On-line Computer Test System for Remote Assessment of Neurological Patients: Part B Dedicated Device and Web Portal

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Abstract- The work presents a proprietary development of a device specifically designed to be used in conjunction with the on-line system for neurological tests presented in part A of this work. The device was specifically developed for supervised tests where patients are asked to complete a sequence of tests for potential early diagnosis of neurological conditions. The device achieves very good accuracy of 2-5 ms and further allows measuring the applied force in real time. The software connects to a web portal allowing remote participation of a neurologist and is expected to enable better group differentiation among patients in terms of disease type, progression and treatment response.

Keywords: - presents a proprietary development, differentiation among patients in terms of disease type

I. INTRODUCTION

The first part of this work focused on the use of standard across the computer range – form desktop with a keyboard through laptop and tablets. All in all these devices ensure that they can be used in the comfort of the patient home and small practices with limited IT support and facilities. However, there is a big drawback as the typing/interactive human-computer interfaces (HCI) are not design to be measuring devices but to provide reliable means to enter appropriate characters and commands. As such they are designed with a built-in delay from 20 to 80 ms that allows ignoring incidental short lasting touches. However, this built-in delay is comparable to our reaction times and therefore reduces the resolution of the system described in part A of this work. Hence a natural further development is to develop a device with better temporal response and possibility to measure the scale of applied force, i.e. to ignore accidental touches. In this work we describe the device we developed.

II. SPECIALIZED DEVICE DEVELOPMENT

Although the keyboard device is suitable for certain tests such as measuring the speed, frequency and correctness of key pressings, it cannot be used to subtly analyse key press actions i.e. how hard it was pressed and is limited due to size and speed of response. A device similar to a keyboard was designed and developed to fulfil the requirements for testing reaction times and other parameters of MS and PD patients. Piezoelectric and Hall sensors were selected and competitively tested using a mini prototype of the device.

Revised Version Manuscript Received on December 22, 2015.

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The Hall sensors performed substantially better than Piezoelectric for particular application the first was used to create full scale prototype.

a) The device consists of two identical parts with 64 keys each. Hall sensors are used to emulate keys for the device and to measure the pressure applied. Each key can be illuminated in 3 different colours - red, green or blue. Two parts of the device will slide to increase or decrease the distance between keys while being used for Test 4 in the first part of this work.

b) A device consisting of 2 similar parts with four spots of sensors with 11 sensors each on the left part of the device, and one spot of sensors with 11 sensors each on the right part of the device. As with the concept "a" Hall sensors is used to create keys for the device. Two parts of the device slide apart to increase or decrease the distance between keys while being used for Test 4.

Considering all the pros and cons of each concept and due to the fact that the second concept limits users for the number of tests, the first concept has been used to develop a device, although it requires more processor time to process all 128 key values. The final design and technical specification of the device is shown in Figure 1 below.

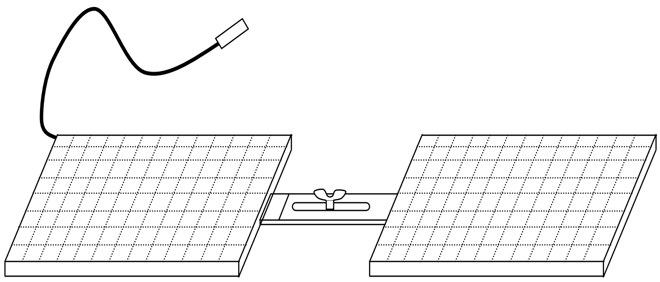

Figure 1. Stroop test device

A brief technical description is provided below:

1. Every cell has a 2 number address;
2. Every cell has a sensor and 3 colour LED (Red, Green and Blue) to illuminate cells to be pressed.
3. Device is split into 2 sections, with adjustable length.
4. Signals under X mV and over Y mV are ignored.
5. X and Y values are changeable (calibration).
6. Each side of the keyboard has 8x8 cells = 64x2 = 128 cells in total, square 20mm x 20mm.
7. Cell address format is XX by YY. Where XX is horizontal line from left to right (01,02,…,15,16); and YY is vertical line from top to bottom (01,02,…,07,08);.
8. Signal character sequence is XXYYVVV. (VVV is

the value of pressure in mV).

9. Signal, from the device, is sent every 2msec.
10. Signal from PC to device is XXYYCC (CC defines colour 00-Off, 01-Red, 02-Green, 03-Blue).

Testing the software also allowed evaluation of each cell pressure value and the effects on adjacent cells. While testing the device, several improvements were made to the communication protocol and the device functioning achieving a substantive reduction in communication volume between the device and the PC. As an example, the previously described test has been considered where the user would press 2 keys located within 15cm from each other. The main 2 cells of the device were set as 49 and 56. Since adjacent cells may be pressed by accident an additional 5 cells for each main cell (41,42,50,57,58 and 48,47,55,63,64) have been monitored leaving us with 52 disabled cells. The device allowed us to measure how precise the pressed points were and how hard the key-cells were pressed. We also have portable mini device for tests 1 to 3 in Fig. 2 below and the full scale (half device is in Fig. 3. technical details are provided in the appencies. All software tests were adjusted to be used with the specialized device and have proven to deliver much more reliable and only the necessary data for analysis compared to the ordinary keyboard.

Figure 2. Portable mini-device for Stroop test software (LED design).

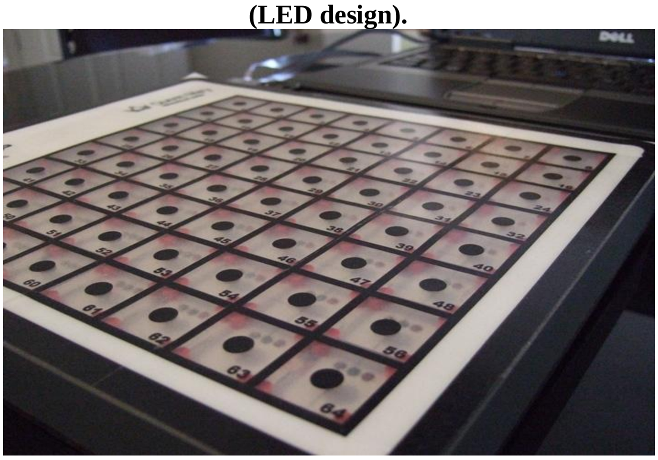

Figure 3. Full scale device for Stroop test software (keys layout)

III. WEB PORTAL DEPLOYMENT

This device still aims to remotely test potential patients and is therefore essential to be accessed from numerous points. Hence a web portal was developed to allow users (medically trained professionals who supervise the tests) to register and download the application for installation. The portal incorporates several pages including a user forum for discussions. The sketch of the web portal is displayed in Fig. 4 below. Web based software distribution was made available only for a keyboard based Stroop test software at this initial stage. Users can download and install the application similar to other software such as Skype, Chrome or Firefox browser. In order to use the software, users are required to register and they receive username and a password. Use of a dedicated website allows faster distribution of the software.

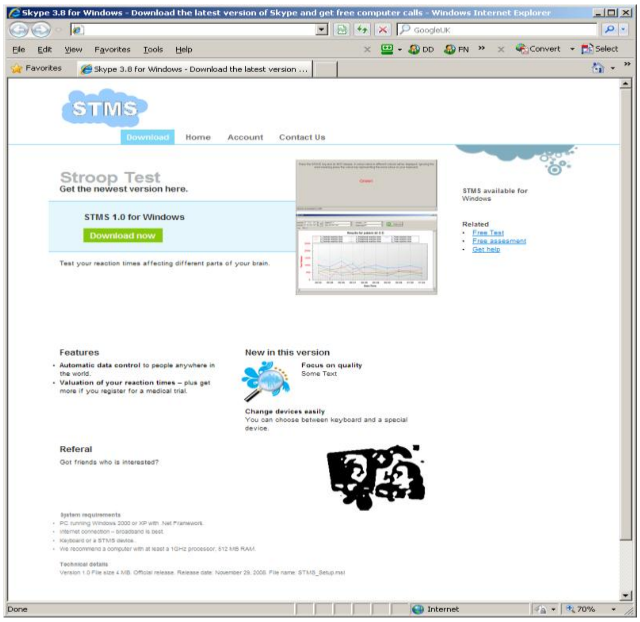

Figure 4.Web portal design for Stroop test software distribution.

IV. ASSESSMENT PROCESS AND PROPOSED ACTIONS

Assessment of the current state of MS patients and healthy population is performed using the reporting module of the software which provides preliminary data for analysis. It is not currently pre-programmed but allows a flexible setup for the system to monitor progress through its testing features and inform health professionals if certain parameters are likely to go beyond threshold values. These could be caused by regression in the test results or a sudden drop in result parameters. Having sufficient data for analysis the software can provide advice on the state of the MS patient allowing appropriate action to be taken in improving or at least stabilizing patient's status.

The Stroop test software can be customized for use in other diseases affecting Central Nervous System such as Parkinson's disease - progressive neurological condition affecting movements such as walking, talking, writing and exhibiting following symptoms:

1. Tremor - which usually begins in one hand? This is the first

symptom for 70% of people with Parkinson's

2. Slowness of movement (bradykinesia) - people with Parkinson's may find that they have difficulty initiating movements or that performing movements takes longer.
3. Stiffness or rigidity of muscles - problems with activities such as standing up from a chair or rolling over in bed may be experienced.

These symptoms can be identified using the specialized device with Test 4 as described earlier.

V. Discussion

The presented software application can potentially become a valuable diagnostic tool, in conjunction with other tests, in identifying patients with neurological diseases such as MS and PD, using Stroop test analysis. As a result a keyboard based Stroop test software was developed including reporting tools for analysis. Four types of tests have been pre-programmed with different applied techniques. The software will be freely distributed by the use of a web portal with registration capabilities. Due to the keyboard limitations a specialized device was designed and manufactured for which patent is currently pending. The device consists of 64 cells equipped with Hall sensors, which can identify the speed and the pressure applied to each cell. The precision of applied pressure can be identified much more precisely hence the analysis of error rates is more accurate. This will allow performing a more accurate and refined analysis compared to the data produced by the keyboard version. Although the Stroop test software and device are in the development stage it can prove to be useful in identifying a disease at early stages or provide continuous monitoring of MS patient’s health state. The Stroop test can be part of assessments when identifying some other neurological diseases affecting cognitive functions. It could become a key tool in the first step of patient diagnosis before referring to more advanced tests for further investigation. This might reduce the number of unnecessary tests which uses invasive techniques and other tests which are more expensive such as MRI and CT scans.

VI. Conclusion

Automation of healthcare processes by introducing intelligent technologies require appropriate data which can be reliable and consistent. Eradication of erroneous data can save time and improve the quality of patients care. The presented modules form part of a larger EDC (Electronic Data Capture system) incorporating a set of other applications in order to minimise and when possible eradicate manual interference [1]. The devised software solutions and protocols ensure correctness of results by having reliable data and remote analysis and control. A set of security measures are used to ensure that communicated data is transmitted reliably enabling consistent diagnosis. An audit trail feature is integrated into the software applications as a standard safety measure. The developed EDC system equipped with rudimentary intelligent features allows the prevention of errors and inconsistency in collected data. The system has been used in a clinical trial environment, after conducting thorough validation procedures, and has been consistently shown to be consistently accurate in data collection processes and valuable in providing ongoing data monitoring and patient management. Another advantage of the system is the introduction of automated technologies by utilizing the existing medical devices, cutting the costs to a minimum. The EDC system has been tested against conventional procedures and showed the advantages of the system compared to existing techniques. Comparisons of the results proved the system reliability and advantage in data collection. All software solutions have been developed to be compliant to the FDA (Federal Drug Agency in the US) requirements. The system architecture is flexible allowing the inclusion of additional devices together with post processing modules. The system require further mathematical developments similar to the ones in [2,3] Development of data acquisition systems using existing devices is important but rather limited by existing devices. Therefore, new type of input device was developed for building a Data Acquisition System for analysis and monitoring patients with neurological diseases. Hardware is designed with proprietary communication protocol and set of applications were developed for MS and PD patients allowing the use of Stroop test techniques. Initially, a keyboard based software for testing cognitive and muscular impairments as a result of diseases affecting Central Nervous System such as MS and PD was developed. The keyboard based application includes 4 varieties of tests which use similar techniques but with a different level of complexity. A web portal will be used for distributing and marketing the software. The specialized peripheral device has been designed and manufactured consisting of 64 cells equipped with Hall sensors, which can identify the speed (up to 2msec) and the pressure applied to each cell with more precision for which Patent is currently pending. The device can identify the precision of applied pressure much more accurately making possible deeper analysis. Using the software together with the specialized device can be potentially valuable in identifying diseases at an early stage, saving patients from invasive diagnosis techniques and may reduce the number of unnecessary tests. The application calculates 6 parameters that correspond to disease severity: total number of keys, the number of keys pressed correctly, Kinesia Score - the number of keystrokes in 60 seconds, Akinesia Time - cumulative time that keys are depressed, Dysmetria score - a weighted index calculated using the number of incorrectly hit keys corrected for speed and Arrhythmia score - a measure of rhythmicity which corresponds to the variance of the time interval between keystrokes. A custom set of statistical analysis can be performed by using raw data provided by the software. The Stroop test software cannot fully ensure the diagnosis of MS or PD but can make significant contribution in the process of diagnosis and monitoring.

FUTURE WORK

Pervasive computing is penetrating all walks of life [4] but is still rather limited in medical applications due to heavy regulation. Electronic Data Capture system developed as a web based system allowing the performance of measurements without local network connection is way forward but introduction in clinical practice is cumbersome even on the basic application. The system is currently used only through charities and clinical research organisations as regulatory hurdles are too difficult to negotiate. The Stroop test application can be expanded by including additional tests. New patterns of results can be identified by specialists for easier monitoring of the state of patients. Disease progression can be monitored automatically by the software and a consultant notified only in case of emergencies Such elements of artificial intelligence are essential for future developments [5,6, 7, 8]. An improvement can be made to a database structure by placing tables with personal information into a separate database such as names would be saved in another database and data would be recognised by Name-IDs only. The same approach can be used for Audit trail tables by placing them separately where even application database owner will not be able to access audit trail data.

LITERATURE

1. Pervasive computing systems for medical monitoring Proceedings of the 1st WSEAS international conference on Biomedical electronics and biomedical informatics, D. Djumanov, P. Dabnichki, R. Arezina, World Scientific and Engineering Academy and Society (WSEAS), Stevens Point, Wisconsin, USA, ISBN: 978-960-6766-93-0, 2008, pp. 168-172
2. Stress and Strain in Biological Tissues - Mathematical Definition and Physical Concepts, P. Dabnichki, Mathematical and Computer Modelling of Dynamical Systems, 16, 2010, 431 – 442
3. Skin temperature distribution and thermoregulatory response during prolonged seating, M.D.P. Garcia-Souto, P.Dabnichki, Building and Environment, 69, 2013, 14–21
4. Ubiquitous Computing in Sports: A Review and Analysis, A. Baca, P. Dabnichki, M. Heller, Ph. Kornfeind, Journal of Sport Sciences, 27, 2009, 1335-1346.
5. Introduction to the special issue on intelligent technologies in medicine and bioinformatics, G. Magoulasa, G. Douniasb, Computers in Biology and Medicine, 36, 2006, 1155-1184.
6. Old Age, New Technology, and Future Innovations in Disease Management and Home Health Care, J.F. Coughlin, J.E. Pope, B.R. Leedle, Home Health Care Manag & Prac, 2006, 18, 2006, 196-207.
7. A Decision Support System for Rheumatic Evaluation and Treatment in Oriental Medicine Using Fuzzy Logic and Neural Network, C. Thang, E.W. Cooper, Y. Hoshino, K. Kamei, Modeling Decisions for Artificial Intelligence, Lecture Notes in Comp Sc, 3558, 2005, 399-409.
8. Self-Learning Fuzzy Logic Control in Medicine", D.G. Mason, D.A. Linkens, N.D. Edwards, Lecture Notes In Computer Science; 1211, Proceedings of the 6th Conference on Artificial Intelligence in Medicine in Europe, 1997, pp. 300-303.

Appendix 1

Stroop test device communication protocol

REFLEX CONTROL COMMANDS

The communication with the PC is master slave mode.

Master : PC

Slave : Matrix

1 º Command Field one character length

2 º Operation Field (0-255) one character length

3 º Data Field variable length

READ

Field 1 : "R" (82 decimal) read command

Field 2 : "@" (64 decimal) The mat Transmit to the PC a stream with 2*128 bytes of the position & value of each sensor [(position1, value1)(position2,value2)…(position n, value n)]

Example: PC transmits: "R" "@"

The mat returns: VX1 VX2 ….. VX128

(VX1….VX128 is a stream with the value of each cell, 128 data)

TRIGGER

Field 1 "T": Command Level

Field 2 Trigger Level

Example: PC Transmit "T" 50

The mat working in "S" 1 mode will transmit only the sensors above 50

OPERATION

Field 1 "S" Start / Stop : Start: continuous TX

Field 2 0 = Stop transmission

Field 2 1 = Start transmitting only the sensors above predefined trigger level (continuously mode)

WRITE

Scripture commands are used to turn on / off the LEDs

Field 1 º "W": (decimal 87): Writing

Field 2 "R" (decimal 82): network is the 3 rd field position led

Field 2 "G" (decimal 71): green field is the 3 rd position led

Field 2 "B" (decimal 66): blue field is the 3 rd position led

Field 3 255 : All LedsON

Field 3 0 : All Leds OFF

Field 3 Position Led

(Field 4)* Flag On/Off Led: If previously led ON now led OFF and vice versa

Examples:

"W" "R" 74 1 decimal stream 87 82 74 1 : Puts ON the Red led the of the cell 74

"W" "B" 75 1 decimal stream 87 82 75 0 : Puts OFF the Blue led the of the cell 75

"W " 255 decimal stream 87 255 All Leds ON

"W " 0 decimal stream 87 0 All Leds OFF

SPECIAL COMMANDS

C This command is only to test the communications and only contains one field

The PC send "C"

The mat returns "C"

Appendix 2

Stroop test device communication protocol testing

COMMAND BUTTONS

READ SENSOR

If option Continuous Read is not activated, program reads and represents value of 16 sensors only once. Otherwise, if option is ON, values are represented continuously, until we press STOP (Figure A1).

READ SENSORS TRIGGER

When the button is pressed, display shows (continuously) sensors above trigger level. Trigger level is indicated (and it can be modified) in the text box allocated in left side of button. In the text box on the right side of screen sensors and values will be shown above trigger level (Figure A2). When we want to stop this operation, we must press the STOP button. When we press this button, a new window will open up with the option save file (Figure 4).

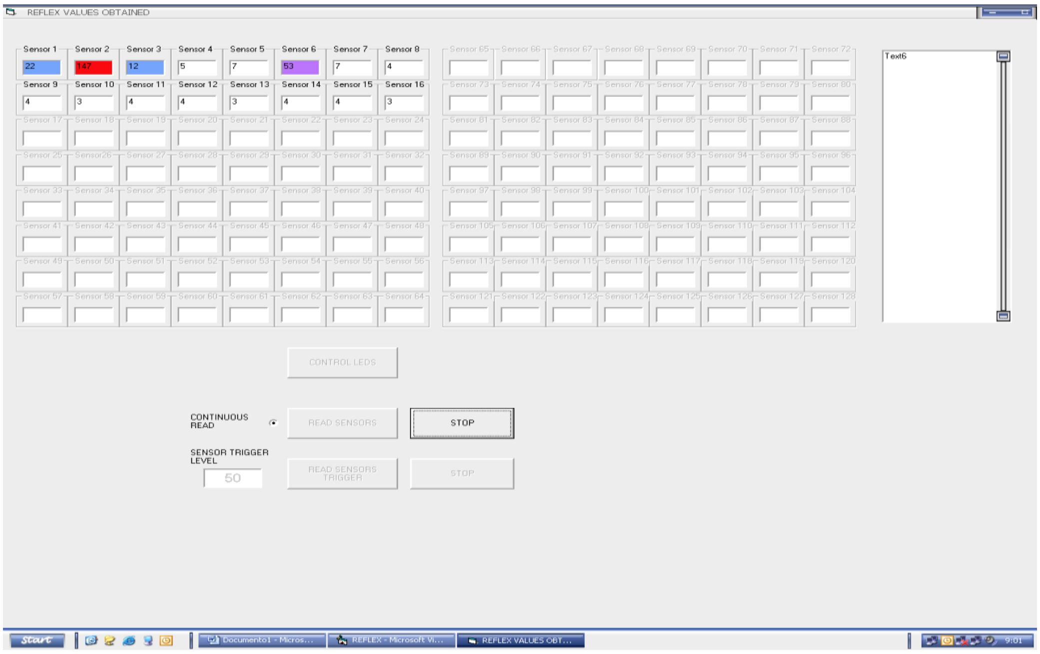

Figure A1

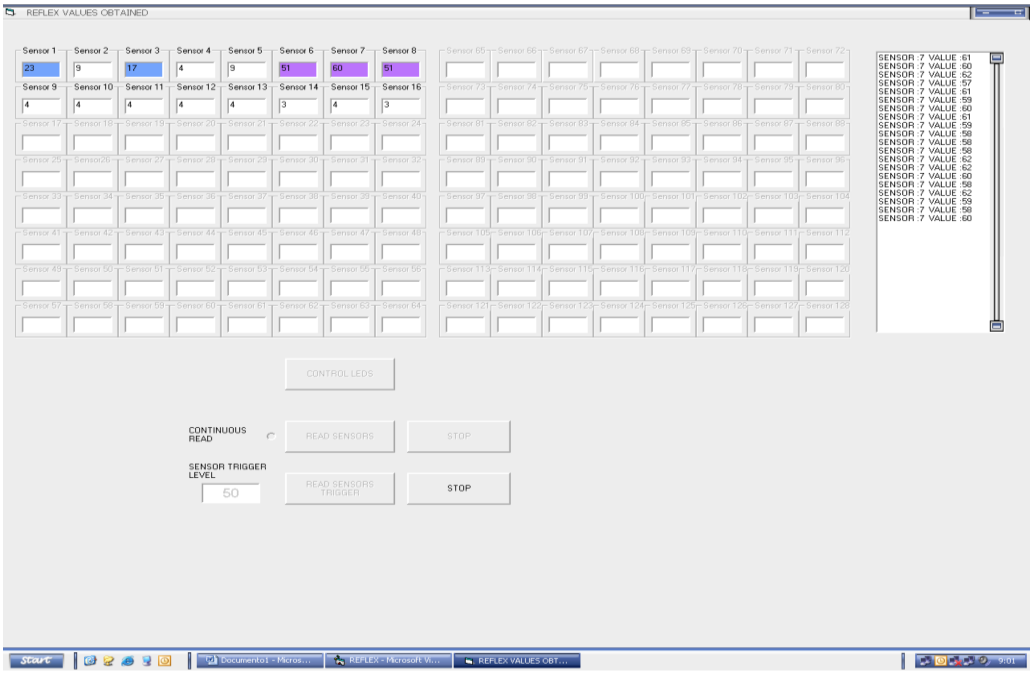

Figure A2

CONTROL LEDS: Once this button is pressed, led control screen will be displayed.

In this new screen we'll find 3 command buttons:

- ALL LEDs OFF
- ALL LEDs ON
- SENSOR VALUES: Returns to the previous screen.

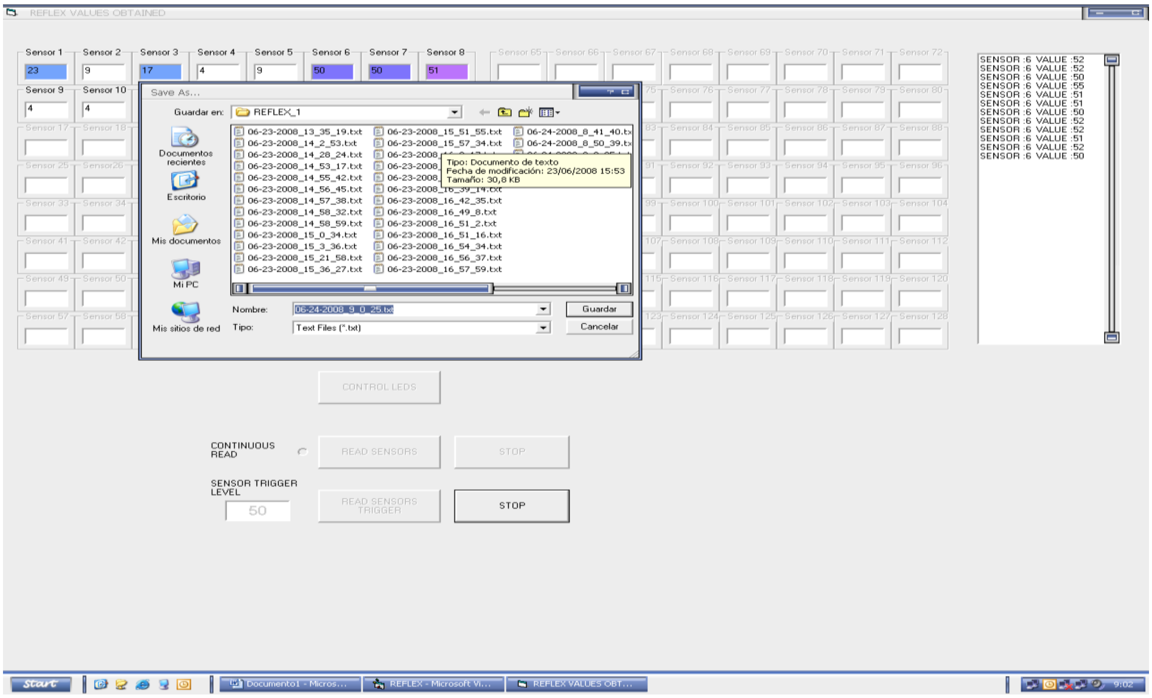

Figure A3

In control leds screen we can control each LED individually, pressing in each symbol, see Figure A4.

Figure A4