New Calibration Algorithm for Camera-IMU Sensors

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Contribution

We present a **new algorithm** for estimating the relative translation and orientation between an inertial measurement unit (IMU) and a camera, that are rigidly connected (see photo below).

Motivation

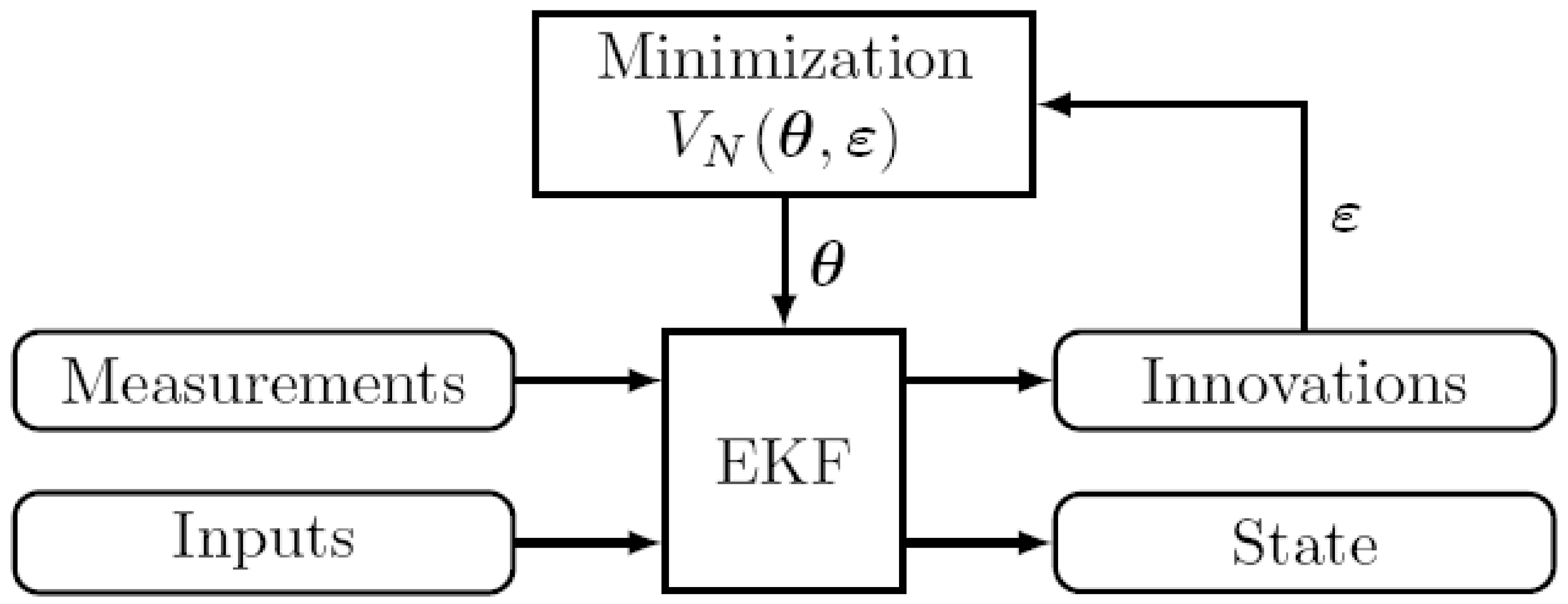
- The **combination** of vision and inertial sensors is very suitable for many applications.
- The present algorithm provides an **easy to use** algorithm which does not require additional hardware, except a piece of paper with a checkerboard pattern.
- For high precision applications, good sensor calibration is **absolutely essential**.

Algorithm

The problem can be cast as a **gray-box** system identification problem. The algorithm is based on a model of the sensor unit motion

$$x_{t+1} = f(x_t, u_t, \theta) + w_t,$$
$$y_t = h(x_t, \theta) + e_t,$$

which of course depends on the relative translation and orientation, here denoted θ.



Based on the model we can form and solve

$$\widehat{\theta} = \arg\min_{\theta} V(\theta, Z),$$

$$V(\theta, Z) = \frac{1}{2}\sum_{t=1}^{N} \|\epsilon_t(\theta)\|^2_{S_t(\theta)^{-1}},$$

where the prediction error $\epsilon_t(\theta)$ is given by

$$\epsilon_t(\theta) = y_t - \hat{y}_{t|t-1}(\theta)$$

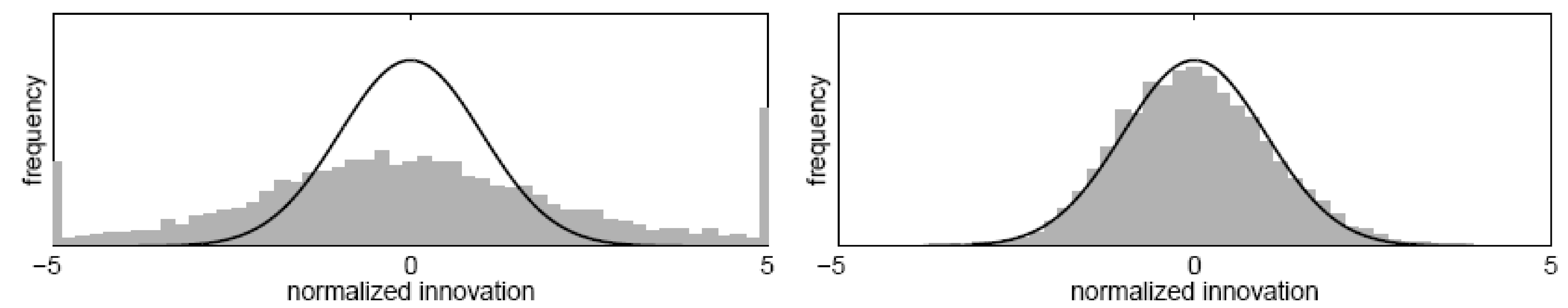
Finally, we make use of an **EKF** to find the predictions.

Experiments

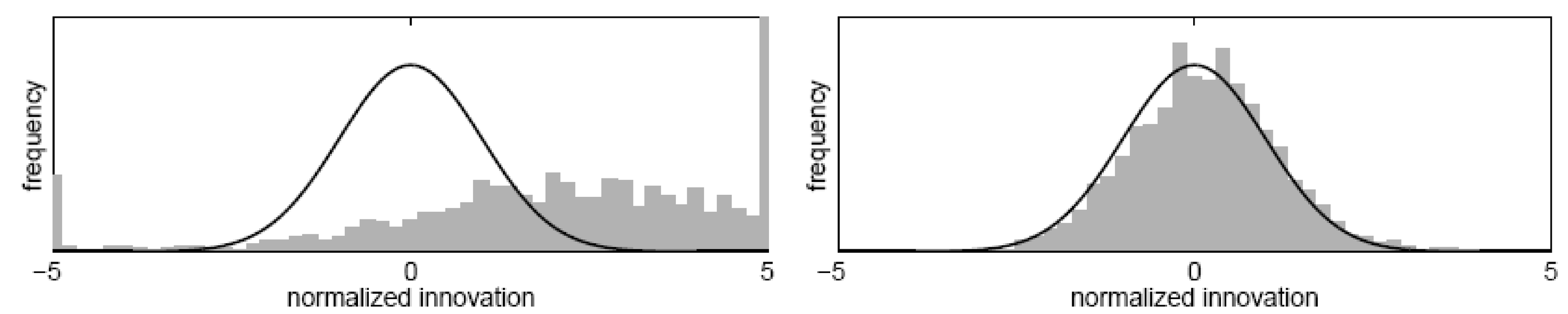
Below we plot the **normalized innovations**

$$\varepsilon_t = S_t^{-1/2}\epsilon_t$$

for validation data using the initial guess and the result from our new algorithm, respectively.

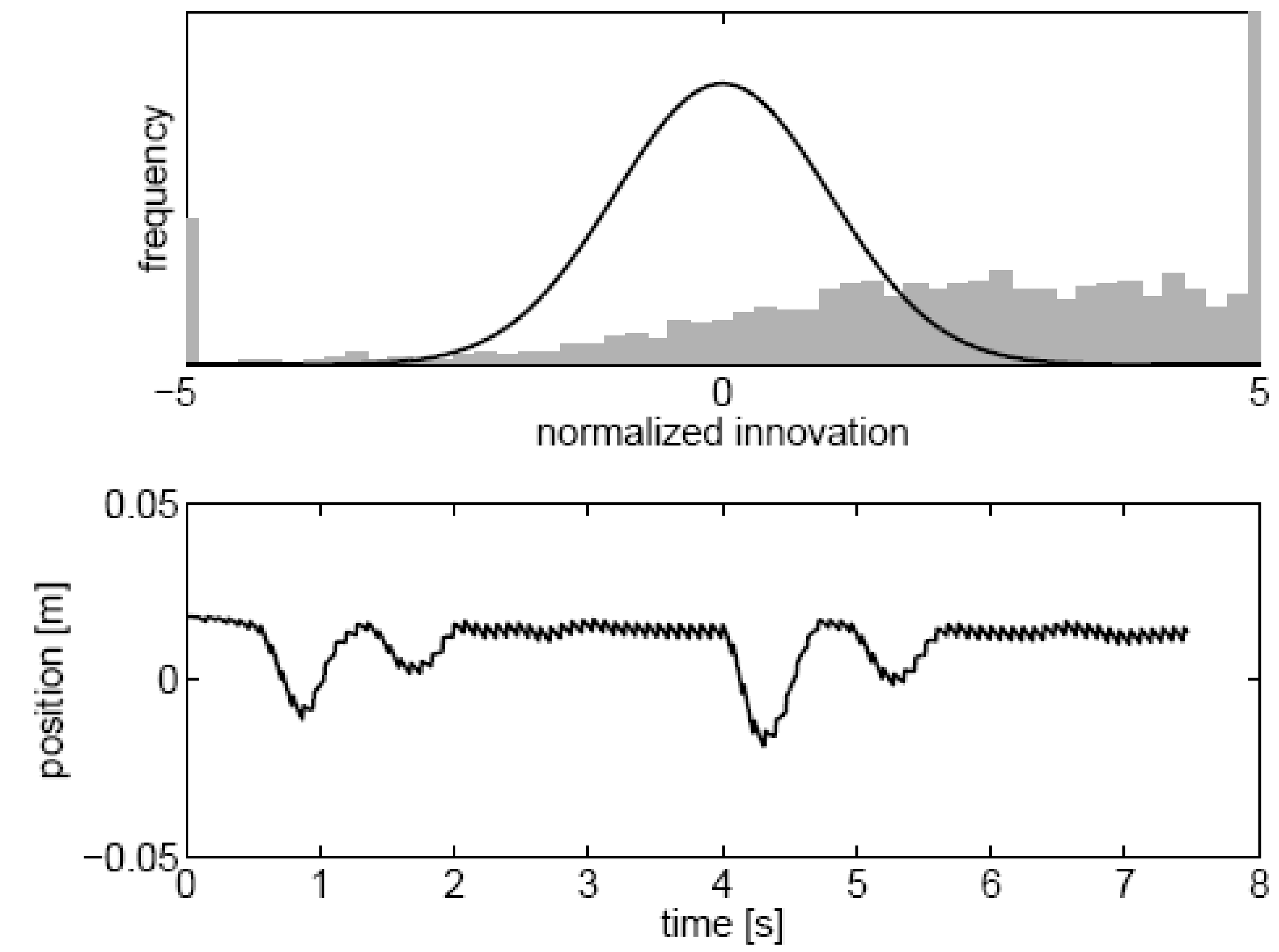


(a) fisheye lens, using $\boldsymbol{\theta}_0$ (b) fisheye lens, using $\hat{\boldsymbol{\theta}}$



(c) perspective lens, using $\boldsymbol{\theta}_0$ (d) perspective lens, using $\hat{\boldsymbol{\theta}}$

In the plot below the identified θ from one sensor unit is used with data from a different unit.



Clearly accurate calibration is **necessary**.