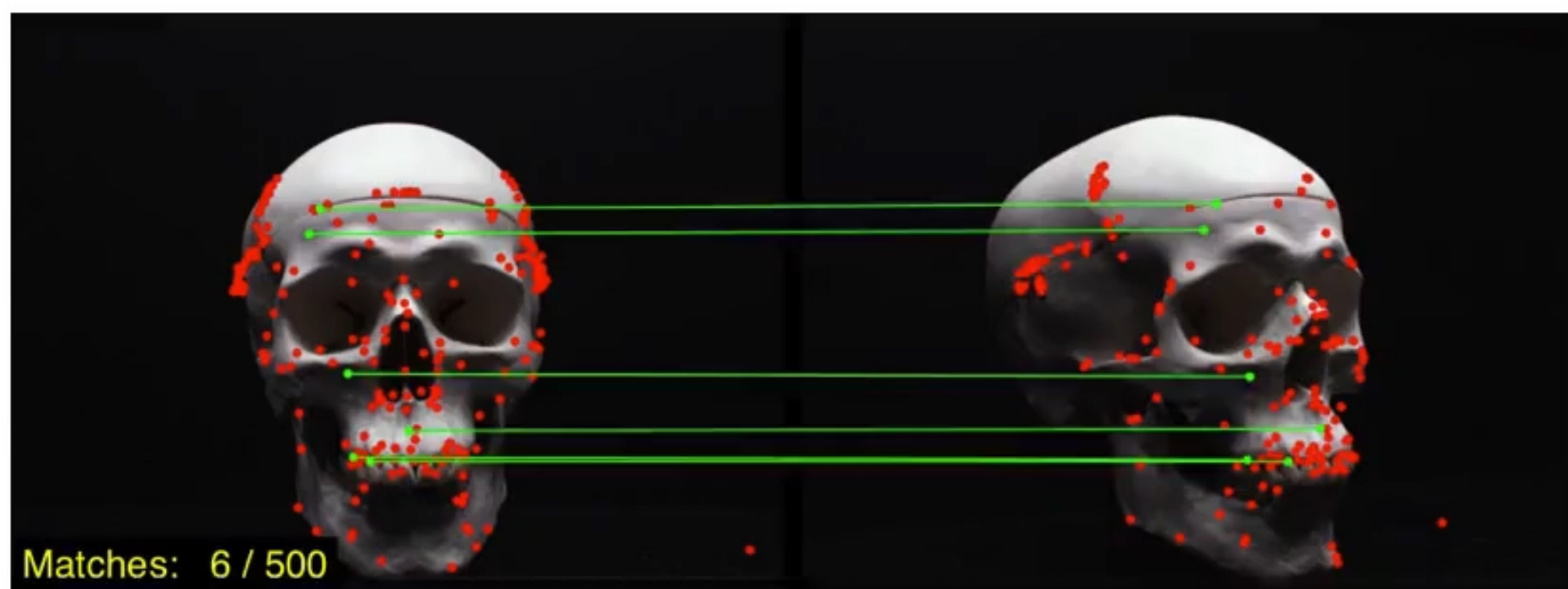


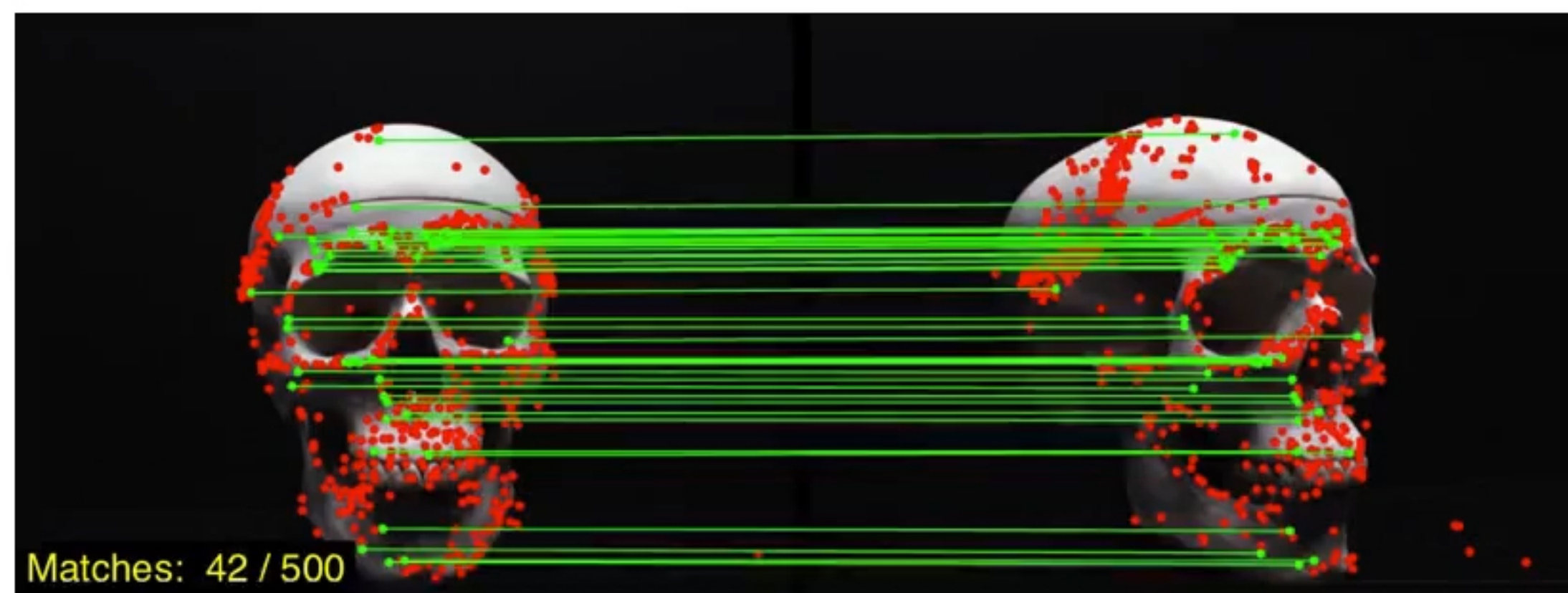


LIFT: Learned Invariant Feature Transform

Kwang Moo Yi, Eduard Trulls, Vincent Lepetit, Pascal Fua
Poster: S-4A-08



SIFT



LIFT

Feature point pipeline

KEYPOINT DETECTION



- Harris, C., Stephens, M., "A Combined Corner and Edge Detector", AVC 1988.
- Mikolajczyk, K., Schmid, C., "Scale and Affine Invariant Interest Point Detectors", IJCV 2004.
- Förstner, W., Dickscheid, T., Schindler, F., "Detecting Interpretable and Accurate Scale-Invariant Keypoints", ICCV 2009.
- Rosten, E., Porter, R., Drummond, T., "Faster and Better: A Machine Learning Approach to Corner Detection", TPAMI, 2010.
- Zitnick, C., Ramnath, K., "Edge Foci Interest Points", ICCV 2011.
- Mainali, P., Lafruit, G., Tack, K., Van Gool, L., Lauwereins, R., "Derivative-Based Scale Invariant Image Feature Detector with Error Resilience", TPAMI 2014.
- (...)

ORIENTATION ESTIMATION



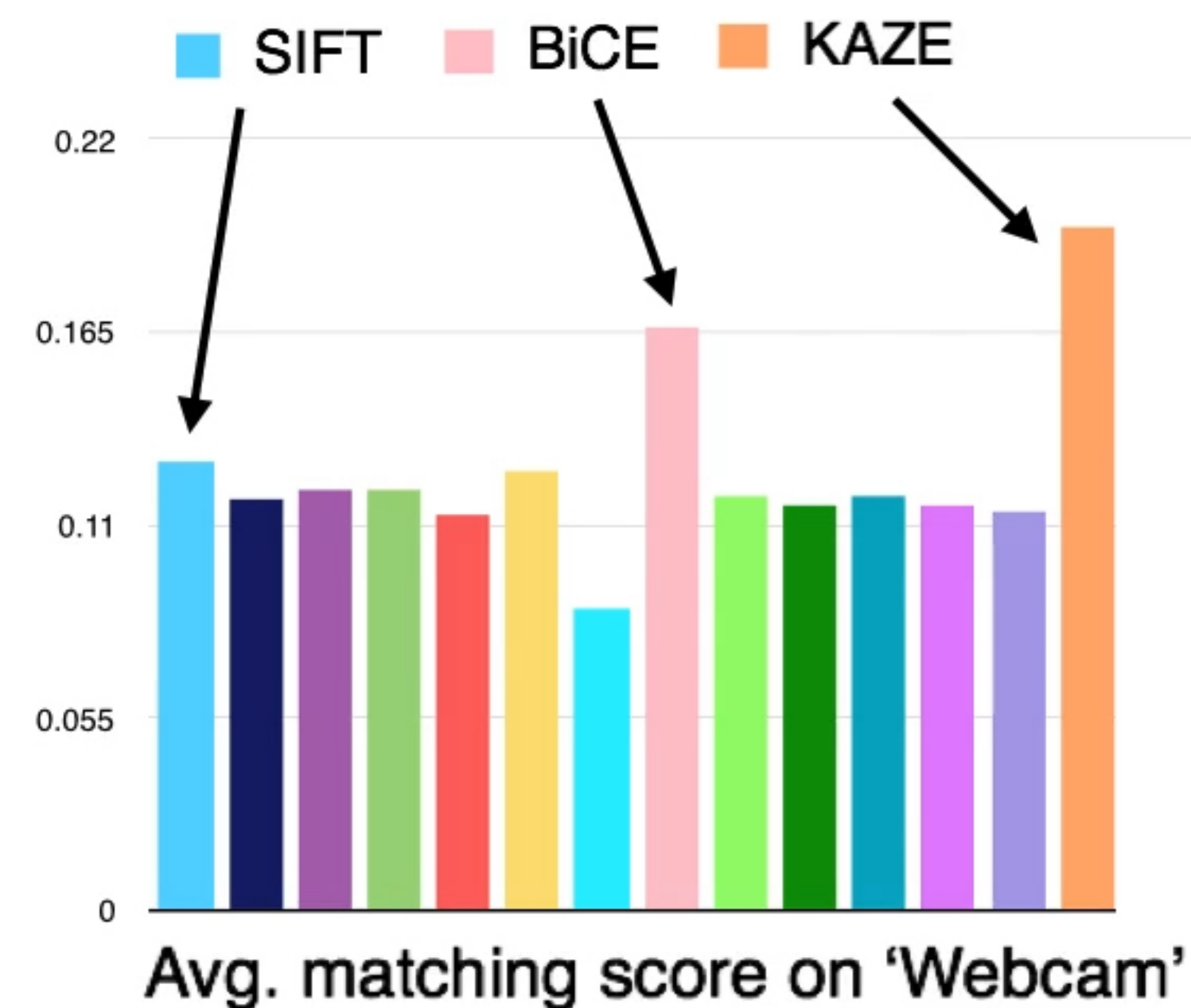
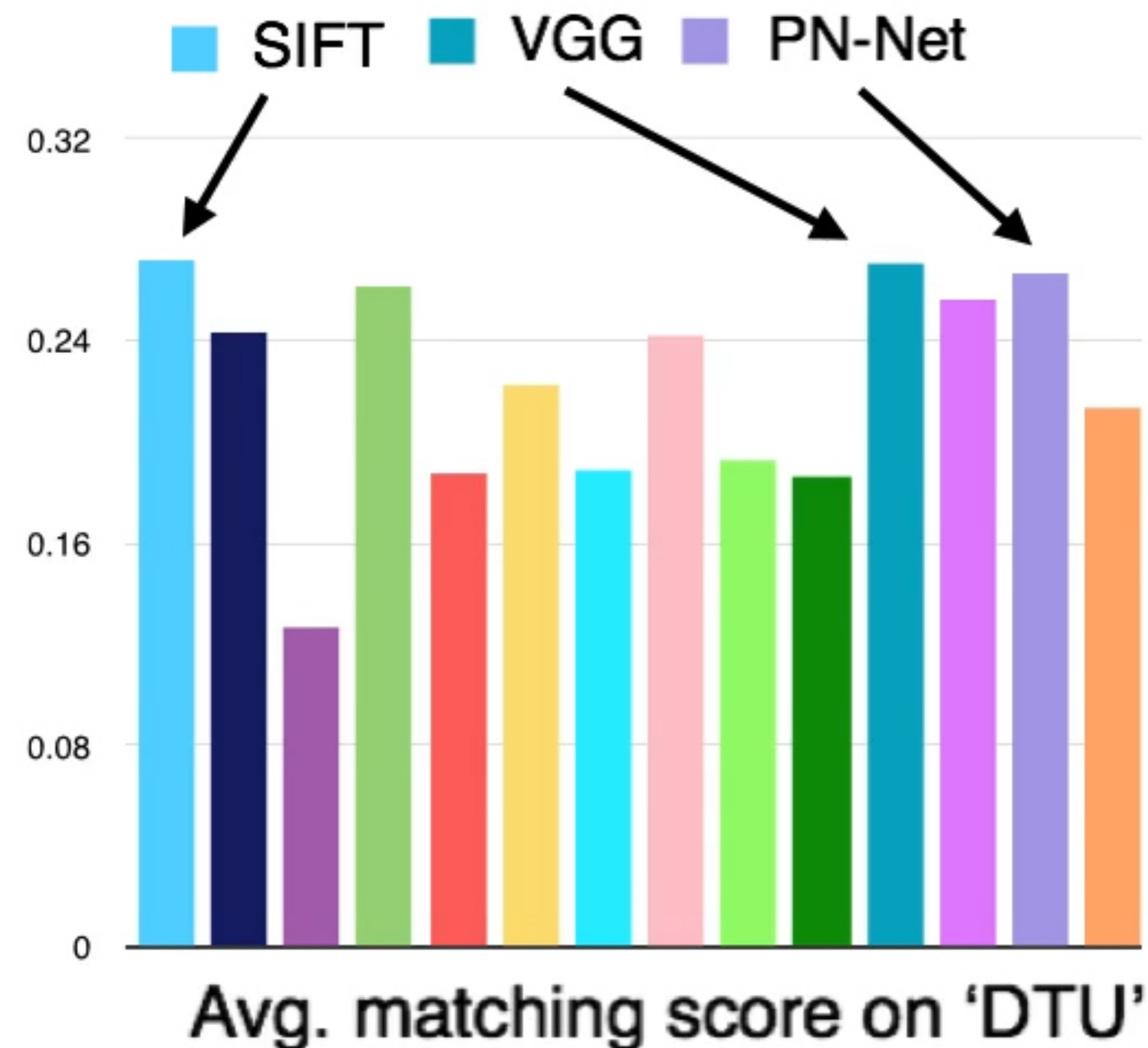
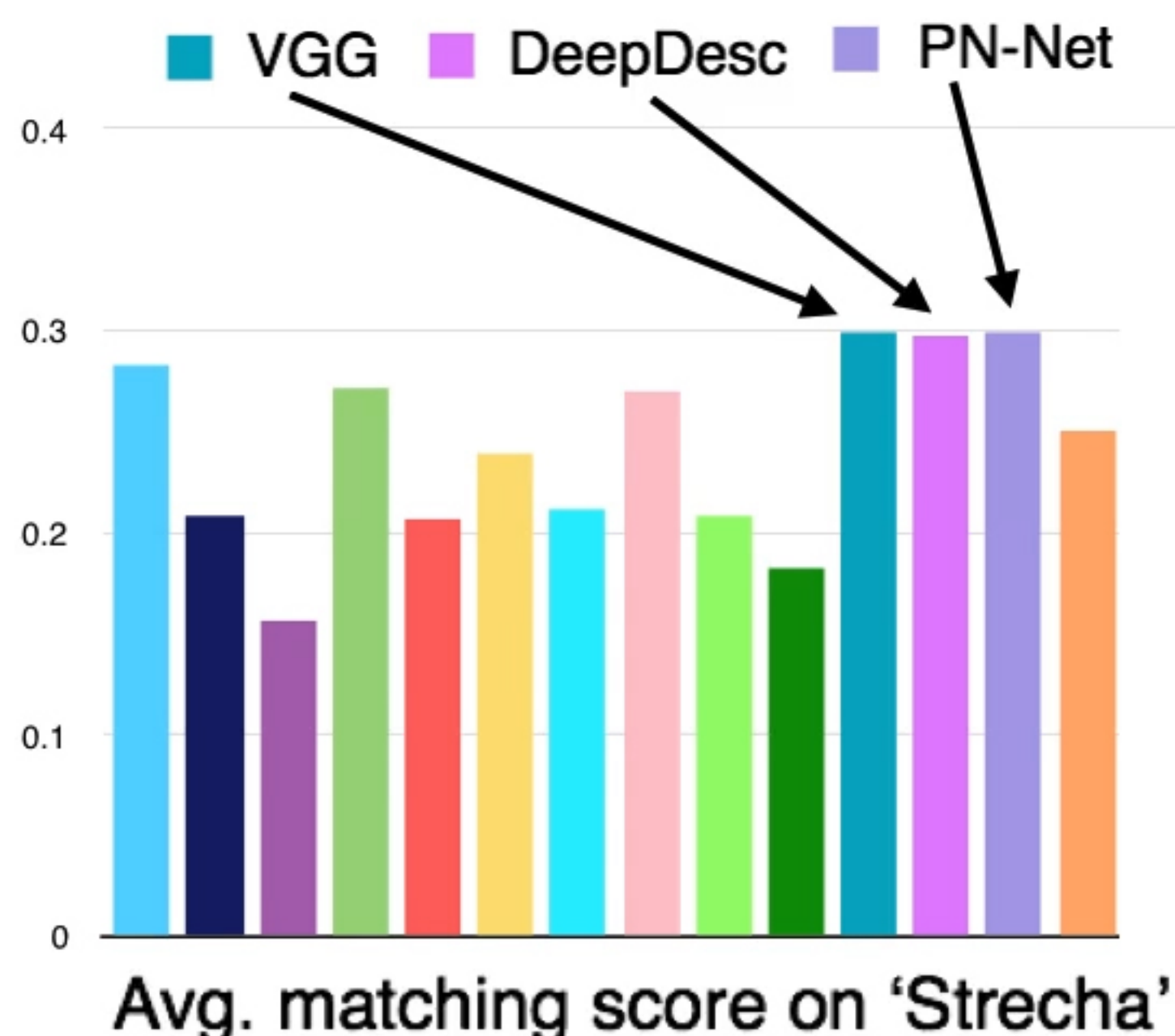
- Gauglitz, S., Turk, M., Höllerer, T., "Improving Keypoint Orientation Assignment", BMVC, 2011
- Heuristics:**
- Dominant Gradient Orientations (SIFT, SURF, ...)
 - Center of Mass (ORB, ...)
 - (...)

FEATURE DESCRIPTION

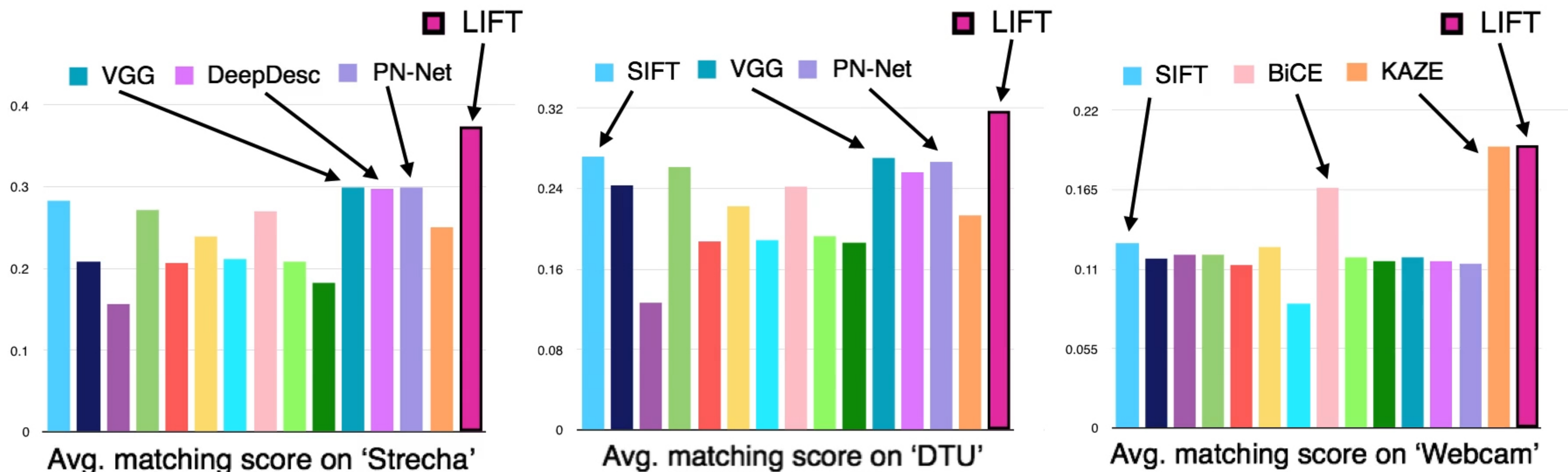


- Winder, S., Brown, M., "Learning Local Image Descriptors", CVPR 2007.
- Tola, E., Lepetit, V., Fua, P., "A Fast Local Descriptor for Dense Matching", CVPR 2008.
- Fan, B., Wu, F., Hu., Z., "Aggregating Gradient Distributions into Intensity Orders: A Novel Local Image Descriptor", CVPR 2011.
- Alahi, A., Ortiz, R., Vandergheynst, P., "FREAK: Fast Retina Keypoint", CVPR 2012.
- Simonyan, K., Vedaldi, A., Zisserman, A., "Learning Local Feature Descriptors Using Convex Optimisation", TPAMI 2014.
- (...)

Enhanced performance with Deep Learning



Enhanced performance with Deep Learning



Learned Local Features

KEYPOINT DETECTION



Y. Verdie, K.M. Yi, P. Fua, V. Lepetit:
"TILDE: A Temporally Invariant
Learned DEtector", CVPR 2015.

ORIENTATION ESTIMATION



K.M. Yi, Y. Verdie, V. Lepetit, P. Fua :
"Learning to Assign Orientations to
Feature Points", CVPR 2016.

FEATURE DESCRIPTION



**E. Simo-Serra, E. Trulls, L. Ferraz,
I. Kokkinos, P. Fua, F. Moreno-
Noguer:** "Discriminative Learning
of Deep Convolutional Feature
Point Descriptors", ICCV 2015.

Learned Local Features

KEYPOINT DETECTION

ORIENTATION ESTIMATION

FEATURE DESCRIPTION

LIFT Network

- **Drop-in** replacement for SIFT
- **Practical** runtime (1.5x ~ 3x SIFT)

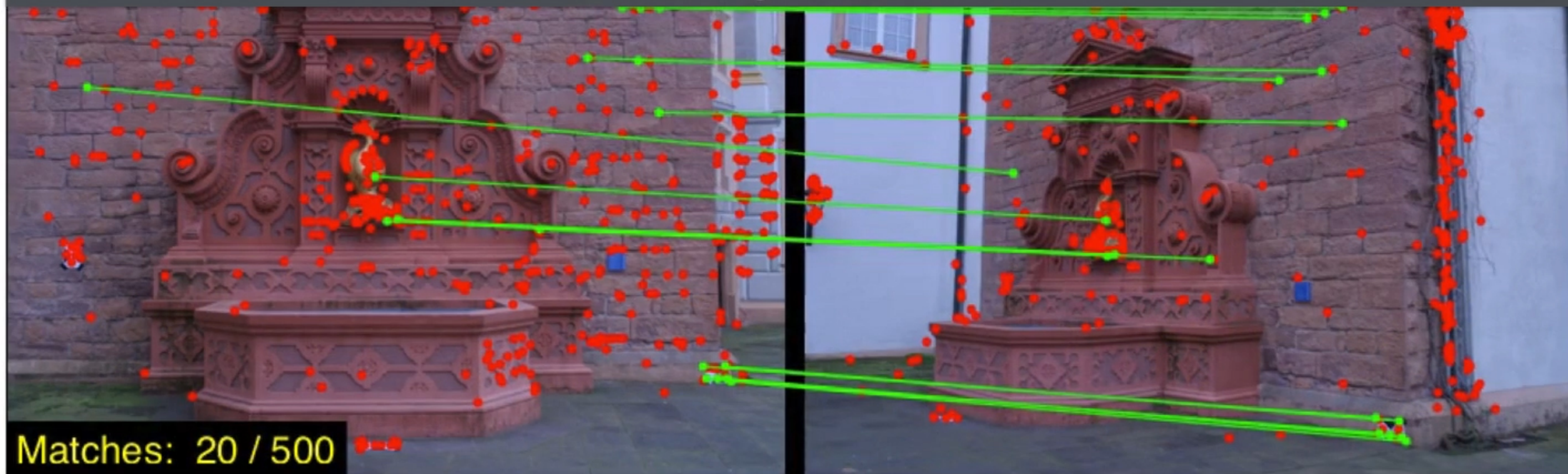
Y. Verdier, K.M. Yi, P. Fua, V. Lepetit:
"TILDE: A Temporally Invariant
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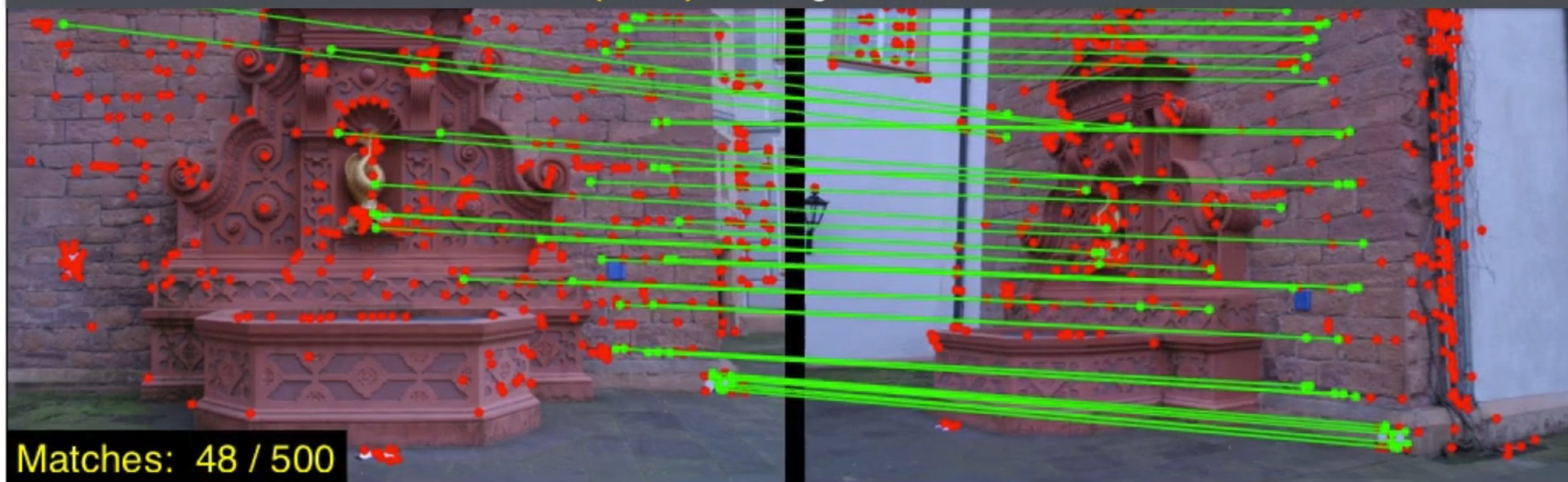
Matching features on '**Strecha**', sequence '**Fountain**'.
Correct matches shown with **green** lines.

SIFT. Average: **60.2** matches



Matches: 20 / 500

LIFT (Ours). Average: **98.6** matches

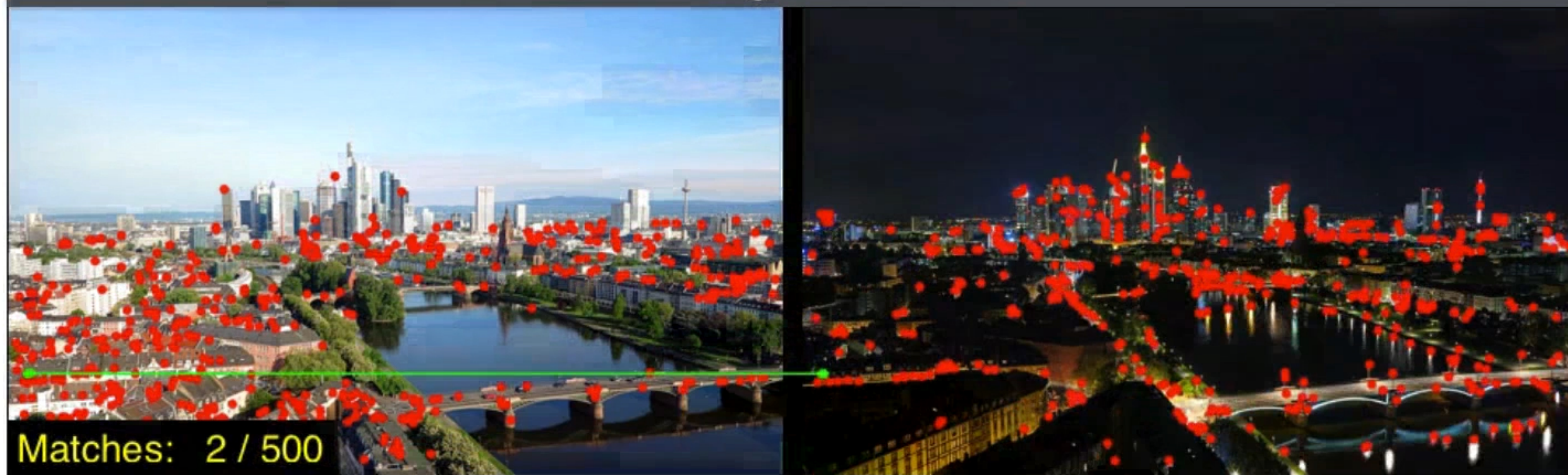


Matches: 48 / 500

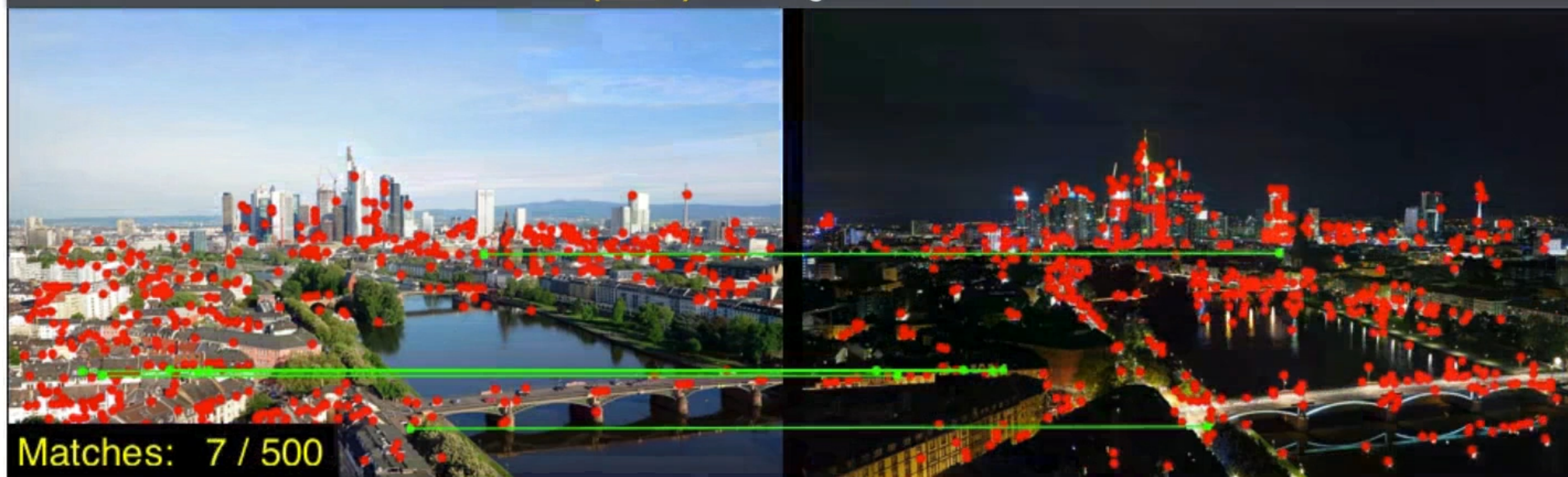
+64%

Matching features on **Webcam** sequence 'Frankfurt'.
Correct matches depicted by **green** lines.

SIFT. Average: **23.1** matches



LIFT (Ours). Average: **60.6** matches



+162%

The LIFT Network

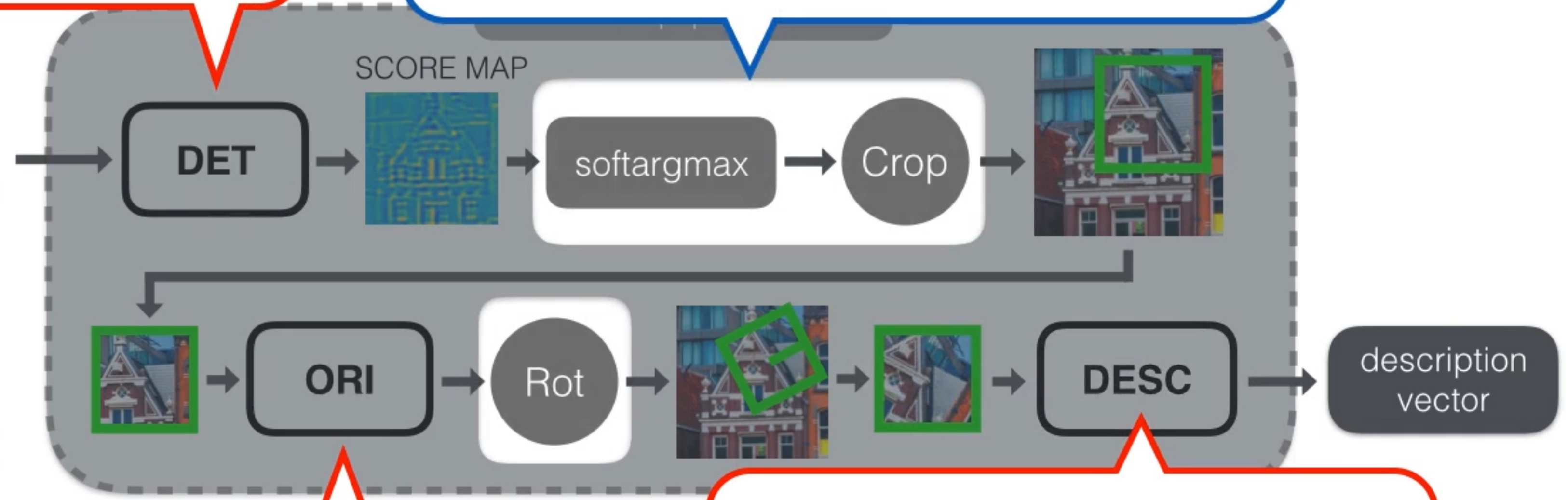
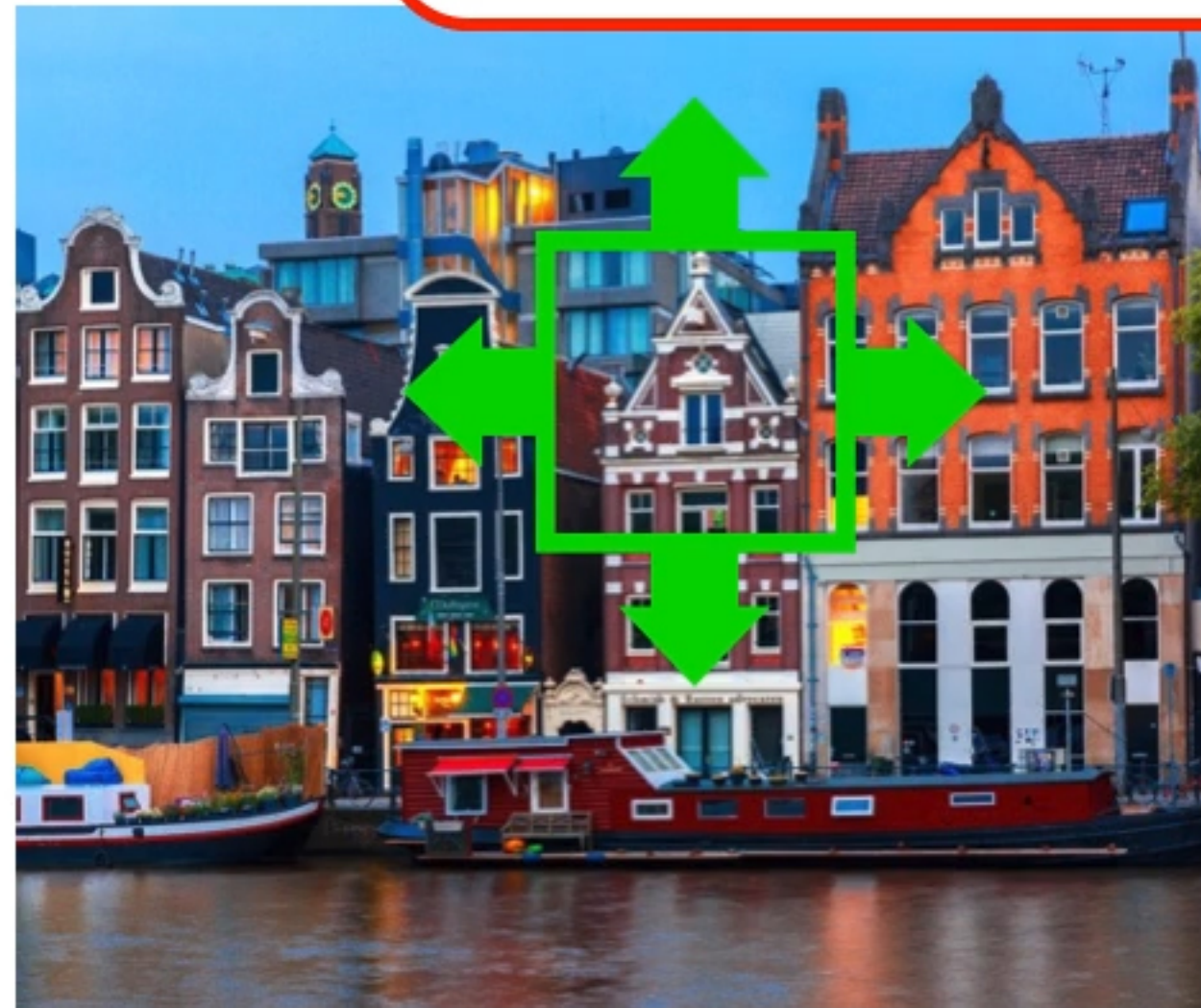
**Patch based pipeline for scalable learning
(at training time only)**



The LIFT Network

Y. Verdie, K.M. Yi, P. Fua, V. Lepetit:
"TILDE: A Temporally Invariant
Learned DETector", CVPR 2015.

"Glue", to preserve differentiability:
• Spatial Transformer Networks, NIPS 2015.
• Soft argmax, Information Retrieval 2009.



K.M. Yi, Y. Verdie, V. Lepetit, P. Fua :
"Learning to Assign Orientations to
Feature Points", CVPR 2016.

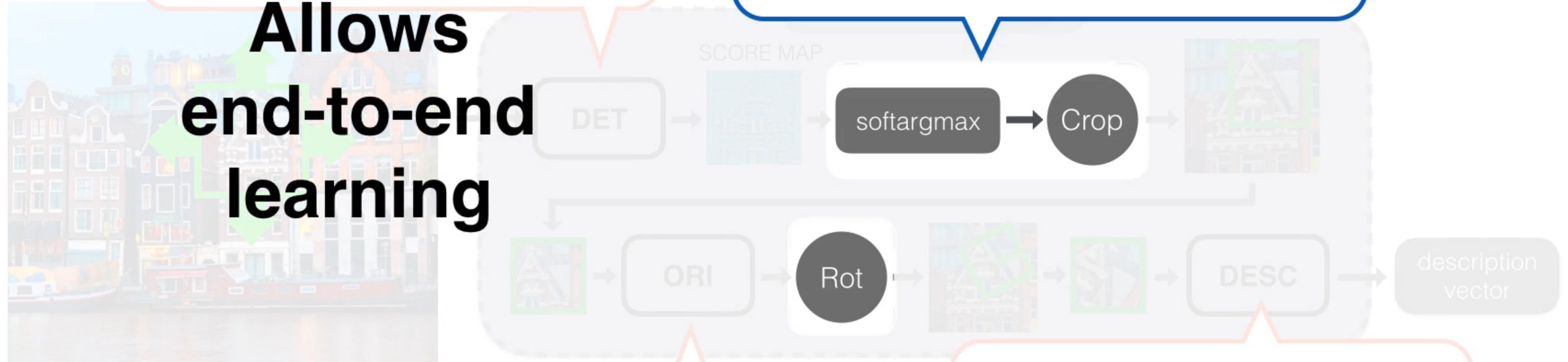
E. Simo-Serra, E. Trulls, L. Ferraz,
I. Kokkinos, P. Fua, F. Moreno-
Noguer: "Discriminative Learning
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The LIFT Network

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"Glue", to **preserve differentiability**:
• **Spatial Transformer Networks, NIPS 2015.**
• **Soft argmax, Information Retrieval 2009.**

**Allows
end-to-end
learning**

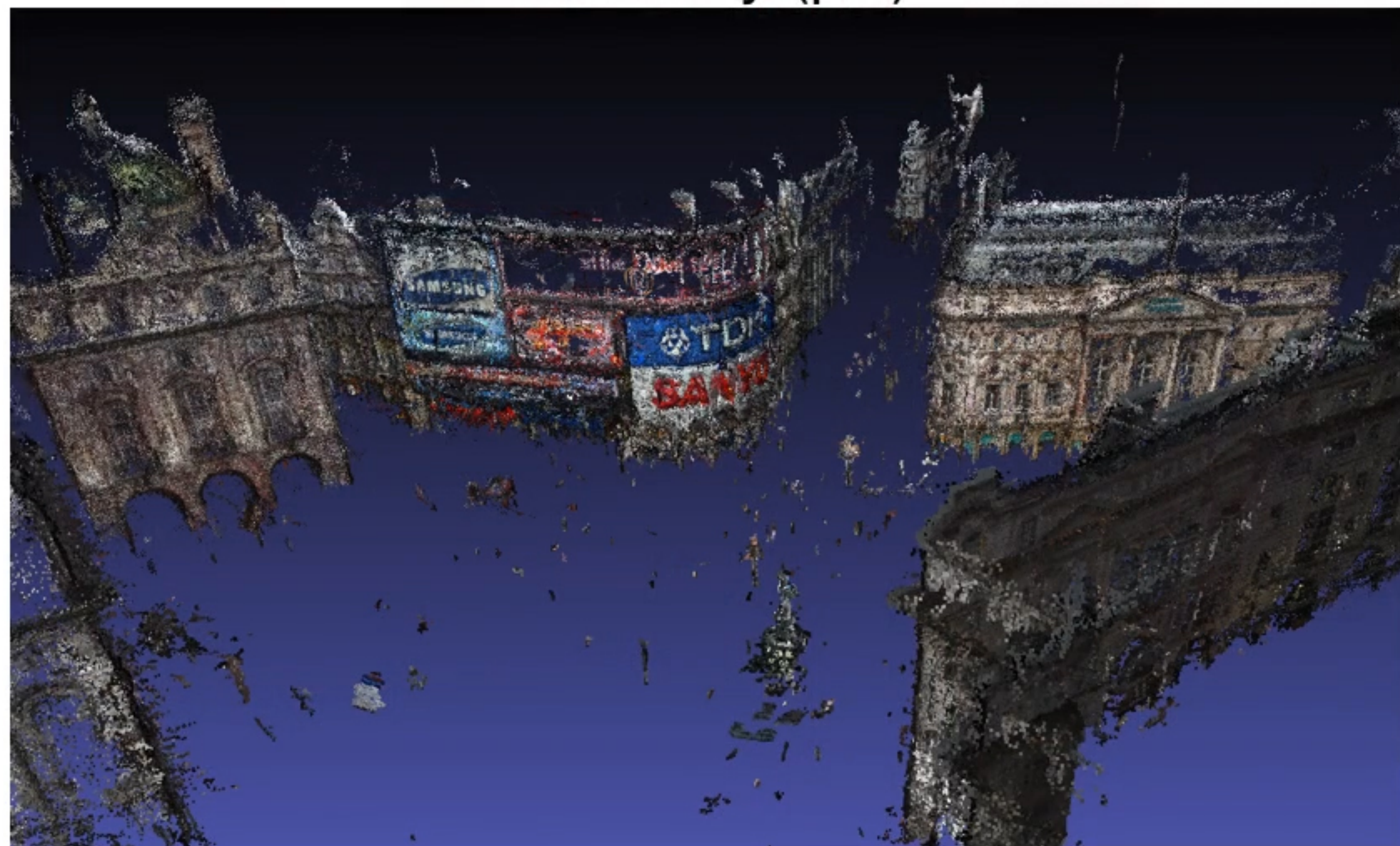


K.M. Yi, Y. Verdie, V. Lepetit, P. Fua :
"Learning to Assign Orientations to
Feature Points", CVPR 2016.

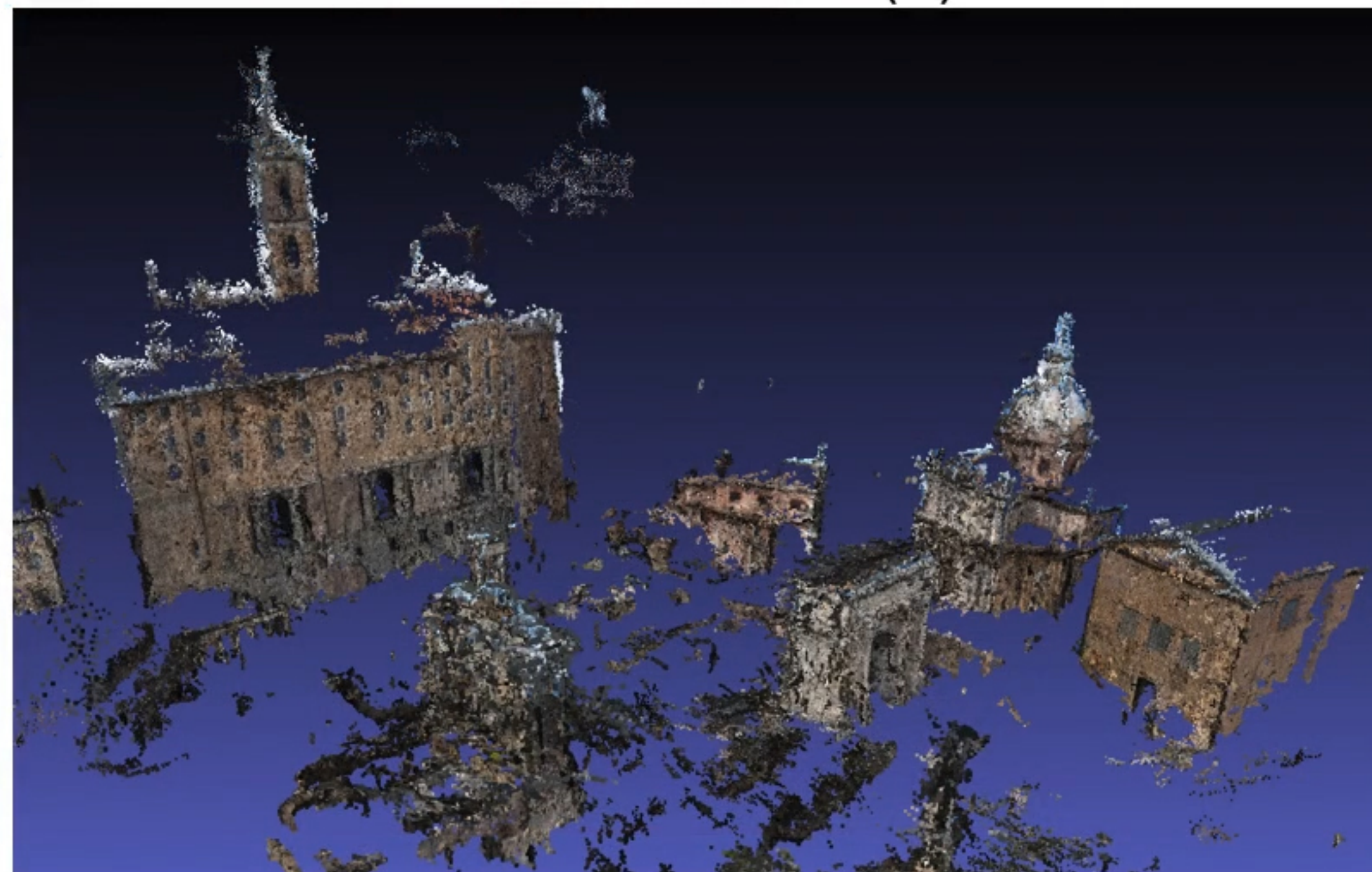
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I. Kokkinos, P. Fua, F. Moreno-
Noguer: "Discriminative Learning
of Deep Convolutional Feature
Point Descriptors", ICCV 2015.

Training with patches from SfM

Piccadilly (pic)

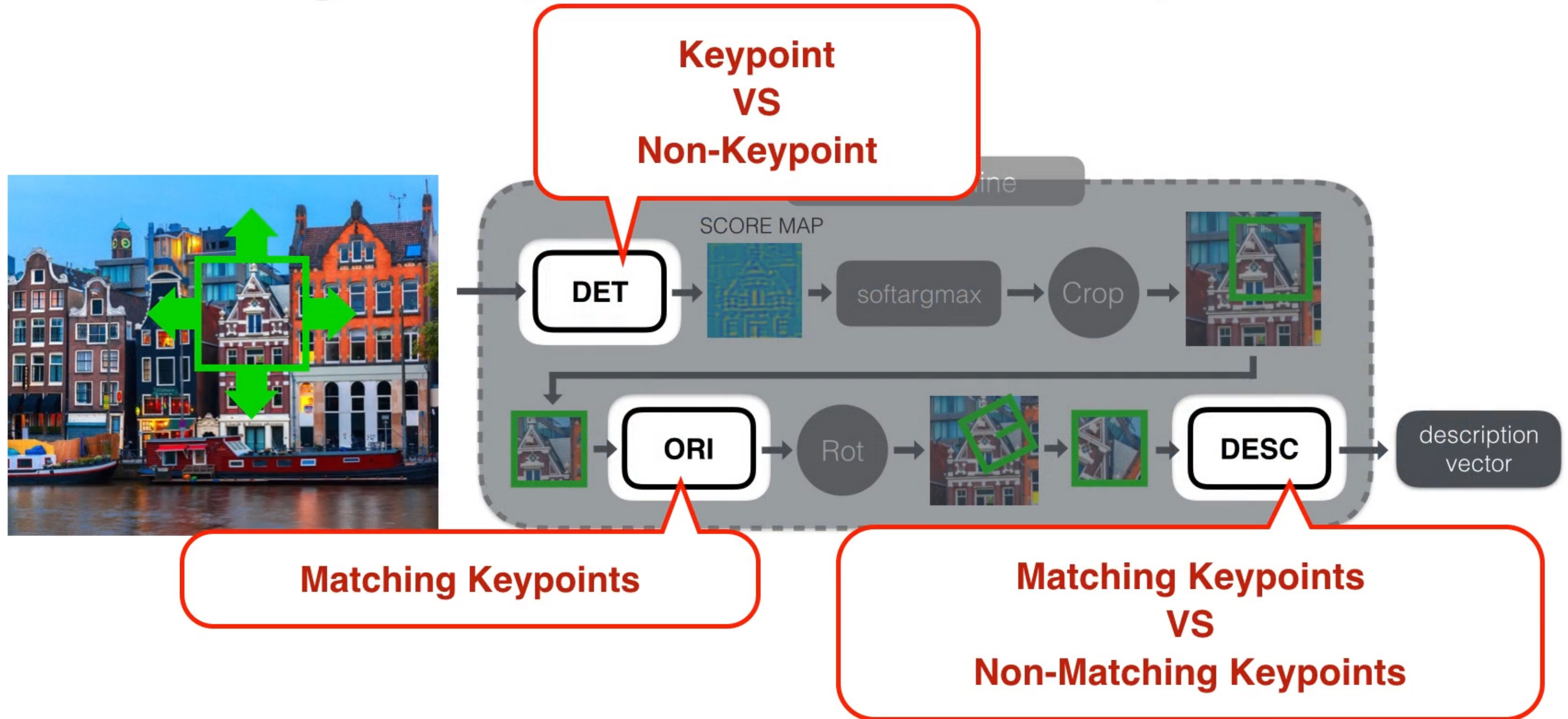


Roman Forum (rf)

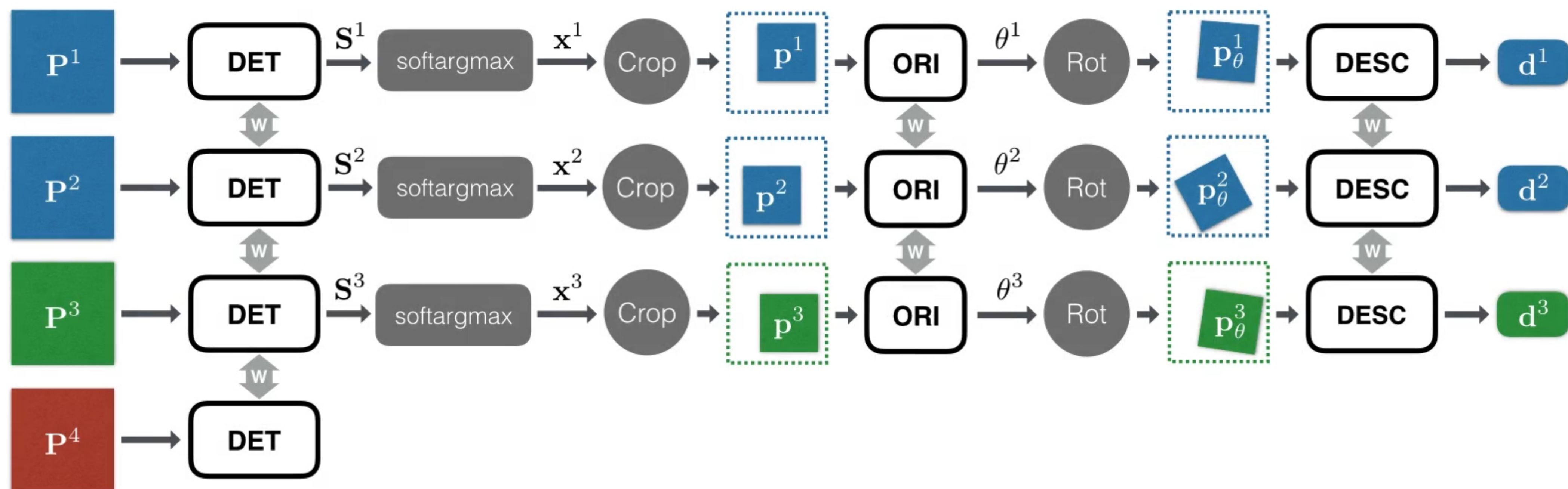


- We generate training pairs with **Structure from Motion (SfM)**.
- We use **two photo-tourism sets**, for robustness to imaging changes

Training requires various patches



Quadruplet Siamese Network



A single, global cost function

$$\min_{\{f_\mu, g_\phi, h_\rho\}} \sum_{\{(\mathbf{P}_1, \mathbf{P}_2, \mathbf{P}_3, \mathbf{P}_4)\}} \gamma \mathcal{L}_{class}(\mathbf{P}^1, \mathbf{P}^2, \mathbf{P}^3, \mathbf{P}^4) + \mathcal{L}_{pair}(\mathbf{P}^1, \mathbf{P}^2)$$

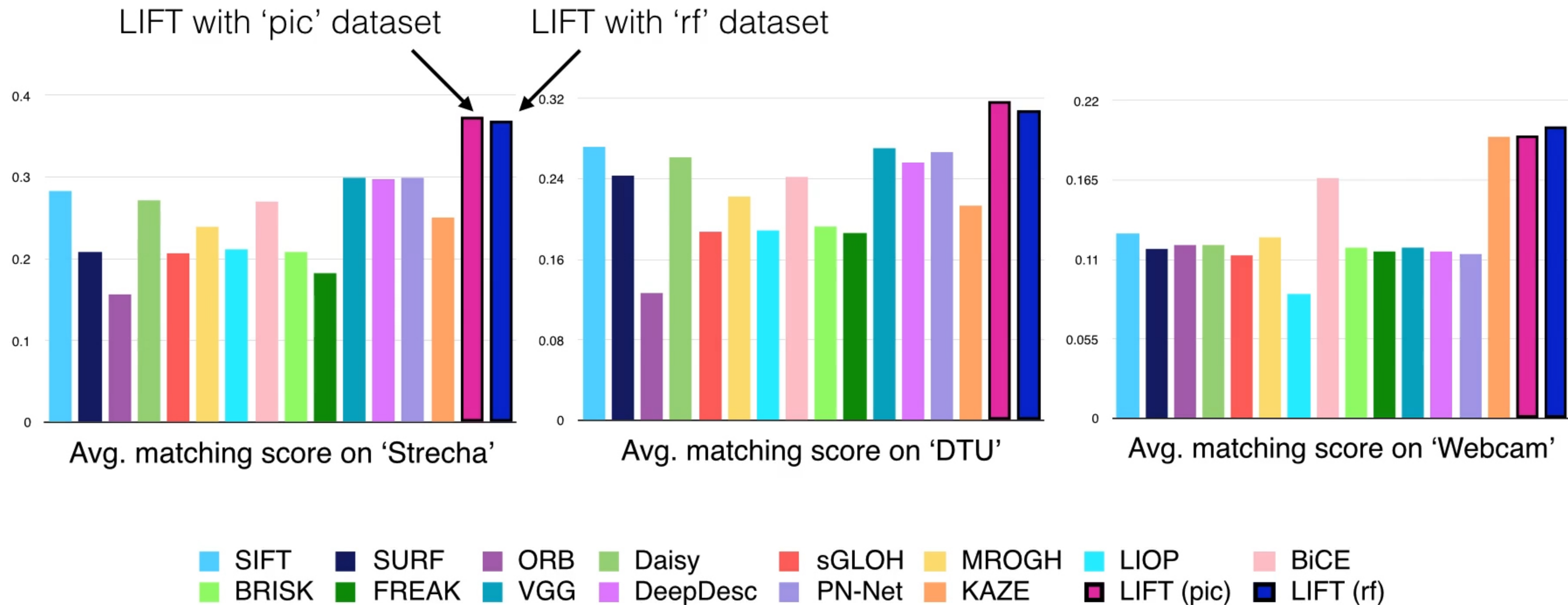
detector
orientation
descriptor

$$\mathcal{L}_{class}(\mathbf{P}^1, \mathbf{P}^2, \mathbf{P}^3, \mathbf{P}^4) = \sum_{i=1}^4 \alpha_i \max(0, (1 - \text{softmax}(f_\mu(\mathbf{P}^i)) y_i))^2$$

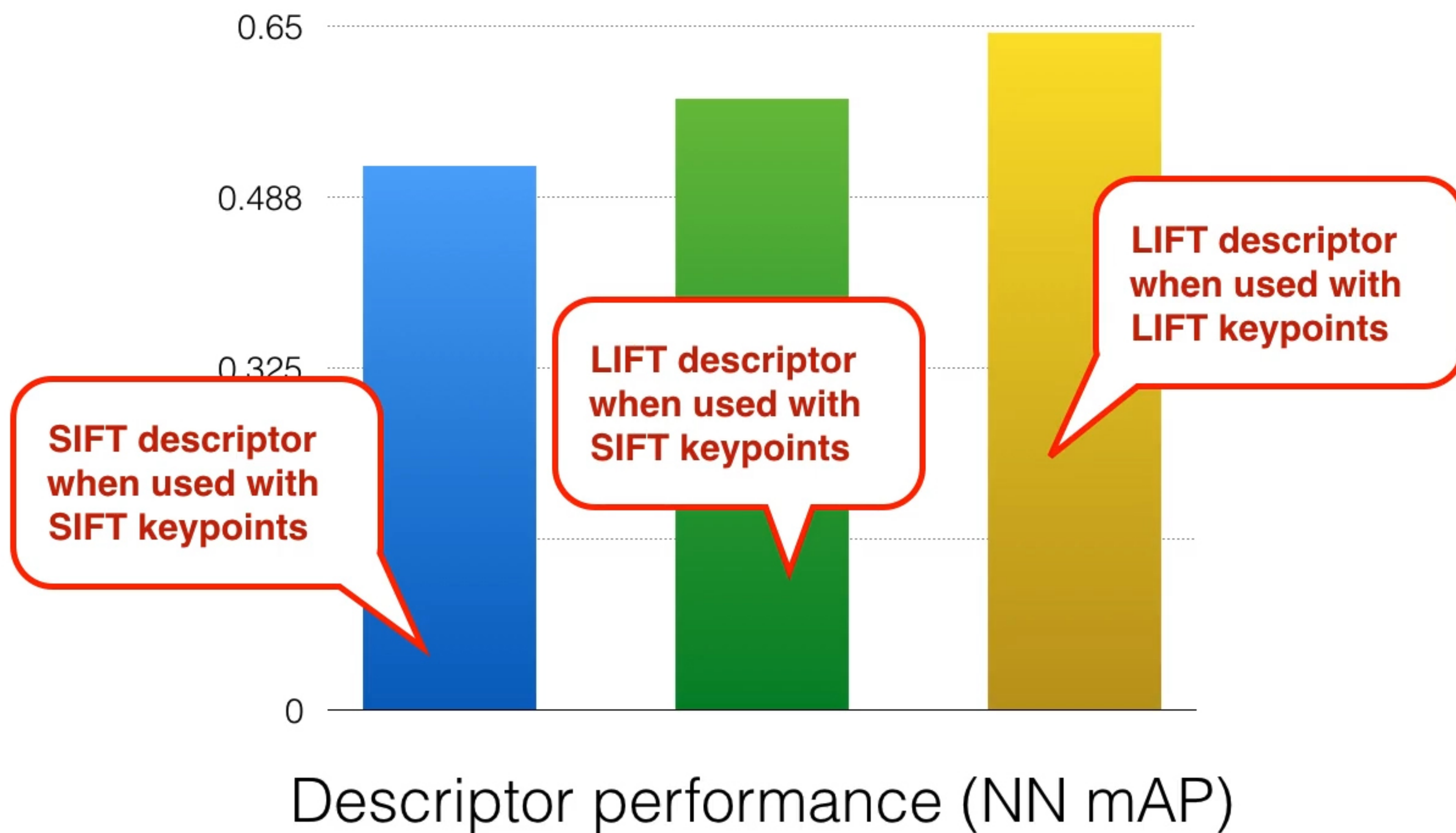
$$\mathcal{L}_{pair}(\mathbf{P}^1, \mathbf{P}^2) = \| h_\rho(G(\mathbf{P}^1, \text{softargmax}(f_\mu(\mathbf{P}^1)))) - h_\rho(G(\mathbf{P}^2, \text{softargmax}(f_\mu(\mathbf{P}^2)))) \|_2$$

$$G(\mathbf{P}, \mathbf{x}) = \text{Rot}(\mathbf{P}, \mathbf{x}, g_\phi(\text{Crop}(\mathbf{P}, \mathbf{x})))$$

Significant improvement over state-of-the-art



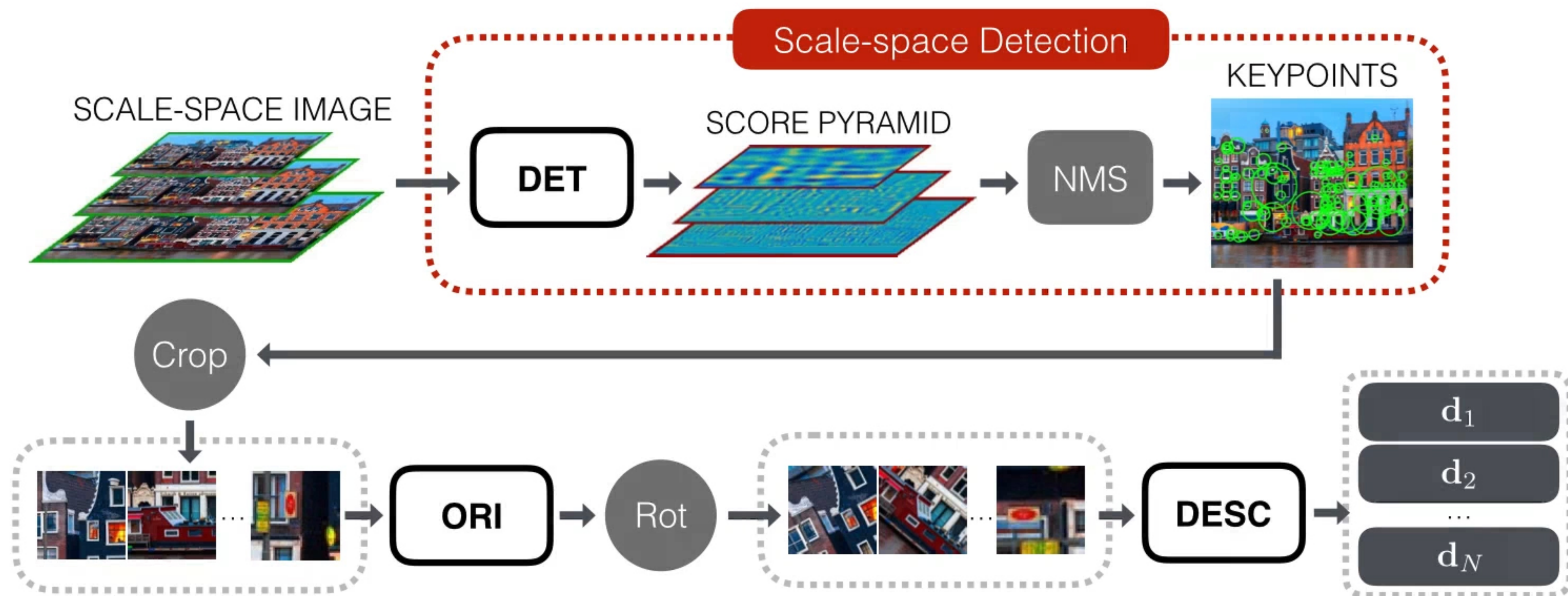
Each component is *meant for* each other



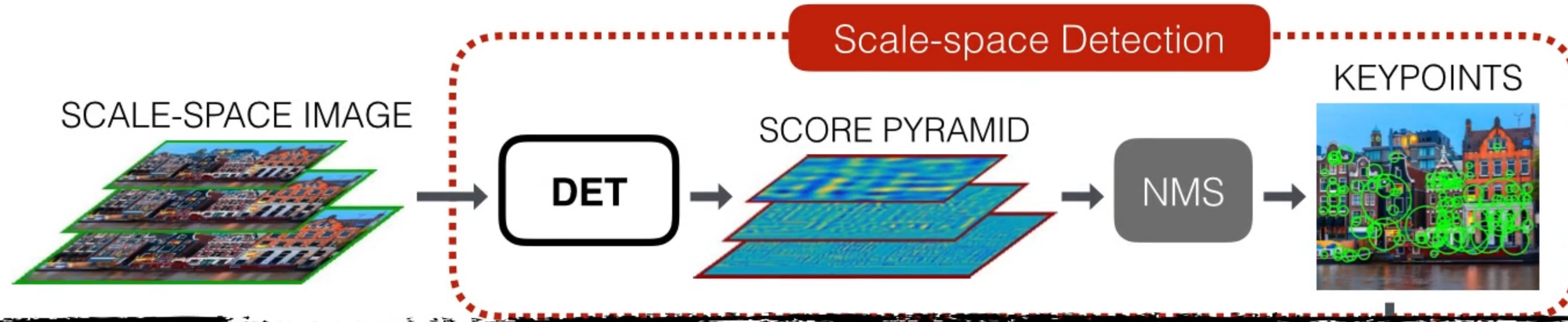
Each component is ***meant for*** each other



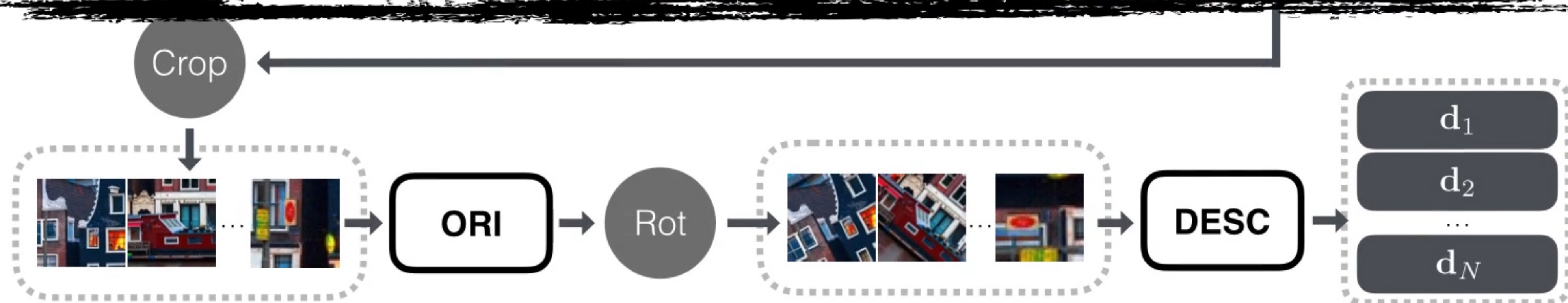
Practical runtime



Practical runtime



Can be decoupled for efficient evaluation



Summary

- **LIFT: Learned Invariant Feature Transform**
- Practical, **drop-in** replacement for SIFT
- **Efficient** and **outperforms** the state-of-the-art
- **Code** available at <https://github.com/cvlab-epfl/LIFT>
- Poster S-4A-08