Machine Learning Dublin Meetup,
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Object Detection on Street View Images: from Panoramas to Geotags

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Fondúreacht Eolaíochta Éireann
Dá bhfuil romhainn
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For what's next

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Object detection. Intro.

- *Motivation*. Billions of images (by ***Google***, *Bing*, *Mapillary*) covering mlns of kms of road.

~1 mln km coverage

>500 km

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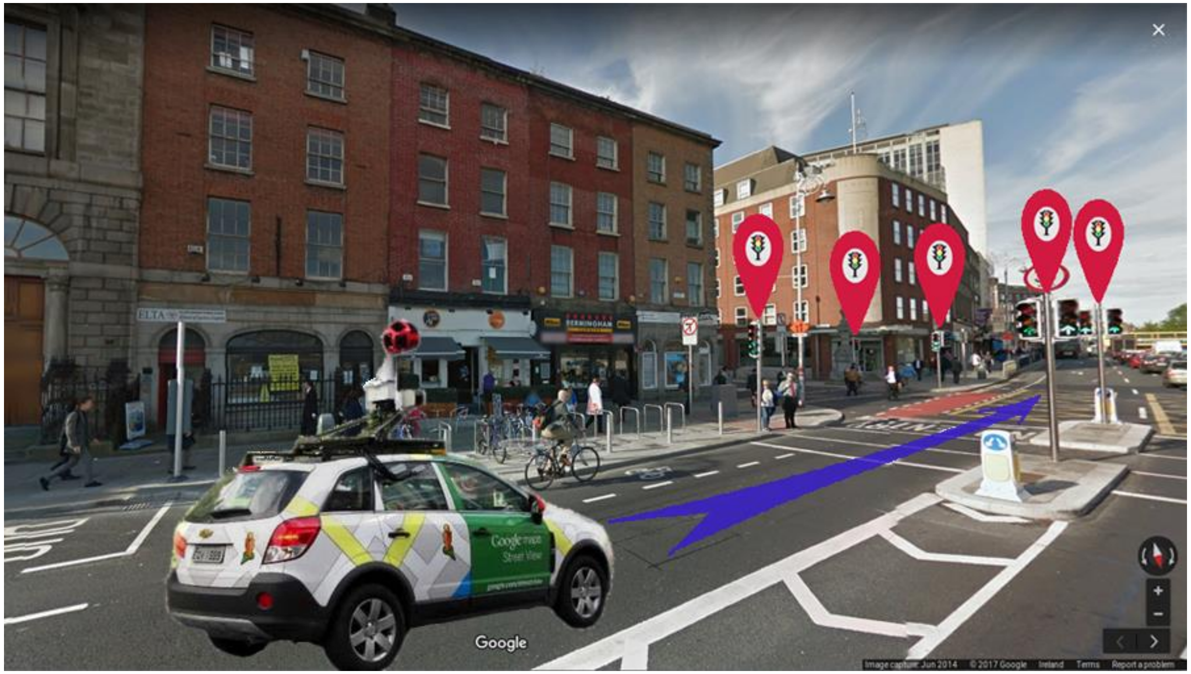
- *Target*. Automatic mapping of stationary recurring objects **from Street View**.



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- *State-of-the-art*: **Object recognition.**

Mapillary Vistas Dataset

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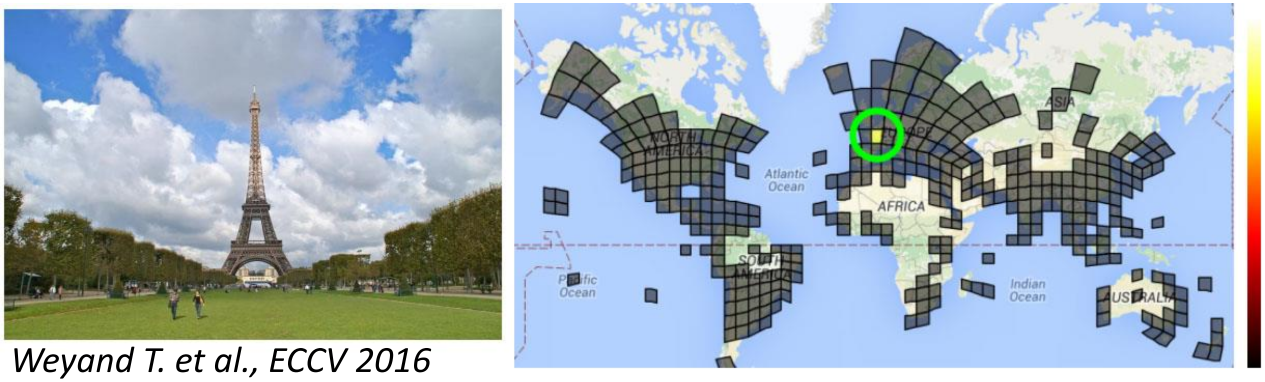
Lin T. et al., CVPR 2015



Weyand T. et al., ECCV 2016

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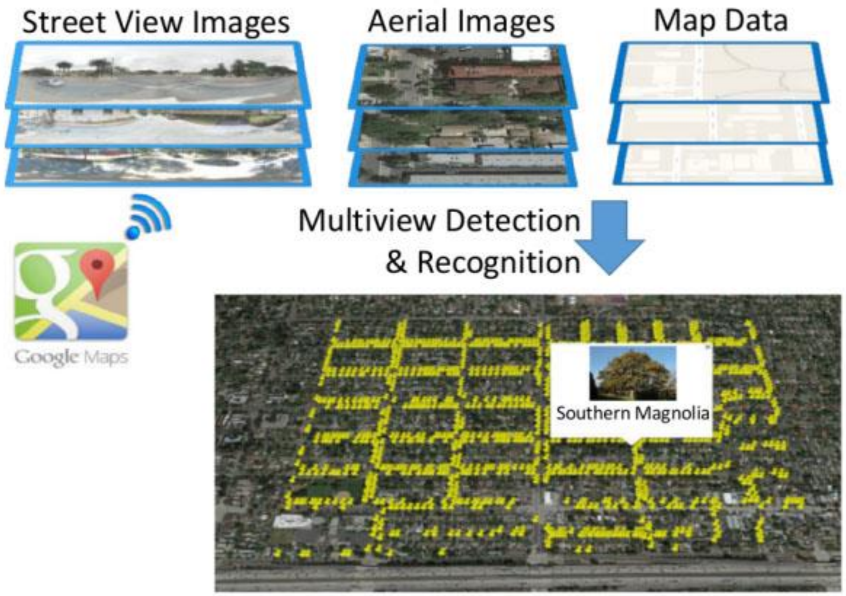
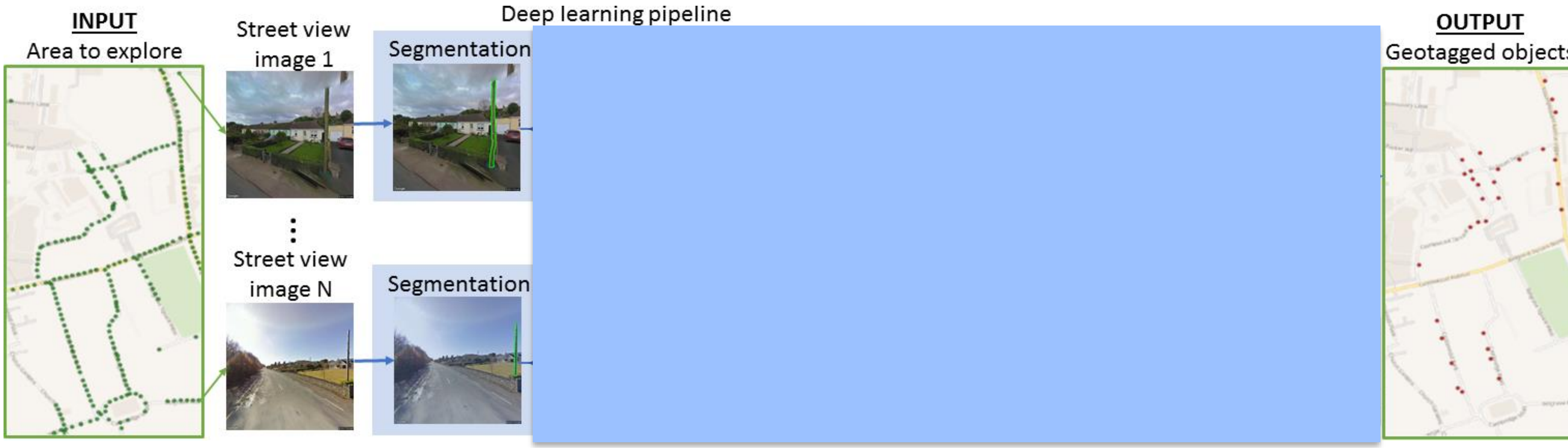
- *State-of-the-art*: Object recognition. Image geolocation. **Object geolocation**.



Fine-Grained Geographic Tree Catalog
Wegner, J. et al., CVPR 2016

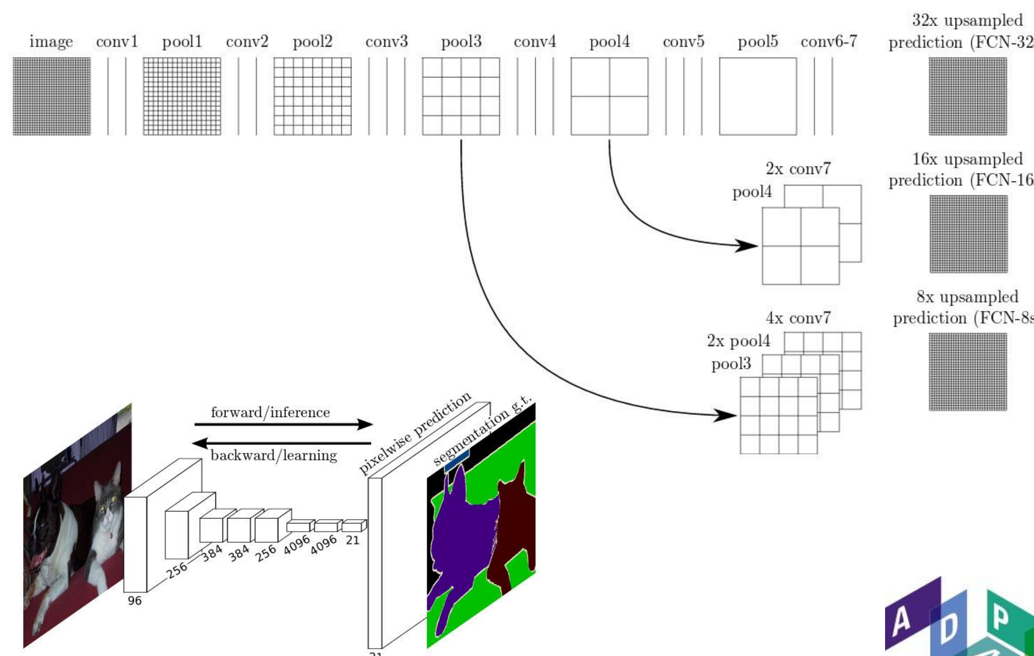
Processing pipeline: semantic segmentation



- ***Object detection:***
  Semantic segmentation
  with **Fully Convolutional NNs**:

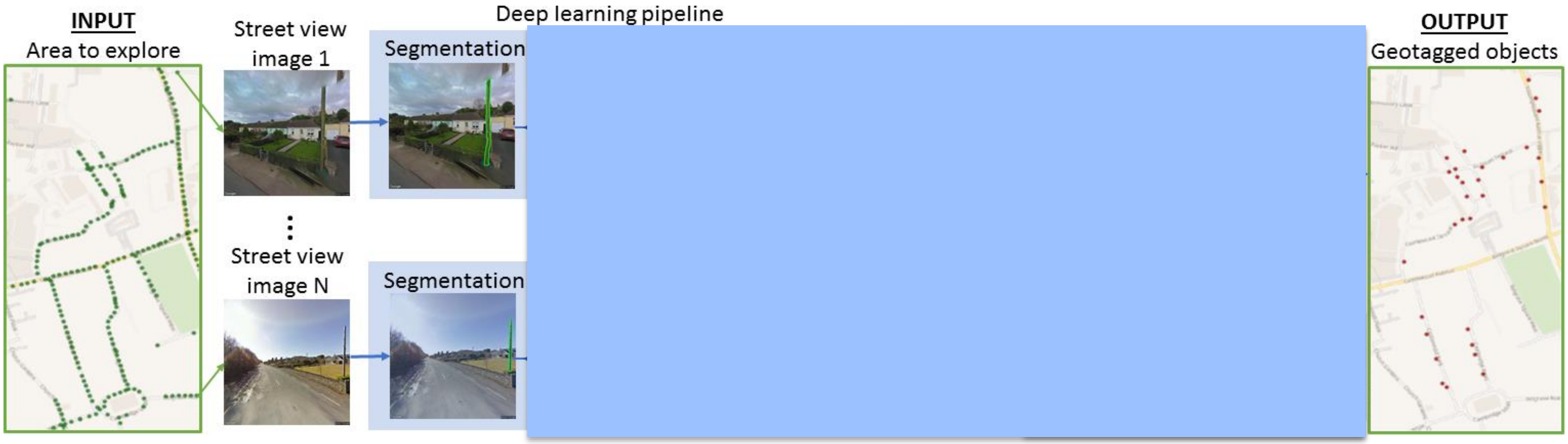
  - Introduce *extra FP penalty*

  - *Retrain* on one or multiple classes of objects: on *Mapillary Vistas, Cityscapes*



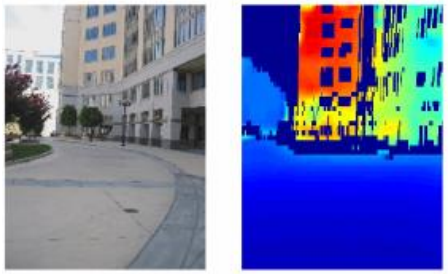
Shelhamer E. et al., IEEE T-PAMI 2017

Processing pipeline: monocular depth estimation



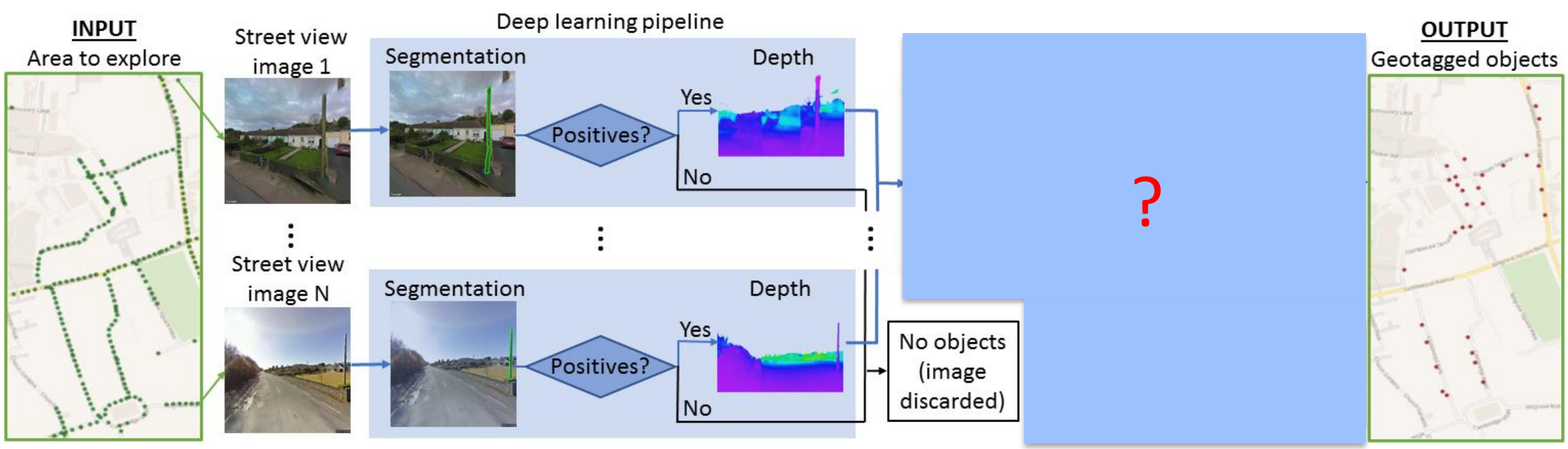
➢ *Spatial scene analysis:*

- Stereo-vision, Structure-from-Motion
  - *Requires more data, assumptions.*
- Monocular depth estimation
  - *Provides approximate accuracies;*
  - *Requires segmented objects.*

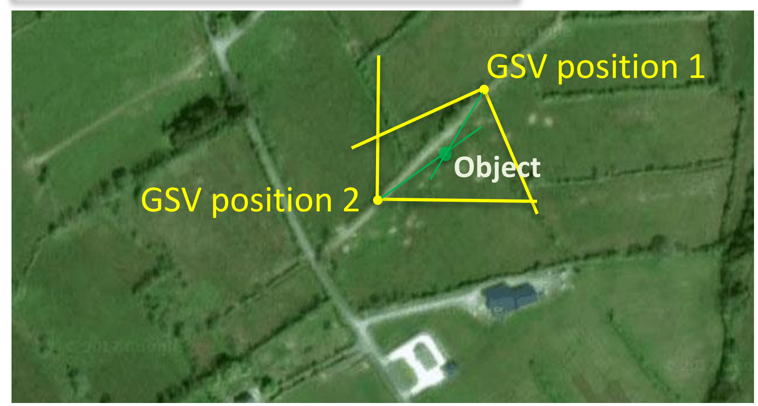


Laina I. et al., 3d Vision 2016

Processing pipeline: geotagging



- Strategies to estimate the position of objects from images:
  - Depth-based
  - Triangulation-based



- ✓ Single view: sensitivity
- ✓ Single view: false positives
- ✓ Low accuracy: up to 7m error

- ✓ High accuracy
- ✓ Multiple views
- ✓ Matching required

Processing pipeline: geotagging

- We define a **Markov Random Field** (MRF) model over the space of all view-rays intersections:
  - label *z=0* if not occupied by object
  - label *z=1* if occupied

- MRF configuration is characterized by its corresponding energy *U*. *Optimal = minimum of U.*

  Energy terms:
  - Unary term. *Consistency with depth.*

$$u_1(z) = z \sum_{j=1,2} \|\Delta_j - d_j\|$$

  - Pairwise term. *No occlusions. No spread.*

$$u_2(z) = z \sum_k z_k \, \|x - x_k\|$$

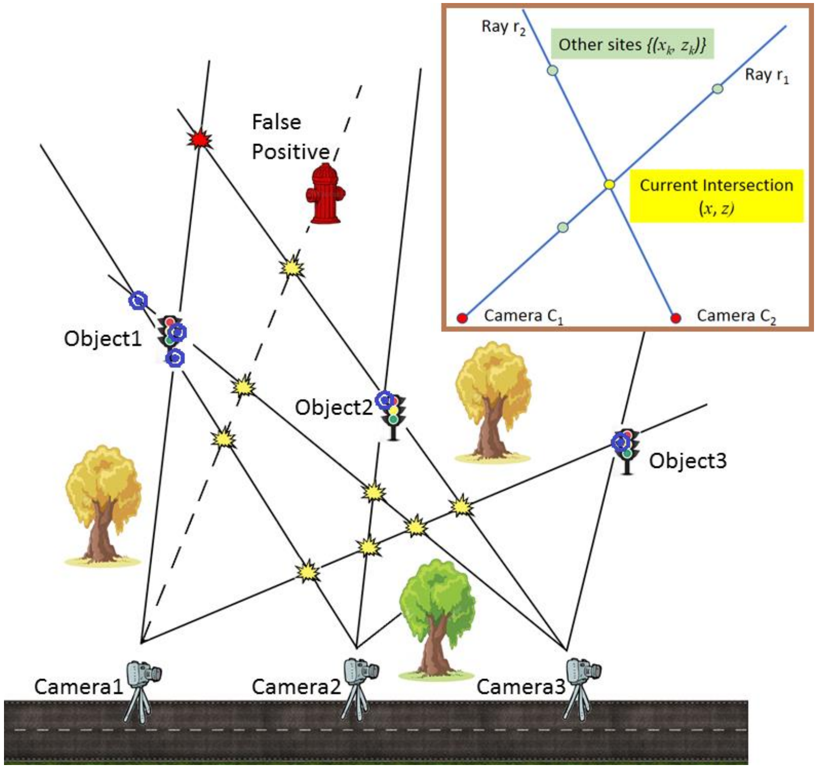
  - Ray term. *Penalize not matched rays.*

$$u_3(z) = (1-z) \prod_k (1 - z_k)$$

Total energy:

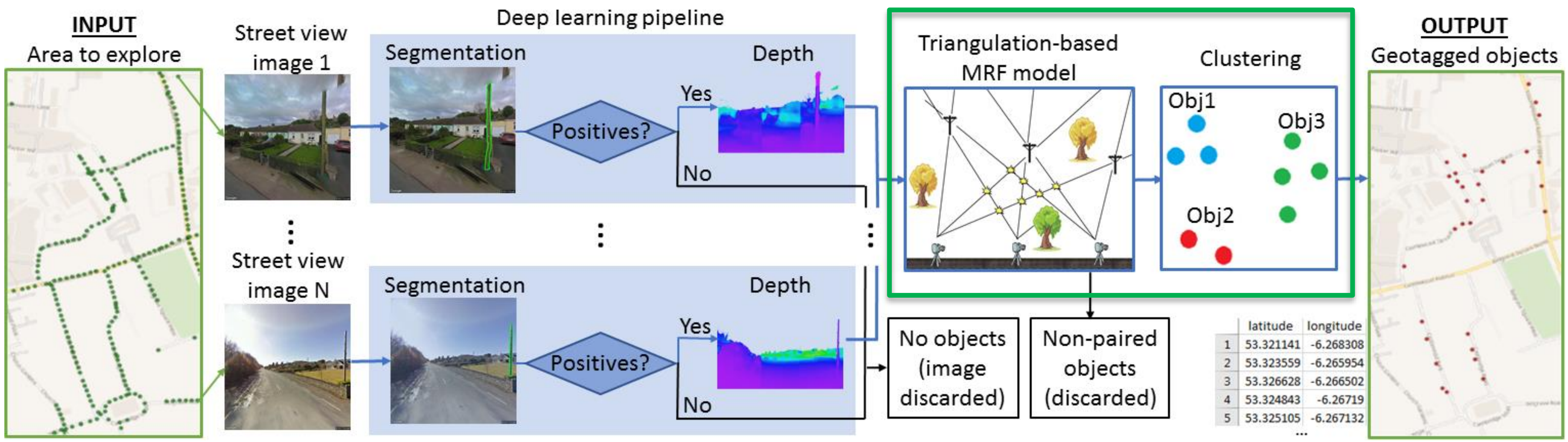
$$\mathcal{U}(\mathbf{z}) = \sum_{i=1}^{N_Z} \left[\alpha \, u_1(z_i) + \beta \, u_2(z_i) + (1-\alpha-\beta) \, u_3(z_i) \right]$$

$$\alpha, \beta \geqslant 0, \ \alpha + \beta \leqslant 1.$$



Δ – depth estimates
d – triangulated distances
x – Euclidean intersections

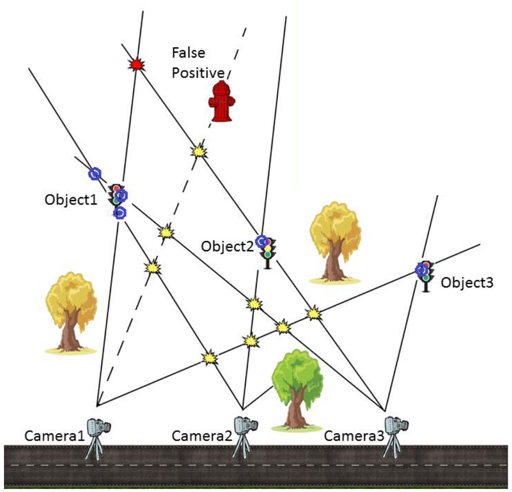
Processing pipeline: geotagging



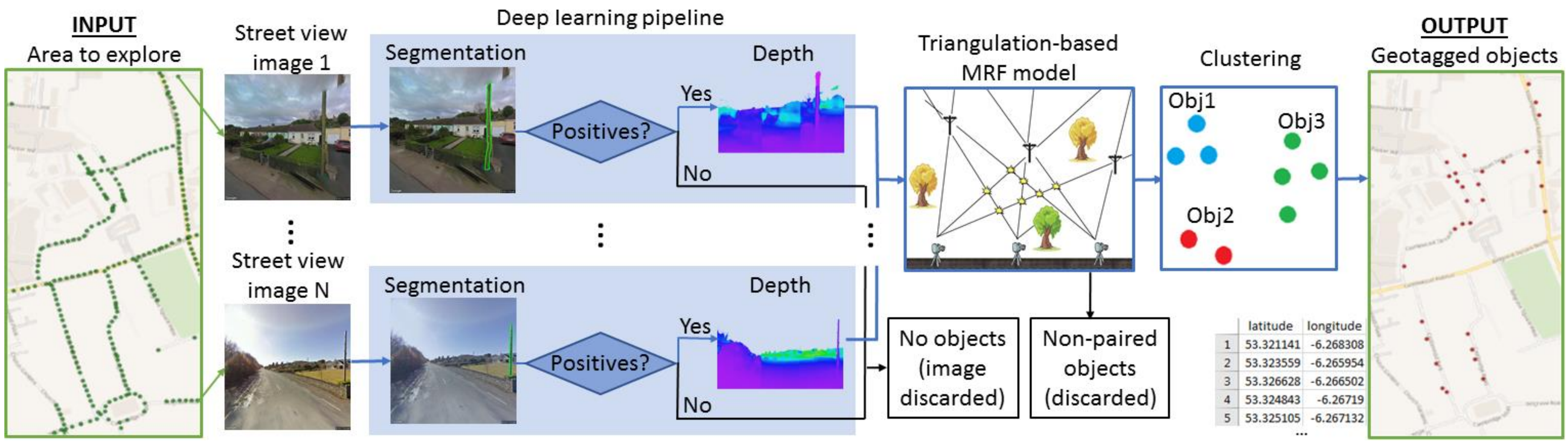
	latitude	longitude
1	53.321141	-6.268308
2	53.323559	-6.265954
3	53.326628	-6.266502
4	53.324843	-6.26719
5	53.325105	-6.267132

...

- The geotagging is performed as follows:
  - ✓ Calculate the space of all intersections;
  - ✓ Optimize the MRF model;
  - ✓ Discard non-paired instances;
  - ✓ Cluster the results. Take intra-cluster averages:
    - *Sparsity assumption*.



Processing pipeline: OVERVIEW



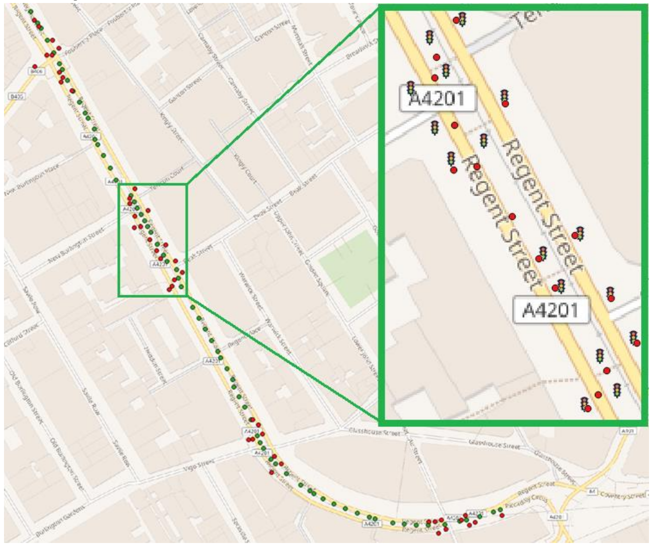
Object detection pipeline:

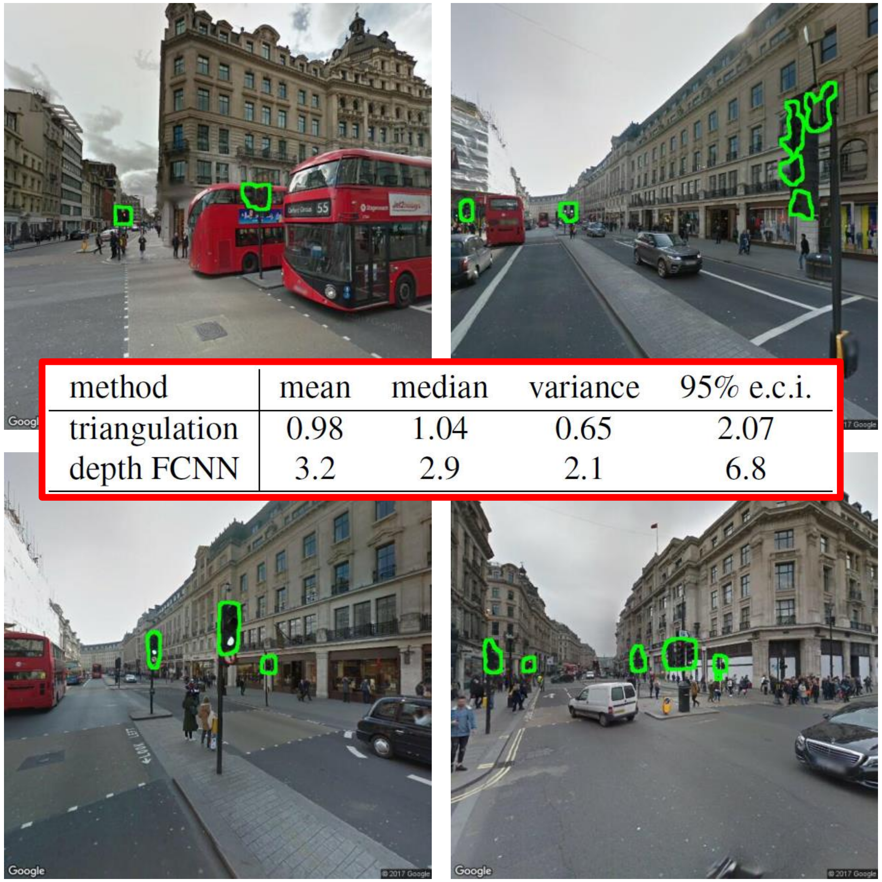
- DL: pixel-level **segmentation** to identify objects;
- DL: monocular **depth** (camera-to-object distance) estimation:
  - *max distance from camera: 25m;*
- **GPS-tagging** based on triangulation and Markov Random field model:
  - *mild object sparsity assumption - 1m apart;*
- Clustering.

Results: traffic lights

- Geotagging of **traffic lights** in Regent str., London, UK:
  - 87 GSV panoramas, 47 out of 50 objects discovered (94% recall)

Map view:





method	mean	median	variance	95% e.c.i.
triangulation	0.98	1.04	0.65	2.07
depth FCNN	3.2	2.9	2.1	6.8

Quantitative performance:

Object	#Actual	#Detected	TP	FP	FN	Recall	Precision
	50	51	47	4	3	94.0%	92.2%

Results: DEMO

- Geotagging of **telegraph poles** over a 2km road, co. Kildare:
  - 170 GSV panoramas, 37 out of 38 objects discovered (97.4% recall)

- We gratefully acknowledge financial support and expertise of ***eir*** in producing these results

Conclusions

We have developed an image processing pipeline that:

- Is fully **automatic**;
- The geotagging accuracy **comparable** with commercial-range GPS-unit;
- Detects and geotags objects at approx. 1.1 GSV panorama per second rate (***~3.000 km*** in 24h on a desktop PC with 2 GPUs);
- Can accommodate custom detection and depth estimation modules.

ADAPT

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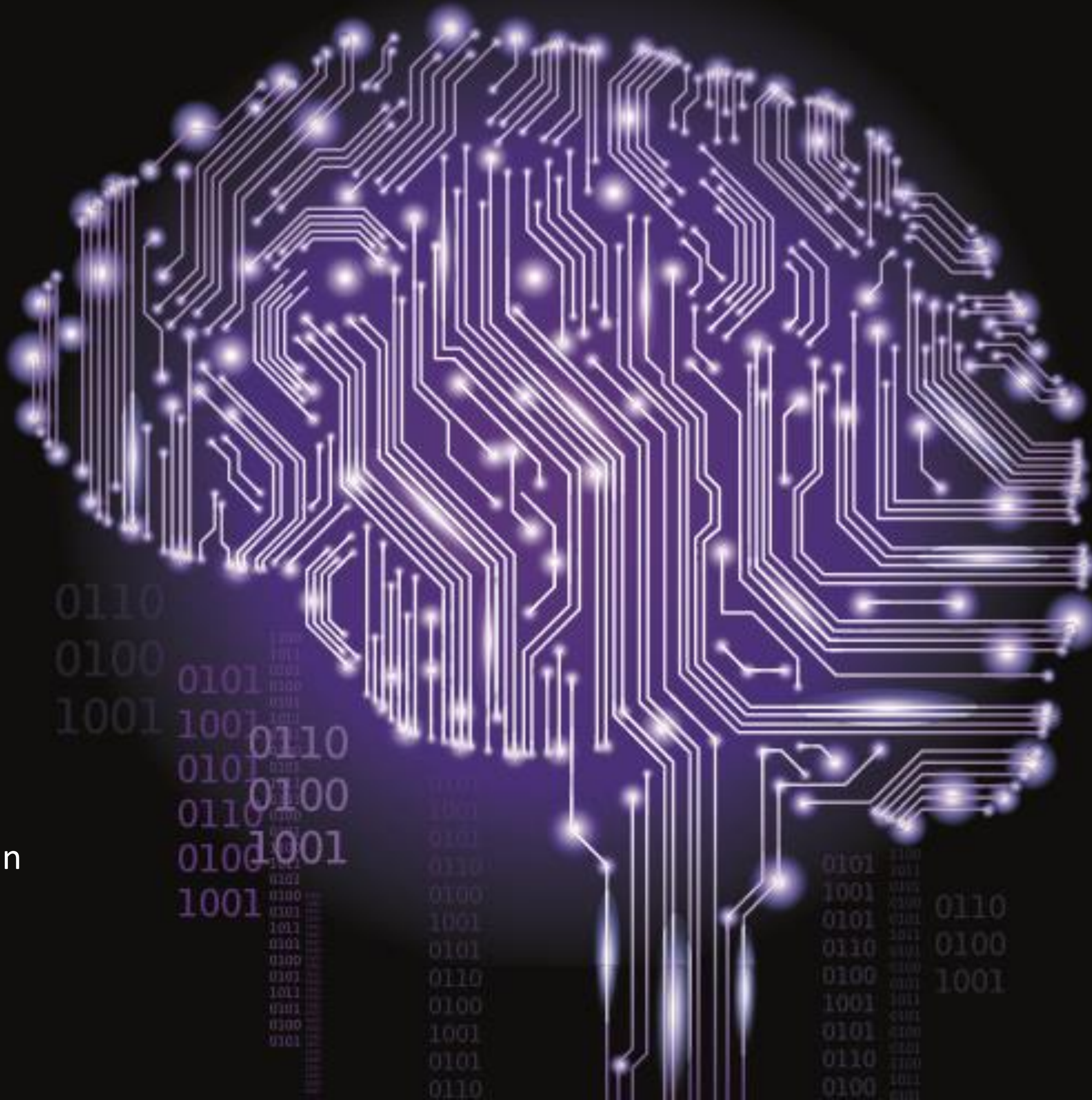
Thank you!



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