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TACTILE GRAPHICAL DISPLAY FOR THE VISUALLY IMPAIRED INFORMATION TECHNOLOGY APPLICATIONS

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ABSTRACT

This paper presents an interactive tactile graphical display, for the visually impaired information technology access applications. The display consists of a matrix of dots. Each dot is an electro rheological micro actuator. The actuator design and development process is presented in this paper. Prototype size 124x4 dots was manufactured. An advanced software tools and embedded system based on voltage matrix manipulation has been developed, to provide the display near real time control. The experimental tests carried out into the developed prototype showed that each actuator of the matrix was able to provide a vertical movement of 0.7 mm and vertical holding force of 100 to 200 mN. The stroke and dynamic response tests showed the practicability of the developed tactile display, for the visually impaired information technology applications.

Keywords: Visually Impaired IT applications, Tactile Graphical Display, ER- Industrial Applications

1 INTRODUCTION

Electronic refreshable graphical tactile display is one of the most effective interactive tactile interfaces approaches for the visually impaired access to Information Technology (IT). Tactile displays show the information by simulating the sense touch. They are used as reading and IT interactive tools for visually impaired and blind people. The most common patterns available commercially are in one row form and called a text display. In most cases the display is placed under a conventional computer keyboard or laptop keyboard or integrated as part of the keyboard and enables the end user to read the contents of the computer screen by touch in Braille. Each cell has eight dots made of metal or nylon, which are electronically controlled to move up and down, to display a Braille version of characters, numbers, punctuation that appear on the personal computer screen (H. Fisher, R. Trapp, B. Hofman, 1996, P. D. Atherton and K. Uchino, 1998, Kohl, S. Durr, E. Just and D. Pirck, 1998, Fricke and H. Baehring, 1994, Yobas L., Lisy F. J., Schmidt R. N., Huff M. A., 1998). Braille displays designed for use with desktop PCs are around 70 to 80 cells in length. The conventional Commercial actuators used in these applications were electro-mechanical actuator in a form of very tiny solenoid or piezo-ceramic bending element actuator (P. D. Atherton and K. Uchino, 1998). The electro- mechanical actuator using very tiny solenoid has been used to latch a pin, up or down. One of the major problem faced these kind of actuators were prone to stick, due to dust and dirt. The piezoelectric actuator concept is based on using a little piece of ceramic substrate that's shaped to the right dimensions, applying 200 volts and precise operating frequency on it, the dimension of the piezo actuator element changes (P. D. Atherton and K. Uchino, 1998, Kohl, S. Durr, E. Just and D. Pirck, 1998). The main issues with those actuators technology is that they are expensive since the price of a Braille cell of eight dots, is about 35 Euros and the cost of a Braille display of one line of text around 10,000 Euros.

One of the proposed universal approaches to reduce the cost is a force display that has a pointer device, such as a computer mouse and a small tactile display on it. The VirtTouch mouse is based on the idea of, a finger or few fingers are rest on the display and the content is refreshed as the mouse is moved along, to interpret virtual tactile image. The cost of this type of displays is around 5,000

Euros. However the information these devices can transmit, to the skin is limited. This is because much information is collected by dynamic mechanoreceptors in the skin while fingers explore a surface, because of the slip or tangential forces. This cost barrier show that none of these micro actuators technology is economically good enough, to be implemented in high resolution and large scale displacement tactile graphics displays that are explored with the finger. Therefore, there is still a great attention in new micro actuators technology which could allow a more inventive functioning in terms of operability, manufacturing process, integration, performance and cost (S. Hata, T. Kato, T. Fukushige, A. Shimokobe, 2003, Fricke J., 1993, Taylor P. M., Pollet D. M. Hosseini-Sianaki A., and Varley C. J., 1998, Moy G., Wagner C., Fearing R. S., 2000, Moy G., Singh U., Tan E., and Fearing R. S., 2000).

There are a wide variety of prospective and most of the activities were focused on electrical simulation, which is an old idea but it has not got the desired results yet (Kohl, S. Durr, E. Just and D. Pirck, 1998, Fricke and H. Baehring, 1994, Yobas L., Lisy F. J., Schmidt R. N., Huff M. A., 1998). Here are some examples: Shape memory alloy (SMA) actuators, these are actuators made of wires and its length changes to around 5% when heated by a current of a level of 2A. Most problems to be solved for such technology are small stroke, high power consumption, slow response and need of small mechanical structures. Pneumatic actuators, these are actuators electro-statically actuated. These are bulky ones, unless they use micro actuators, to control the flow, such as, actuators in Micro-Electro-Mechanical Systems (MEMS) technologies (P. D. Atherton and K. Uchino, 1998, Kohl, S. Durr, E. Just and D. Pirck, 1998, Yobas L., Lisy F. J., Schmidt R. N., Huff M. A., 1998).

Pneumatic micro actuators that are based on Electro- Rheological (ER) fluid technology have great attention since the response of the ER-fluid is fast, almost in msec, but the resolution and stroke are poor (Taylor P. M., Pollet D. M. Hosseini-Sianaki A., and Varley C. J., 1998, Block, H. et al, 1989, P M Taylor, et al, 1996, M. Shafik, et al, 2005, M Shafik, 2012). The main phenomenon of the ER-fluid is focused on the physics nature of the fluid and its natural sensation to change from one phase to another when an electric field is applied. The density of such fluid changes as the electric field increase. The ER-fluid is comprises of a colloidal dispersion consisting of insulative base oil and a slightly conductive dielectric solid particles, in the size of 10 to 50 microns. A commonly accepted explanation of the ER-fluid effect is that in the presence of an electric field, the particles became polarised and attract each other accordingly. It is the electrostatic forces between particles that hold the structure together in a solid state. These forces are obviously dependent on the strength of the electric field applied (Kohl, S. Durr, E. Just and D. Pirck, 1998, Block, H. et al, 1989, P M Taylor, et al, 1996, M. Shafik, et al, 2005, M Shafik, 2012). Fricke J., 1996 has developed a display based on these fluids and has showed the possibility of improving the performance. The tactile display developed in this research is presenting a real breakthrough in IT access application and overcome most of the aforementioned technical barriers, at lower cost.

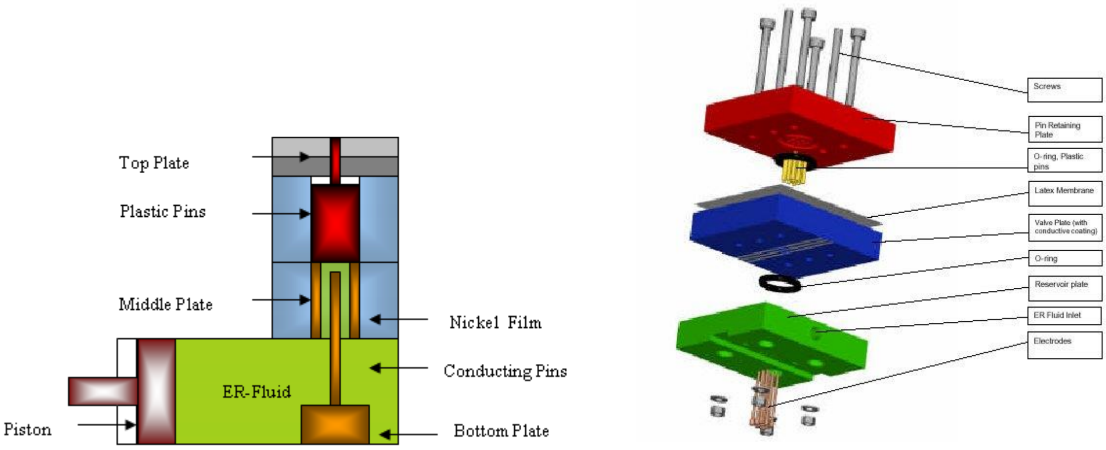
2 STRUCTURE OF THE PROPOSED MICRO-ACTUATOR

There are several key approaches that can be used to form the convexity of a surface, to meet the standard criteria of Braille display IT access applications. These can be classified into two main principles, which are linear movement and rotational movement. The proposed micro actuator structure is based on the linear movement principles. Figure 1 shows the schematic of the proposed micro actuator. The actuator consists of a small cylinder made of ABS material, with dimension of 1.5 mm diameter and 10mm long. The inner surface of the cylinder is coated by nickel. A coaxial conducting rod of 1.02 mm diameter and 10 mm long is fitted vertically in the centre of the cylinder.

The coated surface is used as first electrode and the coaxial conducting rod is used as a second electrode, to form the micro actuation high voltage area. Each micro-actuator was design based on linear vertical movement principles.

3 MICRO ACTUATOR WORKING PRINCIPLES

The principle of operation of the proposed micro actuator is mainly based on the ER-fluid phenomena. When the system is at static start and or at the beginning of a cycle, all pins are down. When the piston is pressurised the fluid underneath, all the pins will be pushed upward to their mechanical limit. Application of an electric field across the high-field area will "solidify" the fluid between the conductors and isolate the pins from the pressure developed in the main reservoir. Conversely if the piston depressurized, the free pins will be pushed down to their initial state. This means that at the end of each cycle, when the voltage is released and the electric field on the high voltage area is vanished, all the pins will be pushed down to the beginning cycle by atmospheric pressure. The proposed design allows operation using only double of the actuator number of a display of size NxN matrix. N is the number of rows and or columns in the display matrix. This is made it possible by the perpendicular orientation of the two sets of conductors, i.e. horizontal and vertical ones. Two methods can be applied, time multiplexing and voltage multiplexing. Voltage multiplexing is currently preferred and has been adapted as suggested by Fricke J., 1996.



(a) (b)

Figure 1: Schematic of (a) proposed micro actuators (b) 3x3 matrix of micro actuator

4 PROTOTYPING, EXPERIMENTS TEST AND VALIDATION

Figure 1 (b) shows an exploded schematic of the 3x3 matrix design structure. Perspex material has been used in manufacturing the first prototype. Perspex is a transparent thermoplastic material which would allow the observation of revolutionize of the fluid characteristics with the existence of the electric field. The prototype is made of three main plates, the top, middle and bottom plate. The top plate was designed to accommodate the plastic pins and to allow vertical movements of 0.7 mm in any position (vertical, horizontal or upside down). This is the standard movement needed for IT Tactile application. The middle plate is to accommodate the ER-fluid and the conduction pins. The thickness of the middle plate was determined considering the ER-fluid characteristics and the vertical holding force needed. The plates were machined in a matrix of holes, each-hole of a size of 1.5 mm diameter. The inner of each hole has been coated with Nickel film of 10 µm thickness using electroless process. The bottom plate was designed as a reservoir for the ER-fluid and has been machined in a matrix of holes of size 1.00 mm. These holes are to hold the conduction pins. The center conduction pins has been made of phosphor- bronze and of a dimension of 1.02 mm diameter.

This gives a distance of 250 µm in the center plate, to be filled with ER-fluid. This was calculated to allow the use of 250 volts drive and to satisfy the standard of domestic invention. The shape of the actuator has been designed on a cylindrical structure, to make sure that a uniform electric field has been created inside the actuator since non-uniform electric field can affect the steady flow of the fluid. The region occupied by fluid which lies between the vertical conducting pins and the coated surface is known as the high-field region. The fluid within the micro actuators is driven by a master piston.

The conducting pins are also co-axial cylindrical electrodes, to ensure that the electric field strength is distributed calculably with radial and axial symmetry in this region. Consequently if the horizontal conductors are grounded and the center conductors are brought to high voltage, the small gap size ensures that the electric field strength is high in this region and this region only. An O-ring of rubber has been used to seal the middle and the bottom plate. Rubber sheeting elastic material was used as a membrane and this was selected to provide three functions for the micro actuator system

(Barlow, F., W., 1993, Blow, C., M., and Hepburn, 1982). These functions are: to insulate the ER-fluid from the other parts of the system. The second one is to deform easily with a minimum amount of pressure and recover its original structure without any fatal destruction into the material micro structure. The last function is to isolate the main parts and stop any fluid leaking. The EPDM rubber sheeting was the optimum options. The Chemical and Physical Properties of EPDM rubber sheeting used were: Tensile stress (TB): 12.8MPa, Elongation at break (EB): 150%, Hardness, shore (HS) = Shore A 78, Volume Resistively: 10Ωcm, Resistively: Oil resistance material, Working temperature: 40 0C app, Physical dimensions: 0.050x360 x 360 mm, 0.1x360 x 360 mm.

The necessary test rig has been built. This was composed of a hydraulic drive, DC ER-fluid electronic drive, frequency generator and power MOSFET switching unit. Several tests have been carried to the first developed 3x3 prototype. The first test was air pressure test, this aimed to ensure the legitimacy of the movement principles used on the actuators design. The second one was fluid test and this was aiming to test the ER-fluid practicality. Voltage multiplexing has been used during the test process. This arrangement allows updating the 3x3 matrix prototype one row at a time, i.e. conductors 1 – 3 can be at either 0 or 350V. Individual actuators on row 1 will be controllable by the column drive circuitry. It is then possible to build up a complete tactile graphical display of any large scale using this methodology and would be able to display a complete "image" on the array row by row.

Series of theoretical and experimental analysis to define the performance of the developed micro actuators to be implemented in high resolution tactile graphical display has also been conducted. The main standard criteria of Braille were considered as a first priority. A consideration of expected behaviour of the micro actuators due to the manufacturing tolerances was then conducted followed by a consideration of current consumption against the position of the conducting pins in the core of the micro actuators.

4.1 Standard Criteria of Braille

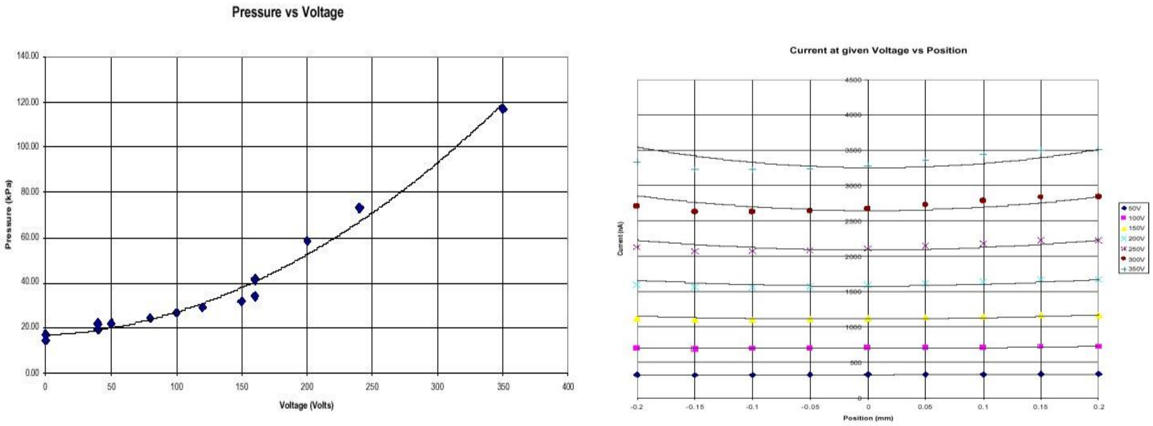
The vertical holding force for each micro actuator was measured and it was found that each one was able to carry a vertical holding force equal to 200 mN. The practical test showed that the actuators were able to provide 0.7 mm at a pumping pressure of 2.5 Pascal. This was measured at the end of the pumping tube and with an EPDM rubber with a thickness of 50 µm.

4.2 Current and Power Consumption

Current and power consumption tests showed that the developed prototype operates at an acceptable voltage on the range of (±250 to ±350 V). This voltage is low enough that the protection of the end-user can be achieved without great difficulty and low cost devices may be used for electronic drive circuitry (<±400 V). Current consumption at room temperature has been measured at 1.5 µA per actuator, giving rise to approximately 3W power consumption in normal operation.

4.3 Expected Variation of Actuators

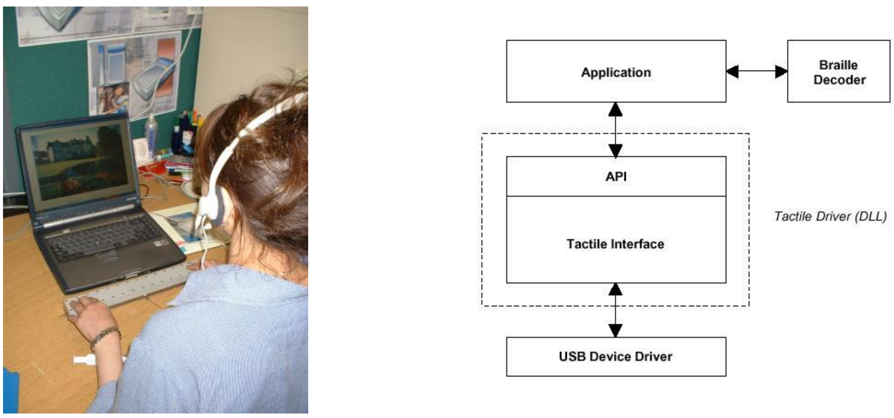
For such micro-actuator technology, studying the manufacturing tolerances consequence on the system performance is an essential process. The manufacturing tolerance in the current system can change the position of the conducting electrode in the center core of the actuator. 1.00 mm holes is used for 1.02 mm diameter electrode pins (tolerance ± 0.01 mm) to ensure a proper interface fit that compensate the drilling tolerance. This is achieved by employing a smaller diameter holes than the pins accurate positioning of the electrode. Variation of the actuators behaviour is therefore only affected by misalignment or slightly bending of the pins. Figure 2 (a) shows the expected behaviour of the micro actuators due to the manufacturing tolerances. Experimental tests were conducted to determine the maximum tolerance allowed, at different voltage, for these circumstances. Expected variations in the actuators behaviour were both focused on power consumption and vertical holding force. The test was carried out using a single 1.00 mm diameter conducting pin inside a 1.5mm cylindrical hole. The conducting pin could be moved from its center position to simulate misalignment. The system was then fitted with a micrometer to accurately measure any offsets from the center pin location. To hold out the desired finger print of 150 mN, the required pressure equals approximately 11 kpa. This is the pressure required for comfortable reading of the pins for the tactile graphical display application. The force required to depress the pins in order to register feedback should be more than 150 mN, but less than 350 mN force. Figure 2 (b) shows the current consumption versus the position of the conducting pins. It is clearly observable that the current consumption remains fairly constant independent of the position. This means that perfect alignment is not crucial as long as the gap between the conducting pins and the cylindrical tube is bigger than the size of ER-fluid particles which is in the range of 10 to 100 µm.



(a) (b)

Figure 2: (a) Expected behavior of the actuators due to manufacturing tolerances & (b) Current consumption versus position of the conducting pins

A prototype size 128x4 dots have been manufactured and this is shown in Figure 3 (a). The prototype was equipped with a dedicated control unit. The controller unit consists of a micro controller µC, a hydraulic drive and 270 volt DC power supply card. The µC with the serial interface, 64 Byte RAM, and 128 KByte flash ROM are mounted on a single board. The power supply card and the other electronics are plugged onto this host module. Figure 3 (b) shows an overview of electronic interface & Protocol layout and data flow block.



(a) (b)

Figure 3: The developed (a) 128x4 interactive interface display prototype & (b) Overview of electronic & Protocol layout and data flow block diagram

The control unit receives the image data via a USB serial interface from an external computer. The image is stored in the RAM of the host module. The control unit continuously reads the data and calculates the pattern to be displayed on the tactile matrix correspondent to the actual image data provided. The software consists of two independent parts running on the µC software and the external computer respectively. The µC software is executed in a time loop of Hz. In this loop the µC read out the data of the image to be displayed and activate the correspondent dots in the tactile matrix. In the next step, it receives new images from the computer and saves them in the local RAM. The software running in the external computer has the task to generate images to be displayed on the tactile matrix display. Tools have been developed to send parts from the graphics files (*.jpg or *.bmp or html format) to the tactile display. It is also possible to draw directly in the display using a mouse of external computer. For the graphical interface the QT library is used, which allows to run the program under different operating system (such as Windows or Linux).

5 CONCLUSIONS

A tactile graphical display for visually impaired IT access applications has been developed. Prototype size 124x4 on a matrix form, with a separation distance of 2.54 mm, was designed and fabricated. Tests carried out into the developed prototype showed that each micro actuator was able to provide a vertical movement of 0.7 mm and a vertical holding force of 100 to 200 mN. These results satisfy the necessary requirement of Braille IT access applications. The experimental results of the stroke and dynamic response showed the practicability of the developed graphical tactile display, for visually impaired information technology access applications.

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