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Computer Terminal for Blind and Visually Impaired

R. Bansevicius, A. Zvironas
Mechatronics Centre for Research, Studies and Information, Kaunas University of Technology,
Kestucio str. 27, LT-44025, Kaunas, Lithuania, phone: +370 687 50284
J. A. Virbalis
Department of Electrical Engineering, Kaunas University of Technology,
Studentu str. 48, LT-51367, Kaunas, Lithuania, phone: +370 699 84937

Introduction

Paper describes a novel high-resolution touch-feedback tablet, which can provide touch screen the controlled perception of a “textured” surface. The tactile perception can be used as a source for 2D graphics and related information for blind and visually impaired [1], extending their ability to work with Internet and adding the chances of orientation at home or street.

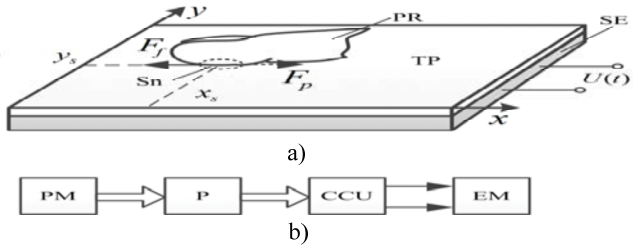
The relief and other information, which the blind perceives by his finger, can be created by different means. It is realized in [2, 3] by controlling of the relief on the plane by electrorheological fluid (ERF). Its main disadvantage is the necessity to arrange the valves with ERF in plane, on which the relief is created - increasing the resolution of tactile information requires dramatic increase of the number of valves.

The relief variation on the plane the blind can feel can be related to variation of force by which he pushes on this plane some sensor (e.g. in a form of a thimble or a penny sized thin disk). The variation of the force can be related not only to the variation of the relief, but indirectly to color, intensity or with other 2D graphics information, e.g. by modulating the force in specific frequency range, depending on information. Therefore, the frequency of the force, affecting the contact area of the finger, can carry the additional channel of information for the blind.

In [4] a device, in which the sensor is realized as miniature electromagnet which is scanned by finger on the touch sensitive screen with a layer of ferromagnetic film, is analyzed. The intensity and frequency of the electromagnet excitation is related to specifics of 2D information in the point which is related to the position of the sensor on the screen. The main problem of this device is that power supply is needed to actuate sensor, by which the current is passed to the electromagnet winding. When the sensor is moving, the cable can create additional force, not related to the information on the screen.

The structure of high resolution touch feedback tablet

In this paper we present the device, in which finger is contacting with passive thimble, made in a form of ferromagnetic penny-size thin disk. It can be made convenient for the touch by the finger and easily sliding on the plane surface. Tablet consists of spiral electromagnet in a form of plate; on which it is mounted thin layer of touch sensitive active film with increased friction properties on the surface, contacting with disk (Fig. 1).



a)

b)

Fig. 1. View of the terminal (a) and schematics of the device (b)

TP is touch sensitive film, PR is a finger of the blind, Sn is the sensor, SE is a spiral electromagnet. A measurement unit PM, using touch sensitive film, measures the sensor's coordinates x_s and y_s continually and information about it transfers to a processor P. The processor forms control signal $U_v(x_s, y_s)$ dependent on the information on the screen, related to this contact point and sends it to an electromagnet excitation current control unit CCU. This unit forms the frequency and the amplitude of the excitation current $I_e(x_s, y_s)$ of the electromagnet EM. The spiral electromagnet with specific configuration is used for the generation of controlled magnetic field.

Spiral electromagnet

The purpose of spiral electromagnet is to ensure controlled friction force between sensor Sn and touch sensitive film TP in all area of tablet. It is made in a form of two ferromagnetic plates with intersecting poles (Fig. 2). Important condition when designing spiral electromagnet is that in case $U(t)$ = const, variation of friction force at various points of tablet must be minimum.

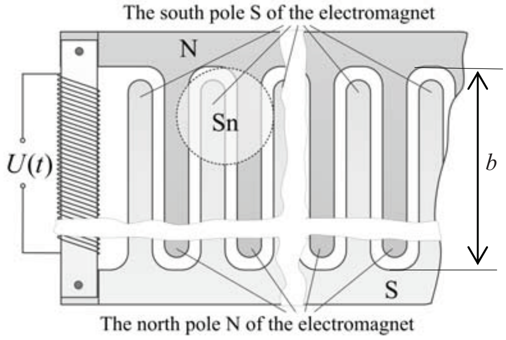


Fig. 2. The view from above to the spiral magnet fragment

Different modification of spiral magnet is shown in Fig. 3; here the thickness of the plate h is bigger, but the distribution of magnetic field between the poles in whole tablet area is more even.

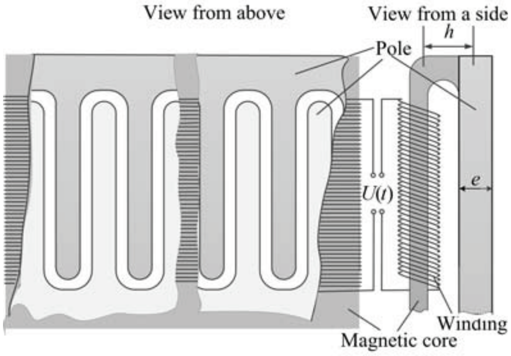


Fig. 3. The view of one pole and the winding of the spiral electromagnet

The pole bars are parallel one to other and the distance between the sidelong surfaces of neighbouring bars of different poles is the same (see Fig. 2). When the electromagnet winding is actuated, quasiuniform magnetic field H_t is created in the spiral interstice between the poles.

The processor P together with the unit CCU forms the winding excitation current $I_e(x_s, y_s)$, related to sensor's position. The current I_e creates magnetic field which acts the sensor Sn with the force T, perpendicular to the tablet's surface.

Analysis of the magnetic circuit

The similar magnetic circuits are analyzed in [5, 6]. We suppose that the magnetic field in the air gap between the poles is distributed uniformly. Near the sensor the magnetic field is distorted, but this distortion is local, and we can suppose with small error that magnetic flux, which circulate in the sensor, passes into it of the magnetic circuit part, which width is equal to d (d is the sensor diameter). Therefore we can suppose that magnetic circuit is composed of the parallel branches with the width d. The same magnetomotive force F_m acts in any of these branches

$$F_m = NI_e, \tag{1}$$

where N is number of the winding turns, I_e is exciting current. We analyse the area in which the sensor is situated. Its magnetic circuit is composed of the magnetomotive force F_m, electromagnet magnetic core with the magnetic resistance R_{mm} and gap with the magnetic resistance R_{m0}. The sensor is presented by the magnetic resistance $R_{ms,}$ connected parallel to the resistance R_{m0}. The equivalent electric scheme of this magnetic circuit is presented in Fig. 4.

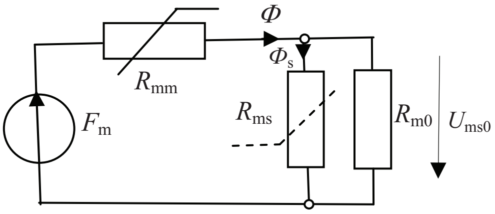


Fig. 4. The equivalent electric current of the part of the

The magnetic resistance of the magnetic core strip with the width d is

$$R_{mm} = \frac{l_m}{\mu_{rm}\mu_0 S_m}, \tag{2}$$

where l_m is the length of the any magnetic field line, $l_m \approx 2h + 2b$, b is the terminal width (see Fig. 2), h is the distance between the central lines of the upper and lower parts of the magnetic core (see Fig. 3), S_m is the area of the cross-section of the magnetic core strip with the width d, equal

$$S_m = d \cdot e, \tag{3}$$

where e is the thickness of the magnetic core (Fig. 3).

The magnetic resistance of the gap is

$$R_{m0} = \frac{l_o}{\mu_0 S_o}, \tag{4}$$

where l_o is the width of the gap, and $S_o \approx S_m$.

We can evaluate magnetic resistance $R_{ms,}$ investigating the path of the magnetic flux Φ_s via the sensor. It is shown in the Fig. 5.

The path of the sensor magnetic flux can be divided into three parts. We presented these parts by the suitable magnetic resistances: the magnetic resistance R_{msp1} of the input part via the nonmagnetic terminal plate, the magnetic resistance R_{msp2} of the output part via the nonmagnetic terminal plate and the magnetic resistance of the sensor. We will not evaluate the value of the sensor magnetic resistance because it is not more than 1 - 2 % of the total magnetic resistance R_{ms} of the circuit. The R_{ms} value we express analogically to (4) in this way

$$R_{\mathrm{ms}} = R_{\mathrm{msp1}} + R_{\mathrm{msp1}} \cong \frac{2l_{\mathrm{sp}}}{\mu_0 S_{\mathrm{sv}}}, \tag{5}$$

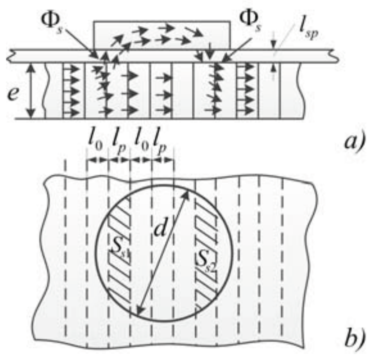


Fig. 5. The distribution of the magnetic flux in the sensor neighbourhood (a), the view from above to the sensor (b)

where l_{sp} is thickness of the terminal plate and S_{sv} is the mean value of the area of the sensor part which is on the pole bar. The magnetic flux $\varPhi_{\mathrm{s}}$ is branched via this area. It can be expressed as the area of the some rectangle

$$S_{\mathrm{sv}} = \alpha d l_{\mathrm{p}}, \tag{6}$$

where α is a factor with the value laying in the interval [0,6; 0,8]. When the pole bar coincides with the edge of the sensor circle the main part of the flux will branch via the part of the circle which covers major area of the pole bar.

The equivalent resistance R_{m0b} of the parallel connection of the magnetic resistances R_{ms} and R_{m0} can be expressed as follows

$$R_{\mathrm{m0b}} = \frac{R_{\mathrm{m0}} R_{\mathrm{ms}}}{R_{\mathrm{m0}} + R_{\mathrm{ms}}} = \frac{1}{\mu_0 (S_0/l_0 + S_{\mathrm{sv}}/2l_{\mathrm{sp}})}. \tag{7}$$

The force of the magnetic field depends on the density B_{s} of the magnetic flux $\varPhi_{\mathrm{s}}$

$$B_s = \frac{\varPhi_{\mathrm{s}}}{S_{sv}}. \tag{8}$$

We express the flux $\varPhi_{\mathrm{s}}$ by Ohm's law (see Fig. 4)

$$\varPhi_{\mathrm{s}} = \frac{U_{\mathrm{ms0}}}{R_{\mathrm{ms}}} = \frac{R_{\mathrm{m0b}} \cdot \varPhi}{R_{\mathrm{ms}}} = F_{\mathrm{m}} \frac{R_{\mathrm{m0b}}}{R_{\mathrm{ms}} (R_{\mathrm{mm}} + R_{\mathrm{m0b}})}. \tag{9}$$

Evaluating (2), (4) and (5) we obtain

$$\varPhi_s = \frac{F_{\mathrm{m}} [\, 1 \big/ \mu_0 (S_0/l_0 + S_{\mathrm{sv}}/2l_{\mathrm{sp}})]}{\dfrac{2l_{\mathrm{sp}}}{\mu_0 S_{\mathrm{sp}}} \cdot [\dfrac{1}{\mu_0 \mu_{\mathrm{rm}} S_{\mathrm{m}}/l_{\mathrm{m}}} + \dfrac{1}{\mu_0 (S_0/l_0 + S_{\mathrm{sv}}/2l_{\mathrm{sp}})}]}. \tag{10}$$

After transformation we can write

$$\varPhi_s = \frac{F_{\mathrm{m}} \cdot \mu_{\mathrm{rm}} S_{\mathrm{m}}/l_{\mathrm{m}}}{\dfrac{2l_{s0}}{\mu_0 S_{\mathrm{sv}}} \cdot (\dfrac{S_0}{l_0} + \dfrac{S_{\mathrm{sv}}}{2l_{\mathrm{sp}}} + \dfrac{\mu_{\mathrm{rm}} S_{\mathrm{m}}}{l_{\mathrm{m}}})}. \tag{11}$$

We designate the maximal possible value of sensor magnetic flux as $\varPhi_{\mathrm{smax}}$

$$\varPhi_{\mathrm{s\,max}} = \frac{F_{\mathrm{m}}}{2l_{sp}/(\mu_0 S_{\mathrm{sv}})} = \frac{F_{\mathrm{m}} \mu_0 S_{\mathrm{sv}}}{2l_{\mathrm{sp}}}. \tag{12}$$

It will be obtained when the influence of magnetic resistances R_{mm} ir R_{m0} to $\varPhi_{\mathrm{s}}$ is vanishing.

The $\varPhi_{\mathrm{s}}$ can be expressed as follows

$$\varPhi_{\mathrm{s}} = K_{\Phi} \varPhi_{\mathrm{smax}}, \tag{13}$$

where K_{Φ} is the coefficient of the flux diminution.

It can be expressed using (11) and by employing $S_{\mathrm{o}} \approx S_{\mathrm{m}}$

$$K_{\Phi} = \frac{1}{1 + \dfrac{l_{\mathrm{m}}}{\mu_{\mathrm{rm}} l_0} + \dfrac{S_{\mathrm{sv}}}{S_{\mathrm{m}}} \dfrac{l_{\mathrm{m}}}{\mu_{\mathrm{rm}} \cdot 2l_{\mathrm{sp}}}}. \tag{14}$$

Expressions of the electromagnet force and the magnetomotive force

The magnetic field force T, which acts on sensor, can be calculated using expressions which are presented in [2]. Evaluating, that the force T is created in the area S_{s1} via which magnetic flux $\varPhi_{\mathrm{s}}$ passes into sensor and in the area S_{s2}, via which this flux returns into electromagnet, and evaluating that in the nonmagnetic media $B_{\mathrm{S}} = \mu_0 H_{\mathrm{s}}$, we can write

$$T = \frac{B_{\mathrm{s}} H_{\mathrm{s}}}{2} 2S_{\mathrm{sv}} = \frac{B_{\mathrm{s}}^2 S_{\mathrm{sv}}}{\mu_0}. \tag{15}$$

Using (8), (12) and (13) we can express B_{s}

$$B_s = (K_{\Phi} \mu_0 F_m) / 2l_{sp}. \tag{16}$$

Substituting (16) into (15) and by employing (1), we obtain

$$T = \mu_0 K_{\Phi}^2 N^2 I_{\mathrm{e}}^2 \frac{S_{\mathrm{sv}}}{(2l_{sp})^2}. \tag{17}$$

Supposing that friction coefficient of the terminal plate is f, we can relate the resistance force F_{p} to the blind finger (see Fig. 1) with the magnetic attraction force T

$$F_p = fT. \tag{18}$$

Using (6), (17) and (18), we express magnetomotive force NI_{e}

$$NI_e = \frac{1}{K_{\varPhi}} \sqrt{\frac{F_{\mathrm{p}}}{f\mu_0} \frac{(2l_{sp})^2}{\alpha d l_{\mathrm{p}}}}. \tag{19}$$

Evaluation of the real electromagnet parameters

Such electromagnet will be used effectively, when coefficient K_Φ will be close to 1. The ratios $l_m/\mu_{rm}l_0$, S_{sv}/S_m ir $l_m/\mu_{rm}l_{s0}$ must be reduced for this. We calculate the K_Φ value for the real parameters. Sensor must be handily touched by the finger. The convenient diameter of the sensor is close to 1 cm. We accept that d=10 mm. To warrant the sufficient resolution the two or three gaps must be under the sensor. We accept that l_0=l_p=2 mm. The other dimensions are accepted as follows: the thickness of the terminal plate, l_{sp}=0,5 mm, the thickness of the magnet poles e=5 mm, the distance between the upper and lower parts of the electromagnet core h=25 mm, the terminal width b=150 mm, and the relative permeability of the magnetic core μ_{rs}=1000. Therefore, l_m=350 mm, S_m=50 mm^2, S_{sv}=14 mm^2, $l_m/\mu_{rm}l_0$=0,175, S_{sv}/S_m=0,28, $l_m/\mu_{rm}l_{sp}$=0,35. For these ratios values we obtain $K_\Phi\approx$0,8. This factor is especially sensitive to the value of the relative permeability. When μ_{rs}=5000, $K_\Phi\approx$0,95.

We calculate the value of the magnetomotive force supposing that f=0,3, $K_\Phi\approx$0,8, d=10 mm, α=0,7, l_p=2 mm, l_{s0}=0,5 mm and the resistance force F_p must be 1 N. Evaluating that $\mu_0\approx1{,}25\cdot10^{-6}$ H/m, we obtain $NI_e\approx$560 A. We accept the excitation current equal to I_e=1 A. In this case the excitation winding must have N=560 turns. We can see of the condition $d_l = 0{,}55 - 0{,}65\sqrt{I_e}$ that it is suited for the winding the copper wire with diameter equal to 0,65 mm. The windings fill factor is equal to k_w=0,25 – 0,35. Therefore, the cross-section of the winding must be: $Q_a \ge N\dfrac{\pi}{4}\dfrac{d^2}{k_w} \approx 730\ \text{mm}^2$. This winding can be situated without problems in the magnetic core, with sidelong h=25 mm, and width b=150 mm.

The mean length l_w of the one turn will be equal to $l_w\approx$2h+2b$\approx$50+300=350 mm=0,35 m (see Fig. 2 and Fig 3). Therefore, it is needed for the electromagnet excitation winding the copper wire with diameter 0,65 mm and length $l \approx$ 196 m. The electric resistance of the winding will be equal to $R = \rho l \Big/ \dfrac{\pi d^2}{4} \approx 9{,}5\ \Omega$, (the specific copper resistance is ρ=1,6·10^{-8} Ω·m). For the accepted excitation current I_e=1 A the power equal to $P = I_e^2 R \approx 9{,}5$ W is needed for the magnetic field excitation. This power is the same for the direct current and for the current of the low frequency (up to 100 - 150 Hz), that the blind can feel.

Conclusions

1. When blind moves the thimble in a form of thin ferromagnetic penny size disk on electromagnetic screen by his finger, it feels the variation of friction force due to control of the magnetic field and variation of its frequency, which can be related to represent various parameters of 2D graphics or images.
2. To create the magnetic field the spiral electromagnet with specific configuration can be used. It creates the sufficiently uniform magnetic field with sufficient resolution and small time response.

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The computer terminal is a ferromagnetic plate with spacial configuration. on which the blind moves by his finger the sensor of a ferromagnetic material. The finger feels the variations of the friction force due to variations of magnetic field and its frequency, which can represent the variations of the different visual information. The magnetic field is created by the spiral electromagnet. It is situated under all terminal and is created the sufficiently uniform magnetic field with well resolution. Analysis of the electromagnet magnetic circuit is performed. Ill. 5, bibl. 6 (in English; abstracts in English and Lithuanian).

R. Bansevičius, A. Žvironas, J. A. Virbalis. Kompiuterio terminalas akliesiems // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 3(109). – P. 3–6.

Kompiuterio terminalas gali būti feromagnetinė plokštė, ant kurios neregys pirštu judina feromagnetinės medžiagos jutiklį. Pirštas jaučia trinties jėgas, sukeltas magnetinio lauko ir jo dažnio pokyčių, kurie gali koreliuoti su įvairios vizualinės informacijos pokyčiais. Magnetinis laukas, kuriamas spiraliniame elektromagnete, esančiame po visu terminalu, susiejamas su grafikos ar vaizdo specifiniais parametrais (spalva, intensyvumu ir kt.). Spiralinis elektromagnetas užtikrina gerą skiriamąją gebą ir sukuria gana tolygų magnetinį lauką. Atlikta tokio elektromagneto magnetinės grandinės analizė. Il. 5, bibl. 6 (anglų kalba; santraukos anglų ir lietuvių k.).