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Magnetic sensor signal analysis by means of the image processing technique

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Abstract. We have been proposing the image processing methodology where the human voice signals are transformed into the three-dimensional image data by means of the three-dimensional Lissajous diagram [1]. In this paper, we apply the image cognition technology to the cognition of the magnetic sensor signals. At first, the time domain signals are converted into the three-dimensional images, which construct the database system. Secondly, when we measure a time domain signal, this signal is also converted into a three-dimensional image. This three-dimensional image becomes an input vector of a least squares means. Least squares solution gives a composite signal as a linearly combined database signals. Extracting the most dominant term from the least squares solution reveals the cognized signal. Thus, we have succeeded in the time domain magnetic sensor signal cognition by means of the image cognitive technology [2].

1. Introduction

Generally, as the way of using the magnetic sensor, it can be thought about the nondestructive use to detect the metallic materials. The nondestructive test is based on the principle that detects the disturbance of the magnetic distributions caused by the magnetization vectors in the magnetic materials or by the eddy currents induced by the alternating magnetic fields.

Principal purpose of this paper is to introduce a new signal handling methodologies of the magnetic position sensors based on an image processing technique [2].

In order to convert the magnetic sensor signals into the three-dimensional images, we propose a three-dimensional Lissajous, which counts the overlapped points while conventional Lissajous does not take into account the overlapped points in a two-dimensional plane. Since the magnetic sensor signal contains various information concerning with a target physical properties, i.e., physical dimensions and magnetic materials. Our three-dimensional Lissajous methodology makes it possible to cognize the distinct physical property of targets.

As a result, it is revealed that least squares mean along with three-dimensional Lissajous improves the sensibility of magnetic position sensor.

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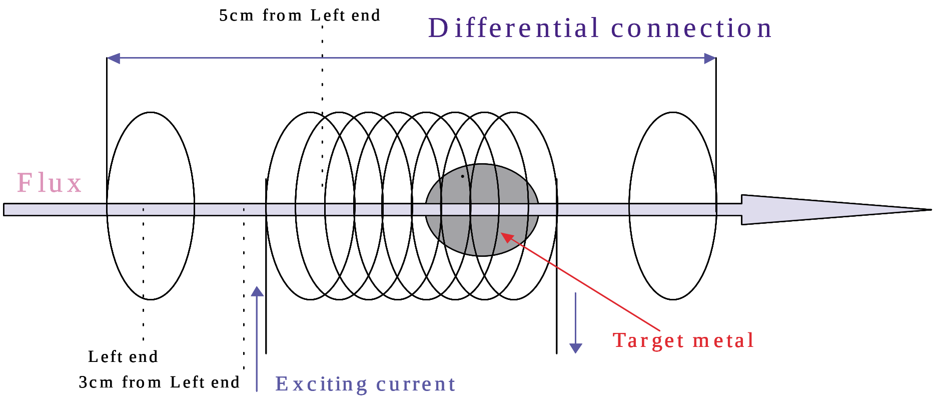


Fig. 1. Schematic diagram of a magnetic position sensor.

Table 1
Various constants of a tested sensor

Coil	Number of turns	Coil diameter	Coil length	Material
Exciting coil	100	34 mm	90 mm	Enameled wire with 0.8 mm diameter
Sensing coils	60	34 mm	28 mm	Enameled wire with 0.4 mm diameter

2. Magnetic position sensor

2.1. Operation principle

Figure 1 shows a schematic diagram of the magnetic position sensor. This sensor is composed of an exciting coil, two sensing coils connected in differentially, and targets. When alternating current is flowing into the exciting coil and a target metallic material locates at a center of exciting coil, no induced voltage is observed at the sensing coils because they are differentially connected and their linkage magnetic fluxes are the same. However, when the target metallic material locates at any position along with an exciting coil axis excepting the center of exciting coil, a difference of the magnetic flux linkages between the left- and right-sided sensing coils yields a sensing signal. This is a basic operating principle of the magnetic position sensor.

Specification of our tested sensor is listed in Table 1.

2.2. Input and output signals

Figure 2 shows an input sinusoidal voltage having 50 kHz frequency and 1V peak amplitude. Figure 3 shows a typical sensor output signals when an aluminum ball having 20 mm diameter is locating at the left end, 3 cm and 5 cm from the left end of the tested sensor. Comparison the input with output signals reveals that any of the output signals contain a relatively higher frequency noise.

3. Sensor signal cognition

3.1. Three-dimensional lissajous diagram

To remove the time phase difference of sensor signals, one of the best ways is to draw a Lissajous diagram. Taking the one time dependent signal to the x-axis and the other time dependent signal to the y-axis can draw the Lissajous diagram. When the same signals are taken to the x- and y-axis, the Lissajous

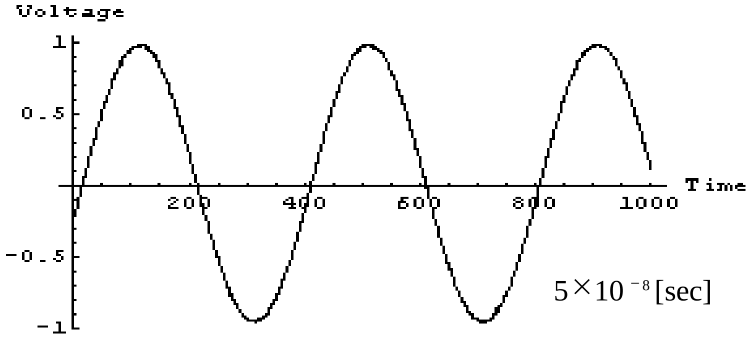
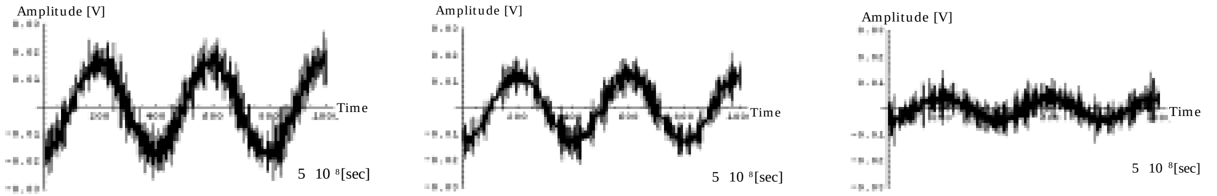
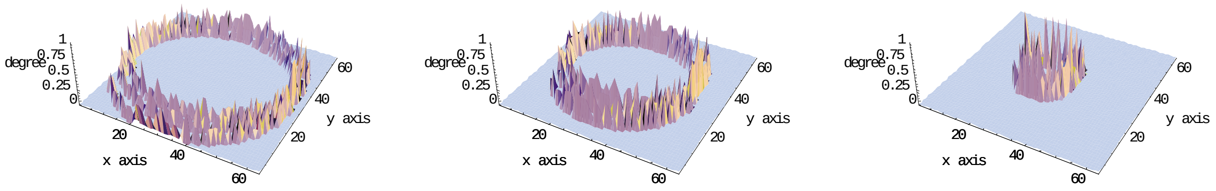


Fig. 2. Input wave.



(a)0cm apart from left end. (b)3cm apart from left end. (c)5cm apart from left end.

Fig. 3. Sensor output waveform.



(a)0cm apart from left end. (b)3cm apart from left end. (c)5cm apart from left end.

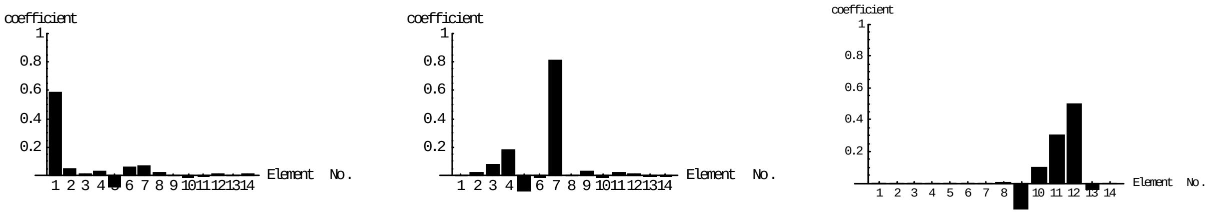
Fig. 4. Three-dimensional Lissajous diagram of the sensor signals.

diagram becomes a simple straight line. A simple line image does not have rich information as an image. Thereby, it is reasonable that one is an original signal and the other is the signal having 90-degree phase difference in time. This generates a circular Lissajous diagram, which has rich information as an image.

Further, conventional Lissajous diagram does not take account of the information concerning with overlapped points. However, when we take into account the overlapped points information by means of the histogram, it is possible to draw a three-dimensional Lissajous diagram as one of the three-dimensional images having rich information, which are amplitude, frequency, phase and so on.

The signal having 90-degree phase difference in time from the original signal can be generated by two operations that are the time integral and differential. But, when the output signal contain the noise, it is obvious that the differential operation amplifies the noise effects but the integration one suppresses the noise effects. Thus, we have employed the integral type three-dimensional Lissajous diagram.

Since the amplitude of output signals in Fig. 3 coordinates with the distance from the center of exciting



(a)0cm apart from left end. (b)3cm apart from left end. (c)5cm apart from left end.

Fig. 5. Example of the solution vector.

coil to target metals positions, the radius of circular three-dimensional Lissajous diagram should be proportional to the amplitude of sensor signal. Figure 4 shows the three-dimensional Lissajous diagrams corresponding to the output signals in Fig. 3.

3.2. Least squares solution

When we regard that the three-dimensional Lissajous diagrams are the image data having 64 by 64 resolution, it is possible to apply the image cognitive technology.

To apply our image cognitive technology, each of the image data is rearranged into a column-wise form, which constitutes an image vector $C_i, i = 1, 2, \ldots, n$ with order 4096, where n is a number of database images. Thus, we have a system matrix C as

$$C = [c_1, c_2, \ldots, c - n]. \tag{1}$$

Similarly, denoting an input image vector $\mathbf{Y}$ yields a following system of equations:

$$\mathbf{Y} = \mathbf{CX}, \tag{2}$$

where the solution vector $\mathbf{X}$ is composed of the n^{th} elements.

If a condition $n < 4096$, is held, then a least squares solution

$$\mathbf{X} = (C^T C)^{-1} C^T \mathbf{Y}, \tag{3}$$

could be obtained.

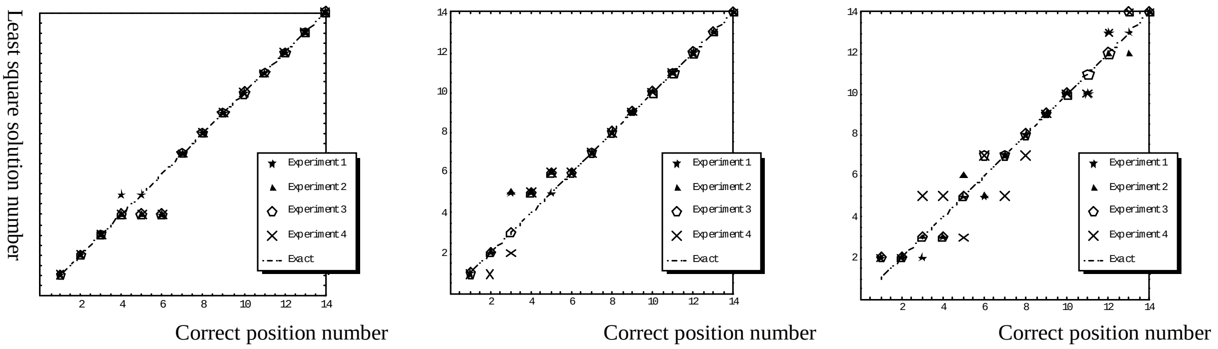
The magnitude of elements in the solution vector $\mathbf{X}$ suggests a cognized image vector. Namely, the element taking the maximum amplitude in the solution vector $\mathbf{X}$ reveals the cognized image [3].

3.3. Target position sensing

We have carried out the measurements of sensor output signals shifting the target from the right to left sides with 5 mm pitch. This yielded the 14 three-dimensional Lissajous images, which constructed a rectangular system matrix C with 4096 rows and 14 columns.

When we construct the input vector $\mathbf{Y}$ from the column vector $\mathbf{C}_i = 1, 2, \ldots, 14$ it is possible to cognize the exact position for any input vector $\mathbf{Y}$ by Eq. (4).

However, the noise included in the measured sensor output signals does not have any regularity and depends on the electromagnetic environments. This means that the sensor output signal does not take the same even if the same target position.



(a) sphere of aluminum 20mm in diameter.

(b) sphere of iron 20mm in diameter.

(c) sphere of iron 12mm in diameter.

Fig. 6. Result of cognition.

To check up the validity of our methodology, we have carried out the 4 times measurements to the sensor signal at the same target position changing the electromagnetic environments. Figure 5 shows an example of the solution vector .

Taking the element taking the maximum amplitude in the solution vector **X** as an exact solution reveals a cognized position. In Fig. 6, x- and y-axes correspond to the exact and cognized solutions, respectively. Figure 6 shows the cognized results, where the correct position is a straight line from origin and the cognized positions are shown by the symbols, ▲, ⬠, x, ♠.

4. Conclution

In this paper, we have proposed a new signal processing methodology along with the three-dimensional Lissajous diagram.

Our proposed method has been applied to the magnetic position sensor signals. As a result, a fairly good result has been obtained as an initial test.

References

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