Drone is coming!

University-1652: A Multi-view Multi-source Benchmark for Drone-based Geo-localization

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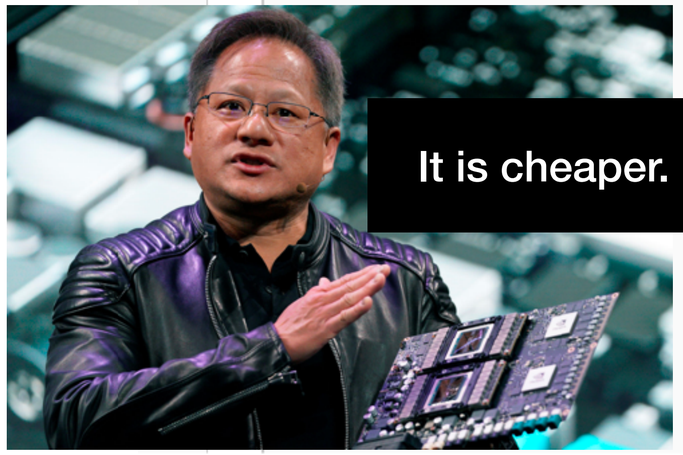

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$1499

Use Cases: What can Drones do? Why we study?

Drone is a new platform.

- Accurate Delivery (e.g., send mask)
- Agriculture (e.g., pesticide)
- Event Detection (e.g. traffic jam)
- ….

https://www.youtube.com/watch?v=j65tqT-sQMo

Outline

- Task (Visual Gap)
- Dataset
- Baseline & Experiment

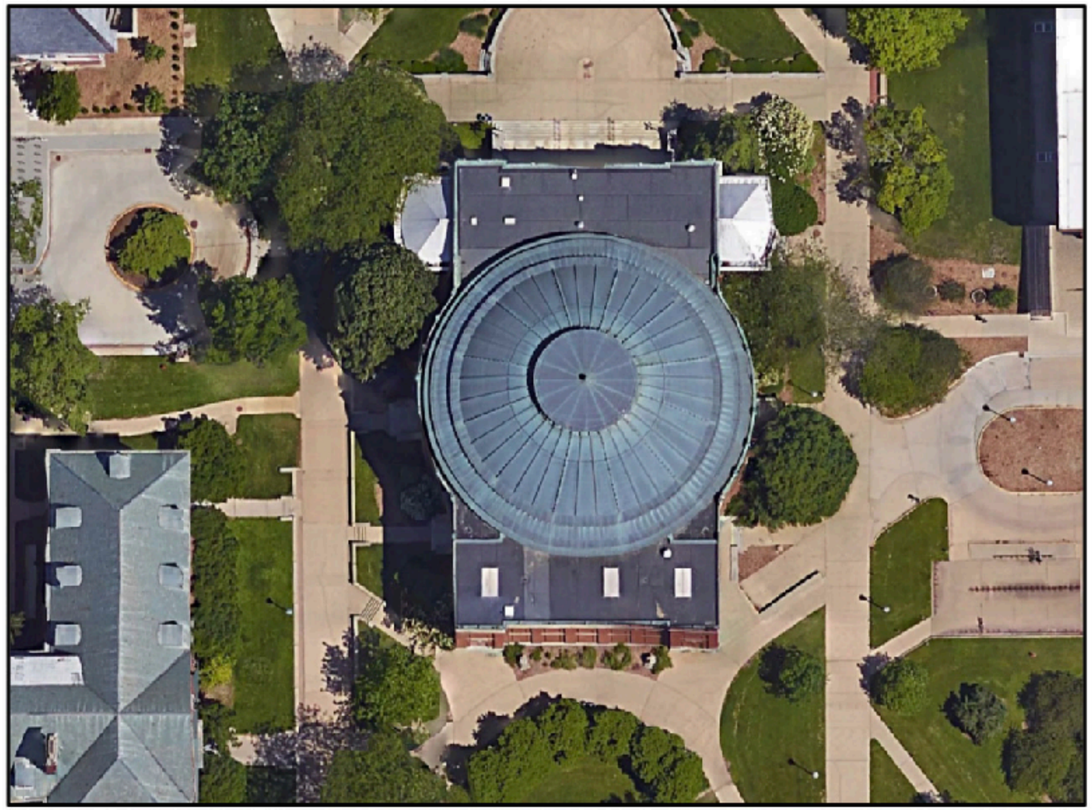
University-1652

- We consider one conventional task: cross-view Geo-localization.

Ground-view Images

Gap

Satellite-view Images (GPS tag)



Limited Roof

Whole Roof

We notice that the drone can be **a bridge.**

Ground-view ⟷ **Drone-view** ⟷ **Satellite-view (GPS tag)**

No dataset to verify it.

Outline

- Task
- Dataset (Missing in existing works)
- Baseline & Experiment

University-1652

- We collect the data from three platforms of 1652 buildings.
- More training images per class (instead of image pairs).
- More viewpoints -> More intra-class variants

Datasets	University-1652	CVUSA [34]	CVACT [16]
#training	701 × 71.64	35.5k × 2	35.5k × 2
Platform	Drone, Ground, Satellite	Ground, Satellite	Ground, Satellite
#imgs./location	54 + 16.64 + 1	1 + 1	1+1
Target	Building	User	User
GeoTag	✓	✓	✓
Evaluation	Recall@K & AP	Recall@K	Recall@K

- Me: I want to build one dataset.
- Supervisor: No! Too much cost.
- Me: We use free data from Internet.
- Supervisor: Do it!

Building names from Wikipedia

Building Names	
BibliothÃĺque Saint-Jean, University of Alberta	Clare Drake Arena
Foote Field	Myer Horowitz Theatre
National Institute for Nanotechnology	St Joseph's College, Edmonton
Stollery Children's Hospital	Universiade Pavilion, University of Alberta
University of Alberta Hospital	Alberta B. Farrington Softball Stadium
Decision Theater, University of Alberta	Gammage Memorial Auditorium
HarringtonâĂŞBirchett House	Industrial Arts Building
Irish Field	Louise Lincoln Kerr House and Studio
Matthews Hall, University of Alberta	Mona Plummer Aquatic Center
Old Main (Arizona State University)	Packard Stadium, University of Alberta
Security Building (Phoenix, Arizona)	Sun Devil Gym, University of Alberta
Sun Devil Stadium, University of Alberta	United States Post Office (Phoenix, Arizona)
Wells Fargo Arena (Tempe, Arizona)	Administration Building, University of Alberta
Wheeler Hall, University of Alberta	Marting Hall, University of Alberta
Malicky Center, University of Alberta	Burrell Memorial Observatory
Kleist Center for Art and Drama	Wilker Hall, University of Alberta
Kamm Hall, University of Alberta	Dietsch Hall, University of Alberta
Telfer Hall, University of Alberta	Ward Hall, University of Alberta
Thomas Center for Innovation and Growth (CIG)	Kulas Musical Arts Building, Baldwin Wallace University
Boesel Musical Arts Center, Baldwin Wallace University	Merner-Pfeiffer Hall, Baldwin Wallace University
Ritter Library, Baldwin Wallace University	Lindsay-Crossman Chapel, Baldwin Wallace University
Presidents House, Baldwin Wallace University	Student Activities Center (SAC), Baldwin Wallace University
Strosacker Hall (Union), Baldwin Wallace University	Bonds Hall, Baldwin Wallace University
Durst Welcome Center, Baldwin Wallace University	Lou Higgins Center, Baldwin Wallace University
Tressel Field @ Finnie Stadium, Baldwin Wallace University	Rutherford Library
Rudolph Ursprung Gymnasium, Baldwin Wallace University	Packard Athletic Center (formerly Bagley Hall), Baldwin Wallace University
Baldwin-Wallace College North Campus Historic District	Baldwin-Wallace College South Campus Historic District
Binghamton University Events Center, Binghamton University	Commonwealth Avenue, Boston University
Boston University Photonics Center, Boston University	Boston University School of Law, Boston University
Boston University Track and Tennis Center, Boston University	Boston University West Campus

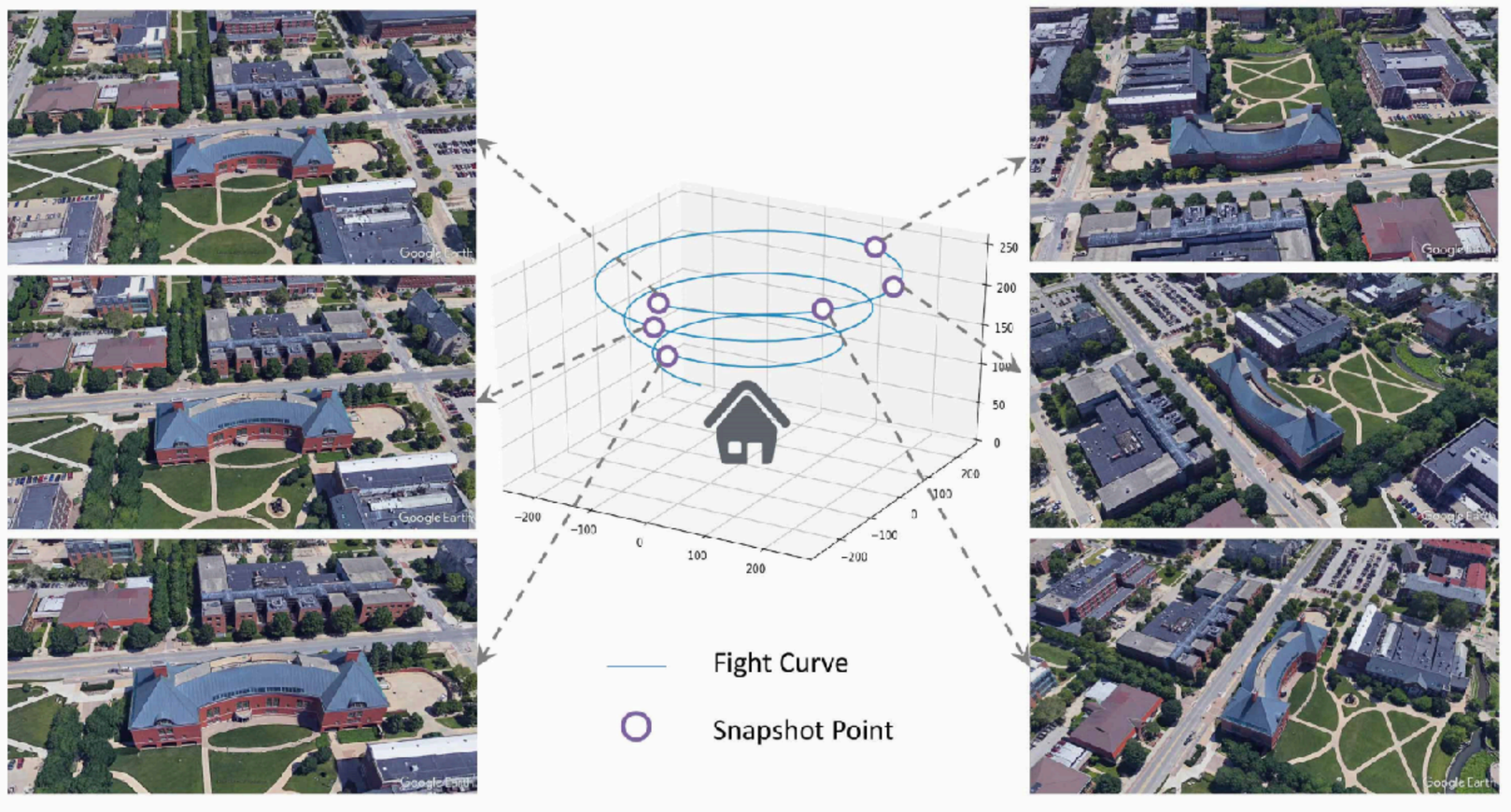
Get latitude/longitude from GoogleMap

Attributes	Value
name	Grainger Engineering Library
longitude	-88.22691719995214
latitude	40.11249969950067
altitude	18.56522342850079

Attributes	Value
name	Foellinger Auditorium
longitude	-88.22728640012006
latitude	40.10594310015922
altitude	23.78598631063875

Drone-view Data

- Due to the privacy concerns and the cost, we deploy the simulated data via Google Earth. We write scripts to drive the engine as drone camera.




Google Earth

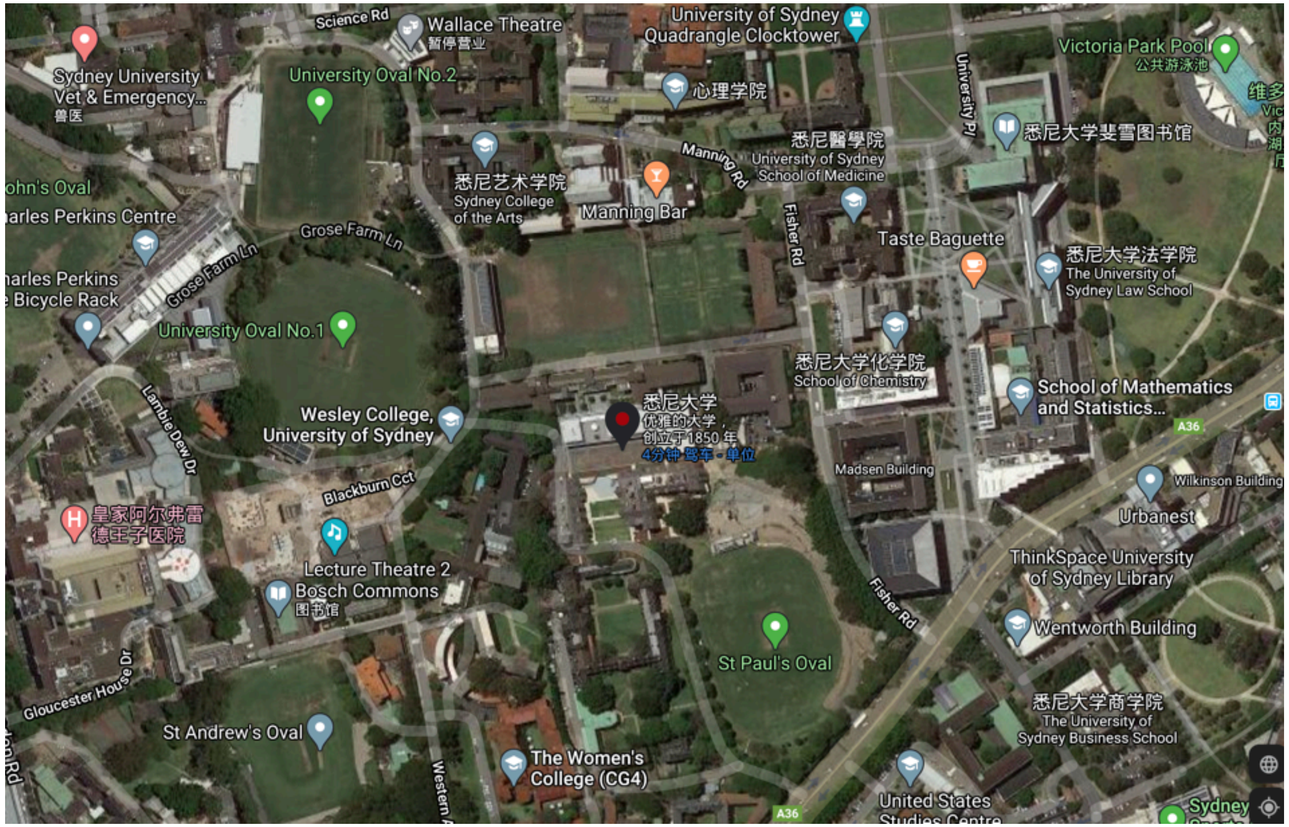

Google Earth


Google Earth


Google Earth

Ground-view Data from GoogleMap

Satellite-view Data from GoogleMap



Noisy Ground-view Data from GoogleImage

Building Names	
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Boston University Photonics Center, Boston University	Boston University School of Law, Boston University
Boston University Track and Tennis Center, Boston University	Boston University West Campus

- We search the building name and download images from GoogleImage
- We then remove the indoor images and duplicate images.

Krause J, Sapp B, Howard A, et al. The unreasonable effectiveness of noisy data for fine-grained recognition[C]//European Conference on Computer Vision. Springer, Cham, 2016: 301-320.

Outline

- Task
- Dataset (Now we have data.)
- Baseline & Experiment

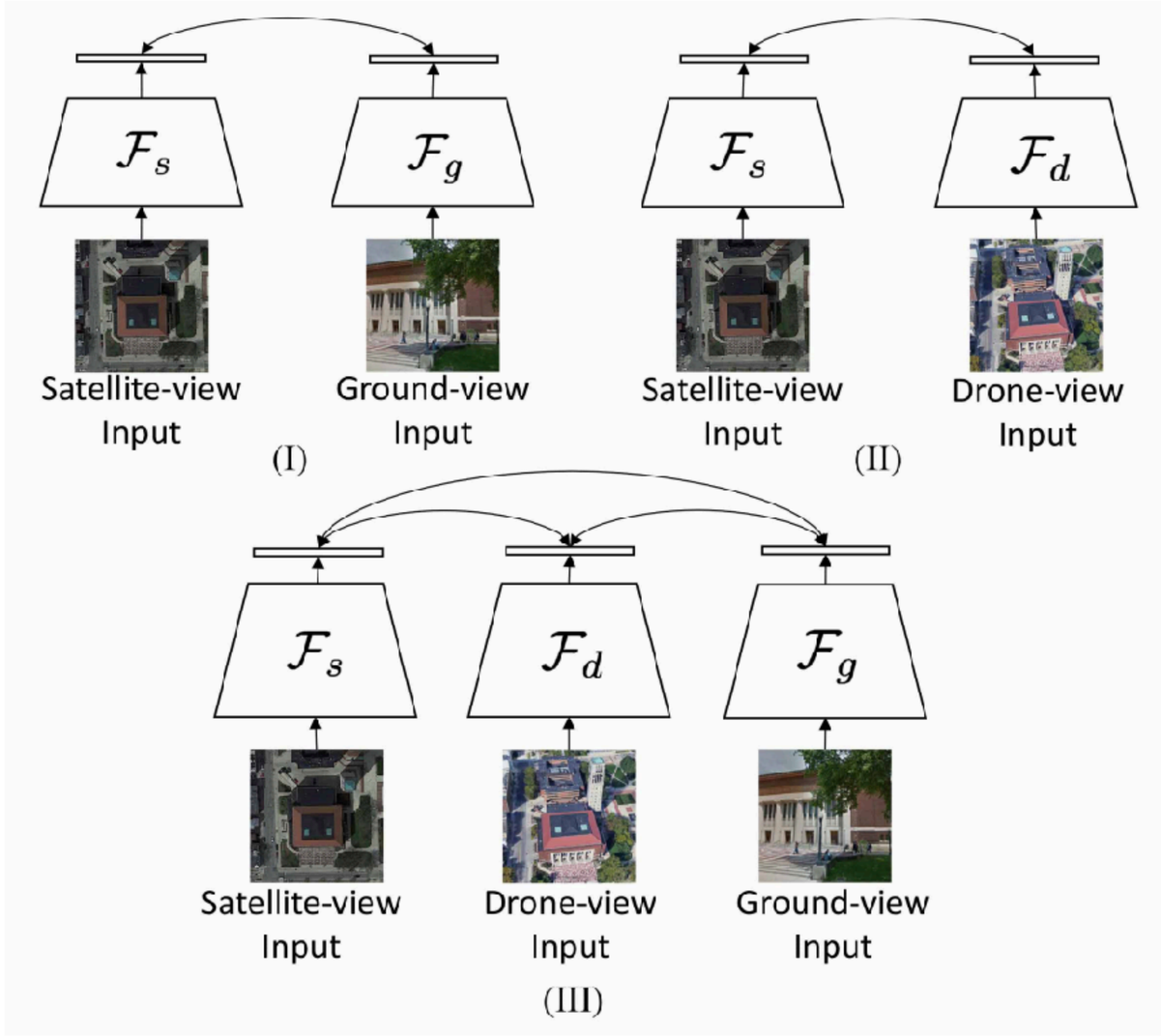
Baseline

Flexible and Strong Baseline

- Objective: Instance Loss (Share Classifier)
- Structure: Generally, the backbone
- network do not share low-level patterns

New data ->

add one branch!



Zheng Z, Zheng L, Garrett M, et al. Dual-Path Convolutional Image-Text Embeddings with Instance Loss[J]. ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM), 2020, 16(2): 1-23.

Baseline

CVUSA

Methods	R@1	R@5	R@10	R@Top1%
Workman [31] ICCV 2015	-	-	-	34.40
Zhai [34] CVPR 2017	-	-	-	43.20
Vo [29] ECCV 2016	-	-	-	63.70
CVM-Net [11] CVPR 2018	18.80	44.42	57.47	91.54
Orientation [16]† CVPR 2019	27.15	54.66	67.54	**93.91**
Ours	**43.91**	**66.38**	**74.58**	91.78

Table 9: Comparison of results on the two-view dataset CVUSA [34]. †: The method utilizes extra orientation information as input.

Oxford and Paris

Method	Oxford	Paris	ROxf (M)	RPar (M)	ROxf (H)	RPar (H)
ImageNet	3.30	6.77	4.17	8.20	2.09	4.24
$\mathcal{F}_s$	9.24	13.74	5.83	13.79	2.08	6.40
$\mathcal{F}_g$	25.80	28.77	15.52	24.24	3.69	10.29

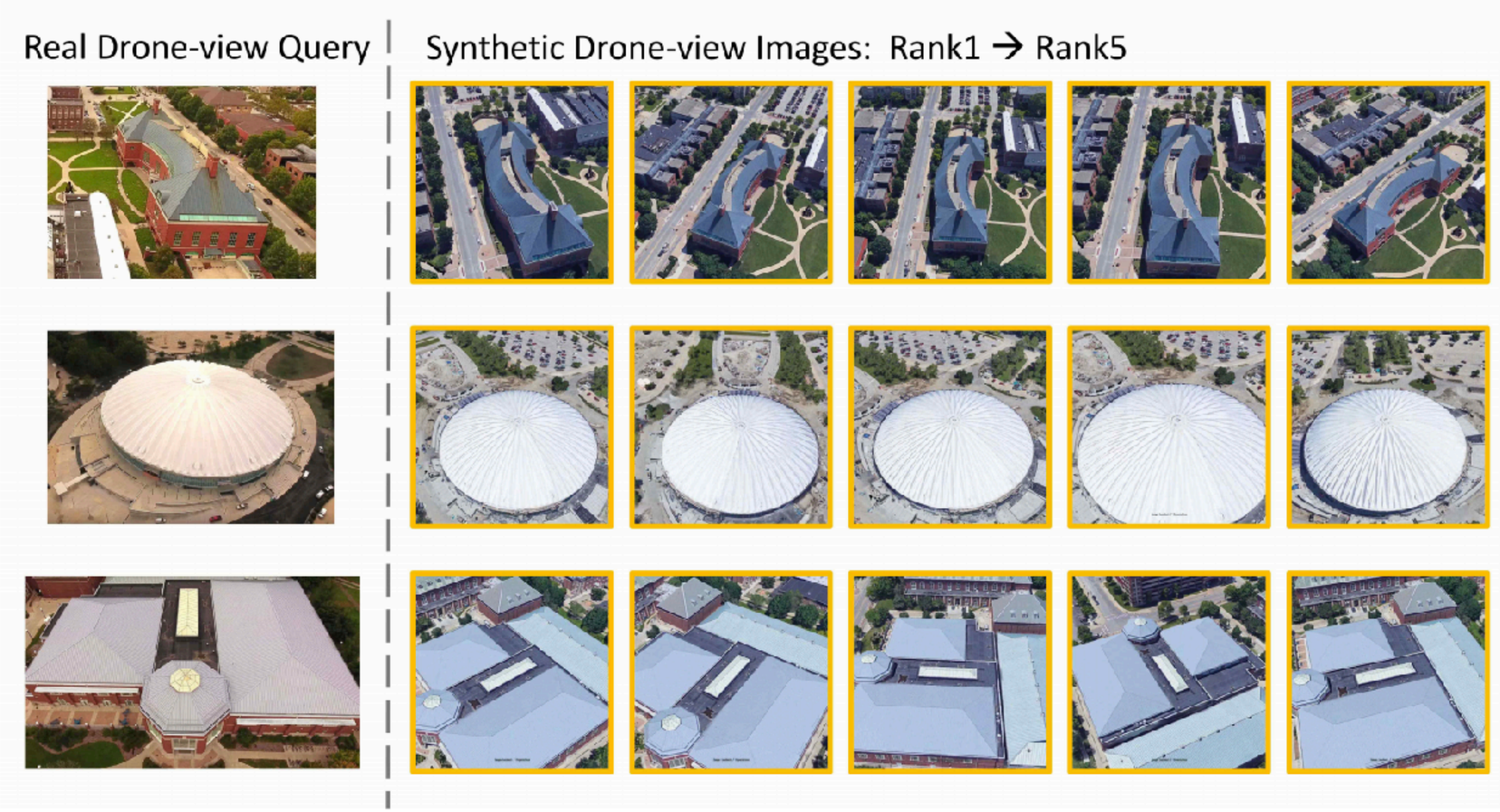
Table 10: Transfer learning from University-1652 to small-scale datasets. We show the AP (%) accuracy on Oxford [19], Paris [20], ROxford and RParis [21]. For ROxford and RParis, we report results in both medium (M) and hard (H) settings.

Ground-view query vs. drone-view query.

Query → Gallery	R@1	R@5	R@10	AP
Ground → Satellite	1.20	4.61	7.56	2.52
Drone → Satellite	58.49	78.67	85.23	63.13
*m*Ground → Satellite	1.71	6.56	10.98	3.33
*m*Drone → Satellite	69.33	86.73	91.16	73.14

Table 4: Ground-view query vs. drone-view query. *m* denotes multiple-query setting. The result suggests that drone-view images are superior to ground-view images when retrieving satellite-view images.

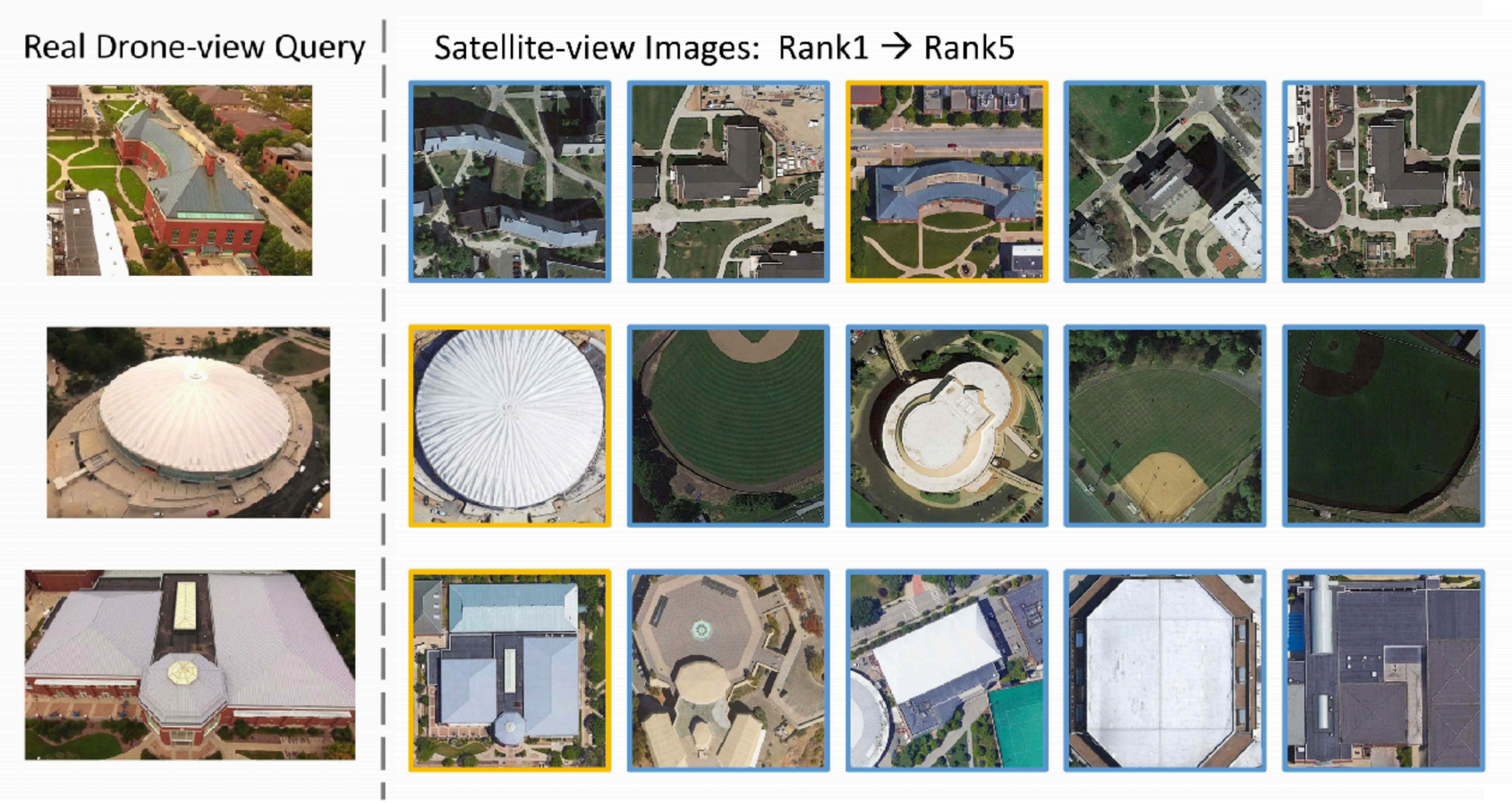
Apply the model trained on University-1652 to real drone videos.



[Fly High #1 "UIUC" https://www.youtube.com/watch?v=jOC-WJW7GAg](https://www.youtube.com/watch?v=jOC-WJW7GAg)

The model haven't seen any data of UIUC.

Apply the model trained on University-1652 to real drone videos.



The model haven’t seen any data of UIUC.

Ablation Studies

Different Loss Functions

Loss	Drone → Satellite		Satellite → Drone	
	R@1	AP	R@1	AP
Contrastive Loss	52.39	57.44	63.91	52.24
Triplet Loss (margin=0.3)	55.18	59.97	63.62	53.85
Triplet Loss (margin=0.5)	53.58	58.60	64.48	53.15
Weighted Soft Margin Triplet Loss	53.21	58.03	65.62	54.47
Instance Loss	58.23	62.91	74.47	59.45

Table 5: Ablation study of different loss terms. To fairly compare the five loss terms, we trained the five models on satellite-view and drone-view data, and hold out the ground-view data. For contrastive loss, triplet loss and weighted soft margin triplet loss, we also apply the hard-negative sampling policy.

Whether Share Weights

Method	Drone → Satellite		Satellite → Drone	
	R@1	AP	R@1	AP
Not sharing weights	39.84	45.91	50.36	40.71
Sharing weights	58.49	63.31	71.18	58.74

Table 6: Ablation study. With/without sharing CNN weights on University-1652. The result suggests that sharing weights could help to regularize the CNN model.

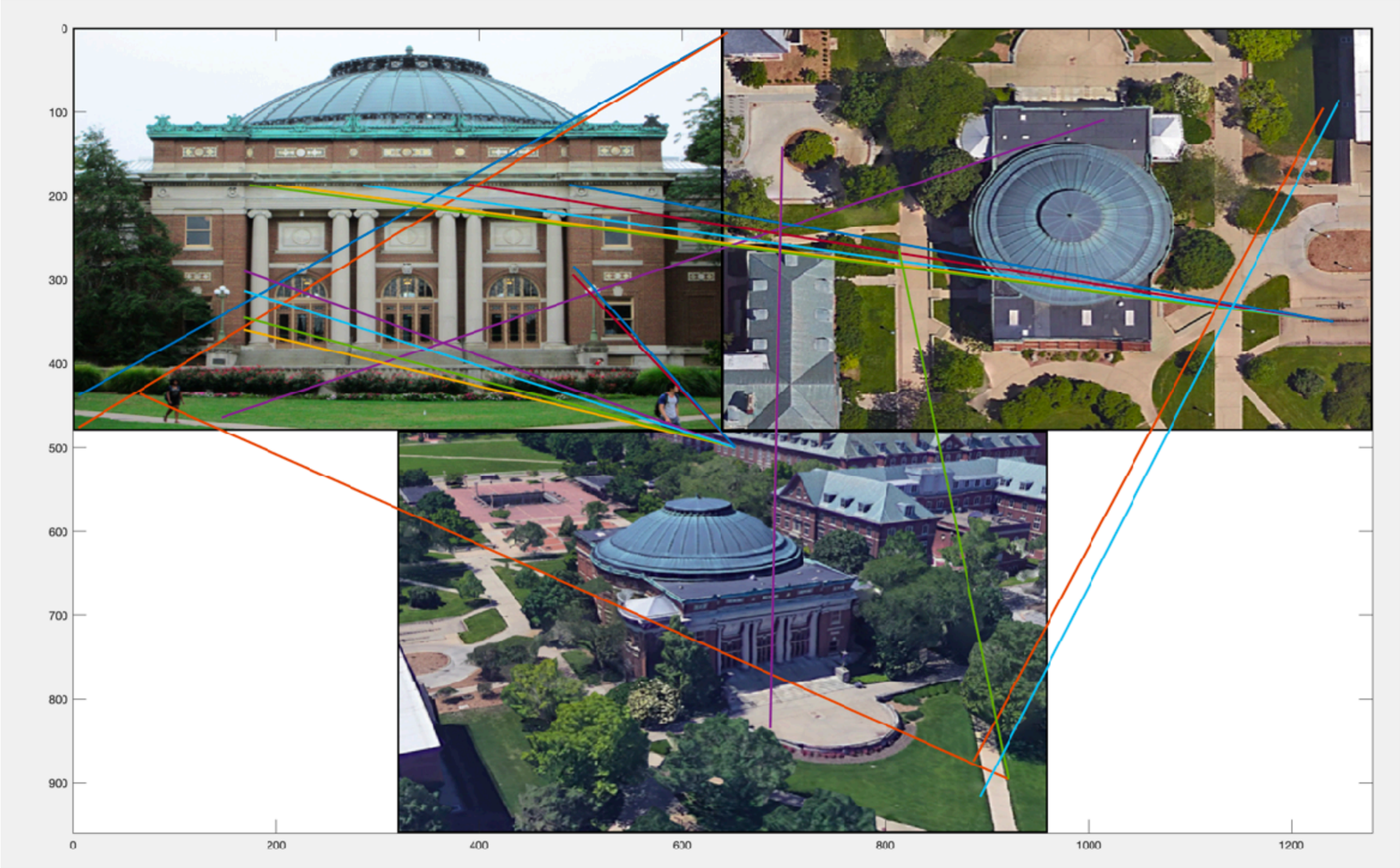
Different Input Sizes

Image Size	Drone → Satellite		Satellite → Drone	
	R@1	AP	R@1	AP
256	58.49	63.31	71.18	58.74
384	62.99	67.69	75.75	62.09
512	59.69	64.80	73.18	59.40

Table 7: Ablation study of different input sizes on the University-1652 dataset.

Future Works - Keypoint Matching

SIFT does not work very well. Deeply-learned Methods are needed.



Future Works - Boost Performance

We run a leaderboard.
You are welcomed to push the state-of-the-art performance.

Awesome Geo-localization

University-1652

Methods	R@1	AP	R@1	AP	Reference
Contrastive Loss	52.39	57.44	63.91	52.24	
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ACM multimedia
Seattle,USA Oct 12-16 2020

Thanks a lot!

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Dataset & Code

Have been downloaded
By 300+ times.

Data License

- We carefully check the data license from Google. There are two main points.
- First, the data of Google Map and Google Earth could be used based on fair usage. We follow the guideline on this official website 3 .
- Second, several existing datasets have utilized the Google data. In practice, we adopt a similar policy of existing datasets 4, 5 to release the dataset based on the academic request.

3. https://www.google.com/permissions/geoguidelines/
4. http://www.ok.ctrl.titech.ac.jp/~torii/project/247/
5. http://mvrl.cs.uky.edu/datasets/cvusa/