



**Faculty of Power and
Aeronautical Engineering**

WARSAW UNIVERSITY OF TECHNOLOGY

Adaptation of inertial navigation systems in robot's positioning systems

Master's diploma seminar

Wojciech Gajda, Eng.

January 23rd, 2023

**Warsaw University
of Technology**



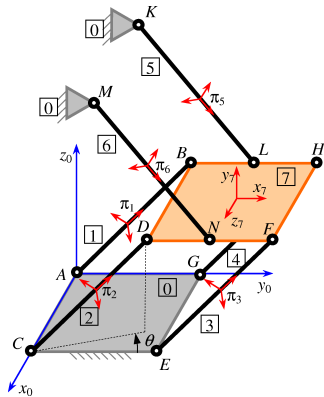
Agenda

1. Introduction
2. The state of knowledge
3. Summary

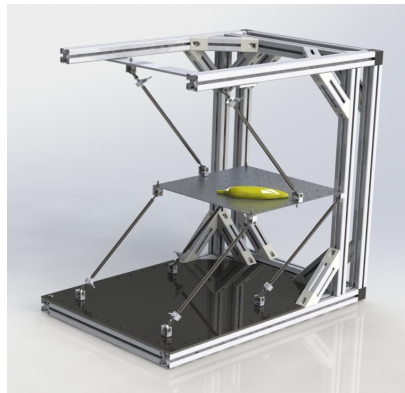
Motivation

Multi-body system with 1 DOF

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Multi-body system with 1 DOF



Render of MBS

Aim of the thesis

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- ▶ Utilizing knowledge of design and constraints of the multi-body system.
- ▶ Review of sensor measurements filtration and fusion methods.
- ▶ Design of testing platform and prototype.

Sensors

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- ▶ Accelerometer – linear acceleration

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- ▶ Gyroscope – angular velocity

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Sensor's error & calibration

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Error components:

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- ▶ Noise

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Sensors have finite resolution and sampling time.

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Bias is especially harmful, if measurements are integrated!

Data filtration and sensor fusion

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- ▶ Conventional filter: LPF, HPF, Notch filters, Smoothing filter.

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Sensor fusion:

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Sensor fusion:

- ▶ Position: numerical integration
- ▶ Orientation: Complementary filter, DCM
- ▶ Both: Kalman filter

Extended Kalman Filter

Extended Kalman Filter

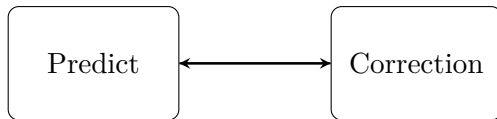
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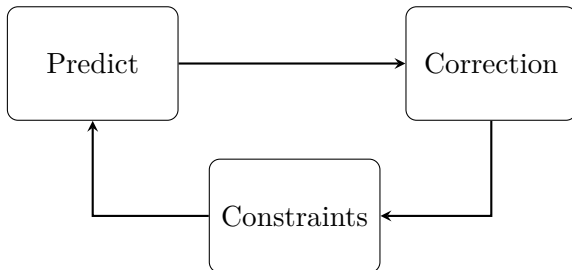
EKF with constraint correction

EKF with constraint correction

- ▶ Constraints based on multi-body system design

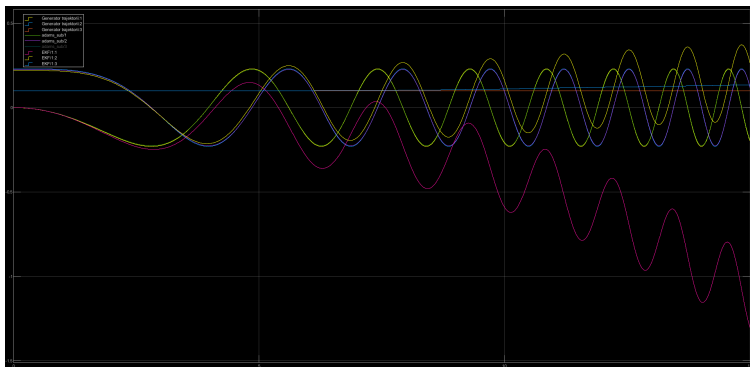
EKF with constraint correction

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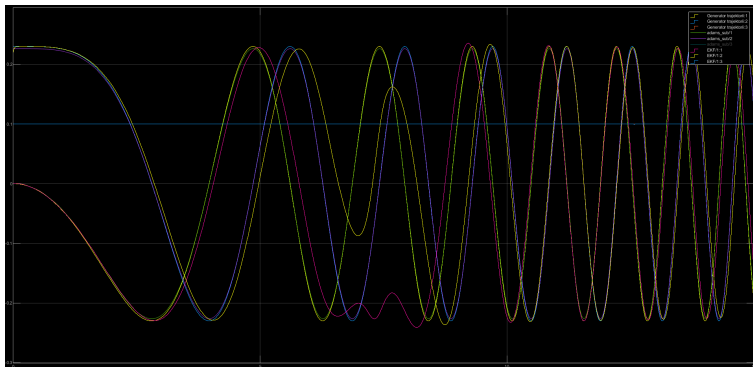
Simulation

Simulation



EKF without constraints

Simulation



EKF with constraints

Work schedule

Work schedule

Task description	Start time	End time
State of knowledge review	–	Feb 24, 2024
Design of sensor board prototype	Feb 17, 2024	Mar 16, 2024
Develop source code for gather measurements	Mar 9, 2024	Mar 30, 2024
Develop source code for filtration & sensor fusion	Mar 23, 2024	Apr 13, 2024
Connect prototype with force measurement system and move controller	Apr 13, 2024	May 4, 2024
System tuning	May 4, 2024	May 18, 2024
Completion of documentation	May 11, 2024	Jun 1, 2024

Summary

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Expected results of thesis:

Summary

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- ▶ gathering theoretical knowledge of position & orientation measurement system

Summary

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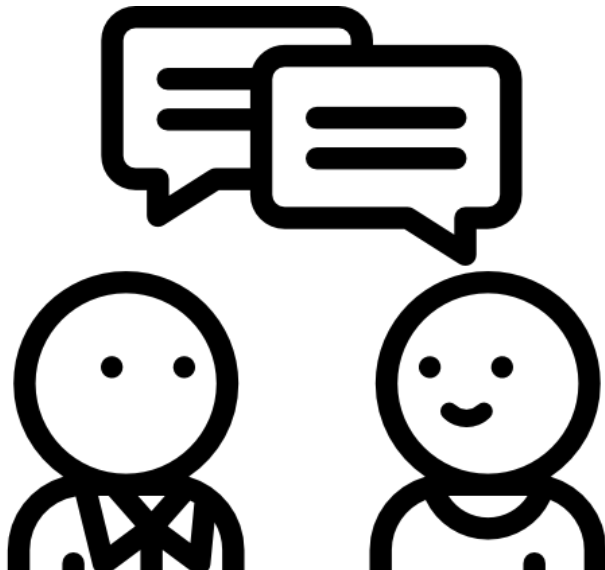
- ▶ gathering theoretical knowledge of position & orientation measurement system
- ▶ design of universal device to estimate knowledge of position

$$A = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \quad B = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \quad C = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \quad D = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}.$$


References

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Simon, D. and Tien Li Chia
-  [2009] Direction Cosine Matrix IMU: Theory
Premerlani, William and Bizard, Paul
-  [2021] Cascaded Complementary Filter Architecture for Sensor Fusion in Attitude Estimation
Narkhede, Parag and Poddar, Shashi and Walambe, Rahee and Ghinea, George and Kotecha, Ketan

Questions?



Thank you!