Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
*Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird*
*DAAAM Symposium*

# NEW METHOD FOR MAGNETOMETER OFFSET COMPENSATION

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***Abstract:*** *The article deals with an offset of magnetometer. It is a significant problem when the magnetometer is used as an electronic compass. Some of the most popular methods for an offset compensation (in practice) are described here. It was developed a new method which is better in some points of view. This new method and the test results on a real magnetometer are described here.*
***Key words:*** *magnetometer, compass, offset*

## 1. INTRODUCTION

As well as a compass needle does not point to the north in the vicinity of the magnetic materials, the magnetometer is sensitive to anything that distorts Earth's magnetic field. Magnetic metals and various sources of parasitic magnetic fields (transformers, motors, power supplies ...) are some of the parasitic influences (Caruso et al., 1998; Hauser at al., 2000).

Removing all sources of parasitic influences from the vicinity of magnetometer is the best way to eliminate the offset. Especially sources of parasitic magnetic fields should not be in a close range of magnetometer. The object made from magnetic material should be away from the magnetometer at least twice its own size. Unfortunately, it is not usually possible. Magnetometer is usually placed on a robot body. This body contains magnetic materials. Using a compensation algorithm is necessary in this case.

## 2. SET/RESET COMPENSATION METHOD

Some types of magnetometers include so called Set/Reset strap elements. These elements can be used to compensate the offset by toggling the Set/Reset elements between set and reset conditions (***, 2002; Caruso, 2003). This causes toggling the output voltage polarity, but the offset voltage remains a consistent bias on the output. Fig. 1. shows the toggling routine graphed with typical output levels.

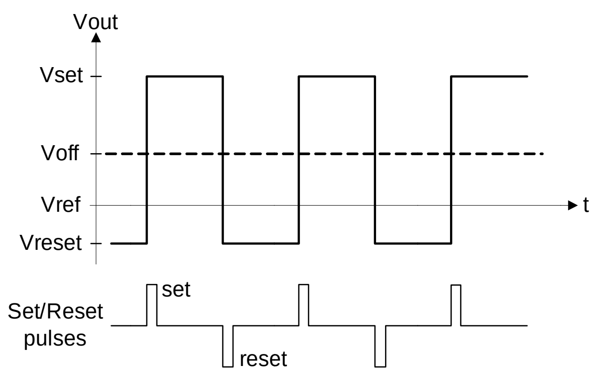


Fig. 1. Set/Reset routine

Offset (Voff) is computed from the “set pulse” output voltage (Vset) and the “reset pulse” output voltage (Vreset) by (1).

$$V_{off} = \frac{V_{set} + V_{reset}}{2} \qquad (1)$$

This compensation method reduces the magnetometer offset but does not remove it completely. The power consumption is higher and it requires a complicated hardware.

## 3. MIN-MAX COMPENSATION METHOD

The most popular method for removing the magnetometer offset in practice is the Minimum-Maximum method (Caruso, 2002). It is measured minimal and maximal output of X-axis and Y-axis ($X_{max}$, $X_{min}$, $Y_{max}$ and $Y_{min}$) of the magnetometer (parallel to the earth surface) by rotating along Z-axis (perpendicular to the earth surface - azimuth) in the 360° range. Calibration values are computed by (2).

$$\begin{aligned} X_{sf} &= \frac{Y_{\max} - Y_{\min}}{X_{\max} - X_{\min}} \; or \; 1 \quad \Leftarrow what\ is\ bigger \\ Y_{sf} &= \frac{X_{\max} - X_{\min}}{Y_{\max} - Y_{\min}} \; or \; 1 \quad \Leftarrow what\ is\ bigger \\ X_{off} &= \left( \frac{X_{\max} - X_{\min}}{2} + X_{\min} \right) \cdot X_{sf} \\ Y_{off} &= \left( \frac{Y_{\max} - Y_{\min}}{2} + Y_{\min} \right) \cdot Y_{sf} \end{aligned} \qquad (2)$$

Measured values are compensated by (3).

$$\begin{aligned} H'_{ex} &= H_{ex} \cdot X_{sf} - X_{off} \\ H'_{ey} &= H_{ey} \cdot Y_{sf} - Y_{off} \end{aligned} \qquad (3)$$

Symbols $H_{ex}, H_{ey}$ are the measured magnetic fields and $H'_{ex}, H'_{ey}$ are the compensated magnetic fields in X-axis and Y-axis.

Sometimes this compensate method is complicated to use in practice. For example if the magnetometer is mounted on a robot body. A slow rotation move is pretty complicated to make in this case. Next disadvantage is a long time required for the compensation.

## 4. FOUR-POSITIONS COMPENSATION METHOD

We developed a new compensation method which reduces these disadvantages. It is called the Four-positions method. The aim of the method is a measurement of the magnetometer output in four positions. Positions must be mutual rotated by 90° ($H_1, H_2, H_3, H_4$). Then goniometric functions are used (4).

$$\begin{aligned} H_1 &= A\sin\alpha + c \\ H_2 &= A\sin(\alpha + 90) + c = A\cos\alpha + c \\ H_3 &= A\sin(\alpha + 180) + c = -A\sin\alpha + c \\ H_4 &= A\sin(\alpha + 270) + c = -A\cos\alpha + c \end{aligned} \quad (4)$$

The $A$ symbol is signal amplitude and the $c$ symbol is signal offset.

Equation $H_1$ is subtracted from $H_3$ and equation $H_2$ is subtracted from $H_4$. Then the initial rotation angle is computed by (5).

$$\left.\begin{aligned} H_1 - H_3 &= 2A\sin\alpha \\ H_2 - H_4 &= 2A\cos\alpha \end{aligned}\right\} \quad \alpha = \arctan\frac{H_1 - H_3}{H_2 - H_4} \quad (5)$$

The amplitude $A$ is computed from the first equation in (5). The offset $c$ is computed by summing equations $H_1$ and $H_3$.

$$A = \frac{H_1 - H_3}{2\sin\alpha} \qquad c = \frac{H_1 + H_3}{2} \quad (6)$$

The measurements and the calculations are done in X-axis and Y-axis. Compensation values are then computed by (7).

$$\begin{aligned} X_{sf} &= \frac{A_y}{A_x} \text{ or } 1 \quad \Leftarrow \textit{what is bigger} \\ Y_{sf} &= \frac{A_x}{A_Y} \text{ or } 1 \quad \Leftarrow \textit{what is bigger} \\ X_{off} &= c_x \cdot X_{sf} \\ Y_{off} &= c_y \cdot Y_{sf} \end{aligned} \quad (7)$$

Measured values are compensated by (3).

The comparison between the Minimum-maximum and Four-positions method is demonstrated in Fig. 2. The measured magnetic field in X-axis and Y-axis dependence on the azimuth is shown in figure on top. Each axis has a different offset and amplitude.

The average error of rotation angle dependence on the position of the first compensation point is shown in figure on bottom. The other compensations points are mutual rotated by 90°. The graph was created by this scheme:

- The first compensation point was chosen. The other compensations points are mutual rotated by 90°.
- The compensation data was computed from the compensation points.
- The measured data was compensated.
- The azimuth was computed from the compensated data.
- The average error of the azimuth is computed.
- This error is drawn as a Y-value in graph. X-value is the corresponding first compensation point.

The efficiency of compensation depends on the position of compensations points, because the measured functions are not exactly sinusoidal shape.

The dashed line in graph is the error of the azimuth by using Minimum-maximum method.

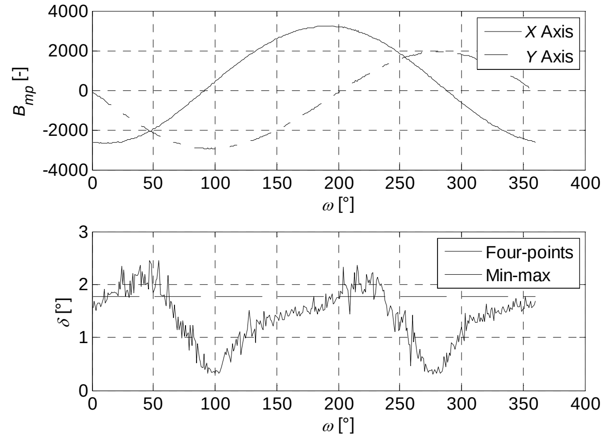


Fig. 2. Comparison between Min-max and Four-positions method

## 5. CONCLUSION

The two popular methods for magnetometer offset compensation were described here. The Set/Reset compensation is good bud it requires a complicated hardware. The power consumption is also higher. The Min-Max method is simple but does not accurate enough.

The Four-positions method reaches the same or better results as the Minimum-maximum method. The method depends on the position of compensations points and the positioning accuracy each point. The main advantage is a short time required for compensation.

## 6. ACKNOWLEDGEMENTS


This work has been supported in part by Ministry of Education, Youth and Sports of the Czech Republic (Research Intent MSM0021630529 Intelligent systems in automation), Grant Agency of the Czech Republic (102/09/H081 SYNERGY - Mobile Sensoric Systems and Network) and by Brno University of Technology. Without kind support of the above-mentioned agencies and institutions the presented research and development would not be possible.


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