Geometry for computer Vision

Lecture 6b: sample consensus strategies

Lecture 6b: Sample Consensus Strategies

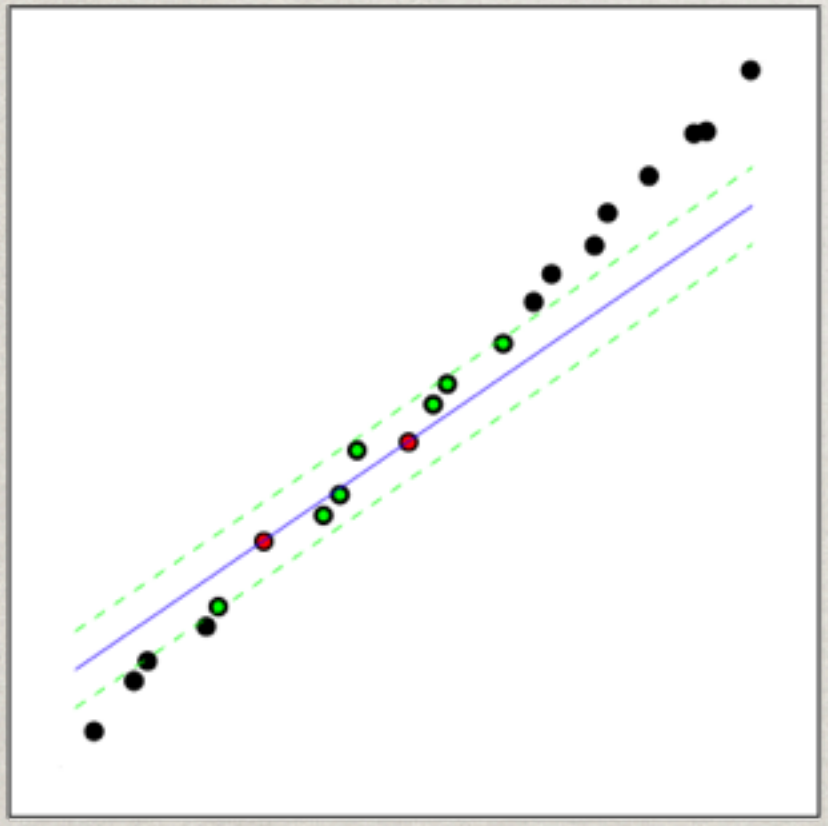
- LO-RANSAC
- Preemptive RANSAC
- DEGENSAC
- Today's paper: PROSAC
- Not covered here: All the other variants MLESAC, NAPSAC etc.

RANSAC issues

- In lecture 3 we introduced RANSAC (Fischler&Bolles 81).
- It finds a **model with maximal support** in the presence of **outliers**
- Approach: randomly **generate hypotheses** and **score** them.
- Most novelties since 1981 covered in thesis by: **Ondrej Chum, *Two-View Geometry Estimation by Random Sample and Consensus*, July 2005**

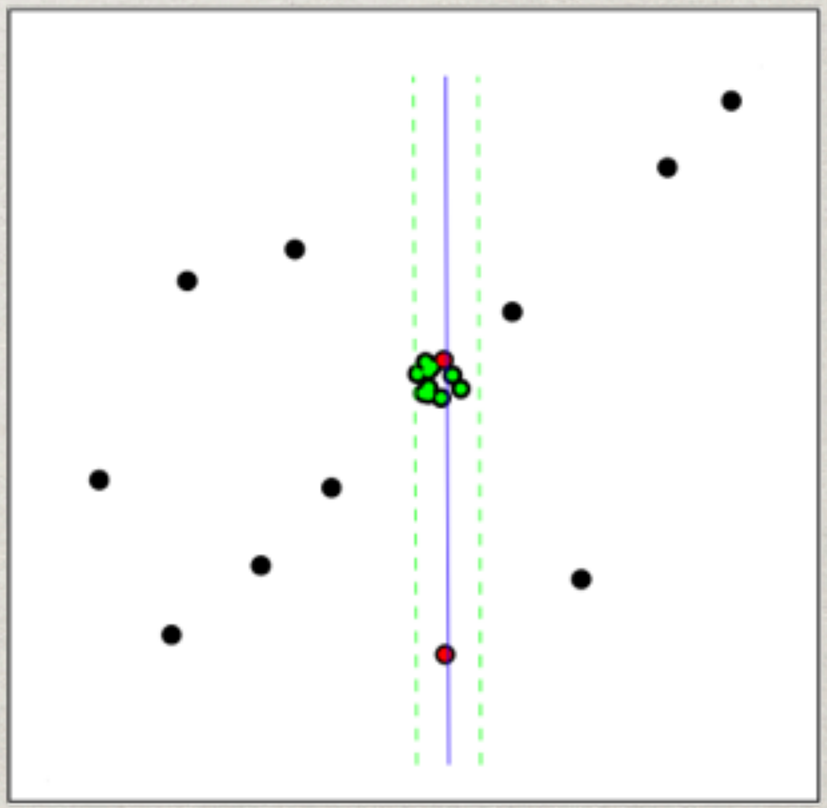
RANSAC issues

- Two problems with the original approach:



(a)

Inlier noise



(b)

Near degeneracies

RANSAC issues

- Near degeneracies can be dealt with by sampling non-randomly, e.g.

- DEGENSAC, for **F** estimation in plane dominant scenes. **Chum et al.,** ***Two-view Geometry estimation unaffected by a Dominant Plane,*** **CVPR05**

- Distance constraint for points used in **E** estimation. **Hedborg et al.,** ***Fast and Accurate Structure and Motion Estimation,*** **ISVC09**
  Reduces #iterations by 50% in forward motion.

LO-RANSAC

- Inlier noise means that the heuristic for number of samples to draw:

$$N = \log(1-p)/\log(1-w^s)$$

  is overly optimistic.

- A small modification makes the heuristic work again: **Chum et al., *Locally Optimized RANSAC*, DAGM03**

LO-RANSAC

- Small modification

RANSAC

loop:
1. Select random sample
2. Estimate model
3. Score model
4. If new high-score
   store model and score

LO-RANSAC

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RANSAC

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LO-RANSAC

loop:
1. Select random sample
2. Estimate model
3. Score model
4. If new high-score
   run local optimisation
   then store model and score

LO-RANSAC

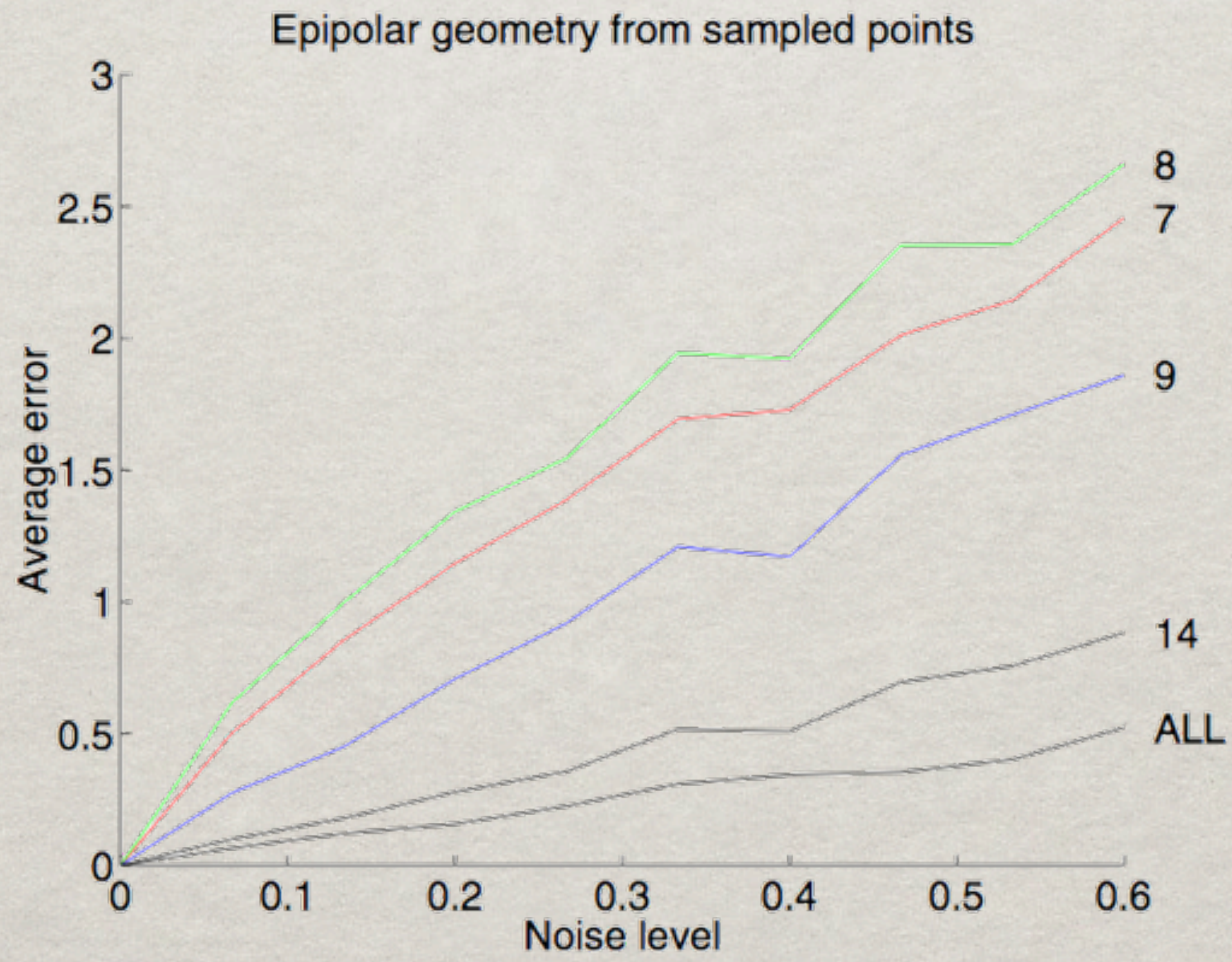
- Chum tries four variants of local optimisation:

  1. Linear estimation from all inliers
  2. Iterative linear estimation with decreasing inlier threshold.
  3. Inner RANSAC
  4. Inner RANSAC with #2.

- #2 and #4 worked best, and came close to the heuristically expected #samples.

LO-RANSAC

- The inner RANSAC step uses non-minimal sample sets. Errors for linear **F** estimation:



Preemptive Ransac

- **David Nister, *Preemptive RANSAC for live structure and motion estimation*, ICCV03**
- Total time for RANSAC is given by:

$$t = k(t_M + E[m_S]t_V)$$

- k- #iterations t_M-model estimation time, t_V-verification time. m_S - #models/iteration

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- k- #iterations t_M-model estimation time, t_V-verification time. m_S - #models/iteration
- If many correspondences, t_V will dominate.

Preemptive Ransac

- Idea: Do a probabilistic verification instead.

$$t = k(t_M + E[m_S]t_V)$$

- In a real-time system, t is fixed, so if we reduce t_V we may increase k.
- Preemptive RANSAC does this by evaluating all hypotheses in parallel.

Preemptive Ransac

- **Preemptive RANSAC**:

  1. Generate f(1) hypotheses in parallel.
  2. For n=1 to N
  3. Evaluate f(n) hypotheses on a random correspondence
  4. Keep the f(n+1) best hypotheses according to accumulated score.

- f(1)=M and $f(n+1) \leq f(n)$

Preemptive Ransac

- f(n) - the preemption function

$$f(n) = \lfloor M 2^{-\lfloor \frac{n}{B} \rfloor} \rfloor$$

- B - block size (f only changes every B steps)
- M - number of models
- Accumulated scoring $L(m) = \sum_{n=1}^{N} \rho(n, m)$
- Log-likelihood of sample *n* given model *m*

$$\rho(n, m)$$

Degensac

- **Chum, et al., *Two-view Geometry Estimation Unaffected by a Dominant Plane*, CVPR'05**
- Planar **dominant** scenes are also problematic

Degensac

- Actually, the **F** estimation problem is even worse than it might appear, as 5 points in a plane +2 ***arbitrary*** correspondences gives an **F** compatible with the plane.

Degensac

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- In le5 we saw that if all seven points are in a plane, then

$$\mathbf{x}_k^T\mathbf{F}\mathbf{y}_k = 0\,,\; \mathbf{x}_k = \mathbf{H}\mathbf{y}_k, \quad k = 1\ldots 7$$

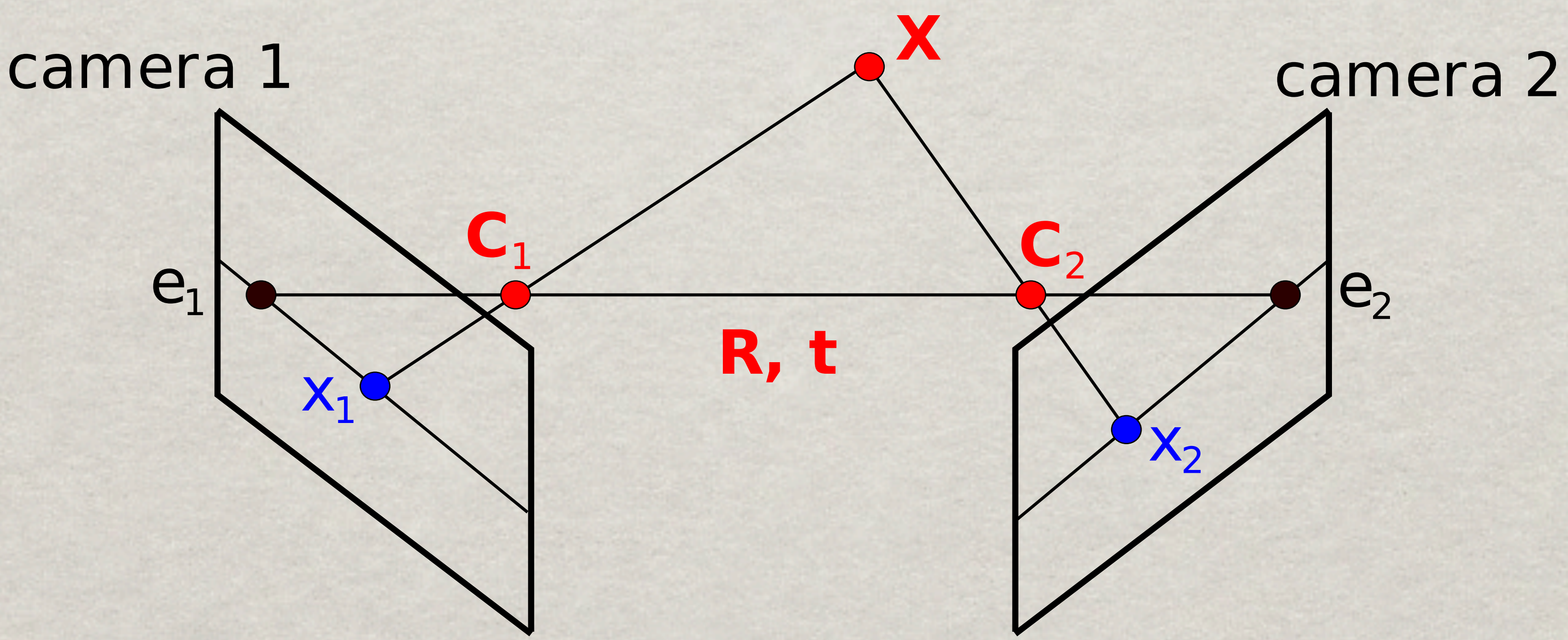
and $\mathbf{F} = [\mathrm{e}]_\times\mathbf{H}$ for any epipole **e** (**why epipole?**)

Degensac

- If ***six*** points are in a plane

$$\mathbf{x}_k^T\mathbf{F}\mathbf{y}_k = 0\,, \quad k = 1\ldots 7 \quad \mathbf{x}_k = \mathbf{H}\mathbf{y}_k\,, \quad k = 1\ldots 6$$

$$\mathbf{F} = [\mathbf{e}]_\times \mathbf{H} \quad \text{for} \quad \mathbf{e} \in \mathbb{R}^3\,,\; \mathbf{e}^T(\mathbf{H}\mathbf{x}_7 \times \mathbf{y}_7) = 0$$



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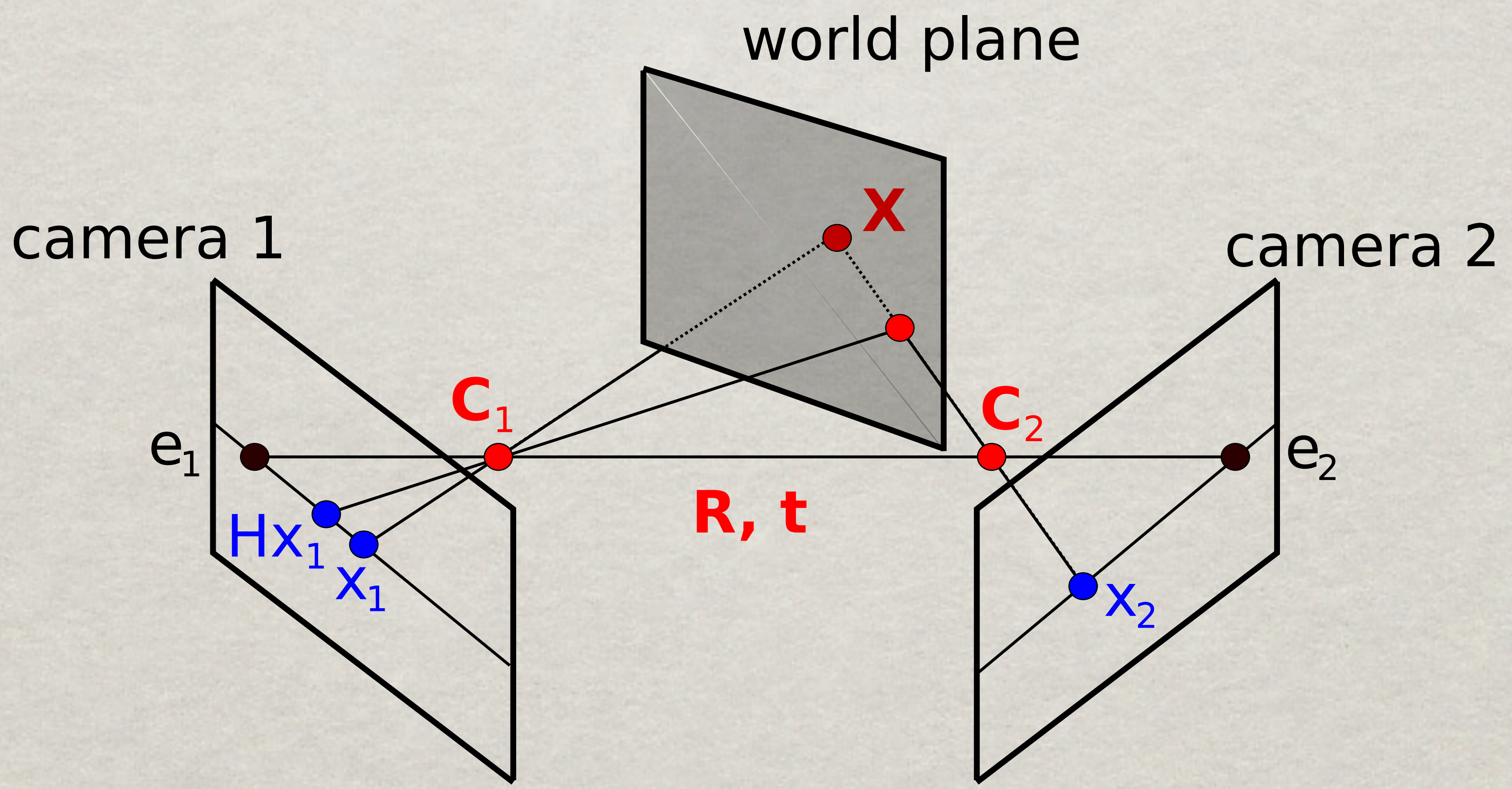

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- For *five* points in the plane

$$\mathbf{x}_6 \times (\mathbf{H}\mathbf{y}_6) \quad \text{and} \quad \mathbf{x}_7 \times (\mathbf{H}\mathbf{y}_7)$$

define two lines that intersect in **e**. **F** will have all points consistent with **H** as inliers.

DEGENSAC

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define two lines that intersect in $\mathbf{e}$. $\mathbf{F}$ will have all points consistent with $\mathbf{H}$ as inliers.

- Also used in plane+parallax algorithm

Degensac

- From $\mathbf{F}$ and $\{\mathbf{x}_k \leftrightarrow \mathbf{y}_k\}_{k=1}^{3}$ we can compute a homography

$$\mathbf{H} = \mathbf{A} - \mathbf{e}_1(\mathbf{M}^{-1}\mathbf{b})^T$$

where $\mathbf{A} = [\mathbf{e}_1]_\times \mathbf{F}$ $\mathbf{M} = [\mathbf{x}_1 \ \ \mathbf{x}_2 \ \ \mathbf{x}_3]^T$

and $b_k = (\mathbf{x}_k \times \mathbf{A}\mathbf{y}_k)^T(\mathbf{x}_k \times \mathbf{e}_1)||\mathbf{x}_k \times \mathbf{e}_1||^{-2}$

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- This $\mathbf{H}$ is now checked for two additional inliers. If found, $\mathbf{F}$ is said to be $\mathbf{H}$-degenerate

Degensac

- There are $\binom{7}{5} = 21$ ways to pick five points from 7.

- But, if we pick the 3 points that define **H** as

$$\{1,2,3\},\{4,5,6\},\{1,2,7\},\{4,5,7\},\{3,6,7\}$$

- We will have covered all 21 permutations.

- Thus at most **five** **H** need to be computed and tested to find out if **F** is **H**-degenerate.

Degensac

- DEGENSAC algorithm

1. Select 7 random correspondences and estimate **F**
2. IF best support this far
3. IF **H**-degeneracy
4. Do inner RANSAC and estimate **F** from **H** and 2 correspondences (Plane+Parallax algorithm) that are inconsistent with **H**
5. IF new **F** has even bigger support, store **F**
6. ELSE store **H**

Discussion

- Discussion of the paper:
  Ondrej Chum and Jiri Matas, *Matching with PROSAC -- Progressive Sample Consensus*, CVPR'05

FOR NEXT WEEK...

- Hartley&Zisserman, Appendix A4.3
- **K. Shoemake, *Animating Rotation with Quaternion Curves*, SIGGRAPH85**