:

- *difference in estimated 3D position and actual position of landmarks*

- 3D map of campus

- 20 images in dataset

- **feature matching - 30m**
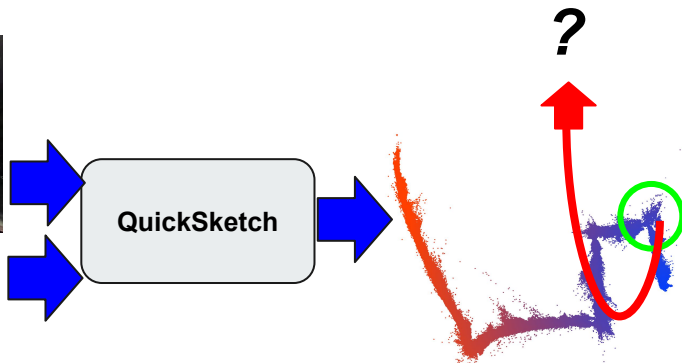- **QuickSketch - 1.5m**

order of magnitude more accurate localization

QuickSketch

What
-   rapidly building 3D representations of unknown environments

How:
-   crowdsource data collection & stitch 3D map segments

Why:
-   contextual and situational awareness

Where & When:
-   emergency & rescue operations, battlefield & war zones

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Thank you