Expert Sample Consensus Applied to Camera Re-Localization

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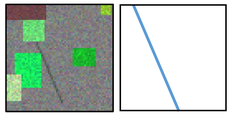
Code and trained models:

Problem Statement

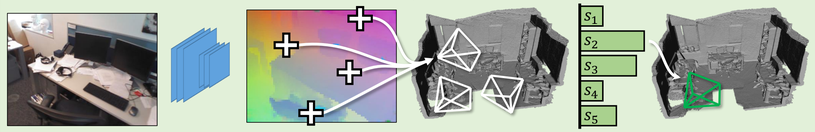
Estimate a parametric model from an observation. Observations are **complex** and **ambiguous**. There is no analytical solution to go from observation to model.



Observation Fitted Model

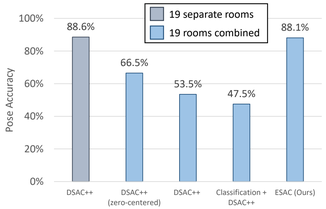
Our application: Estimate the **6D camera pose** (position + orientation) relative to a known scene **from a single RGB image**.

State-of-the-art: DSAC++ [Bra18] (our previous work)



observation scene coordinate regression hypothesis sampling scoring selection fitted model

Scalability issues in large and ambiguous environments:



Contributions

- Expert Sample Consensus (**ESAC**): a combination of **Differentiable RANSAC** (DSAC) and **Mixture of Experts** (MoE) [Jac91]
- ensemble of networks **trained jointly and end-to-end**
- **large-scale camera re-localization** in ambiguous environments

[Bra18] Learning Less is More - 6D Camera Localization via 3D Surface Regression, Brachmann and Rother, CVPR18
[Bra17] DSAC - Differentiable RANSAC for camera localization, Brachmann et al., CVPR17
[Jac91] Adaptive Mixtures of Local Experts, Jacobs et al., Neural Computation 1991
[Sho13] Scene coordinate regression forests for camera relocalization in RGB-D images, Shotton et al., CVPR13
[Val16] Learning to navigate the energy landscape, Valentin et al., 3DV16
[Sat18] Benchmarking 6dof outdoor visual localization in changing conditions, Sattler et al., CVPR18
[Sat16] Efficient & effective prioritized matching for large-scale image-based localization, Sattler et al., TPAMI16

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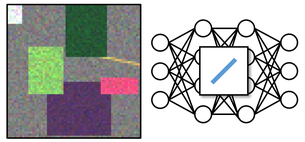
European Commission Horizon 2020 European Union funding for Research & Innovation

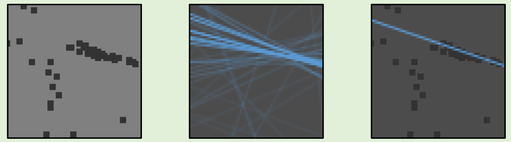
DSAC [Bra17] for a Toy Problem

Which line?



observation I network f_e

RANSAC / DSAC



prediction $\mathcal{Y}_e$ hypotheses $\mathbf{h}_j$ fitted Model $\hat{\mathbf{h}}$

RANSAC: $\hat{\mathbf{h}} = \mathbf{h}_j$ with $j = \underset{j}{\operatorname{argmax}}\, s(\mathbf{h}_j, \mathcal{Y}_e)$ with $\mathcal{Y}_e = f_e(I; \mathbf{w})$

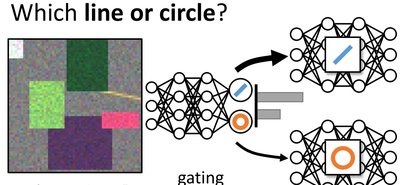
DSAC: $\hat{\mathbf{h}} = \mathbf{h}_j$ with $j \sim p(j) = \frac{\exp(s(\mathbf{h}_j, \mathcal{Y}_e))}{\sum_{j'} \exp(s(\mathbf{h}_{j'}, \mathcal{Y}_e))}$

soft inlier count: $s(\mathbf{h}, \mathcal{Y}) = \alpha \sum_{\mathbf{y} \in \mathcal{Y}} \text{sig}[\tau - \beta d(\mathbf{y}, \mathbf{h})]$

DSAC Training Objective: $\mathcal{L}(\mathbf{w}) = \mathbb{E}_{j \sim p(j)}\left[\ell(\mathbf{h}_j)\right]$

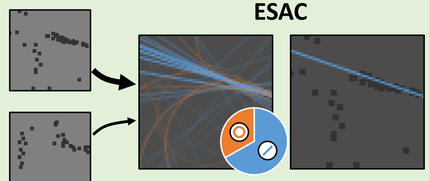
ESAC for a more Complex Toy Problem

Which **line or circle**?



observation I gating network g experts f_e

ESAC



predictions $\mathcal{Y}_e$ hypothesis pool $\mathcal{H}$ (line **and** circle hypothesis) fitted model $\hat{\mathbf{h}}$

The gating network **distributes model hypotheses** among experts: $p(\mathcal{H}) = \frac{N!}{\prod_e n_e!} \prod_e g(e, I; \mathbf{w})^{n_e}$

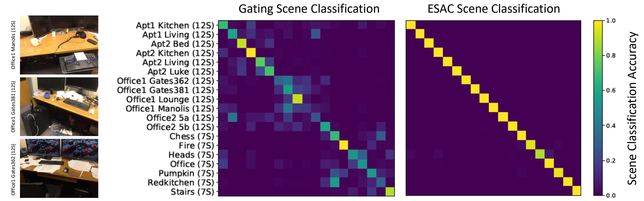
ESAC: $\hat{\mathbf{h}} = \mathbf{h}_{(e,j)}$ with $(e, j) \sim p(e, j|\mathcal{H}) = \frac{\exp(s(\mathbf{h}_{(e,j)}, \mathcal{Y}_e))}{\sum_{e'} \sum_{j'} \exp(s(\mathbf{h}_{(e',j')}, \mathcal{Y}_{e'}))}$

ESAC Training Objective: $\mathcal{L}(\mathbf{w}) = \mathbb{E}_{\mathcal{H} \sim p(\mathcal{H})} \mathbb{E}_{(e,j) \sim p(e,j|\mathcal{H})}\left[\ell(\mathbf{h}_{(e,j)})\right]$

ESAC for Indoor Camera Re-Localization

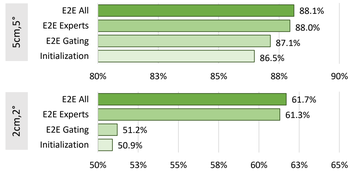
We combine the **7Scenes** [Sho13] and **12Scenes** [Val16] re-loc. datasets.

Both datasets contain multiple ambiguous offices, kitchens, etc.



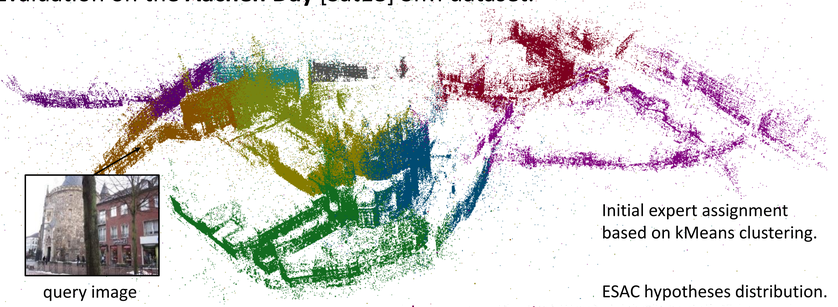
	Max. Experts	Avg. Experts	Accuracy	Avg. Time (ms)
DSAC++	-	-	53.3%	940
Expert Selection	1	1	47.5%	307
ESAC (Ours)	1	1	49.9%	276
	2	2	67.2%	343
	3	2.9	75.3%	398
	19	6.1	88.1%	555
Uniform Gating	19	19	87.8%	1,377
Oracle Gating	1	1	89.0%	120

Effect of end-to-end training.



ESAC for Outdoor Camera Re-Localization

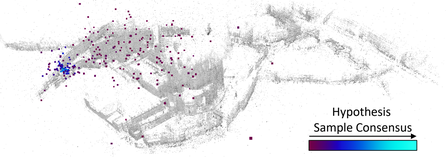
Evaluation on the **Aachen Day** [Sat18] SfM dataset.



query image

Initial expert assignment based on kMeans clustering.

ESAC hypotheses distribution.



Method	0.25m, 2° / 0.5m, 5° / 5m, 10°
DSAC++	0.4% / 2.4% / 34.0%
ESAC (10 Experts)	30.3% / 49.3% / 73.7%
ESAC (20 Experts)	39.7% / 55.9% / 77.8%
ESAC (50 Experts)	42.6% / 59.6% / 75.5%
Active Search [Sat16]	**57.3% / 83.7% / 96.6%**