# ICSV14

Cairns • Australia

9-12 July, 2007

14th International Congress on Sound & Vibration

# NOISE SOURCE IDENTIFICATION IN MAGNETIC FIELD USING SVDD (SUPPORT VECTOR DATA DESCRIPTION)

Dong-Chul Kwon[1], Jong-Bok Lee[1], Il-Kwan Ko[1], Dae-Sung Kang[1], Kyoung-Kook Kim[2] and Hoon Heo[3]

[1] Graduate Students, [3] Professor,
Department of Control & Instrumentation Engineering, Korea University,
1-5ka, Anam-Dong Sungbuk-ku, Seoul 137-701, Korea

[2] President of Segye Scientific Co.,LTD.
Duck-bong B/D, 41, Garak-Dong Songpa-ku, Seoul 138-160, Korea

greenkk@korea.ac.kr

## Abstract

In order to deal with noise problem, successful identification of noise in the system is very important. For the purpose adequate method to find its characteristics must be formulated. In the study, the SVDD (Support Vector Data Description) is utilized to identify the noise in magnetic fields. Much of the study has been carried out to figure out the normality and abnormality for the system determined based on the generated signal in accordance with environmental conditions. In the paper, magnetic field signal from electric system is studied. Besides the SVDD, one of the most well-known one-class classification methods is used to classify the magnetic field signals, which are compared to conventional classification methods and stochastic analysis methods as well. Experiment confirms simulation results.

## 1. INTRODUCTION

One of the objectives of control is to stabilize the system. Reducing disturbance in the system in active way using a controller has been a big issue. Prior to deal with noise problem in system, the property of the noise in the system must be identified first. Conventional methods to identify the noise source have been to classify the normal and abnormal condition using the signal such as spectrum.

The noise property in electro magnetic system is adopted to classify by using the magnetic flux existing along with normal/abnormal conditions. Magnetic field has less been used to electric field in daily life. Normally magnetic field is regarded as a disturbance in the electric system. In order to distinguish the abnormality of the system, magnetic signal could be a valuable tool to use. For the classification of differences between normal and abnormal conditions SVDD(Support Vector Data Description), one of the most well-known one-class

classification methods, has been used. [1][2][3] The performance of the method is compared to those of conventional method and stochastic method as well. The SVDD method is confirmed to be far superior to those.

The SVDD method is explained in section 2 and basic information of magnetic field is also described in section 3. The experimental results are presented and different types of features drawn from the data set are discussed in section 4. In section 5 conclusions is made.

## 2. SVDD (SUPPORT VECTOR DATA DESCRIPTION)

The Support Vector Data Description (SVDD) is the method which we can describe characteristics of group of data. The idea of the method is to find the sphere with minimal volume which contains all data. Assume we have a data set containing N data objects $\{x_i, i = 1, \cdots, N\}$, and the sphere is described by centre $a$ and radius R. We now try to minimize an error function containing the volume of the sphere. Following equations can be revealed to satisfy this objective.

$$\min \quad L_0(R^2, a, \xi) = R^2 + C\sum_{i=1}^{N}\xi \tag{1}$$

$$\text{s.t. } \|x_i - a\|^2 \leq R^2 + \xi_i, \xi_i \geq 0, i = 1, \cdots, N \tag{2}$$

In the above equation, the variable $\xi_i$ is a penalty related to i-th learned data escaped from the sphere. Trade-off constant C regulates the relative and important value of each term. Since it is difficult to deal in input space $R^d$, dealing is made in feature space F. It could be easy to obtain the sphere with small radius and many data using following QP (Quadratic Problem).

$$\min \quad L_F(R_F^2, a_F, \xi) = R_F^2 + C\sum_{i=1}^{N}\xi_i \tag{3}$$

$$\text{s.t. } \|\phi(x_i) - a_F\|^2 \leq R_F^2 + \xi_i, \xi_i \geq 0, i = 1, \cdots, N \tag{4}$$

If equation (3), (4) is solved using Lagrange function, dual problem and kernel trick, following these equations can be obtained.

$$\min \sum_{i=1}^{N}\sum_{j=1}^{N}\alpha_i\alpha_j K(x_i, x_j) - \sum_{i=1}^{N}\alpha_i K(x_i, x_j) \tag{5}$$

$$\text{s.t. } \sum_{i=1}^{N}\alpha_i = 1, \alpha_i \in [0, C], \forall_i \tag{6}$$

When we replace the inner products by Gaussian kernels for instance, we obtain:

$$K(x, z) = \exp(-\|x - z\|^2 / \sigma^2) \tag{7}$$

where $K(x, z)$ is 1.

Using the relationship, equations (5), (6) can be expressed as following equations (8), (9).

$$\min \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j K(x_i, x_j) \tag{8}$$

$$\text{s.t. } \sum_{i=1}^{N} \alpha_i = 1, \alpha_i \in [0, C], \forall_i \tag{9}$$

The condition satisfying optimal solution of Lagrange function in input space can be following equation
.

$$a = \sum_{i=1}^{N} \alpha_i x_i$$

And same condition in feature space can be the equation (10).

$$a_F = \sum_{i=1}^{N} \alpha_i \phi(x_i) \tag{10}$$

Because the distance between each support vector $\phi(x_i)$ located on decision boundary and center $a_F$ of the sphere becomes a radius of sphere, following equation can be derived.

$$R_F^2 - \|\phi(x_i) - a_F\|^2 = R_F^2 - \left(1 - 2\sum_{i=1}^{N} \alpha_i K(x_i, x_j) + \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j K(x_i, x_j)\right) = 0 \tag{11}$$

Using equation (11), equation (12) is derived to identify abnormality of test data in feature space.

$$f_F(x) = R_F^2 - \|\phi(x_i) - a_F\|^2 = R_F^2 - \left(1 - 2\sum_{i=1}^{N} \alpha_i K(x_i, x_j) + \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j K(x_i, x_j)\right) \geq 0 \tag{12}$$

# 3. ANALATICAL MODEL OF A MAGNETIC SYSTEM

## 3.1 Biot-Savart's Law

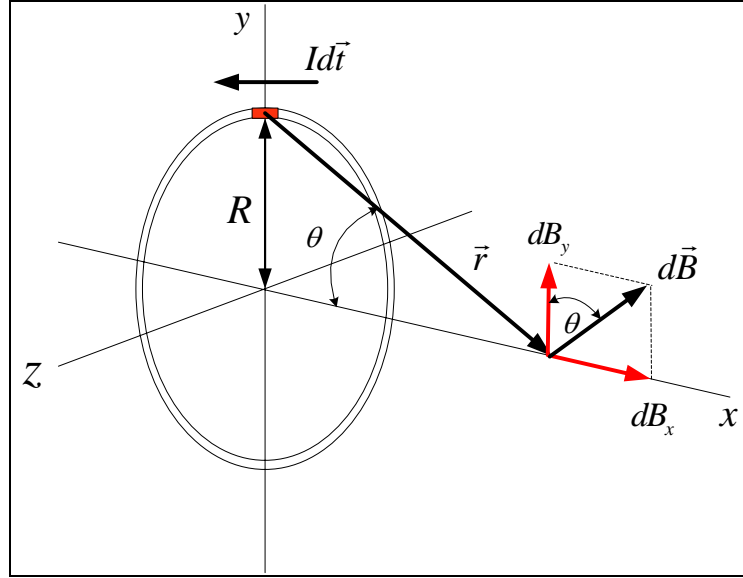Magnetic flux around leading wire can be obtained via Biot-Savart's law.



**Figure 1. Magnetic field in circular wire**

Figure 1 describes the magnetic field in circular wire. When current I flow in circular wire with radius R, magnetic field of arbitrary point P in central axis is calculated. Magnetic field $dB$ at point P due to the current I in a small length of wire $dl$ can be obtained using Biot-Savart's law as shown in equation (13)

$$dB = \frac{\mu_0 I}{4\pi} \frac{\overline{dl} \times \vec{r}}{r^2} \tag{13}$$

where vectors $\overline{dl}$ and $\vec{r}$ are perpendicular each other.

So it can be rewritten as equation (14).

$$dB = \frac{\mu_0 I dl \sin 90°}{4\pi r^2} = \frac{\mu_0 I dl}{4\pi r^2} \tag{14}$$

.

Vector $\overrightarrow{dB}$ can divide $dB_x$ and $dB_y$ components. The summation of component can be zero according to symmetric property. Then if we only consider magnetic field of $x$ coordinate component we can obtain the equation (15).

$$B = \int dB_x = \int dB \sin \theta \tag{15}$$

Substituting $dB$ of equation (13) and $\sin \theta = \dfrac{R}{r}$ into equation (15), equation (15) can be

following form as equation (16).

$$B(x) = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$$ (16)

Since $\mu_0$ is permeability of vacuum, following is utilized.

$$\mu_0 = 4\pi \times 10^{-7} (T \cdot m / A)$$

If the number of coil winded is N, equation (16) can be rewritten by multiplying N as shown in equation (17)

$$B(x) = \frac{N \cdot \mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$$ (17)

## 4. EXPERIMENT AND RESULTS

### 4.1 Experiment

Major equipments for the experiment consist of circular coil, which can generate magnetic field, and hall sensor measuring the intensity of magnetic field. Other equipments are A/D converter, power supply, function generator and the computer where the program LabVIEW and MATLAB is installed.

Hall sensor is the SS496A1 of Honeywell. Intensity of magnetic field can be measured using DAQ board without Tesla-meter. So the data can be saved and analyzed by using computer.

Figure 2 is a schematic diagram of experiment system. Intensity of magnetic field from circular coil can be obtained by equation (17) analytically and in the experiment 2 ampere is given as an input current. Then normal and abnormal data are acquired depending on noise source.
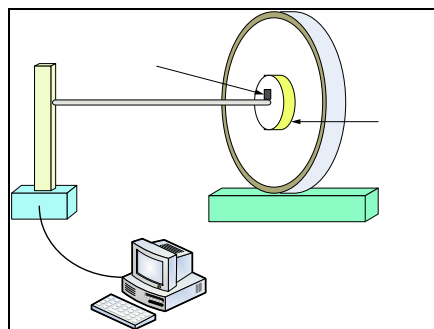


**Figure 2. Experimental setup**

Noise source is given using function generator and the type of noise source is sinusoidal. Figure 3 shows data from hall sensor with noise source according to the levels respectively.
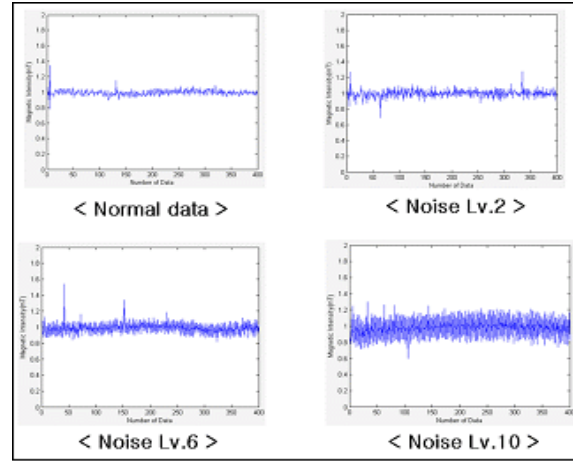
**Figure 3. Data according to noise source level**

## 4.2 Error estimation

The error can be estimated by the numbers of false positive and false negative. False positive is to identify the abnormal data as a normal data and false negative is to identify the normal data as an abnormal data. As a result, total error can be estimated by following equation (18)

$$E(\%) = \frac{false\ positive + false\ negative}{2}(\%) \qquad (18)$$

In using SVDD method, 50 normal data is used to learn. These normal data was compared with each abnormal data. Besides, STD (standard deviation) and cross-correlation is used to identify the error rate using false positive and false negative. Figure 4 shows the errors of two methods.

Table 1. Total Error

| | Total error (%) | | |
|---|---|---|---|
| | SVDD | STD | Peak in Cross-correlation |
| Noise Lv.2 | 5 | 25 | 45 |
| Noise Lv.4 | 5 | 0 | 40 |
| Noise Lv.6 | 5 | 0 | 40 |
| Noise Lv.8 | 5 | 0 | 40 |
| Noise Lv.10 | 5 | 0 | 40 |

STD (Standard Deviation) method gave the good result in case of high noise level as shown in Figure 4. However, it is not possible to identify and distinguish abnormality between the conditions in case of low noise level. SVDD method shows reasonably good performance in low level noise. SVDD method can be a good method for the system which is exposed to low level noise.

## 5. CONCLUSION

In this paper noise source identification in magnetic field is studied. Support Vector Data Description method is used to identify normal data and abnormal data in magnetic field and compared to the conventional method. It is not easy to identify the normal and abnormal conditions using conventional method. But SVDD is efficient for identifying the noise source of low level because SVDD method is to analyze the pattern of data. Further study is being conducted to identify the noise in magnetic field and to design controller for reduction the noise.

## REFERENCES

[1]   R.O. Duda and P.E. Hart. *Pattern Classification and Scene Analysis*. John Wiley & Sons, New York, 1973

[2]   D.M.J. Tax and R.P.W Duin. "Support Vector domain description", *pattern Recognition Letters*, Vol.20, pp. 1191-1199 (1999).

[3]   D.M.J Tax, Alexander Ypma and Robert P.W. Duin "Support Vector data description applied to machine vibration analysis", *Proceeding 5th Annual Conference of the Advanced School for Computing and Imaging*, pp. 398-405,  15-17 June 1999, Heijen.