Estimation of a video sequence camera motion

Léo Girardin & David Lafontaine

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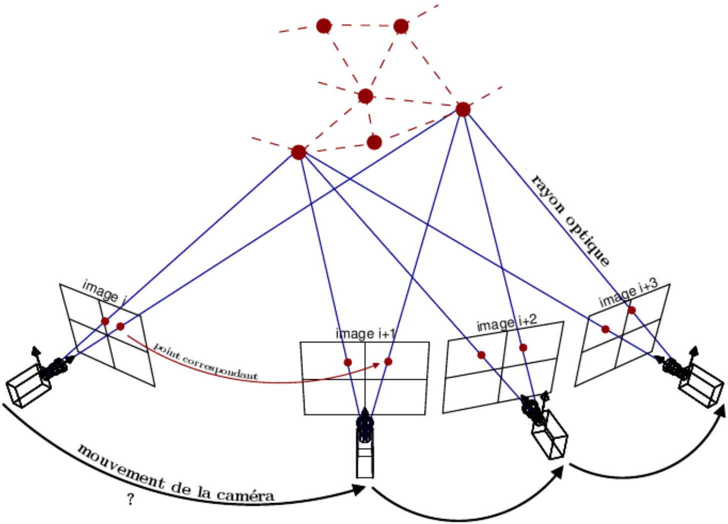
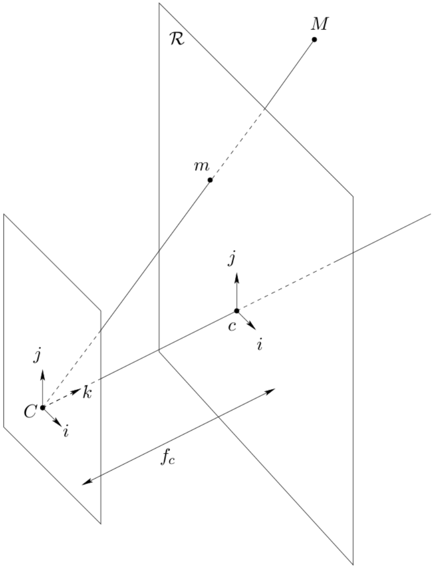


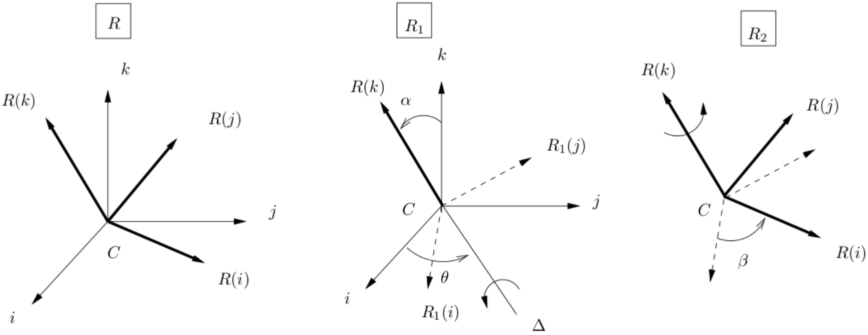
rayon optique
image i
image i+1
image i+2
image i+3
point correspondant
mouvement de la caméra
?

Pinhole camera model



Motion decomposition and parameterization

$R = R_2 \circ R_1$ is parametrized by (θ, α, β):



$\tilde{t} := \frac{t}{Z_0} = (-A, -B, -C)$ in $(R(i), R(j), R(k))$.
From now on, $\Theta = (\theta, \alpha, \beta, A, B, C)$.

Optical flow approximation

For a unitary focal length

$$\begin{cases} x' = \frac{r_{1,1}x+r_{2,1}y+r_{3,1}-\left\langle \frac{t}{Z(x,y)}, R(i)\right\rangle}{r_{1,3}x+r_{2,3}y+r_{3,3}-\left\langle \frac{t}{Z(x,y)}, R(k)\right\rangle} \\ y' = \frac{r_{1,2}x+r_{2,2}y+r_{3,2}-\left\langle \frac{t}{Z(x,y)}, R(j)\right\rangle}{r_{1,3}x+r_{2,3}y+r_{3,3}-\left\langle \frac{t}{Z(x,y)}, R(k)\right\rangle} \end{cases}$$

Under three hypotheses, the more limiting one being a quasi-constant depth:

$$\begin{pmatrix} x'-x \\ y'-y \end{pmatrix} \simeq \begin{pmatrix} A-\alpha\sin\theta \\ B+\alpha\cos\theta \end{pmatrix} + \begin{pmatrix} -C & \beta \\ -\beta & -C \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} -\alpha\sin\theta & \alpha\cos\theta & 0 \\ 0 & -\alpha\sin\theta & \alpha\cos\theta \end{pmatrix} \begin{pmatrix} x^2 \\ xy \\ y^2 \end{pmatrix}$$

A differential algorithm

Minimization over Θ of the quantity $\sum_{(x,y)\in S} (u_\Theta(x,y) - u(x,y))^2$.

u_Θ is linear in $(c_1, c_2, a_1, a_2, q_1, q_2)$, where

$$\begin{aligned} c_1 &= A - \alpha \sin\theta \\ c_2 &= B + \alpha \cos\theta \\ a_1 &= -C \\ a_2 &= \beta \\ q_1 &= -\alpha \sin\theta \\ q_2 &= \alpha \cos\theta \end{aligned}$$

We use a classical least-square method using in input an optical flow computed by Horn-Schunk method.

Jonchéry's algorithm

Jonchéry's idea: minimize in mean over Θ the quantity

$$DF_{\Theta,\xi}(x,y) = g((x,y) + u_{\Theta}(x,y)) - f(x,y) + \xi$$

Incremental scheme:

$$(\Theta_{k+1}, \xi_{k+1}) = (\Theta_k, \xi_k) + (\Delta\Theta_k, \Delta\xi_k)$$

Limited development at first order:

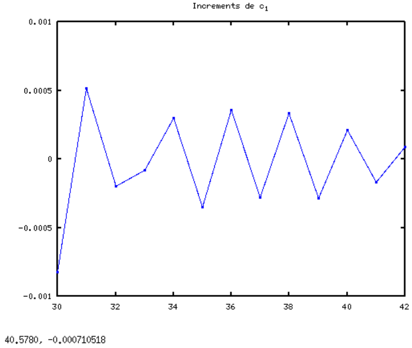
$$DF_{\Theta_{k+1},\xi_{k+1}} \simeq r_{\Delta\Theta_k,\Delta\zeta_k} := DF_{\Theta_k,\zeta_k}(x,y) + \nabla g((x,y) + u_{\Theta_k}(x,y)) \cdot u_{\Delta\Theta_k}(x,y) + \Delta\zeta_k$$

Computation of $(\Delta\Theta_k, \Delta\xi_k)$: minimization of the quantity

$$\sum_{(x,y)\in S} r^2_{\Delta\Theta_k,\Delta\zeta_k}$$

Stopping criterion

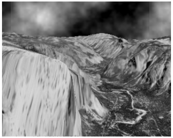
The increments oscillate after enough iterations:



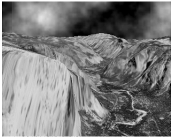
At step N, we stop the iterations if $\left|\sum_{k=N-5}^{N} \Delta {a_1}_k\right| \leq \frac{|\Delta {a_1}_N - \Delta {a_1}_{N-1}|}{2}$.

Experimentations

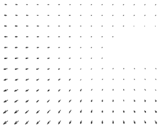
- Scenes satisfying the hypotheses
- Scenes with two depth plans
- Scenes with a small object in movement
- Textures
- Scenes with many depths



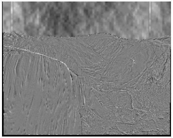
I_1



I_2



Optical flow



Warped difference

Comparison between the two algorithms

- Running times are equivalent.

Pair of images	Jonchéry's algorithm	Differential algorithm
baboon	1,01	0,91
vcbox	4,25	1,32
pepsi-complete	0,60	0,65
street	1,30	0,57
fortuny	2,74	4,57
urban	5,56	4,26
homography	2,24	0,99
pluto	9,70	29,04

Table: Running times in seconds

- However, Jonchéry's algorithm can adress larger motions.

	θ	α	β	A	B	C
Expected	any	0	$8.73 \cdot 10^{-2}$	0	0	0
Jonchéry	2.06	$1.55 \cdot 10^{-4}$	$8.65 \cdot 10^{-2}$	$3.60 \cdot 10^{-4}$	$-6.70 \cdot 10^{-5}$	$7.57 \cdot 10^{-3}$
Differential	4.12	$8.021 \cdot 10^{-2}$	$7.96 \cdot 10^{-2}$	$-7.39 \cdot 10^{-2}$	$4.50 \cdot 10^{-2}$	$3.07 \cdot 10^{-2}$

Table: Result of the algorithms for a rotation of 5 degrees

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