Offloading UAV Navigation Computation to the Cloud

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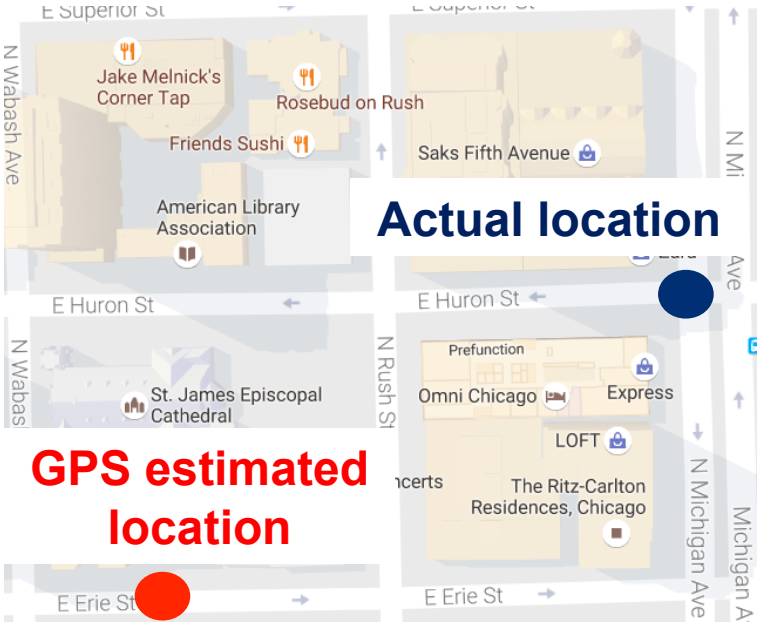
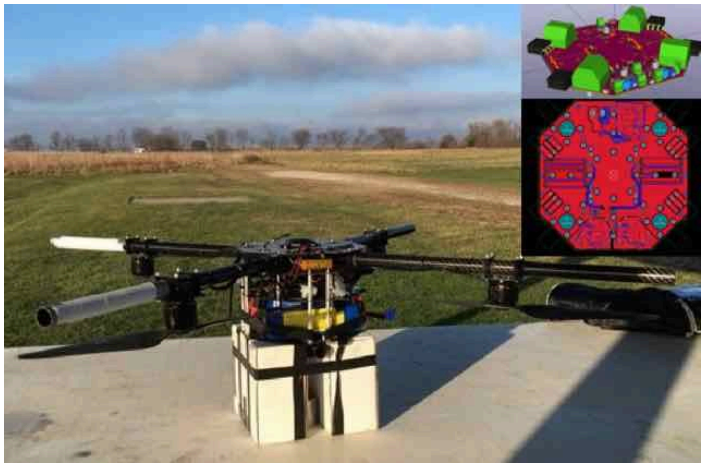
UAV Navigation in Urban Areas

- Challenges
  - Limited battery life
  - Restricted cost and weight
  - Finite computational capacity
  - Standalone GPS not sufficient



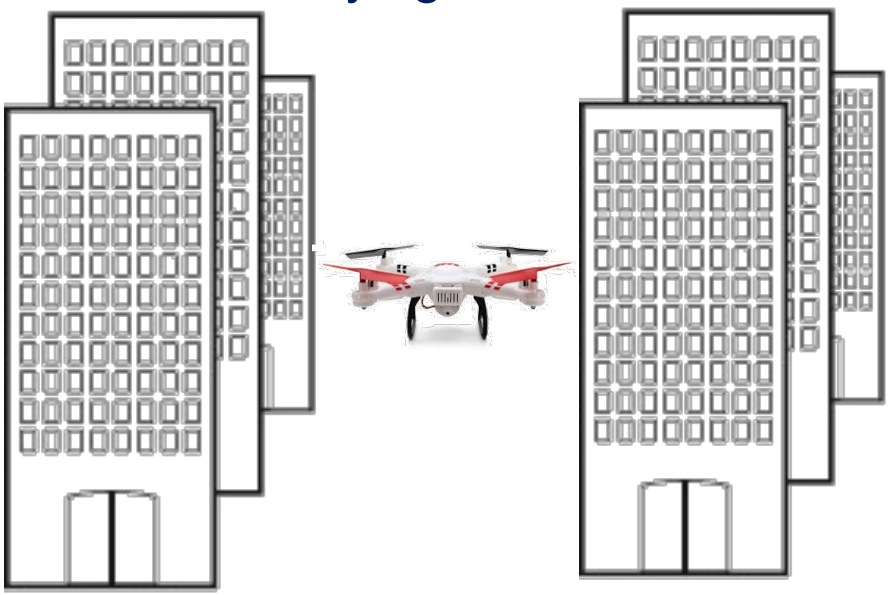


[iBQR Quadrotor,
Prof. Grace Gao's research group]

Objectives

- Improve the position accuracy of UAV in urban areas
- Optimize on-board computational load

UAVs flying in urban area



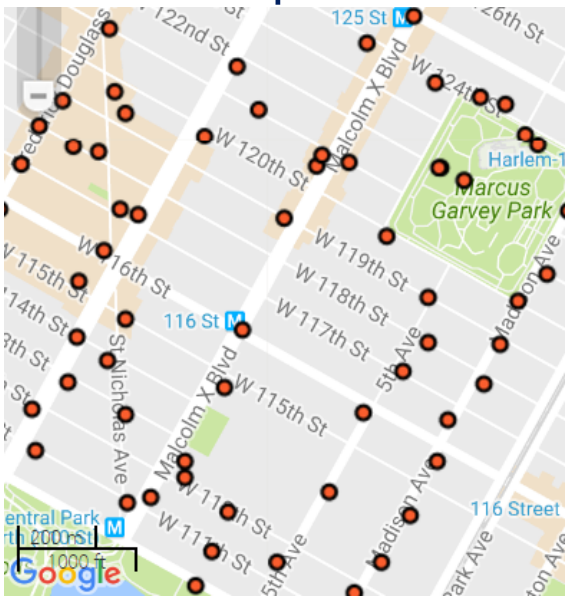
Outline

- Approach
- Cloud-based GPS and Vision Fusion
- Setup and Evaluation
- Experimental Results
- Summary

Approach: Access to the Cloud

- Access to internet: WiFi, cellular, etc.
- Uses of the Cloud:
  - Low cost
  - Unlimited storage
  - High computing capacity
  - Access to online database
  - Huge infrastructure reduction

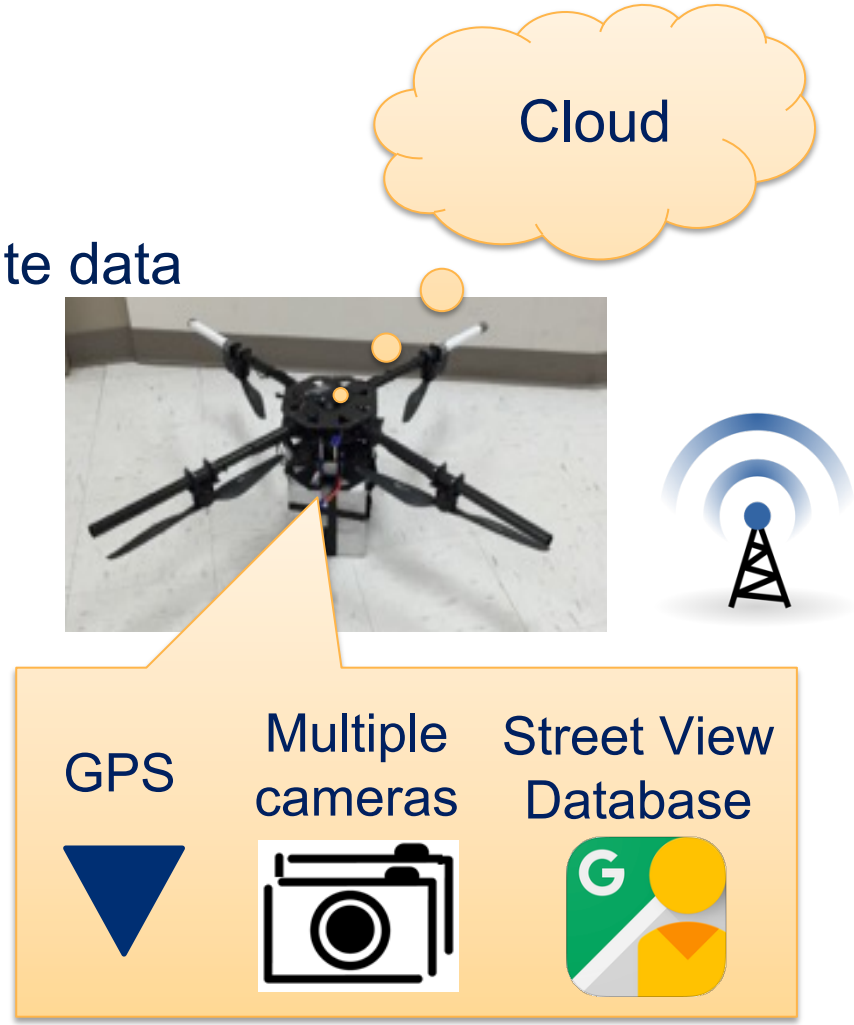
WiFi hotspots in NYC



[NYC Opendata]

Approach: Various Sensors

- GPS
  - Global coverage
  - Reliable high elevation satellite data
- Multiple cameras
  - Rich visual features
  - Feature tracking
- GPS and vision fusion
  - Sensors aid each other
  - Better accuracy



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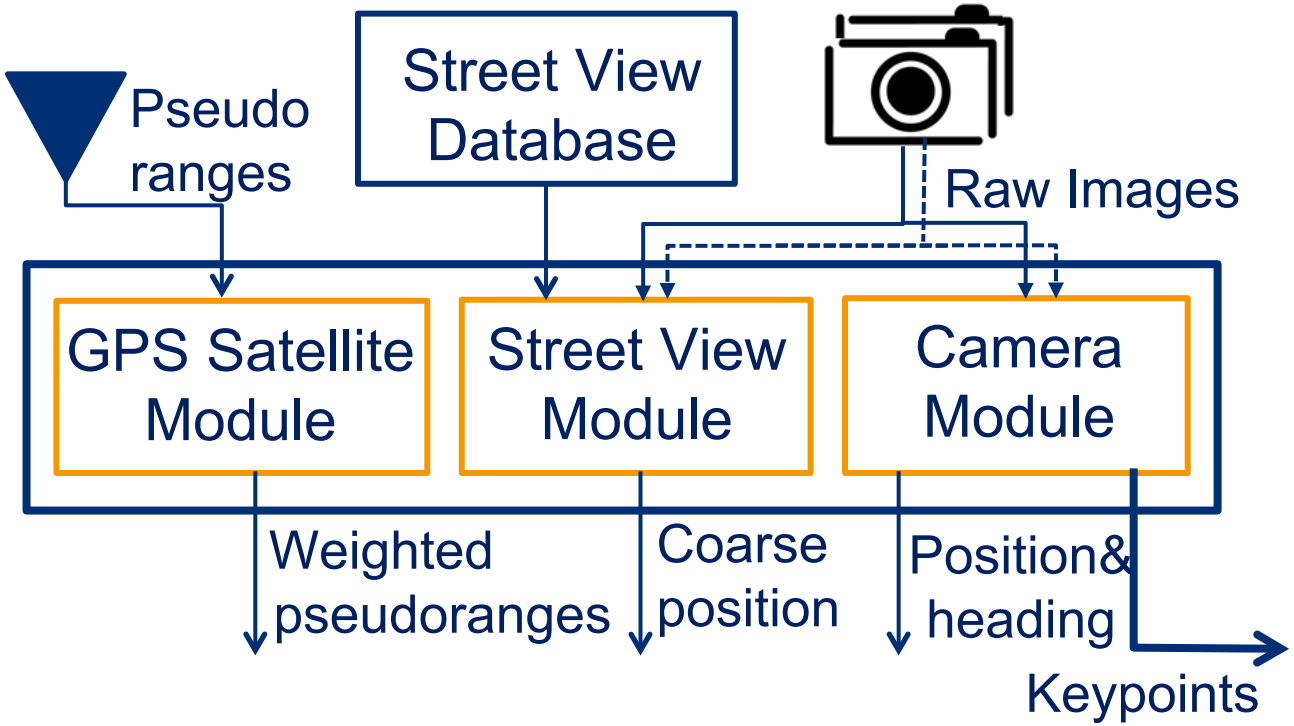
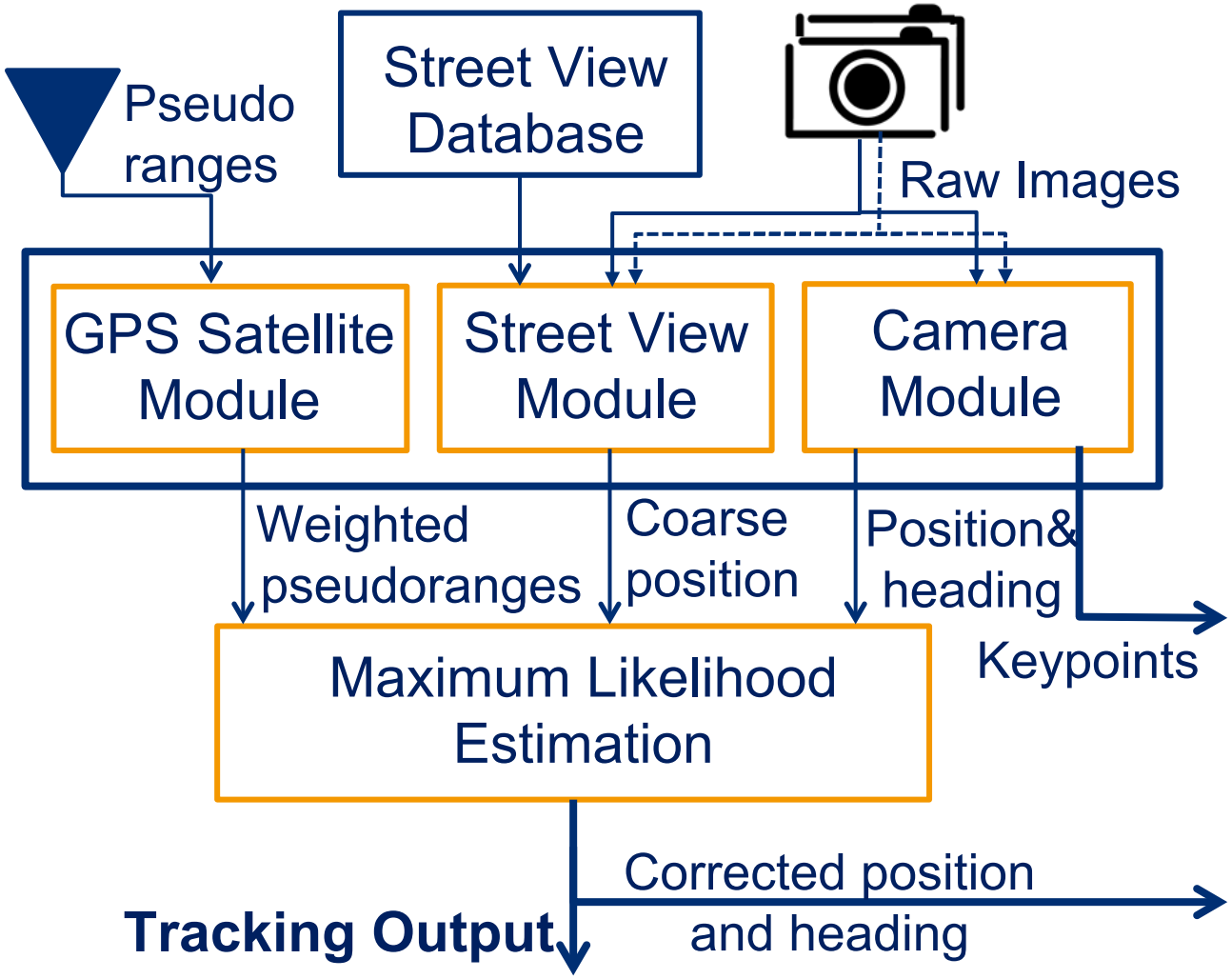
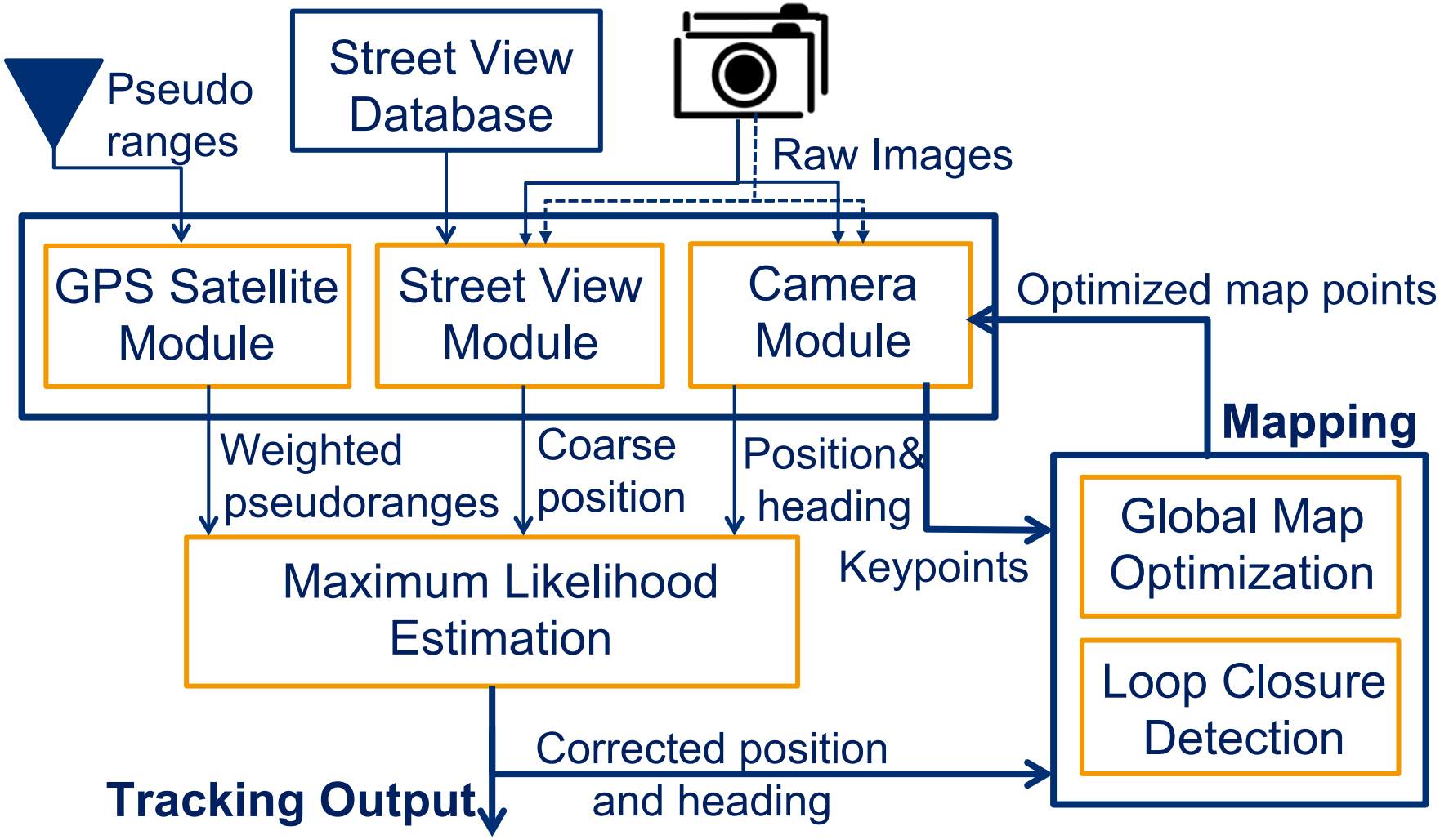
Architecture



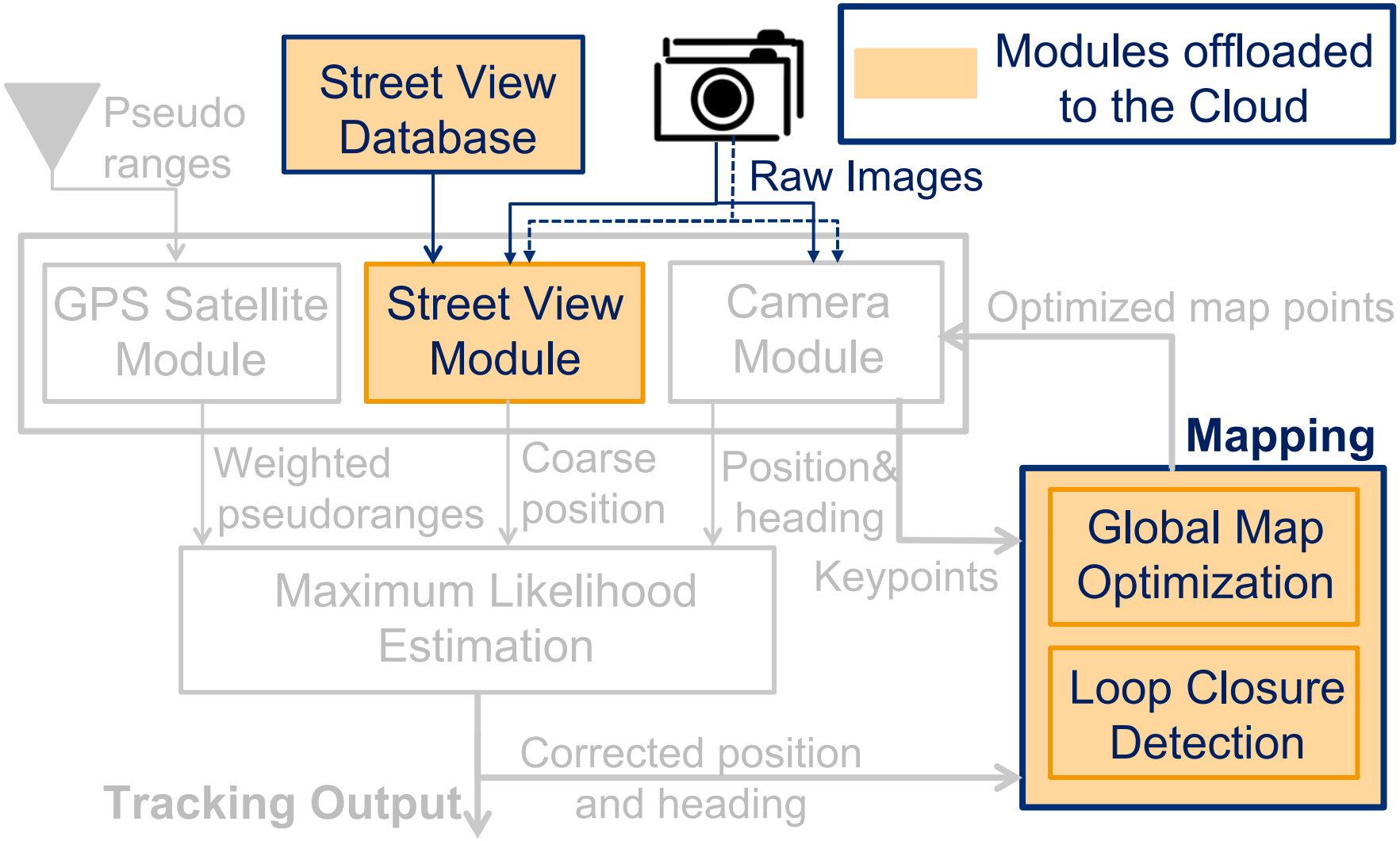
Architecture



Architecture



Architecture: Offload to the Cloud



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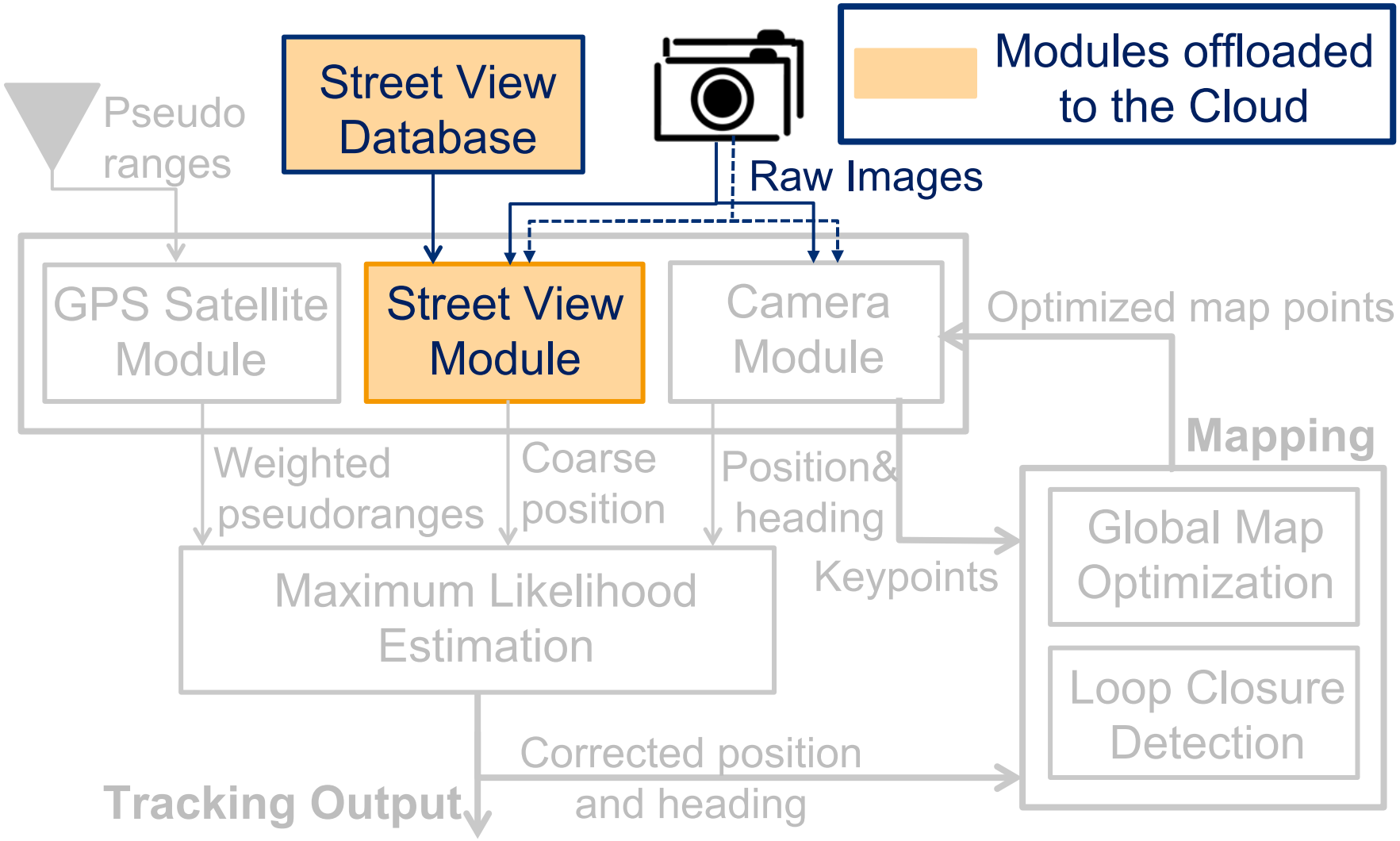
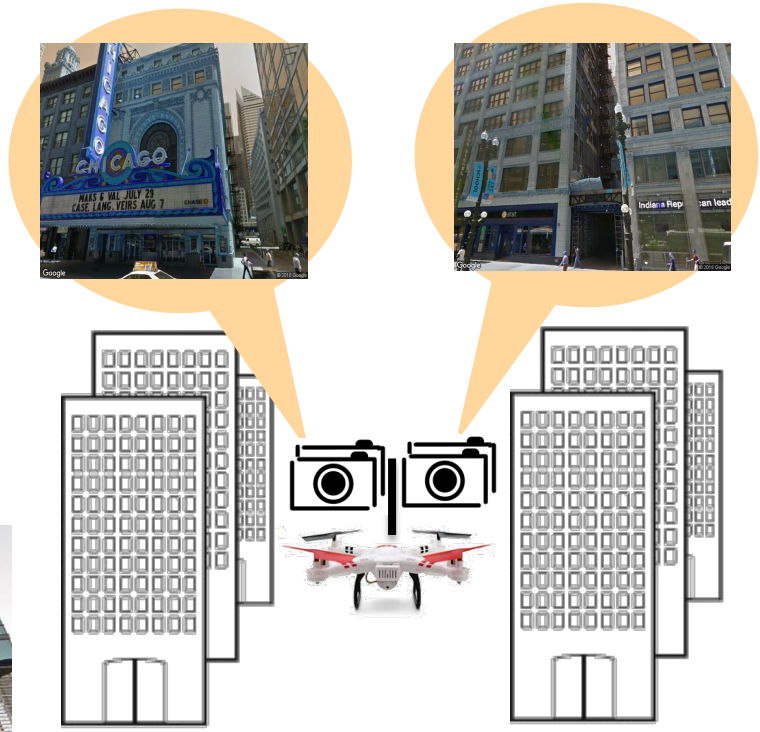


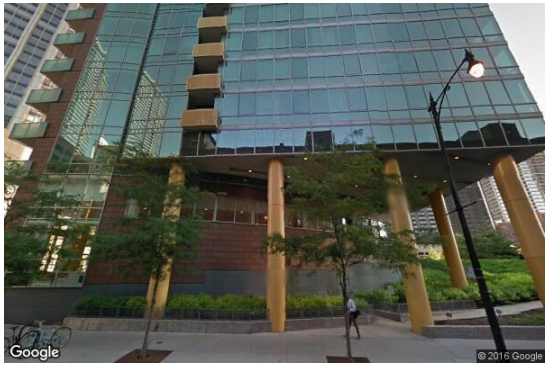
Street View Module - #1

- Extended Street View image database
  - Account for viewpoint changes
- Constrained multi-camera setup
  - Resolve ambiguities due to similar looking architecture



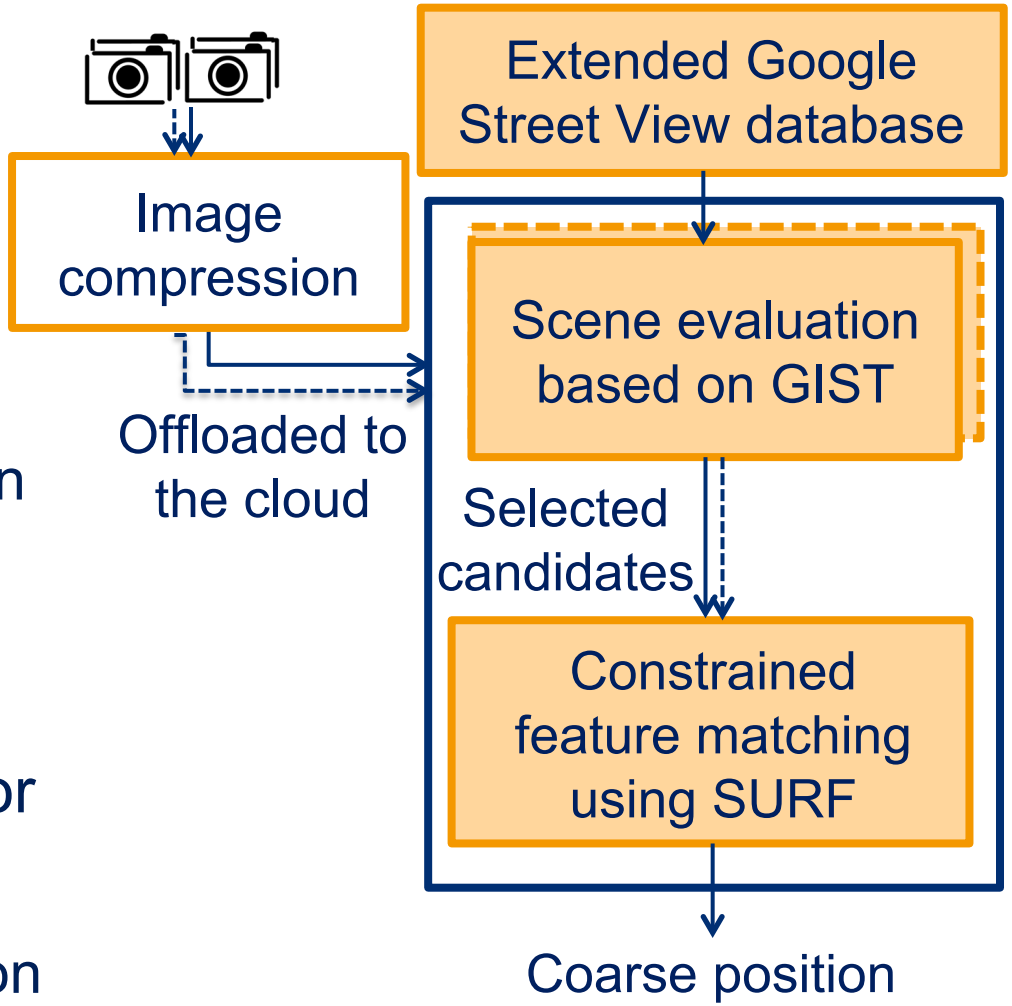
camera image

Street View image

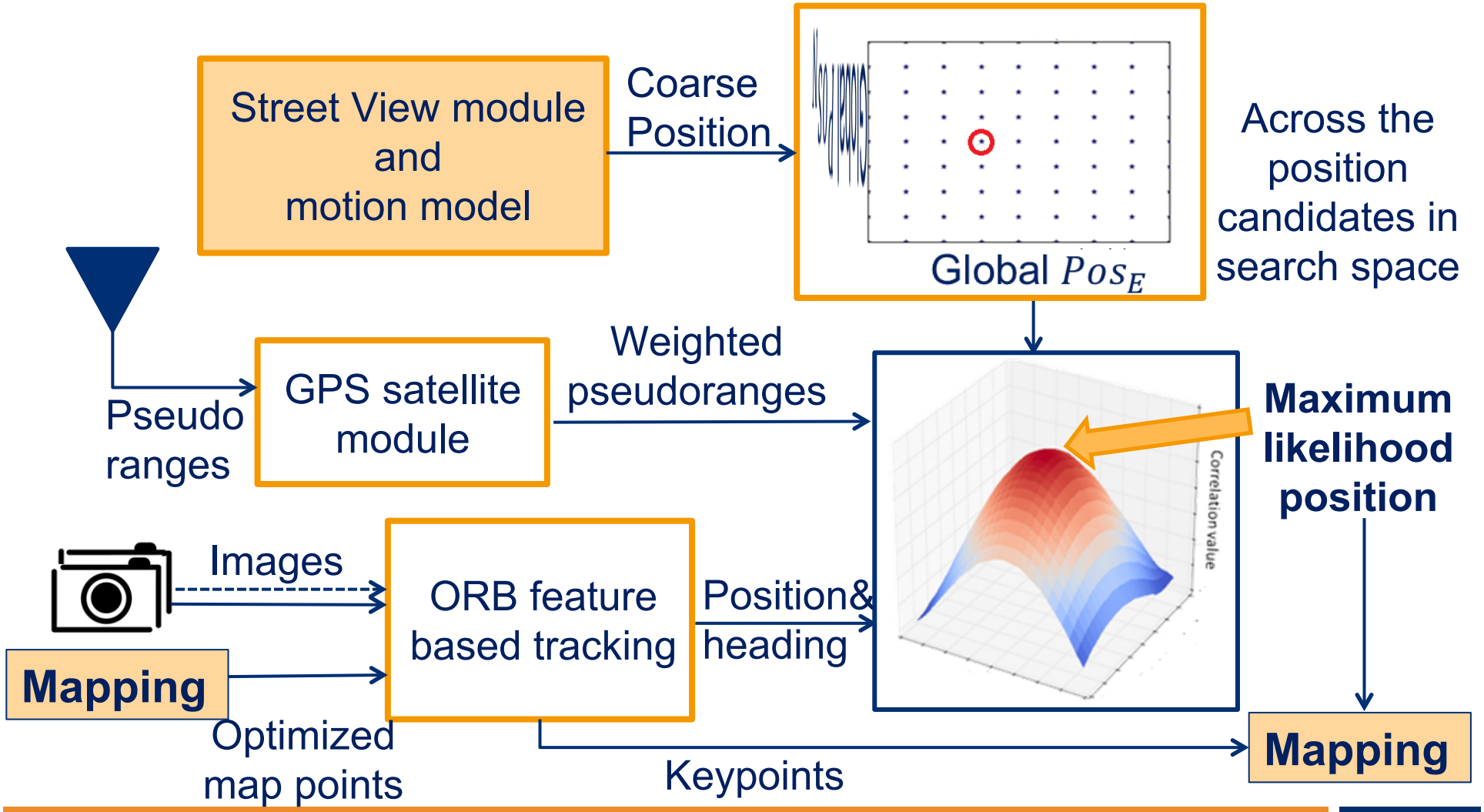


Street View Module - #2

- Image compression
  - Haar wavelets
- GIST- Global descriptor
  - Low dimensional semantic segmentation
  - Choose the potential image candidates
- SURF- Feature descriptor
  - Invariant to scale, illumination and rotation



GPS and Vision Fusion



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Communication Setup

- Robot Operating System (ROS) setup on UAV and Cloud
- Google Cloud Platform – compute engine used for the Cloud based computations

Modules in the Cloud	Execution details
Image compression	1 compressed image 70kB bandwidth
Street View module	UDP link when sufficient bandwidth
Mapping module	TCP link when high bandwidth

ROS Master - #2

iBQR Quadcopter
ROS Master - #1

Computational Time

Regions	Latency involved (ms)
US-west	91.5
US-east	59.0
US- central	**32.2**
Europe-west	131

- Latency depends on location of data center
- Implemented 8-core parallel processing on the Cloud

US- central zone

Mode of transmission	Bandwidth available
Downlink	Upto 9 Mbps
Uplink	Upto 5 Mbps

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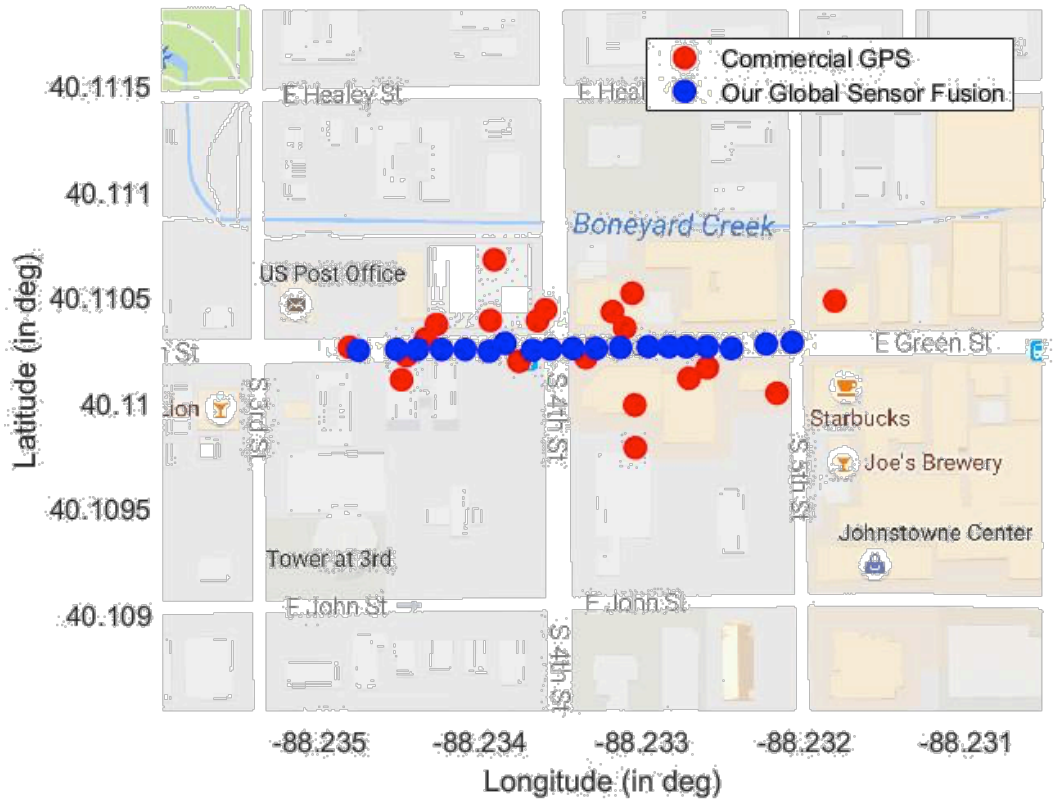
Outdoor UAV: Experiment Video

UAV Flight on UIUC Campus



Our approach achieved higher accuracy than the commercial GPS solution

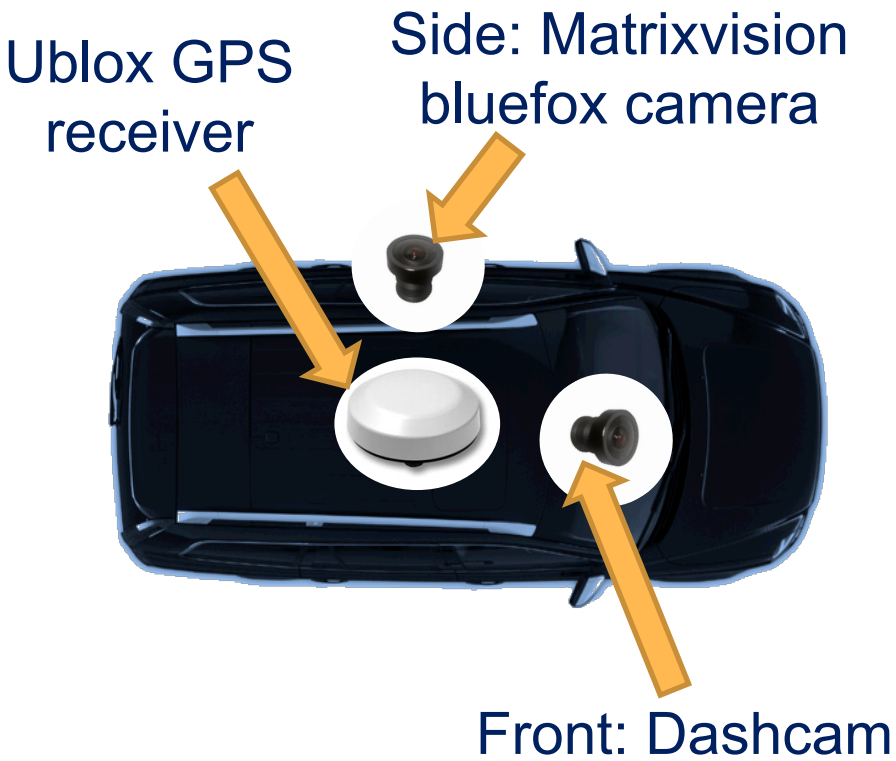
Computational Time

Methodology	Processing time for each instant		
	Latency	Image compression	Computation
On-board computation with brute-force Street View	---	--	~89.2s
On-board computation with our Street View module	--	--	~15.4s
Cloud-based computation with our Street View module	31.2ms	7.3ms	~1.24s

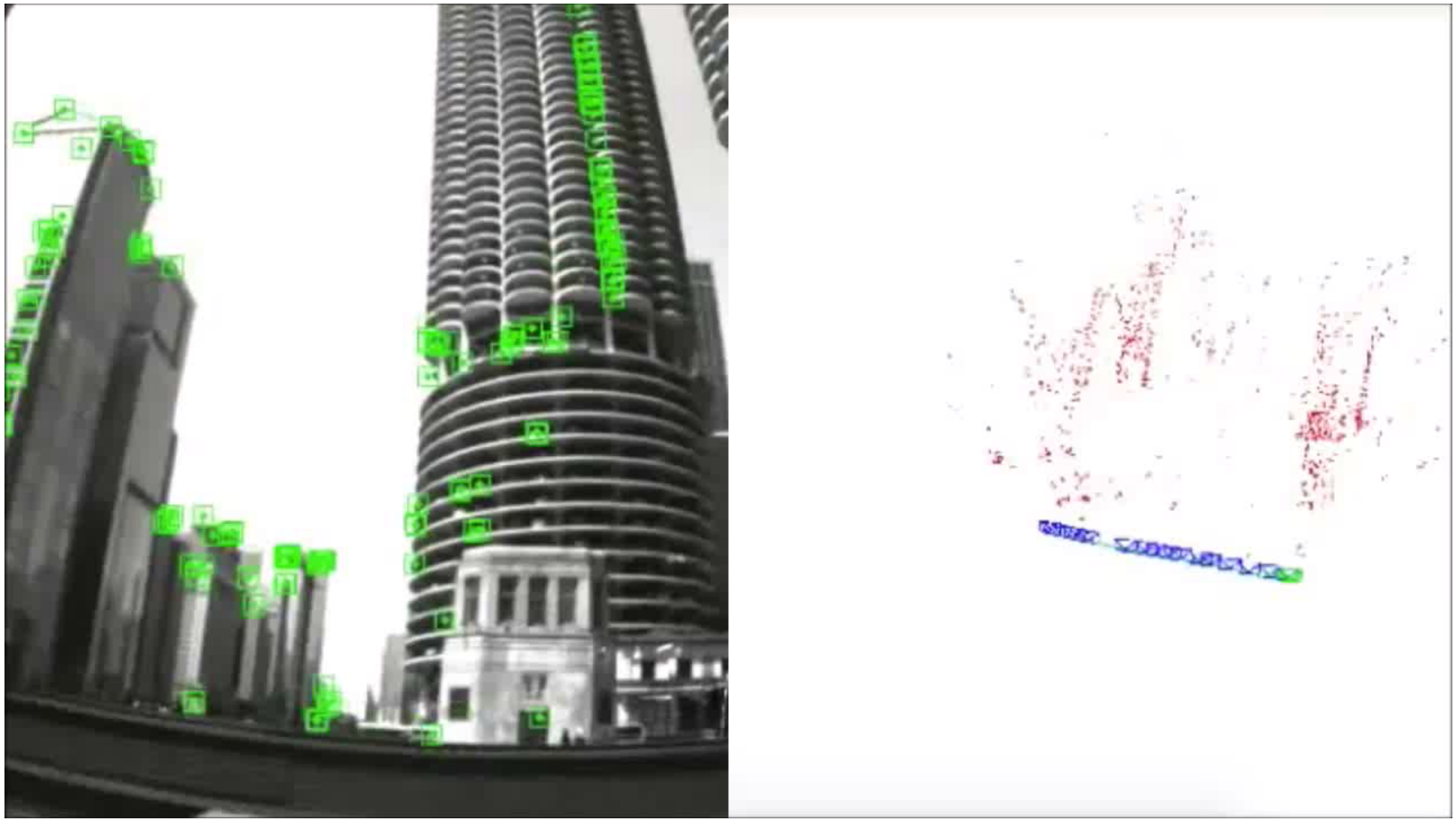
Downtown Chicago: Setup

- Street View database of radius 1km considered
- GPS and two cameras (forward and sideways)

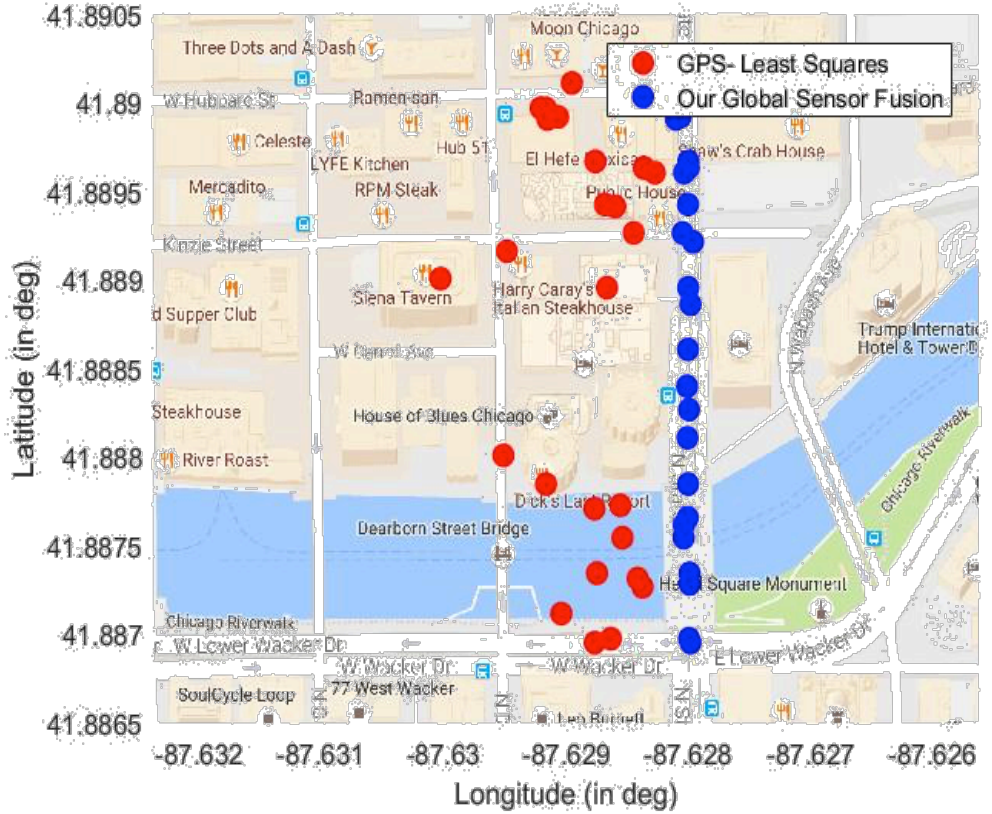
Top View of the car



Downtown Chicago: Video



Downtown Chicago: Accuracy



Our approach achieved high accuracy and takes about ~1.7s to process a single time instant

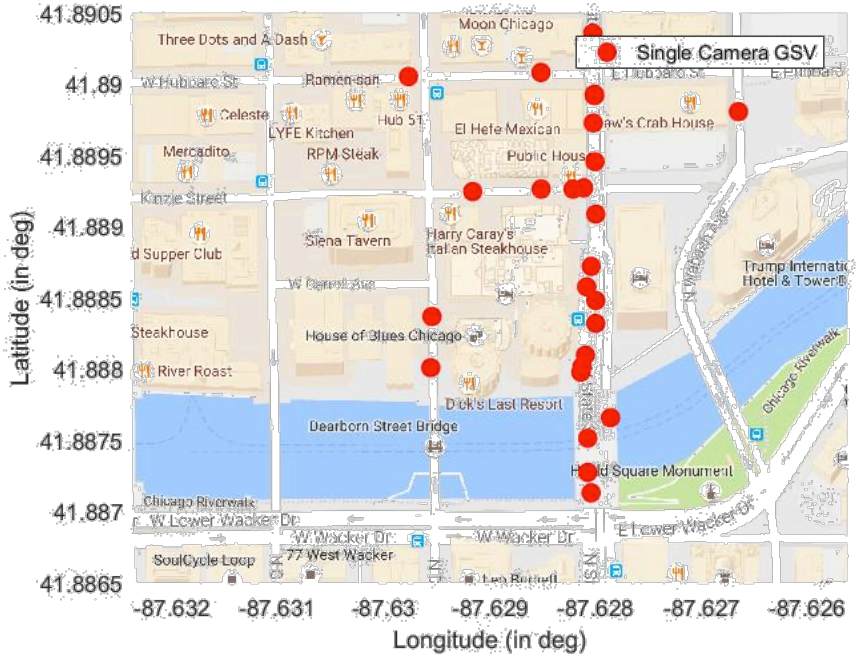
Summary

- Developed a Cloud-based GPS and vision fusion technique for UAV navigation
- Optimized the UAV on-board computational load
- Verified the position accuracy through different urban experimental scenarios

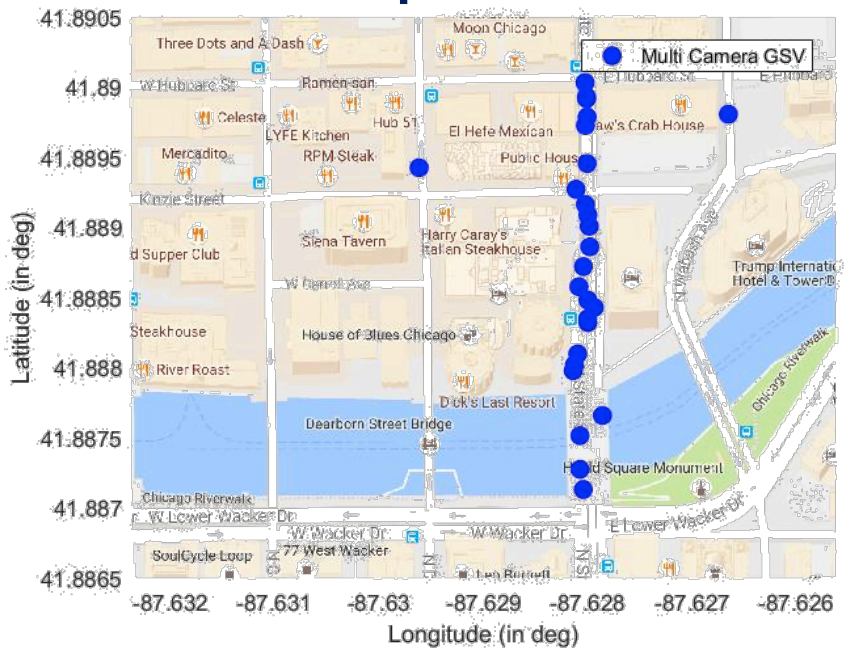
Acknowledgements

Downtown Chicago: Street View

Single Camera



Multiple Camera



Multiple camera Street View localization more robust than a single camera case