Attitude independent movement determination using MEMS for screen-less pedestrian navigation

Master Final Talk

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Context

FootPath

- Indoor Pedestrian Navigation System on Smartphone
- Currently only handheld
- Feedback via device Display

Goal

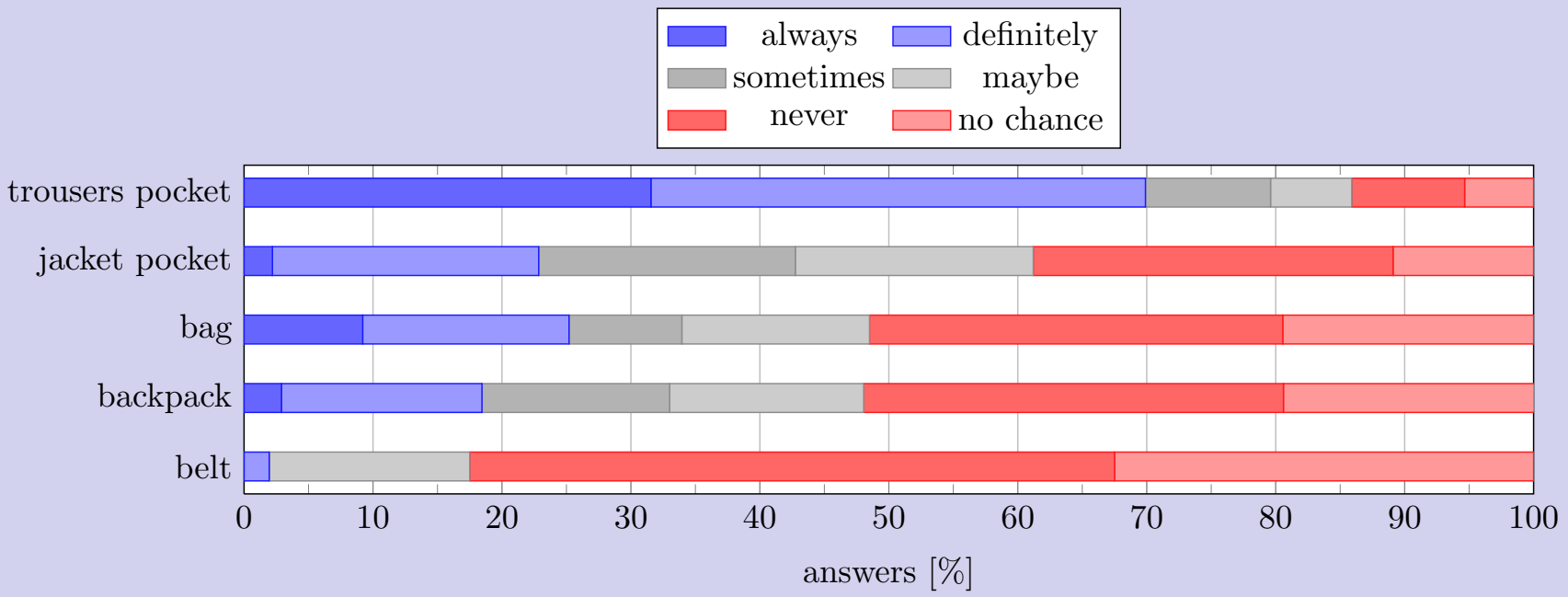
We make it attitude independent!

⇒ Survey

"Where do you carry your Smartphone?"

Attitude Independent? - Survey

"Where do you carry your Smartphone?"
"What place would also be acceptable?"



⇒ Focus on **Trousers Pocket** & **Jacket Pocket**

Smartphone integrated Sensors: MEMS

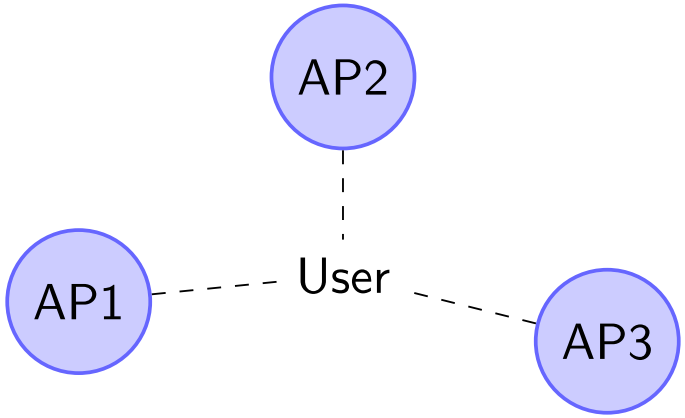
Microelectronic-mechanical System

- Accelerometer
- Gyroscope
- Magnetometer

Sensor Fusion: Combining information

- Rotation Vector
- Linear Acceleration

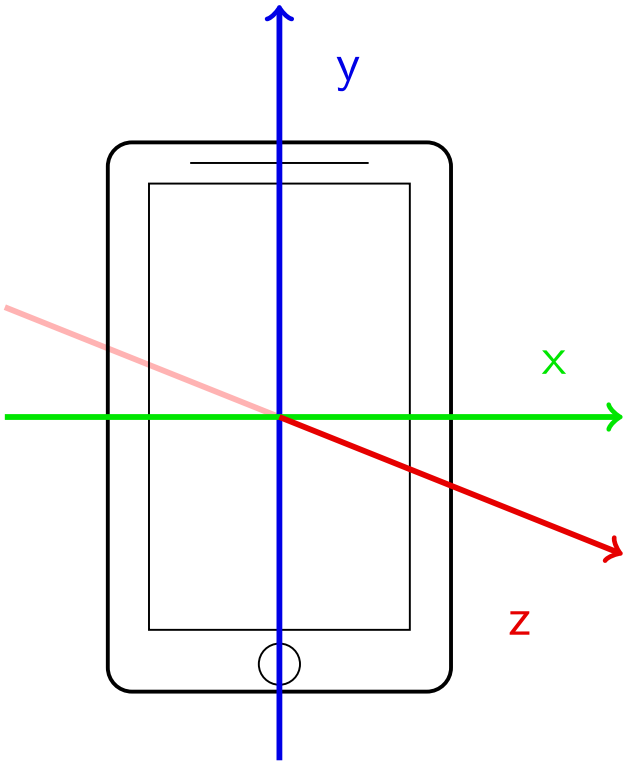
Other Solutions

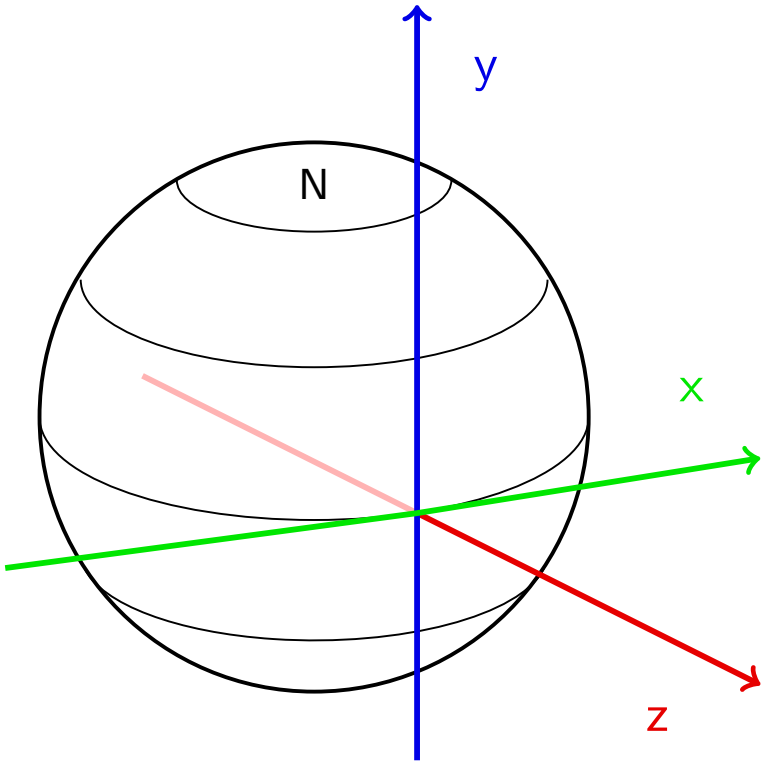


- WiFi Localization
- Using RFID Tags
- Pedestrian Dead Reckoning
  - Specialized Footmounted Devices
  - Map aided using Particle Filter
  - Visual

*Picture from Feliz at al. "Pedestrian tracking using inertial sensors"

Intrinsic vs. Extrinsic Coordinates

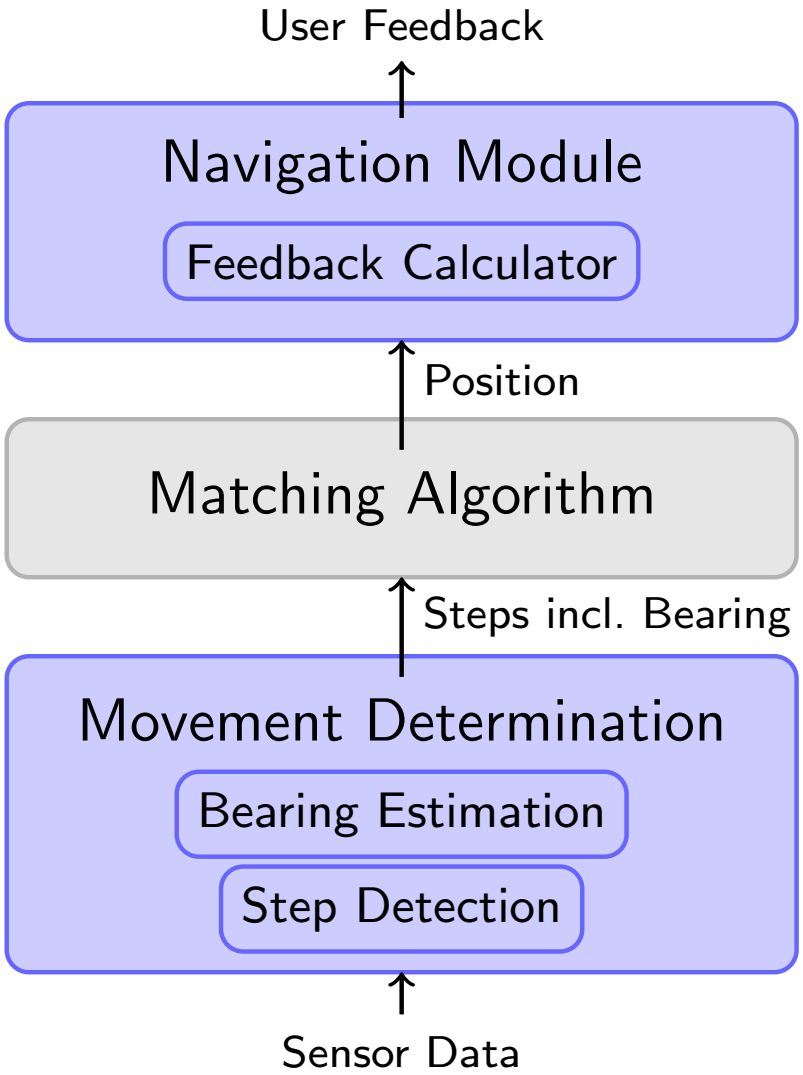




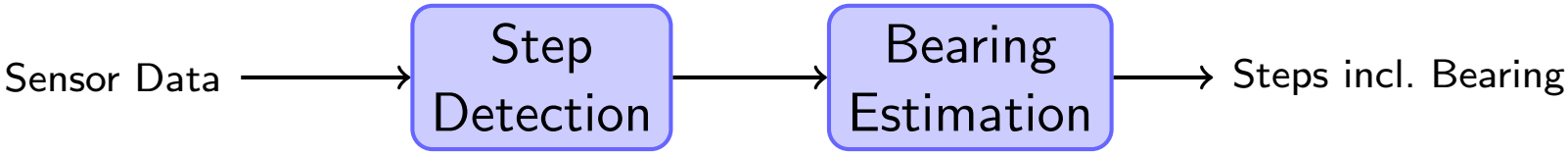
Transformation via Rotation

$$\vec{V}_{\text{extrinsic}} = R * \vec{v}_{\text{intrinsic}}$$

Schematic Overview



Movement Determination



Common Approaches for Bearing Estimation (handheld)

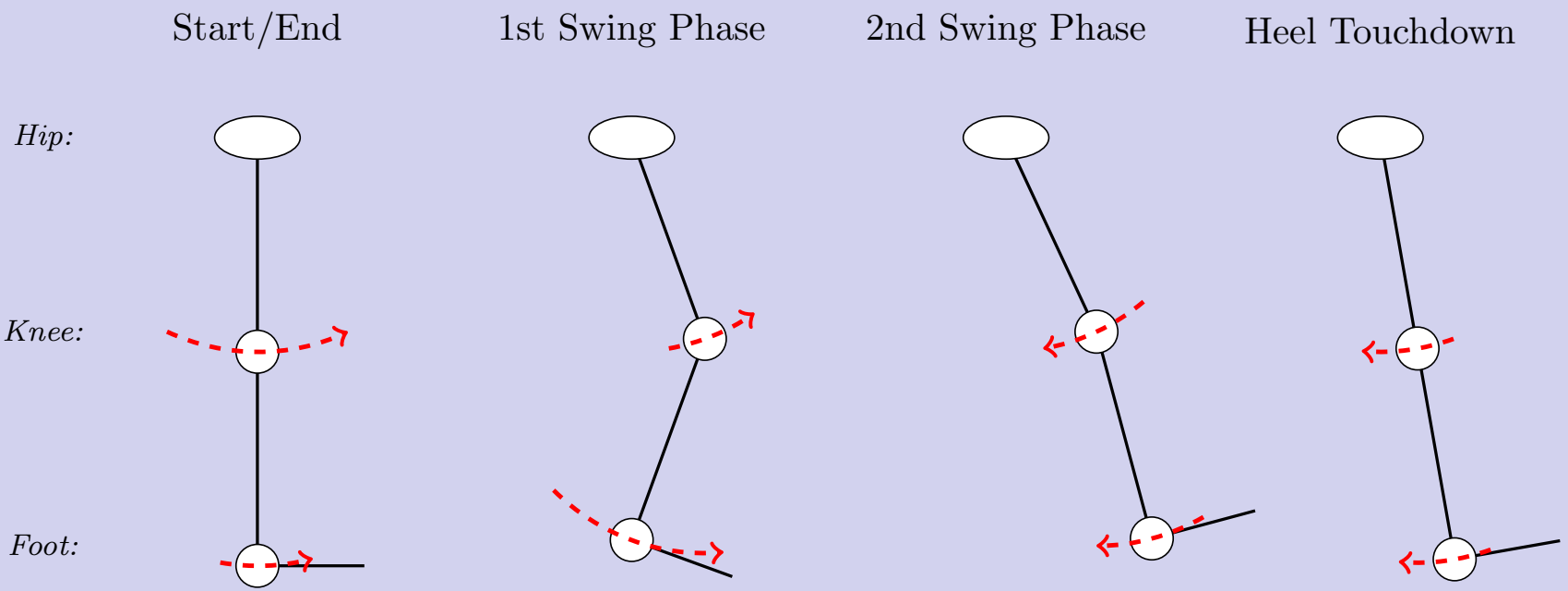
- Rotation Vector
- Magnetic Field & Accelerations
- Direct Accelerations

But,

they fail at non-handheld locations!

New Bearing Estimation Model

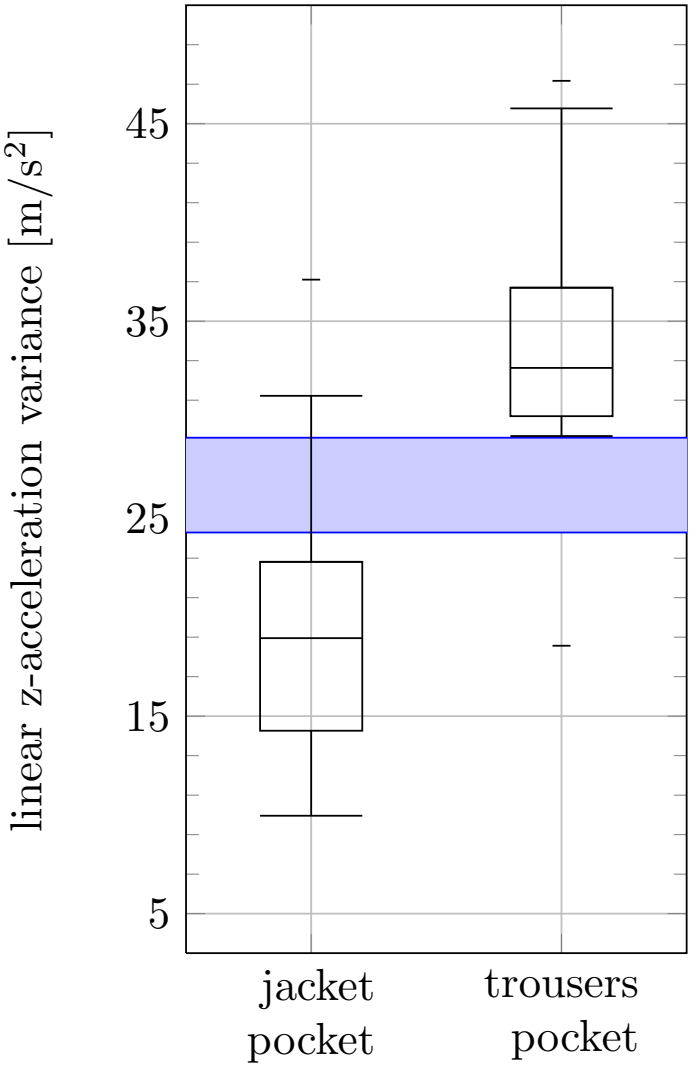
Walking Motion

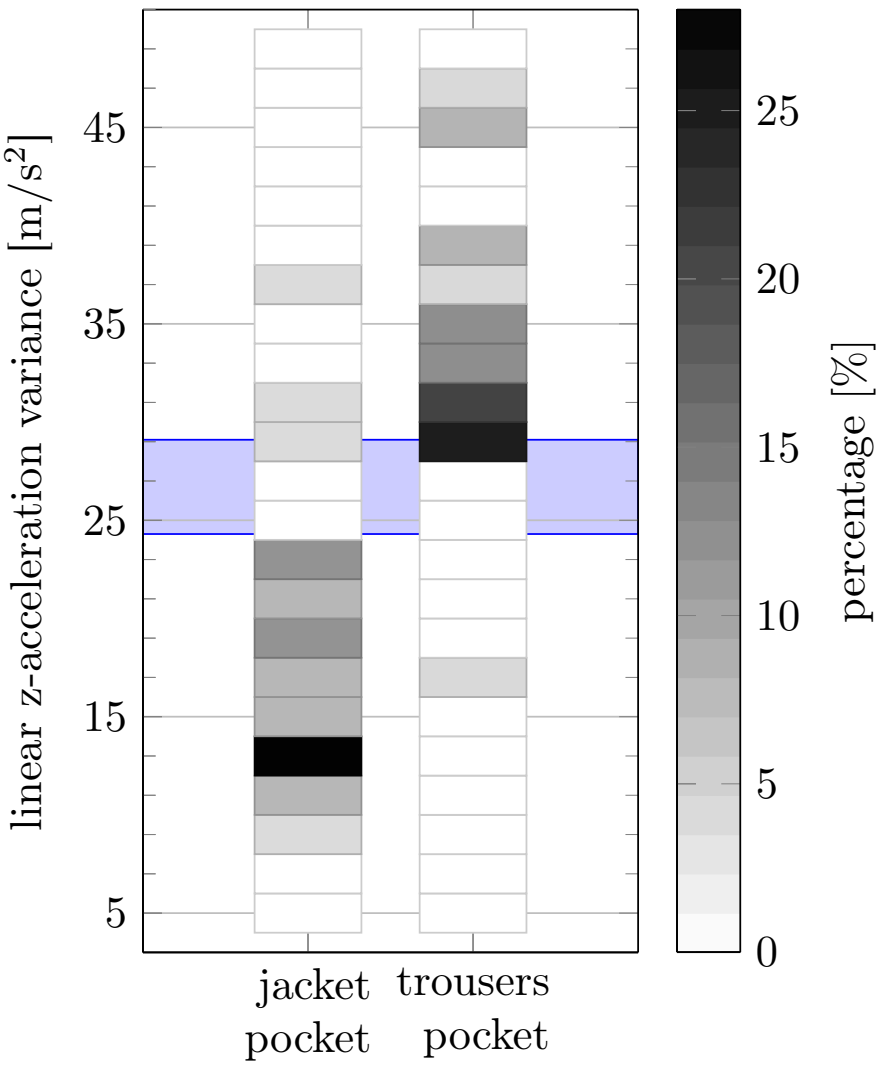


$\Rightarrow$ Slice of Highest Displacement

$\Rightarrow$ Relative interval $[i_0, i_1] \in [0, 1]^2$

Device Location Estimation



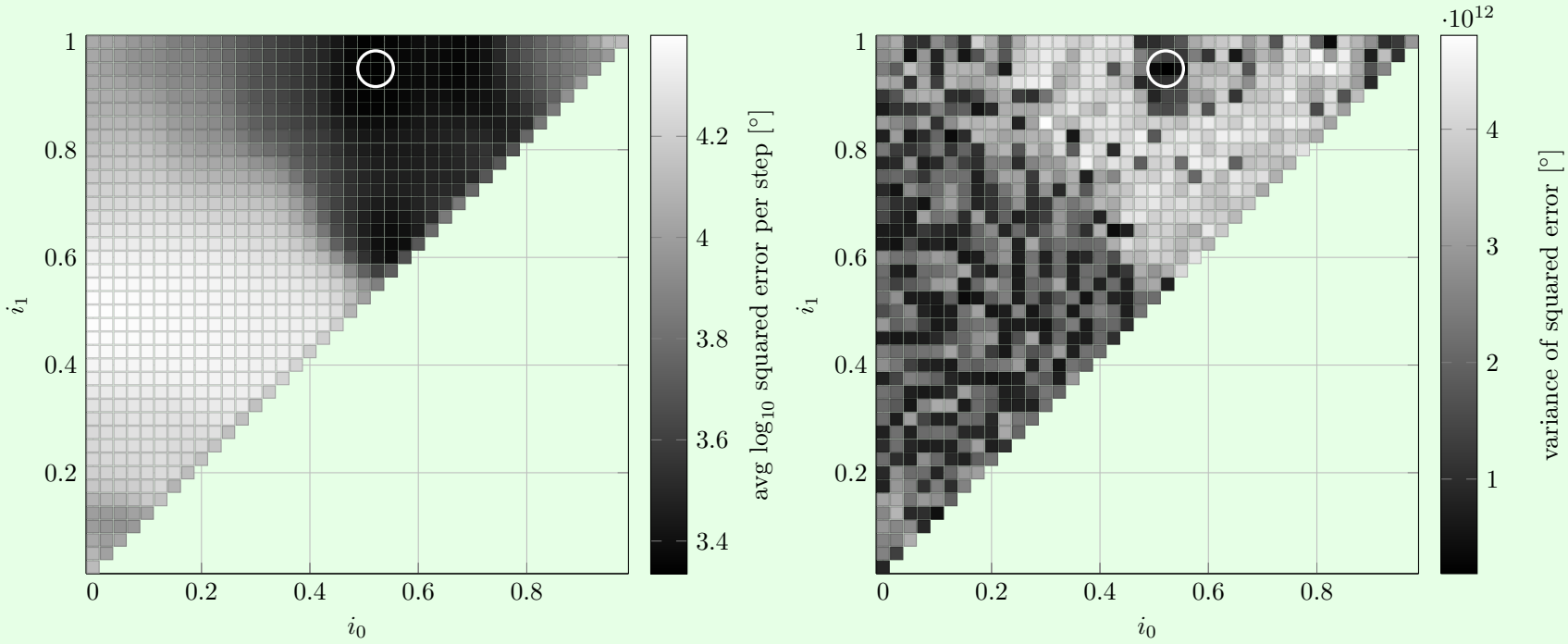


Model Parameter Optimization

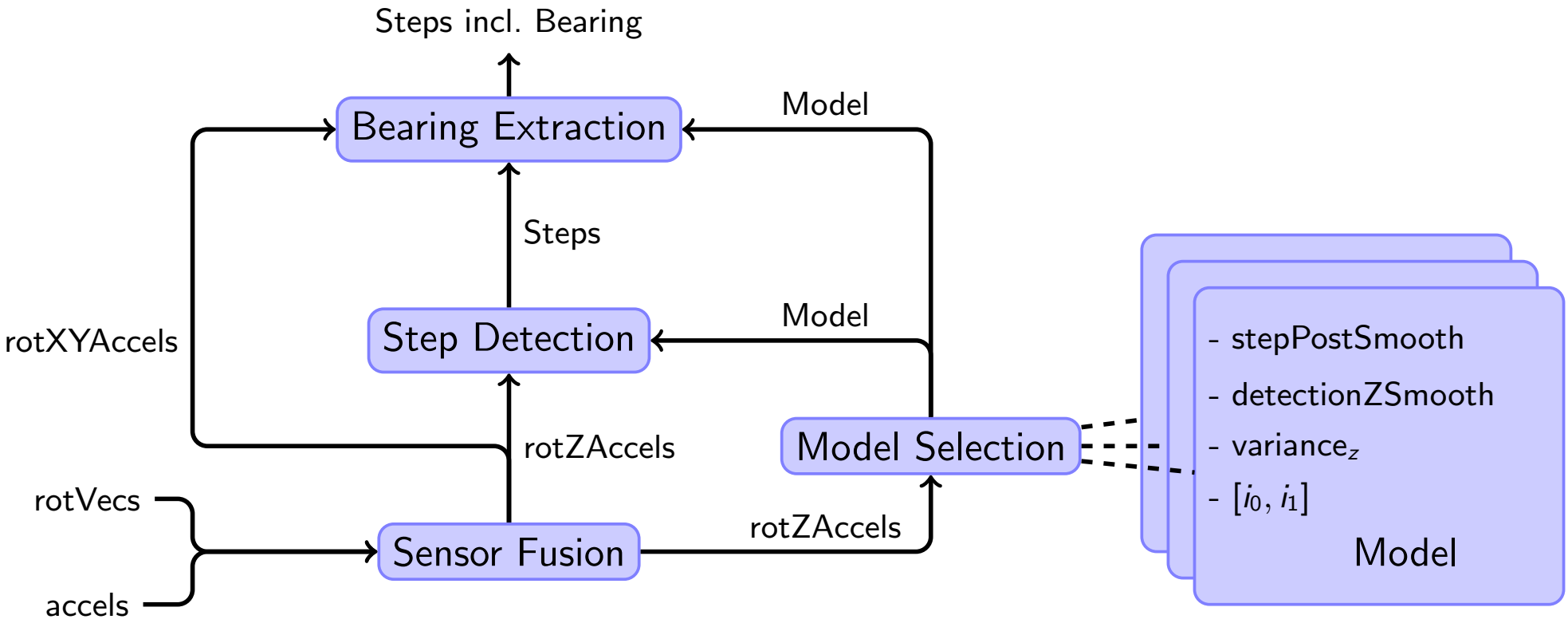
- Test all possible Interval Parameter Combinations
- Two measures:
  - Average Error per Step
    - $\Rightarrow$ Good Results
  - Error Variance over Datasets
    - $\Rightarrow$ Stability

Model Parameter Optimization

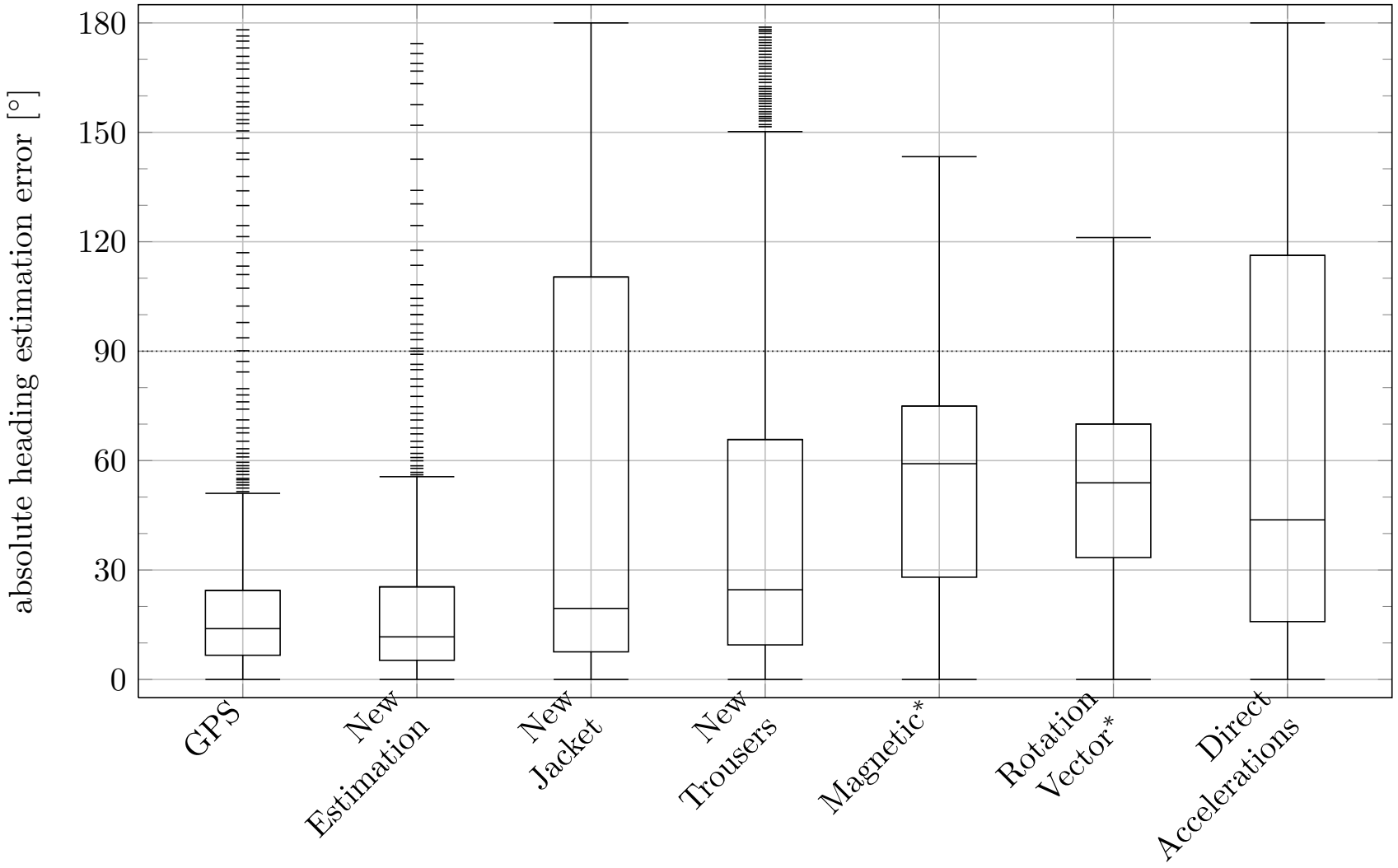
Jacket



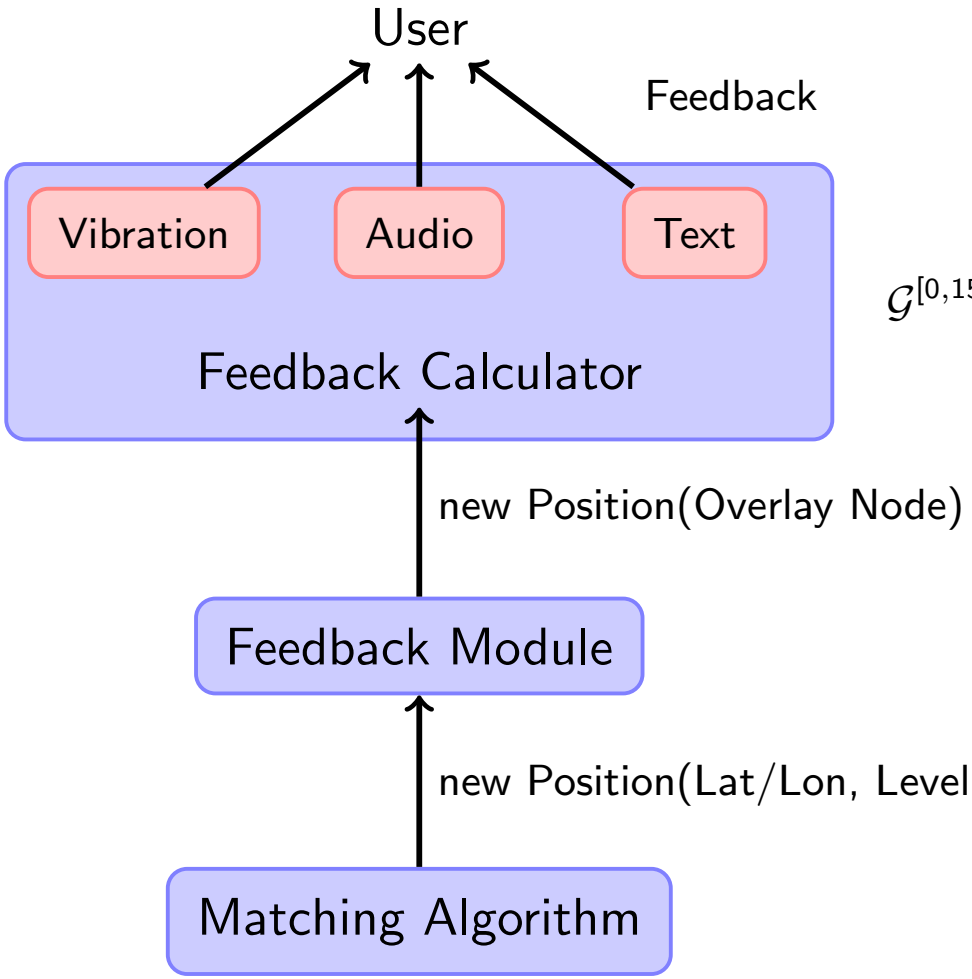
Bearing Estimation Pipeline



Bearing Estimation Results

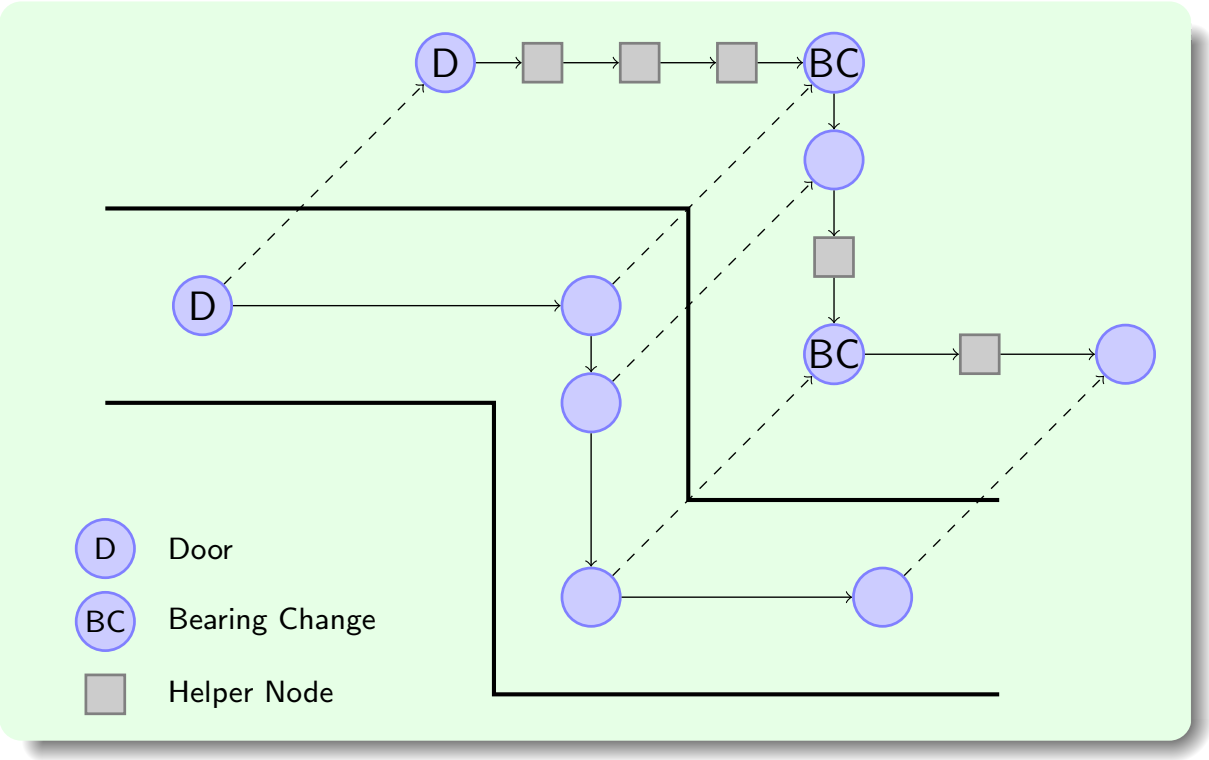


Navigation Feedback Framework



$$\mathcal{G}^{[0,15]} \neg (\text{Door} \vee \text{Stairs} \vee \text{LevelChange}) \wedge \mathcal{F}^{[0,15]} \text{BearingChange}$$

Navigation Feedback Framework



Overlay Graph
with Interestpoints:

- Doors
- Stairs
- Bearing Changes
- Level Changes
- ...

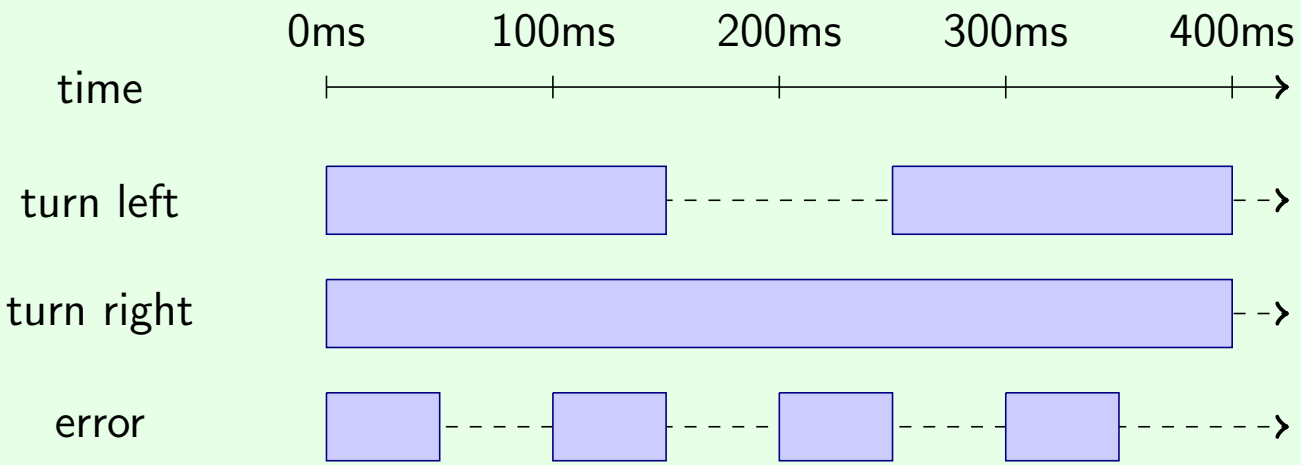
Alternative Feedback

Audio

Turn left soon and then pass the upcoming door.

Go upstairs to level 3 now.

Vibration



Future Work

- Enhanced Device Location Estimation & Step Detection
- Other new Models
- Individual Model Fitting & Learning
- Evaluation on User Feedback Rules

Conclusion

- General Model for Heading Estimation

$\Rightarrow$ Stepsegment: Interval with most information $[i_0, i_1]$

- Two new Models: Jacket & Trousers

$\Rightarrow$ Reliable Distinction via z-Acceleration

- "Good" Parameters via Optimization

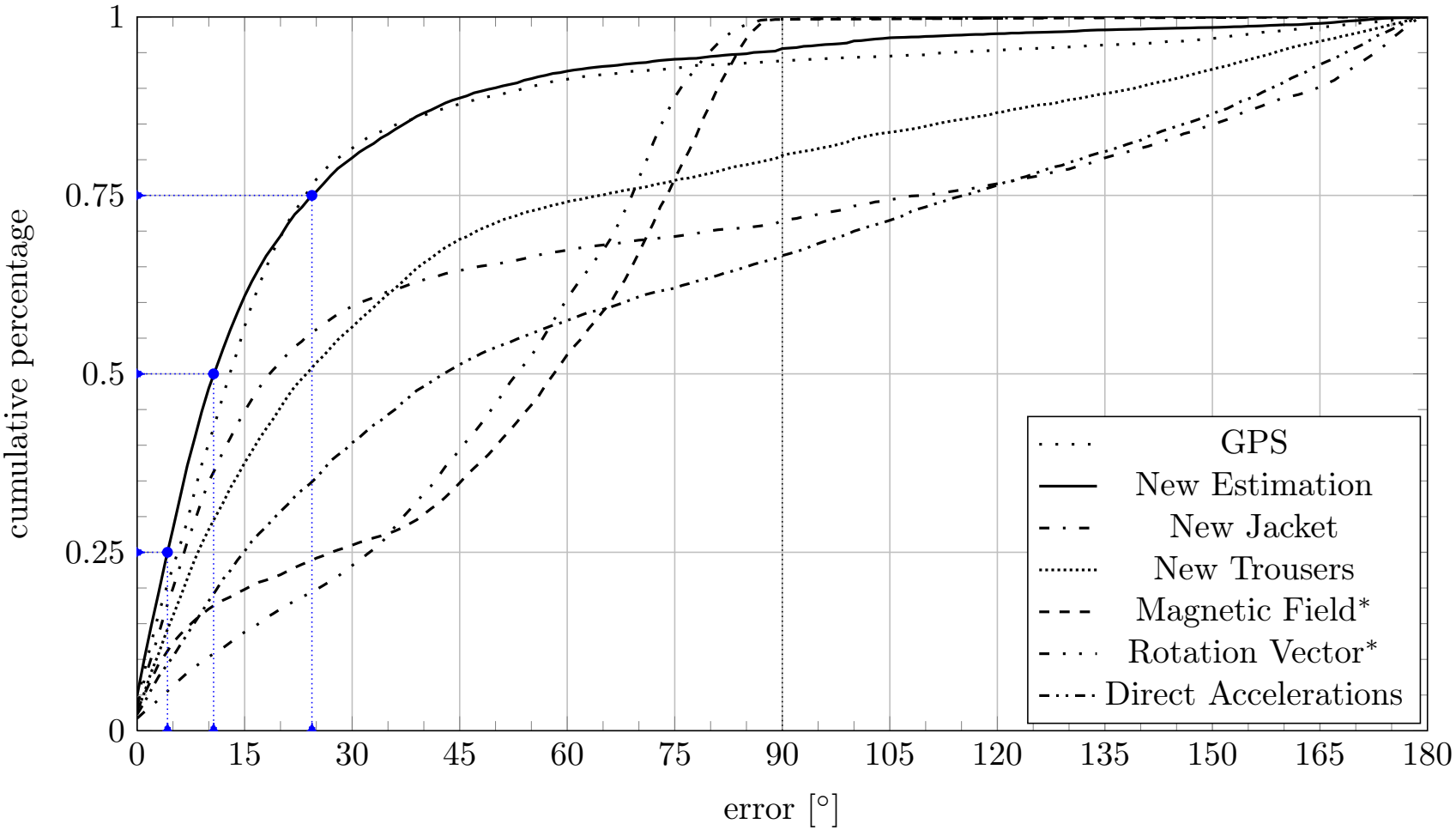
$\Rightarrow$ Reliable Heading Estimation

- Screen-less User Feedback via Audio & Vibration

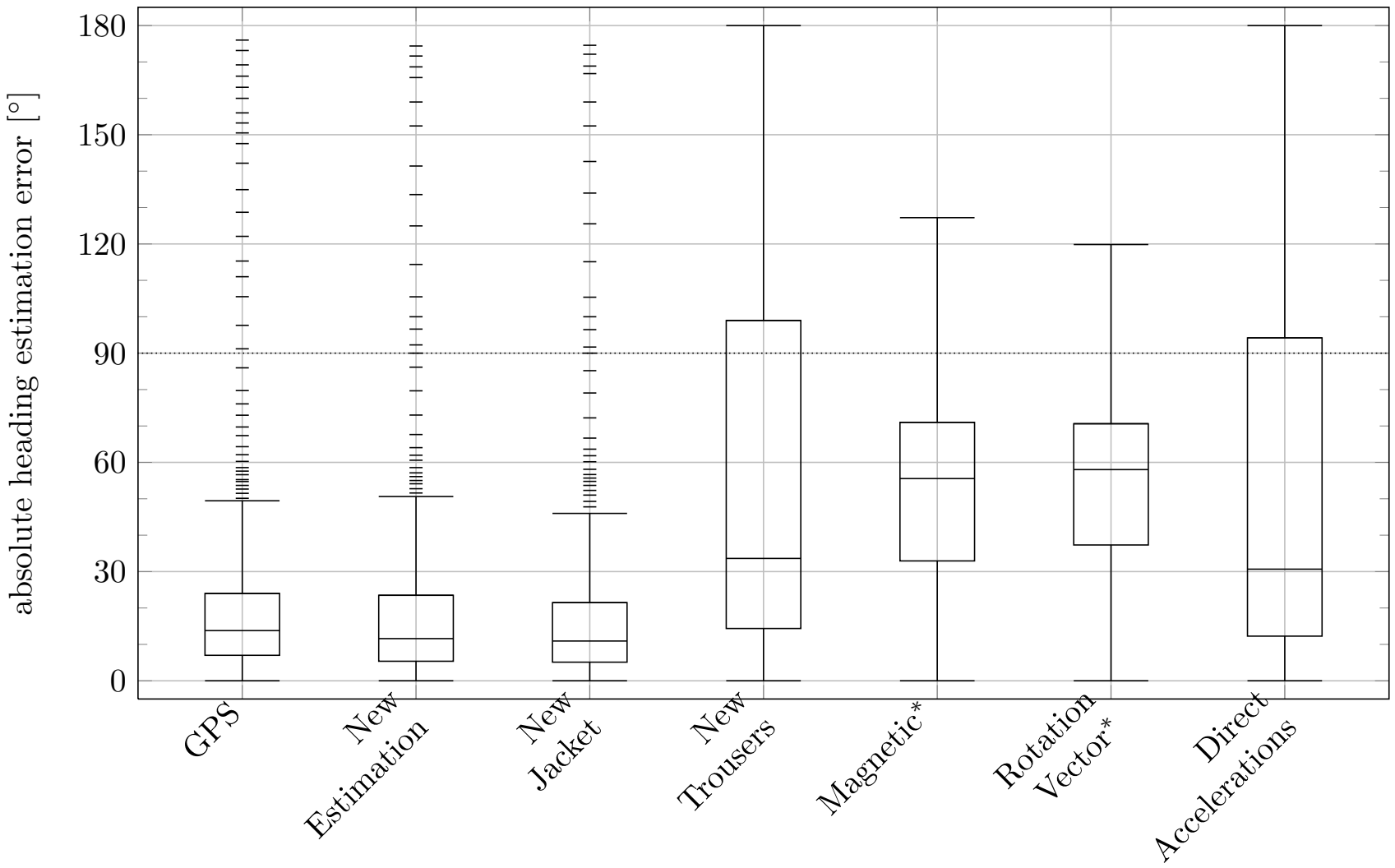
Thanks for your Attention!

Questions
&
Answers

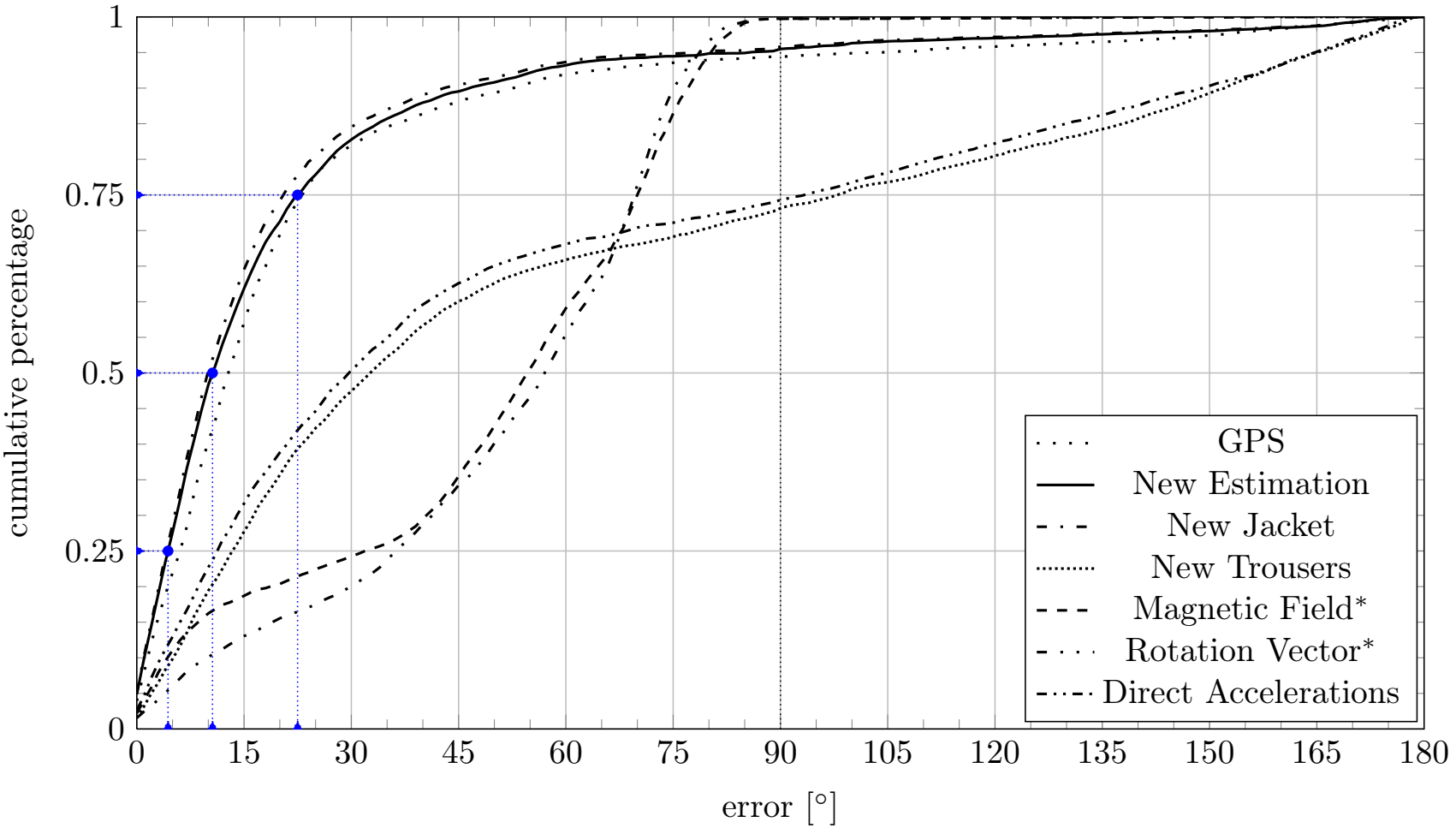
Model Evaluation - Overall Error Distr.



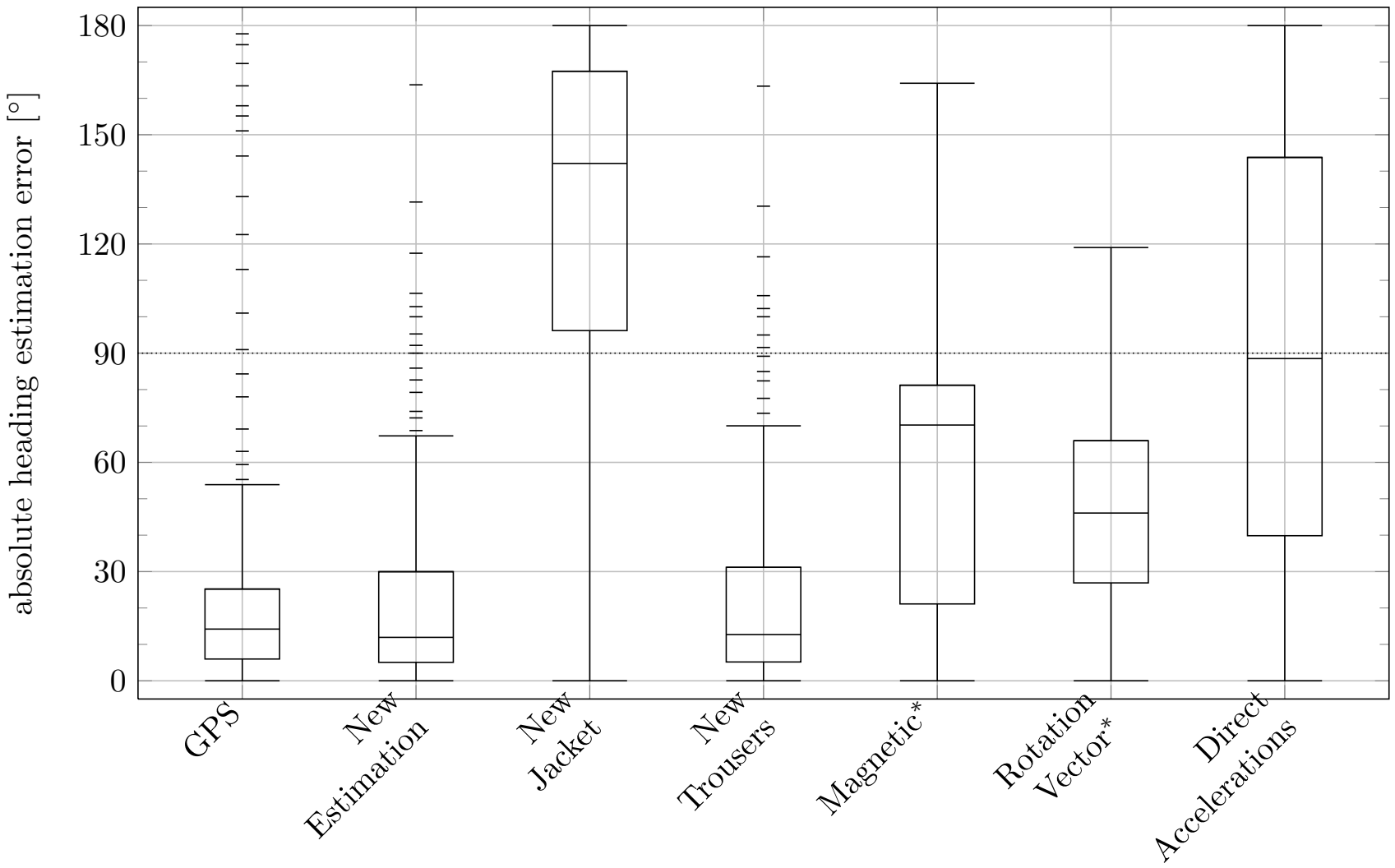
Model Evaluation - Jacket Boxplot



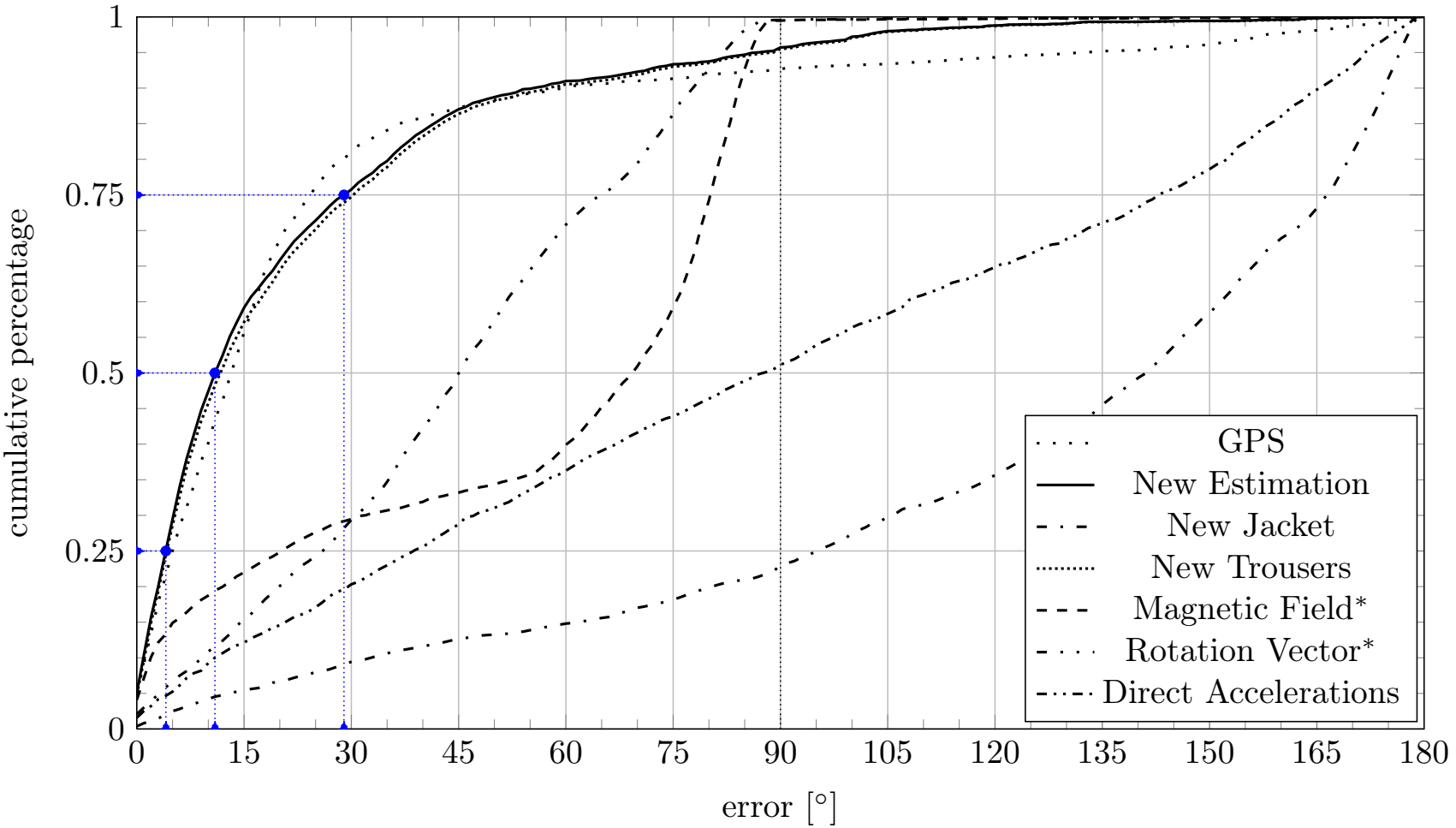
Model Evaluation - Jacket Error Distr.



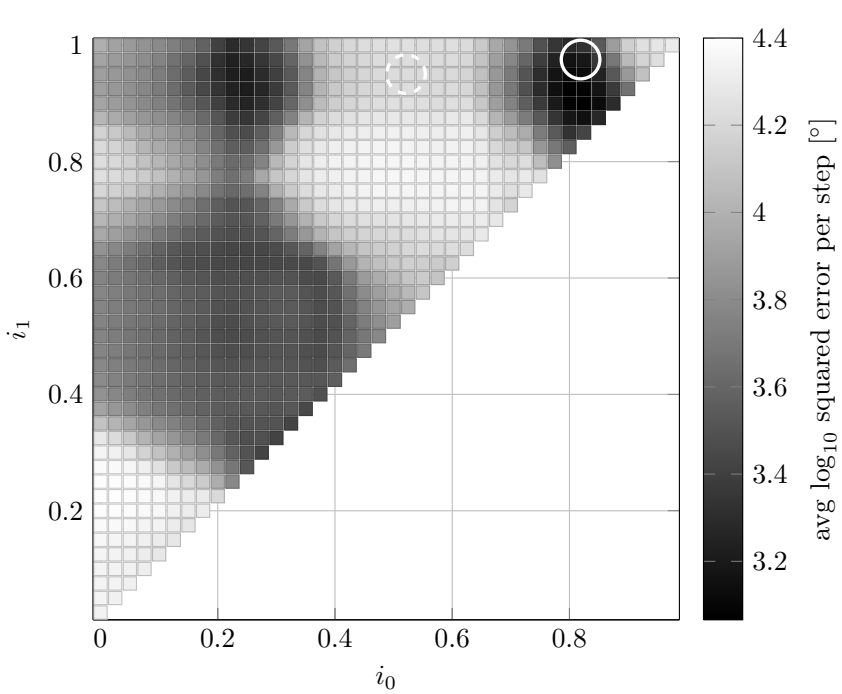
Model Evaluation - Trousers Boxplot

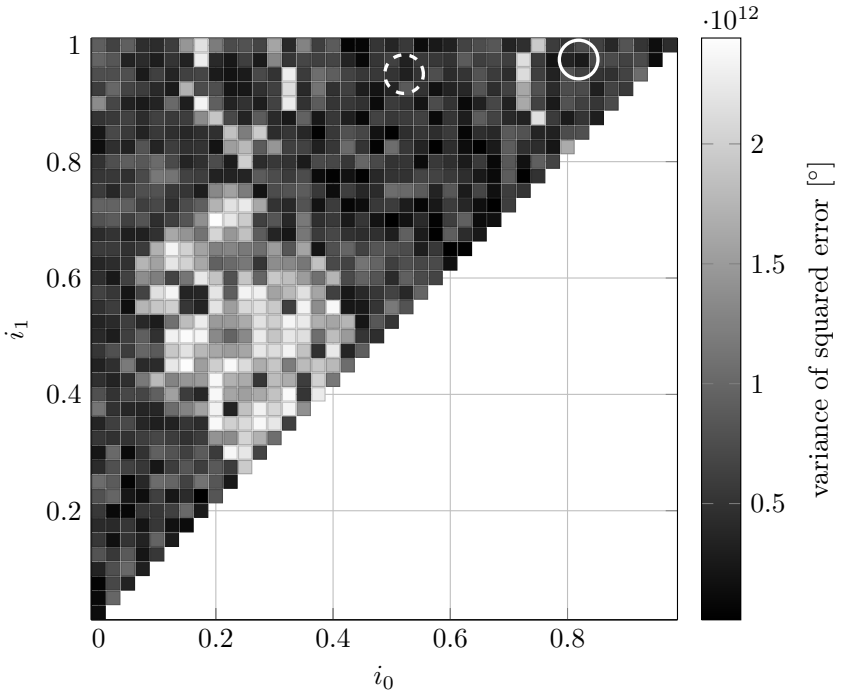


Model Evaluation - Trousers Error Distr.

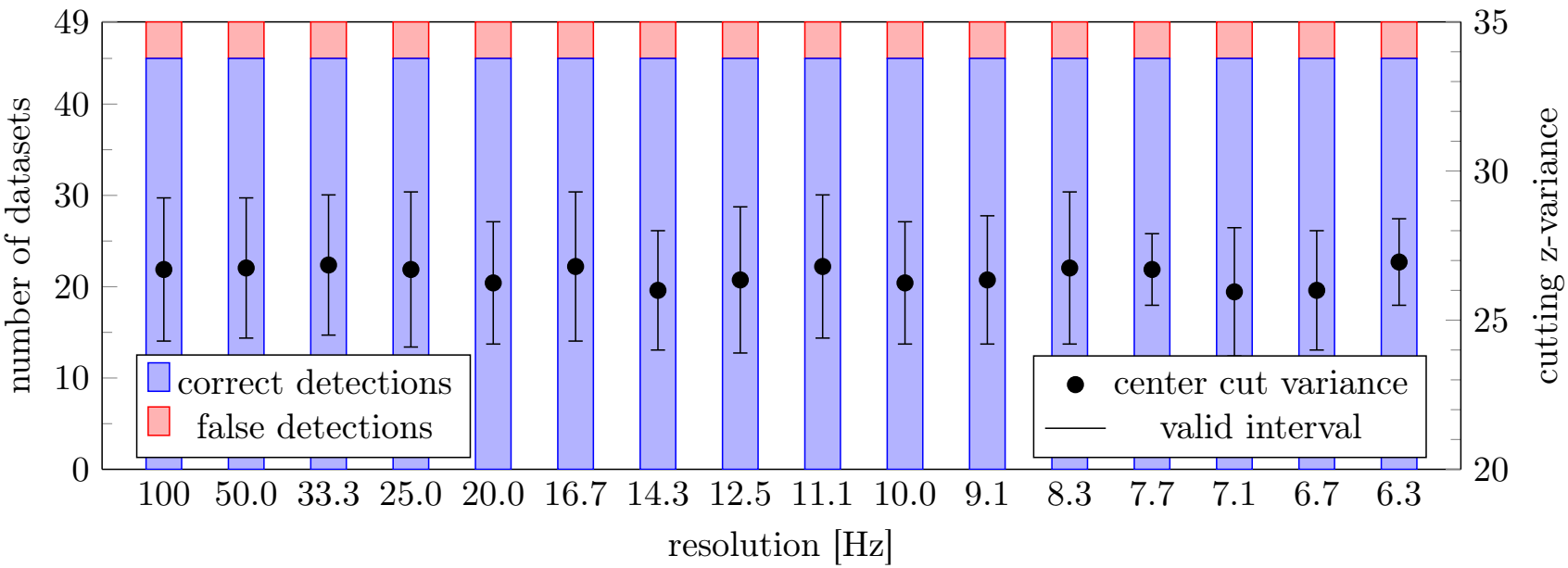


Optimization for Trousers

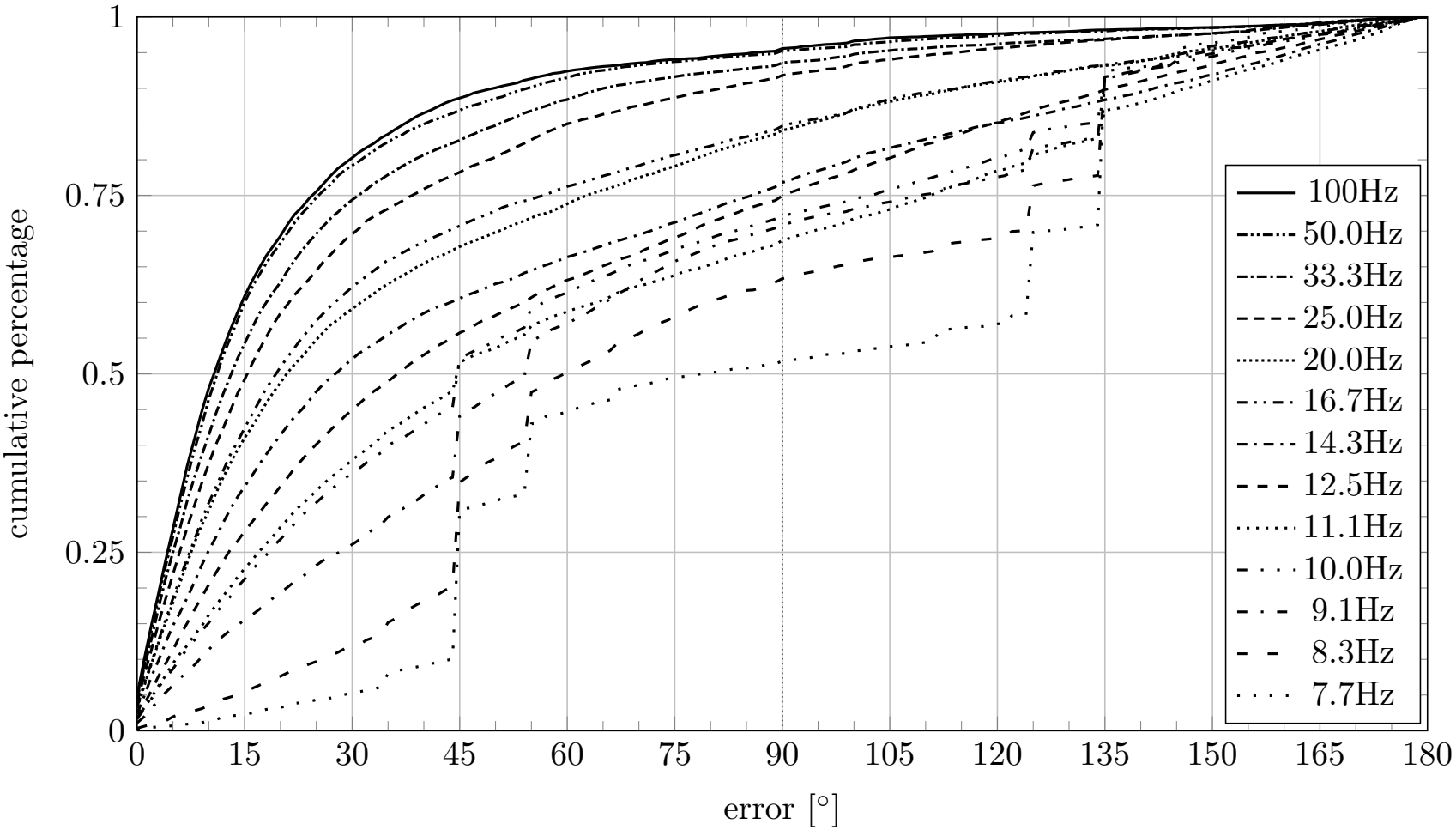




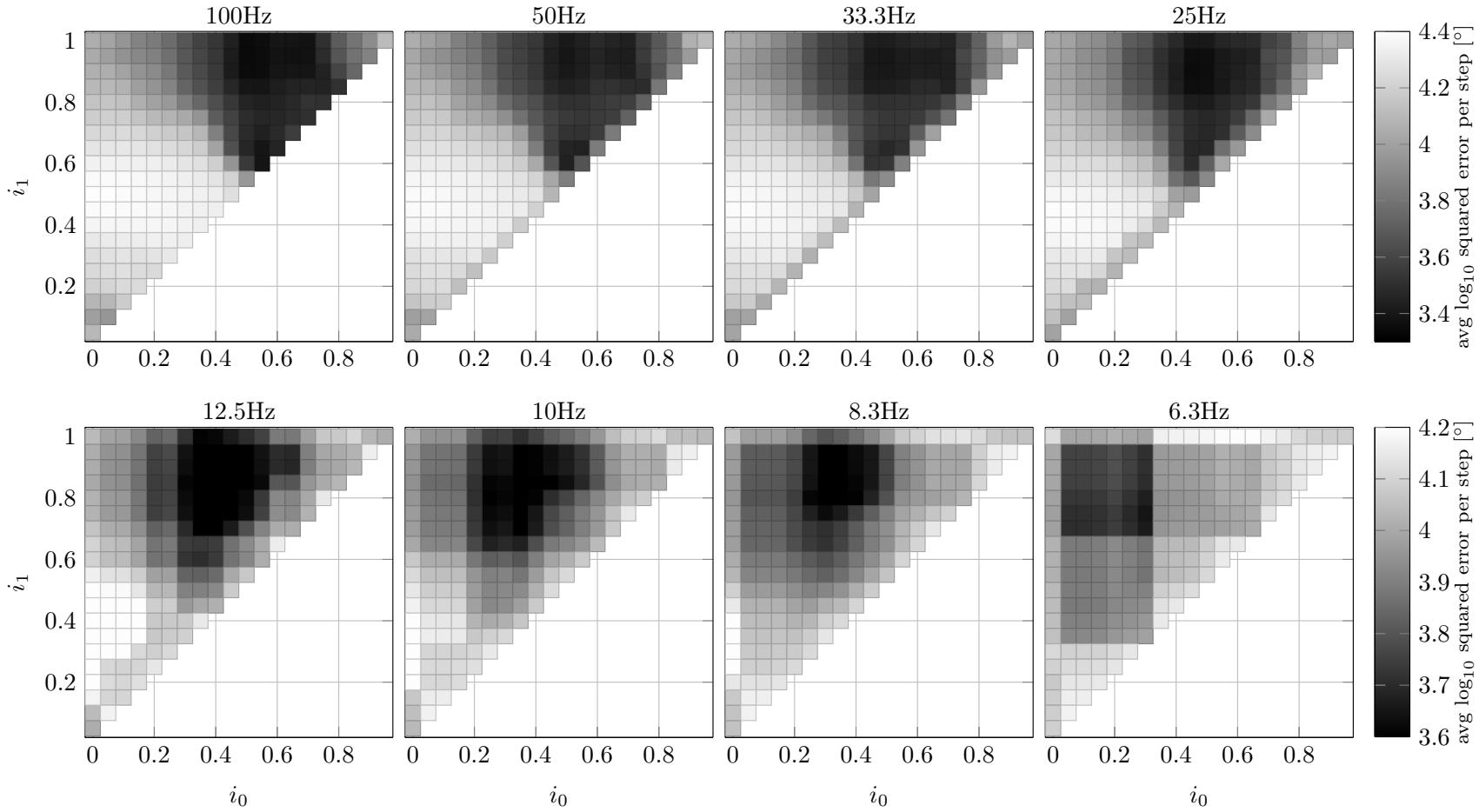
Model Distinction low Frequencies



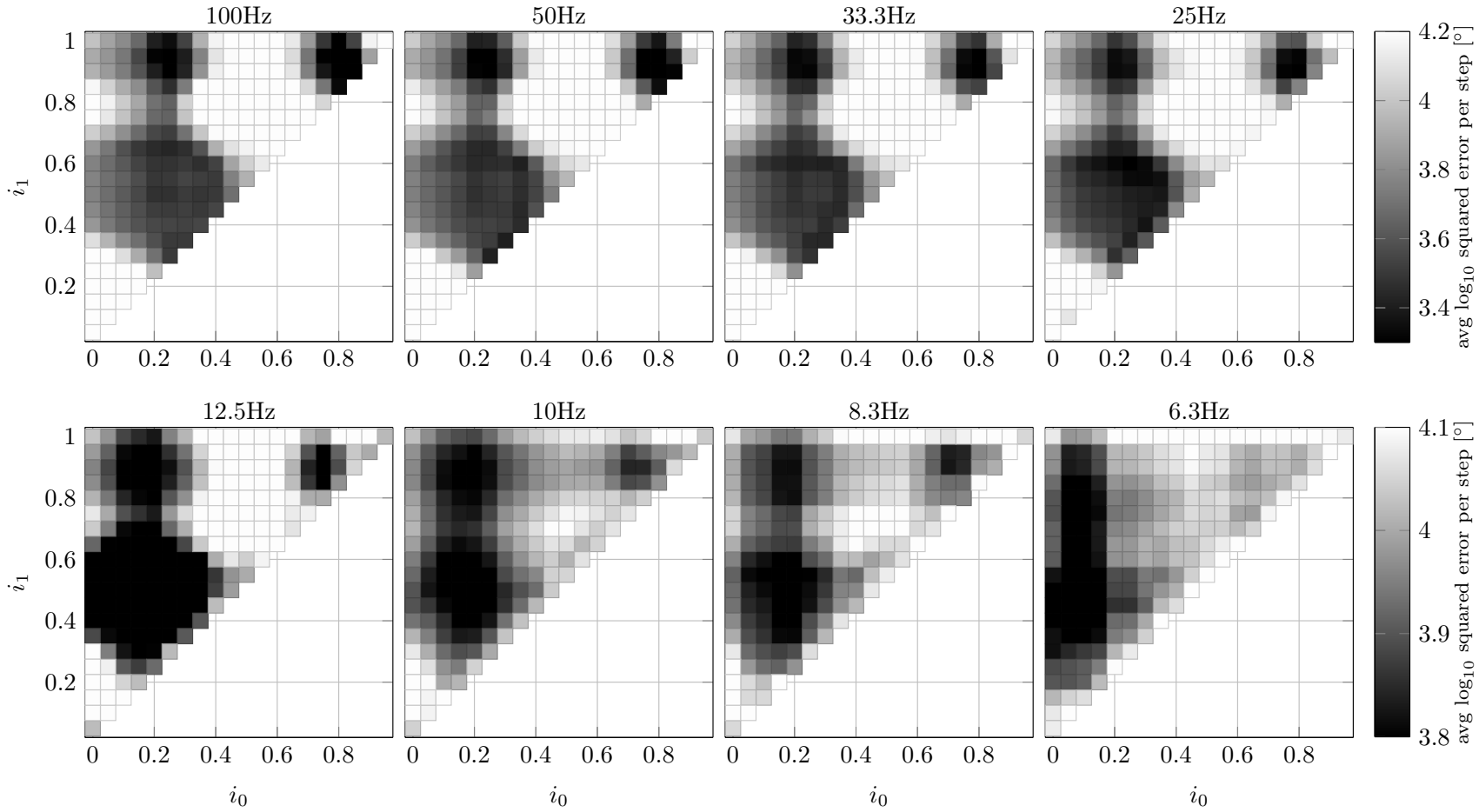
Model Results low Frequencies



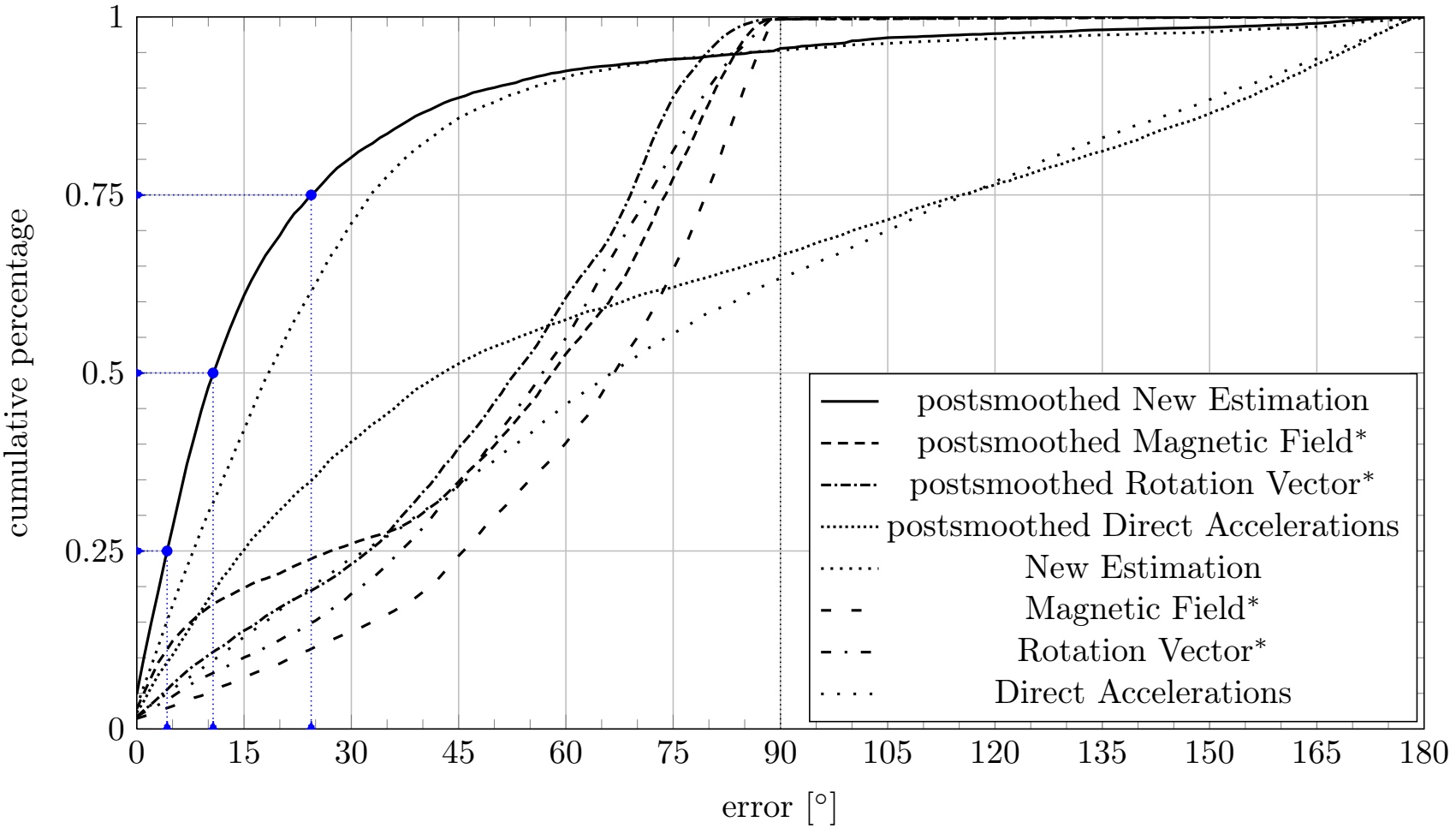
Optimization low Frequencies - Jacket



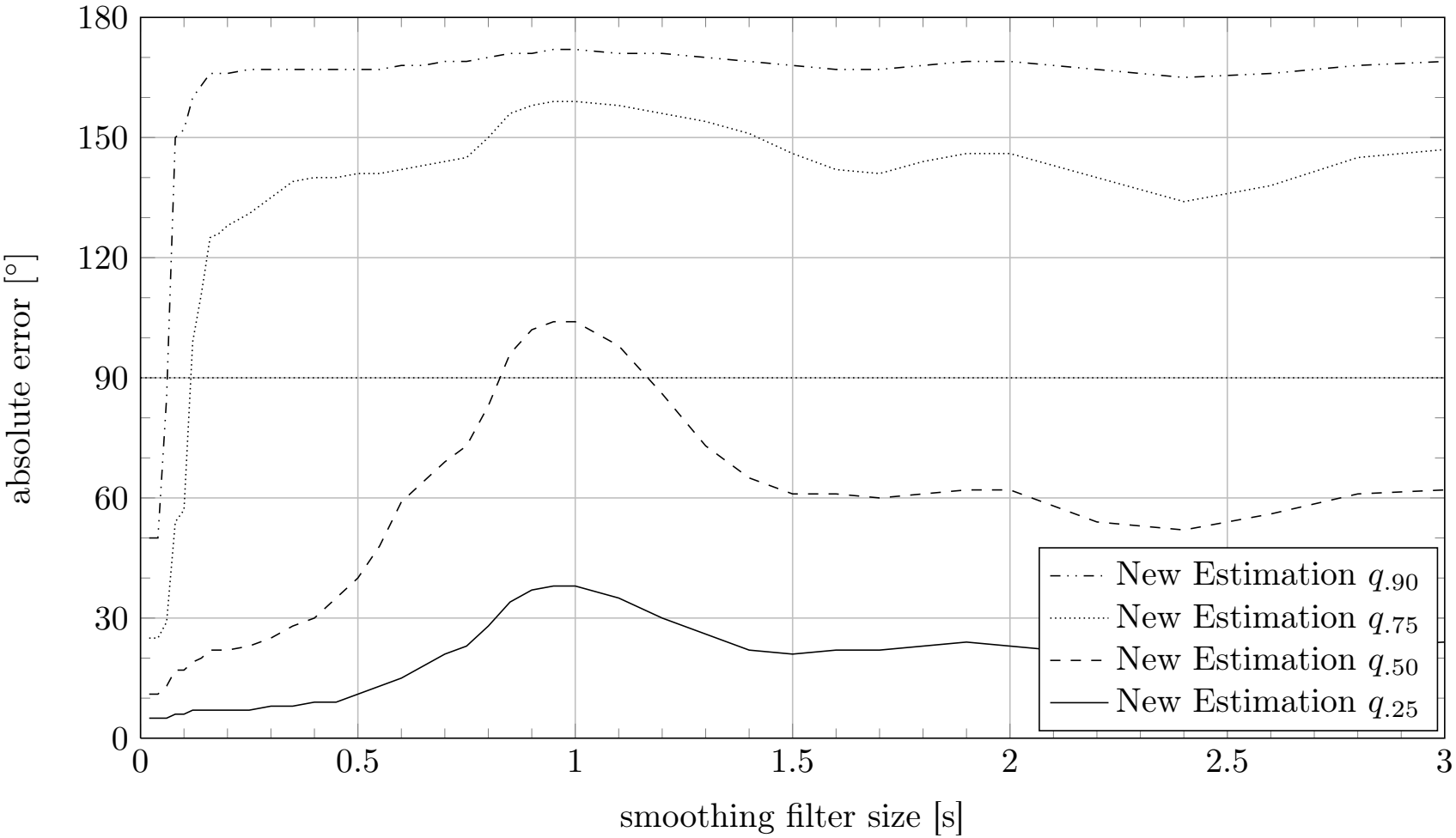
Optimization low Frequencies - Trousers



Postsmoothing



Presmoothing - New Method



Model Evaluation - Online vs. Offline