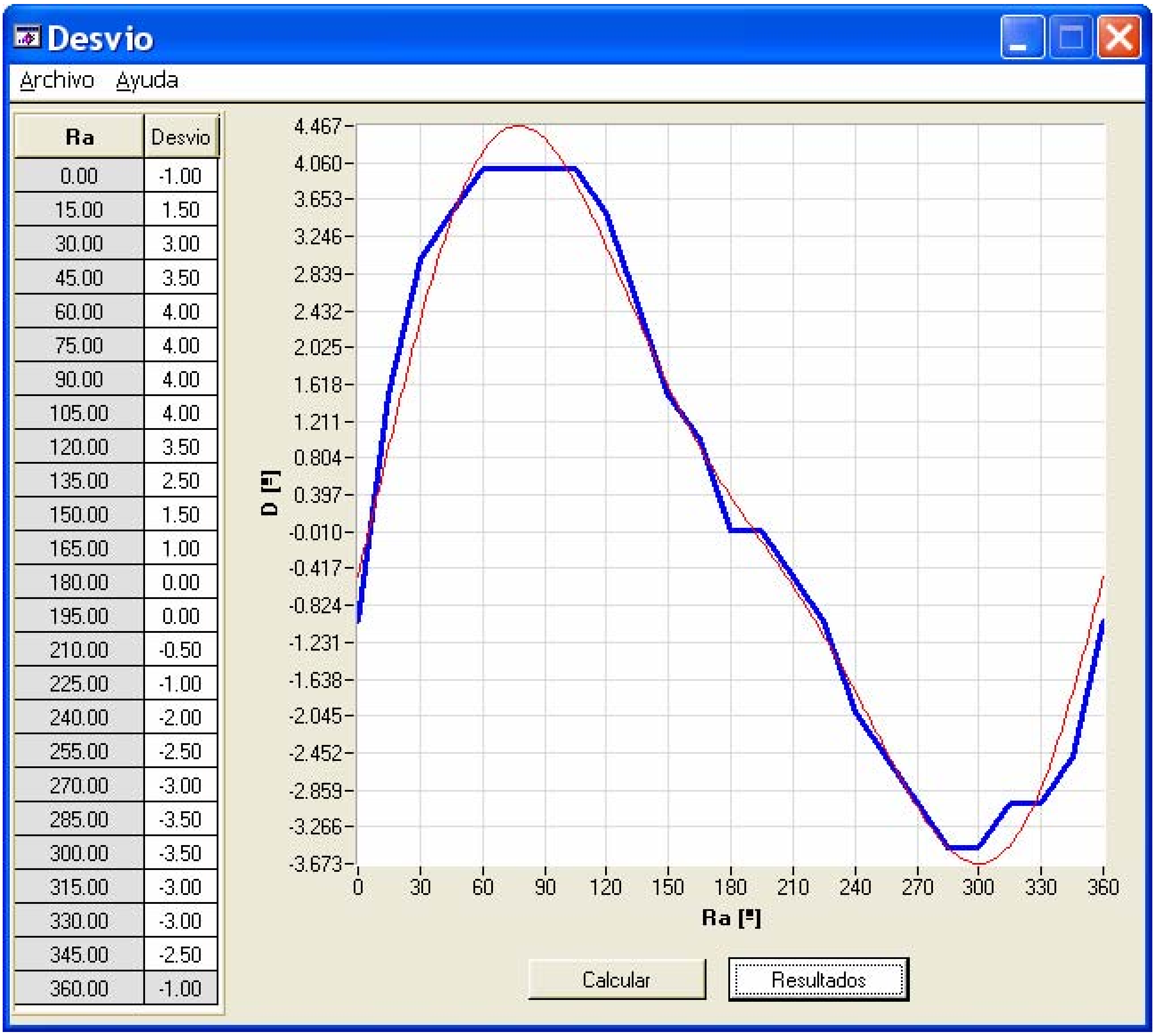
NAVIGATIONAL ALGORITHMS

Deviation curve of the magnetic compass



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Abstract

An analytic method for obtaining the deviation curve of a magnetic compass is presented, in its general and in its simplified form, thus allowing obtaining the value of the deviation for any course.

June 1999
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Variables

Ra Course of the compass

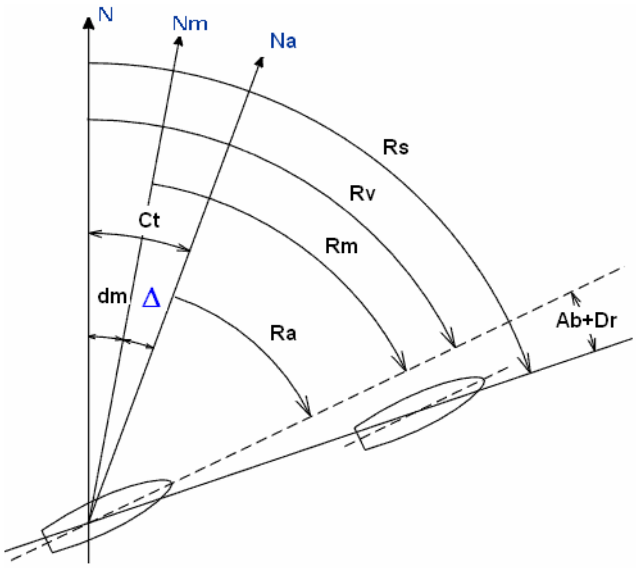
Δ Deviation

NE (+) y NW (–)

The Deviation of the magnetic compass

The magnetic compass deviation, Δ, is the angle formed by the magnetic meridian of the place, i.e., magnetic north, with northern needle. Is due to local magnetic fields generated by electric currents, large structures of iron (aboard the metal hulls and electronic devices).

Δ = ANG(Nm, Na)



Na to the **E** of Nm ⇨ **Δ = (+)**

Na to the **W** of Nm ⇨ **Δ = (-)**

The Deviation curve

Once the traditional deviation table is obtained, which indicates Δ for each course, since the deviation is a function only of Ra, it can be obtained by adjusting the values of a trigonometric curve as shown.

$$\Delta = \Delta(Ra)$$

$$\Delta = A + B * \sin Ra + C * \cos Ra + D * \sin 2Ra + E * \cos 2Ra$$

To calculate the coefficients A, B, C, D, E, the error between the actual value and the adjustment function is minimized:

$$S = \sum_{i=1}^{n} \left[\Delta_i - \Delta(Ra_i) \right]^2$$

$$S = \sum_{i=1}^{n} \left[\Delta_i - A - B \cdot \sin Ra_i - C \cdot \cos Ra_i - D \cdot \sin 2Ra_i - E \cdot \cos 2Ra_i \right]^2$$

$$\frac{\partial S}{\partial \lambda_r} = 0, r = 1,5$$

$$\lambda_r = A, B, C, D, E$$

Resulting a system of five equations with five unknowns, which in matrix form is:

$$[A] = \begin{bmatrix} n & \sum \sin Ra & \sum \cos Ra & \sum \sin 2Ra & \sum \cos 2Ra \\ \sum \sin Ra & \sum \sin^2 Ra & \sum \cos Ra * \sin Ra & \sum \sin 2Ra * \sin Ra & \sum \cos 2Ra * \sin Ra \\ \sum \cos Ra & \sum \cos Ra * \sin Ra & \sum \cos^2 Ra & \sum \sin 2Ra * \cos Ra & \sum \cos 2Ra * \cos Ra \\ \sum \sin 2Ra & \sum \sin 2Ra * \sin Ra & \sum \sin 2Ra * \cos Ra & \sum \sin^2 2Ra & \sum \cos 2Ra * \sin 2Ra \\ \sum \cos 2Ra & \sum \cos 2Ra * \sin Ra & \sum \cos 2Ra * \cos Ra & \sum \cos 2Ra * \sin 2Ra & \sum \cos^2 2Ra \end{bmatrix}$$

$$\{X\} = \begin{bmatrix} A \\ B \\ C \\ D \\ E \end{bmatrix} \qquad \{L\} = \begin{bmatrix} \sum \Delta \\ \sum \Delta * \sin Ra \\ \sum \Delta * \cos Ra \\ \sum \Delta * \sin 2Ra \\ \sum \Delta * \cos 2Ra \end{bmatrix}$$

[A]{X} = {L}

$$\begin{bmatrix} n & \sum \sin Ra & \sum \cos Ra & \sum \sin 2Ra & \sum \cos 2Ra \\ \sum \sin Ra & \sum \sin^2 Ra & \sum \cos Ra * \sin Ra & \sum \sin 2Ra * \sin Ra & \sum \cos 2Ra * \sin Ra \\ \sum \cos Ra & \sum \cos Ra * \sin Ra & \sum \cos^2 Ra & \sum \sin 2Ra * \cos Ra & \sum \cos 2Ra * \cos Ra \\ \sum \sin 2Ra & \sum \sin 2Ra * \sin Ra & \sum \sin 2Ra * \cos Ra & \sum \sin^2 2Ra & \sum \cos 2Ra * \sin 2Ra \\ \sum \cos 2Ra & \sum \cos 2Ra * \sin Ra & \sum \cos 2Ra * \cos Ra & \sum \cos 2Ra * \sin 2Ra & \sum \cos^2 2Ra \end{bmatrix} \begin{bmatrix} A \\ B \\ C \\ D \\ E \end{bmatrix} = \begin{bmatrix} \sum \Delta \\ \sum \Delta * \sin Ra \\ \sum \Delta * \cos Ra \\ \sum \Delta * \sin 2Ra \\ \sum \Delta * \cos 2Ra \end{bmatrix}$$

The matrix [A] is symmetric. Solving the system of equations, the five coefficients are obtained.

If you have an analytic expression for the deviation curve, you can obtain for any value of Ra the Δ, and plot a graphic with the obtained values.

Special case:

For Ra from 0º to 360º, taken in increments of 15º, the matrix is diagonal; Dij = 0. Then:

$$A = 1/n \sum \Delta_i \qquad B = \frac{\sum \Delta_i \sin Ra_i}{\sum \sin^2 Ra_i} \qquad C = \frac{\sum \Delta_i \cos Ra_i}{\sum \cos^2 Ra_i} \qquad D = \frac{\sum \Delta_i \sin 2Ra_i}{\sum \sin^2 2Ra_i} \qquad E = \frac{\sum \Delta_i \cos 2Ra_i}{\sum \cos^2 2Ra_i}$$

A1. Example

Ra	des
0º	1.0
30º	3.0
60º	4.0
90º	4.0
120º	3.0
150º	2.0
180º	-1.0
210º	-3.0
240º	-5.0
270º	-6.0
300º	-4.0
330º	-2.0

des sin Ra	(sin Ra)2	des cos Ra	(cos Ra)2	des sin 2Ra	(sin 2Ra)2	des cos 2Ra	(cos 2Ra)2
0.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0
1.5	0.3	2.6	0.8	2.6	0.8	1.5	0.3
3.5	0.8	2.0	0.3	3.5	0.8	-2.0	0.3
4.0	1.0	0.0	0.0	0.0	0.0	-4.0	1.0
2.6	0.8	-1.5	0.3	-2.6	0.8	-1.5	0.3
1.0	0.3	-1.7	0.8	-1.7	0.8	1.0	0.3
0.0	0.0	1.0	1.0	0.0	0.0	-1.0	1.0
1.5	0.3	2.6	0.8	-2.6	0.8	-1.5	0.3
4.3	0.8	2.5	0.3	-4.3	0.8	2.5	0.2
6.0	1.0	0.0	0.0	0.0	0.0	6.0	1.0
3.5	0.8	-2.0	0.3	3.5	0.8	2.0	0.3
1.0	0.3	-1.7	0.8	1.7	0.8	-1.0	0.2
28.9	6.0	4.7	6.0	0.0	6.0	3.0	6.0

Ra	des	Error
0º	1.0	0.0
30º	3.0	0.0
60º	4.0	0.0
90º	4.0	0.0
120º	3.2	0.1
150º	1.6	-0.2
180º	-0.6	-0.6
210º	-3.2	0.1
240º	-5.1	0.0
270º	-5.6	-0.1
300º	-4.4	0.1
330º	-1.8	-0.1

A =	-0.33
B =	4.81
C =	0.79
D =	0.00
E =	0.50