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Assistive graphical interface presenting cultural-historical heritage for low sighted and blind people

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***Abstract**: It is difficult for a visually impaired person to get a graphical information from modern computers. The article presents an approach for transforming data from the cultural and historical heritage, so that the low sighted or blind people can see and understand them.*

***Key words**: cultural-historical heritage, graphical interface, Braille screen*

1. Introduction

Currently the classical 2D digitization scenario (one picture represented as one image) is kept within 3D modeling: one object is digitized as one 3D model. This is perhaps due to the fact that yet there are no easy to use technologies for reliable semantic decomposition of images and 3D models. The other variant for visual impaired people is a presentation via a Braille Display equipped with relevant software, and validates it with real users in live environments.

There are devices with small screens (e.g. mobile phones) where graphical objects are explored with one finger only. They are irrelevant for detail presentations. Here we provide additional information about the three most mature pin-array Displays, which are described as most representative about the present state of the art.

Graphiti (fig. 1) features a touch interface to enable the user to “draw” on the display; tracing a shape with a fingertip raises the pins along the path traced. The touch interface allows traditional forms of touch commands such as scrolling, multi-touch gestures such as pinch-to-zoom, etc. In addition, it enables novel uses such as “pushing” or “nudging” an object on the display to physically move it. The device is equipped with ports that make it highly connectable to computers, tablets, smartphones, and to any device with a video display output. Graphiti also includes a cursor pad for navigation, and an SD-card slot for loading files for reading and editing in a standalone mode. The proprietary technology is fundamentally scalable and enables development of refreshable graphic displays of any size, at a fraction of the cost of graphic displays in the market today. The first model has 2,400 pins in an array of 60 x 40 pins, and can be used in a portrait or landscape orientation. The picture shown here is a one-quarter size prototype [1].

BlindPAD (fig. 2) is a tactile tablet made of 192 ‘taxels’ (12 x16 pins) on an 8 mm pitch with a 10 ms refresh time per taxel. It transforms images into tactile representations. BlinPAD device consists of an array of 12× electromagnetic actuators using a novel magnetic shield concept that enables high fill 16 latching factor, and eliminates cross-talk. The vertical travel is 0.8 mm, the holding force - 200 mN. The figure gives the diagram and key elements assembly of the 4×4 haptic display: (a) Schematic view of a single taxel and the main components; (b) Photo of the 6-layer PCB containing the array of planar coils; (c) Top view. The magnetic layer is formed by the 16 moving magnets; (d) a 3D printed pin interface completes the device as a final layer. The load force and the displacement curve for one taxel, for the two pulling-pushing configurations were studied. In the pulling configuration, the up-taxel state is dominated by the spring effective constant of the membranes. In the pushing configuration, the up-taxel state reflects the magnet/coil repulsion force. The experiments were studied for the 4×4 haptic display [2].

Fig. 1. Graphity Braille Display

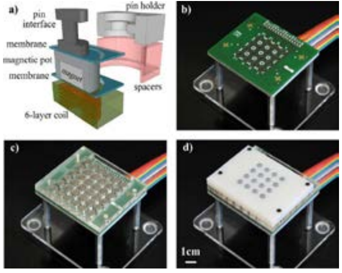

Fig. 2. BlindPAD Braille Display

HyperBraille (fig. 3), produced by Metec Ingenieur AG, is build up with 624 braille cells each with 10 dots. The piezo driven dots (104x60) support Braille and graphic output. The tactile area with 150x260 mm is touch-sensitive. Additional 14 buttons provide special functions like zooming and scrolling. The display is connected via USB. This device is on the market in various models, [3]:

The **Screen-reader** works independently. It may also connect to JAWS or Window Eyes, and uses displays touch sensors to invoke mouse clicks, to route the cursor or to start audio explanation. Screen-reader can been enhanced by programming. Its specifications are: Unit: 370x245x60 mm, Tactile area: 150x260 mm, Weight: 4,5kg, Dot spacing: 2.5mm, Cell spacing 5x12,5 mm Tactile Force >30cN, Power supply: 12V 4A.

Hyperflat (fig. 4) is a tactile Display connected to a Smartphone or PAD. The usage of the home screen and the apps is completely similar to the Pad. The touch sensitive surface allows input and control directly to the Pad so one can operate the Pad with its own touch or with the touch on the Hyperflat. The buttons and the cursor provide additional functionality for navigation and direct actions. Zoom and wipe are possible with gesture and/or buttons. The Display has its own software MVBD for Windows. Hyperflat is build up with 76x48 piezo driven dots. This correlates to a dot spacing of 2.5mm at a tactile area of 190x120 mm for graphic output. The devise has mathematic software called HyperBraillegeo and shows GeoGebra graphical objects.

Fig. 3. HipreBraille Braille Display

Fig. 4. Hiperflat Braille Display

2. Braille Display

Here we present a prototype of a Braille Display based on the patent application WIPO PCT/BG2014 000038 “Braille Display”,. Also we present the research on design, optimization and development of magnetic based linear actuator, in order to motivate advantages. The control human-computer interface this device is proposed.

The **Braille Display** represents a matrix comprised of a base with fixed electromagnets. They are arranged thereon, including an outer cylindrical magnetic core, in which a winding magnetic core locking up the cylindrical magnetic core at the top side. A winding magnetic core locking up the cylindrical magnetic core at the bottom side are placed. The magnetic cores are with axial holes. Into the space between the windings is placed a movable non-magnetic cylindrical body, carrying a permanent cylindrical magnet axially magnetized and a non-magnetic needle. The needle is passing axially through the permanent magnet and the axial holes of the magnetic cores. On the top side of the permanent magnet is arranged a ferromagnetic disc having an axial hole. On its underside is arranged a ferromagnetic disc having an axial hole. The upper disc and the upper magnetic core have cylindrical poles and the lower magnetic core and the lower disc have conical poles. Above the electromagnets is placed a lattice. The needles pass through the openings.
The electromagnets can be placed in one line in the matrix as well as in two, three or more lines. They can be side by side at an offset along two axes (x and y) and a different length of the movable needles along the third axis (z). They overlap and occupy less space in the matrix, and the tips of the needles are in one plane - the plane of the lattice with openings of the Braille display [5], [6], [7].

Actuator Construction. The actuator is a linear electromagnetic microdrive **(Fig. 5**). The mover is a permanent magnet. Its magnetization direction is along the axis of rotational symmetry. The upper and lower coil are connected in series. This connection is realized so that the flux created by each of them is in opposite directions in the mover zone. Thus by choosing proper power supply polarity, the motion of the mover will be in desired direction. For example, in order to have motion of the mover in upper direction, the upper coil has to be supplied in a way to create air gap magnetic flux, which is in the same direction as the one of the flux created by the permanent magnet. The lower coil in this case will create magnetic flux which is in opposite direction to the one of the magnetic flux created by the permanent magnet. In this case motion up will be observed. In order to have motion down, the lower coil should be supplied in a way so that its flux is in the same direction as the flux by the permanent magnet. The upper coil then will create magnetic flux in opposite direction. In order to fix the moving part to the Braille dot, non-magnetic shaft is used. Additional construction variants of the actuator have also been considered, in which two small ferromagnetic discs are placed on both sides **-** upper and lower **-** of the moving permanent magnet [8].

This actuator is also energy efficient, as energy is used only for changing the position of the moving part from lower to upper and vice versa. Both at lower and at upper position, no energy is used. At these positions, the mover is kept fixed due the force ensured by the permanent magnet (sticks to the core).

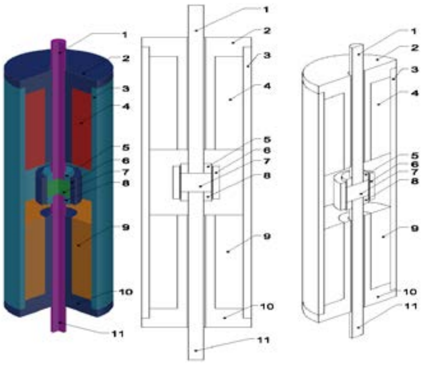

Fig. 5. Principal geometry of the permanent magnet linear actuator: 1 - Needle (shaft); 2 - Upper core; 3 - Outer core; 4 - Upper coil; 5 - Upper ferromagnetic disc; 6 - Non-magnetic bush; 7 - Permanent magnet; 8 - Lower ferromagnetic disc; 9 - Lower coil; 10 - Lower core; 11 – Needle (shaft).

Use of the Braille Display: When transmitting a short voltage pulse with positive polarity to the coils, the nonmagnetic needle rigidly connected to the non-magnetic body carrying the permanent magnet with ferromagnetic discs is moved upwards until the appropriate ferromagnetic plate next to the pole of the upper magnetic core is reached. It is kept in this top position after the decline of the pulse due to the attractive forces between the permanent magnet and the magnetic core, as needle protrudes above the lattice with holes of the Braille display. When transmitting a short voltage pulse to the coils with opposite polarity, the nonmagnetic needle moves down-wards until the ferromagnetic disc next to the pole of the lower magnetic core is reached. It remains in that lower position after the decline of the pulse due to the forces of attraction between the permanent magnet and the magnetic core, as the needle does not protrude above the lattice with holes of the Braille display [9]. All electromagnets are controlled simultaneously and in a synchronized manner, such that to obtain a general image with needles - text or graphics on the entire matrix. The visually impaired person feels by touching only those needles that protrude above the lattice with holes of the Braille display, since the permanent magnets are in upward position.

Static Force Characteristics are obtained for different construction parameters of the actuator. The outer diameter of the core is varied. The air gap between the upper and lower core (δ), the length of the permanent magnet and the coils height have been varied too [10]. **In Figures 6-9** the force-displacement characteristics are given for varied values of the permanent magnet height *hm*, coil height *hw*, magnetomotive force *Iw* and apparent current density in the coils *J*.

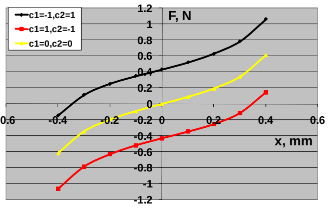

Fig. 6. *hm*=2mm, δ=3mm, *hw*=5mm,

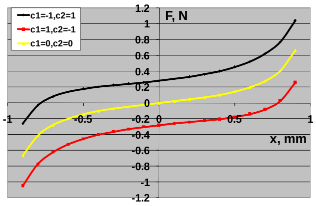

Fig. 7. *hm*=2mm, δ=4mm, *hw*=5mm,

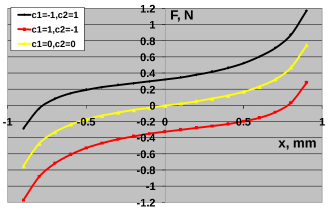

Fig. 8. *hm*=3mm, δ=5mm, *hw*=5mm

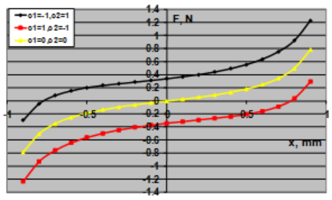

Fig. 9. *hm*=4mm, δ=6mm, *hw*=5mm

The polarity and value of the supply current of the coils is denoted with *c1* and *c2*. "*c1=-1, c2=1*" corresponds to supply for motion in upper direction; "*c1=1; c2=-1*" – motion down, "*c1=0, c2=0*" – without current in the coil, i.e. this force is due only to the permanent magnet. Here *Iw*=180A, *J*=20A/mm^2.

3. Finite Element Modelling

Magnetic field of the construction variant of the permanent magnet linear actuator with two ferromagnetic discs on both sides of the permanent magnet is analysed with the help of the finite element method [11]. The program FEMM has been used and additional Lua Script® language was developed for faster computation. The field is analysed as an axisymmetric one due to the rotational symmetry of the actuator. The weighted stress tensor approach has been utilized for evaluating the electromagnetic force on mover - **Fig. 10**.

Optimization. The optimality criterion is the minimal magnetomotive force NI of the coils. The optimization factors are geometrical parameters (height of the permanent magnet, height of the ferromagnetic discs and height of the coils. The optimization is carried out subject to the following constraints - minimal electromagnetic force acting on the mover, minimal starting force and overall outer diameter of the actuator have been set [12]. Minimization of magnetomotive force NI is in direct correspondence to minimization of the energy consumption. Constraints for Fs and Fh have already been discussed. The radial dimensions of the construction are directly dependent by the outer diameter of the core – D which fixed value was discussed earlier. The influence of those parameters on the behavior of the construction have been studied in [12] that make clear that there is no need radial dimensions to be included in the set of optimization parameters.The lower bounds for the dimensions are imposed by the manufacturing limits and the upper bound for the current density is determined by the thermal balance of the actuator. The results of the optimization are as follows: $NI_{\mathrm{opt}}=79.28$ A, $hw_{\mathrm{opt}}=5$ mm, $hm_{\mathrm{opt}}=2.51$ mm, $hd_{\mathrm{opt}}=1.44$ mm, $J_{\mathrm{opt}}=19.8$ A.
The force-displacement characteristics of the optimal actuator are shown in **Fig. 11**.

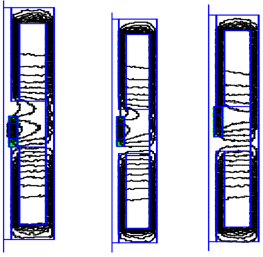

Fig. 10. Typical flux lines distribution for three different mover positions

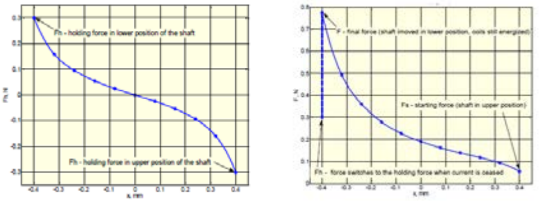

Fig. 11. F/D Characteristics with and without current in the coils

4. Conclusion

We see the following advantages of our development [13], [14]:

(i) the retention of the needles in their final positions does not need an external power supply, as it is provided by the permanent magnet;

(ii) the lack of additional energy source allows very precise control of the feed force for realizing of the tactile feedback;

(iii) the intermittent power supply voltage with which an extremely low power consumption is achieved (only for moving the needle from one end to the other), as well as more efficient use of materials and reducing of the size of the matrix;

(iv) the extremely low electric and mechanical time constants, resulting in very good velocity and dynamic characteristics;

(v) the considerably wider range of the realizable tactile feedback due to the fact that all electromagnets can be operated simultaneously and synchronously, which gives the operator a more realistic and closer to reality tactile perception;

(vi) the extremely high positioning accuracy of the needles and the stability of the retaining forces for them into their final positions;

(vii) the chosen propulsion method is distinguished by its exceptional reliability and trouble-free operation and requires no additional settings and service;

(viii) the technology as a whole, with its simplicity and easy maintenance, is convenient for the realization of the matrix.

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Спомогательные графические интерфейсы, представляющие культурно-историческое наследие для слабовидящих и слепых людей

Димитър Карастоянов Николай Стоименов Станислав Гьошев

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