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## Conference Agenda

Overview and details of the sessions of this conference. Please select a date or location to show only sessions at that day or location. Please select a single session for detailed view (with abstracts and downloads if available).



## Session Overview

## Session

### PA-A1: Education, Electromagnetic Sensors, Sensing and Metrology

*Time:* **Tuesday, 16/Jul/2019: 2:20pm - 4:10pm** *Location:* **Patio 44-55**
*Session Chair:* **Hakeim Talleb**
*Session Chair:* **Luca Di Rienzo**

## Presentations

### Analysis of Electromagnetic Vibration of PM motor considering time and space Harmonics

**Iksang Jang**[1], **Suyeon Cho**[2], **Won-Ho Kim**[3]
[1]HYUNDAI MOBIS, Korea, Republic of (South Korea); [2]Korea Automotive Technology Institute, Korea, Republic of (South Korea); [3]Energy IT, Gachon University, Republic of (South Korea)

The permanent magnetic motor has different characteristics according to the number of slots, even when it has the same number of poles. This is because the time harmonic and space harmonic of the radial force density, and the excitation force of the electronic vibration, differ depending on the combination of the number of poles and slots. This thesis analyzed and compared the characteristics of the harmonics of gap flux density according to the number of poles and slots of the 8-poled surface permanent magnet synchronous motor (SPMSM) model. From the results of the time harmonic and space harmonic of the air gap flux density, the excitation force was separated and compared. Utilizing this information, the characteristics of the vibration have been analyzed. Electromagnetic-vibro coupled analysis was performed to verify the validity of the analysis of the characteristics of vibration.

PA-A1-1.pdf

### Modelling Demagnetized Permanent Magnet Synchronous Generator for Fault Diagnosis

**Sveinung Attestog, Huynh Van Khang, Kjell Gunnar Robbersmyr**

University of Agder, Norway

The partial demagnetization in a four-pole 1.5 kW surface mounted permanent-magnet synchornus-generator was modeled by using time discretizated finite element anaylysis (FEA). The windings are sinusoidally distributed in the 24 stator slots. The demagntization in one of north poles in the rotor was modelled by reducing the remnenet magnetic flux density to 0 T. The results from simulation showed that the average output power was almost cut to the half in the demagntized generator. The parameter that higlighted the demagntization the best was the polar plot of magntix flux density in the middle of the air-gap of the generator.

PA-A1-2.pdf

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### Magnetic Hysteresis Analysis of a Pipeline Re-Inspection by Using Preisach Model

**Chang Geun Heo[1], Sang Hyeon Im[1], Sung Ho Cho[2], Gwan Soo Park[1]**

[1]Pusan National University, Korea, Republic of (South Korea); [2]Korea Gas Corporation, Korea, Republic of (South Korea)

The magnetic flux leakage type pipeline inspection is normally performed periodically. Due to the large applied magnetic field of the magnetic flux leakage type pipeline inspection, the remanent magnetization remains in the pipeline after inspections, which has undesirable effects on the subsequent inspection of the pipe. Sometimes, the inspections can be performed in opposite directions, and the remanent magnetizations of pipeline are affected by inspection directions, so that a magnetic hysteresis of a pipeline is necessary to be analyze by inspection directions. This paper analyzes the variation of magnetization during pipeline inspection and the effect of the remanent magnetization, according to inspection directions. In addition, the results of the analysis are verified through experiments.

PA-A1-3.pdf

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### A Study on the Estimation of External Metal in Underground Pipeline Inspection

**HuiSeog Jeong[1], ChangGeun Heo[1], SungHo Cho[2], GwanSoo Park[1]**

[1]Pusan National University, Korea, Republic of (South Korea); [2]Korea Gas Corporation, Korea, Republic of (South Korea)

The non-destructive testing (NDT) using magnetic flux leakage (MFL) is often conducted as a method for detecting defects in underground pipe made of ferromagnetic materials. The strong magnetic field of the MFL saturates the outer wall of the pipe and causes the distortion of the magnetic field signal in anomalies such as defects. However, depending on the shape of the signal, metallic materials outside the pipe also show distortion of magnetic signals. This paper models a 30-inch diameter pipeline inspection gauge (PIG) in operation at Korea Gas Corporation (KOGAS) and conducts magnetic field analysis through finite element analysis (FEA). Based on the simulation, we have extracted the characteristics of the MFL signals according to the shape of the external metal and the distance from the pipe. And applying this algorithm, we could estimate the geometry of the external metal by the MFL signal. The estimated results from the algorithm were compared with the simulation to obtain good results.

PA-A1-4.pdf

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### Magnetic Field Visualization System using 3-axis Magnetic Field Sensor and Augmented Reality for Education

**Shinya Matsutomo[1], Reiji Tanizaki[1], Kouhei Yamauchi[1], Tomohisa Manabe[1], Vlatko Cingoski[2], So Noguchi[3]**

[1]National Institute of Technology, Niihama College, Japan; [2]Faculty of Electrical Engineering, University “Goce Delcev” – Stip, Macedonia; [3]Graduate School of Information Science and Technology, Hokkaido University, Japan

Since the magnetic field is inherently invisible, it is useful if there are effective teaching materials that will make the first scholar imagine the magnetic field. We had developed a method to combine AR technology and real-time simulation to visualize the electromagnetic field, but this visualization system did not measure the actual magnetic field. Therefore, we newly developed a teaching material to measure the magnetic field distribution by using many 3-axis magnetic sensors, and we are studying a method to effectively visualize the magnetic field. In this paper, we report the developed hardware configuration and software function. This visualization system utilizes AR and it is possible to observe in 3D space where magnetic field is measured.

PA-A1-5.pdf

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### Magnetic Imaging of Ferromagnetic Materials with 3-axis GMR Probe

**Natalia Sergeeva-Chollet[1], Aurélie Solignac[2], Anastassios Skarlatos[1], Fawaz Hadadeh[1,2], Myriam Pannetier-Lecoeur[2], Claude Fermon[2]**

[1]CEA LIST, France; [2]SPEC CEA Saclay, CNRS, Université Paris Saclay, France

A three-component magnetic field probe for near surface field measurements is presented. The developed probe consists of four GMR sensors mounted on the sides of a square pyramid thus yielding four simultaneous field measurements at different directions. The probe is conceived for magnetic imaging applications with a submillimeter lateral resolution with emphasis in material characterization applications. Numerical simulation is used for the enhancement of the acquired images interpretation, the probe calibration and optimization.

PA-A1-6.pdf

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### Numerical Simulations of Portable Systems for Motion-Induced Eddy Current Testing

**Marek Ziolkowski[1,2], Jan-Marc Otterbach[1], Reinhard Schmidt[1], Hartmut Brauer[1], Hannes Toepfer[1]**

[1]Technische Universität Ilmenau, Germany; [2]West Pomeranian University of Technology, Szczecin, Poland

The paper presents simulations of portable systems for motion-induced eddy current testing. Two approaches, quasi-stationary and transient, to model rotating systems are discussed in details. Measurements and corresponding numerical results are also given.

PA-A1-7.pdf

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## Design of a Computer Experiment for Analyzing the Effects of Gradient and RF Coils during K-Space Acquisition

**Mazlum Unay, A. Emre Kavur, Busra Kahraman, E. Yesim Zoral, M. Alper Selver**
Dokuz Eylul University, Turkey

Playing a significant role on the education and research studies of senior year undergraduate and graduate electrical and electronics engineering (EEE) students, understanding medical imaging systems, particularly magnetic resonance imaging (MRI), is a crucial but also a very challenging task. MR constitutes an important and emerging modality, which require a complete understanding of underlying physics, instrumentation, data acquisition, and image formation steps in order to fulfill the learning outcomes. There exist many well-organized MR lectures tailored for the EEE curriculums, but accompanying laboratory studies of these lectures are mostly limited to image analysis. One of the challenging tasks that students are having difficulty to understand is the acquisition of the patient data directly in k-space, which represents the frequency domain matrix used to obtain the image via inverse Fourier transform. The spatial positioning of the data points to be collected on this matrix depend on the use of gradient coils while reading out the data relies on receiving RF coils. The synchronous use of these coils create the origin of pulse sequences, which are one the key topics of the MRI lectures. Accordingly, in this study, a new experiment is designed and implemented for providing hands-on experience to the students about the effects of various parameters related to RF and gradient coils. The proposed laboratory has been adapted to senior year MIS and graduate MRI lectures at Dokuz Eylul University and experiences after its application have been presented.

PA-A1-8.pdf

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## Time-Domain Frequency-Domain Based Detection of Stator Incipient Failures in Vector Controlled Machines using Dispersal Magnetic Field

**Hassan Eldeeb[1], Haisen Zhao[1,2], Osama Mohammed[1], Yanli Zhang[1]**
[1]Department of Electrical and Computer Engineering, Florida International University, USA; [2]School of Electrical and Electronics Engineering, North China Electric Power University, Beijing, 102206, China

In this digest an online non-invasive condition monitoring (CM) technique is proposed to detect the stator winding's inter-turn failure (ITF) of Direct Torque controlled (DTC) induction machine (IM). Fault diagnosis (FD) is accomplished through analyzing the radiated magnetic field in the time-domain-frequency-domain (TDFD) using the discrete wavelet transformation (DWT). The radiated magnetic field is captured by an external magnetic loop antenna simulated in the Co-simulation platform. A finite element analysis (FEA) simulation of 1 hp IM was done in Infolytica/MagNet environment, and interactively co-simulated to the power electronic voltage source inverter (VSI), DTC algorithm and FD routine models developed in MATLAB/Simulink. Results shows the ability of the DWT based FD to detect incipient ITFs more accurately than the spectrum based techniques in the DTC driven IMs.

PA-A1-9.pdf

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## Estimation of the Magnetization of Magnet from the Measured Surface Magnetic Field Utilizing the Truncated Singular Value Decomposition

**Yoshihiko Hibino[1], Kyoichi Haragashira[2], Hiroyuki Yano[3], Yasushi Kondo[4], Kengo Sugahara[2]**
[1]Graduate School of Science and Engineering Research, Kindai University; [2]Department of Electric and Electronics, Kindai University; [3]ELF Co., Ltd.; [4]Department of Physics, Kindai University

We have been developing a low-cost tabletop NMR system. We have reported that a field homogeneity as good as 50 ppm was achieved with a simple NMR magnet by employing two facing ferrite magnets with iron disks in between and even more as good as 1 ppm field homogeneity by a simple shimming mechanism. One of the causes of the inhomogeneity is the individual differences of magnetization distributions of the ferrite magnets. In this paper, we show the method of estimating the magnetic field distributions from the measured surface magnetic field utilizing the truncated singular value decomposition. We construct a 3d magnetic field measurement system rebuilt from a 3D printer with a 3d magnetic sensor attached to its head. We also incorporate the truncated singular value decomposition method to the electromagnetic solver based on the magnetic moment method. The reconstructed magnetic field from the obtained magnetization agrees well with the measured results.

PA-A1-10.pdf

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## A Modified Rectangular Vertical Probe for Plate Eddy Current Test

**Lantao Huang, Jiahao Zou**
Ximan University, China, People's Republic of

Eddy current testing is one of electromagnetic methods that are suitable for the inspection of conductive materials. Compared to the regular circular coil, rectangular perpendicular coil can induce a more uniform eddy current distribution in the plate. With other advantages such as directional properties and less sensitive to lift-off variations, the rectangular coil is considered superior to the circular one in certain applications. However, the eddy current of the rectangular perpendicular coil is comparatively small as the weak coupling between the coil and the conducting plate. It challenges to the sensitivity and accuracy of the detective probe. In this study, a novel probe with a metal shell is proposed to improve sensitivity and accuracy of the rectangular perpendicular coil. A simulation model is set up with the finite element method to verify the performance of the designed probe. The results show that the eddy current density in the plate is improved by the designed probe. And when a defect is present, the change of the equivalent impedance of the proposed probe is more obvious than the original rectangular perpendicular coil.

PA-A1-11.pdf

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## Analysis of Grid-Connected PMSG Coupled to an Average VSC Model

**Jesus Gonzalez, Silvia Padilla, Jacob Martinez, Concepcion Hernandez, Marco A Arjona Lopez**
Instituto Tecnologico de la Laguna, Mexico

Wind Energy Conversion Systems (WECS) are important power generator sources, because they do not harm or pollute the environment with gas emissions. This paper presents the transient analysis of a WEC using a 30 kW permanent magnet synchronous generator (PMSG) connected to the electrical distribution network by means of a power electronic converter. The contribution of this paper is to present a comprehensive analysis by coupling the finite element model of the PMSG with an average voltage source converter (VSC) model which

allows to reduce the computation time with respect to a detailed power converter model. The comparison of the model results of the generator in 2D and 3D will be shown and discussed in full paper as well as the closed-loop operation of the averaged model of the converter; initial 2D results are given in this digest.

PA-A1-12.pdf

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## Experimental and Virtual Prototype for Electric Machinery Courses

**Felipe Gonzalez-Montañez**[1,2], **Victor Jimenez-Mondragon**[2], **Rafael Escarela-Perez**[2], **Juan Carlos Olivares-Galvan**[2], **Jose Jimenez-Gonzalez**[2]

[1]Universidad Nacional Atonoma de Mexico, Mexico; [2]Universidad Autonoma Metropolitana, Mexico

Experimental and virtual prototypes can help students to grasp difficult concepts of electrical machines in short periods of time. In this paper, experimental and virtual prototypes are proposed for introducing electrical machines to undergraduate students. The experimental prototype consists of a single-phase induction motor coupled to a permanent magnet dc-generator using a torque meter. Electrical and mechanical variables are measured using sensors and and a data acquisition system has been implemented in Simulink Real-Time. A virtual prototype based on Finite Element Method (FEM) is established for students to better understand and visualize the theoretical part of the course. Numerical results thus obtained are compared with experimental results showing an excellent match. Finally, the advantges of using such teaching tools to improve the understanding of the subject are discussed.

PA-A1-13.pdf

# Magnetic Field Visualization System using 3-axis Magnetic Field Sensor and Augmented Reality for Education


Shinya Matsutomo[1], Reiji Tanizaki[1], Kouhei Yamauchi[1], Tomohisa Manabe[1], Vlatko Cingoski[2], and So Noguchi[3]

[1]National Institute of Technology, Niihama College, Niihama 792-8580, Japan, shin@ect.niihama-nct.ac.jp
[2]Faculty of Electrical Engineering, University "Goce Delcev" – Stip, Skopje, 1000, Macedonia
[3]Graduate School of Information Science and Technology, Hokkaido University, Sapporo 060-0814, Japan



**Since a magnetic field is inherently invisible, it is useful to develop effective-teaching materials which can make beginning electromagnetics-learners imagine a magnetic field. We have previously developed a method to combine Augmented Reality (AR) technology and real-time simulation to visualize an electromagnetic field, however this visualization system cannot depict an actual magnetic field. Therefore, we have newly developed a teaching material to measure an actual magnetic field distribution by using many 3-axis magnetic field sensors, and we have studied a method to effectively visualize a magnetic field. In this paper, we report a developed hardware configuration and software functions. This developed visualization system utilizes AR technology, and it is possible to observe a measured magnetic field in 3D space.**



***Index Terms*— Augmented reality, magnetic sensor, visualization.**


## I. Introduction

Electromagnetics is a foundation in the discipline of electric, electronic and information engineering, and it is an important academic field. As teaching-material development in electromagnetics education, we had previously developed a magnetic field visualization system using Augmented Reality (AR) techniques [1-3]. Since it is difficult to instantaneously measure the magnetic field distribution, these visualization systems do not measure the actual magnetic field. Tuan *et al*. have studied a method of visualizing a magnetic field using hall sensors [4]. However, due to a small number of hall sensors, it is impossible to measure enough amount of 3-axis magnetic fields in order to build a vector field distribution map. In this paper, we report on the development of a 3-axis magnetic field sensor board and software to three-dimensionally visualize a magnetic field with combination of AR technology and magnetic field measurement data.

## II. Developed Measurement and Visualization System

The developed sensor board consists of 150 3-axis magnetic sensors arraying on 10 × 15 vertically and horizontally. The embedded magnetic sensors can simultaneously measure a magnetic field intensity map in 3-axis directions. In addition, the measurement data of every sensor can be acquired using an I2C bus with serial communication. The integration of sensor measurement data and the control of measurement are executed with a FPGA.

This measurement board device can receive communication with a PC and power through a USB cable. Therefore, the device operates with only one PC connecting with a USB cable. The developed applications on the PC use control libraries to communicate with the device. The control libraries can be easily used with C ++ or C # applications, and they can also be used with *Unity*, which is a freely-distributed game engine. The magnetic field is measured 50 or more times per second, and it is possible to apply the measurement data to AR applications. Figure 1 shows the Hall sensor and the sensor board embedded with Hall sensors. The configuration of the sensor board connecting with the PC is illustrated in Fig. 2, together with a photo. Table I lists the specifications of the developed sensor board.

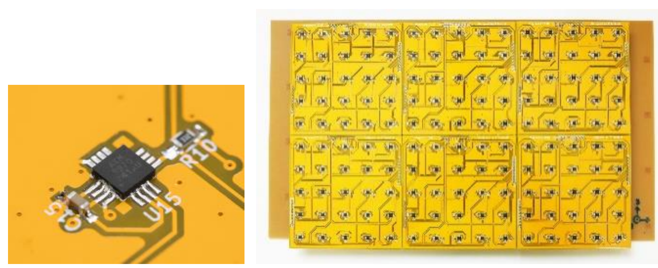

Fig. 1. Hall sensor (left) and sensor board embedded with Hall sensors (right).

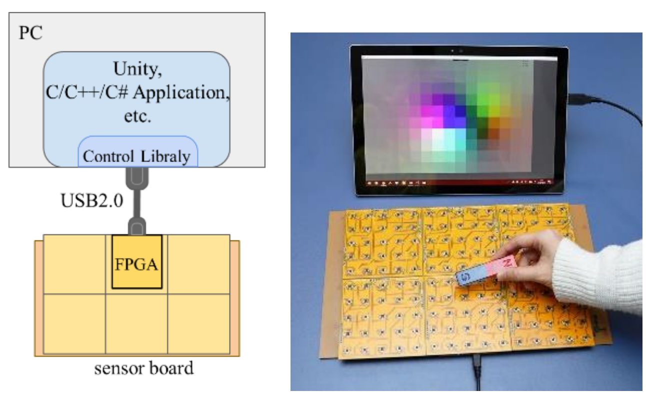


Fig. 2. Configuration of hardware connecting with PC and its photo.

TABLE I
Specifications of Developed Sensor Board

| | |
|---|---|
| Communication interface | USB 2.0 |
| 3-axis magnetic sensor | AK09970N |
| Board dimensions | 200 mm × 300 mm |
| Number of sensors | 150 (10 × 15) |
| Sensor interval | 20 mm |

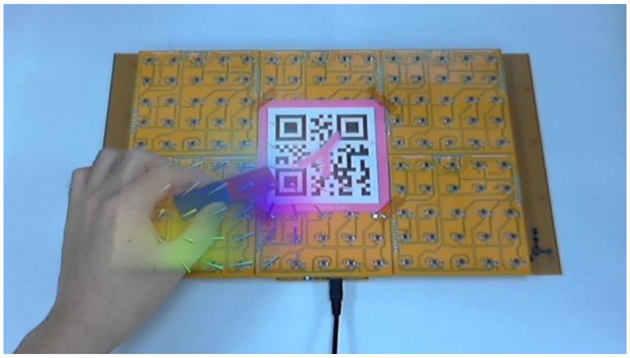

Fig. 3. Visualized 3D magnetic field distribution on sensor board.

For recognition of AR markers, *Vuforia*, which is a development library of AR software, is used. This library can register arbitrary markers. Also, *Unity* is used to generate magnetic field visualized images.

As a calibration process, it is necessary to put an AR marker on the sensor board and register it so that the position of the sensor board is specified from the camera image. And then, as a main process, the developed system visualizes the measurement data with color, cone, etc. and combines it with a captured camera image. As a result, it is possible to observe the 3D magnetic field map on the sensor board (Fig. 3).

## III. 3D Scan of Magnetic Field

Since the sensor board measures three-dimensional vector field data, it is possible to scan a vector magnetic field in three-dimensional space by moving the sensor board (Figs. 4 and 5). In order to obtain three-dimensional vector data, virtual voxels are set in the space, and the sensor is moved to measure the magnetic field for each voxel. By using this function, the magnetic field map not only on the 2D board surface but also in the 3-D space can be observed. Furthermore, when a permanent magnet is registered with an AR marker, it is also possible for a user to move the marker and to observe the magnetic field at the viewpoint he/she wants to see (Fig. 6). In addition, streamlines can also be drawn from three-dimensional magnetic field data.

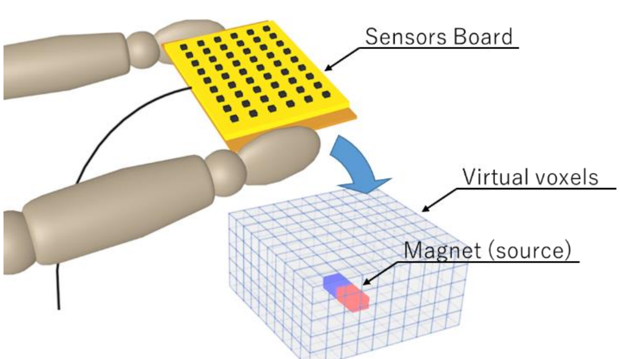


Fig. 4. 3D magnetic field scan function. A user moves sensor board and magnetic field in 3-D space is scanned.

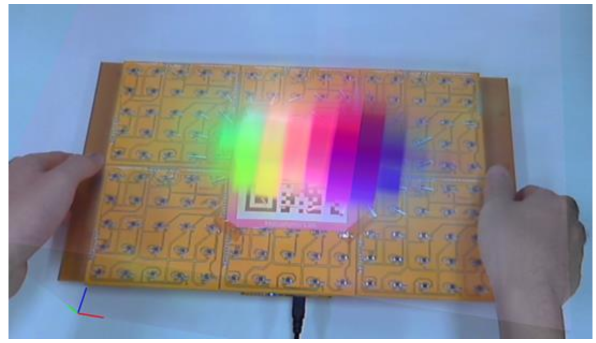

Fig. 5. A user vertically moves sensor board, and magnetic field at each voxel is stored. Magnetic field map built form measured data is visualized.

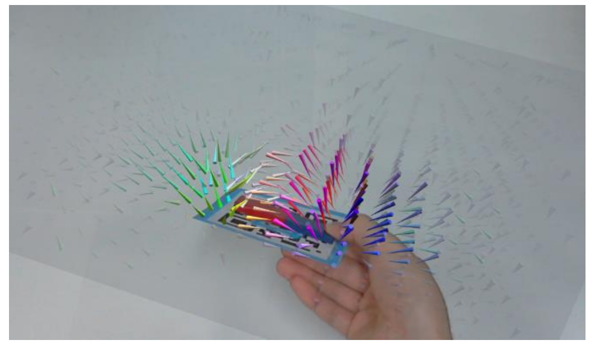

Fig. 6. Magnetic field can be three-dimensionally spatially observed with colored cones after scanning.

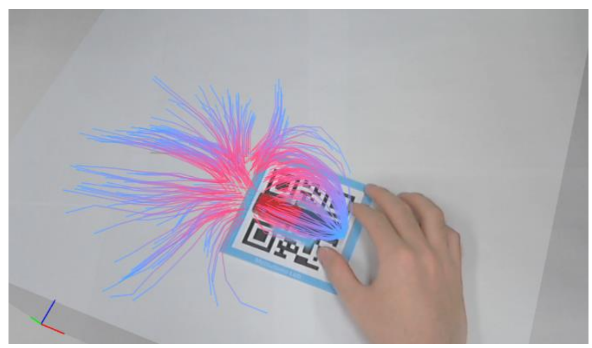

Fig. 7. Streamlines can also be drawn from three-dimensional magnetic field data.

## References

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