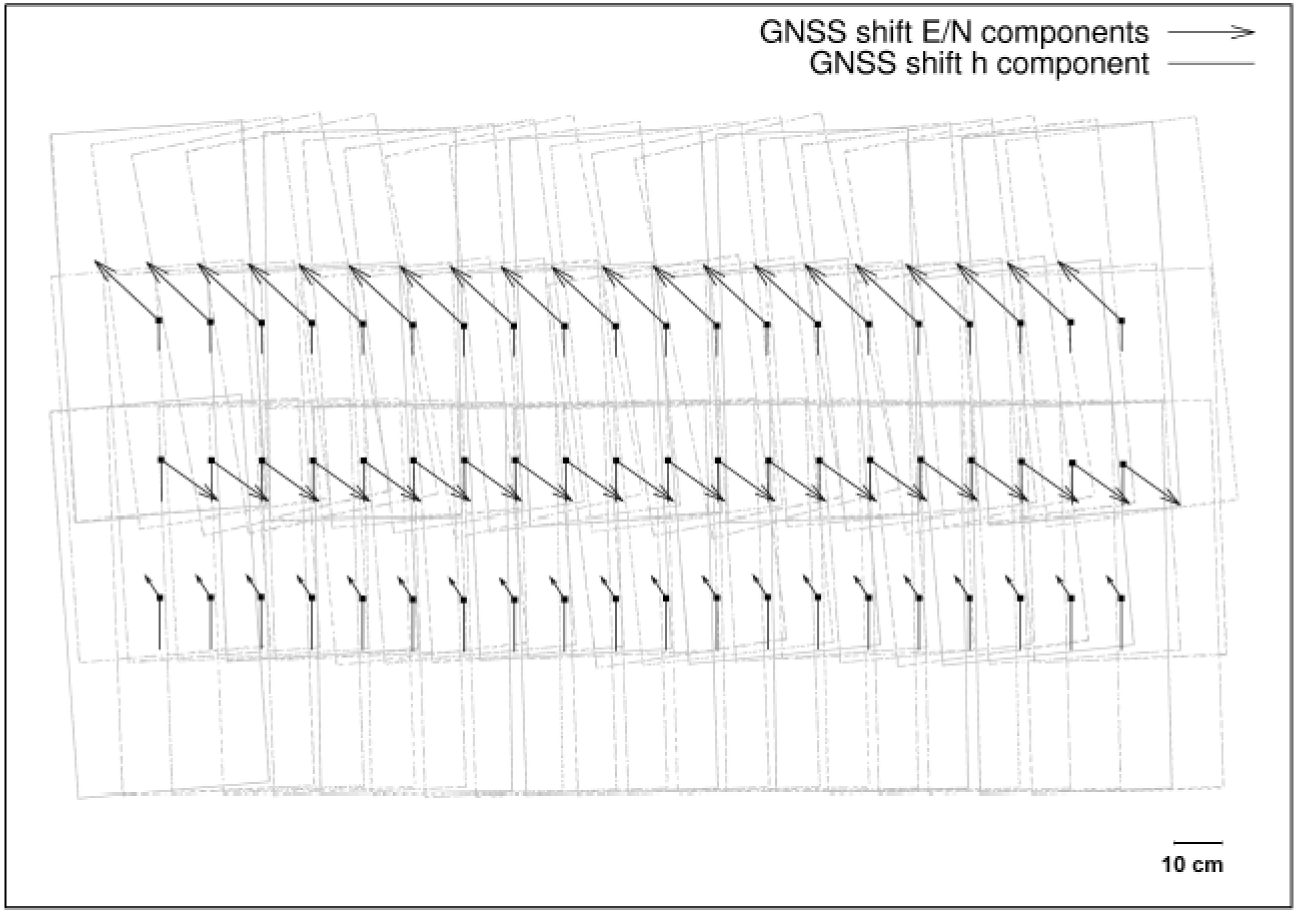
EuroCOW 2014, Castelldefels

Pose versus state: are sensor position & attitude sufficient for modern photogrammetry and remote sensing?

I.Colomina, CTTC
M.Blázquez, GeoNumerics

What is this?



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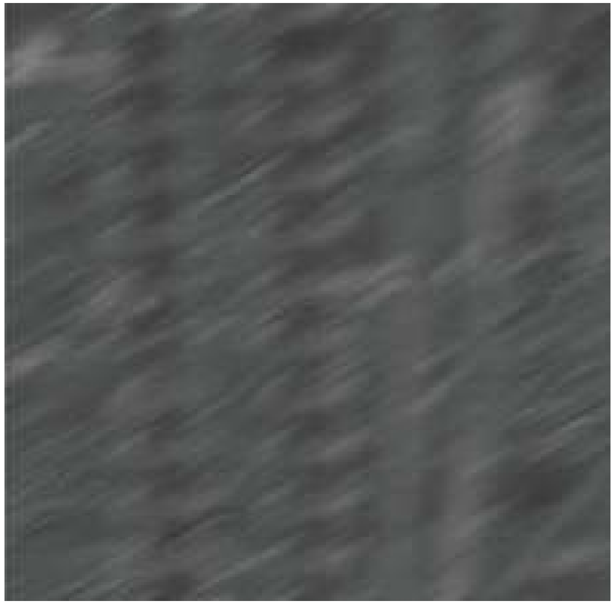
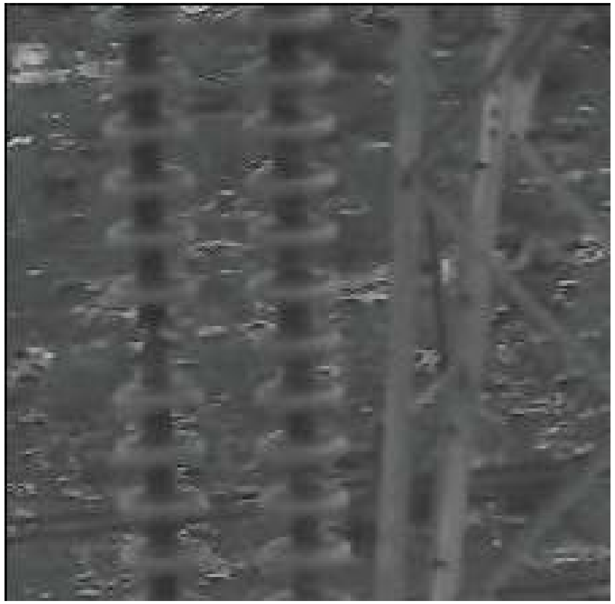
…

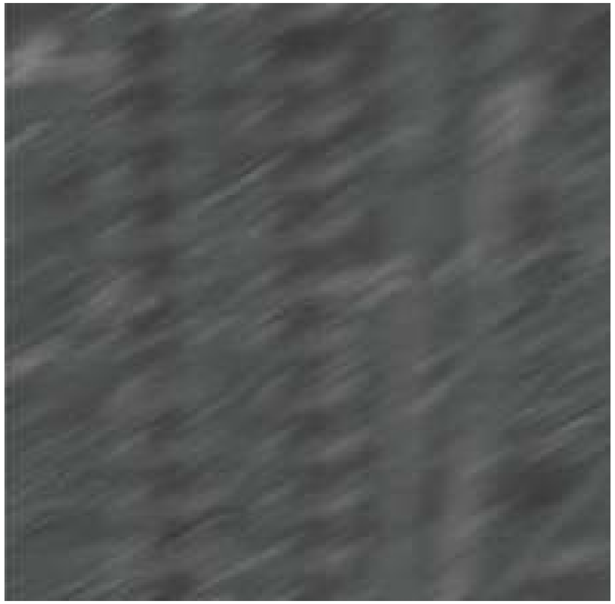
synchronisation error!

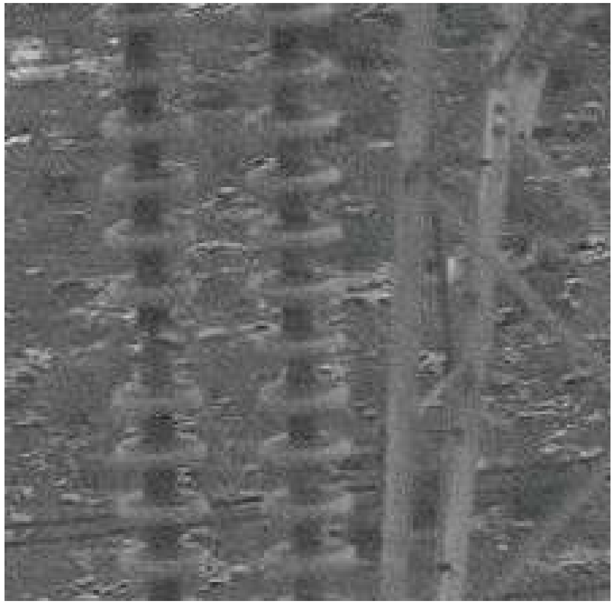
What is this?



Montion-induced blur.







Tong,W-g., Pei, Y-l., Li,B-s., Xu, R-j., 2011. Blurred Image Processing of Aerial Image Based on Improved Wiener Filter and Wavelet Transform. Electric Information and Control Engineering (ICEICE), 2011 International Conference on. Wuhan, China

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What is this?

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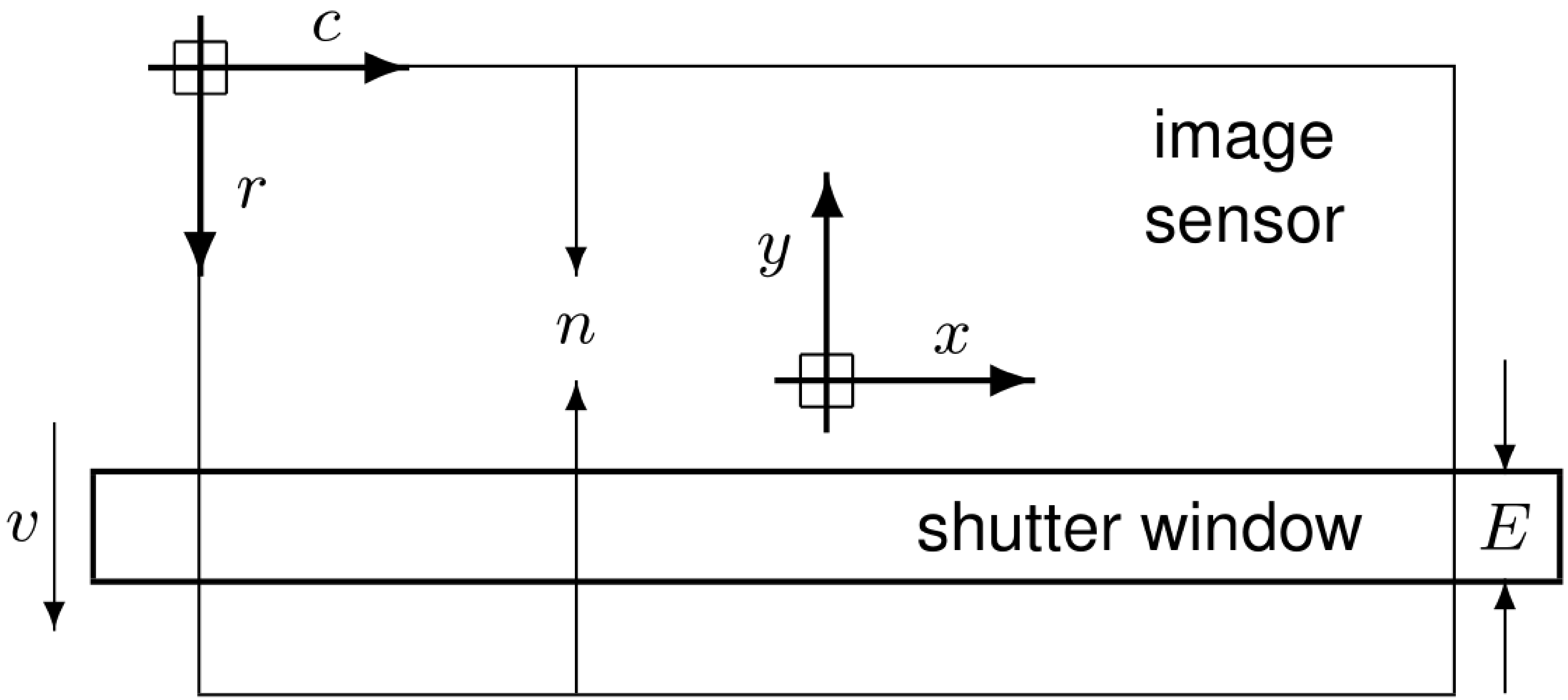
Focal-plane shutter effect



In a number of problems we were missing the camera’s linear & angular velocity.

And therefore we can ask ourselves the question: orientation or orientation++?

Agenda

1. Sensor state parameters
2. Mathematical structure
3. How to compute them
4. Applications
   - image deblurring
   - sensor-system synchronization
   - focal-plane shutter geometry modeling

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Sensor state parameters

$$s^l_c = (\,p^l, v^l, \gamma^l_c, \omega^c_{lc}\,)$$

$$o^l_c = (\,p^l, \qquad \gamma^l_c \qquad)$$

$$\dot{p}^l = v^l, \quad \dot{R}(\gamma)^l_c = R(\gamma)^l_c \Omega(\omega)^c_{lc}.$$

Mathematical structure of o_c^l

$$
\begin{array}{lcl}
p^l & \in & \Re^3 \\
SO(3) & & \text{special orthogonal group of } \Re^3 \\
 & & \\
SE(3) & & \text{special euclidean group of } \Re^3 \\
SE(3) & = & SO(3) \rtimes \Re^3 \\
SE(3) & & \text{is a Lie group under the operator}
\end{array}
$$

$$
\begin{bmatrix} R(\gamma) & p \\ 0 & 1 \end{bmatrix}
$$

Mathematical structure of s_c^l

$$
\begin{array}{lcl}
p^l & \in & \Re^3 \\
v^l & \in & \Re^3 \\
SO(3) & & \text{special orthogonal group of } \Re^3 \\
W(3) & & \text{skew symmetric matrices of } \Re^3
\end{array}
$$

geometrics numerics

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Mathematical structure of s_c^l

$\Re^3 \times \Re^3 \times SO(3) \times W(3)$ is a group under

$$\begin{bmatrix} R(\gamma) & R(\gamma)\Omega & v \\ 0 & R(\gamma) & p \\ 0 & 0 & 1 \end{bmatrix}$$

Mathematical structure of s_c^l

$$\begin{bmatrix} \varphi'(x) \\ \varphi(x) \\ 1 \end{bmatrix} = \begin{bmatrix} R(\gamma) & R(\gamma)\Omega & v \\ 0 & R(\gamma) & p \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \\ x \\ 1 \end{bmatrix} = T \begin{bmatrix} \dot{x} \\ x \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x^l(t) \\ \dot{x}^l(t) \end{bmatrix} = \begin{bmatrix} R(\gamma)^l_{c(t)}\, x^{c(t)} + p^l_{c(t)} \\ R(\gamma)^l_{c(t)} \Omega^{c(t)}_{l\,c(t)}\, x^{c(t)} + R(\gamma)^l_{c(t)}\, \dot{x}^{c(t)} + \dot{p}^l_{c(t)} \end{bmatrix}$$

Mathematical structure of s_c^l

$$\begin{bmatrix} \varphi'(x) \\ \varphi(x) \\ 1 \end{bmatrix} = \begin{bmatrix} R(\gamma) & R(\gamma)\Omega & v \\ 0 & R(\gamma) & p \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \\ x \\ 1 \end{bmatrix} = T \begin{bmatrix} \dot{x} \\ x \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x^l(t) \\ \dot{x}^l(t) \end{bmatrix} = \begin{bmatrix} R(\gamma)^l_{c(t)}\, x^{c(t)} + p^l_{c(t)} \\ R(\gamma)^l_{c(t)}\Omega^{c(t)}_{l\,c(t)}\, x^{c(t)} + R(\gamma)^l_{c(t)}\, \dot{x}^{c(t)} + \dot{p}^l_{c(t)} \end{bmatrix}$$

Computation

- from INS/GNSS integration & system calibration

$$\Omega(\omega)^c_{lc} = R^c_b \, \Omega(\omega)^b_{lb} R^b_c$$

plus two strategies:

- extend the INS differential eq. of motion;
- or correct angular rates with calibration states

- from orientation parameters in time-tagged image sequences

$$(t_k - t_{k-1})\Omega^k_{k-1,k} = \log R^k_{k-1}$$

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Computation

- from orientation parameters in time-tagged image sequences

$$(t_k - t_{k-1})\Omega^k_{k-1,k} = \log R^k_{k-1}$$

$$\Omega(\omega)^k_{lk} = R^k_{k-1}\Omega^{k-1}_{l,k-1}R^{k-1}_k + \Omega^k_{k-1,k}$$

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APPS: motion deblurring

- Blurred and latent images. Blur kernel.

$$B + v = L \otimes k$$

- Deconvolution: integral equation
  - blind deconvolution: *L, k* unknown
  - non-blind deconvolution: *L* unknown
- Blur kernel

$$\int\int k(x,y)dxdy = 1$$

$$k(x,y) = P(x,y,e) = \{(x + \delta_x(\tau), y + \delta_y(\tau)\}_{\tau \in [-e/2, e/2]}$$

APPS: motion deblurring

- In general, P(x,y,e) is a curve

$$F(s_c, x^l, p^(t+\tau), R_l^c(\gamma(t+\tau)))$$

- It can be approximated by a straight-line

$$\begin{bmatrix} x \\ y \end{bmatrix} + \frac{\partial F}{\partial(s_c, x^l, p^l(t), R_l^c(t))} \cdot \frac{\partial(s_c, x^l, p^l(t), R_l^c(t))}{\partial \tau} \cdot \tau$$

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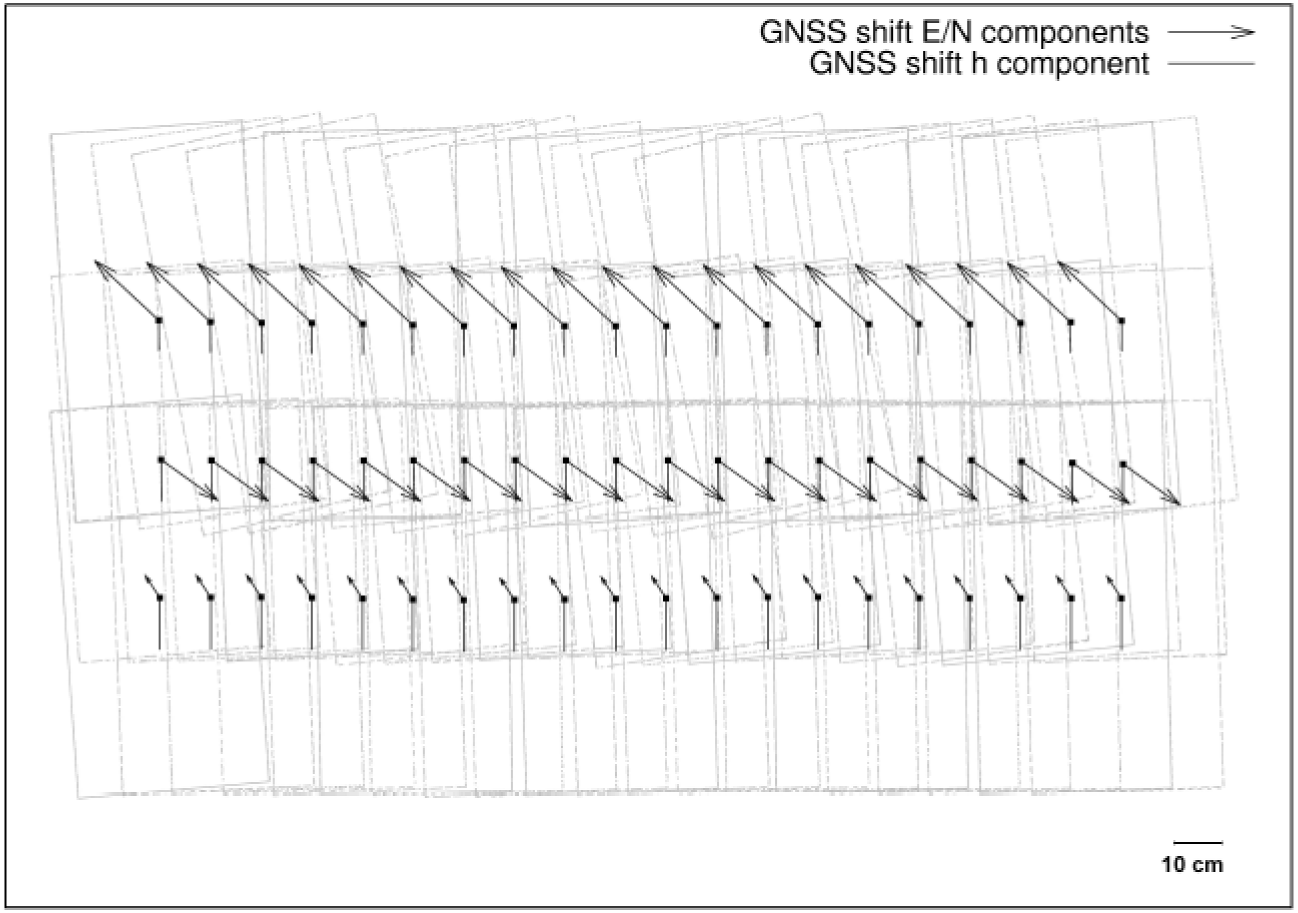
APPS: synchronisation



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synchronisation

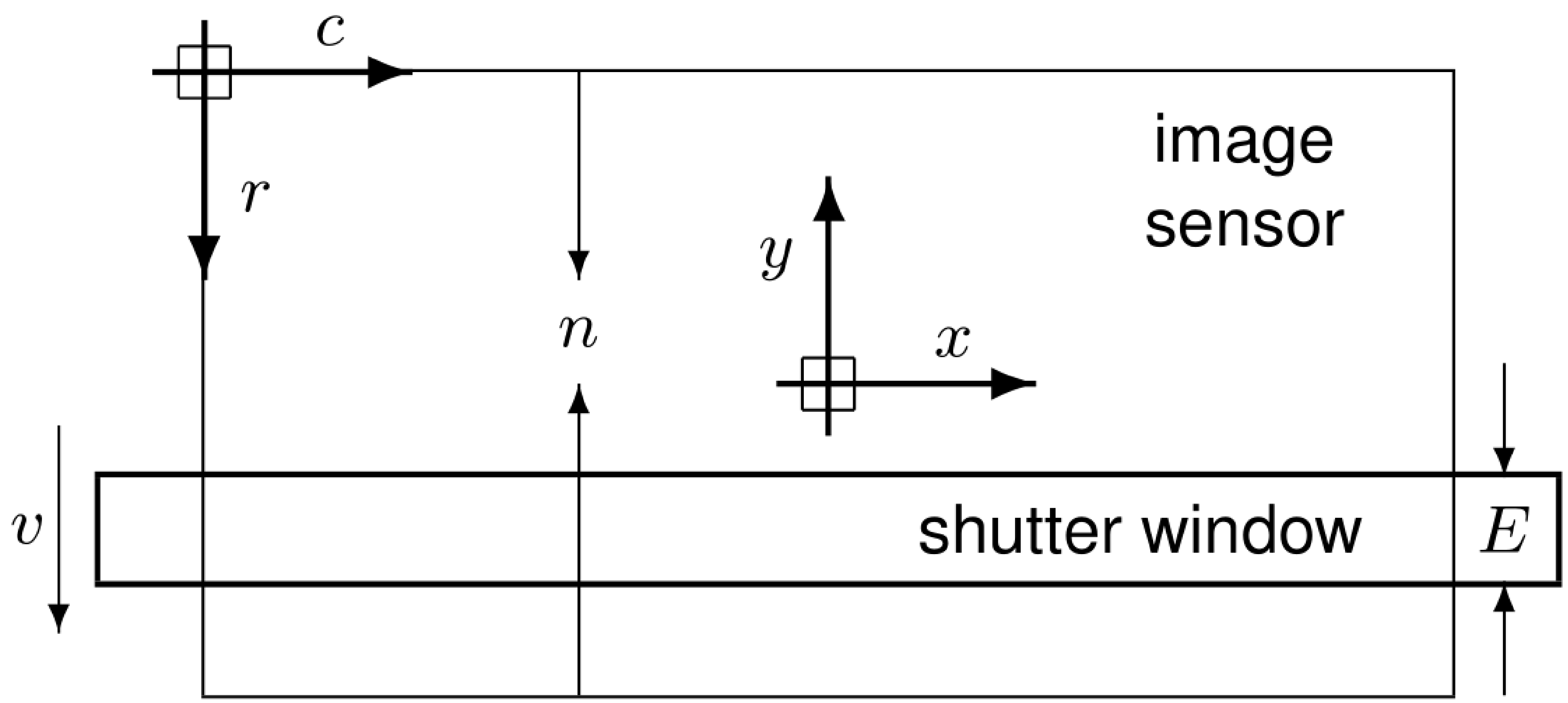
$$\tilde{\mathrm{x}}^{\mathrm{l}} + \tilde{\mathrm{v}}_{\mathrm{x}}^{\mathrm{l}} =$$

$$\tilde{\mathrm{X}}^{\mathrm{l}} + \mathrm{R}_{\mathrm{c}}^{\mathrm{l}}(\Gamma) \cdot (\tilde{\mathrm{A}}^{\mathrm{c}} + \tilde{N}^{c}) + \tilde{\mathrm{S}}^{\mathrm{l}} - \boxed{(\tilde{\mathbf{v}}^{\mathrm{l}} + \tilde{\mathrm{v}}_{\mathbf{v}}^{\mathrm{l}}) \cdot \Delta \mathrm{t},}$$

$$\mathrm{R}_{\mathrm{c}}^{\mathrm{l}}(\Gamma) =$$

$$R_{l'}^{l} \cdot [\mathrm{R}_{\mathrm{b}'}^{\mathrm{l}'}(\chi + \tilde{\mathrm{v}}_{\chi}) + \boxed{\dot{\mathrm{R}}_{\mathrm{b}'}^{\mathrm{l}'}(\chi + \tilde{\mathrm{v}}_{\chi}) \cdot \Delta \mathrm{t}}] \cdot R_{b}^{b'} \cdot \mathrm{R}_{\mathrm{c}}^{\mathrm{b}}(\Upsilon)$$

APPS: focal-plane shutter



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Focal-plane shutter model

$$x^l = p^l + \mu \cdot R_c^l \begin{bmatrix} x \\ y \\ -f \end{bmatrix}^c$$

$$x^l = p^l(x,y) + \mu \cdot R_c^l(x,y) \begin{bmatrix} x \\ y \\ -f \end{bmatrix}^c$$

$$p^l(x,y) = p^l + \Delta t(y) \cdot v^l,$$
$$R_c^l(x,y) = R_c^l \cdot (I + \Delta t(y) \cdot R(\omega)_{lc}^c).$$

CONCLUSIONS

- (p,v,γ,ω) extend (p,γ)
- Sensor state parameters (extension of sensor orientation) have a similar [group] mathematica structure to orientation
- They can be easily estimated from INS/GNSS
- Also from image sequences (?) ,,,
- We presented ways to use them in
  - Motion-based image deblurring
  - Sensor-system synchronisation
  - Modeling focal-plane shutter geometry
- We still need to unerstand better the mathematical structure of (p,v,γ,ω)