Automatic Scoring System for Lines of Magnetic Force Written by a Learner's Hand

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Abstract

The purpose of this study was to develop a prototype of an automatic scoring system for handwritten lines of magnetic field. It's difficult to score automatically for handwritten lines by image recognition method. In this paper, a new method was proposed to score handwritten lines generated by the virtual magnetic source attached on a paper. It's effective educational method for learners to be assessed for their handwritten lines generated by some magnetic sources at any points on the paper. It is, however, labor works for their teacher of his class to score with accuracy within the class constrained by time. The new system can compare a tangential line of handwritten lines with calculated lines. The system needs a conventional Windows PC, a white paper, and small circle seals. As the first step, the learner attaches some seals with two types of color on a white paper. The seals indicate two kinds of virtual point magnetic charges on the paper. As the second step, the learner imagines the lines of magnetic force on the paper and draws the lines by using his black pencil. After the handwritten paper is scanned by using scanner, the positions of the magnetic charges are searched by image recognition and calculated the two dimensional distribution of magnetic field. Finally, the tangible line was compared for each pixel point on the line and the degree of coincidence with ideal tangential lines at each pixel was calculated to score the lines written by the learner. As a result, it was confirmed that the system can automatically create a graphic composite image proportional to the score on each hand writing lines based on scanned original paper image for the case of dipole field.

Keywords: an automatic scoring system, lines of magnetic field, handwritten, tangible line, dipole field.

1. Introduction

A concept of lines of magnetic force is often used to explain how to work the force on a magnetic field generated by magnetic charges. It's important for beginners who try to understand the invisible physical phenomena on electromagnetics to draw the lines of magnetic force around the magnetic charges exactly. As methods in existence, the learners can see the exact lines even on the complicated magnetic fields through either graphical images calculated by some useful simulation tools⁽¹⁻⁵⁾ or experiments by using iron sands and real magnetics. On the other hands, these methods can't give the objective assessment for learners' handwritten lines of magnetic force in any ways. As a point of view to maximize educational effectiveness, it's necessary to allow learners to imagine their various original magnetic fields created by learners themselves with their trying to draw the lines several times in each original field before the observation of the calculation or experimental results.

Therefore, the purpose of this study was to develop a prototype automatic scoring system based on a new assessment algorithm in order to score lines of magnetic force written by a learner's hand. In this paper, a new assessment algorithm was proposed and demonstrated for a sample of handwritten lines in the case of a magnetic dipole.

2. Automatic Scoring System

2.1 System Overview

The prototype system was developed to demonstrate whether the new algorithm works. Figure 1 is an overview of automatic scoring system. Figure 2 is a new algorithm to assess for handwritten lines. The system is used as follows. As the first step, a learner put circled seals at any place on a A4 format paper. Red and blue seals represent magnet charge of N-pole and S-pole, respectively. The overlap between each seal is not considered to avoid complication for a procedure of image recognition in the prototype

Step 1. A learner put circled seals on a paper. Red and blue seals are N-pole of magnet charge and S-pole, respectively.

Step 2. The learner uses a black pencil to draw lines of magnetic force.

Step 3. The paper is scanned and saved as a JPEG file.

Step 4. Magnetic charges and lines are recognized by image processing.

Step 5. Assessment for handwritten lines of magnetic lines by comparison with the tangent line of ideal line on each pixel.

Fig. 1. System overview.

Fig. 2. A new algorithm to assess for handwritten lines.

system. As the second step, the learner uses a black pencil to draw lines of magnetic force on the paper attached the seals. As the forth step, the paper is scanned at 300dpi as a JPEG image file. As the final step, pixel information of both each center of seal (red or blue) and handwritten lines (black) on the image file are acquired by image recognition method after a processing of image noise rejection for original image. It is supposed that there is a virtual magnetic charge for each center position of a seal in the system. The magnetic field $H(i, j)$ at pixel position (i, j) is calculated over the paper as follow Eq. (1).

$$H(i, j) = \frac{1}{4\pi\mu_0} \sum_{n=1}^N \frac{m_n}{((i-i_{cn})^2 + (j-j_{cn})^2)^{3/2}} (i-i_{cn}, j-j_{cn}) \quad (1)$$

Where N is number of point magnetic charge, (i_{cn}, j_{cn}) is the center position of n th point magnetic charge m_n . After calculation of magnetic field, lines of magnetic field are calculated to show a model answer for the learner as follow Eq. (2).

$$(i_{k+1}, j_{k+1}) = (i_k, j_k) + \frac{H(i_k, j_k)}{|H(i_k, j_k)|} ds \quad (2)$$

Where two dimensional pixels coordinate at (i_k, j_k) is the position on a line of magnetic field at k_{th} calculation step, and (i_{k+1}, j_{k+1}) is the next $k_{th}+1$ position on the line ds movement toward magnetic field. The lines are acquired by sequential computation oriented from fine segment ds toward a unit vector of magnetic field at a position (i_k, j_k) . The start position is isotropically set on the radius line of each seal. After the calculation, the handwritten lines of magnetic force are scored by using a new assessment algorism.

2.2 A New Algorithm to Assess for Handwritten Lines

Figure 3 is a procedure to assess the rating for handwritten lines of magnetic force. Black circles mean the pixel on a black line written by learner's hand. The red circle is a target pixel (i, j) for rating. The black line used a pencil has the finite thickness so that a summation of each distance L_{mn} from a vector of calculated magnetic field at a rating pixel in a target area is assumed to be proportional to the error at the rating pixel (i, j) . The distance L_{mn} [pixel] between a black pixel (m, n) in the target area and the vector of $H(i, j)$ is calculated as follow Eq. (3).

$$L_{mn} = \frac{|H_y(i, j) \cdot (m - i) - H_x(i, j) \cdot (n - j)|}{|H(i, j)|} \quad (3)$$

Summation of L_{mn} for each black circle inner the target area is defined D_{ij} [pixel] as follow Eq. (4). It's assumed that D_{ij} is a good parameter to assess the score of handwritten lines of magnetic force.

$$D_{ij} = \sum_{m=i-a}^{i+a} \sum_{n=j-a}^{j+a} L_{mn} \quad (4)$$

3. Demonstration

An original image was prepared to demonstrate the effectiveness of a new assessment method as shown in Fig. 4-(a). A pair of red and blue seal was attached on an A4 format paper. Each seal represents magnetic point charges of N-and S-pole. After image recognition, the ideal lines of magnetic force were calculated and the system created a graphic file as shown in Fig. 4-(b). We can see 16 lines for a typical magnetic dipole. D_{ij} was calculated for each black pixel on the paper. The pixel position at which D_{ij} is less than 50, 100, and 400 was output as shown in. Fig. 5 - (a), (b), and (c), respectively. We can guess that the

Black Circles Mean the Pixel on a Line Written by Learner's Hand

Fig. 3. A new scoring method.

(a) An scanned original image

(b) Ideal lines of magnetic force (green lines)

Fig. 4. A calculation result based on Eq. (2)

discrimination parameter D_{ij} indicates a degree of an error from the ideal lines of magnetic force. A two-dimensional distribution map for the value of D_{ij} on the handwritten lines was drawn, as shown in Fig.6. By comparison with Fig.4-(b), we can also see that the pixel similar to ideal lines of magnetic force was well reproduced as red color lines. The lines on the inside of red or blue seal was seems to be lower score because the area was excluded to assess

for handwritten lines.

(a) $D_{ij} < 50$

(b) $D_{ij} < 100$

(c) $D_{ij} < 400$

Fig. 5. Automatic scoring results for a sample of scanned picture (Gray lines are handwritten lines)

Fig. 6. A two-dimensional distribution map for the value of D_{ij} on the handwritten lines

4. Conclusions

The purpose of this study was to develop an automatic scoring system for lines of magnetic force written by a learner's hand. In this paper, a new method was proposed to score handwritten lines of magnetic force generated by the virtual magnetic source attached on a paper. Our new system can compare a tangential line of handwritten lines with calculated lines of magnetic force.

A learner can imagine the lines of magnetic force on the paper and draws the lines by using his black pencil before he compares with the precise calculation result. As a result, it was confirmed that the system can automatically create a graphic image proportional to the score on each hand writing lines based on scanned original paper image for the case of dipole field. As future work, assessment for symmetry of handwritten lines will be taken account of.

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