Absolute scale velocity determination combining visual and inertial measurements for micro aerial vehicles

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INRIA

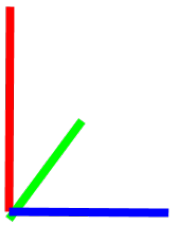
June 24, 2015

Section 1

Sensor fusion

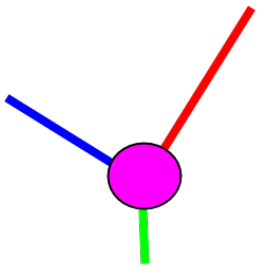
Micro aerial vehicle

Micro aerial vehicle

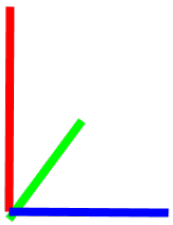


Global Frame

Micro aerial vehicle

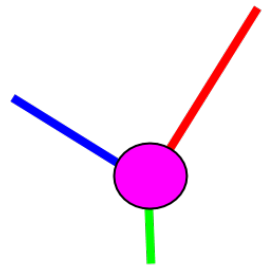


Particle



Global Frame

Micro aerial vehicle



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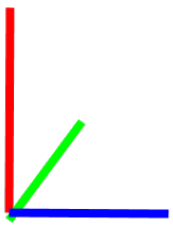


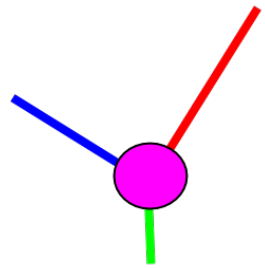
Global Frame

A basic state vector:

$$X = \begin{bmatrix} r \\ \dot{r} \\ q \end{bmatrix}$$

- r position;
- $\dot{r}$ velocity;
- q orientation.

Micro aerial vehicle



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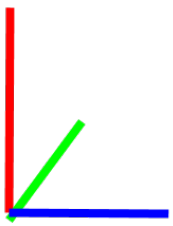

Global Frame

A basic state vector:

$$X = \begin{bmatrix} r \\ \dot{r} \\ q \end{bmatrix}$$

- r position;
- $\dot{r}$ velocity;
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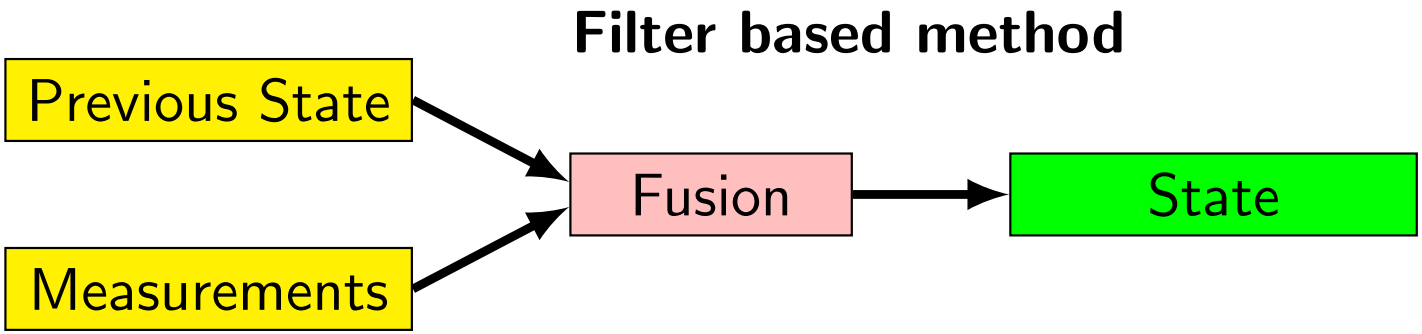
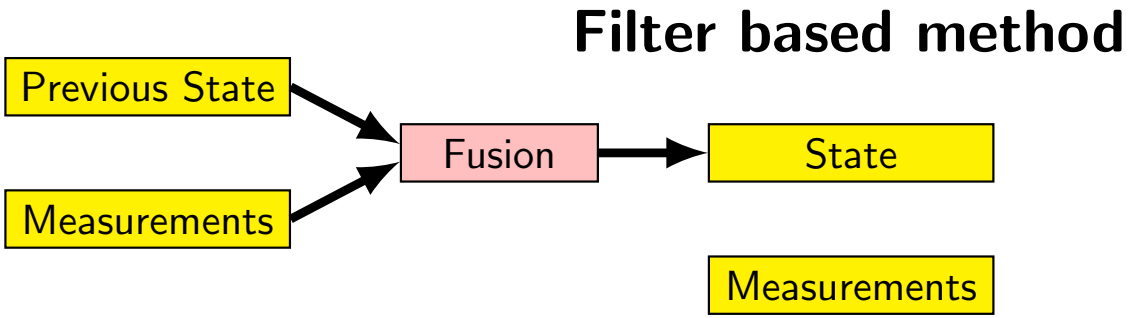
The goal of sensor fusion is to recover the state X

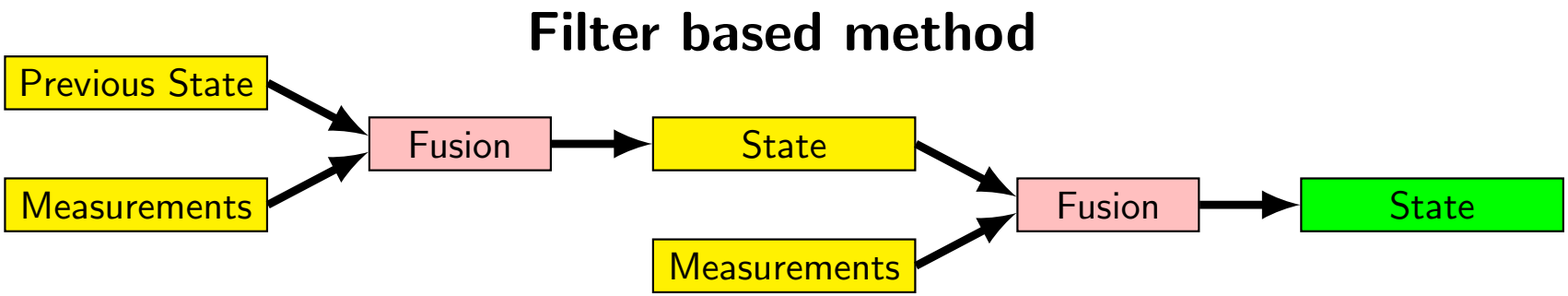
Visual-inertial sensor fusion



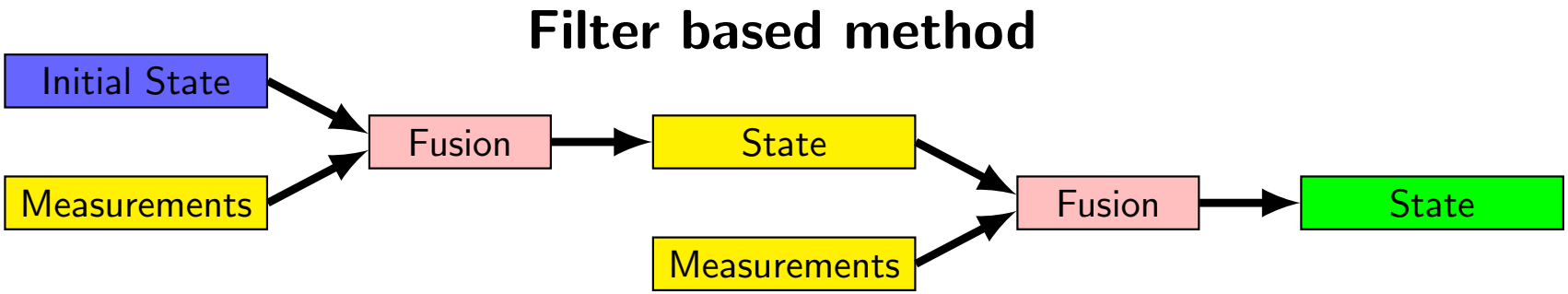
Visual-inertial sensor fusion



Visual-inertial sensor fusion

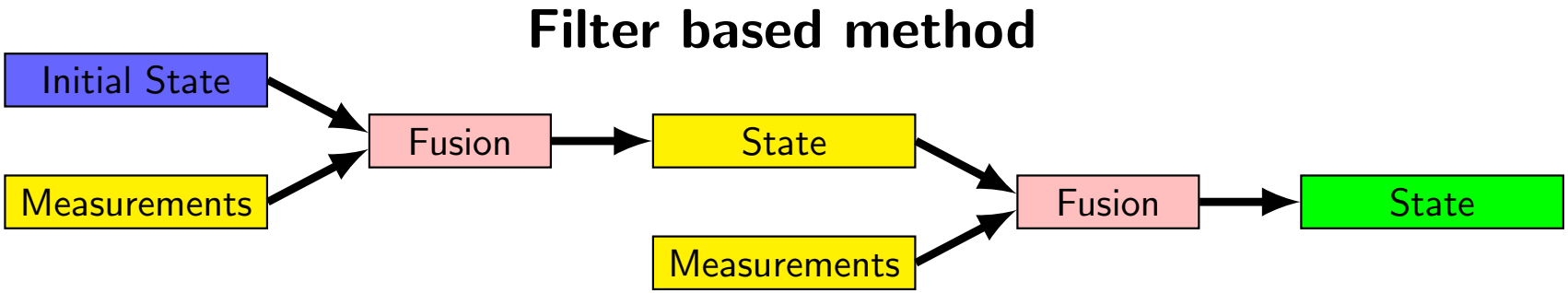


Visual-inertial sensor fusion

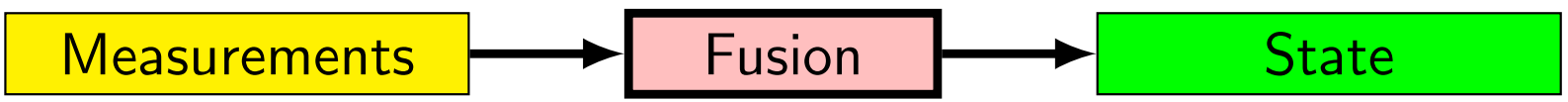


How to recover the **initial state**?

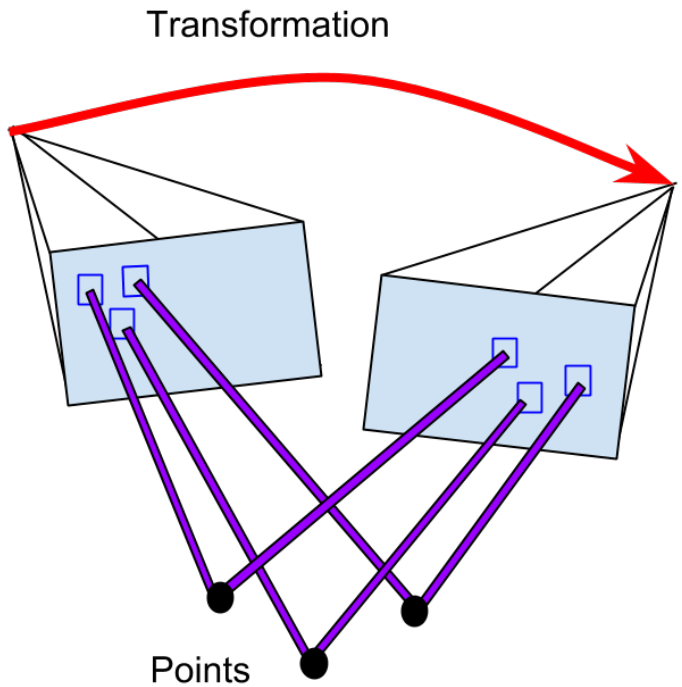
Visual-inertial sensor fusion



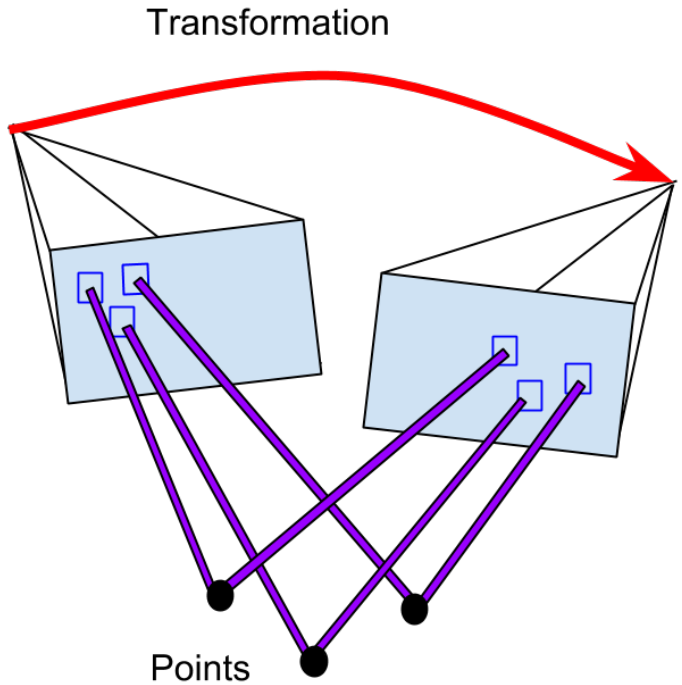
How to recover the **initial state**?
We need a **deterministic solution**



Deterministic solutions in Computer Vision

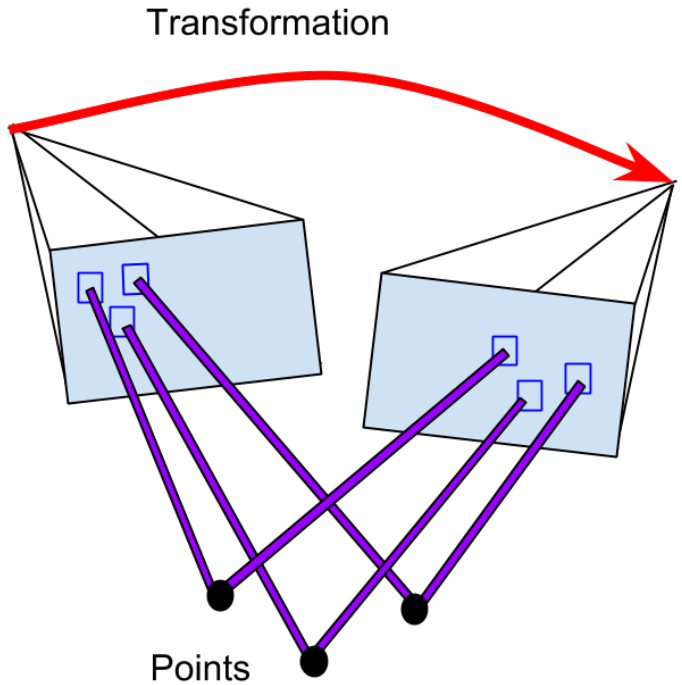


Deterministic solutions in Computer Vision



- 8-point algorithm;
- sparse model-based image alignment;
- ...

Deterministic solutions in Computer Vision



- 8-point algorithm;
- sparse model-based image alignment;
- ...

But the relative translation and distance to features are recovered only **up to scale**

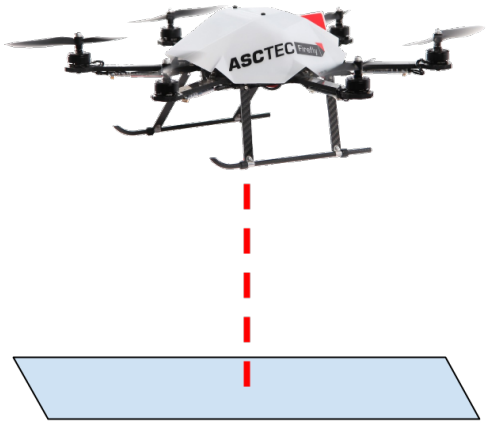
Absolute scale from visual measurements

How big is this building?

Absolute scale from visual measurements

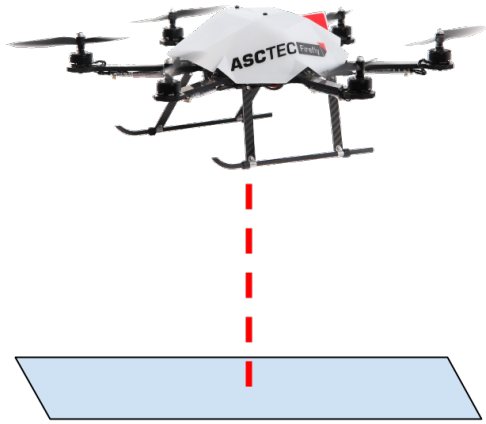
Methods to recover the absolute scale

Methods to recover the absolute scale



Methods to recover the absolute scale

Not suited to unknown environments



Unprecise, works only in hover

Inertial Measurement Unit (IMU)

The IMU consists of two sensors providing **physical quantities**:

- Accelerometer: linear acceleration (m/s^2);
- Gyroscope: angular velocity (rad/s).

Title

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The closed-form solution - 2014

Deterministic solution

Input:

- Matching point-features over a time interval;
- Linear acceleration;
- Angular velocity;
- External Camera IMU transformation.

Output:

- Initial velocity;
- Distance to point-features;
- Attitude.

The closed-form solution - 2014

Deterministic solution

Input:

- Matching point-features over a time interval; camera
- Linear acceleration; IMU
- Angular velocity; IMU
- External Camera IMU transformation. calibration

Output:

- Initial velocity; absolute scale
- Distance to point-features; absolute scale
- Attitude.

The closed-form solution - 2014

One equation, verified for all point features, at each observation
Overconstrained linear system

Table of Contents

Problem: noisy sensors

Bias: systematic error

Numerical stability

Small error in input yields big error in the output

Accelerometer bias

Robust

Gyroscope bias

Sensitive
Can we solve this?

Estimating the gyroscope bias

Minimizing the residual WRT gyro bias