Adaptive model estimation, a real time demonstration

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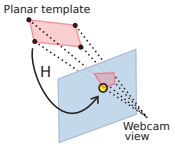
WHAT WE SHOW ? HOMOGRAPHY FITTING USING A THRESHOLD-FREE ROBUST ESTIMATOR

- A threshold-free model estimation method:
  - adapts to noise,
  - works in real time,
  - works with large outlier contamination.



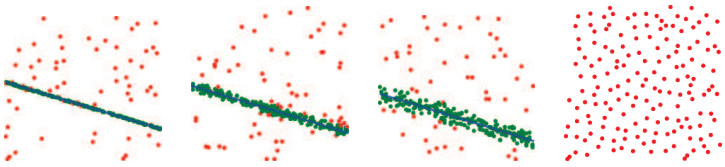
- Underlying mathematical tool: *a contrario* RANSAC (AC-RANSAC)
  - finds both a model and an associated confidence score.
- Used for:
  - F matrix [1], H matrix [2], Structure from Motion [3].

THE ROBUST ESTIMATION PROBLEM: THE THRESHOLD DILEMMA

RANSAC requires the choice of a threshold T, which must be balanced:

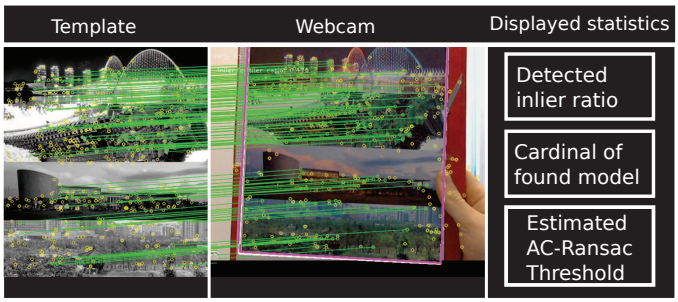
- Too small: too few inliers, leading to model imprecision,
- Too large: models are contaminated by outliers (false data).

Robust line estimation:



Goal: making T adaptive to data and noise.

Demonstration scenario: Homography estimation:



Validated inliers in green. Estimated homography is pictured by reprojecting template boundaries: RANSAC estimation in magenta, AC-RANSAC estimation in white.

From left to right: impact of RANSAC threshold (transfer error through homography):

$T = 0.5$ pixels: 6 points correspondences | $T = 2$ pixels: 19 points | $T = 6.8$ pixels: 50 points

$T = 6.8$ **was automatically computed with the *a contrario* technique, that statistically determines a confidence threshold.**

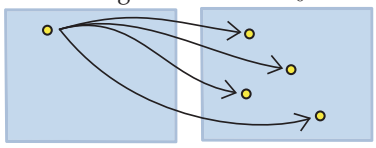
A CONTRARIO MODEL ESTIMATION : A THRESHOLD-FREE FRAMEWORK

***AC*-RANSAC. A threshold-free rigid model estimation framework.**

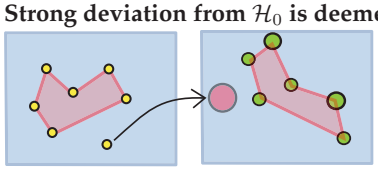
- The method answers the question:
  "Could the rigid set of data have occurred by chance?"
- The threshold T adapts for inlier/outlier discrimination.
- It provides a confidence score for each model.

A contrario criterion [1]:

- Use a background model $\mathcal{H}_0$: uniform distribution.



- **Strong deviation from $\mathcal{H}_0$ is deemed meaningful.**



$\mathbb{P}(\text{residual} \leq T|\mathcal{H}_0) = \frac{\pi T^2}{w \times h}$
(ratio of radius T disk and image areas)

***AC*-RANSAC relies on the following definitions:**

- Number of False Alarms (NFA) measures model fitness to data.
- Given model M, assuming k inliers among n correspondences, T_k denotes the k^{th} smallest residual.

$$NFA(M,k) = N_{\text{tests}}(n,k,N_{\text{sample}})\mathbb{P}(\text{residual} \leq T_k|M,\mathcal{H}_0)^{k-N_{\text{sample}}}$$

Expectation: $NFA(M) = \min_{k=N_{\text{sample}}+1\ldots n} NFA(M,k) \leq 1$.
RANSAC maximizes inlier count wrt sample at fixed T.
AC-RANSAC minimizes NFA wrt sample with varying T_k.

- ACCV12 paper [3], Poster PF-36:
  - AC-RANSAC for SfM. Released in the openMVG library.

REFERENCES

[1] L. Moisan and B. Stival. A Probabilistic Criterion to Detect Rigid Point Matches Between Two Images and Estimate the Fundamental Matrix. In *IJCV 2004*.
[2] L. Moisan, P. Moulon and P. Monasse. Automatic homographic registration of a pair of images, with a contrario elimination of outliers. In *IPOL 2012*, `http://dx.doi.org/10.5201/ipol.2012.mmm-oh` (with online demo and source code)
[3] P. Moulon, P. Monasse and R. Marlet. Adaptive Structure from Motion with *a contrario* model estimation. In *ACCV 2012*.