



A hybrid opto-inertial Tracking System Prototype

Faisal Kalim

Faisal.kalim@tum.de

Supervisor: Benjamin Busam
Partners: IFL & FRAMOS

Intermediate Presentation

Computer Aided Medical Procedures (CAMP) Technische Universität
München, Germany April 22, 2016



Technische Universität München



JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

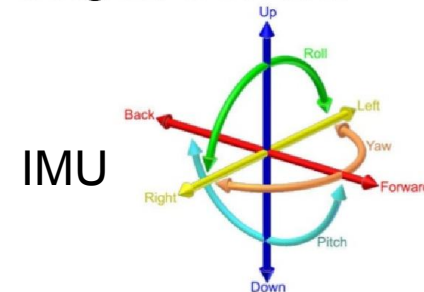
Problem Statement

To develop a software prototype that fuses the data streams of both an inertial measurement unit (IMU) and an optical tracking system (OTS)

Requirements and Specifications

- Tracking
 - Tracking of device based on IMU data
 - Data Fusion
- Evaluation
 - Compare results of IMU based tracking to OTS
- GUI
 - Display individual + hybrid pose values

6 degrees of freedom



IMU

- Accelerometer: Left-Right, Back-Forward, Up-Down
- Gyroscope: Pitch, Roll, Yaw

OTS



B. Busam – Optical Tracking for Medical Applications

<http://image.slidesharecdn.com/mpu6050-slides-160111030027/95/mpu6050-imu-with-arduino-5-638.jpg?cb=1455865197>



Current Status

- IMU interfacing with computer
- Calibration of IMU



Calibration of Accelerometer

➤ Calibration Model

➤ Calibration Method

$$\begin{pmatrix} A_x \\ A_y \\ A_z \end{pmatrix} = \begin{pmatrix} 1 & M_{xy} & M_{xz} \\ M_{yx} & 1 & M_{yz} \\ M_{zx} & M_{zy} & 1 \end{pmatrix} * \begin{pmatrix} S_x \\ S_y \\ S_z \end{pmatrix} * \begin{pmatrix} V_x & - & B_x \\ V_y & - & B_y \\ V_z & - & B_z \end{pmatrix}$$

- Measurements in different static position
- Net acceleration in static condition equals g
- Gauss-Newton nonlinear optimization

➤ Results

$$\begin{matrix} \text{➤ } M = & \begin{pmatrix} 0.9992 & -0.0012 & 0.0090 \\ -0.0012 & 0.9976 & -0.0195 \\ 0.0090 & -0.0195 & 0.9971 \end{pmatrix} & B = & \begin{pmatrix} -0.0266 \\ 0.0095 \\ 0.0218 \end{pmatrix} \end{matrix}$$



Iuri Frosio, Federico Pedersini, N. Alberto Borghese "Autocalibration of MEMS Accelerometers"
 IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 58, NO. 6, JUNE 2009

Current Status

- IMU interfacing with computer
- Calibration of IMU
 - Gyroscope calibration pending
- Kalman filtering



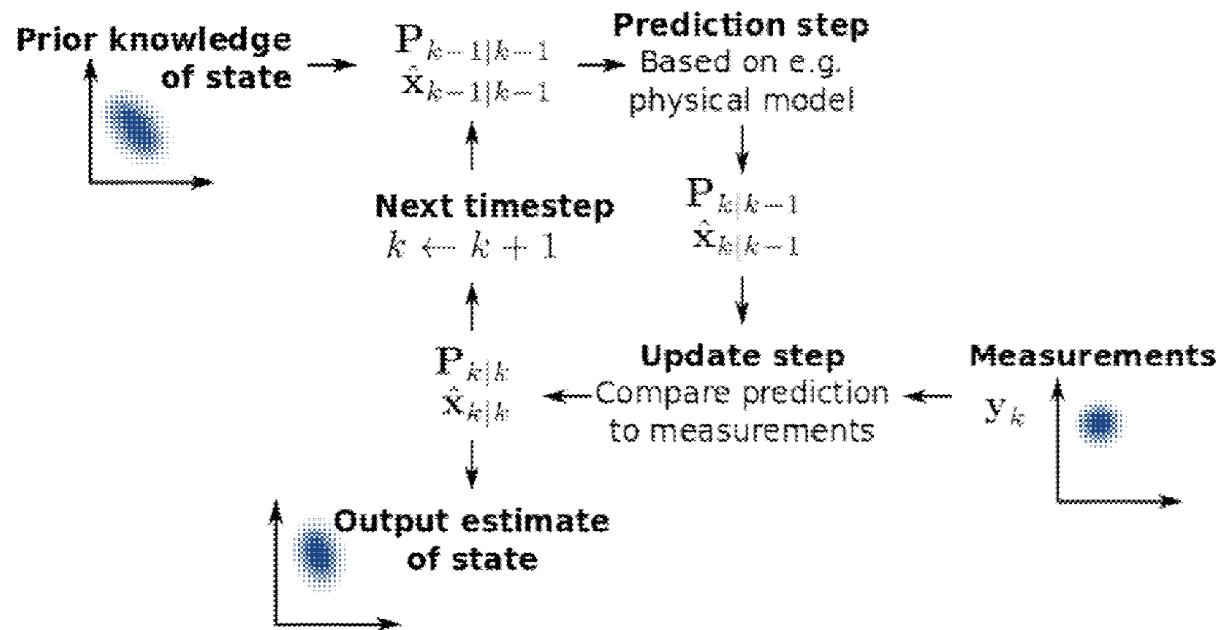
Kalman Filtering

- State Vector
- Process Model
- Measurement Model
- Kalman Filter Cycle

$$\mathbf{x} = (x, y, z, \dot{x}, \dot{y}, \dot{z}, \ddot{x}, \ddot{y}, \ddot{z})^T$$

$$\mathbf{x}_k = A\mathbf{x}_{k-1} + B\mathbf{u}_k + \mathbf{w}_{k-1}$$

$$\mathbf{z}_k = H\mathbf{x}_k + \mathbf{v}_k$$

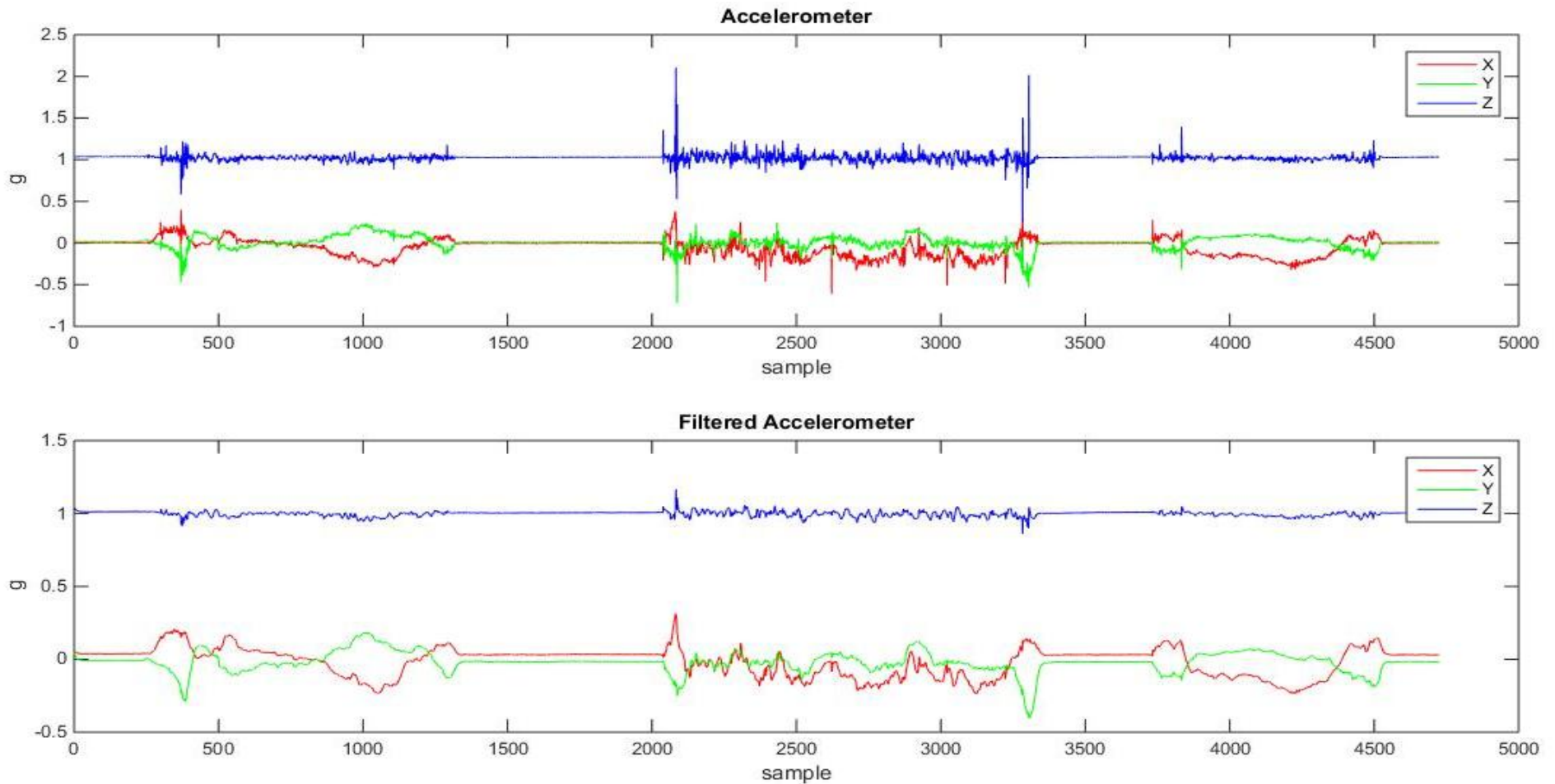


<http://campar.in.tum.de/Chair/KalmanFilter>

https://upload.wikimedia.org/wikipedia/commons/thumb/a/a5/Basic_concept_of_Kalman_filtering.svg/800px-Basic_concept_of_Kalman_filtering.svg.png



Kalman filtering of accelerometer data



Current Status

- IMU interfacing with computer
- Calibration of IMU
 - Gyroscope calibration pending
- Kalman filtering
- Pose Estimation
 - Yaw, Pitch and Roll estimated by AHRS algorithm
(<http://www.x-io.co.uk/open-source-imu-and-ahrs-algorithms/>)
- Tilt compensated acceleration
 - Conversion from IMU frame of reference to earth frame of reference
- Writing code for position and pose estimation



Challenges Faced

- Position estimation is extremely challenging
 - Precise calibration of IMU
 - Navigation grade IMU is more precise
 - How to take into account centripetal acceleration

Grade	Accelerometer Bias Error	Horizontal Position Error [m]			
	[mg]	1s	10s	60s	1hr
Navigation	0.025	0.13 mm	12 mm	0.44 m	1.6 km
Tactical	0.3	1.5 mm	150 mm	5.3 m	19 km
Industrial	3	15 mm	1.5 m	53 m	190 km
Automotive	125	620 mm	60 m	2.2 km	7900 km

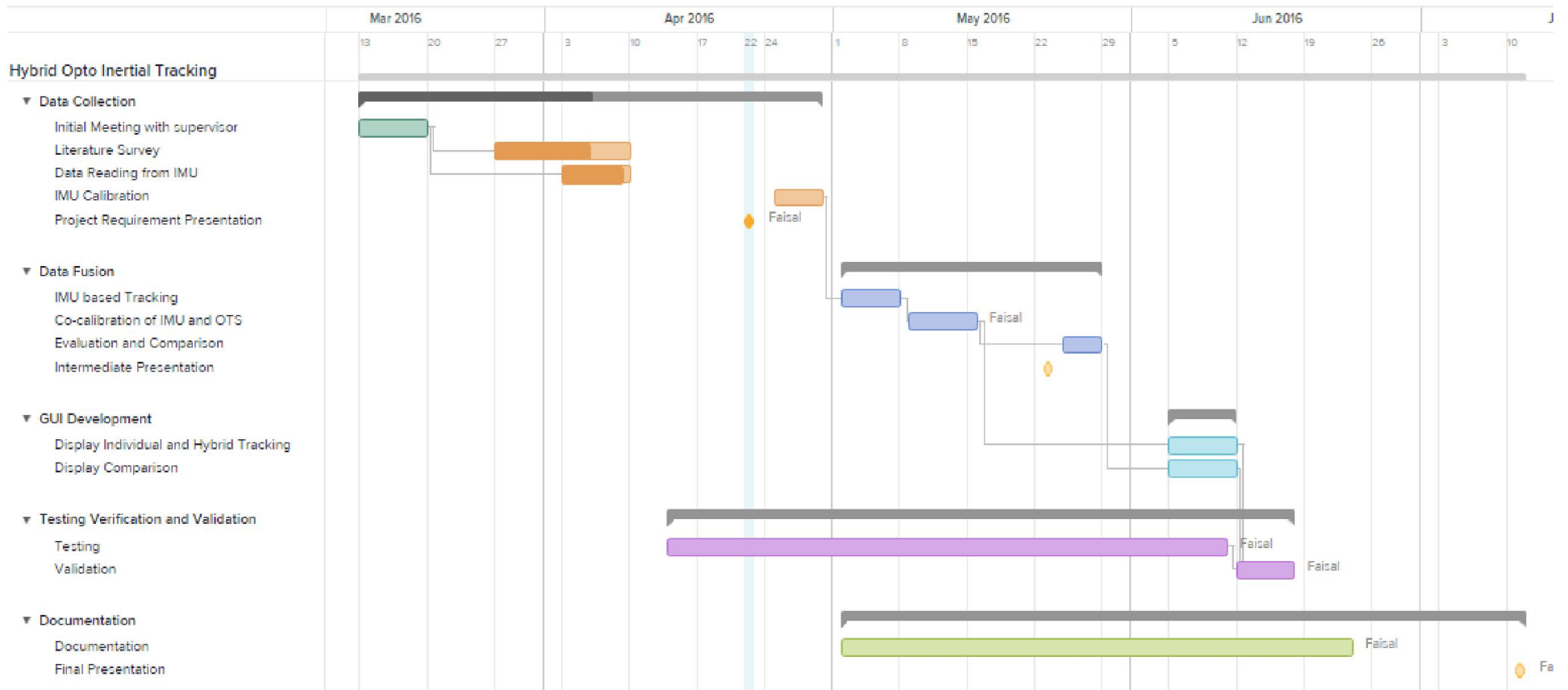
Pending Tasks

- Gyroscope Calibration
- Co-Calibration of OTS Pose and IMU Pose
- Data Fusion
- GUI



<http://www.vectornav.com/support/library/imu-and-ins#unaided-position-estimate>

Gantt Chart [1]



[1] Created with Team Gantt

Thanks



http://www.techlivez.com/wp-content/uploads/2010/07/cloud_question_mark.jpg