

ELECTROMAGNETIC FIELD VISUALIZATION

BY IMAGE PROCESSING

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Abstract. An inverse approach is applied for image improving during visualization of electromagnetic fields. The red, green, blue color (RGB) model is used. The RGB color sources have been evaluated using the RGB color distributions of the electromagnetic field data set. The Generalized Sampled Pattern Matching method is applied to solve an ill posed linear system of equations for the corresponding inverse problem. The new color distributions is generated and visualized using the obtained color sources. The images obtained during the electromagnetic field visualization of the most commonly used sensor coils are used and essentially improved.

Keywords: visualization, electromagnetic field, inverse problem.

INTRODUCTION

Visualization of electromagnetic fields distribution is of main importance during investigations of electromagnetic devices [1]. The fields of different devices are usually investigated using Finite Element Method (FEM) or Boundary Element Methods (BEM). The results obtained are visualized using different visualization techniques. Some of the visualization tools of the FEM or BEM packages characterize with insufficient image processing abilities and it is needed additional techniques in order to improve or to change the image characteristics. Sometimes the images are with not good quality or the data obtained do not correspond of the area of interest. To obtain new results it is required new FEM or BEM calculations, which is accompanied with a lot of efforts and computational time. This is very important especially for interactive simulation and visualization systems and it is one of the main difficulties building such systems. Many other applications require development of the effective methods and tools for image processing.

In order to improve the images we propose an approach using formulation and solution of the inverse problem over the image [2]. The available field data set is visualized and the image obtained is processed. The image quality depends on the image resolution and color distributions. The image part of interest is extracted. The image is considered as 2D-distribution of color components – Red, Green, and Blue (RGB). The 2D-Poisson equation in

Cartesian coordinate system is imposed to be satisfied by each of RGB color components with homogeneous open boundary conditions. In order to determine the color component distribution in the image part of interest we determine the color component source distribution utilizing the Green functions. The inverse problem for color source determination is formulated. The Generalized Sampled Pattern Matching (GSPM) method is applied to solve the composed ill posed linear system of equations [3]. The new visualization of the color distribution is carried out from the evaluated color sources. Several visualization examples demonstrate usability and applicability of the proposed inverse approach for visualization of electromagnetic field distributions as well as for image processing. The magnetic field distributions of the most commonly used sensor coil are considered.

INVERSE PROBLEM FOR COLOR SOURCE DISTRIBUTION

Let us consider the image color model building on the base of Red, Green and Blue (RGB) colors. The image colors are considered as 2D-distribution of color components – Red, Green, and Blue. A pixel-oriented strategy has been utilized, which makes algorithms very fast. The 2D-Poisson equation in Cartesian coordinate system is imposed to be satisfied by each of RGB color components with homogeneous open boundary conditions

$$(1) \quad \frac{\partial^2 A}{\partial p_x^2} + \frac{\partial^2 A}{\partial p_y^2} = -\sigma,$$

where A , σ , p_x and p_y are the any of the color components RGB, color sources, pixels in x- and y-directions, respectively. The color component A can be represented utilizing the Green functions over image pixels

$$(2) \quad A = \frac{1}{2\pi} \int_S \sigma \ln \frac{1}{r} dS,$$

where r is the radius vector between the pixel of the color component A and the pixel of the current integration, S is the area of the image.

In order to determine the color component sources we compose the system of equations

$$(3) \quad \mathbf{CX} = \mathbf{Y},$$

where \mathbf{C} , \mathbf{Y} and \mathbf{X} are the n by m system matrix, n -th order column vector of the color component and m -th order column vector of unknown color sources. The $n \times m$ system matrix \mathbf{C} we call “system matrix of relations”. To improve the image, the color components

as well as color sources have to be determined in the x-, y-pixels of image area. The red, green and blue color components are separated. For each of them systems of equation (3) are composed. The systems of equations are linear and ill posed.

The inverse problem for color source determination is formulated. In order to solve the systems of equations (3) the Generalized Sampled Pattern Matching method is applied [2]. The color sources are determined. The new visualization of the color distributions is carried out from the evaluated color sources. The image improvement is estimated using correlation factor. If it is necessary the iterative procedure can be organized. For the RGB color distributions we recalculate the color source distributions.

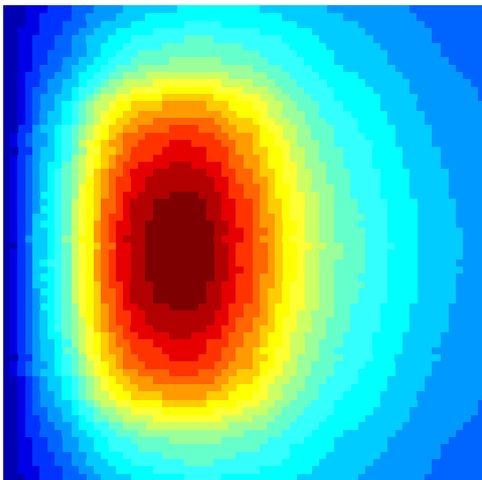
IMPLEMENTATION

The images obtained during visualization of the field distributions of electromagnetic devices have been improved by solving the inverse problem formulated above.

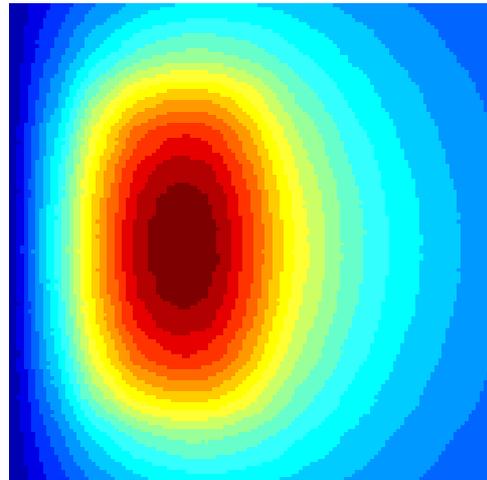
The magnetic field distribution of sensor coil has been considered. The coil is with circular shape. The inner diameter is $r_1 = 0.01m$, the outer diameter $r_2 = 0.03m$ and height $h = 0.04m$. The magnetic field under consideration is axisymmetrical and can be easily visualized using different visualization tools.

The quality of the image is expressed by image resolution. When the image available is with low resolution or the data are with essential noise then it is difficult to be analyzed properly.

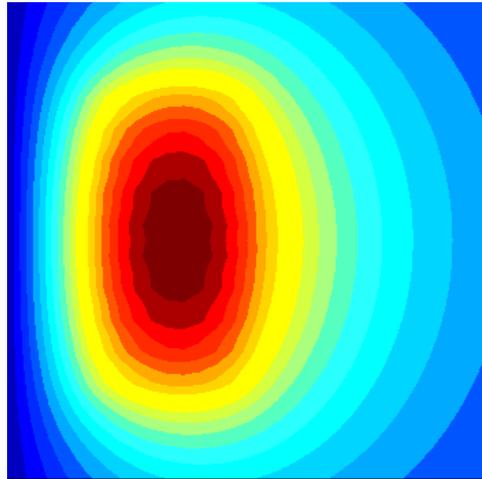
In order to improve the image we apply the proposed inverse approach. In Fig. 1 are given the magnetic field distributions of the investigated sensor coil with different image resolution - (a) 64x64; (b) 128x128 and (c) original high resolution.



(a) 64x64



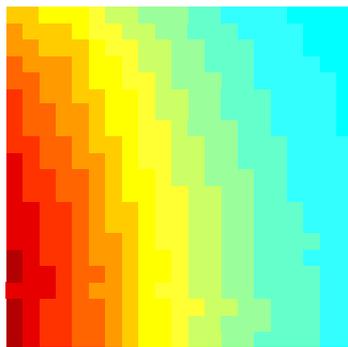
(b) 128x128



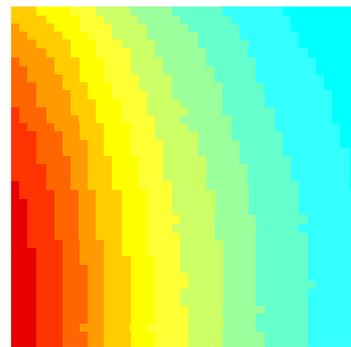
(c) original

Figure 1. Magnetic field distributions with different image resolution.

Image processing of entire image region required essential computational time and resources. In many cases the region of interest is a small part of the image and it can be extracted and processed with proposed inverse approach instead of entire image. In such cases the computational time can be essentially reduced. The part of the image, representing magnetic field distribution, has been extracted and presented at Fig. 2.



(a) Part of 64x64 image



(b) Part of 128x128 image

Figure 2. Part of the image with different resolution.

The red, green and blue color distributions of the image in Fig. 2(a) are obtained and shown in Fig. 3. The color source distributions are presented in Fig. 4.

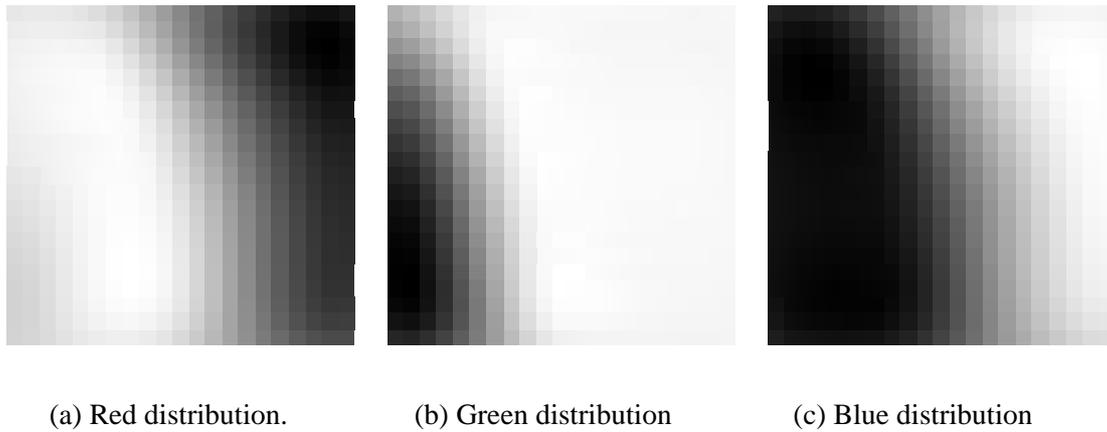


Figure 3. Color distributions.

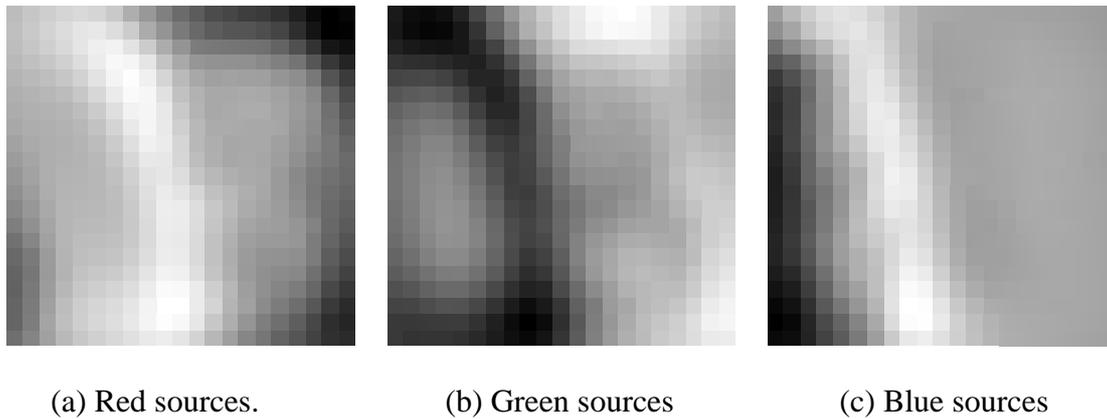


Figure 4. Color source distributions.

The image in Fig. 2(a) with 64x64 pixels is refined utilizing the inverse approach. The 64x64 dimensional well-posed system of equations is solved for the each of RGB colors and corresponding 64x64 dimensional matrixes of color sources are calculated – Fig. 4. The 64x64 RGB colors are generated and visualized in Fig. 5(a). Better results in image improving can be obtained if the number of pixels of the color source determination is two or more times increased. In such case the ill-posed system of equation is solved. For the high-resolution color sources obtained we calculate and visualized the new RGB color distribution. As an example, we compose high-resolution ill-posed systems of equations and 128x128 dimensional matrixes of color sources are obtained. The 128x128 resolution color distribution, shown in Fig. 5(b), demonstrates good improvement of the low-resolution image, shown in Fig. 2(a). Analyzing these results, it can be found that the image processing can be provided with low-resolution images and after that utilizing the proposed inverse approach the results to be improve successfully. In such way the computational expenses can be reduced essentially.

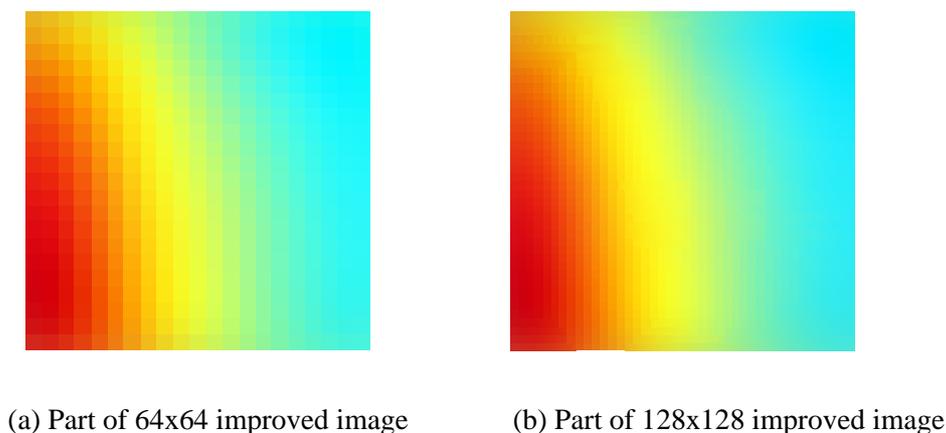


Figure 5. Color distributions of original and improved images

CONCLUSION

In this article, we have applied the inverse approach utilizing GSPM for image improving of the magnetic field distribution of sensor coil. For the image color model, the Poisson equation with open boundary condition is imposed. The color source distributions are calculated solving linear systems of equations by GSPM. A pixel-oriented strategy has been utilized, which makes algorithms very fast. The new RGB color distributions are generated. The low-resolution images can be improved by high-resolution color source determination. The inverse approach can be applied only over image parts of interest, instead of image processing of whole image. That essentially reduces the computational expenses. The approach characterizes with large abilities and was successfully applied for quality improving of the images during magnetic field visualization. The results obtained reveal that the proposed inverse approach can be effectively applied for image processing in data set visualization of many other applications.

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