Networked Braille Learning Environment

Team: Smart Writers

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1. Executive Summary

In 2002, the World Health Organization estimated there were 161 million (about 2.6% of the world population) visually impaired people in the world, of whom 124 million (about 2%) had low vision and 37 million (about 0.6%) were blind. People in developing countries are significantly more likely to experience visual impairment. While vision impairment is most common in people over age 60 across all regions, children in poorer communities are more likely to be affected by blinding diseases than are their more affluent peers.

A considerably amount of visually impaired people don't use computers (70% according to the Lighthouse for the Blind). This bleak outlook is changing however due to concerted efforts to ensure the accesibility of information technology to all potential users , including the blind.

Our project joins this main stream in making technology more accessible to all. The product we are developing is intended to give visually disabled people a chance to learn more easely the Braille alphabet.

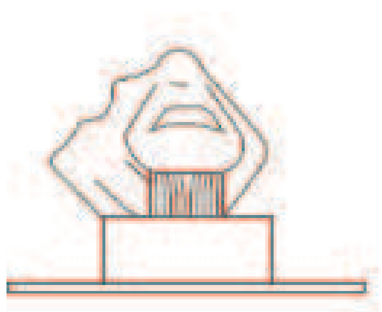


Fig.1 One finger Braille Reading

The idea of a one finger Braille display came after observing the available products on the market that addressed this problem. Most of them are intended for advanced Braille users with an extensive PC using experience. The knowledge requirements for the use of such devices make them inappropriate for Braille learning stages both in schools and for home users. We also considered the fact that existing devices are difficult to acquire do to their high prices.

We intend to help all categories of Braille learners both sighted (ex. Braille instructors) and blind by bringing a new approach to the Braille learning process.

In contrast to other Braille tactile displays that can be found on the market our project 'prints' only one ASCII character at a time. This ensures a small physical dimension which helps portability and cost reduction. The device is able to be configured so it can suit the individual needs of the owner in terms of character printing speed. The physical platform is accompanied by specialized, easy to use software in the form of basic Braille lessons.

Our prototype is a multipurpose Braille tactile display that can be used by anyone who wants to learn Braille by himself, in a home environment, or in a specialized institution.

2. Market Overview

2.1 Problem addressing

The project we are developing will help blind people adapt more easily in the society by giving them a tool to facilitate their access to knowledge and technology. It is a platform that is intended to be used in educational facilities and home use.

The developed prototype and the software which accompanies it are specially designed to address the learning issues of Braille writing.

The system hardware (Braille tactile display) is able to print one Braille character at a time. The printed character is then firmly maintained on the display until another command is issued. The characteristics of the prototype facilitate the development of a stronger tactile sensibility by the user ensuring an easier way to learn Braille. Also the device allows the navigation through the eBox/PC application menu.

The software developed for the embedded device will offer support in the form of a set of Braille lessons which are designed to offer both audio and visual assistance to the student, ensuring by this the coverage of all possible Braille learning candidates indifferent of the nature of their visual problem (ex . completely or partially blind, sighted). Also the software application ensures multilanguage support and permits the adjustment of the character printing speed on the hardware device to better suit the user needs.

2.2 Conducted research

Today the interaction between a visually disabled student and the IT world is made by using refreshable Braille displays. Research in this area has been conducted for a long time but the solutions available are very expansive and unpractical for classroom study.

A refreshable Braille display is an electro-mechanical device for displaying Braille characters, usually by means of raising dots through holes in a flat surface. The display usually sits under the computer keyboard. It is used to present text to computer users who are blind. Speech synthesizers are also commonly used for the same task, and a blind user may switch between the two systems depending on circumstances.

Because of the complexity of producing a reliable display that will cope with daily wear and tear, these displays are expensive. Usually, only 40 or 80 Braille cells are displayed. The cost of Braille displays is in the $3,000 to $15,000 price range, depending on number of characters displayed. Also all refreshable Braille devices need screen reader software which drives the display .Screen readers are in their turn complex and expensive, this adding important cost to the overall purchasing price of a Braille display. Also all refreshable Braille displays are peripheral devices that can not work without a computer, by this restricting the market coverage area to users that already poses a PC. Here you can see a list with some of the products available on the market and their purchase value without including the software costs:

Braille Display	Producer	Price
Brailliant 24	Pulse Data HumanWare	$3,495
Braillex EL 40s	PAPENMAIER	€3,700
Braille Lite M40	Freedom Scientific	$5,595
BrailleNote BT32	Pulse Data HumanWare	$5,795
ALVA Satellite 570	ALVA Access Group	$9,995
Focus 84	Freedom Scientific	$10,595
Handy Tech Braille Star 80	Pulse Data HumanWare	$10,999
Braillex EL 2D-80	PAPENMAIER	€12,757

Table1.Braille refreshable displays/producers/prices

- **Note:** The prices above were obtained over the internet and represent the product cost at the factory gate. They may vary from dealer to dealer and they are subject to modification without notice from the producer.

A new development, called the rotating-wheel Braille display, was developed in 2000 by the National Institute of Standards and Technology (NIST) and is still in the process of commercialization. Braille dots are put on the edge of a spinning wheel, which allows the user to read continuously with a stationary finger while the wheel spins at a selected speed. The Braille dots are set in a simple scanning-style fashion as the dots on the wheel spins past a stationary actuator that sets the Braille characters. As a result, manufacturing complexity is greatly reduced and rotating-wheel Braille displays will be much less expensive than traditional Braille displays.

We are aiming the same area of devices development for visually impaired, but our solution is not based on a single actuator for tactile display, neither is it driven by a wheel mechanism. In contrast to the NIST device we intend to realize a platform more suitable with classroom study which will bring closer the blind student with the IT world developing around him.

For this purpose we conducted a preliminary survey at the "Moldova" College for the visually impaired.

We presented them with a similar project description to the one we transmitted to the Imagine Cup first phase of the competition. The feedback provided by the specialized staff underlined the following problems and advantages in our project design:

1. By developing a one finger device we encounter a problem in the fact that most of the advanced Braille readers use a whole hand (thumb excluded) or even both hands to speed up the process of reading. So no matter at what frequency we will emulate the Braille character on the device the reading speed will still be slower than the actual reading of a Braille written sheet of paper and will necessitate some accommodation time from a new user unfamiliar with this kind of mechanism (the explanation comes from the fact that even the actual reading is conducted by the blind reader with the index finger the other fingers are used to 'foreseen' the characters to come, in much the same way a normal reader is able to see most of the next word and anticipate it). However we consider that the small dimensions of the device we are developing and the portability will compensate for this downfall.
2. We were informed by the difficulties in learning Braille encountered especially by the visually impaired students that still have some remains of visual sense (ex. possibility to distinguish sources of light) and which are tempted to try to see rather than use their tactile sensibility. The same problem it is encountered in Braille students that are not visually impaired and are willing to become Braille instructors or simply improve their communication with a close person that is suffering from this handicap . We are aiming to address to this problem by accompanying our device with a software set of

simple lessons to learn the Braille alphabet and a very intuitive user interface. Both the interface and the lessons will be assisted by sound messages intended to help the student navigate better through the lesson menu and focus better on the characters he is studying without felling the need to 'see' them.

3. Another category of Braille students are visually impaired adults which lost their seeing ability later in their lives. These are the ones most reluctant to accept reading 'through their hands' rather than with their eyes as they were used to. The problem is created both by psychological factors and by the fact that the grownups tactile sense is more difficult to develop at the high sensibility required to read Braille. To encounter this we are trying to introduce an option that will allow small vibrations to be produced in the 'dots' of the mechanism at a frequency that can be felt by the user, improving his tactile sensibility without disturbing his reading.

4. The learning process conducted in this kind of educational facilities it is very similar to the ones in normal schools, by this making our device ideal for classroom based study as we had anticipated.

Based on this feedback we adjusted our primary objectives concentrating our efforts on developing a prototype able to fulfill the main requirements for an efficient Braille learning device. The prototype development phase conducted us to tree main solutions for the final product:

- **Stand alone device** (One finger reading platform) – used as a serial interfaced product with eBox/PC/Mobile, addressing the home user who intends to develop a more accurate tactile sense and learn Braille.
- **Classroom learning platform** (One finger reading platform)– used as a reliable, inexpensive tool for Braille learning in a specialized environment. The device is able to achieve wireless communication with a main coordinator from which it receives data in form of ASCII encoded Braille characters. The wireless communication is accomplished according to IEEE 802.15.4 standard for Wireless Personal Area Networks.
- **eBox refreshable Braille display –** a platform which incorporates the eBox device within a refreshable Braille display with the capability to display more than one character at a time. This device is meant to coup with the complex one finger reading speed problem as pictured in our primary feedback .It represents a product intended for advanced Braille users.

Our marketing policy is to exploit an overall market break with the first two platforms .By this we intend to elude the existing competitors as there are virtually no other products except the NIST device available in this market sector. The third device will be release later as it involves more complex hardware and software developing and testing which we were unable to cope completely until the time of the current report.

Exploiting these three alternative products we seek to achieve a full coverage of the identified problem addressing both the initial one finger reading approach and the information access ensured by a multi-cell refreshable Braille display.

2.3 Economical manufacturing

The manufacturing of the hardware takes into consideration the fact that the electronic components will be mounted on a printed circuit board (PCB). The PCB itself will be mounted in a case along with the servo motors in the Stand Alone Device solution, or with the piezoelectric Braille cell in the Classroom Learning platform.

The PCB can be produced in high quantities at a low price by specialized companies. The mounting of the electric components on the printed circuit board will be realized in Surface Mount Technology (SMT) also using manufacturers. Although the developed prototypes are made in through-hole technology, surface mounting lends itself well to a high degree of automation, reducing labor cost and greatly increasing production rates. Surface mounted devices can be one-quarter to one-tenth the size and weight, and one-half to one-quarter the cost of through-hole parts.

The design and manufacture of the outer cases for the products will be achieved also in collaboration with specialized firms because self production will enquire expensive equipment that will ad to the overall cost of the product.

The mounting of the components can be done in a small working space, with a relative small number of working personnel.

The software application and the required documentation will be burned on a CD/DVD which will be delivered along with the end product.

We intend to obtain a continuous or "in flux" production organizing system in order to minimize the dead manufacturing times and the inefficient use of manpower and equipment.

2.4 Performance requirements

In order to achieve complete market coverage we ensured that our platforms will have complementary characteristics and requirements.

For establishing a comprehensive requirements list for our products we presented the prototypes in a secondary survey at The Moldova College for the visually impaired. Based on the received observations the final specifications for the products were developed.

The Stand alone device is intended to ease the early stages of education process that are taken by a visually disabled person as well as a normal person, helping them to learn and comprehend the Braille alphabet and characters faster and more efficient. Therefore, the device must generate firmly the Braille character and it must accompany it with a corresponding acoustic signal. Also it must benefit from a series of user accessibility options in terms of character "printing" speed, dot high parameters and special tactile sense development based on raising the dot temperature. To ensure compatibility with eight dots Braille cells we adjusted the refresh timing of the servo motors so the device will be able to be configured with two more actuators with minimum modifications in the future development if needed.

The Classroom learning device must be a small portable device which can be carried easily by the owner. The implementation used in the device should ensure the communication with other likewise platforms in ad-hoc networks with no required configuration data set by the user.

Both the Stand alone device and the Classroom learning platform must be backed up by a simple robust application which will not generate unwanted overhead for the user in terms of accessibility and reliability.

The highest performance requirements in terms of software application development and embedded programming are for the eBox Braille refreshable display. This device must 'print' a full 40 cell line (equivalent to half of a DOS screen line), maintain the displayed line until another command is issued, ensure full audio support in terms of a screen reader software, and wireless communication in a wireless personal area network according to the IEEE 802.15.4.

2.5 User experience

The user experience had an important impact on our work, as we took into consideration that this device should be used by a large number of visually disabled persons. We have concentrated our efforts in developing 2 scenarios:

1. We considered that the end-user is a student attending classes. The student will have the Braille tactile device attached to his finger. The classes will be held by a teacher that uses the PC

application that we provide. The teacher will explain one alphabet or numeric character at a time, while, with the help of a command given from the EBOX application, the Braille tactile device will display the Braille correspondent. Therefore no prior PC or Braille experience is needed.

2. The second scenario supposes that the end-user would want to learn Braille on its own. Given the fact that there is no teacher around the student that can explain the alphabet or numeric characters and teach the lessons, prior PC use experience is needed. The PC/EBOX application that we will provide will have audio help on how to use the software as well as the hardware components. Moreover each EBOX application button will have an audio support, so that the user will know at anytime the localization in the application.

The fact that we considered two scenarios for the use of the system is a serious plus for the design as it widens the applicability of the platform. Visual disabled persons and normal persons alike can benefit from this.

The other perspective we approached in the third device addresses a more experienced user in computer and Braille using without requesting advanced computer operating knowledge.

We intend to provide a full enriching experience to the user so operating eBox refreshable Braille display should come as a natural simple activity, a step forward after entering the Braille world in the guidance of the first two learning devices.

2.6 Project usefulness

In order to provide estimated cost of the final product to be released complex analysis of the production costs and of the market is required. Always it should be clear that the price of the market product is considerably lower than the prototype price as it uses dedicated components and not development boards and it benefits from the cost reduction generated by producing a large number of devices.

Our devices even in the prototype development phase are chipper than any other market available product.

When considering the utility factor of our products it must always be a head stone the fact that we will provide devices capable to fulfill specific educational requirements unavailable to visually disabled students world wide today both by economic and technical reasons. We are not aiming to present a technological breakthrough but a simple, reliable solution to improve the education and life stile of many less fortunate than us. Making education free it is more close to a utopia than to reality but that doesn't mean that making it cheaper and more accessible to everyone shouldn't be a priority to all persons involved in this process.

Pic. 1 - Components used in the development

Maybe the best way to explain how useful our project will be it is by this quote:

We have a hunger of the mind which asks for knowledge of all around us, and the more we gain, the more is our desire; the more we see, the more we are capable of seeing.

Maria Mitchell (1818-1889, the first acknowledge woman astronomer in the Unites States).

3. Technical Overview

3.1 System specifications

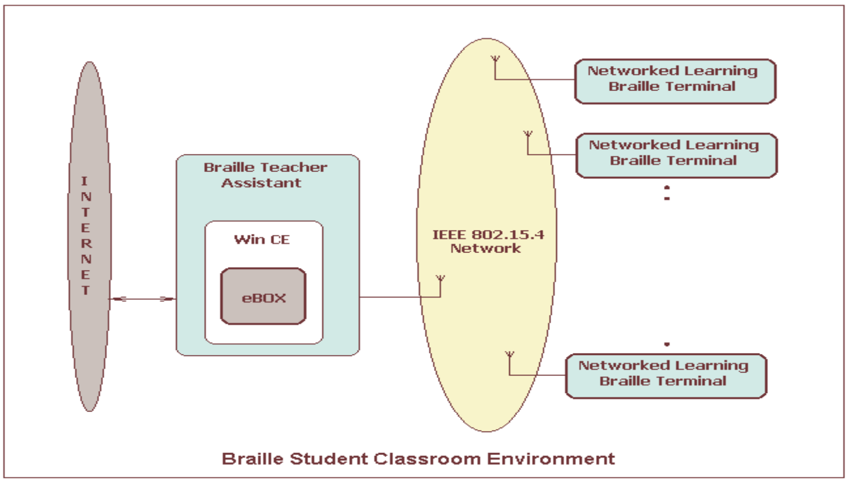


Fig.2 – Project development structure

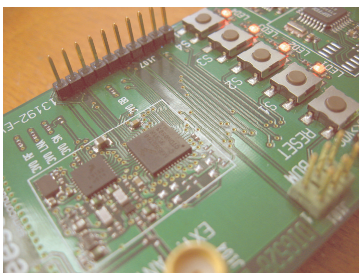
Figure 2 represents the initial project structure as a server – client based system. The server side is the EBOX while the client is the Braille tactile display (Network Learning Braille Terminal). From this initial thought a complex prototype was developed following the requirements of a functional device provided from our research and feedback procedures involving a blind specialized educational facility. The prototype followed a series of complementary development directions from which after different stages of testing three main branches emerged as final solutions. By choosing these alternative products we intended to provide a complete coverage of the addressed problem:

- **Stand Alone Device**
- **Classroom Learning Platform**
- **eBox Refreshable Braille Display**

All this solutions can be regarded simply as parts of the main prototype. In conclusion the following section of this document will address the hardware, software and algorithms used for the prototype development, particularizing them, if necessary, according to each market proposed product.

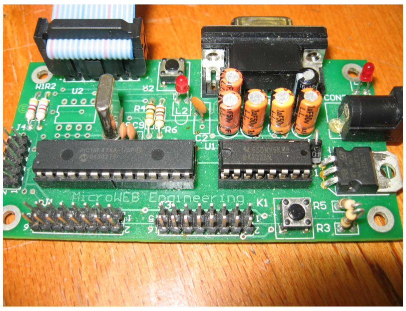
The hardware components used in the developing process:

The **eBox** is used for the front-end application. The application includes the Braille lessons which will send the characters to the Braille tactile display using standard serial communication. Also eBox will host the teacher's application in classroom based learning.



Pic. 2 – EVB 13192

The **13192-EVB**, Freescale ZigBee development board was used to realize wireless communication between the eBox and the Classroom platform and to provide a wireless solution for the eBox Refreshable Braille Display. For the final products we developed our own printed circuit board on which to include Motorola HC08 microcontroller along with a radio transceiver in the intend to eliminate the redundant use of PIC16F876A in the Classroom Learning Platform. This solution is still in testing and represents an optimization of the final product. The communication is realized in compliance with IEEE 802.15.4 standard for Wireless Personal Area Network. The HCS08 takes the data from the EBOX via the serial port protocol and sends it out through the radio transceiver on the network. It is also responsible for receiving the signals sent through the network and sends them to the PIC16F876 via serial port protocol, in the prototype solution.



Pic.3 – SBC876 with PIC16F microcontroller

The **PIC16F876A** accomplishes the receiving of the data from the EBOX and the sending of the specific commands to 6 servos. The commands are sent according to the data received from the EBOX.

The **servos** are used for the physical representation of a character in Braille alphabet.

The **Braille Cell** is used in much the same way as the servos but it represents a better solution in the case of a portable device as it has a reduced size compared with the motors. This solution is not suited to replace the servo altogether as it can not be used by the Stand Alone Device which aims, among other features, the improvement of the tactile sensitivity of the user (using thermal and mechanical factors).

The Microchip microcontroller, PIC16F, is mounted on a university developed single board computer (SBC876) in order to provide modular expanding capabilities to the device and assure extended debugging features. The general layout of the single board computer can be seen in the following figure:

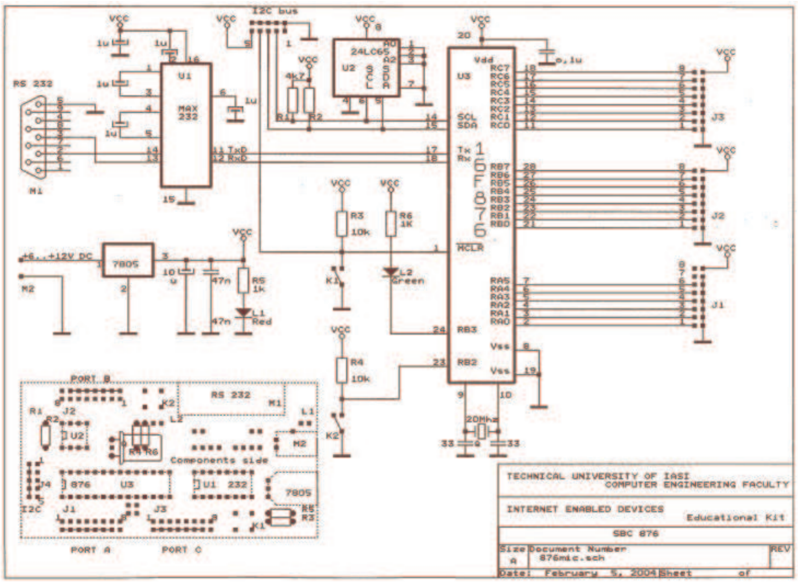


Fig. 2 - SBC876 general layout

The SBC876 uses a MAX232 circuit to convert the output voltages from the PIC Rx and Tx ports to the necessary serial transmission standard. Also it provides a simple pin out configuration that ensures expandability of the SBC. In this manner we used RB pin out to connect and command the servo motors.

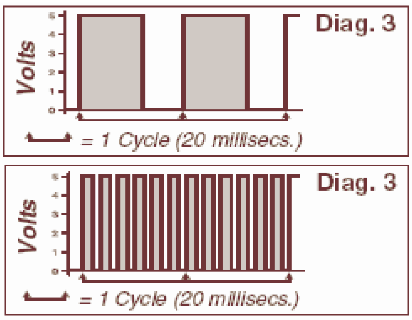


Fig. 3 - servomotor control timing

The command for character printing used by the motors is realized using very strict timing as this type of devices use a logic one pulse between one and two milliseconds to generate an appropriate movement of the gear heads. Because of scattered information about servo motor control available we used different types in the early project development phase so we were able to obtain optimal timing sequence that can be used to command both 90° and 180° digital servomotors as well as 90° analog servos.

The display speed of the characters using servos is generated by the receiving rate over the serial and it is software controlled by the eBox application. This parameter can be set by the user according to his preferences as it is presented in the software area of this document.

Note: the servos used in our testing and development were Futaba S3151, FS251S and S3001.

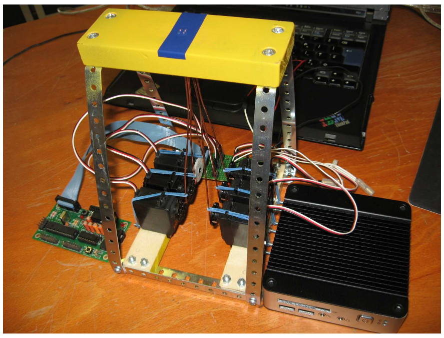
The software components developed for the project:

For the software applications necessary for the developed products we elaborated two main approaches:

- The first assumes that the user is a sighted person or partially visually impaired which is still able to distinct shapes and large format text. For this category of users we developed using C#.NET 2005 a one screen lesson structure completed with audio and enhanced visual support. To eliminate the need for computer keyboard, the application uses the mouse as the primary interface peripheral. The structure considered for this application is based on the form of the 6 dot Braille cell so a useful parallel is achieved between the final purpose of the end device and the user interface. The application has multilanguage support capabilities based on a 6 language .wav files library. This solution requires more storage space and it is less versatile than a TTS (Text To Speech) engine but it is easier and less time consuming in what implementation is concerned over WinCE, and it is more economic in terms of final product production costs. The feature of correlating sound signals with Braille character generation on the physical device is meant to ease and quicken the learning process.
- The second approach addresses the persons affected by blindness in a higher degree. The application in this case also has Braille cell to speech synchronization and all the accommodations delivered by the previous one like Braille printing speed or multilanguage support, but it also supports a fully audio menu controlled from the device itself using four micro-switches. For better understanding of the development of this audio interface see the flowchart presented in **fig. 4**.

The micro-switches functionalities are designed for the visual impaired persons with no experience in using computers, but their ease of use makes them a good choice for all persons.

Using the 4 micro-switches the user can navigate the menu in the same way as a keyboard. The student can choose the desired lesson menu or button by going forward and backward in the application. The activation of the button is made using the ENTER micro-switch. The exit from a lesson is done using the ESCAPE micro-switch. The micro-switches functions vary depending on the menu the user is accessing. We adopted this solution in order keep the button number as low as possible without limiting the user options provided. Having a limited button number on the platform ensures that the user will not be confused even if he has very little or no prior experience with the device. The button function changing is announced and explained every time to the user, extended explications being provided by easy accessing of the help menu.



Pic. 4 – servo driven Braille Refreshable display

Prototype design and functioning:

The Braille tactile display consists of 6 servos and 4 micro-switches connected to the Microchip PIC 16F876 microcontroller. The PIC16F876 uses a UART communication with a Freescale HCS08 microcontroller.

The wireless communication between the EBOX and the Braille tactile devices is made with the help of Freescale HCS08 microcontrollers, each connected to a 802.15.4 radio transceiver. The EBOX application sends the character through the RS232 serial port to a HCS08. The HCS08 sends the character to the HCS08 microcontrollers located on the Braille tactile display via 802.15.4 communication.

In the end, using a Serial communication, the character reaches the PIC16F876 microcontroller. Using a PWM algorithm the PIC16F876 brings the 6 servos in the position that corresponds to the character.

In the redesign of the Classroom learning platform we considered the replacement of the servo-motors with a refreshable Braille Cell.

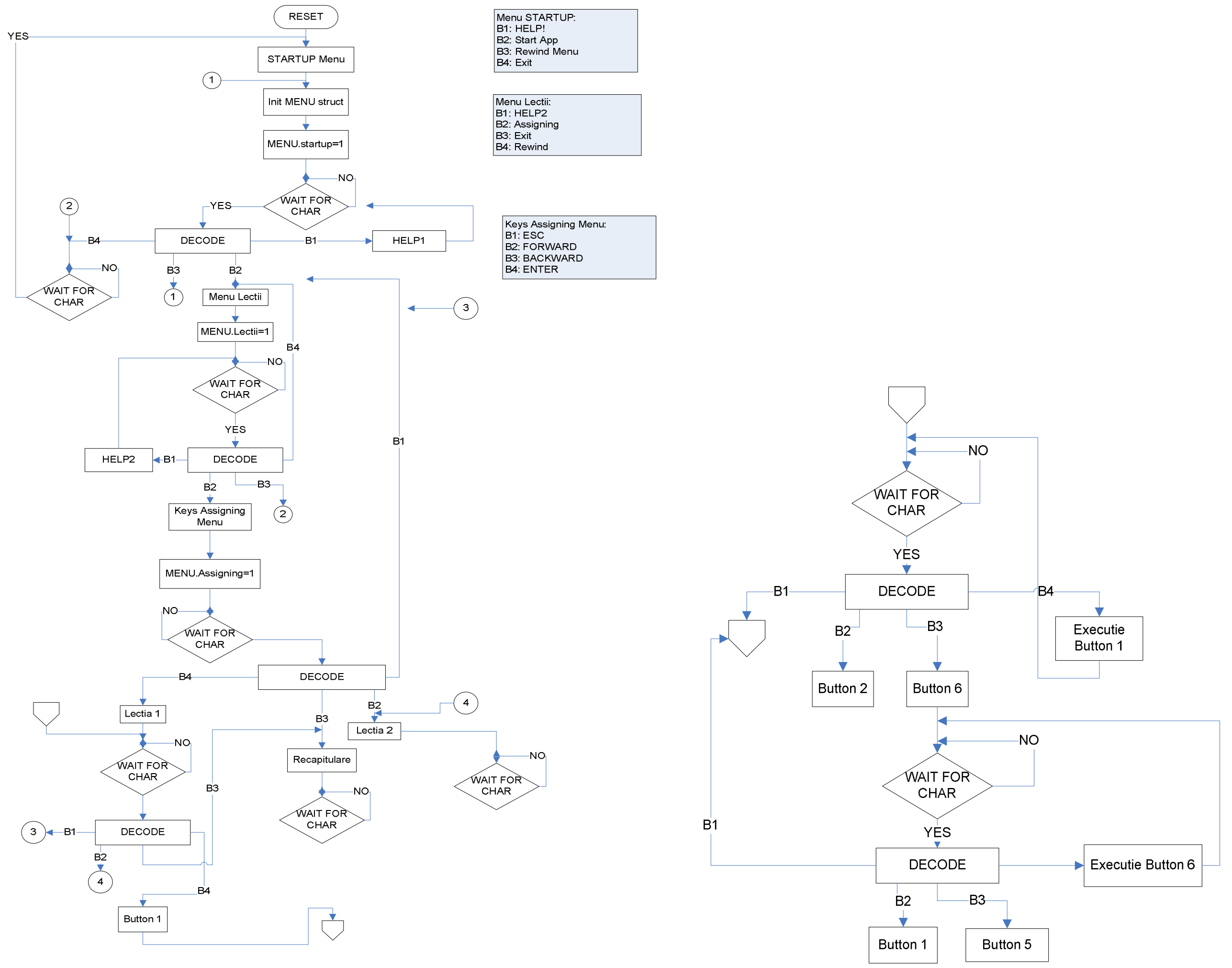


Fig. 4 – audio interface flowchart diagram

- **Note:** The flowchart presented in this figure is only partial; as the development for all the lessons is very similar we provided here only the lesson 1 chart in order to save report space;

Technical details:

What is 802.15.4 ?

802.15.4 is an IEEE standard that defines the protocol and interconnection of devices via radio communication in a personal area network (PAN). The standard uses carrier sense multiple access with a collision avoidance medium access mechanism and supports star as well as peer-to-peer topologies. The media access is contention based.

Wireless personal area networks (WPANs) are used to convey information over relatively short distances. Unlike the wireless area networks (WLANs), connections effected via WPANs involve little or no infrastructure. This feature allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

General description of LR-WPAN (Low Rate Wireless Personal Area Network)

A LR-WPAN is a simple, low cost communication that allows network connectivity in application with limited power and relaxed throughput requirements. The main objectives of an LR-WPAN area are the ease of installation, reliability, short-range operation, extremely low cost and reasonable battery life, while maintaining a simple and flexible protocol.

Some of the characteristics of an LR-WPAN are:

- Over-the-air data rates of 250 kb/s, 40 kb/s, and 20 kb/s
- Star or peer-to-peer operation
- Allocated 16 bit short or 64 bit extended addresses
- Fully acknowledge protocol for transfer reliability
- Low power consumption
- Link quality indication
- 16 channels in the 2450 MHz band, 10 channels in the 915 MHz band, and 1 channel in the 868 MHz band.

Two different device types can participate in an LR-WPAN network: a full function device (FFD) and reduced function device (RFD). The FFD can operate in three modes serving as a personal area network (PAN) coordinator, a coordinator, or a device. An FFD can talk to RFDs or other FFDs, while an RFD can talk only to an FFD.

General description of the developed software application

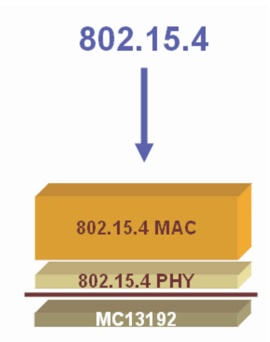


Fig. 5 802.15.4 application stack

Application was built over the 802.15.4 MAC (medium access control).

The MAC is completely decoupled from network application. Communication between application and MAC is realized with message transmitting mechanism.

On the FFD was built a software state machine that implies the: 802.15.4 MAC initialization, an energy scan detection used to view if there are other PANs in his own personal operating space (around 10m), generate a PAN ID (indemnificatory), select a communication channel, start the PAN coordinator, and go in a listen state where the device waits data from end devices or transmit data.

The RFD's concept application is much the same as the PAN's: first state is initialization state, next the device starts an active scan to discover the nearest PAN coordinator, evaluating the scan response from MAC and choose the best link quality. After that, the RFD must associate to the PAN coordinator sending an associate request message. After receiving the associate response the RFD can send/receive data to/from PAN coordinator.

Algorithms

Algorithms utilized include PWM servo control, 802.15.4 device pairing, 802.15.4 communication, UART communication.

For the PWM servo control we used real-time operating systems concepts. Since we had to control 6 servos in the same time, a multitasking algorithm was developed. The application uses 3 PIC16F876 interrupts: 2 for the internal timers and one for the serial communication.

The TIMER1 interrupt is used for the refresh of the PWM signal sent to the servos. Each servo must be refreshed at 20 milliseconds. In these conditions we used a 2.5 (20/8) milliseconds TIMER1 interrupt. At every 2.5 milliseconds the interrupt will be activated and a servo will be refreshed. The refreshing will take 15 milliseconds for all of the 6 servos. Therefore an expansion to an 8 Braille dots system is possible.

In the algorithm, the servos are represented as tasks. When the program starts the tasks are initialized with specific angle and task state values. Whenever a TIMER1 interrupt occurs the task context is saved, the current task is blocked and the next task is activated.

The TIMER0 interrupt is used for the control of the servo angle. A value is loaded in the TIMER0 counter according to the PWM pulse needed for a servo to get to the specific angle.

The serial interrupt accomplishes the communication with the HCS08 and it is activated when a character is sent from the HCS08 or a button is pressed from the Braille tactile display.

The PIC16F876 and Freescale HCS08 UART communications are easily done with the use of UART initialization functions. The functions enable specific registers of the microcontrollers in order for the communication to be done.

The EBOX UART communication is done using the SerialPort class in the .NET 2.0 Compact Framework.

3.2 Software tools

The **Microchip MPLAB IDE** was used for the writing and debugging of the C language real-time PWM servo control program which was delivered on the PIC16F876 microcontroller. It includes specific PIC16F876 libraries that were needed for program writing.

Hitech PICC LITE compiler was used for the compiling of the C language servo program and for obtaining the .HEX file that was needed to be written on the PIC16F876 microcontroller.

The **PICdownloader** program was used for the downloading of the C servo application on to the PIC16F876 microcontroller.

The **Freescale CodeWarrior IDE** was needed for the application developed on the Freescale HCS08 microcontroller. Unlike the MPLAB, CodeWarrior was used for the writing, debugging and compiling of the 802.15.4 C language application. It also has a direct role in the downloading of the application on the HCS08 microcontroller.

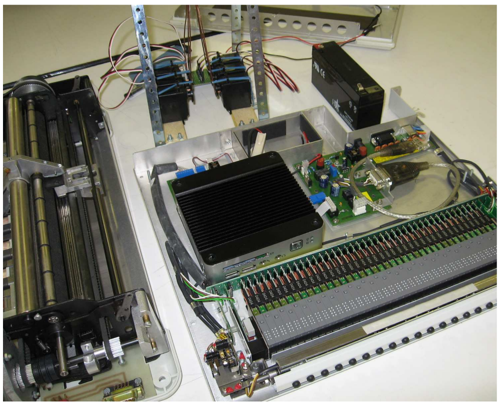
The **WinMerge** was used for achieving necessary source code comparison in the wireless network application.

The **Platform Builder for Windows CE 6.0** was used in order to build and generate the operating system image for the eBox 2300. The *Industrial Device* for *Internet Appliance* template macro was used to initially build the image. After running a Clean Build and Sysgen, the new image was then tested on the eBox 2300 through a direct Ethernet upload using the built-in boot loader.

We used Mike Hall's application CEFileWiz to integrate our software and the necessary sound libraries in the OS image.

The two main utilities that we regularly used were the Remote Registry Viewer and the Remote Process Viewer. The device registry acts as an intermediate node for system settings. Our main process references the registry while the user interfaces write to the registry as needed. The Process Viewer allowed us to monitor the number of running applications and threads as well as view other important system information such as CPU load, memory usage, and network activity.

Visual Studio 2005 was used for the development of the EBOX application. Also with the use of .NET Compact Framework and the custom-image SDK we could deploy the image on the EBOX through the TCP Connect Transport protocol.



Pic.5 – eBox refreshable Braille display development

3.3 Tradeoffs and optimization

The main tradeoff we were forced to consider in our design was the elimination of complex text reading on the One Finger Display as the reading speed would be reduced considerably (this was presented in the first feedback area of this document). In order to cope with this problem we are developing the eBox Refreshable Braille Display which includes a whole line of Braille Cells.

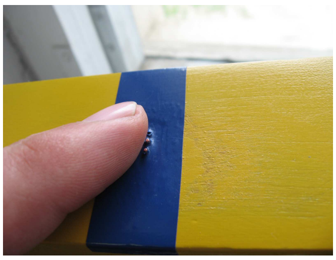
The EBOX application was initially developed on computers with Windows XP and the .NET framework installed. As we had no previous experience with the Windows CE and the .NET Compact Framework the real problems issued when we tried to move the code on Windows CE. Because of the fact that the .NET Compact Framework is a subset of the .NET Framework, some of the functions critical to our application had to be rewritten. For example there was no WAV play function. In consequence we had to use SoundCard specific API functions in order to get the audio played.

Another important aspect was the need to consider multithread programming for our applications in order to provide a better user control over critical areas where playing long wav files would freeze any other activities.

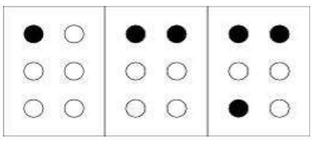
In what the physical platform is concerned we had to make an important compromise in terms of size for the Stand Alone Device where we had to maintain the servo motors for motion control as in the prototype. This decision was taken because of the servos capability of more accurate and complex movement which provides a wider range of user options for tactile sensibility development.

An optimization was obtained for the Classroom Learning Device by using the Braille Cell instead of servo motors.

3.4 Product testing



Pict.6 – Finger reading



A -> C -> M

Testing was conducted between development phases at the Moldova College for the visually impaired.

The final feedback obtained before the final report concluded that we have a fully functioning learning device. Over a series of tests we ensured that all the printed characters in the Braille alphabet were accurate and according to Braille standards.

The lessons structure was simple and easy to follow and the form in which the actual printing on the Stand Alone Device is done helps in character association and recognition.

Ex.: The letter M is composed for dots 1, 3 and 4. The dots in this letter also form the A character (dot number 1) and the C character (dots 1 and 4), so a more logic way to study this letters would be to learn at first the letter A then C and finally M. The manner in which we drive the servo motors induces no reset state (all dots retracted) between character printing, so after rising dot 1 for reproducing Braille A, we keep it up and rise dot 3 for completing the C and so on.

Another possible using of the Stand Alone Device we discovered in our last survey would be that of increasing sensibility in all fingers not just in the index ones. This will help in increasing the reading speed for users that use the other fingers only for page orientation.

In this feedback we concluded that our applications need more features in terms of more Braille knowledge tests. Also future development of the software for the Classroom Learning platform by adding a database will ensure better use of the 802.15.4 wireless communication and will improve the manner in which the teacher conducts the classes.

3.5 Product reliability

The feedback we received from the "Moldova College" for the visual impaired has proven to us that the learning of Braille aplhabet is possible with just one Braille cell display.

Since the learning of the Braille alphabet is a difficult and slow process (as people try to use their visual sense in order to see the characters) our solution offers a simple way of sensing them. The person can „stay" and sense/learn a character for as long as he/she needs without worrying about the degrading of the medium on which the letters are printed as it happens with paper. The system offers the students the possibility of repeating a character to them for as long as it's needed. The audio help and the assistance that is given to the user makes the project an easy and intuitive learning tool. And last but not least our product will do all this without 'burrning a hole' into the costumers pocket.

4. Team Overview and Project Status

The team members are Bogdan T,Alex ,Bogdan H and Ionel all students in the fourth year at Computer Engineering department.

All team members have background knowledge in algorithms, microcontrollers and windows platform programming.

In the first stage all team members have explored the Braille data processing systems and WinCE universe.

Bogdan T has developed the WinCE OS image and ensured all the conditions for integrating the developed application. Also he designed the scheduler algorithm for the Braille display using servos.

Bogdan H has developed the application module for the wireless communication used in the Classroom Learning device according to the IEEE 802.15.4 standard. He also created text-to-Braille algorithms.

Alex has designed the lesson curricula and maintained the continue interaction with the Braille instructors from the Tg. Frumos College for the visually impaired. He was directly involved in actual testing using visually impaired students, ensuring the continuous improvement of the project prototype with the blind student's reactions and their teacher's advice.

Ionel has developed the audio library support for the Braille speech module-English, Italian, French, German and Romanian. He was involved in the design of the eBox application flowchart. He also developed programming sequence for servo control.

The project development stages:

1. Identifying the problem requirements.

Feasibility research.

Tactile sensibility parameters.
Braille writing.
Low cost study.
Objectives:

- Dynamic Braille character generation.
- Braille basics lessons.

In classroom Braille learning architecture and software tools.

2. Draft solution.
3. Preliminary prototype design & development.
4. Text-to-Braille algorithms development.
5. Preliminary test with end-user and reactions analysis.
6. Software development for:

Basic functions.
Software applications.

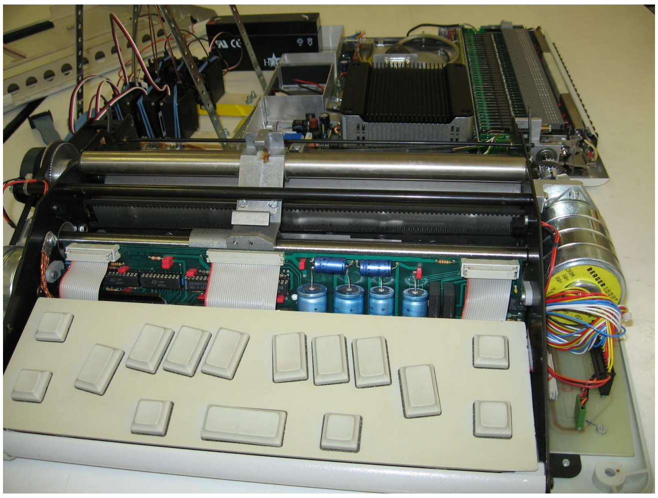
7. Real conditions testing with visual disabled subjects in a classroom. Final feedback integration.
8. Technological redesigning of the project in order to achieve a market competitive product.

- Standardization.
- Functional modularity.
- Expandability.
- Miniaturization/low cost/low power/wireless network.

We have achieved all the targeted objectives. Setbacks were met in some areas of the technological redesign in terms of efficient power management. At this moment we are using lead accumulators as a power source. The solution is efficient but increases the overall weight of the system. More efficient Lithium ion polymer battery could solve this problem in the future but for now we weren't able to conduct a consistent research in this area.

5. Summary

We have developed a Braille cell display controlled by a WindowsCE application and test sequences using blind students. After blind teacher's advice and students reactions we have developed classroom curricula for primary Braille learning stage.



The wireless communication for Classroom Braille Learning Device was successfully developed and tested according to the IEEE 802.15.4 protocol.

We are now developing a more complex device that will incorporate a complete refreshable Braille cell line.

The research conducted during this project revealed a multitude of alternative technologies useful for miniaturization and power consumption reduction. Using a piezo-electric Braille cell, an 802.15.4 communication device and 2 Li-ion 3.6V cells with physical dimensions of 2.10 x 1.50 x 0.30 inches each, the system dimension is reduced with 80% compare to actual system. This fact, combined with flexible materials, will allow developing a more compact and light device, featuring a complete Braille cell line that could be attached to the owner's hand as depicted.

Pic. 8 – Intelligent clothing

Moreover a Romanian Centre of Inventions has developed a new generation of actuators for Braille monitor cells, using cold plasma. The advantages of plasma actuators over conventional piezoelectric ones include the reduced electric power (8 to 10 times), their luminosity, their small size, and their lower manufacturing costs (Romanian Patent Office (OSIM) Nr. A/ 01549).

Based on the development of these new types of actuators, and on specially designed textile fabrics we are even considering implementing a refreshable Braille cell line into the user's clothing.

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