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| **CONFIDENTIAL** |
| **Calibration Algorithm Design Document**  Venue. Survey  **Revision: 1.1** |

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| **Document Code** |

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| REVISION: 1.1 - ISSUED FOR USE | |
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| **PERMIT STAMP** | **ENGINEER’S STAMP** |
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A picture containing shape

Description automatically generated

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## Version Log

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Version | Date  (D/M/Y/ | Author | Checker | Update Description |
| 0.0 | 15/04/2021 | D. Churikov | Draft | 0.0 |
| 1.0 | 15/05/2021 | D. Churikov |  | Initial version |
| 1.1 | 21/05/2021 | D. Churikov |  | Add calibration script description |
| 1.2 | 23/06/2021 | D.Churikov |  | Update calibration levels |

## Figures

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## Tables

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## Equations

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## Acronyms

|  |  |
| --- | --- |
| Abbreviation | Definition |
|  |  |
|  |  |

# General calibration process description



# Interaction with calibration library and calibration data flows



|  |  |  |
| --- | --- | --- |
| **Calibration parameter** | **Value** | **Description** |
| dH | 45 deg | Robot rotation angle around vertical axis |
| iteration\_number | 8 | Calibration iterations number |

# Estimate Magnetic/Accelerometer Bias Algorithm



## Estimate temperature variation and average

1. Smooth temperature data for calibrated sensor by slide window filter with 1 second averaging interval
2. Calculate temperature variation as maximal span of the smoothed temperature
3. Calculate temperature average

Acceptable temperature variation during the calibration is less than 5C

## Sensor data preprocessing

To be described

## Check data consistence

Data acceptance criterion is:

Calibration points number: not less than 200

Maximal calibration duration: 20 min

## LSEF calibration

The algorithm of soft and hard iron calibration is according to the conference paper: Qingde Li and J. G. Griffiths, "Least squares ellipsoid specific fitting," Geometric Modeling and Processing, 2004. Proceedings, 2004, pp. 335-340.

Correction for unknown Earth mag field in the location of calibration was provided with help of Freescale’s AN-4246.

## Estimate DOP factor

Describe the algorithm here

DOP acceptance criterion: (DOP <= 0.3) || (any dop(i) <= 0.2) || stdev(dop) <= 0.1)

## Estimate bias uncertainty

Estimate bias uncertainty as calibrated sensor data magnitude RMS

## Estimate calibration level and update status

Magnetometer calibration level depending on calibration status and bias uncertainty

|  |  |  |  |
| --- | --- | --- | --- |
| Input: Calibration status | Bias uncertainty | Calibration level | Updated status |
| STATUS\_TOO\_LONG\_CALIBRATION\_TIME, STATUS\_UNSTABLE\_TEMPERATURE, STATUS\_INSUFFICIENT\_DATA,  STATUS\_HIGH\_DOP |  | 0 | No update |
| STATUS\_SUCCESS | > 5uT (50mG) | 1 | STATUS\_LOW\_CALIBRATION\_ACCURACY |
| STATUS\_SUCCESS | < 5uT (30mG) | 2 | STATUS\_LOW\_CALIBRATION\_ACCURACY |
| STATUS\_SUCCESS | < 3uT (10mG) | 3 | STATUS\_LOW\_CALIBRATION\_ACCURACY |
| STATUS\_SUCCESS | < 1uT (5mG) | 4 | STATUS\_SUCCESS |
| STATUS\_SUCCESS | < 0.5uT (2.5mG) | 5 | STATUS\_SUCCESS |
| STATUS\_SUCCESS | < 0.25uT (1mG) | 6 | STATUS\_SUCCESS |
| STATUS\_SUCCESS | < 0.1uT (0.5mG) | 7 | STATUS\_SUCCESS |

Table for reference: Restoring mag bias uncertainty from calibration level

|  |  |
| --- | --- |
| Calibration level | Bias uncertainty, uT |
| 0 | 1e6 |
| 1 | 1e3 |
| 2 | 5 |
| 3 | 3 |
| 4 | 1 |
| 5 | 0.5 |
| 6 | 0.25 |
| 7 | 0.1 |

Accelerometer calibration level depending on calibration status and bias uncertainty:

|  |  |  |  |
| --- | --- | --- | --- |
| Input: Calibration status | Bias uncertainty | Calibration level | Updated status |
| STATUS\_TOO\_LONG\_CALIBRATION\_TIME, STATUS\_UNSTABLE\_TEMPERATURE, STATUS\_INSUFFICIENT\_DATA,  STATUS\_HIGH\_DOP |  | 0 | No update |
| STATUS\_SUCCESS | > 0.1 m/sec^2 | 1 | STATUS\_LOW\_CALIBRATION\_ACCURACY |
| STATUS\_SUCCESS | < 0.1 m/sec^2 | 2 | STATUS\_SUCCESS |

# How to apply calibration parameters to measurements of magnetometer and accelerometer

After magnetometer calibration process has been successfully completed with return status 0, calibration parameters can be applied to each magnetometer measurement as follows:

Where:

is 3x1 vector of calibrated magnetometer measurements,

is 3x1 vector of raw (uncalibrated) magnetometer measurements,

is 3x3 matrix of soft iron/scale/non-orthogonality compensation determined by method EstimateMagneticCalibrationParams,

, , are hard iron (bias) compensation parameters determined by method EstimateMagneticCalibrationParams.

Correction of accelerometer measurements are provided in the same way:

Where:

is 3x1 vector of calibrated accelerometer measurements,

is 3x1 vector of raw (uncalibrated) accelerometer measurements,

is 3x3 matrix of scale/non-orthogonality compensation determined by method EstimateAccelCalibrationParams,

, , are bias compensation parameters determined by method EstimateAccelCalibrationParams.

# Calibration library

# Class diagram



# Appendices

## Appendix A