Master in
Computer Vision
Barcelona

Module: 3D Vision
Project: 3D recovery of urban scenes
Session 3

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Session 3

Goal: compute the fundamental matrix that relates two images

Algorithms:

- Normalized 8-point algorithm (algebraic method).
- Robust normalized 8-point algorithm.

Application: Photo-sequencing.

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Mandatory tasks:

- Function that estimates the fundamental matrix F with the normalized 8-point algorithm.
- Compute the theoretical fundamental matrix that relates two images with correponding camera matrices $P = [I|0]$, and $P' = [R|t]$.
- Function that robustly estimates F using the previous function and RANSAC (you can use as a basis the provided function in lab 2: 'Ransac_DLT_homography').
  The inliers are obtained with a threshold on the first order approximation of the geometric error: **Sampson distance**,

$$\sum_i \frac{(x_i'^T F x_i)^2}{(Fx_i)_1^2 + (Fx_i)_2^2 + (F^T x_i')_1^2 + (F^T x_i')_2^2}$$

- Compute the epipolar lines of the matching points in both images.
- Apply the theoretical concepts to do photo-sequencing.

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Geometric distance
(used for determining the inliers in the RANSAC function)

$$\sum_i d([x_i],[\hat{x}_i])^2 + d([x_i'],[\hat{x}_i'])^2 \text{ s. t. } \hat{x}_i'^T F \hat{x}_i = 0 \ \forall i$$

where the different matchings $x_i \longleftrightarrow x_i'$ are the data,
[.] is the projection operator to Euclidean coordinates.

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Geometric distance
A variant is (we use the distance of a point to a line $d(x, l) = |x^T l|/||l||$):

$$\sum_i d(x'_i, Fx_i)^2 + d(x_i, F^T x'_i)^2$$

$$= \sum_i (x'^T_i F x_i)^2 \left(\frac{1}{(Fx_i)_1^2 + (Fx_i)_2^2} + \frac{1}{(F^T x'_i)_1^2 + (F^T x'_i)_2^2} \right)$$

We will use the **Sampson error**
(1st order approx. of the geometric distance)

$$\sum_i \frac{(x'^T_i F x_i)^2}{(Fx_i)_1^2 + (Fx_i)_2^2 + (F^T x'_i)_1^2 + (F^T x'_i)_2^2}$$

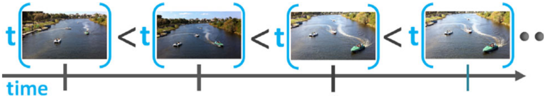
Photo Sequencing

Int J Comput Vis (2014) 110:275–289
DOI 10.1007/s11263-014-0712-x

Photo Sequencing

Tali Dekel (Basha) · Yael Moses · Shai Avidan

Given a set of images of a dynamic scene taken at different viewpoints and different time instants, the photo-sequencing algorithm establishes an ordering of the images according to the time they were taken.



There are two underlying hypothesis:

- Object trajectories can be approximated by straight lines.
- Two of the images are taken from approximately the same position.

Photo Sequencing

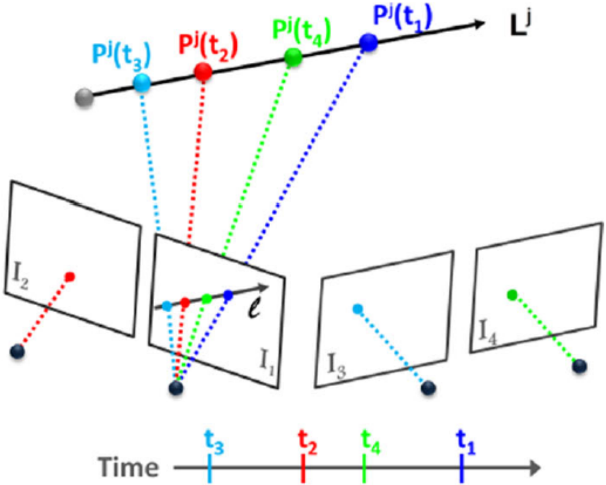


Photo Sequencing

Computing static and dynamic features (thanks to hypothesis 2)

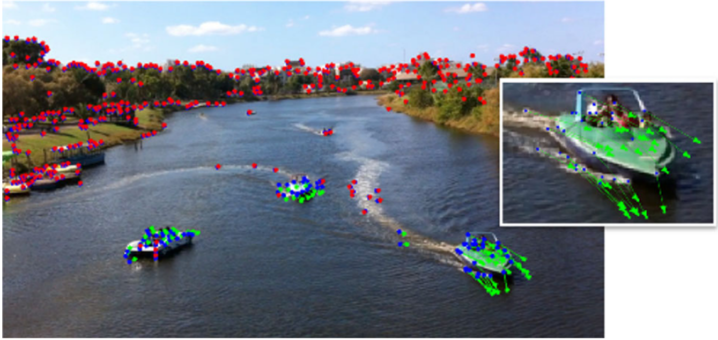


Photo Sequencing

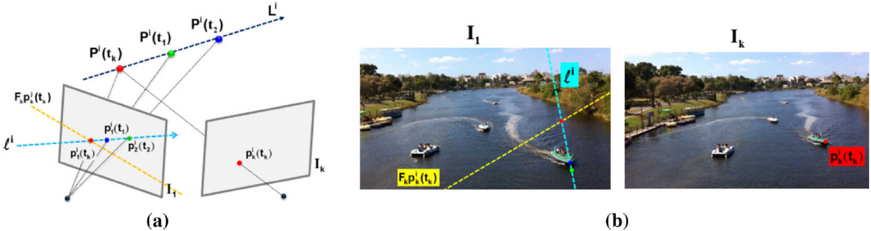


Fig. 5 (**a**) The projection of the trajectory, L^i, of the point P^i, forms the line ℓ^i on image I_1. The feature points $p_1^i(t_1)$, $p_2^i(t_2)$, in image I_1, and $p_k^i(t_k)$ in image I_k, are corresponding dynamic features. The line ℓ^i intersects the *epipolar line* (in *yellow*), which corresponds to p_k^i. The intersection point, $p_1^i(t_k)$, is the projection of P^i onto I_1 at time step t_k. The spatial order of $p_1^i(t_1)$, $p_2^i(t_2)$, and $p_1^i(t_k)$, along ℓ^i, defines the temporal order between I_1, I_2 and I_k. (**b**) The computation on real images: the projected trajectory, ℓ^i, in cyan; the *epipolar line* in *yellow*; the intersection in *red*

Photo Sequencing

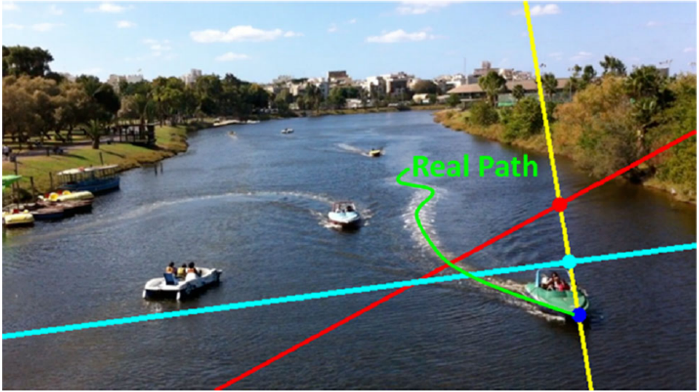
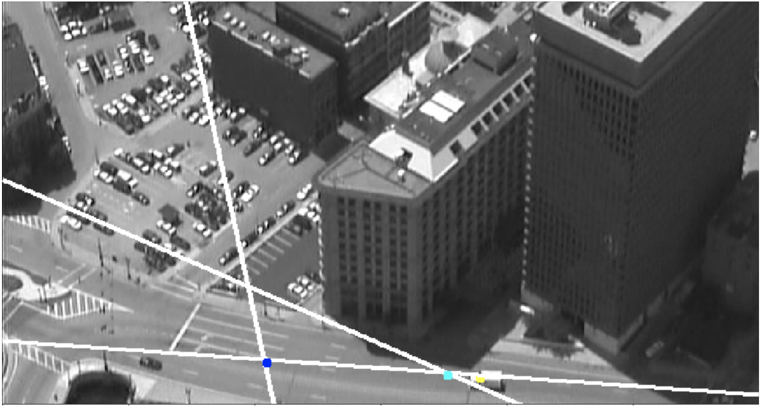


Fig. 6 Linear Motion Assumptions: In *green*, the real path of the green boat; in yellow, the approximated 2D image line. The epipolar lines intersect both the real path and the 2D image line. The spatial order of both sets of intersections is the same

Photo Sequencing



Session 3

Language: Python

To Do:

- Complete the code in lab3.ipynb as indicated in the same file (e.g. ground-truth F, epipolar lines)
- Write the function fundamental_matrix
- Write the function Ransac_fundamental_matrix
- Complete the code on photo-sequencing, dynamic feature given

Evaluation

To deliver **before 9am of the day before** the next lab session:

- **Code deliverable:**
  - READY TO BE LAUNCHED on the provided images
- **Short document (10 pages):**
  - Results
  - Problems and comments, conclusions

Evaluation

Grading:

- Report: **2 points**
- Normalized 8-point algorithm: **2 points**
- F from P1 and P2: **1 point**
- Robust 8-point algorithm (RANSAC): **2 points**
- Epipolar lines: **1 point**
- Photo-sequencing: **2 points**