Estimation of the distance from a surface based on local optic flow divergence

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Overview

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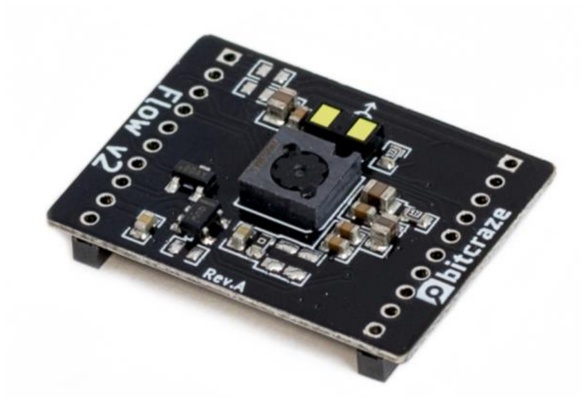
The problem of distance/height estimation

Navigating in an unknown environment
→ Importance of accurate visual distance estimation with minimalistic equipement

Previous studies:

- Stereovision [Moore et al. (2009)]
- Monocular vision for depth perception [Saxena et al. (2007)]
- Optic flow (OF) cues [Serres et al. (2017), Ho et al. (2017)]

Images taken from a stereo pair of cameras, and the depthmap calculated by a stereo system [Saxena et al. (2007)].



Flow deck V2 by Bitcraze [5]

Self-oscillations in honeybees

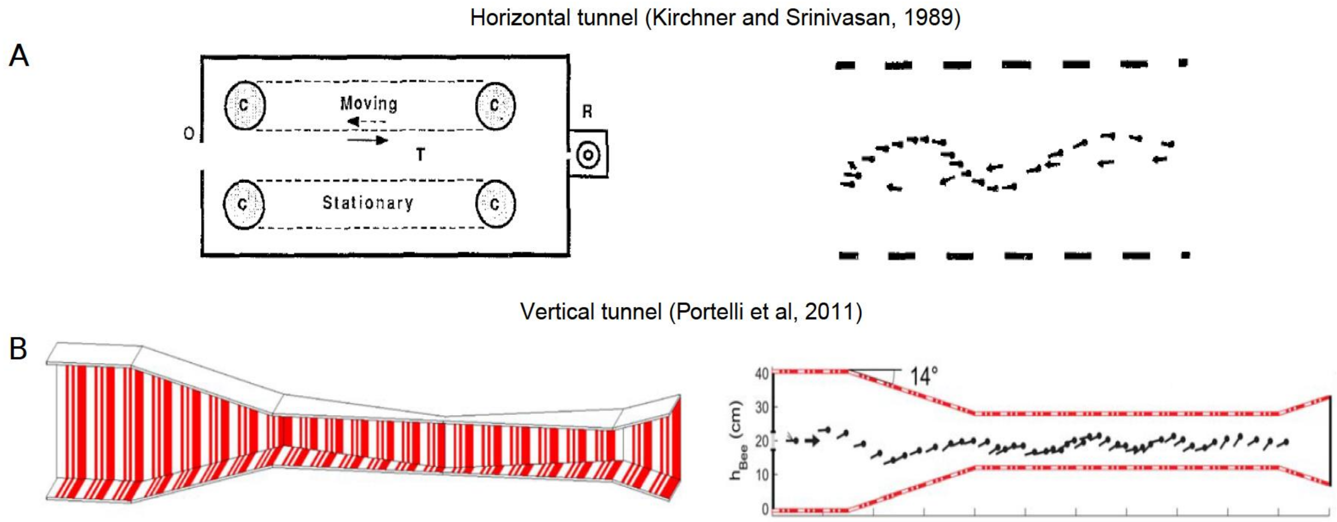
OF divergence: pattern of contractions and expansions in the OF vector field

$$\omega_{DIV}^{th} = \frac{v_h}{h} \qquad (1)$$

↓

used to observe the state vector of the oscillating system

$$X = [h; v_h] \qquad (2)$$

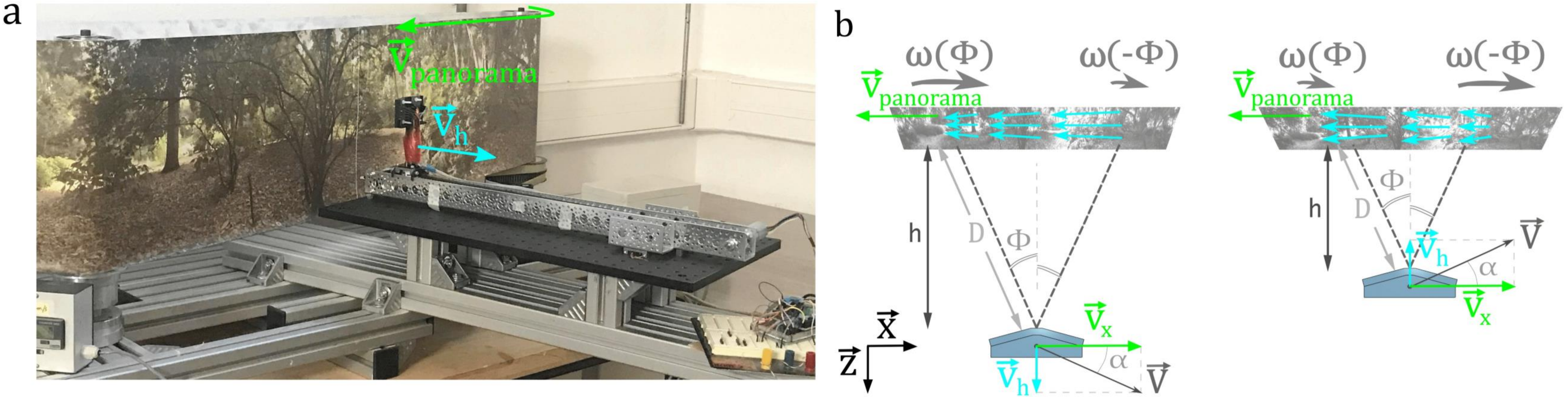


Self-oscillations observed in honeybees in horizontal (A) and vertical (B) tunnels.

Computation of the OF divergence

The OF divergence can be computed as the **subtraction** between the magnitudes measured by two OF sensors.

$$\omega_{DIV}^{meas} = \omega(\phi) - \omega(-\phi) \qquad (3)$$



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Local OF divergence measurement

$$\omega(\phi) = \frac{||\vec{V}||}{D}\sin(\widehat{\vec{D},\vec{V}}) \quad (4) \longrightarrow \quad \omega(\phi) = \frac{\sqrt{v_x^2 + v_h^2}}{D}\sin\left(\frac{\pi}{2} - \phi + \alpha\right) \quad (5)$$

$$\omega(\phi) = \frac{v_x}{D}\sin\left(\frac{\pi}{2} - \phi\right) + \frac{v_h}{D}\sin(\phi) \quad (6)$$

$$\omega(-\phi) = \frac{v_x}{D}\sin\left(\frac{\pi}{2} - \phi\right) - \frac{v_h}{D}\sin(\phi) \quad (7)$$

Using (6) and (7), (3) can be expressed as:

$$\omega(\phi) - \omega(-\phi) = 2\frac{v_h}{D}\sin(\phi) \quad (8)$$

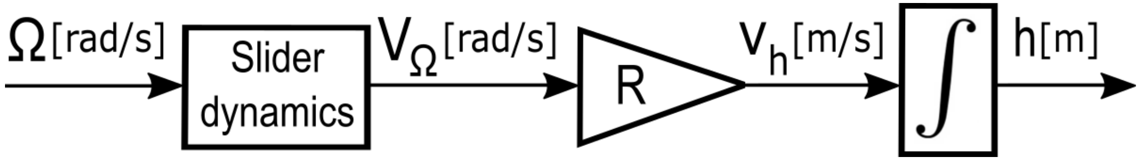
Since $D = h\cos(\phi)$:

$$\omega(\phi) - \omega(-\phi) = 2\frac{v_h}{h}\sin(\phi)\cos(\phi) \quad (9)$$

$$\omega(\phi) - \omega(-\phi) = \frac{v_h}{h}\sin(2\phi) \quad (10)$$

The test bench

The model:



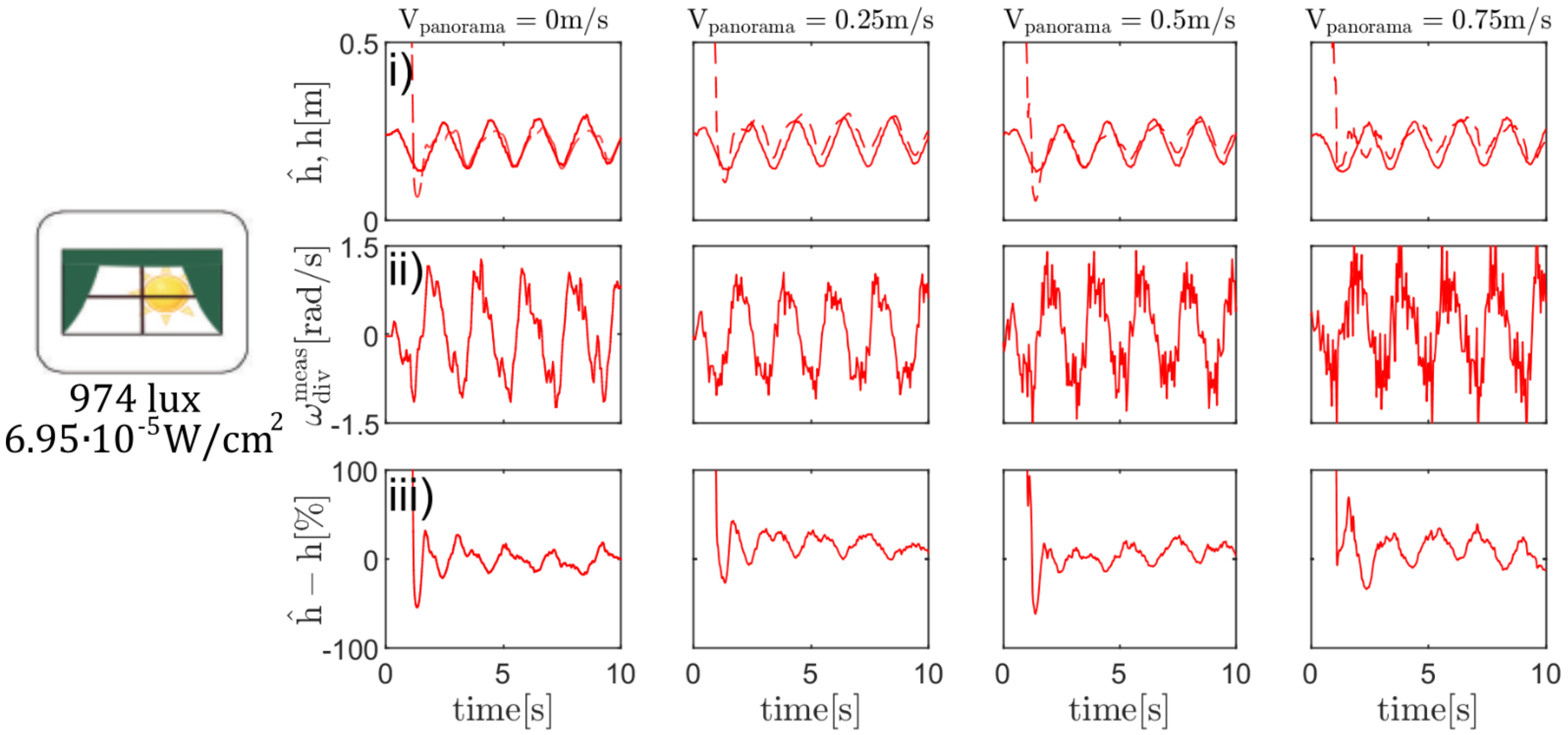
$$\begin{cases} \dot{X} = A \cdot X + B \cdot u = \begin{bmatrix} 0 & 1 \\ 0 & -54.27 \end{bmatrix} X + \begin{bmatrix} 0 \\ 0.3498 \end{bmatrix} u \\ Y = C \cdot X + D \cdot u = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} X \end{cases} \tag{11}$$

Non-linear measurement equation

$$Y = \omega_{DIV} = \frac{v_h}{h} \tag{12}$$

→ use of an Extended Kalman Filter (EKF)

Distance estimation: bright illuminance



Average error values computed after convergence (3s): 0.31%, 12.09%, 3.29% and 8.29%.

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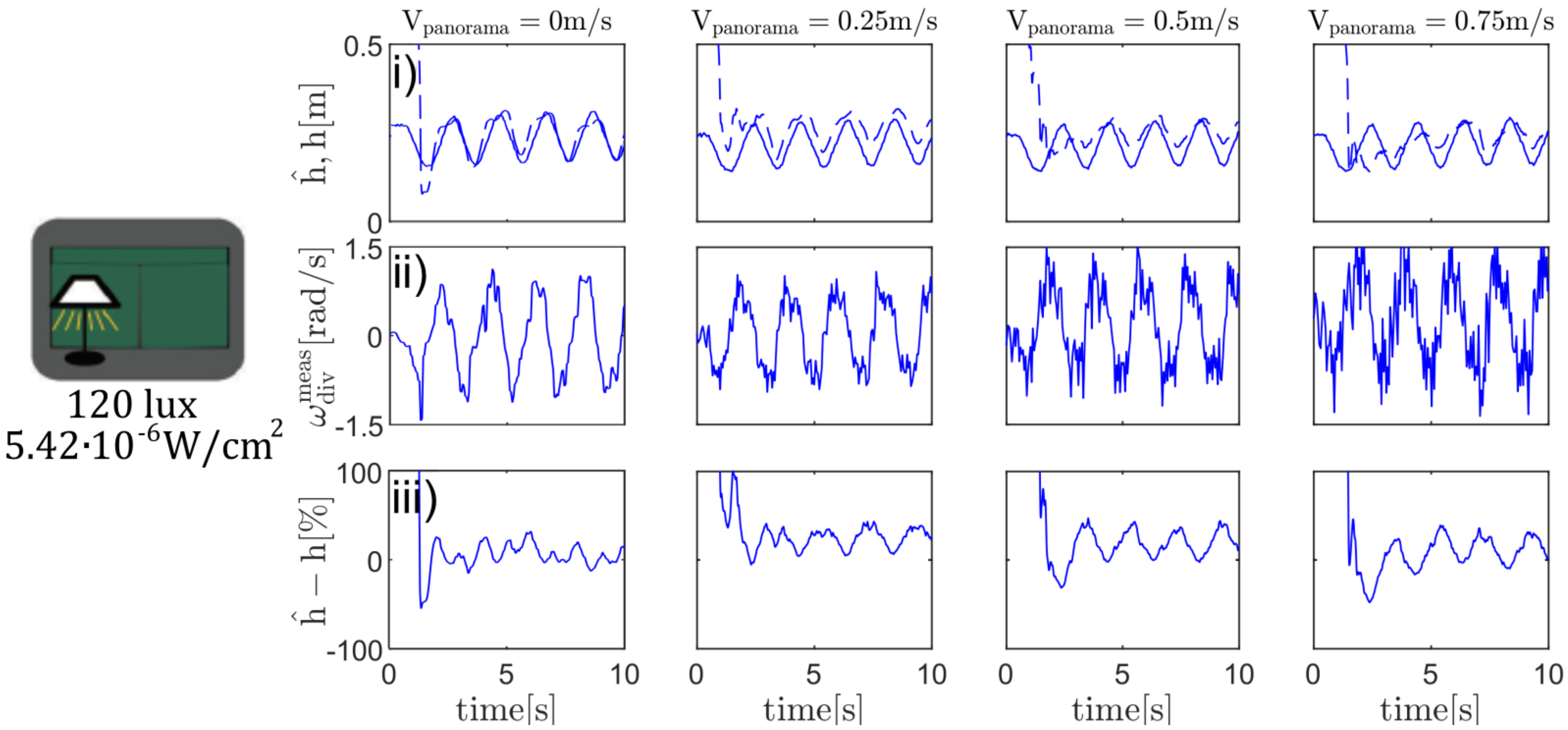
Distance estimation: low illuminance



Average error values computed after convergence (3s): 4.49%, 15.73%, 12.03% and 5.41%.

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Conclusions & Future work

- Reliability of the computation of the OF divergence as the subtraction of two OF magnitudes

- Reliability of the distance estimation performed with OF divergence computed

- Interesting for flying robotic applications

- Future work:
  - ➢ To estimate larger distance with larger ϕ angle
  - ➢ To sense optic flow with wider optical aperture lenses
  - ➢ To test this method on a flying robot in front of a surface

Draco-R UVIFY [8]

Thank you for your attention ☺

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