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# THE OBJECT DETECTION USING A MAGNETIC PICTURE

**Jozef Puttera* — Aurel Sabó** — Jozef Šuriansky*****

The paper deals with multidimensional measurement of magnetic field which is use for ferromagnetic object detection. Multidimensional magnetic field measurement by adequate sensors provides the idea about space layout of the magnetic field intensity. The magnetic field measurement presents good solution for observation and detection of objects. Our work describes possibility of a mine detection in soil by using spatial magnetic measurements. We verified possibility of detection on a model which uses multidimensional measurement.

Keywords: magnetic image, ferromagnetic objects detection, spatial magnetic measurement, and geomagnetic field.

## 1 INTRODUCTION

Magnetic measurements are one of the most effective methods investigating natural geophysical fields (magnetic field of Earth). Magnetic measurements are famous as one of the oldest geophysical methods being used firstly for navigation and subsequently for geology. Applied magnetic research is concentrated to multidimensional measurements as well. 2D measurement provides information which is used for study of distribution and dynamics of the geomagnetic field and it´s suitable for measurement and interpretation of magnetic anomalies.

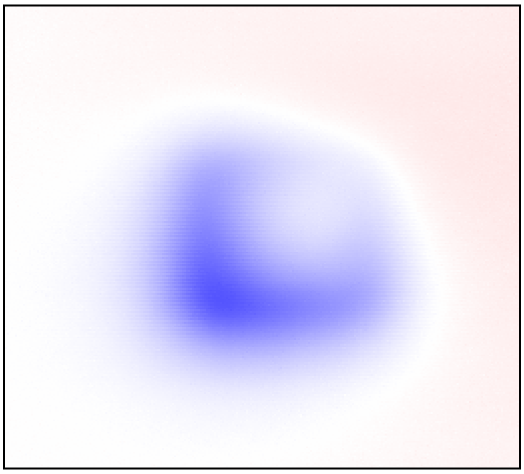

**Fig. 1.** Magnetic image

The presence of ferromagnetic materials (like a pliers, girders, etc.) distorts the local Earth's field and causes a disturbance. Ferromagnetic objects distort the Earth's field by affecting the strength and direction of it. For example, if the sensors are set up properly, they can detect the presence of a vehicle. Of course, vehicle size affects the magnitude and duration of the pulse when the vehicle passes by. Motorcycles would cause a small short blip, and truck would cause a strong long blip. The size of the blip depends on how much ferrous material is on the vehicle (iron, steel, nickel, etc.)

## 2 THE PRINCIPLE OF MEASUREMENT AND DATA IMAGING

Multidimensional magnetic field measurement by adequate sensors provides the idea about space layout of the magnetic field intensity. Measurement is realised in the separate points of the matrix NxM. We obtain non-standard image of the objects by measured value visualisation, which describes their magnetic properties (fig. 1). This image presents intensity of magnetic field that is sensed in separated points of image signals f(x,y) (Image matrix $\underline{F}(x,y)$). Picture element is creating by 128 levels of blue colour and 128 levels of red colour. It means that picture element can take on 256 levels. Every colour level presents quantized magnetic field intensity $H_{ext}$.

Orientation of magnetic field is presented by two colours magnetic image. Colour of image informs about polarity of magnetic field. We can present this image as binary image and we can process this image by corresponding methods. Magnetic images that represent magnetic field intensity in plane we can process by methods of multilevel image processing. We need $N^2K$ bits for image signals expression whose picture element has K bits. Generally, an images request a very large number of bits for its representation. Image processing requires very large number of data that must be processed. Digital image pre-processing (data compression) is suitable for a next image processing. We can use a linear or non-linear of geometric transforms, image segmentation and etc.

The pre-processing is intended to reduce the local granularity of the original image without affecting its contours, so that not too many small regions are obtained after region growing. In magnetic image are coherent regions with few differences brightness intensity. These regions contain of a redundancy.

Described method is based on the fact that the Earth is surrounded by a homogenous magnetic field. This magnetic field is distorted when a piece of ferromagnetic material is present. The distortion can be measured and contains information about the size and the depth of the ferromagnetic object (Fig. 2). Bombs and UXO contain a

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large amount of steel or casted steel which is highly ferromagnetic.

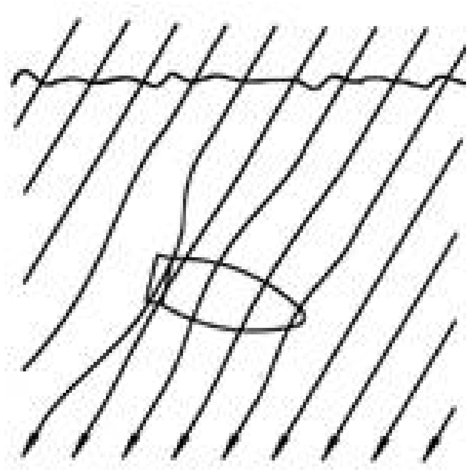

**Fig. 2.** Distorsion of Earth's magnetic field

Resulting effect of magnetic moments is much stronger in ferromagnetic materials unlike paramagnetic or diamagnetic materials. Magnetic moments inducted by weak magnetic field in ferromagnetic materials are very strong and affecting the acting field. Inducted moments are such intensive, that their effects are often dominant in surrounding fields. Field of spacely distributed magnetic dipole can be described by its scalar potential. If we introduce an analogy to the electric field, volume and square density of the magnetic charge is described by next formula:

$$\sigma_m(\mathbf{r}) = \mathbf{M}(\mathbf{r}).\mathbf{n}, \qquad \rho_m(\mathbf{r}) = -\nabla.\mathbf{M}(\mathbf{r}), \tag{1}$$

where **M(r)** is volume density of the magnetic dipole moment in point **r** and **n** is normal vector of plane. We can define scalar magnetic potential as:

$$\varphi_m(\mathbf{r}) = \frac{1}{4\pi}\left[\oint_S \frac{\sigma_m(\mathbf{r})}{R} dS + \int_V \frac{\rho_m(\mathbf{r})}{R} dV\right]. \tag{2}$$

Magnetic flux density **B(r)** of the examined field is given by formula (3) for the point with zero magnetization.

$$\mathbf{B}(\mathbf{r}) = -\mu_0.\mathrm{grad}\,\varphi_m(\mathbf{r}). \tag{3}$$

Homogenous body with a sphere shape (or better ellipsoid shape), which is placed into external homogenous field B0 is homogenously magnetised. If we label its magnetisation as a $M_0$ resulting magnetic dipole moment of this entity will be equal to:

$$\mathbf{m}_v = \mathbf{M}_0.\mathrm{V}. \tag{4}$$

Resulting magnetic field is given by the superposition of surrounding field $B_0$ and field $B_m$, which is created by a magnetic sphere in this point. This method can be used for detection on the surface, in boreholes and under water.

## 3 EXPERIMENTAL MEASUREMENT SYSTEM

The magnetic field sensing in plane can be realised by two basic ways, with simple sensor, which is electromechanical moving into simple measurement points and homogeneous sensors network with NxM sensors. Measurement workplace for magnetic image acquisition was realised by simple magnetic field sensor with electromechanical moving. In case of plane sensing of magnetic field we obtain matrix of NxN points.

Schematic diagram of measurement workplace is shown in figure 3. The computer PC, which is embedded with measurement and data acquisition card, is provided for measurement control and evaluate. The measurement and data acquisition card includes AD converters, DA converters, and power sources and clock impulse sources. Data acquisition from sensor is realised through measurement card via 12-bits AD converter.

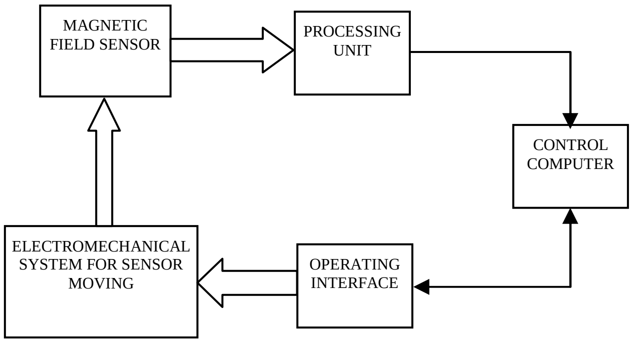


**Fig. 3.** Block scheme of measuring apparatus

The control of the sensor moving in plane insures the electromechanical sensor moving system, which is controlled by voltage from DA converter of the measurement card.

Magnetic field is measured by magnetoresistive sensor HMC 1001. This sensor comes under series of the weak magnetic field magnetoresistive sensors. This sensor type is manufactured by thin film technology. The film of NiFe material is placed on the silicon substrate. Sensor function is based on the anisotropy magnetoresistance. Anisotropy magnetoresistance exists in ferromagnetic materials. It happens in the case where the electric current, flowing in the thin film of the ferromagnetic material, is exposed to effect of magnetic field, which is influenced in the vertical direction. Sensor measures intensity and direction of the magnetic field induced by changes of the ferromagnetic objects or conductors, through which electric current flows. Its resolution is less than $10^{-8}$ T. The range of described system which measure magnetic flux density is approximately $\pm$ $1.10^{-4}$ T for minimal gain. For maximal gain is range of measurement approximately $\pm$ $1{,}4.10^{-5}$ T. Of course, ambient field is setting to zero and measurement system senses just variation of magnetic flux density in plane (Fig. 4).

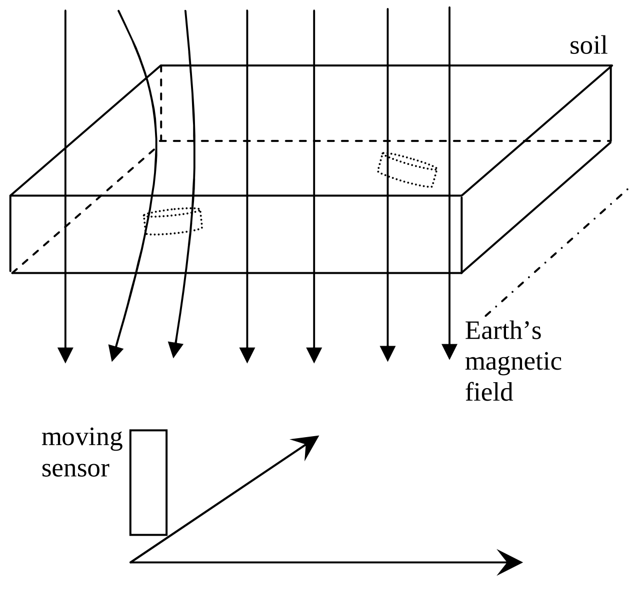


**Fig. 4.** Principle of the measurement

## 4 EXPERIMENTAL RESULTS AND DISCUSSION

We measured distribution map of the magnetic flux density in plane, which size was 250 x 250 mm. Distribution map of the geomagnetic field without ferromagnetic specimen in the direction of the sensor's sensitivity was measured as is shown in Fig. 4. There was placed ferromagnetic specimen (silicon steel) into geomagnetic field. Specimen cased disturbance of geomagnetic field in place where the specimen was laid. Measured disturbance of geomagnetic field shown object position. This method is shown as suitable for locating and identifying search objects concealed in the ground under and ground surface. Preferred search objects are mines and UXO. It is possible search plastic mine, as well. Plastic mines contain a plastic body and at least one metallic part, particularly an igniter. Prior to the investigation of the search area the electrical conductivity and magnetizability of the ground can be increased by impregnating with a liquid, which contains salt water and magnetizable particles.

Matrix NxM of measured value is converted to the image signal f(x,y) into the control computer. Magnetic field is measured to 256x256 points raster. Acquired magnetic image contains of 65535 picture elements. We realized 16384 measurements, 128 in the each direction (x, y). It means that measurement distance was about 1,95 mm. Distance of the sensor from measured object was 24 mm. Results representation of the magnetic flux density for specimen in the geomagnetic field is shown in Fig. 5.

The application of the magnetoresistive sensor for evaluation of magnetic flux density, which is influenced by ferromagnetic bodies, was examined. Presented examples were shown to demonstrate the validity of the method as well as the accuracy of the evaluated results. We have shown some important influences of ferromagnetic objects to resulting magnetic flux density in plane.

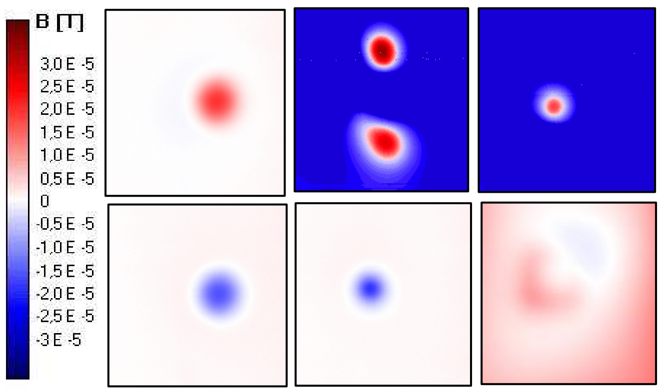


**Fig. 5** Measurement results

The operations of edge detection should be used for magnetic image pre-processing to reduce of data number. Edge operations are based on detection edges to magnetic image function. The object edges can be defined in the places where the quick chance of the brightness level of the neighbouring picture element happens. The edge in the image is the attribute of the picture element and its neighbourhood. The pre-processing is intended to reduce the local granularity of the original image without affecting its contours, so that not too many small regions are obtained after region growing. In magnetic image are coherent regions with few differences brightness intensity. These regions contain of a redundancy.

## 5 CONCLUSIONS

We designed an automated system which allows making magnetic measurements. Circuit solution of system was designed according to relevant requirements. We used magneto-resistive sensors for a sensing system. Automatic compensation of ambient magnetic field was chosen for elimination of geomagnetic influences.

Sum up, the magnetic field measurement presents good solution for observation and detection of objects. Our work describes possibility of a mine detection in soil by using spatial magnetic measurements. We verified possibility of detection on a model which uses multidimensional measurement. Finally, we designed model of system for battlefield observation which can be used for observation of ferromagnetic objects.

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