CILAMCE 2017
Florianópolis - Santa Catarina - Brazil

COMPARING TWO METHODS OF COARSE SELF ALIGNMENT USING HIGH ACCURACY SINS

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Abstract. *Inertial alignment is a classical problem existing when one needs to bootstrap an inertial navigation system (INS) based on inertial sensors such as gyros and accelerometers. When no external aid is present one needs to provide the INS with some self-starting procedures. This study performs an investigation on the performance of two methods of coarse self-alignment for Strap-down Inertial Navigation Systems (SINS). The probably best-known standard method TRIAD is compared with a new variant method of coarse self-alignment known as ON-TRIAD (Felipe O. Oliveira et al., 2016). The performance assessment between the two methods is given by the comparison between the Euler angles yielded by each method, using actual data from relatively high accuracy SINS (aerospace grade). Using the initial static part of high sampling data, both methods are exercised and the Euler angles are computed several times. It was also analyzed the influence on the accuracy of a simple pre-processing to identify gross outliers, with little additional computer burden. In short, this work describes the results of both procedures depicting the influence of different mathematical tools on the data processing, accounting for the measurement quality as well.*

Keywords: *Aided Navigation, Inertial Navigation, Coarse Alignment*

1 INTRODUCTION

A significant number of modern Strap-down Navigation Systems (SINS) have a self-alignment feature. This feature is very important for navigators due to the capacity of determining the alignment of the system without an external aid. However, self-alignment procedure for a SINS, without external sensors or data to provide aiding, demands the system to be stationary with respect to the Earth, according to Grewal et al. (2013).

In general, self-alignment is divided in two phases: the coarse alignment and the fine alignment. Each one can be considered a self-alignment method, but with differences in rapidity and accuracy.

The coarse alignment consists of an analytical method that, with the knowledge of the gravity acceleration and Earth rotation rate, uses the data from the SINS and generates, as its name suggests, a raw estimate of the system orientation.

The fine alignment is a method which uses the estimate of the system orientation provided by some coarse alignment and improves it through the use of an indirect Kalman Filter. However, fine alignment is a slow process due to the use of such indirect Kalman Filter.

The time restrictions of fine alignment method make the study of coarse alignment, and its new improved techniques, attractive for specific jobs such as military maneuvers. Therefore this study aims to evaluate the differences in terms of Euler angles results between two important methods of coarse alignment: the classic coarse alignment method proposed by Britting (1971), referred to as three-axis attitude determination-based (TRIAD) method, and, according to the work of Oliveira Silva et al. (2016), the best known method of coarse alignment referred to as Orthogonal-Normal-TRIAD (ON-TRIAD).

2 ALIGNMENT AND TRIAD METHOD

Alignment, as described by Grewal et al. (2013), is a procedure to establish the initial inertial sensors assembly (ISA) attitude with respect to navigation coordinates. When the SINS sensors are sufficiently accurate and the system is stationary with respect to Earth, it can perform a procedure called self-alignment. The first phase, called coarse alignment, has two steps regarding the sensor data: leveling and gyrocompassing. Leveling consists of determining the orientation of its ISA relative to the local vertical using the knowledge of gravity. Gyrocompassing consists of determining the Earth rotation axes using the Earth rotation.

Once determined the leveling of the system, if the system is stationary and the inertial sensors of the SINS are accurate enough, it is possible for the system to perform a self-alignment. The method proposed by Britting (1971), known later as TRIAD, use the vectors of gravity, obtained by the leveling, and of Earth rotation rate to create three-axis linear independent vectors. The formulation of the problem, using the navigation frame NED (North-East-Down), is given by the following equations as shown:

$$g_p^l = \begin{pmatrix} 0 \\ 0 \\ g_p \end{pmatrix} \tag{1}$$

$$\omega_{ie}^l = \begin{pmatrix} \Omega.\cos(L) \\ 0 \\ -\Omega.\sin(L) \end{pmatrix} \tag{2}$$

$$g_p^l \text{ x } \omega_{ie}^l = \begin{pmatrix} 0 \\ g_p.\Omega.\cos(L) \\ 0 \end{pmatrix} \tag{3}$$

$$g_p^b = \begin{pmatrix} -a_x \\ -a_y \\ -a_z \end{pmatrix} \tag{4}$$

$$\omega_{ie}^b = \begin{pmatrix} \omega_x \\ \omega_y \\ \omega_z \end{pmatrix} \tag{5}$$

$$g_p^b \text{ x } \omega_{ie}^b = \begin{pmatrix} a_z.\omega_y - a_y.\omega_z \\ a_x.\omega_z - a_z.\omega_x \\ a_y.\omega_z - a_x.\omega_y \end{pmatrix} \tag{6}$$

$$C_b^l = \begin{pmatrix} {g_p^l}^T \\ {\omega_{ie}^l}^T \\ (g_p^l \text{ x } \omega_{ie}^l)^T \end{pmatrix}^{-1} . \begin{pmatrix} {g_p^b}^T \\ {\omega_{ie}^b}^T \\ (g_p^b \text{ x } \omega_{ie}^b)^T \end{pmatrix} \tag{7}$$

where,
g_p: Earth gravitational acceleration;
Ω: Earth rotation rate;
L: Local latitude;
g_p^l: Vector of terrestrial gravitational acceleration in navigation frame;
ω_{ie}^l: Vector of Earth rotation rate in navigation frame;
g_p^l x ω_{ie}^l: Vector product between the gravitational acceleration vector and the Earth rotation rate vector in the navigation frame;
g_p^b: Vector of terrestrial gravitational acceleration in body frame;
a_x, a_y, a_z: Accelerations in x, y and z axis in body frame;
ω_{ie}^b: Vector of Earth rotation vector in body frame;
$\omega_x, \omega_x, \omega_x$: Rotation speeds in x, y and z axis in body frame;
g_p^b x ω_{ie}^b: Vector product between the gravitational acceleration vector and the Earth rotation rate vector in the body frame;
C_b^l: Attitude (rotation) matrix that transforms the navigation frame system to the inertial frame.

Consequently, as presented by Oliveira Silva et al. (2016), the direct result of the TRIAD method is

$$C_b^l = \begin{pmatrix} \frac{g_p.\omega_x - \Omega.\sin(L).a_x}{g_p.\Omega.\cos(L)} & \frac{g_p.\omega_y - \Omega.\sin(L).a_y}{g_p.\Omega.\cos(L)} & \frac{g_p.\omega_z - \Omega.\sin(L).a_z}{g_p.\Omega.\cos(L)} \\ \frac{a_z.\omega_y - a_y.\omega_z}{g_p.\Omega.\cos(L)} & \frac{a_x.\omega_z - a_z.\omega_x}{g_p.\Omega.\cos(L)} & \frac{a_y.\omega_x - a_x.\omega_y}{g_p.\Omega.\cos(L)} \\ -\frac{a_x}{g_p} & -\frac{a_y}{g_p} & -\frac{a_z}{g_p} \end{pmatrix} \tag{8}$$

$$\emptyset = arctg\left(\frac{C_{3,2}}{C_{3,3}}\right) = arctg\left(\frac{a_y}{a_z}\right) \tag{9}$$

$$\theta = arcsin(C_{3,1}) = arcsin\left(\frac{a_x}{g_p}\right) \tag{10}$$

$$\psi = arctg\left(\frac{C_{2,1}}{C_{1,1}}\right) = arctg\left(\frac{a_z.\omega_y - a_y.\omega_z}{g_p.\omega_z - \Omega.\sin(L).a_x}\right) \tag{11}$$

where,

$C_{i,j}$: Elements of the attitude matrix C_b^l;

$\emptyset$: Roll Euler angle;

θ: Pitch Euler angle;

ψ: Yaw Euler angle.

The inherent errors of the TRIAD method as well as any coarse self-alignment method can be represented by:

$$\hat{C}_b^l = C_b^l + \delta C_b^l = (I + E).C_b^l \tag{12}$$

where, δC_b^l e E are matrix that contains errors of the matrix $\hat{C}_b^l$.

The error matrix E can be written as

$$E = E_s + E_{ss} \tag{13}$$

$$E_s = \frac{E + E^T}{2} = \begin{pmatrix} \eta_N & O_D & O_E \\ O_D & \eta_E & O_N \\ O_E & O_N & \eta_D \end{pmatrix} \tag{14}$$

$$E_{ss} = \frac{E - E^T}{2} = \begin{pmatrix} 0 & \varphi_D & -\varphi_E \\ -\varphi_D & 0 & \varphi_N \\ \varphi_E & -\varphi_N & 0 \end{pmatrix} \tag{15}$$

where, E_s is a symmetric matrix representing the normalization error vectors η and orthogonality O of the attitude calculated in the directions N (North), E (East) and D (Down). E_{ss} is an anti-symmetric matrix representing the vector of alignment errors φ calculated in the N (North), E (East) and D (Down) directions.

3 O-TRIAD AND ON-TRIAD METHODS

A way to obtain a better result of the TRIAD method is through a method called Orthogonal TRIAD or just O-TRIAD, according the work of Jiang, Y. F. (1998). This method substitute two of the three linear independent vectors also generated by gravity and Earth rotation vectors. The difference is that the new vectors proposed by the method are orthogonal. Equation (16) formulates the idea of the O-TRIAD method. The author of the method has proposed the set of vectors $(g_p\ , g_p \text{ x } \omega_{ie}, g_p \text{ x } \omega_{ie} \text{x} g_p\ )$.

$$C_b^l = \begin{pmatrix} {g_p^l}^T \\ (g_p^l \text{ x } \omega_{ie}^l)^T \\ (g_p^l \text{ x } \omega_{ie}^l \text{ x } g_p^l)^T \end{pmatrix}^{-1} \cdot \begin{pmatrix} {g_p^b}^T \\ (g_p^b \text{ x } \omega_{ie}^b)^T \\ (g_p^b \text{ x } \omega_{ie}^b \text{ x } g_p^b)^T \end{pmatrix} \tag{16}$$

The major idea of the Eq. (16) is to eliminate the errors of orthogonality in Eq. (14). As can be inferred, the resultant Euler angles obtained by the O-TRIAD method will be more accurate than the results of the TRIAD method, since there is less errors in the attitude matrix.

The proposition of Eq. (16) modifies the attitude matrix, but the formulae to obtain the Euler angles still the same. However, when the formulae has been written in function of inertial sensors, gravity and Earth rotation rate we are able to see some differences.

$$\emptyset = arctg\left(\frac{C_{3,2}}{C_{3,3}}\right) = arctg\left(\frac{a_y}{a_z}\right) \tag{17}$$

$$\theta = arcsin(C_{3,1}) = arcsin\left(\frac{a_x}{g_p}\right) \tag{18}$$

$$\psi = arctg\left(\frac{C_{2,1}}{C_{1,1}}\right) = arctg\left(\frac{a_z.\omega_y - a_y.\omega_z}{{a_z}^2.\omega_x - a_x.a_z.\omega_z - a_x.a_y.\omega_y - {a_y}^2.\omega_x}\right) \tag{19}$$

The expansion of the Eq. (17), Eq. (18) and Eq. (19), makes possible to compare with the Euler angle formulae from TRIAD method analyzing Eq. (9), Eq. (10) and Eq. (11). It is possible to state that Eq. (9) is equal to Eq. (17) and Eq. (10) is equal to Eq. (18). The only difference in Euler angle results between TRIAD and O-TRIAD method will be in the yaw angle.

Based in a similar concept of the O-TRIAD, the work of Felipe O. Silva, et al. (2016) brought the coarse alignment Orthogonal-Normal-TRIAD method, also known as ON-TRIAD. The objective of ON-TRIAD is to eliminate orthogonality and normality errors in Eq. (14). The results of O-TRIAD method shown in Eq. (17), Eq. (18), and Eq. (19), has been used to build an attitude matrix with normality and orthogonality properties. According to the classic 1-2-3 sequence of rotations the attitude matrix, using the Euler angles of O-TRIAD method, the ON-TRIAD attitude matrix is given by

$$C_b^l = \begin{pmatrix} c\theta.c\psi & -c\phi.s\psi + s\phi.s\theta.c\psi & s\phi.s\psi + c\phi.s\theta.c\psi \\ c\theta.s\psi & c\phi.c\psi + s\phi.s\theta.s\psi & -s\phi.c\psi + c\phi.s\theta.s\psi \\ -s\theta & s\phi.c\theta & c\phi.c\theta \end{pmatrix} \tag{20}$$

where "c" denotes the function cosine and "s" denotes the function sine. This attitude matrix has $\eta_N = \eta_E = \eta_D = O_N = O_E = O_D = 0$, or orthogonality nor normality errors.

Despite the fact that Eq. (20) is distinct of Eq. (16), as long as Eq. (20) was assembled with the Euler angles of Eq. (17), Eq. (18) and Eq. (19) the Euler angles of ON-TRIAD method are the same of O-TRIAD method.

4 COMPARISON BETWEEN TRIAD AND ON-TRIAD METHODS

As could be seen in section 3, the difference, regarding Euler angles results, between TRIAD and ON-TRIAD coarse self-align methods is just in the yaw angle. The results of angles of pitch and roll will be identical in both methods. This study will focus only in the results of yaw angle.

4.1 The SINS Data

The data used to evaluate the methods was kindly provided by Instituto de Aeronáutica e Espaço (IAE) for academic purposes. It was real data, originated from an inertial navigation experiment performed in a roller coaster, sampled in a frequency of 100 Hz. Each sample has the data from accelerometers and gyros triads.

The use of real data has shown that the system is never perfectly stationary. The sensors always record little variations on acceleration or angular velocity due to real movements or due noise. This fact makes the data processing an important player in the coarse self-alignment study, since impacts directly in the results. Since the TRIAD and ON-TRIAD methods have as a requirement the stationary state of the system, it is necessary a preliminary analysis of the available data to determinate the time and the number of samples to make the coarse self-alignment properly. The Fig. 1, Fig. 2 and Fig. 3 show the raw data of accelerometers triad.

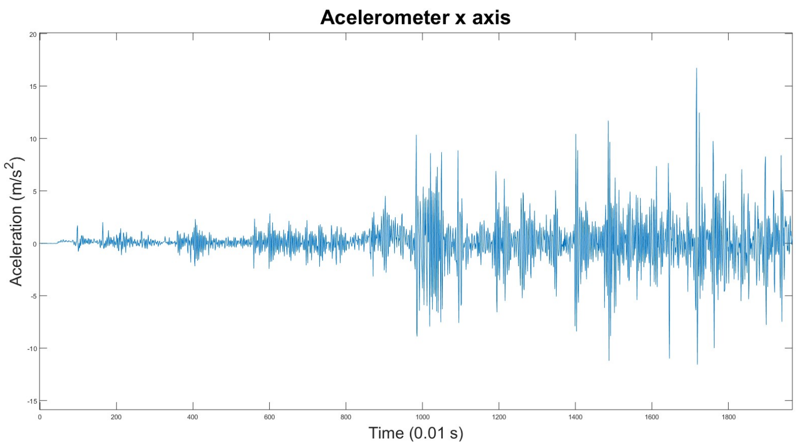

Figure 1. x axis accelerometer data

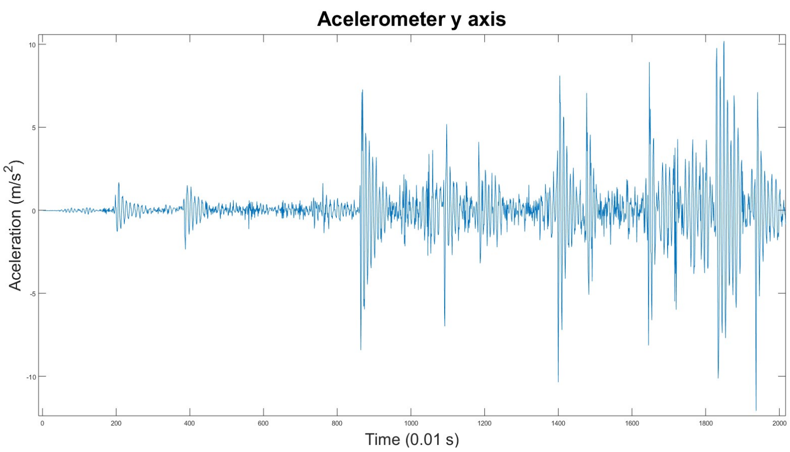

Figure 2. y axis accelerometer data

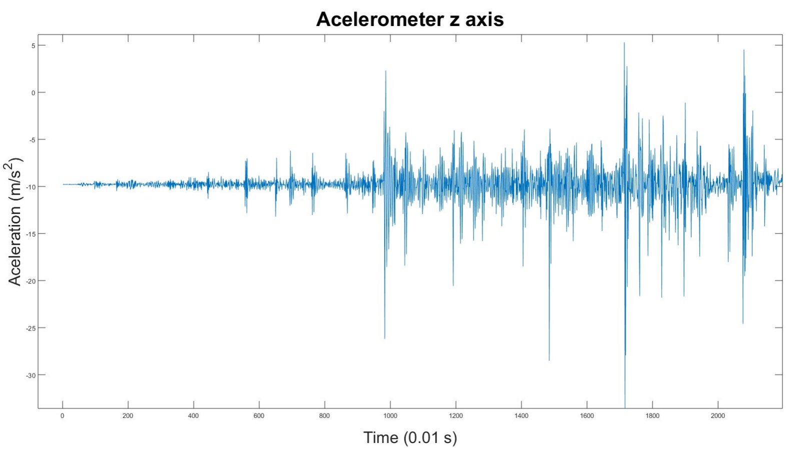

Figure 3. z axis accelerometer data

Figure 1 shows that around 8 seconds after the begining of data there was a movement. Despite the amplitude of the movement, we do not consider the system as stationary after the eighth second. Once set the 800 samples in which the system is considered stationary, four distinct tests have been made to evaluate the differences of performance of coarse self-alignment methods TRIAD and ON-TRIAD and the numerical procedure.

4.2 Determination of Coarse Self-Alignment in each sample

For each sample of the total (800), the Euler angle Yaw was determined by TRIAD and ON-TRIAD methods with Eq. (11) and Eq. (19), respectively. After the calculus, all the results of Yaw of TRIAD and ON-TRIAD methods were used to find its mean value, as Eq. (21) and Eq. (22) show.

$$\psi_M^{TRIAD} = \frac{1}{800}\sum_{i=1}^{800} \psi_i^{TRIAD} \tag{21}$$

$$\psi_M^{ON-TRIAD} = \frac{1}{800}\sum_{i=1}^{800} \psi_i^{ON-TRIAD} \tag{22}$$

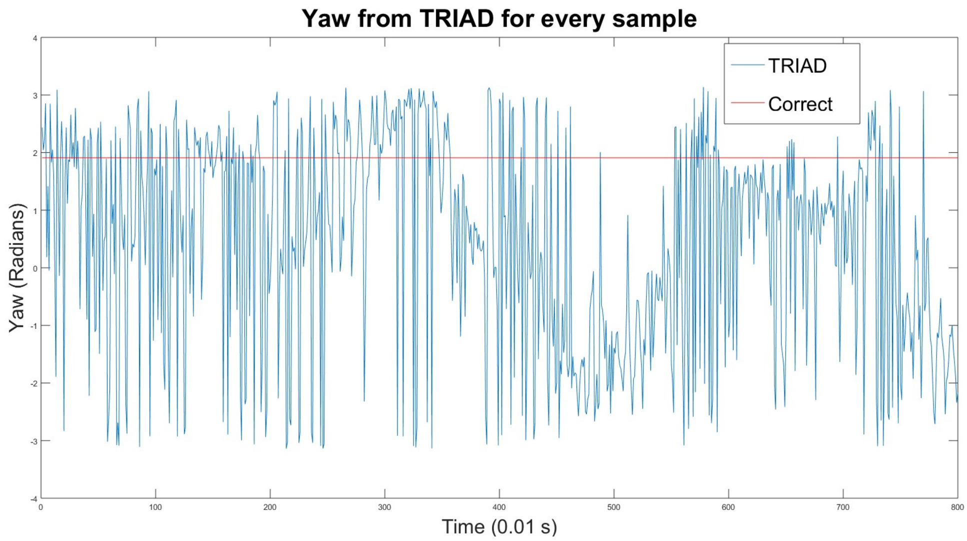

Figure 4. Yaw angles from TRIAD method for every data sample

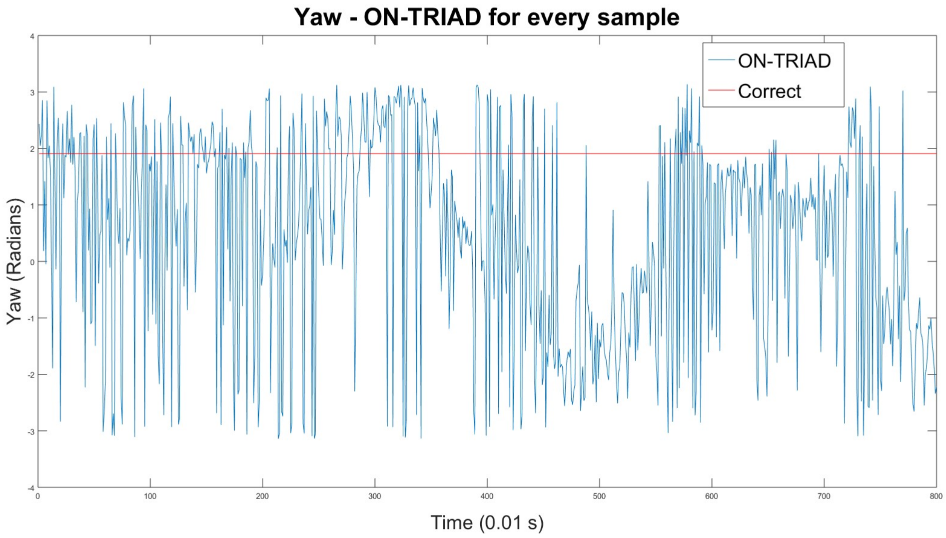

Figure 5. Yaw angles from ON-TRIAD method for every data sample

As can be seen in Fig. 4 and Fig. 5, the variance of the results of yaw angle at both methods is huge, even with the system considered stationary. In addition, it can be seen the best (corrected) value of yaw angle in red at Fig. 4 and Fig. 5. Comparing the arithmetic mean of TRIAD and ON-TRIAD yaw angle result with the assumed correct value of yaw angle, both methods presented results far from the desired one.

Table 1. Results of arithmetic mean of TRIAD and ON-TRIAD Yaw angle for every sample.

Yaw Angle	Value (rad)	Error (rad)	Variance
Yaw (reference)	1.9102545821	-	-
Yaw (TRIAD)	0.4389902881	1.4712642940	3.3844094073
Yaw (ON-TRIAD)	0.4390685178	1.4711860642	3.3718122811

The results of Table 1 show that the determination of the Euler angles by this procedure **does not have reliability** due to high data mass variance. It is noteworthy that, although the yaw results in the ON-TRIAD method are somewhat closer than those obtained in TRIAD, given the magnitude of the difference between the results and the correct value of yaw angle, it is not possible to state superiority of ON-TRIAD over TRIAD in this case.

4.3 Analysis of the results of the yaw angles obtained through the TRIAD and ON-TRIAD methods from the arithmetic means of the input data.

In order to observe the influence of the treatment of the data mass on the Euler angles result of the coarse alignment methods, as each measurement is acquired, one has added the arithmetic mean of the measurements for the determination of yaw with Eq. (11) and Eq. (19). The arithmetic mean of the measurements were obtained with the following simple equations.

$$a_x = \frac{1}{sample}\sum_{i=1}^{sample} a_{x_i} \tag{23}$$

$$a_y = \frac{1}{sample}\sum_{i=1}^{sample} a_{y_i} \tag{24}$$

$$a_z = \frac{1}{sample}\sum_{i=1}^{sample} a_{z_i} \tag{25}$$

$$\omega_x = \frac{1}{sample}\sum_{i=1}^{sample} \omega_{x_i} \tag{26}$$

$$\omega_y = \frac{1}{sample}\sum_{i=1}^{sample} \omega_{y_i} \tag{27}$$

$$\omega_z = \frac{1}{sample}\sum_{i=1}^{sample} \omega_{z_i} \tag{28}$$

The TRIAD and ON-TRIAD methods resulted in the following yaw angles, according to the arithmetic mean of the input data.

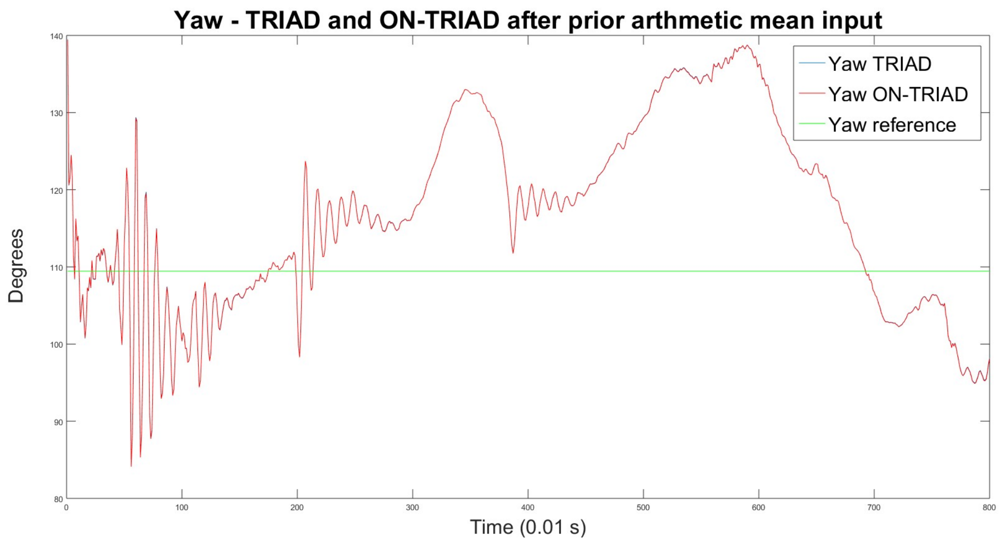

Figure 6. Yaw angles from TRIAD and ON-TRIAD methods for data with prior arithmetic mean

Figure 6 shows that the results for the yaw angle of the TRIAD (blue) and ON-TRIAD (red) methods were very close, practically having one result overlapping the other. However, as the number of samples of the mean grows, the oscillation around the correct yaw value (green) goes away.

It can also be observed that the results, on average, are much closer to the reference in the first two seconds or two hundred first samples.

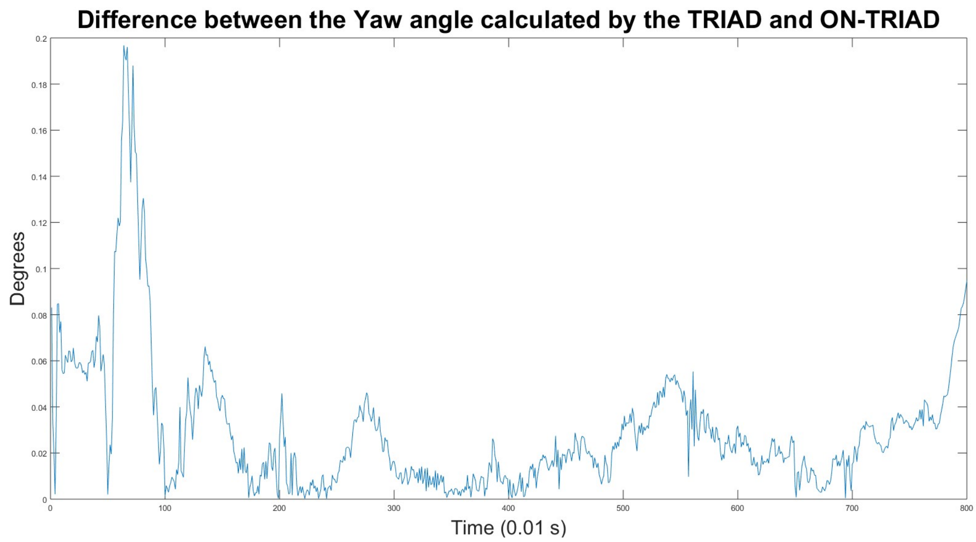

Figure 7. Difference between Yaw angles from TRIAD and ON-TRIAD methods

The absolute value of the difference between the results of the TRIAD and ON_TRIAD methods with respect to the determination of the yaw angle is shown in Fig. 7.

Table 2. Arithmetic mean of TRIAD and ON-TRIAD yaw angle results with arithmetic means in the input data.

Yaw angle	Value (rad)	Error (rad)	Variance
Yaw (reference)	1.9102545821	-	-
Yaw (TRIAD)	2.0373834523	0.12712887	0.0438096579
Yaw (ON-TRIAD)	2.0370951074	0.126840525	0.0438127051

Observing the arithmetic mean results obtained by the two methods at Table 2 it is possible to observe that, for these 800 samples, the ON-TRIAD method is slightly more accurate in determining the yaw angle, compared to the TRIAD method. However, the ON-TRIAD variance is slightly larger than the variance of the TRIAD method.

Figure 6 and Fig. 7 show that the differences in the results of the yaw angle are more pronounced when the data are near a stationary condition. This statement is supported by Fig. 1, Fig. 2 and Fig. 3. Analyzing the interval of the initial 200 samples data, the results show that the ON-TRIAD method provided yaw angles closer to the reference result in 64.5% of the determinations.

4.4 Analysis of the results of the yaw angles obtained through the TRIAD and ON-TRIAD methods from recursive Kalman filtering of the input data.

According to Kuga (2005), the Kalman filter provides the estimates for the instant at which the measure is processed:

$$K_i = \hat{P}_{i-1}.H_i^t.(H_i.\hat{P}_{i-1}.H_i^t + R_i)^{-1} \tag{29}$$

$$\hat{P}_i = (I - K_i.H_i).\hat{P}_{i-1} \tag{30}$$

$$\hat{x}_i = \hat{x}_{i-1} + K_i.(y_i - H_i.\hat{x}_{i-1}) \tag{31}$$

where,

K_i: Kalman gain matrix;

$\hat{P}_i$: Covariance matrix;

H_i: Measurement matrix;

R_i: Inverse weight matrix;

$\hat{x}_i$: State vector;

y_i: Measurement vector;

I: Identity matrix.

Recursive Kalman filter, rather than the arithmetic mean, was implemented before the data processing by the TRIAD and ON-TRIAD methods. Using R_i matrix as the inverse of weight matrix, it adjusts the input data to a better estimate of the real measurement.

After its implementation to handle the input data, Fig. 8 shows the performance of yaw Euler angle with TRIAD and ON-TRIAD methods.

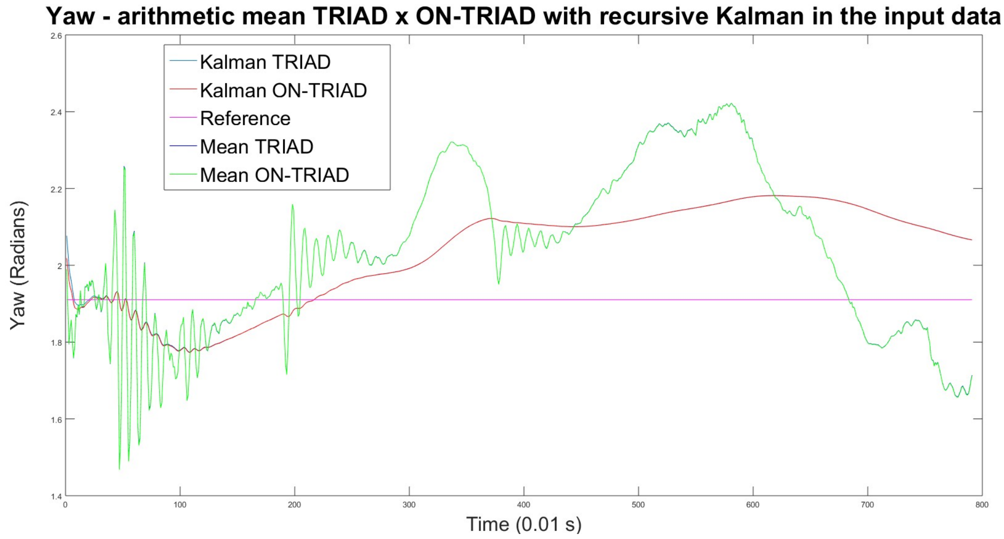

Figure 8. Yaw angles from TRIAD and ON-TRIAD methods with recursive Kalman filter in the input data

As expected, the recursive Kalman filter minimizes the variance (approximately 2.5 times less) of the measurements and, consequently, the results of the TRIAD and ON-TRIAD algorithms. The results of TRIAD and ON-TRIAD measurements for the yaw angle are very close to each other.

Table 3. Arithmetic mean of TRIAD and ON-TRIAD yaw angle results with recursive Kalman filter in the input data.

Yaw angle	Value (rad)	Error (rad)	Variance
Yaw (reference)	1.9102545821	-	-
Yaw (TRIAD)	2.0353027530	0.125048171	0.0184109325
Yaw (ON-TRIAD)	2.0301833158	0.119928734	0.0165496023

Data treated with recursive Kalman Filtering produce in the ON-TRIAD method an estimate whose mean is closer to the actual result, as well as the variance is smaller in relation to the TRIAD method.

4.5 Analysis of the results of the yaw angles obtained through the TRIAD and ON-TRIAD methods from a Median Filter in the data from the sensors.

The median filter have been used in the data mass, rather than the arithmetic mean, before the data processing by the TRIAD and ON-TRIAD methods to verify the performances of the same methods. According to Vaseghi (2000), the median of an odd set of numbers, is insensitive to the presence of samples with outlier values. The output of a median filter with input $y(m)$ and a median window of length 2K+1 samples is given by

$$\hat{x}(m) = \hat{y}_{med}(m) = median\ [y(m-K), y(m-K+1), \dots, y(m), \dots, y(m+K)] \tag{32}$$

The implementation of the median filter in the input data was like the previous numerical methods. The number of samples used, however is different since the median filter always require an odd number of samples. So, just 399 samples (3 to 799) were utilized. Once the results of median filter for each inertial sensor have obtained the results of the yaw angle obtained with the data were presented at Fig. 9.

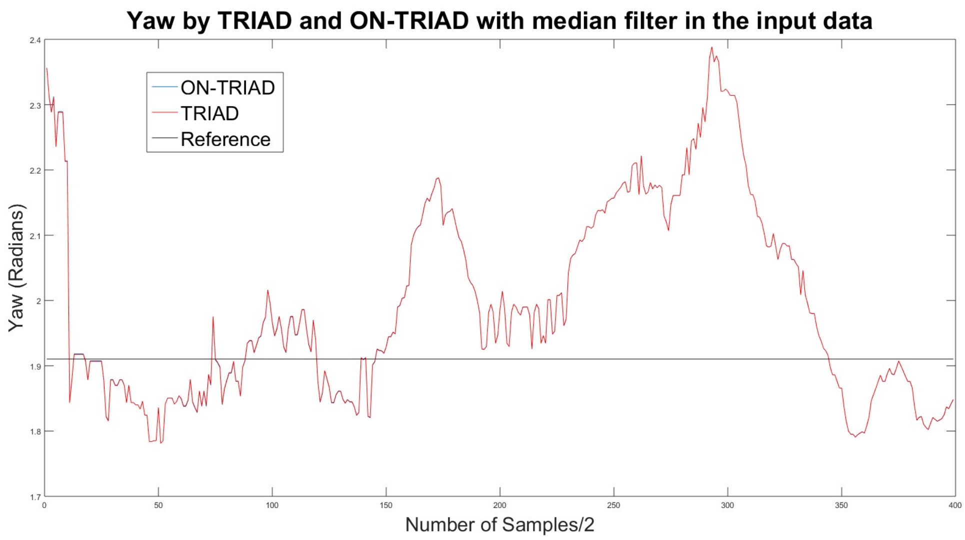

Figure 9. Yaw angles from TRIAD and ON-TRIAD methods with median filter in the input data

Table 5. Arithmetic mean of TRIAD and ON-TRIAD yaw angle results with median filter in the input data.

Yaw angle	Value (rad)	Error (rad)
Yaw (reference)	1.9102545821	-
Yaw (TRIAD)	1.9943738799	0.08411929775
Yaw (ON-TRIAD)	1.9941047473	0.08385016518

The Table 5 shows that the use of median filter in the input data has given the best coarse self-alignment result in this study. It is also interesting to observe that the mean of the yaw angle results of ON-TRIAD method has delivered a better result than TRIAD method. Yet, the results of the two methods were very close so that the difference does not appear in the Fig. 9.

4.6 Comparison between average mean, recursive kalman filter and median filter applied to self-coarse alignment

It is important to compare the performance of the method that impact on ON-TRIAD yaw results.

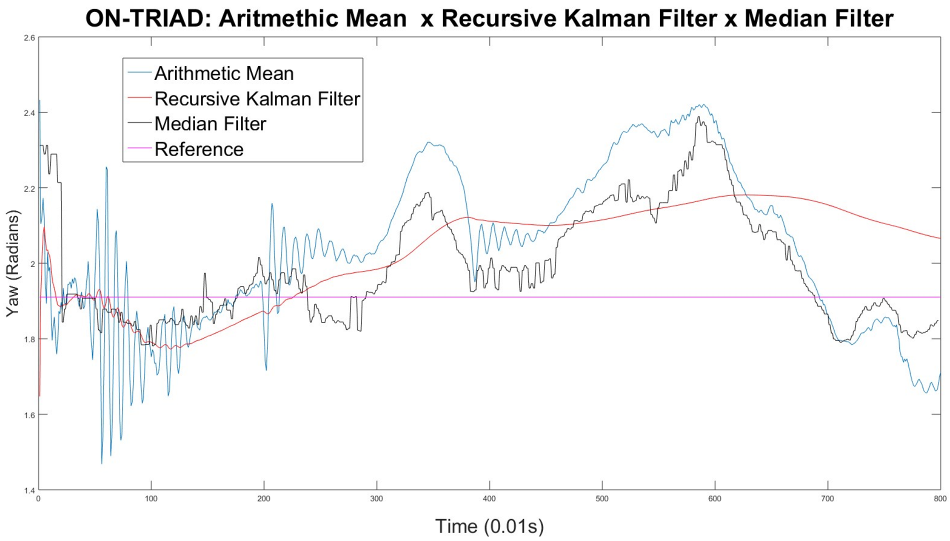

Figure 10. Comparison between the data handling influence in yaw angle result obtained with ON-TRIAD

Figure 10 corroborates the conclusions of the previous chapters. The ON-TRIAD method had a better performance in most of the time using a median filter in the input data. The recursive Kalman filter provide the second best result giving a smooth characteristic for the result, filtering the outliers. Looking at the final result, after 8 s or 800 samples, the results between the methods will be the same, as Table 6 shows.

Table 6. Comparison between ON-TRIAD yaw angle result with different input data handling after 800 samples.

Yaw angle	Value (rad)	Error (rad)
Yaw (reference)	1.9102545821	-
Yaw (Arithmetic. Mean)	1.7120260332	0.19822854900
Yaw (Recursive Kalman Filter)	2.0659518669	0.15569728472
Yaw (Median Filter)	1.8480417588	0.06221282338

5. CONCLUSION

This study has focused in comparing the coarse self-alignment methods TRIAD and ON-TRIAD in terms of the Euler angles computed using real data. The difference between TRIAD and ON-TRIAD methods however does not have influence only in Euler angles, but in inertial navigation results, since they modify the attitude matrix. Albeit incomplete, this study have corroborated the results proposed by the work of Oliveira Silva et al. (2016) showing that coarse self-alignment method ON-TRIAD provides a more accurate result of yaw angle than the TRIAD method.

As a secondary result, it was possible to make some conclusions regarding the impact of data handling in coarse self-alignment method. Among the four distinct data handling methods, the worst result was the method that performs the calculus of coarse self-alignment in every sample of data and makes an arithmetic mean of the results. This procedure does not seems reliable. The other techniques to handle input data have shown good results. The best one was the use of median filter in the input data.

ACKNOWLEDGEMENTS

Thanks to Instituto de Aeronáutica e Espaço (IAE) for kindly providing the data used in this study.

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