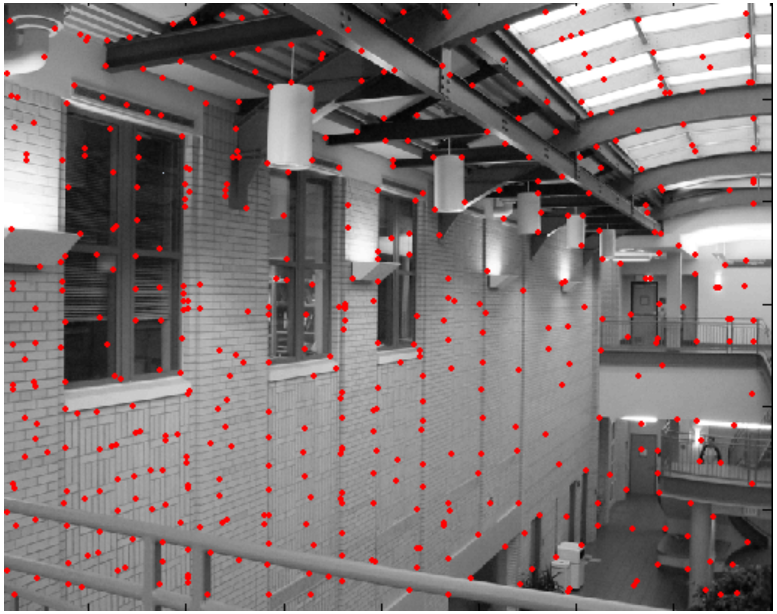
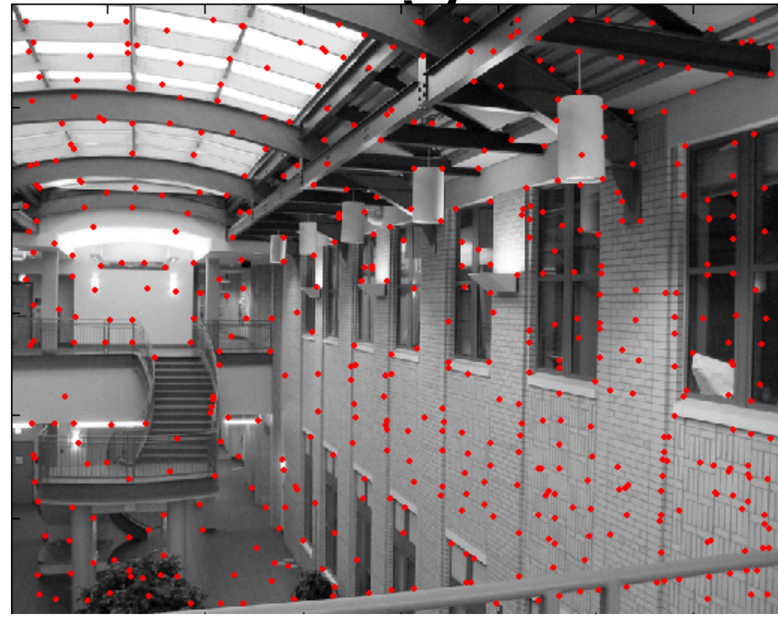
RANSAC

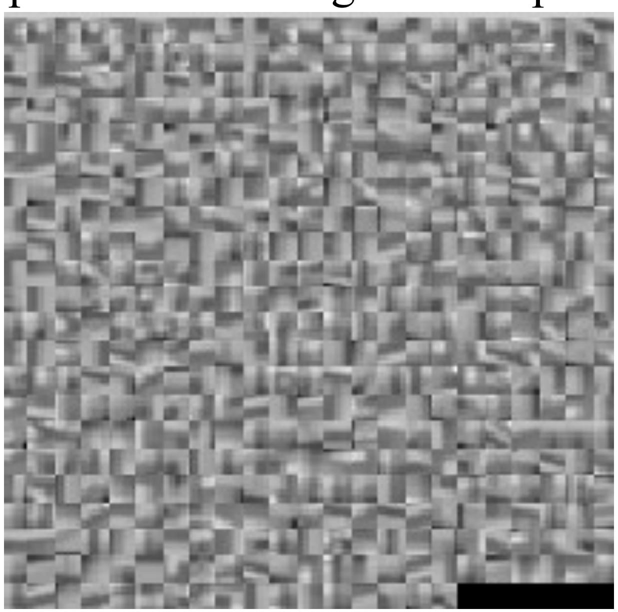
Feature matching

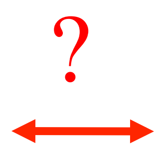


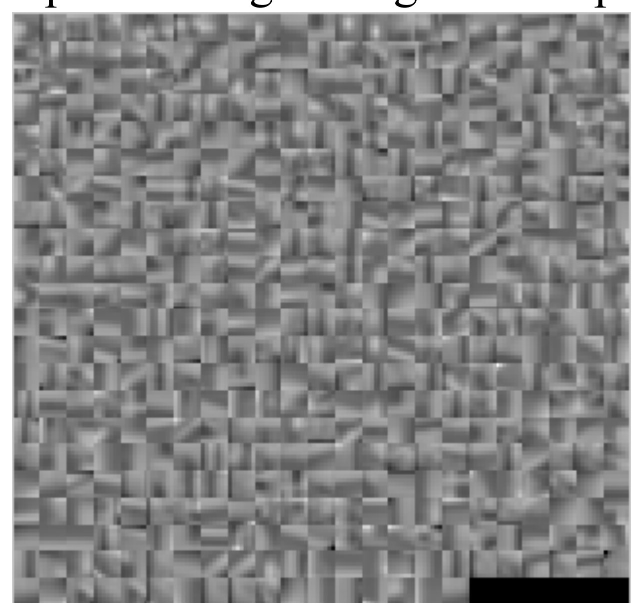


descriptors for left image feature points

descriptors for right image feature points

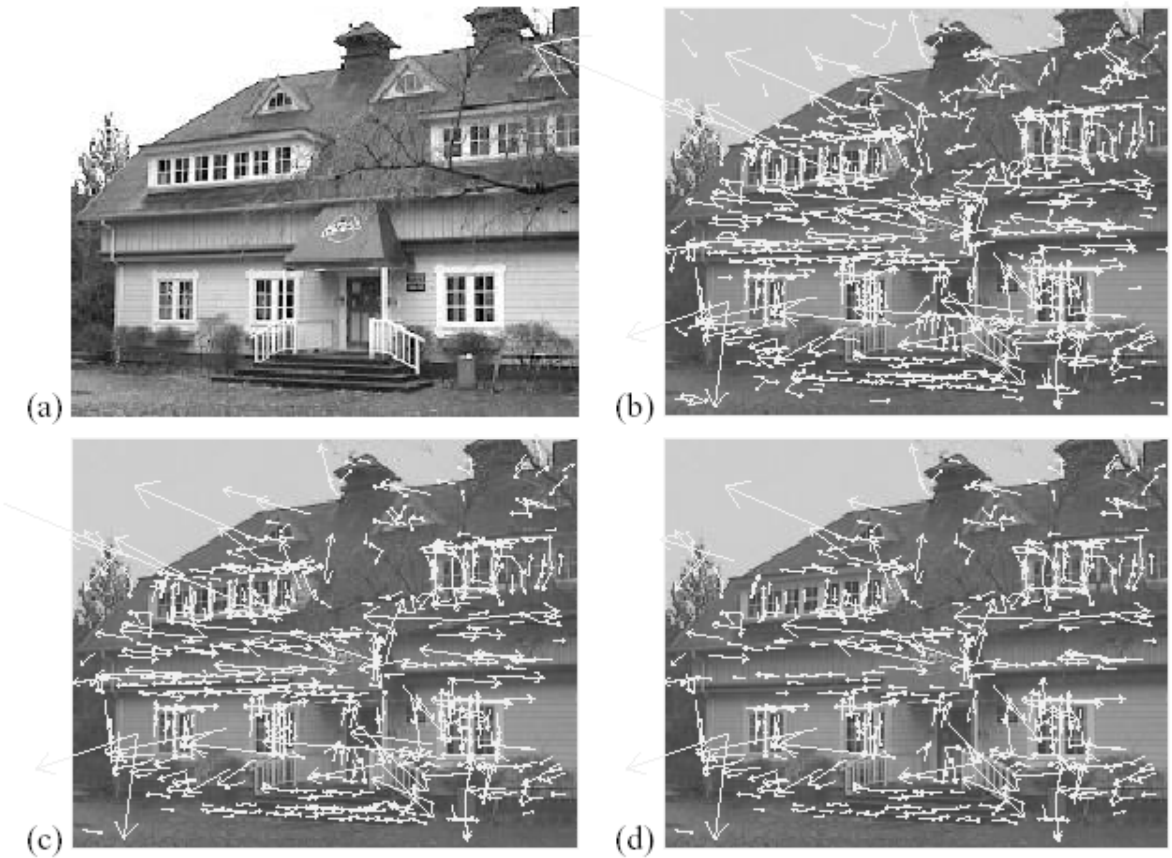






SIFT features

- Example



(a) 233x189 image
(b) 832 DOG extrema
(c) 729 left after peak value threshold
(d) 536 left after testing ratio of principle curvatures

Strategies to match images robustly

(a)Working with individual features: For each feature point, find most similar point in other image (SIFT distance)

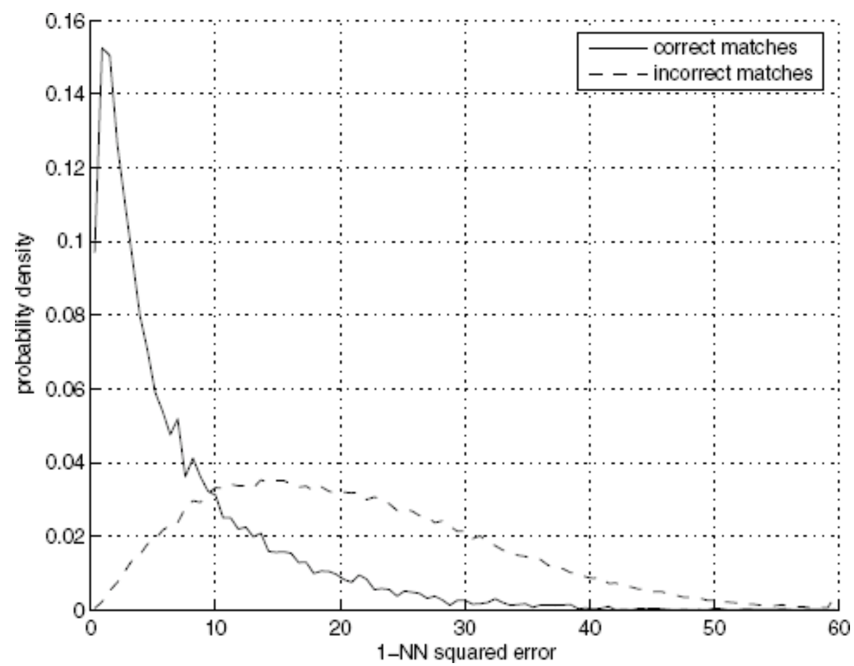
Reject ambiguous matches where there are too many similar points

(b)Working with all the features: Given some good feature matches, look for possible homographies relating the two images

Reject homographies that don't have many feature matches.

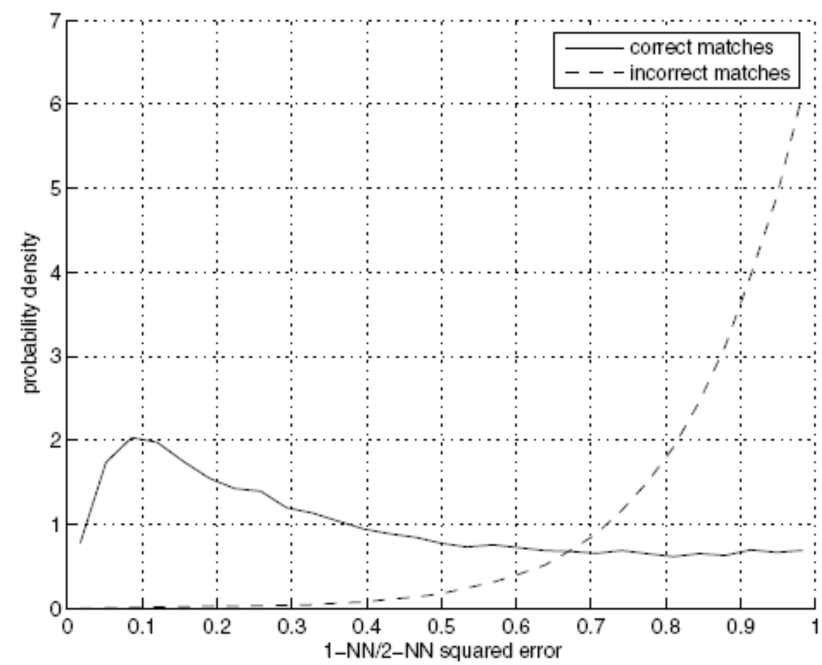
(a) Feature-space outlier rejection

- Let's not match all features, but only these that have "similar enough" matches?
- How can we do it?
  - SSD(patch1,patch2) < threshold
  - How to set threshold? Not so easy.

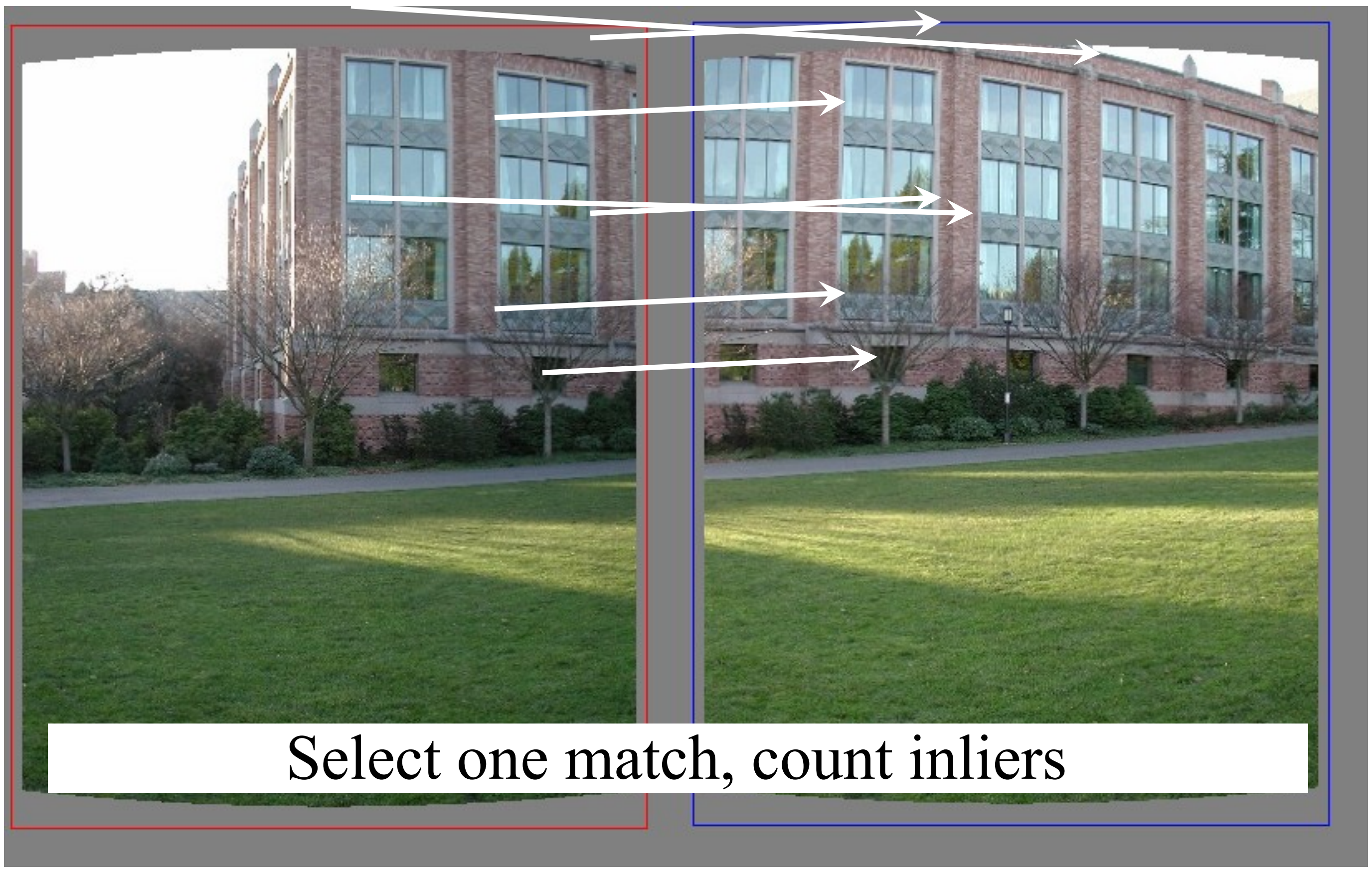


Feature-space outlier rejection

- A better way [Lowe, 1999]:
  - 1-NN: SSD of the closest match
  - 2-NN: SSD of the <u>second-closest</u> match
  - Look at how much better 1-NN is than 2-NN, e.g. 1-NN/2-NN
  - That is, is our best match so much better than the rest?

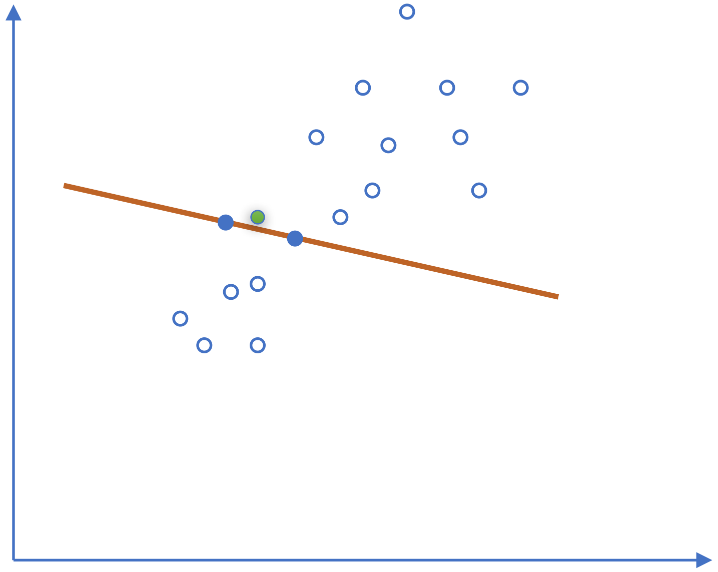


RAndom SAmple Consensus



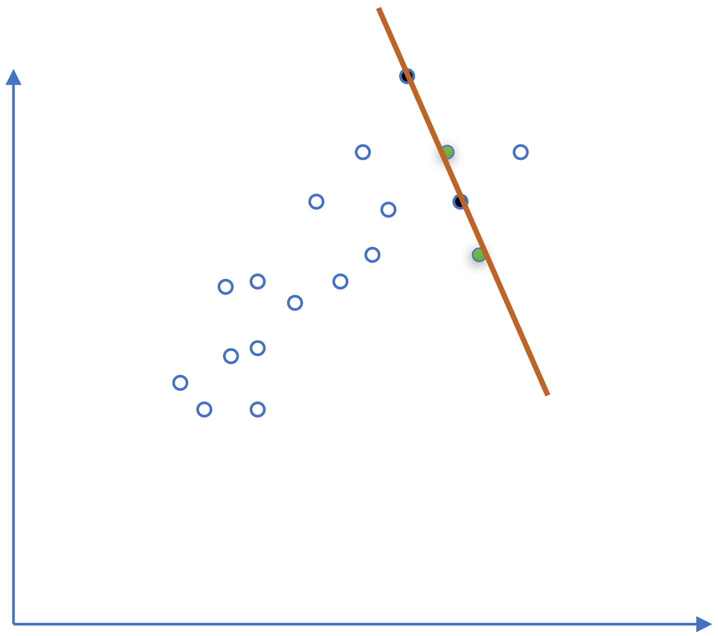
Fit a line

- Pick 2 points
- Fit line
- Count inliers (3 inliers)



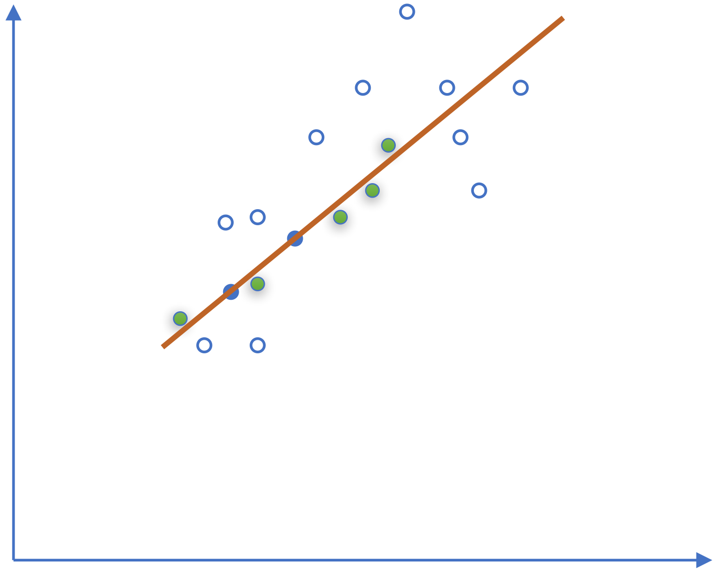
Fit a line

- Pick 2 points
- Fit line
- Count inliers (4 inliers)



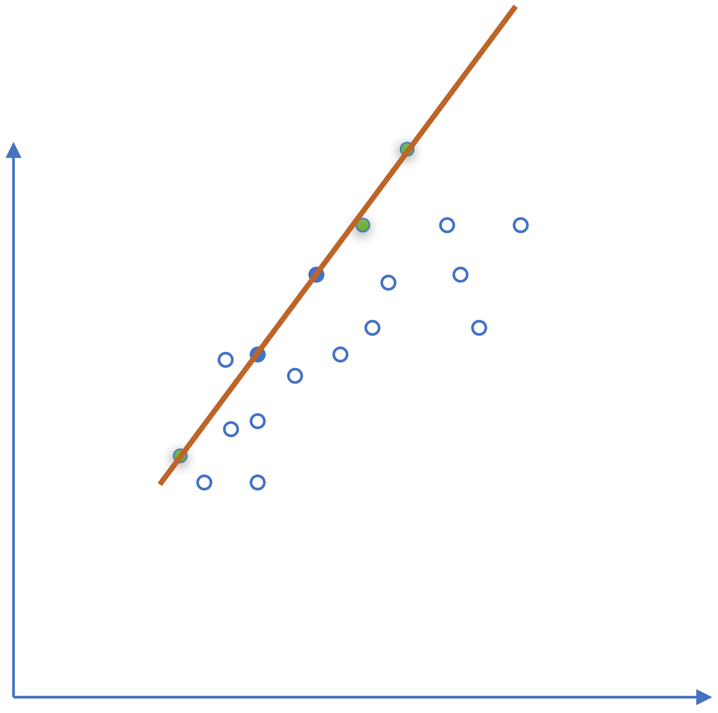
Fit a line

- Pick 2 points
- Fit line
- Count inliers (7 inliers)



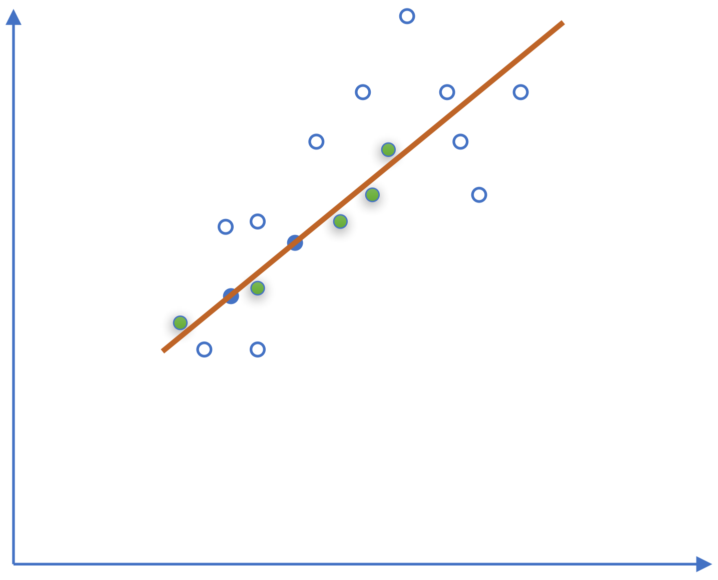
Fit a line

- Pick 2 points
- Fit line
- Count inliers (5 inliers)



Fit a line

- Use biggest set of inliers
- Least squares fit



RANSAC for estimating homography

Determine:
  n—the smallest number of points required (e.g., for lines, $n = 2$,
    for circles, $n = 3$) n=8 for homography
  k—the number of iterations required
  t—the threshold used to identify a point that fits well
  d—the number of nearby points required Size of Inlier set
    to assert a model fits well
Until k iterations have occurred
  Draw a sample of n points from the data
    uniformly and at random
  Fit to that set of n points Compute homography, H
  For each data point outside the sample
    Test the distance from the point to the structure Decision Threshold: $|p' - Hp| < t$
      against t; if the distance from the point to the structure
      is less than t, the point is close
  end
  If there are d or more points close to the structure
    then there is a good fit. Refit the structure using all
    these points. Add the result to a collection of good fits.
end
Use the best fit from this collection, using the
  fitting error as a criterion

Algorithm 10.4: RANSAC: Fitting Structures Using Random Sample Consensus.

Forsyth & Ponce

RANSAC for estimating homography

RANSAC loop:

Select four feature pairs (at random)

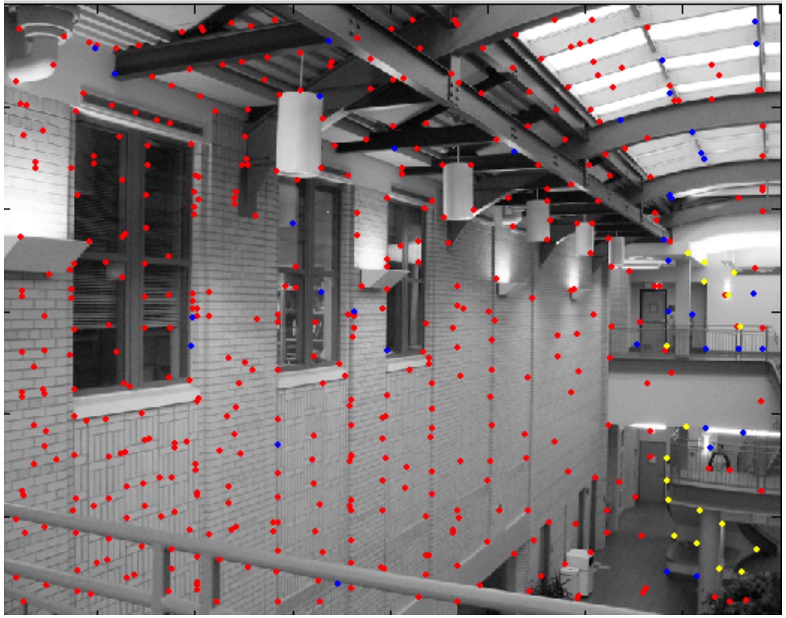
Compute homography H (exact)

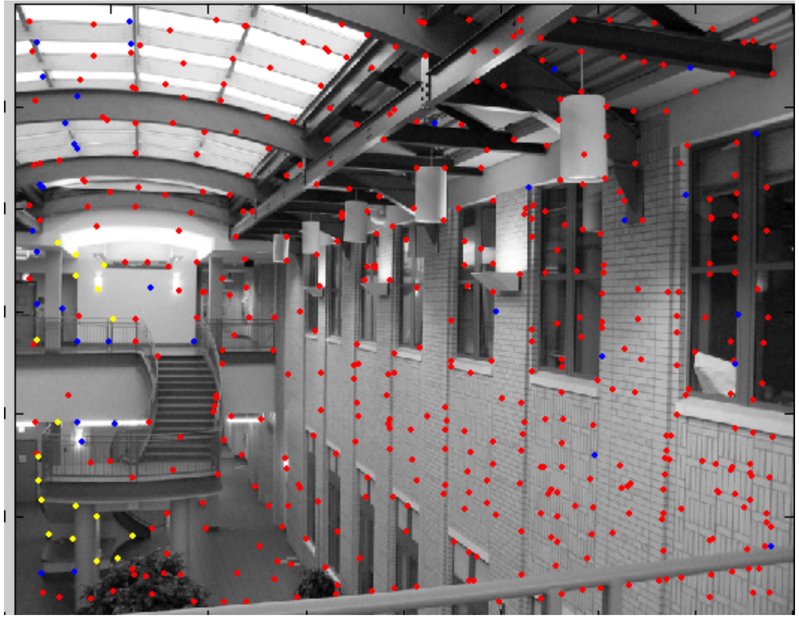
Compute inliers where $||p' - Hp|| < t$

Keep largest set of inliers

Re-compute least-squares H estimate using all of the inliers

RANSAC





red:
rejected by 2nd nearest neighbor criterion
blue:
Ransac outliers
yellow:
inliers

Robustness

- Proportion of inliers in our pairs is g (for "g o o d")
- Our model needs n pairs
  – n = 4 for homography
- Probability that we pick n inliers?

  g^n
- Probability that after k RANSAC iterations we have not picked a set of inliers?
  – $(1 - g^n)^k$

Robustness: example

- Proportion of inliers g=0.5
- Probability that we pick n=4 inlier pairs?
  - $0.5^4 = 0.0625 (6\,\%\, chance)$
- Probability that we have not picked a set of inliers?

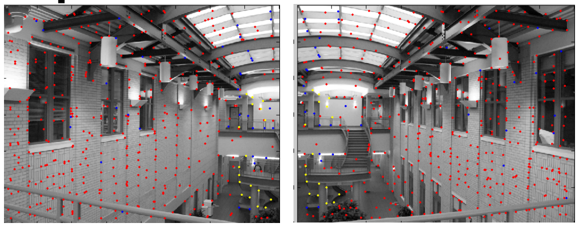
$k = 100$ iterations

$(1 - 0.5^4)^{100} = 0.00157$(1 chance in 600)

$k = 1000$ iterations

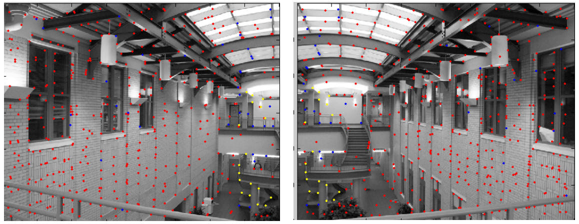
$(1 - 0.5^4)^{100} = 0.00157$(1 chance in 10^{28})

Robustness: example



- Proportion of inliers g=0.3
- Probability that we pick n=4 inlier pairs?
  - $0.3^4 = 0.0081$ (0.8% chance)
- Probability that we have not picked a set of inliers?
  - k=100 iterations: $(1 - 0.3^4)^{100} = 0.44$ (1 chance in 2)
  - k=1000 iterations: $(1 - 0.3^4)^{1000} \to$ (1 chance in 3400)

Robustness: example



- Proportion of inliers g=0.1
- Probability that we pick n=4 inlier pairs?
  - $0.1^4 = 0.0001$(0.01% chances, 1 in 10,000)
- Probability that we have not picked a set of inliers?
  - k=100 iterations: $(1-0.1^4)^{100}=0.99$
  - k=1000 iterations: 90%
  - k=10,000: 36%
  - k=100,000: 1 in 22,000

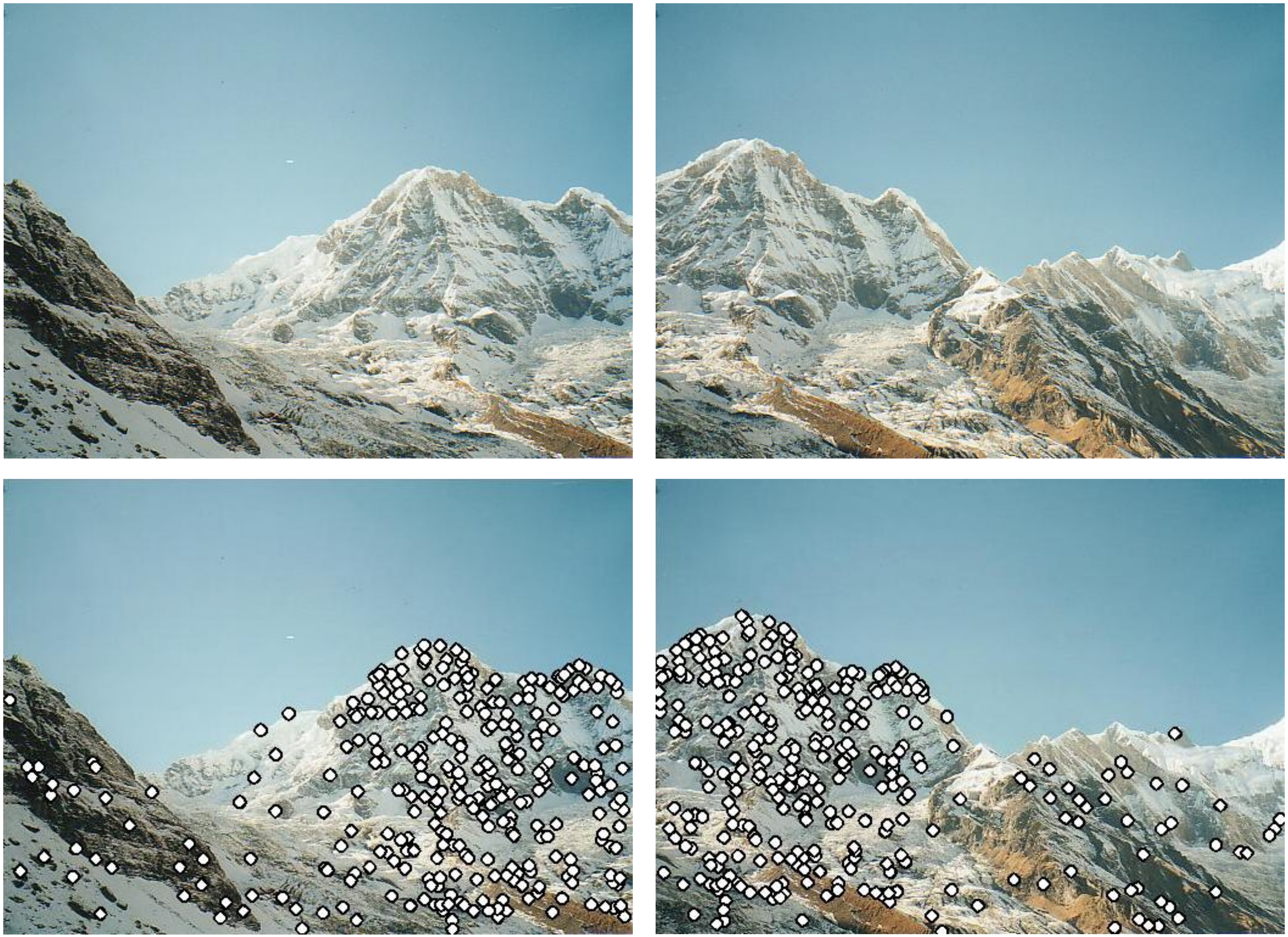
Robustness: conclusions

- Effect of number of parameters of model/ number of necessary pairs
  - Bad exponential
- Effect of percentage of inliers
  - Base of the exponential
- Effect of number of iterations
  - Good exponential

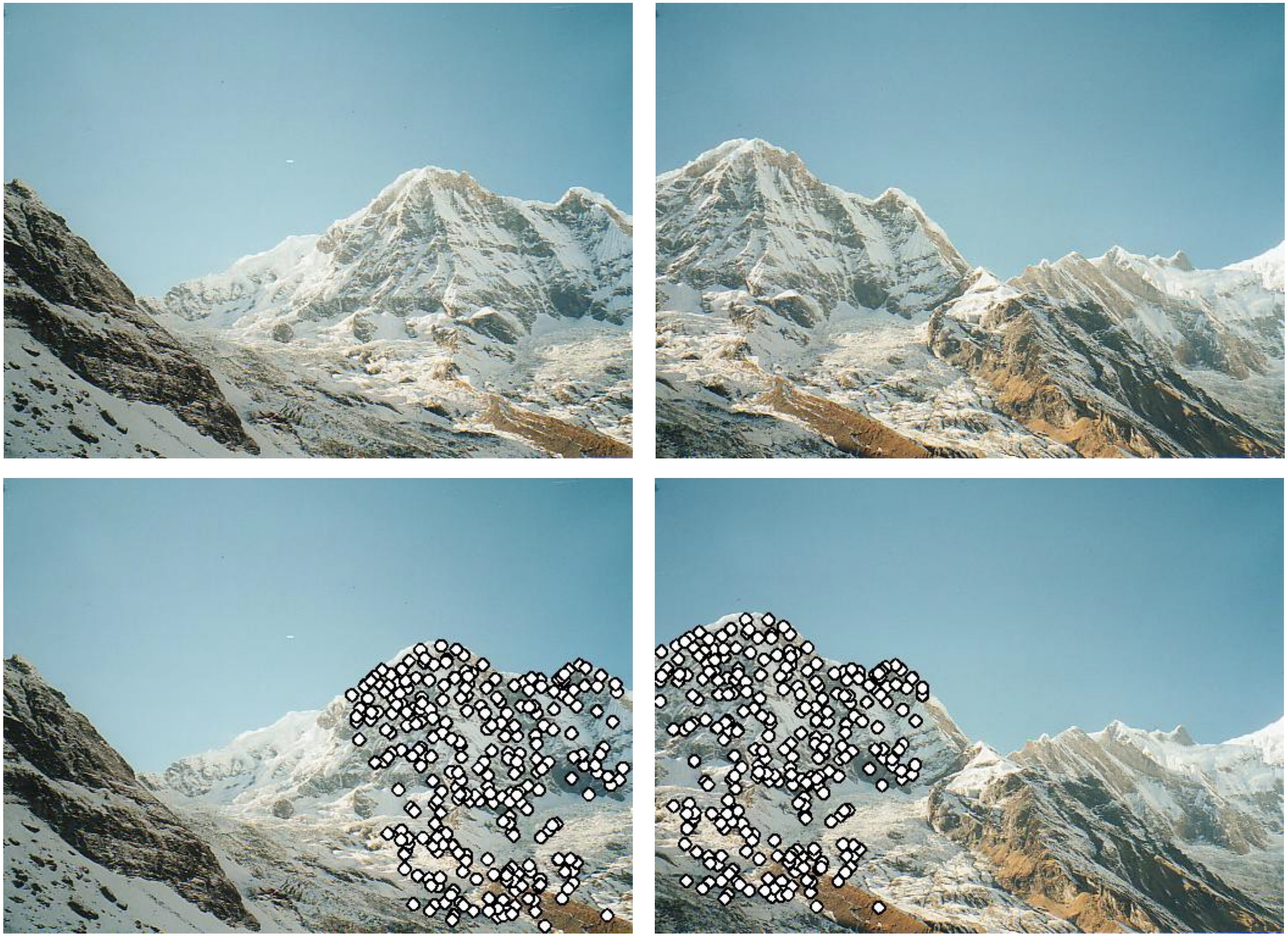
RANSAC recap

- For fitting a model with low number n of parameters (4 pairs for homographies)
- Loop
  - Select n random data points
  - Fit model
  - Count inliers
    (other data points well fit by this model)
- Keep model with largest number of inliers

RANSAC for Homography



RANSAC for Homography



RANSAC for Homography