Project Title

Development of an Electronic Reading Device for Visually Impaired Individuals

TABLE OF CONTENT

1. **Introduction**

According to the data presented by the World Health Organization (WHO) in 2013, there are 45 million visually impaired individuals on earth, while this number is above 77,000 in Turkey. These individuals encounter various difficulties in different portions of their lives, many of which are part of their daily activities. The leading activity during which problems are faced among these is education. According to what is stated by the experts, the studies lay light to vision being the most important factor in learning, playing an 80% role in what is learnt. Still, it is also expressed that the visually impaired can adequately take part in different careers, succeeding as much as the others provided that they are given pre-school education and necessary materials with appropriate content. Nevertheless, education is one of the fields that the visually impaired experience inconveniences the most. Although several efforts were made in this regard with the developing technology, they had important deficiencies such as the inconveniences in use, high cost and addressing specific problems only. However, it is expected that today's technology should give us the opportunity to come up with solutions of higher quality.

As a result of the investigation of current work to solve problems faced by visually impaired people, it is seen that navigation devices that provide auditory guidance along with embossed maps are used. It is also known that the Braille alphabet developed by Louis Braille in 1821 is commonly used. The rest of the materials developed are also seen to have benefited from this alphabet, in which each letter is formed of 6 dots being placed differently. Using this method, texts that can be read by the visually impaired are written. While embossed tablets specially designed for the visually impaired are a choice to apply that, documents can be created with use of needles. These are called the traditional materials and the tools used in mathematics such as embossed rulers, cube stone, metal graphs can also be given as examples. In addition to the traditional materials, there are several works that address the same problem with use of today's technology. The most prominent ones among these are JAWS, DICOMP TRANSFER PROJECT and the VANDERBILT UNIVERSITY PROJECT.

JAWS: It is a programme developed especially to assist the visually impaired in using computers. Being activated as the computer is turned on and till it is turned off, JAWS speaks everything on the screen. This helps the users to type, send or receive emails and benefit from all advantages of the internet.

DICOMP TRANSFER PROJECT: Financed by the “Lifelong Learning Programme” of the EU in 2011, DICOMP Transfer Project gives the visually impaired the opportunity to make use of the internet. Respectively, its purpose is to develop a free screen-reader software programme that resolves the problems the visually impaired experience while reaching email and office applications as well as web applications.

VANDERBILT UNIVERSITY PROJECT: Engineers from Vanderbilt University in Tennessee, USA developed an android application based on the traditional method Graphic Aids For Mathematic. The application makes the tablet computer vibrate if there are objects on the screen while the user is moving their finger, thus helping the visually impaired individual perceive the shape.

In addition to all these, several other screen-reader programmes like JAWS or text-zoom programmes for the people with low vision are existent. However, although many social responsibility projects were made both nationwide and internationally in this regard, absence of a technically collective work along with all separate work being rooted abroad were detected. Hence, a device meant to bring solutions to problems with perceiving shapes, graphs and mathematical symbols as well as reading plain texts in the virtual world is expected satisfy the related loopholes.

The device that was developed within this project is based on the Braille form. It consists six vibration motors in addition to an electronic circuit to send related signals to the vibration motors. The connection between the electronic circuit and the computer, on the other hand, was made with use of a bluetooth module. The device needs the software programme written in the coding language C to be installed into it to function. Following this, as the user touches a character on the screen, the bluetooth module directs the signals sent to the micro-controller, which was placed in the electronic circuit and where these signals are processed. When the process is complete, the micro-controller sends signals relevant to the input received from the computer to the vibration motors, which are placed on a plate and connected to the electronic circuit with use of cables, as shown in Figure 2. The plate on which the vibration motors are placed is to be worn on the user’s wrist. When the user touches the letter A on the screen, for example, the signals arriving in the vibration motors generate a vibration only in the top-left point, having the Braille principle shown in Figure 1 preserved. In this way, the user can “read” what is on the screen as they move their finger across the screen and receive relevant vibrations. Additionally, different codes were formed for spaces, punctuation marks and numbers and necessary precautions were taken for the experience to be fluent. Thus, the system can be used to detect mathematical symbols, and shapes with the same principle. The vibration motors are programmed to be sensitive to colours as well as mentioned characters. As the user moves their finger through a coloured drawing such as one of geometrical shapes, different colours induce signals to the motors matched with the touched colour, helping the user to understand what the shape is through following the vibrations brought about the changes in colour.

This project outpaces other related efforts in terms of both its operating principle and its readiness in being directly used as an educative tool. Along with the products called “Braille tablets” are being yet to be produced in Europe, devices claimed to have the characters appearing as embossments are not spotted up until now.

The device’s compatibility with all tablet computers in addition to the sufficiency of only an electronic circuit and the software for it to function makes it both practically and economically convenient to use. Thus, there will be no need for specially designed educative products for the visually impaired. When necessary, the current materials can be adapted with small arrangements as well, offering the visually impaired a wide range of educative content.

1.1 Project Objective

Producing a prototype of a device that enables the visually impaired individuals to read any virtual text such as e-books is what is aimed in this project. Additionally, the device to be produced is planned to be an educative material for the visually impaired, eliminating the difficulties faced in education as well. Among the objectives of the project is the development of a multi-functional device that can assist the visually impaired in perceiving mathematical symbols and shapes in the e-books prospectively.

2. Method

This project intends to develop to assist the visually impaired in reading digital texts, which are used in education. Following the investigations on the previous works performed, building blocks of the system are determined. The system is expected to offer the digital text giving the impression of the embossments formed in Braille when touched. Thus, it is planned that the problem will be resolved without carrying out any physical alteration. Respectively, it is decided that 6 vibrations motors were needed in the system, while each motor is controlled by the electronic circuit. The connection between the electronic circuit and the computer, on the other hand, was made with use of a bluetooth module. For the interface programme that sends necessary signals from the tablet computer to the electronic circuit, the research done showed C# coding language could be used. Algorithms formed for each character help creation of vibrations peculiar to the character touched on. For instance, key A activates the 1st vibration motor, key B activates both the 1st and the 3rd vibration motors, which will be bound to the user's arm. It is planned that the vibration patterns formed in the user's arm help the user to perceive the characters on the surface they are touching on, thus making it possible for the user to read the text. Among the aforementioned characters, mathematical symbols, punctuation marks and spaces are involved. It is also determined that an additional section is placed in the interface programme for shapes. The working principle of the additional section is planned to be through distinguishing among different colours. As the user moves their finger on the screen where different colours are existent on, signals matched with the specific colours are sent to the related vibration motors. Thus, the user can track the shapes through the changes in colours.

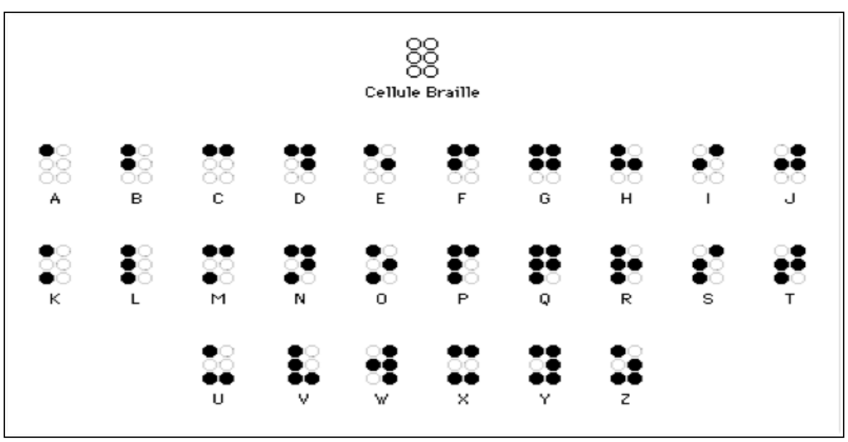

Figure-1 The Braille Alphabet

Putting the project in practise has two main branches, first of which is the coding of the software programme that enables the system to function, second of which is the design and activation of the electronic circuit. The coding language used is C# with 3 forms being existent in total. Each form has a peculiar function.

The electronic circuit functions with use of a micro-controller called PIC18F2550 and its connection with the computer is provided through bluetooth technology and the bluetooth system used is HC-06. 6 identical vibration motors are existent in the circuit. A 9V-2A power supply was used.

The data sent by the computer are processed by the micro-controller, giving the output that will bring about the necessary vibration motors to be activated. The mentioned vibration motors are arranged in a way that they are compatible with the Braille alphabet. The coding language used for the micro-controller is CCS C, which is a language commonly used for micro-controller programming.

2.1 Coding Structure (Software)

The project involves two software programmes written in two different coding languages, first of which is the one for the micro-controller and the second is the one for the computer. Each programme has its own set of functions.

The set of functions for each programme is as stated below.

2.1.1 CCS C-Coding for the Micro-controller

The micro-controller is responsible with processing the input received from the computer to generate the relevant output. It uses various if-else phrases to do this. Respectively, the set of functions for the micro-controller is as listed below.

- Processes the input given by the computer to send necessary output to the vibration motors. (Hence, the main function belongs to the computer.)

- It causes the vibration motors to generate vibrations in the previously matched motor, using the if-else phrases in C coding language.

- Provided that letter A is to be sent from the computer to the micro-controller, output points matched with the command for the letter A are given signals to be activated.

The micro-controller used has 28 pins, several of which have previously defined tasks. While they can be turned off on demand, they are ready to use according to these defined tasks when needed. Henceforth, various pins are defined as outputs (Namely, the controller will treat them as outputs. For example, when lighting a LED light, which necessitates the exportation of voltage, the relevant pin has to be defined as an output. If this output is to be arranged with a button, the button has to be defined as an input as the controller functions according to the signal received from it.).

As the controller is responsible with activating the vibration motors, the pins matched with the motors are defined as outputs. Coding was made in the format stated below.

```
if(Input==’A’) { output_high(motor1); }
```

All in all, the controller processes the data received from the computer with if-else phrases and gives related output to the vibration motors.

2.1.2 C#-Coding for the Computer

The computer owns the coding responsible with the main function. It scans all the tactile contact and sends the previously recognised values to the micro-controller. Respectively, the set of functions for the computer is as listed below.

- The computer scans the geometrical shapes with use of the pixels existent on the screen. In this way, the point being touched is processed for its assessment according to the RGB colour model. For this reason, the colours recognised by the programme are the ones with an RGB code (such as black, which is coded as 0,0,0). Following the recognition of the colour, it sends the data to the micro-controller.

- The computer follows the principle shown in Figure-5. As the text appears, The pictures to express the characters in the text show up on the screen. All the pictures are previously saved in the programme. As the user starts reading, the datum relevant to the letter touched is sent to the micro-controller, which generates vibrations accordingly.

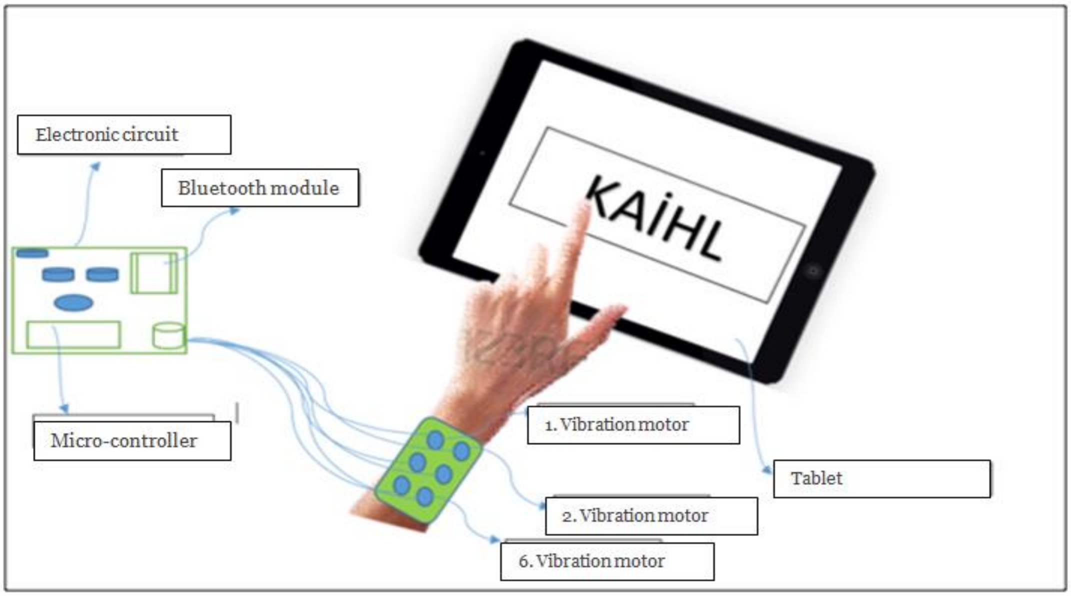

Figure-2 Representation of the System

2.2 Instruments Used in the Production of the Device Developed (Hardware)

Not only the software programmes but also an electronic circuit with necessary elements to process input and give relevant output is a vital part of the system. The mentioned electronic circuit was designed on Proteus PCB Design as seen in Figure-3. Following this, it was printed and the circuit elements were placed. The micro-controller was activated with use of CCS C and also placed in the circuit. After several trials to eliminate minor issues like calibration, the system was made ready to function.

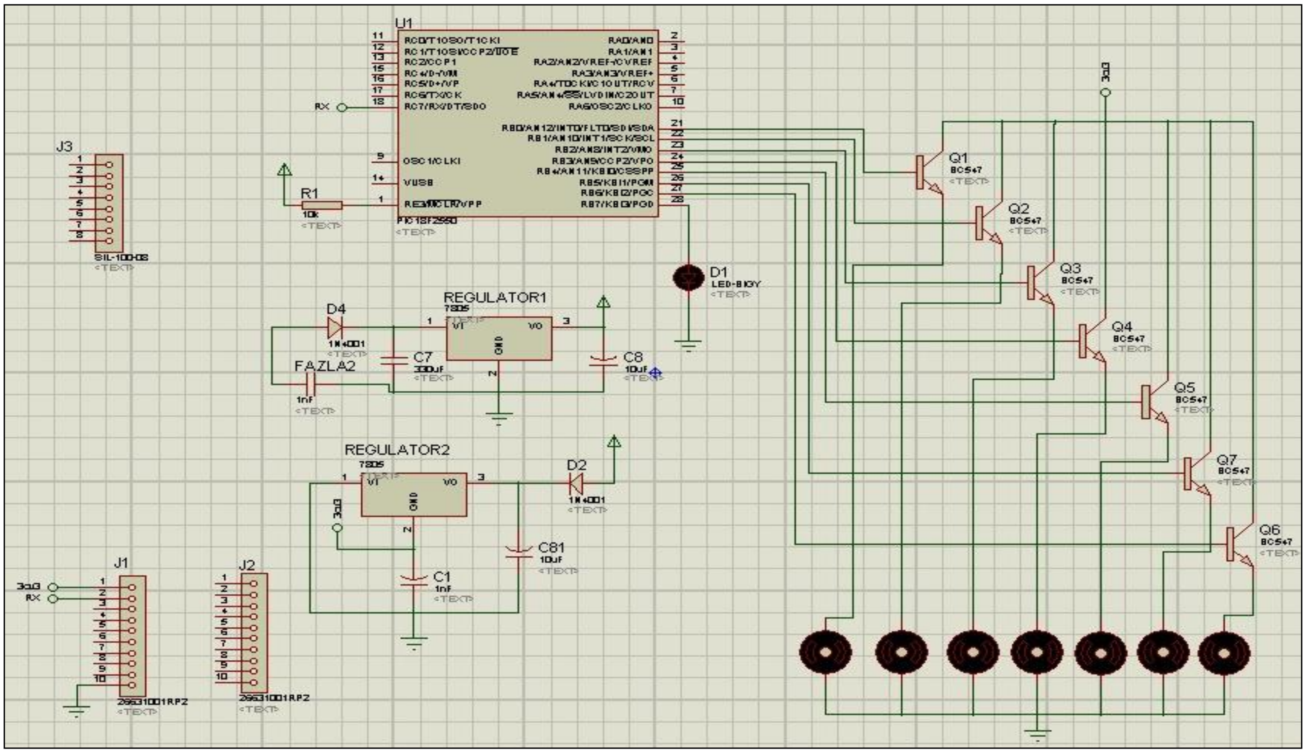

Figure-3 Printed Circuit Board (PCB)

Instrument	Number
Shaftless Vibration Motor 10x3mm	6
BluetoothBee HC06 Bluetooth-Serial Module	1
PIC18F2550 I/SP	1
20X30 EPOXY PLATE FR1	2
7805 Regulator	2
AMS1117 (LM1117) 3V3 Regulator	2
12X12 GREEN LED LIT BUTTON	1
Power Supply Port Connector (Chassis Type)	1
12VDC 3A Plug Type Adaptor	1
Connection cable	15
Condensator	5
Resistance	4

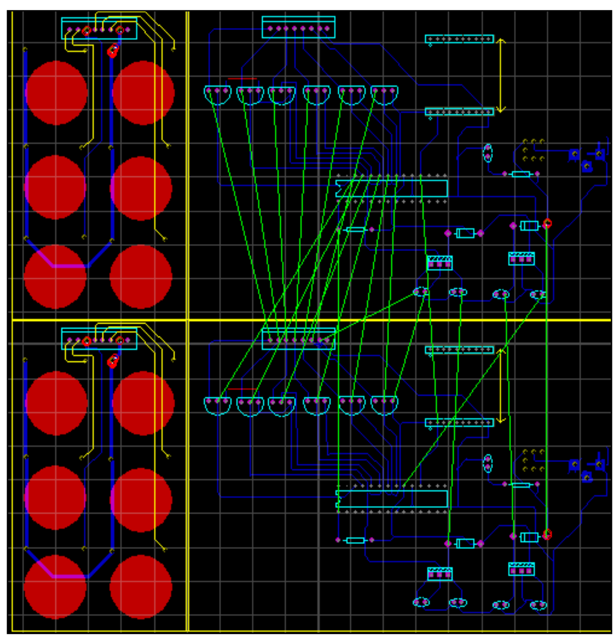

Figure 4- Representation of the Electronic Circuit, Vibration Motors and Instruments used

3. Conclusions and Discussion

The first step taken in this project was the development of a software programme to help the computer to recognise the character touched. When the programme is activated, a window shown in Figure-5 appears on the screen, where there is a bar that texts can be written. When a text input is given, the programme matches each character in the text with its counterpart in the Braille alphabet and retains its memory as an image. These images are also displayed below the bar where the text was written, forming lines of words written in Braille form. When the session is terminated, the device loses its sensitivity to data apart from the ones in Braille form. As the user moves their finger on the text in Braille form, the system recognises the character and sends the relevant signal to the micro-controller through bluetooth. After the signals are processed in the micro-controller, the vibration motors generate the vibration output matched with the character touched. The aforementioned signals are arranged in forms of different combinations created with use of six vibration motors. The combinations used are based on the Braille form. The system responds to spaces, punctuation marks and numbers as well. The user, thus, has the opportunity to perceive these non-letter characters without any interruption. To further smoothen the experience, the vibration motors were placed on a plate and various isolation methods were used to eliminate issues that may root from the vibrations' possibility of being difficult to distinguish between. The system was designed to be worn on the wrist to make it easier for the user to perceive the vibrations.

As stated before, the system is sensitive to colours to help with the perception of shapes. When the drawing section of the programme is opened, signals are sent to the matched vibration motors based on the user's tactile stimulation, helping them distinguish between the shapes. From a point of view, this operating principle has the function of embossments on the tablet computer, where the impression of differences in rise are simulated through the changes in colours. The efficiency in perception of geometrical shapes was tested with healthy individuals having their eyes covered, giving positive results.

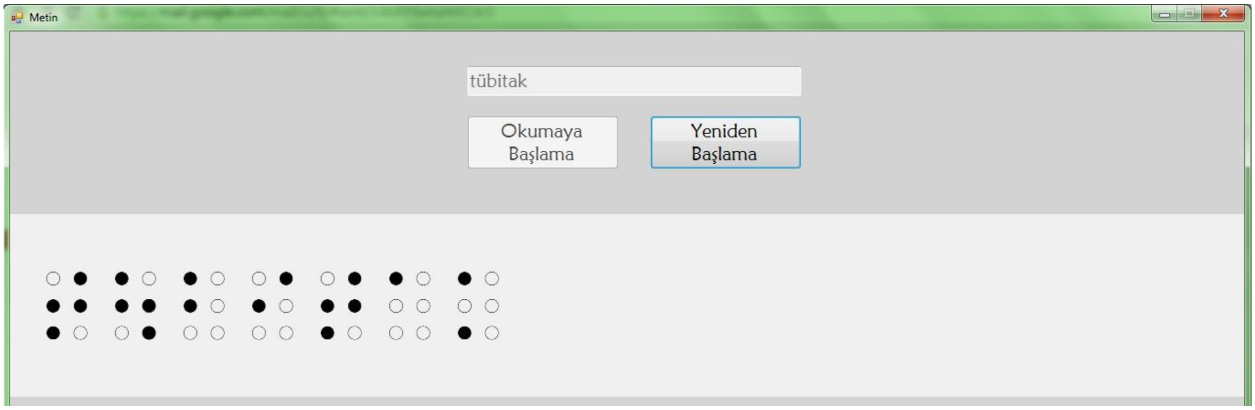

Figure- 5 Text Input and Braille Correspondent

Up to this point, the project succeeded in generating meaningful stimuli for alphabetical characters and geometrical shapes on behalf of the user, while the system necessitates the input having been saved in the system previously. Provided that appropriate content is created, the system promises great benefits in education for the visually impaired.

Prospectively, the efforts will be maintained so as to enable the system to help the user read content without any input having been saved as well as improve the system's overall precision. Parenthetically, efforts to eliminate current issues with the system are in process as this report is being written. Among the endeavours is use of auditory guidance to improve the user's awareness of the text structure such as where the lines end. Additionally, feedback received from the testers continuously result in minor fixes being made. The system functions only when connected to a power source, which creates flaws in mobility. It could be made rechargeable to aid this problem in the future. Along with this, minimising the circuit elements would give a product with a more ergonomically design, which is planned to be put in practice. Improved mobility would greatly enhance the system which is already compatible with any tablet computer, thus largely reducing the cost in mass production level. In this way, the system will be highly accessible to potential users.

The project was evaluated by visually impaired individuals to test its efficiency. 16 volunteer individuals between the ages 16-20 with Braille literacy were asked to estimate the geometrical shapes and alphabetical characters on the screen.

The first stage of the experiment consisted only of a general briefing on the system and asking the volunteers to estimate the shapes/characters that they receive the signals of when they touch the screen. In the second stage, which helped the results being built, the volunteers were given detailed information on how the system functions and they were tested as they were in the exercises. The criteria were set as the estimation of shapes, characters and the words, thus evaluating the accuracy of the answers. The results are shown in Table-1.

	Before exercises	After exercises
Word estimation	54.3%	81%
Geometrical shapes estimation	64%	78%
Alphabetical characters estimation	70.5%	89%

Table-1 Performance Comparison Before and After Exercises

The results demonstrate that the users can quickly adapt to the system, increasing the efficiency. It is expected that increased exercise and optimisation settings will bring the values above close to 100%. When the volunteers were asked of their opinion on the system, it was stated that they found it truly beneficial.

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Appendix-1

C# sample coding structure (descriptions for alphabetical characters);

```
if(gelenVeri == 'a')
motorCalistir(1,0,0,0,0,0);

else if(gelenVeri == 'b')
motorCalistir(1,0,1,0,0,0);

else if(gelenVeri == 'c')
motorCalistir(1,1,0,0,0,0);

else if(gelenVeri == 'ç')
motorCalistir(1,0,0,0,0,1);

else if(gelenVeri == 'd')
motorCalistir(1,1,0,1,0,0);

else if(gelenVeri == 'e')
motorCalistir(1,0,0,1,0,0);

else if(gelenVeri == 'f')
motorCalistir(1,1,1,0,0,0);
```

```

else if(gelenVeri == 'g')
motorCalistir(1,1,1,1,0,0);

else if(gelenVeri == 'ğ')
motorCalistir(1,1,0,0,0,1);

else if(gelenVeri == 'h')
motorCalistir(1,0,1,1,0,0);

else if(gelenVeri == 'ı')
motorCalistir(0,0,0,1,1,0);

else if(gelenVeri == 'i')
motorCalistir(0,1,1,0,0,0);

else if(gelenVeri == 'j')
motorCalistir(0,1,1,1,0,0);

else if(gelenVeri == 'k')
motorCalistir(1,0,0,0,1,0);

else if(gelenVeri == 'l')
motorCalistir(1,0,1,0,1,0);

else if(gelenVeri == 'm')
motorCalistir(1,1,0,0,0,0);

else if(gelenVeri == 'n')
motorCalistir(1,1,0,1,1,0);

else if(gelenVeri == 'o')
```

```
motorCalistir(1,0,0,1,1,0);
else if(gelenVeri == 'ö')
motorCalistir(0,1,1,0,0,1);
else if(gelenVeri == 'p')
motorCalistir(1,1,1,0,1,0);
else if(gelenVeri == 'q')
motorCalistir(1,1,1,1,1,0);
else if(gelenVeri == 'r')
motorCalistir(1,0,1,1,1,0);
else if(gelenVeri == 's')
motorCalistir(0,1,0,0,1,0);
else if(gelenVeri == 'ş')
motorCalistir(1,1,0,0,0,1);
else if(gelenVeri == 't')
motorCalistir(0,1,1,1,1,0);
else if(gelenVeri == 'u')
motorCalistir(1,0,0,0,1,1);
else if(gelenVeri == 'ü')
motorCalistir(1,0,1,1,0,1);
else if(gelenVeri == 'v')
motorCalistir(1,0,1,0,1,1);
```

```
else if(gelenVeri == 'w')
motorCalistir(0,1,1,1,0,1);
else if(gelenVeri == 'x')
motorCalistir(1,1,0,0,1,1);
else if(gelenVeri == 'y')
motorCalistir(1,1,0,1,1,1);
else if(gelenVeri == 'z')
motorCalistir(1,0,0,1,1,1);
else if(gelenVeri == '1')
motorCalistir(1,0,0,0,0,0);
else if(gelenVeri == '2')
    motorCalistir(1,0,1,0,0,0);
    else if(gelenVeri == '3')
    motorCalistir(1,1,0,0,0,0);
    else if(gelenVeri == '4')
    motorCalistir(1,1,0,1,0,0);
    else if(gelenVeri == '5')
    motorCalistir(1,0,0,1,0,0);
    else if(gelenVeri == '6')
    motorCalistir(1,1,1,0,0,0);
    else if(gelenVeri == '7')
    motorCalistir(1,1,1,1,0,0);
```

```
else if(gelenVeri == '8')
motorCalistir(1,0,1,1,0,0);

else if(gelenVeri == '9')
motorCalistir(0,1,1,0,0,0);

else if(gelenVeri == '0')
motorCalistir(0,1,1,1,0,0);

else if(gelenVeri == '.')
motorCalistir(0,0,1,1,0,1);

else if(gelenVeri == ',')
motorCalistir(0,0,1,0,0,0);

else if(gelenVeri == '!')
motorCalistir(0,0,1,1,1,0);

else if(gelenVeri == '?')
motorCalistir(0,0,1,0,1,1);

//case 'sayi':
//motorCalistir(0,1,0,1,1,1);

//case 'kirmizi':
//motorCalistir(1,0,0,0,0,0);

//case 'siyah':
//motorCalistir(1,0,0,0,0,0);

//case 'alanDisi':
```

```
        //motorCalistir(1,1,1,1,1,1);

        Else
motorCalistir(0,0,0,0,0,0);
```