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BRAYLLE SCREEN FOR VISUALLY IMPAIRED

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Abstract. *The graphical interfaces based on visual representation and direct manipulation of objects made the adequate use of computers quite difficult for people with reduced sight. The main scientific aim here is: a concept for development, design and manufacture prototype of combined tactile-voice interface facilitating and allowing visually impaired people work with computers regardless of the user interface or operation system and oriented to graphical surfaces. Static force characteristics of recently developed permanent magnet linear actuator for driving a needle in Braille screen are presented.*

Keywords: *Actuators, permanent magnets, tactile-voice interface, protoype, Braille screen.*

1. INTRODUCTION

Within the European Union, the problem with the access of blind people to computer resources is quite pressing. Studies on European and world scale are carried out in many directions:

- -A basic direction is the attempt for social integration of the visually impaired [1]. Within the Centers for social adaptation of blind peoples optimal conditions for assisting and integration of such peoples were provided.
- Development of Braille terminals and printers and adaptation to computer systems. The impediment here is the fact that there is no unified system for representation of graphical and mathematical elements (e.g. integral, square root, etc.) [2].
- Since the communication man-computer was quite simple (mainly based on text instructions), solution of the problem was sought on the basis of voice synthesis or other forms of feedback [3].
- Development of haptic interfaces based on electrically addressable and deforming polymer layer. Practically, the efforts are aimed at the manufacturing of a haptic dynamic input-output device allowing visually impaired people to obtain video information in other form [4].

2. HARDWARE FOR VISUALLY IMPAIRED

Despite the lack of visual contact, the people with reduced sight obtain information from the surrounding world using the other perceptions, especially touching. By touching, visually impaired people can perceive shape, size, texture, position in space, etc. This process, compared to the visual perception, is much harder, slower and ineffective but allows the unsighted good understanding of the surroundings. It has been established that each person forms his/her own mental model to sustain their reactions. This mental model comprises the operations which can be used by anyone (no matter whether they have reduced sight or not) to perceive information from the environment.

Most of the interfaces developed by visually impaired people are designed for those who had not lost their sight totally. Many interfaces use various other types of feedback like haptic and/or tactile feedback but these interfaces are usually some kind of supplement to the visual communication. There is a set of certain movements of the hand and fingers which are intuitively used by people to perceive different physical properties of the objects by touching. These movements can be grouped to form exploration procedures:

- movement aside;
- pressure;
- static contact;
- encircle and follow object contour.

The people with reduced or no sight use these model in a similar way. An important component of the ability to create cognitive models for objects in the physical world is closely related to the sense of touching. This is the only sense allowing simultaneous input/output interaction in both directions. The usual interfaces use only one direction when interacting with the user while the tactile-voice interface can well utilize the two-way communication, thux increasing the amount of information exchanged between the interface and the user.

3. VOICE INTERFACE MODELLING

So far as the modeling of human speech is concerned, it could be formed by separate components combined in a common system [5]. For this purpose, it is necessary to model a vocal tract which will be the basis for the design

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of the voice synthesizer [6]. Formal modeling could be realized through a model of the oral cavity from the larynx to the lips. To realize comparatively adequate model, certain number of parameter must be introduced to form articulate vector and define the personal characteristics of each individual. The model of human vocal tract basically consists of three components:

- Oral cavity;
- Glottal functional apparatus;
- Acoustic impedance at the lips.

Generally, the oral cavity is modeled as an acoustic tube with slowly changing (in time and space) cross-section $A(x)$ where the acoustic waves propagate unidirectionally. Under these conditions, the following equations are suggested to calculate the pressure $p(x, t)$ and volume velocity $u(x, t)$:

$$-\frac{\partial p}{\partial x} = \frac{\rho}{A(x,t)}\frac{\partial u}{\partial t}, \qquad (1)$$

$$-\frac{\partial u}{\partial x} = \frac{A(x,t)}{\rho c^2}\frac{\partial p}{\partial t}. \qquad (2)$$

Differentiating eqs. (1) and (2) with respect to time and space and eliminating the mixed partials, the equation of Webster is obtained:

$$\frac{\partial^2 p}{\partial x^2} + \frac{1}{A(x,t)}\frac{\partial p}{\partial x}\frac{\partial A}{\partial x} = \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2}. \qquad (3)$$

The eigenvalues of eq. (3) are the frequencies of the formants. Solving eq. (3), it is possible to find a stable sinusoidal transfer function for the acoustic tube, including thermal and viscous effects like losses along tube walls. For this purpose, substituting $p(x,t) = P(x,\omega).e$ and $u(x,t) = U(x,\omega).e$, where ω is the angular frequency and j – imaginary unit, and introducing the terms acoustic impedance $Z(x,\omega)$ and acoustic conductivity $Y(x,\omega)$ to provide possibilities to calculate the losses in the acoustic tube, eqs. (1) and (2) can be transformed to obtain:

$$\frac{d^2U}{dx^2} = \frac{1}{Y(x,\omega)}\frac{dU}{dx}\frac{dY}{dx} - Y(x,\omega)Z(x,\omega)U(x,\omega). \qquad (4)$$

The sinusoidal transfer function of the vocal tract can be calculated by discretization of eq. (4) in space and finding an approximated solution of the differential equation (4). Let us assume the denotation Uik for $U(i\Delta x,k\Delta\omega)$, and allowing spatial discretization $\Delta x=L/n$, at $i = 0$ at the glottis and i = n at the lips, as shown in Fig. 1. Similar to these considerations, $\Delta\omega = \Omega/N$ and let k be c 0 < k < N. Based on these initial assumptions and denotations, eq. (4) is transformed into differential equation which, after slight mathematical transformations can be written as:

$$U_{i+1}^k = U_i^k\left(3 + (\Delta\Delta\tilde{x}^2 Z_i^k Y_i^k - \frac{Y_{i-1}^k}{Y_i^k}\right) + U_{i-1}^k\left(\frac{Y_{i-1}^k}{Y_i^k} - 2\right). \qquad (5)$$

The operation system of the autonomous device should guarantee its performance rate which implies modification of some of its kernel functions. According

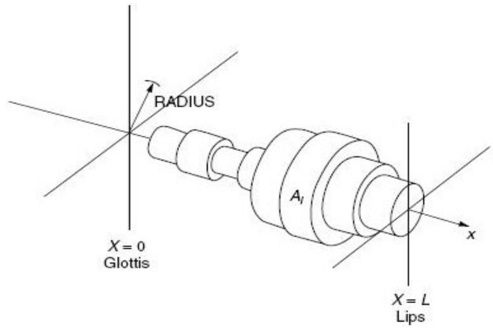

Fig. 1. Scheme of the vocal tract.

to the discussion on the job of the autonomous device, its general structure should be built in modules using as much as possible standard interfaces for communication with computer systems.;

4. PERMANENT MAGNETS

Permanent magnets have been intensively used in the constructions of different actuators in recent years. One of the reasons for their application is the possibility for development of energy efficient actuators. New constructions of permanent magnet actuators are employed for different purposes. One such purpose is the facilitation of perception of images by visually impaired people using the so called Braille screens. Recently, different approaches have been utilized for the actuators used to move Braille dots [7–15]. A linear magnetic actuator designed for a portable Braille display application is presented in [7]. Actuators based on piezoelectric linear motors are given in [8 and 9]. A phase-change microactuator is presented in [10] for use in a dynamic Braille display. Similar principle is employed in [12], where actuation mechanism using metal with a low melting point is proposed. In [13], Braille code display device with a polydimethylsiloxane membrane and thermopneumatic actuator is presented. Braille sheet display is presented in [14] and has been successfully manufactured on a plastic film by integrating a plastic sheet actuator array with a high-quality organic transistor active matrix. A new mechanism of the Braille display unit based on the inverse principle of the tuned mass damper is presented in [15].

5. BRAILLE SCREEN ELEMENTS

We developed a matrix Braille screen with moving elements, giving graphical information for visually impaired people – Fig. 2.

For each matrix element we have several variants. All of them use the electromagnetic pole for moving elements.

Variant 1: Electromagnetic driven balls (shots), [16].

a) The magnetic field pull up the balls (with a spring for neutral position) – Fig. 3

b) The magnetic field beat off the balls – fig. 4

Variant 2: Rotating balls – each ball has North and South poles – Fig. 5, [18].

Variant 3: Actuator with lifters and springs – Fig. 6 [17].

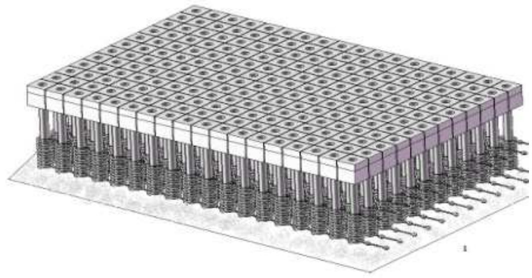

Fig. 2. Graphical Braille screen.

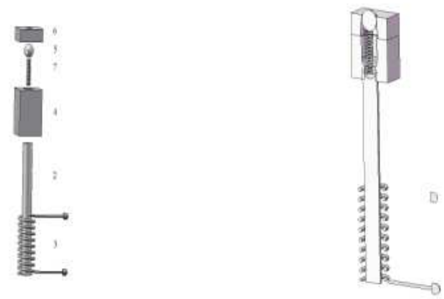

Fig 3. Actuators with springs.

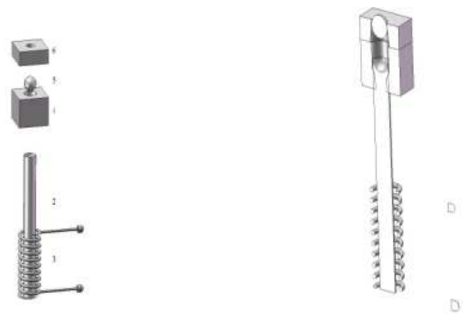

Fig. 4. The field beat off the balls.

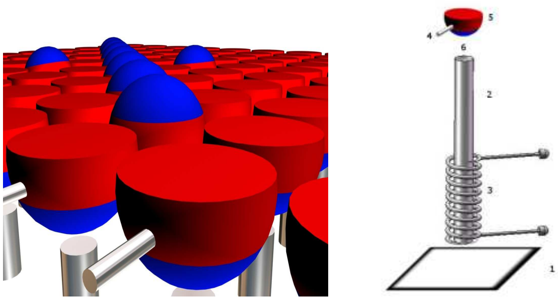

Fig. 5. The magnetic field rotates the balls.

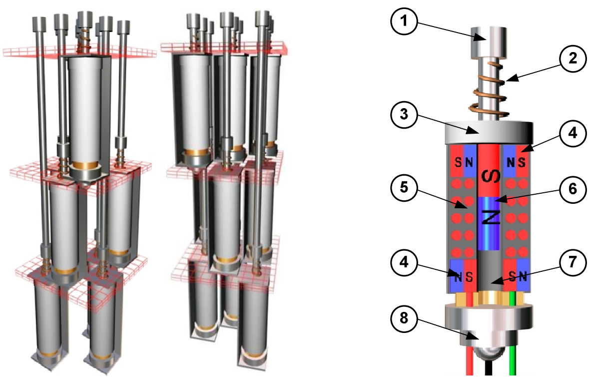

Fig. 6. The pixel lifted and held by the spring.

The finite element method for solving nonlinear magne-tostatic problems with axial symmetry is employed. The computations are carried out using the program FEMM.

The force on the mover is obtained using the weighted stress tensor approach. For automation of the computations, Lua Script® is employed [20].

For cost, power and force reasons we developed a combined actuator construction [19].

The actuator features increased energy efficiency, as the need of power supply is only during the switching between the two end positions of the mover. In each end position, the permanent magnet creates holding force, which keeps the mover in this position [21].

Magnetic field of the actuator is modeled using the finite element method and the program FEMM. For speeding-up the computations, Lua Script® is employed. Axisymmetric model is adopted as the actuator feature rotational symmetry. The electromagnetic force acting on the moving permanent magnet is obtained using the weighted stress tensor approach [21].

The static force characteristics are obtained for different construction parameters of the actuator. The air gap between the upper and lower core, the length of the permanent magnet and the coils height have been varied [21].

6. ACTUATOR CONSTRUCTION

The principal actuator construction is shown in Fig. 7. The moving part is axially magnetized cylindrical permanent magnet.

The two coils are connected in series in such way that they create magnetic flux of opposite directions in the region of the permanent magnet. In this way, depending on the polarity of the power supply, the permanent magnet will move either up or down. When motion up is needed, the upper coil should create flux in the air gap coinciding with the flux of the permanent magnet. Lower coil at the same time will create opposite flux and the permanent magnet will move in upper direction. When motion down is needed, the polarity of the power supply is reversed. The motion is transferred to the Braille dot using non-magnetic shaft, not shown in Fig. 7.

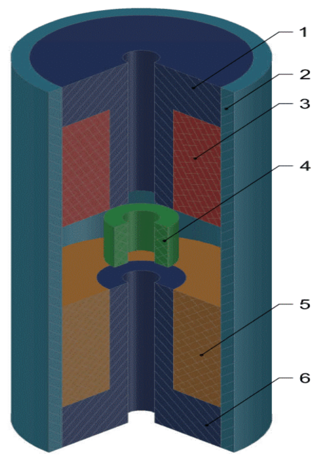

Fig. 7. Principal construction of the studied actuator: 1 – upper core; 2 – outer core; 3 – upper coil; 4 – moving permanent magnet; 5 – lower coil; 6 – lower core.

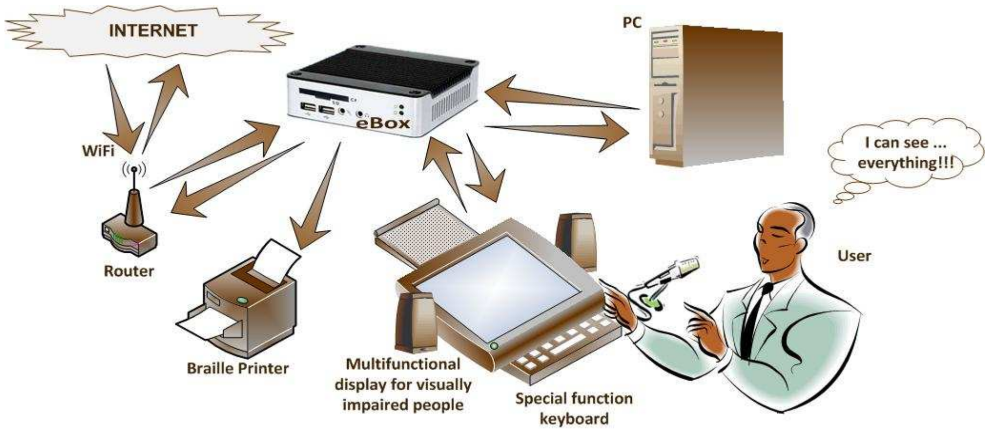

Fig. 8. The whole system.

The actuator features increased energy efficiency, as the need of power supply is only during the switching between the two end positions of the mover. In each end position, the permanent magnet creates holding force, which keeps the mover in this position.

7. SYSTEM DESIGN

In Fig. 8 it is shown the basic scheme of the interface and its place in the frame of LAN working computer system.

The main computer is eBox-3310AMSJK, because of the functionality, small size and universality. Here it works with Windows Embedded CE and it is easy to make the other hardware and software.

8. CONCLUSIONS

The developed actuator has static force characteristics which are suitable for Braille screen application. Further study will include optimization of the actuator and estimation of its dynamic characteristics.

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