

**Fusion**

**Smart Firearm**

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# Executive Summary

This document illustrates the theory and application of attitude and heading reference system (AHRS) intended for smart fire arm project.

# Mathematical Overview

- vector is said to be unit vector if and only if its norm is equal to one. ().

- Angle between two-unit and vectors , is defined by:

- Dot product of two-vector and :

- Cross Product of two-vector and :

- A unit quaternion is a complex number representing a rotation from frame f to frame f’:

u is unitary vector in f and is the angle of rotation.

- Conjugation:

- Quaternion multiplication:

- Transformation of vector v from frame f to frame f’ can be expressed as follow:

; if v

matrix is rotational matrix from body to global frame.

- Quaternion multiplication formula of two vector and :

# Algorithm

Step 1: Transform gyroscopic measurement to the rotation quaternion.

To transform gyroscopic measurement to the rotation quaternion, firstly find the Euler angles [] (pitch, roll, yaw):

; dt(s): sampling rate (rad/s): gyroscope measurement.

Then quaternion vector () that transform between t-1 and t, is defined by:

SCF:

*; ;*

FSCF: (Algorithm Fast Version):

Step 2: Prediction Integration

Quaternion of rotation from predicted frame of the body the earth coordinate frame () can be found by quaternion multiplication:

(Note: Multiplicative Property was utilized; ).

Step 3: Compute reference vectors (predicted mag and acc in body frame)

Normalize accelerometer measurement (measurement in body frame):

; : Accelerometer measurement.

: Normalized Accelerometer measurement.

In global reference acceleration vector compromise only of gravitational vector:

.

Now the predicted accelerometer vector in body frame can be computed as follow:

Which is equivalent to:

.

: from global to body frame ()

In global reference magnetometer vector can not be expressed as a constant because of the distortion due external influences therefor the predicted accelerometer vector can be used.

Magnetometer measurement at instance t is , the global magnetometer vector () can be computed by make use of the previously computed accelerometer vector in body frame.

.

Now the predicted magnetometer vector in body frame can be computed as follow:

Step 4: Compute deviation between predicted and measurement vectors.

To check if the prediction accuracy, we can check the predicted and measured of the magnetometer and accelerometer.

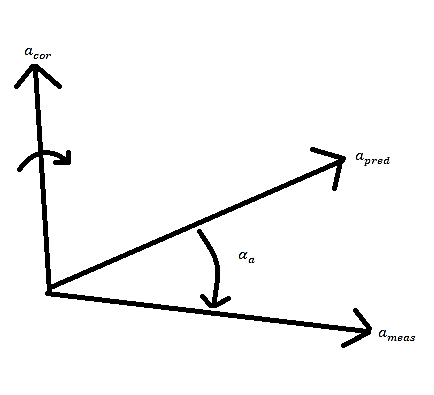


Figure 1.

is a vector orthogonal to both and ; eh predicted coordinate frame must be corrected by the correction angle  that will be applied around as illustrated in figure 1. Same goes for vectors ().

Step 5: Correction

The key component of the filter is the choice of the influence of the deviation on the correction of the predicted coordinate frame.

In this algorithm a correction will be done in the direction of both and and the scale of the correction angle () is varied via defining two functions:

With are tunning parameter.

function possible form:

1. A linear function .
2. A constant function (Madgwick approach).
3. A combination of both cases .

In smart fire arm project, the second form of the function with .

Correction rotation from acceleration measurement can be presented as follow:

SCF:

FSCF: (Algorithm Fast Version):

Correction rotation from magnetometer measurement can be presented as follow:

SCF:

FSCF: (Algorithm Fast Version):

Combining both found vector to get a single quaternion that represent a correction of the predicted reference frame towards the measurements. The combination is done by applying the following three steps:

SCF:

;

FSCF: (Algorithm Fast Version):

.

The performance of SCF is better than FSCF for fast rotational values.

Corrected quaternion vector () is then

The normalization of the estimated quaternion has to be done after each step of the filter.

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Doc Revision** | **Author** | **Description** | **Date** |
| 1.0 | Mohamad AKOUM | Fusion Algorithm | 22/09/2021 |

# References

[1] Fast AHRS for Accelerometer, Magnetometer and Gyroscope Combination with Separated Sensor Corrections.