ASIFT: A New Framework for Fully Affine Invariant Image Comparison

Guoshen Yu
CMAP, Ecole Polytechnique
91128 Palaiseau Cedex, France

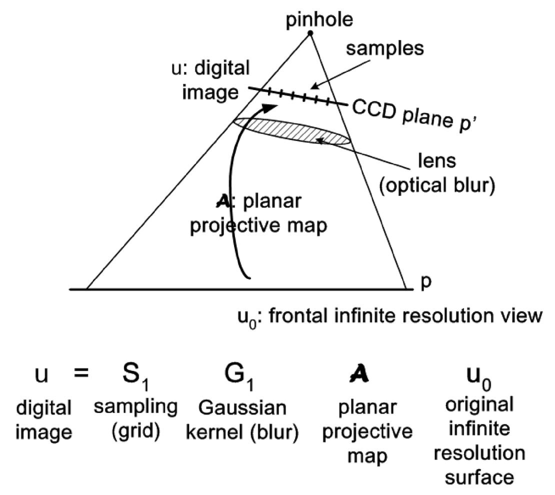
Jean-Michel Morel
CMLA, ENS Cachan, 61 avenue du President Wilson,
94235 Cachan Cedex, France

Abstract

A fully affine invariant image comparison method, Affine-SIFT (ASIFT) is introduced. While SIFT is fully invariant with respect to four parameters namely zoom, rotation and translation, the new method treats the two left over parameters : the angles defining the camera axis orientation. Against any prognosis, simulating all views depending on these two parameters is feasible with no dramatic computational load. The method permits to reliably identify features that have undergone large transition tilts, up to 36 and more, while state-of-the-art methods hardly exceed transition tilts of 2 (SIFT), 2.5 (Harris-Affine and Hessian-Affine) and 10 (MSER).

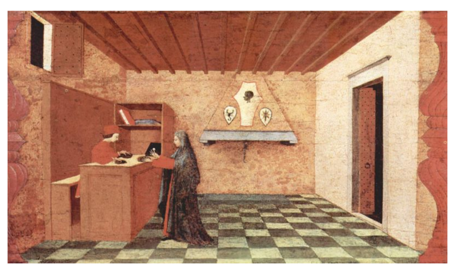
1 The Affine Camera Model

1.1 Image Formation Model



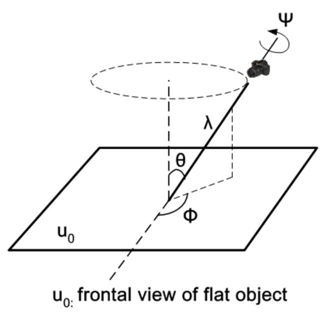
1.2 Affine Simplification

Local perspective effects can be modeled by local affine transforms $u(x, y) \to u(ax + by + e, cx + dy + f)$ in each image region.



The global deformation of the ground is strongly projective (a rectangle becomes a trapezoid), but the local deformation is affine: each tile on the pavement is almost a parallelogram.

1.3 Affine Camera Model



$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} = H_\lambda R_1(\psi) T_t R_2(\phi) = \lambda \begin{bmatrix} \cos\psi & -\sin\psi \\ \sin\psi & \cos\psi \end{bmatrix} \begin{bmatrix} t & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix}$$

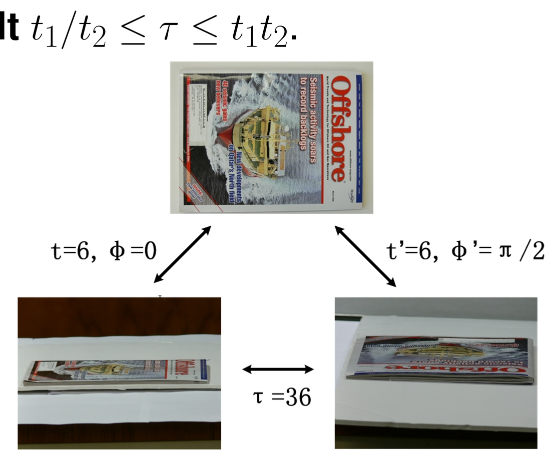
- A: affine map with strictly positive determinant.
- ϕ: *longitude* angle between optical axis and a fixed vertical plane.
- $\theta = \arccos(1/t)$: *latitude* angle between optical axis and the normal to the image plane. **Tilt** $t > 1 \leftrightarrow \theta \in [0°, 90°]$.
- ψ: rotation angle of camera around optical axis.
- λ: *zoom* parameter.

1.4 High Transition Tilts

Both compared images $u_1(x, y) = u(A(x, y))$ and $u_2(x, y) = u(B(x, y))$ are usually slanted views. The *transition tilt* quantifies the tilt between two such images.

$$BA^{-1} = H_\lambda R_1(\psi) T_\tau R_2(\phi).$$

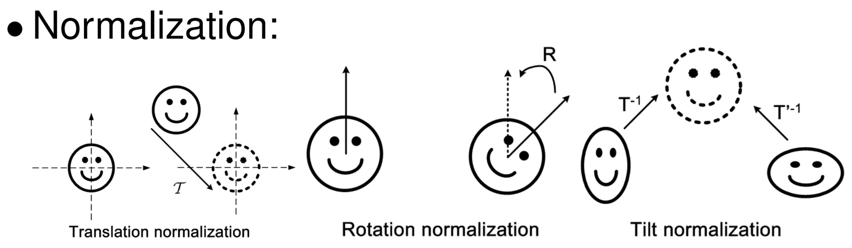
The **transition tilt** $t_1/t_2 \le \tau \le t_1 t_2$.



2 State-of-the-art

2.1 Simulation v.s. Normalization

- Simulation: all 6 parameters impossible, e.g. 10^6.
- Normalization:



– Translation $\mathcal{T}$ and rotation $\mathbf{R}$: OK. $\mathbf{G}_1 \mathbf{R} u_0 = \mathbf{R}\mathbf{G}_1 u_0$.
– Zoom $\mathbf{H}_\lambda$ and tilt $\mathbf{T}$: not exact. $\mathbf{H}_\lambda \mathbf{G}_1 u_0 \neq \mathbf{G}_1 \mathbf{H}_\lambda u_0$.

2.2 SIFT

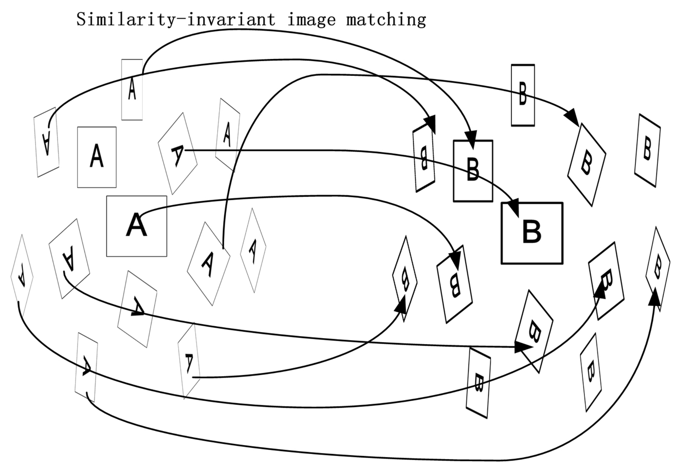
- Rotation and translation are *normalized*.
- Zoom is *simulated* in the scale space.
- No treatment on latitude and longitude: $\tau_{\max} < 2$.

2.3 MSER, Harris-Affine, Hessian-Affine

- Normalize all affine parameters.
- Limited performance on scale- and tilt-invariance.
- MSER: $\tau_{\max} < 10$ in optimal conditions.

3 ASIFT

3.1 Algorithm



1. Simulate latitude, longitude to achieve full affine invariance.
2. Simulated images are compared by a rotation-, translation- and zoom-invariant algorithm, e.g., SIFT.

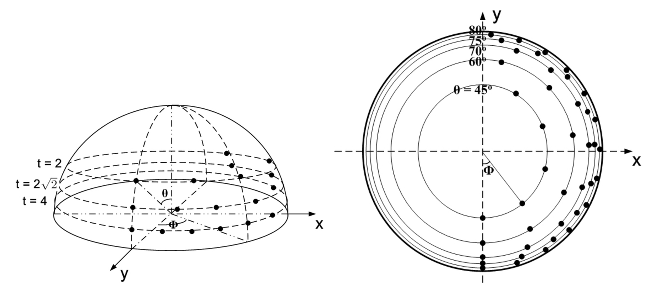
3.2 Full Affine Invariance

Theorem 1 *Let $u = \mathrm{G}_1 A \mathcal{T}_1 u_0$ and $v = \mathrm{G}_1 B \mathcal{T}_2 u_0$ be two images obtained from an infinite resolution image u_0 by cameras at infinity with arbitrary position and focal lengths. Then ASIFT, applied with a dense set of tilts and longitudes, simulates two views of u and v that are obtained from each other by a translation, a rotation, and a camera zoom. As a consequence, these images match by the SIFT algorithm.*

3.3 Why it works? — Inverting Tilts

A tilt in one direction is reversed by simulating a tilt of same amount in the orthogonal direction, up to a zoom-out scale change.

3.4 Parameter sampling



Denser sampling when the latitude angle θ (or tilt t) increases.

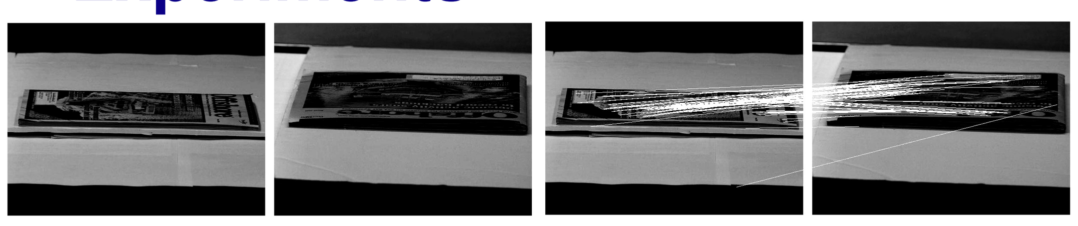
3.5 Two-resolution Acceleration

1. ASIFT on low-resolution images ($r \times r$ sub-sampled) .
2. ASIFT on high-resolution images obtained with the identified good affine transforms (only in case of success in 1.).

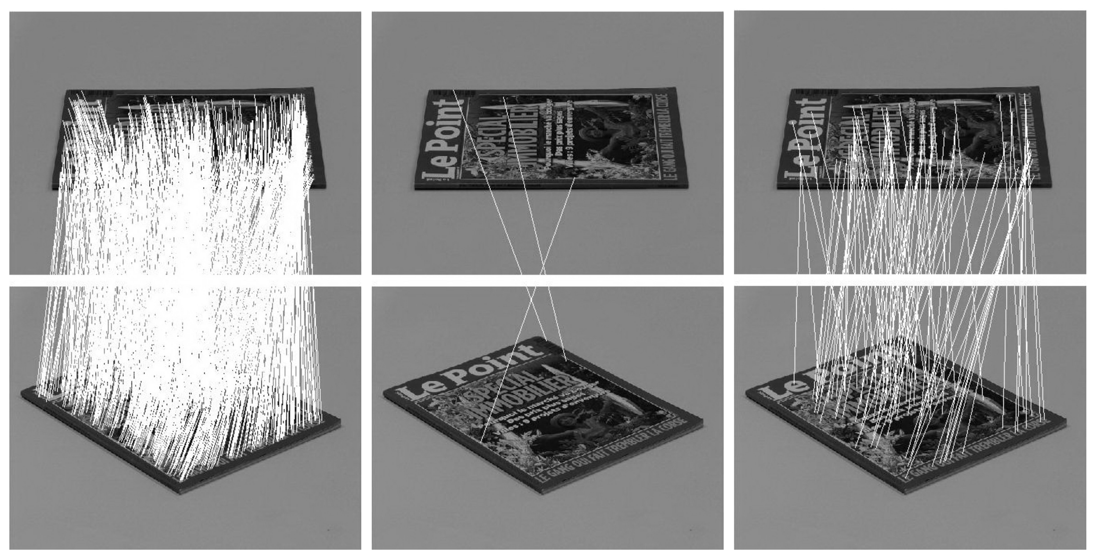
3.6 ASIFT Complexity

- About twice SIFT. ($t_{\max} = 4\sqrt{2} \Rightarrow \tau_{\max} = 32$, $r = 3$)
- SIFT subroutines fully parallizable.

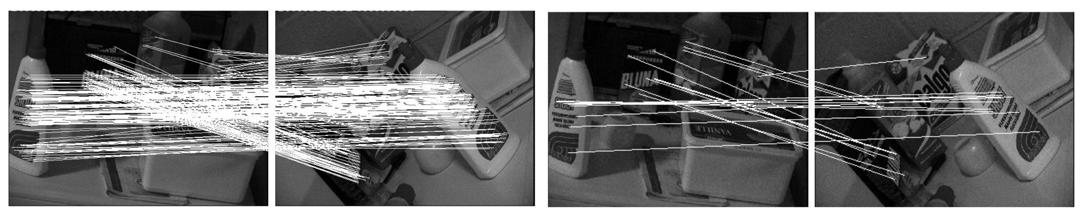
4 Experiments



Transition tilt $t \approx 36$. Bottom: ASIFT (shown) – 116 correct matches. SIFT, Harris-Affine, Hessian-Affine and MSER fail completely.

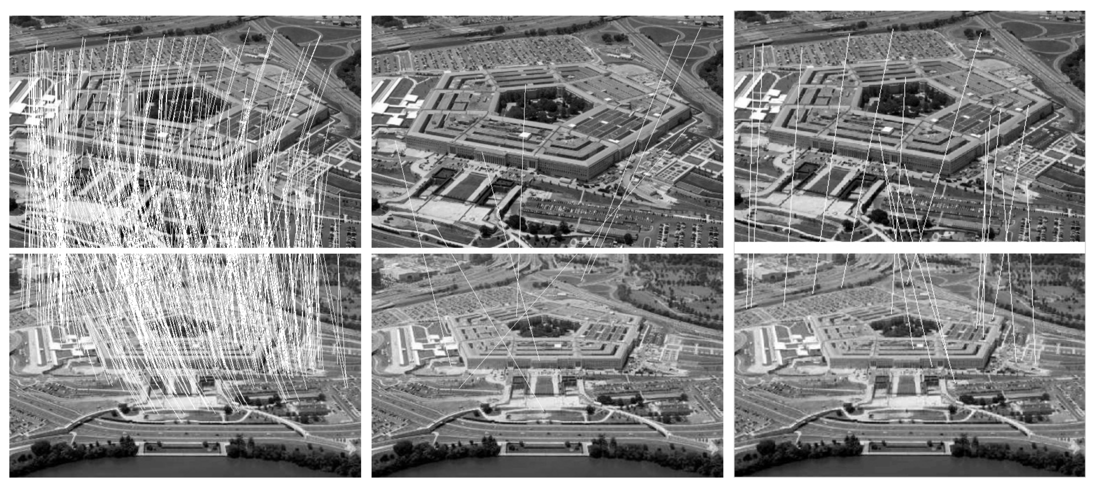


Transition $\tau \approx 5.8$. ASIFT (shown) – 116, SIFT – 1, Harris-Affine (shown) – 1, Hessian-Affine – 0, and MSER (shown) – 2 correct matches.



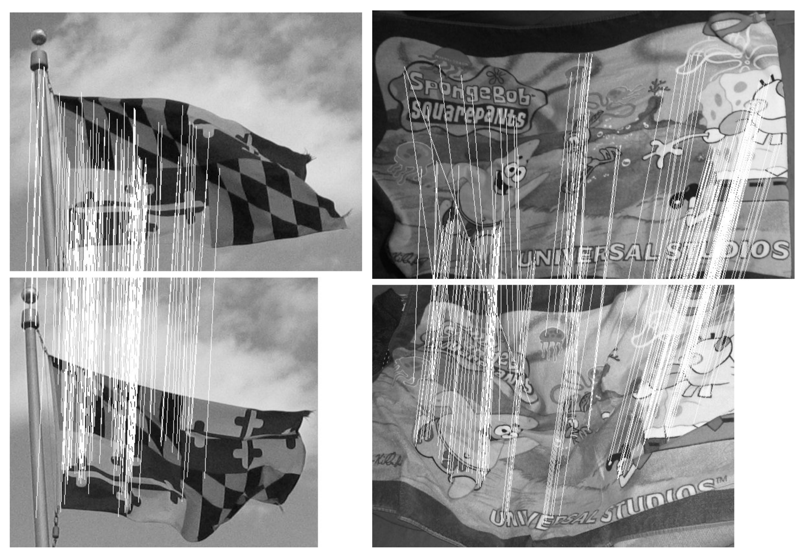
Transition $\tau \approx 3$. ASIFT (shown) – 881, SIFT (shown) – 3, Harris-Affine – 1, Hessian-Affine – 3, and MSER (shown) – 87 correct matches.

Transition tilt: $\tau \in [1.6, 3.0]$ (images proposed by the authors of MSER). ASIFT (shown) – 254, SIFT–10, Harris-Affine–23, Hessian-Affine–11 and MSER (shown) – 22 correct matches.



Transition tilt: $\tau \approx 2.6$. ASIFT (shown) – 50, SIFT – 0, Harris-Affine – 0, Hessian-Affine – 0 and MSER (shown) – 1 correct matches.

Transition $\tau \in [1.3, \infty)$. ASIFT (shown) – 378, SIFT (shown)– 6, Harris-Affine – 2, Hessian-Affine – 8, and MSER (shown) – 17 correct matches.



Transition $\tau \approx 5.8$. ASIFT (shown) – 22, SIFT (shown)– 16, Harris-Affine – 0, Hessian-Affine – 0, and MSER – 0 correct matches.

Object deformation (images proposed by Ling and Jacobs). Left: flag. ASIFT (shown) – 141, SIFT – 31, Harris-Affine – 15, Hessian-Affine – 10 and MSER – 2 correct matches. Right: SpongeBob. ASIFT (shown) – 370, SIFT – 75, Harris-Affine – 8, Hessian-Affine – 6 and MSER – 4correct matches.

References:

- G. Yu and J.M. Morel, A Fully Affine Invariant Image Comparison Method, *IEEE ICASSP, Taipei*, 2009.
- J.M. Morel and G.Yu, ASIFT: A New Framework for Fully Affine Invariant Image Comparison, to appear in *SIAM Journal on Imaging Sciences*, 2009.

For more information, Google ASIFT