Measurement of Multiple Pressure Points Through a Velostat

Research Article
EE3042 Energy Conversion Course Term Project

Pressure Measurement System Design and Prototype Development
Basınç Ölçüm Sistemi Tasarımı ve Prototip Geliştirme

EE3042 Energy Conversion Course Dönem Projesi

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ABSTRACT

A pressure measurement system was tried to be created that measures pressures with 225 (15 by 15 matrix arrays) pressure sensors made of a material called Velostat. Through this system, the pressure values could be measured in each area for instance, after placing an object on a mat sensor, the pressure of the hand could be measured on a unit basis related to the average value measured from signals received twenty-five times from the matrix map regions, where minimum and maximum pressure values is obtained as the matrices table in the output.

Firstly, the copper tapes are implemented for 16 columns and 16 rows to create (15x15 matrix array) pressure sensors on the velostat. The velostat material changes its resistance when pressure is applied to it. These copper tapes are connected to ribbon cables. 16pcs 1 kOhm resistors are added to the cables coming from the copper tapes. For the line, the number of signal connections to 4 pins is reduced by using a multiplexer to connect 16 cables to the Arduino card and connected them to the pins of the Arduino. The same operation is performed in the columns. The circuit and electronic card system are completed by programming with the necessary code to measure pressure parameters by controlling the performance of the prototype on Arduino. The pressure data is observed with great accuracy on Arduino software.

As a result, a pressure measuring system is constructed using velostat, which is a resistance sensitive material in this project.

Keywords: Interactive Mat, Velostat, Pressure Measuring, Arduino Software, Electronics Circuits, Calibrating

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ÖZET

Velostat adı verilen bir malzemeden yapılmış 225 (15 x 15 matris dizisi) basınç sensörü ile basınçları ölçen bir basınç ölçüm sistemi oluşturmaya çalışıldı. Bu sistem sayesinde her alanda basınç değerleri ölçülebiliyordu örneğin, mat sensöre bir nesne yerleştirildikten sonra, elin basıncı, mat sensöre basıncın uygulandığı matris bölgelerinden yirmi beş kez alınan sinyallerden ölçülen ortalama değerlerin okunmasıyla birim bazında monitörden min ve max veriler elde edilebilmektedir.

İlk olarak, bakır bantlar, velostat üzerinde (15x15 matris dizisi) basınç sensörleri oluşturmak için 16 sütun ve 16 sıra için uygulanır. Velostat malzemesi, üzerine basınç uygulandığında direncini değiştirir. Bu bakır bantlar şerit kablolara bağlanır. Bakır bantlardan gelen kablolara 16 adet 1 kOhm direnç eklenir. Kurulan bu devre hattı için, 16 kabloyu Arduino kartına bağlamak ve bunları Arduino'nun pinleriyle bağlantı kurarak iletim sağlamak için bir çoklayıcı kullanılarak 4 pine sinyal bağlantılarının sayısı gönderilerek azaltılır. Aynı işlem sütunlarda da gerçekleştirilir. Devre ve elektronik kart sistemi, prototipin Arduino üzerindeki performansını kontrol ederek basınç parametrelerini ölçmek için gerekli mantıksal bir algoritması olan kodla programlanarak tamamlanır. Basınç verileri Arduino yazılımında büyük bir doğrulukla gözlemlenir.

Sonuç olarak, bu projede dirence duyarlı bir malzeme olan velostat kullanılarak bir basınç ölçüm sistemi oluşturulmuştur.

Anahtar sözcükler: İnteraktif Mat, Velostat, Basınç Ölçme, Arduino Yazılımı, Elektronik Devreler, Kalibrasyon

1. INTRODUCTION

Enhanced a mat body with the help of electronic parts supported with more than one application in the field of pressure measurement could be used for a modular system that is connected to sensor hardware and software tools mat type pressure measurement using the pressure. The pressure to be applied in risky areas could be used to indicate proper monitoring of areas where improvements could be made to develop a system with the applied pressure. The current data according to set out and the above-mentioned pressure measurement sensor software development will have been obtained with the ease of using a serial monitor and plotter and on Arduino software, which contributes to observing the nonlinear graphics without low-pass filter, calibrating and exporting as a document including the pressure forces acting by connecting the pressure sensors with a computer.

1.1 Problem Definition

The pressure measuring mat system is a modular system that can be used for multiple applications in the field of body pressure measurement. In general, we have conducted research to ensure that the pressures of a certain surface are detected based on the search for a comfortable action that is applied to properly adjust the weight of the object for a long period of time.

2. MATERIALS AND METHODS

This conductive material (also referred to as "Velostat") is a good addition to the sensor hacking toolkit. It's pressure-sensitive: squeezing it reduces the resistance, so it's handy for generating flexible sensors. And it is a lot less costly than off-the-shelf pressure or bend sensors. Each order comes with a 11"x11" (28cm x 28cm) and 4mil (0.1mm) thick piece. We may fold the sheet into quarters to ship it and to get rid of any hard creases, simply lay it flat on a table and put a significant book on top to flatten it out.

2.1 Main Parameters

Table 1. The technical details of mat model

Model	Value
Dimensions	280mm x 280mm
Weight	18.66 g
Temperature Limits	-45 ℃ to 65 ℃
Heat Sealable	Yes
Volume Resistivity	<500 Ohm-cm
Surface Resistivity	<31,000 Ohms/sq.cm

2.1.1 Materials and Tools for Making Circuit

The used materials in the construction of a mat are the following such as velostat, copper tape, any type of insulating fabric; ribbon cable, leaded solder, and break away headers.

The used tools in the construction of a mat are the following such as ruler, measuring tape, cutter, glue, crayon/marker, soldering iron and multimeter, wire strippers and diagonal cutters.

The used materials for making the circuit are the following as those 2 multiplexers, a breadboard, an Arduino Uno electronic card, 2 blue led, 16pcs of the 1 kOhm resistors and 2pcs of the 2020 Ohm resistors.

2.2 Mat Design

While summing up, we placed to exist sharing two sides of the mat, one with copper columns and one with copper rows. We needed to own it one by one by using a ribbon cable for ease of use so, we tried to insert the velostat between the two sides of the mat. We needed to paste both sides of the mat to finish and we were ready to start the circuit.

To make a quick test, we have sensed one of the pins of the ribbon cable connected to the copper rows of the mat by using a multimeter with one of the pins of the ribbon cable connected to the copper columns of the mat.

Figure 1. Mat with a flat surface with copper sheets

2.2.1 Pressure Measurement Sensor Features

The key component that makes interactive mat study is the velostat. When pressure is applied to it, the velostat changes its resistance. As seen in the image, we implement a matrix sensor, specifically a 15 by 15 sensor matrix (225 sensors).

2.2.1.1 Easy-to-Fit Sensor Mat Tool

Pillow, seats, car seats, etc. can be easily integrated and used in vehicles.

2.2.1.2 Easy Installation and Maintenance

The pressure sensor mat does not require any installation. It can be redesigned and used only according to the specified area and can be easily transported.

2.2.1.3 Modular system

A modular electronic system can be installed by integrating two or more pressure sensors to monitor larger surface areas.

2.2.1.4 Flexibility

The system can be used in many technology sector products with variable size bed-like soft textures. The stretchability parameter, which provides flexibility, can be examined with a sensor that will be connected to the mat as an option if it is deemed necessary.

2.3 Circuit Diagram

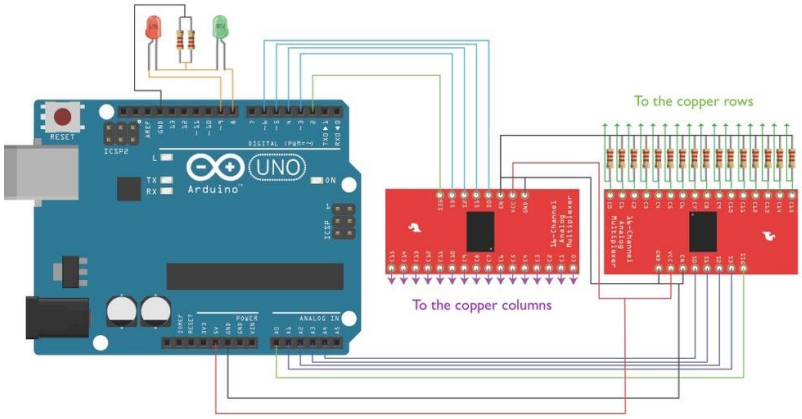

Figure 2. Arduino circuit setup diagram

We used the above circuit diagrams as guidance. When we finish assembling all the parts in our breadboard, connect the two cables/wires of the mat. We have included a diagram of the cable connection of the card with other multiplayer. We have ensured that the noise in the signal is reduced by resistors. We have set up the connection system of the signals to be received from the cells pressurized by copper wires placed according to the row and column matrix axes as above utilizing the corresponding multiplexers.

2.3.1 General Circuit Connections

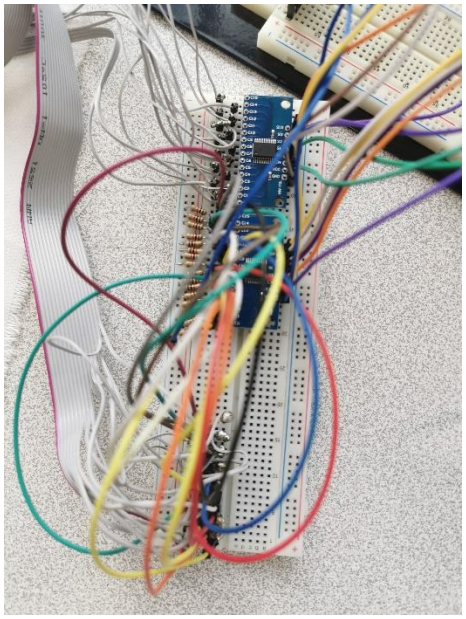

Figure 3. Multiplexers, cables, and resistors

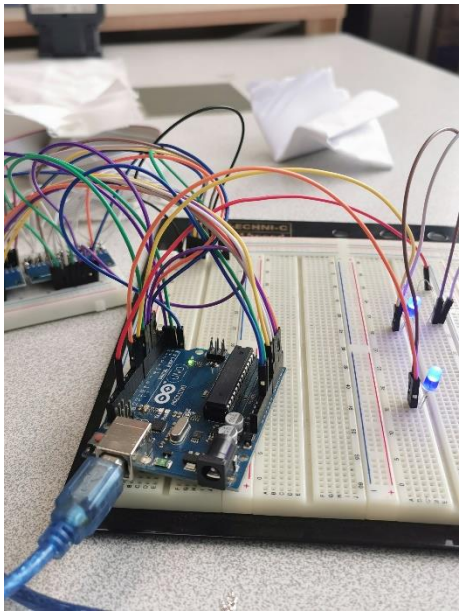

Figure 4. Arduino card and blue led

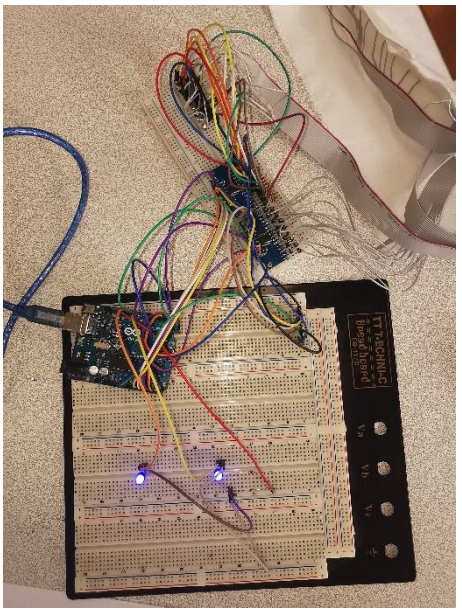

Figure 5. Top view of circuit

We observed that one of the blue LEDs in the image lights up and goes out according to the frequency of signal transmission, keeping the brightness constant based on the delay of the detected signal speed caused by the output of the code we are running in the software.

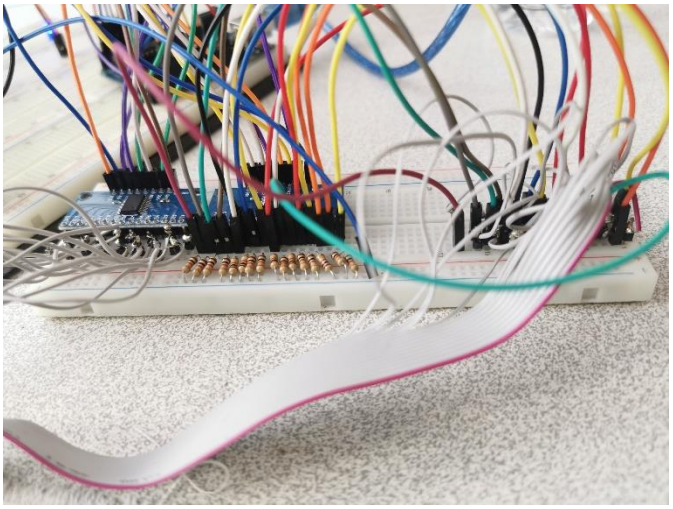

Figure 6. Small breadboard and connections

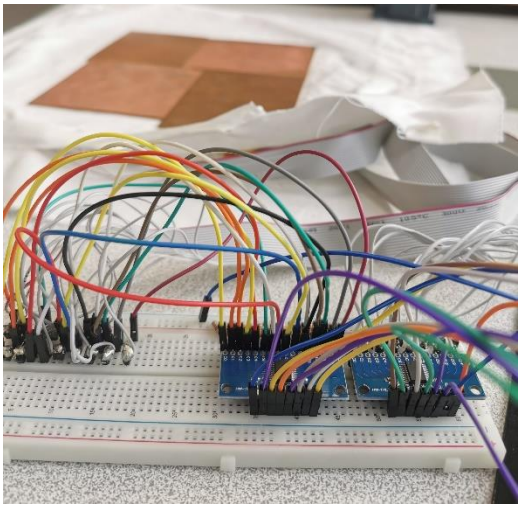

Figure 7. The mat with the circuit

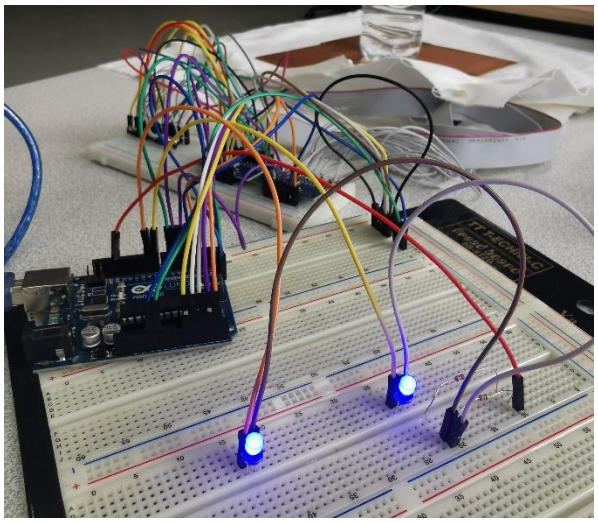

Figure 8. The image of the project, which is all the components

2.4 Programming and Sketching

Before uploading the Arduino sketch to the microcontroller, we checked that the pins are connected as the first lines of the code like the image on the right side.

We connected the Arduino with the computer to sketch and plot on Arduino software.

The configuration is shown for the Arduino card as the circuit diagram that is in the previous step, this configuration is the default configuration in the Arduino sketch.

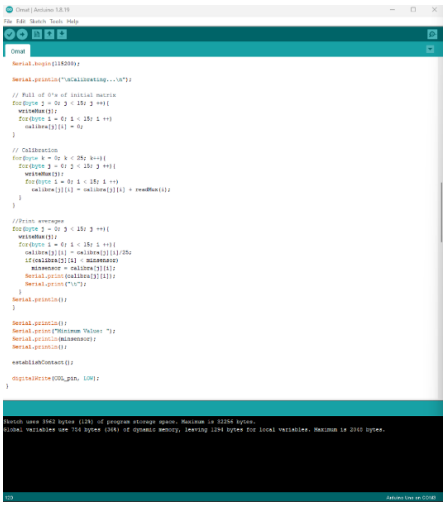

Figure 9. Arduino code compiler

2.4.1 Firmware and Hardware Tools

1. Arduino Uno electronic card to
2. 256 sensor matrices (16x16)
3. Electronic module tool
4. Arduino Program for pressure measuring software
5. Small and big breadboards
6. Multiplexers

3. RESULTS

While applying a bit of weight to the mat and if the resistance changes, we observed that the resistance changes apply weight in other areas and then, we detected a change in the resistance check that we made good welding in the copper areas and the velostat is between.

3.1 Serial Monitoring, Plotter and Objects

While light copper plates are standing in contact with each other on the surface of the matrix, the matrix map obtained after calibration was performed on the output monitor at the time when we ran the Arduino software with its values and the minimum measured results were also included.

3.1.1 Blank Mat Surface

The resultant graph and numerical value of the pressure of copper plates on the floor on the mat surface were calibrated as shown in the figure before the pressure measurement of two objects.

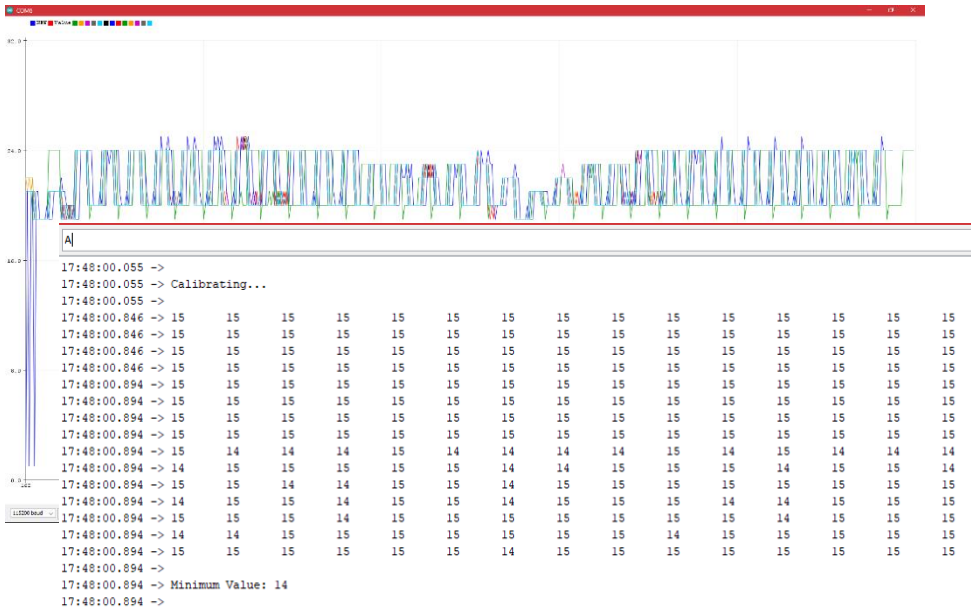

Figure 10,11. Colour graphs and calibration values

3.1.2 An Object on the Mat Surface

The result table and graphic lines corresponding to the unit values of the pressure exerted by a filled 0.5 L bottle that we placed on the surface, transmitted to the sensor by signal transmission, are given below.

```
17:49:34.771 -> NEW
17:49:34.771 ->
17:49:35.565 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.565 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.565 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.565 -> 83      83      83      83      83      83      82      83      83      83      83      83      83      83      83
17:49:35.565 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.565 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.610 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.610 -> 83      83      83      83      83      83      83      83      83      83      83      83      83      83      83
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 75      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 -> 76      76      76      76      76      76      76      76      76      76      76      76      76      76      76
17:49:35.610 ->
17:49:35.610 -> Minimum Value: 13
17:49:35.610 ->
```

Figure 12. Distribution of pressure matrix data taken from a system values **Figure 13.** One bottle on the mat surface

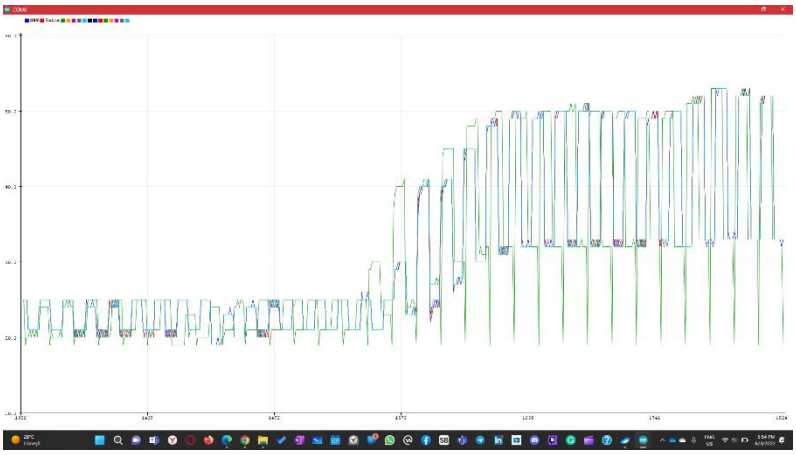

Figure 14. Distribution of pressure matrix data taken from a system

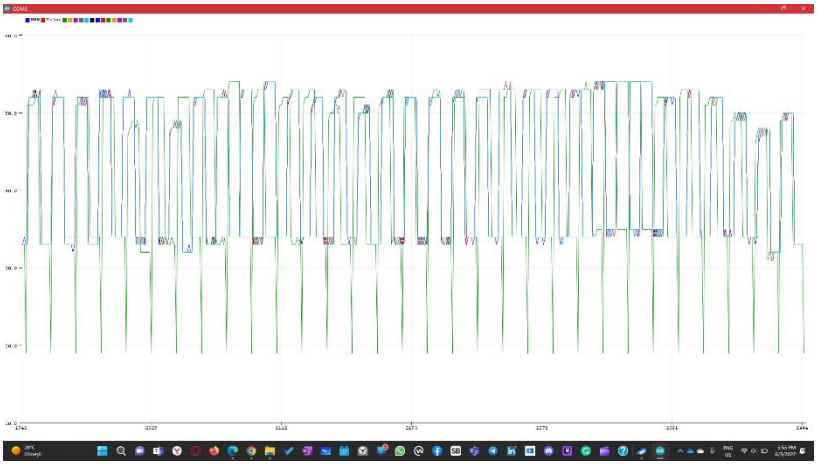

Figure 15. Stable graphical representation of pressure values in a pointwise distribution

3.1.3 Two Objects on the Mat Surface

At first, in the calculation performed on an empty surface, the unit value of only one bottle was measured, and according to the chart outputs taken at this stage and the values read in the graphs, it was observed that the pressure exerted by the two filled 0.5 L bottles we placed on the surface was twice as much.

Figure 17. Two bottles on the mat surface

```
17:51:32.310 -> NEW
17:51:32.310 ->
17:51:33.104 -> 126   126   126   126   126   126   127   127   127   127   127   127   127   127   127
17:51:33.104 -> 127   127   127   127   127   127   127   127   127   127   127   127   127   127   127
17:51:33.104 -> 127   127   127   127   127   127   128   127   127   127   127   127   128   127   128
17:51:33.104 -> 127   128   127   128   128   128   128   127   128   128   128   128   128   128   128
17:51:33.104 -> 128   128   128   128   128   128   128   128   128   128   128   128   128   128   128
17:51:33.104 -> 128   128   128   128   128   128   128   128   128   128   128   128   128   128   128
17:51:33.104 -> 128   128   128   128   128   128   128   128   128   128   128   128   128   128   128
17:51:33.104 -> 128   128   128   128   128   128   128   128   128   128   128   128   128   128   128
17:51:33.151 -> 147   147   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 148   148   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 148   148   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 148   148   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 149   149   148   149   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 148   148   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 -> 148   148   148   148   148   148   148   148   148   148   148   148   148   148   148
17:51:33.151 ->
17:51:33.151 -> Minimum Value: 8
17:51:33.151 ->
```

Figure 16. Distribution of pressure matrix data taken from a system values

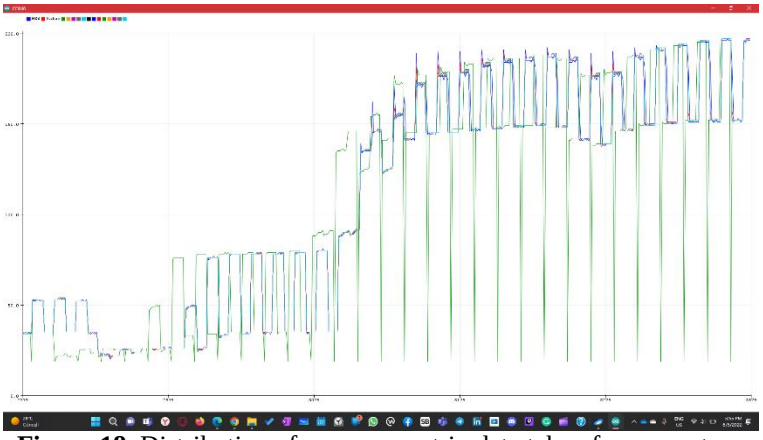

Figure 18. Distribution of pressure matrix data taken from a system

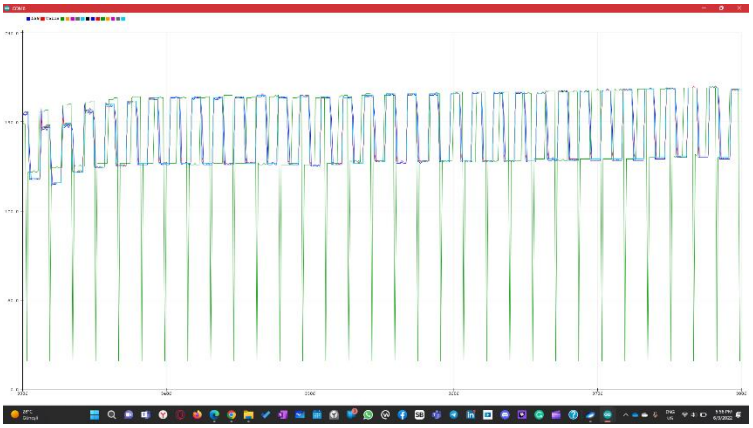

Figure 19. Stable graphical representation of pressure values in a pointwise distribution

3.2 Inference About Serial Monitoring and Plotter

It has been concluded that the pressure exerted by the objects on the mat surface is the highest value indicated by the blue colour and the lowest value indicated by the red colour to see the correct values of the pressure exerted by the load of the two bottles on the vertical axis. In the colour representation of the data matrix concerning the high and low values, the received graphic lines do not look linear, since there is no noise-reducing filter. However, since the flow graph is going to infinity, the values delivered by the signals measured every 0.5 seconds are displayed in the table.

Figure 20. Stable graphical representation of pressure values in a pointwise distribution

4. DISCUSSIONS

It has been set up that there is a similarity in the data obtained from the code that works correctly, avoiding the sequential transmission of the signal passing through the cables because the soldering process implemented in the creation of the circuit didn’t be done with a pie.

By using the pressure measurement sensor software and hardware tool, medical products in health fields such as determining the pressure rate from risky work sites and production areas, developing a patient-friendly product for bed, or sitting applications, monitoring, and evaluating a person's sitting position can also be developed.

By monitoring the pressure correctly, improvements can be made in the regional areas that can be monitored in the human body caused by pressure, and pain in certain parts of the body can be prevented. However, the occurrence of diseases in the sitting-lying area can be prevented by determining the areas where pressure is applied too much during long-term sitting-lying actions.

The areas that can be used have been determined as seat manufacturers, furniture, automotive, and hospital bed services.

5. CONCLUSIONS

By using the software and hardware tools connected to the pressure measurement sensor, it is possible to design improved systems that perform measurements and models in real units to determine the pressure to be applied in risky areas. If improvements could be made to the mat and electronic circuits by placing metric measurements between the copper wires in the areas where pressure is applied to accurately monitor the plots/graphs of pressure values, the error margins and ratios will have been neglected and will ensure that the real result will be achieved.

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CONFLICT OF INTEREST

The author(s) declare that for this article they have no actual, potential, or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions are required for this study.

FUNDING

The funding was received by a project instructor from institutions or agencies for the execution of this research.

6. REFERENCES

a) Article:

Examples:

https://link.springer.com/book/10.1007/978-3-031-03502-9

https://www.mdpi.com/1424-8220/21/13/4539/htm

https://link.springer.com/chapter/10.1007/978-3-030-70601-2_126

e) Web Page:

Examples:
https://www.researchgate.net/publication/261741500_Analysis_of_the_effects_of_surface_stiffness_on_the_contact_interaction_between_a_finger_and_a_cylindrical_handle_using_a_three-dimensional_hybrid_model

https://www.researchgate.net/publication/342320526_Flexible_Resistive_Sensor_Based_on_Velostat

https://www.researchgate.net/publication/352077898_A_Velostat-Based_Pressure-Sensitive_Mat_for_Center-of-Pressure_Measurements_A_Preliminary_Study

For the web page author is unknown:

Examples:
O-mat - YouTube

O-mat : 8 Steps (with Pictures) - Instructables

PMAT: Basınç Ölçüm Mat Sistemi | Akro Engineering (akromuhendislik.com)

https://courses.media.mit.edu/2012spring/mas681/index.html%3Fp=1003.html

Questions About the Project

1. *Why did we use multiplexer in the project?*

We needed 2 multiplexers (16 channels) to read column (16) and row (16) data respectively in this project because if we didn't use them, we would have to use 16+16 inputs in total on Arduino (1 input for each data) and it would be more costly and challenging to set up the circuit. Thanks to the multiplexers, the number of inputs has been reduced to 4+4. The multiplexer has 16 channels, a 4-bit select pin, and 1 signal pin. A signal at one of the channel inputs will be passed into the signal pin based on the four-bit value on the select lines from s0 to s3. Therefore, row and column data can be read by changing the select bit values on the Arduino.

Author 1: Ali TEMİR

2. *How is the matrix layout of the observing data received cyclically provided according to the logical algorithm structure and the working principle of the code that allows the input signal to be received from the Arduino board?*

A matrix data table consisting of 'for' loops are provided, which allows measuring the signal transmitted as noise with a delay frequency of 0.5 s added to the loop function of the code embedded in the Arduino board from data obtained from the ends of vertically overlapped copper bands lined up in a 16x16 row order under the high conductivity of copper plates. The analogue signals of the first of the multiplexers to the quad control pins at the default setting are received for the input part of the code, and then the byte value of the signal is transferred from the output control pins of the second multiplexer to the software embedded in the Arduino to be processed in the software. At this stage, a 16x4 channel matrix was created with the Boolean function of rows and columns. For serial byte values to be printed digitally, a separate assignment was made to each pin value. The high voltage passing through the pins allowed only 36% of the card's dynamic memory to be used in the 115200 bands. In reading the input matrix in a loop in series, the 0 points of the mat are taken as a reference. Near-real numerical data were obtained with the average values of the signals received from the copper wires on the surface of the calibrated mat. The saturation sensor data printed on the multiplexers allows 3D coloring and pressure density mapping by digital reading with java code via a different program for color mapping. Finally, the analogue data read from the signal pins to write digital data in the multiplexers passes through the byte channels, and it is ensured that the matrix table is continuously written to the output in a loop along with the 4 signal pins.

Author 2: Atabey AYDI

3. *What is the Velostat and its main task of it in the project?*

It is a pressure-sensitive conductive material. It is made of carbon. As the pressure on it increases, the pressure decreases. It is placed between two conductive objects and the amount of pressure is found thanks to the pressure resistance change applied to the object.

Author 3: Yusuf BEDİR

Questions About the Project

4. *What is the logic and algorithm of the code written to read the inputs from the mux in the Arduino program?*

The Arduino sensor connections were made with jumpers with the outputs we received from the mux. Then, by defining the sensors according to the correct outputs, we created a matrix form in which we could assign them; we did this by writing two form loops. At the same time, we took 25 measurements inside the Arduino for signals from cells connected to a copper channel and averaged them. This allowed us to make a more accurate measurement. Taking this into the loop, we constantly received outputs.

Author 4: Egemen ŞAHİN

5. *What could be done differently at the mechanical construction stage to minimize errors in the output screen?*

The cables could have been shorter and thus the voltage at the resistors could have been ensured to be less. More December placement of copper cables and gluing at appropriate intervals would ensure stable linear measurement of signals and reduction of interference. Shortly, the cables could have been shorter, so the resistance would have been less. Placing the copper strips more regularly with the help of a machine rather than by hand will also reduce the error.

Author 5: Altan HALIGÜR

6. *How did we verify that the connections of the circuit we made work correctly?*

We used a multimeter for this. First, we measured the resistance of the copper wire, then we pressured the velostat to measure the resistance again. We saw that the measured resistance value decreased as the pressure on the Velostat increased. Thus, we understood that the hardware part was working correctly and there was no error in the connection parts.

Author 6: Eren KARASLAN

7. *What is the arrangement of copper tapes and what are the reasons?*

We placed 10 mm copper tapes on the mat in parallel. A double-sided mat was used in the project because the horizontal and vertical are necessary to know exactly where it is applied. So we'll have 16 on one side of our mat and 16 on the other. In this way, 32 copper tapes were used. Thus, from exactly 256 points pressure can be measured. Intervals are neither too frequent nor it was very wide. If the intervals were too frequent the copper bands may be electrically interacting with each other, and pressure error could be observed in our measurements. Between copper bands, if the intervals were too wide, we might not be able to measure accurately and we would not get the result again. We try to minimize the error by making these intervals 3 mm and we aimed to make the most precise measurement.

Author 7: Muhammed Bahaddin AYDOĞAN

Contributions to the Project

Author 1: Ali TEMİR
Firstly, I stuck copper tapes on fabric and helped measure the mat's size. I helped with the soldering of ribbon cable to break away headers. I checked the connections with a multimeter after soldering. I contributed to writing Arduino code and connections.

Author 2: Atabey AYDI
At the initial stage of the experiment, after the process of assembling different components and equipment to ensure appropriate conditions in the laboratory, I helped Decoupage the mat fabric and velostat following the specified dimensions. Further, I carried out the processes of gluing copper tapes to the open surfaces of the fabric and soldering signal transmission cables to the ends of copper. I have provided the integration of the original board with my friend in the connection section of the circuit board with Arduino. In the Arduino program, in the algorithm of the code and taking infinite outputs from the experiment, I instantly tracked the pressure value flows through different objects and performed real analyzes.

Author 3: Yusuf BEDİR
I assisted in sourcing the materials and cut the copper tapes to the appropriate sizes. I helped my friends who solder. I helped with a multiplexer and Arduino UNO pin connections. While making the measurements, I helped with the adjustments so that the results were correct

Author 4: Egemen ŞAHİN
First, I helped with the mathematical calculations required for cutting fabric and copper cables. Then I took part in the mux cable and Arduino's connections on the breadboard. Finally, I took part in the project tests and corrected the errors in the code.

Author 5: Altan HALIGÜR
Starting from the mechanical part, I prepared each cable length for the corresponding copper line. Then I helped to solder these cables to the copper lines. After that, I soldered another side of cables to the pins to be connected to the multiplexer and I helped maintain the materials of this project.

Author 6: Eren KARASLAN
I am the representative of the group. I provided the necessary materials. I made interviews with Vedat Yeğin to get information about the project. I helped my friends in soldering and cable cutting works.

Author 7: Muhammed Bahaddin AYDOĞAN
I first decided with my friends to decide what size the copper wires would be and how much space there would be between those copper tapes. In line with this decision, I helped cut the copper tapes. After the copper tapes were in place, I helped glue the mats together. After that, I adjusted the lengths of the resistors to be connected to the Arduino. Finally, I helped fix the errors in the coding.