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Implementation of Quality Control System Using Magnetic Image Sensor

Ahmed Saeed Mohammed & Erhan AKIN

Abstract:

This paper depicts an overview and special technique for the recognition, detection, and measuring of the quality of magnetic on materials. It is based on the Hall Effect principle of and signal converter. The board is small but it gives good results in addition to ease of use, less cost, and low power. The magnetic field emitted from the material to be checked is converted to a visual spectrum. This means that magnetic fields can now be seen in real-time, the magnetic sensors used on the tile are some of the most highly sensitive. Visualizing things that are very difficult to normally seen. Because there is so much around that just cannot easily perceive, and how much more important bits of science we would be able to get done if only could easily see them as naturally as seeing things like color. Magnetic field detection in an object into a two-dimensional image will make that important and very useful especially with low cost, power, and easy to use, unlike some costly sensors.

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About Author (s)

Ahmed Saeed Mohammed (Corresponding author), Computer Engineering Department, Faculty of Engineering, Firat University, Elazig, Turkey.
Email: *ahmed.saeed@uoz.edu.krd*

Professor Erhan AKIN, Computer Engineering Department, Faculty of Engineering, Firat University, Elazig, Turkey.

1. Introduction

Because of the nature of ferromagnetism, magnetic characteristics of materials can provide various information to other material characteristics, for example, the measurements of magnetic-hysteresis parameters space that has been affected by the microstructure of the material as well as by residual or applied stresses. Recently, a hard study has shown that magnetic hysteresis, as well as the Barkhausen effect, can be used for testing the state of materials using a variety of non-destructive devices (Atomic Energy Agency, 2005). Measuring and imaging magnetic fields give the ability to evaluate the performance of the magnet so quality control of a permanent magnet, magnetic assembly, or piece of equipment that uses magnets can be controlled. Most of the technical information on magnetic fields that are widely published and taught at the university level relates to magnetic fields generated by electromagnets or active coil products. Modern permanent magnets are more like electrical engineering units than electromagnet units and coils. While both active coils and permanent magnets produce an external magnetic field, permanent magnets have a completely different structure than active coils (Mitchell et al., 2014). The normal magnetic flux leakage signal in each channel had to be processed in the magnetic array data, which further complicated the processing system (Lenz & Edelstein, 2006). This paper will implement a magnetic imaging method using a hall sensor.

2. Literature Review

A two-dimensional hall sensor array is used to measure the position of a magnet matrix by filtering harmonic components. Firstly, a one-dimensional sensor array used for filtering out several synchronized signals is proposed and extended to a two-dimensional sensor array for the place measurement of a magnet matrix. A two-dimensional hall sensor array to filter both fundamental and two-dimensional synchronized components of the magnetic flux and the conditioning circuit board is built for measuring the position of the magnet matrix. Finally, performances of filtering synchronized and measuring the position of the magnet matrix are experimentally verified with an XY linear motion stage (Ahn & Kim, 2014). Another study was done for permanent magnet force action. The most important use is controlling of fully automated apparatus, data acquisition, and processing according to the permanent magnets models, results from visualization, dynamic effects simulation, fast calculations using the cluster, etc. Fully automated devices made possible the measurement of a magnetic field with high accuracy. Comparatively simple models of magnets that are based on numerical integration, were in good compatibility with the experiment. The magnetic field that has been calculated and measured was visualized by parametric graphs, but other more descriptive methods such as flux density vectors or lines were also realized (Mikolanda et al., 2009).

A two-dimensional magnetic field in a current free region is represented in terms of a harmonic expansion. The expansion is derived for object components and extended to Cartesian components. The Cartesian components are described in terms of a complex field as well. The rules for transformation of the expansion coefficients under various types of coordinate transformation are given. In terms of the vector and complex potentials, the relationship between a given current distribution and the resulting field harmonics is explored. Explicit results are presented for some simple geometries. At last, the harmonics allowed under many symmetries in the magnet current have been discussed (Jain, 1998).

3. The goal of The Research

Some issues arise as a result of inconsistencies in widely used unit systems, such as some lack of magnetic measurement equipment and lack of working knowledge of magnetics in most quality control departments. Regardless of the inhibitors. Using a simple and cheap device for quality control implementation and visualizing the magnetic field with showing its measurement in real-time is very important and useful today especially with the industry nowadays

4. Fundamentals of The Research

Electromagnets were previously constructed using theoretical measurements or by using measuring representative voltage maps in electrolytic objects and resistive sheets before computers became commonly used. At that time, measuring magnetic fields on magnets and even intermediate magnet models were needed. Now, it is possible to measure the quality and strength of magnetic fields with impressive accuracy. Performing magnetic measurements on the magnet, on the other hand, are the easiest and most commonly used way to check that the expected field consistency has been achieved (Henrichsen, 1998).

4.1. Choice of Visualizing Method

Several factors influence the process of measuring and visualizing. The strength of the field, variation, homogeneity, and accuracy must all be needed to be considered. The number of magnets to also be measured could determine the process and equipment used. This study is depending on the principle of Hall Effect and signal converter. The board is small but it gives good results in addition to ease of use, low cost, and power, figure 1 and 2 show the combined Hall sensors with the ADC:

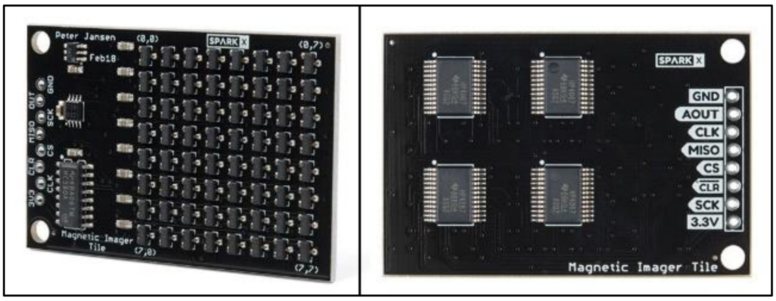

Figure 1: The board of 64 Hall sensors and ADC.

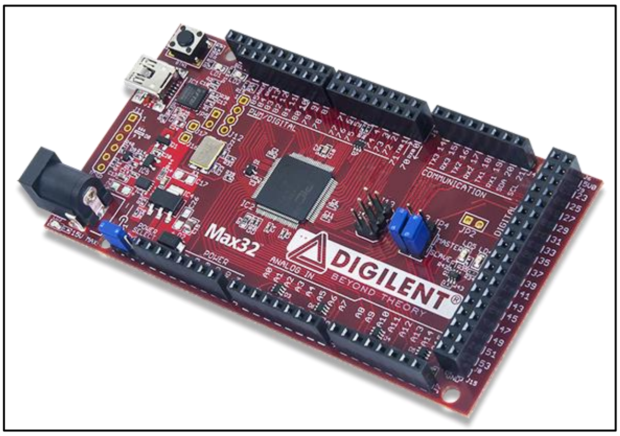

Figure 2: ChipKIT Max32 Microcontroller Board with Mega R3 Headers.

The magnetic field emitted from the material to be checked is converted to a visual spectrum. This means that magnetic fields can now be seen in real-time, the magnetic sensors used on the tile are some of the most highly sensitive.

4.2. Magnetic Image Sensing

Although magnetic sensors (magnetometers) are sensing the magnetic field and measuring the field, human eyes cannot sense (see) that field. So, sometimes we need to visualize the field for some reason as required, for example detecting magnet in objects or biology deals. Some sensors do it directly i.e., capture the magnetic image, and some other sensors need a special method to do it (in the case of used Hall sensor), for example, converting signals generated from the field and convert it to a visual color to see using human eyes (Rahmawati, D., Danudirdjo, D., & Suksmono, 2017). In this research a DRV5053 Analog-Bipolar Hall Effect Sensor has been chosen to visualize a magnet or magnetic field, it's done using an array of 64 sensors, which means a matrix of 8×8 and analyzing the data that has been read from those sensors to implement quality control for it.

5. Theory

Continuous voltage output is generated by linear or analog sensors, which can be increased with a strong magnetic field and decreased with a weak magnetic field. Hall effect sensors in linear output, as the magnetic field intensity increases, the output signal from the amplifier increases as well, until it saturates due to the power supply's limits. Any further increase in the magnetic field will have approximately no effect on the output and will only push it further into saturation. (Edward, 2006). There are two main types of Hall effect sensors, they are Bipolar and Unipolar. A bipolar sensor needs a positive magnetic field (which is the south pole) to operate and a negative magnetic field (which is the north pole) to release, while a unipolar sensor only needs a single magnetic south pole to operate and release as they travel in and out of the magnetic field. When the current-carrying conductor has been placed into a magnetic field, a voltage will be generated in a perpendicular way to both the field and the current. This is the Hall effect principle. The basic theory of the Hall effect is shown in figure 3. It illustrates a current passing through a thin sheet of semiconducting material (Hall element). The output connections are perpendicular to the direction of the current. In case there is no magnetic field (figure 3), the current distribution is uniform, and there is no potential difference across the output.

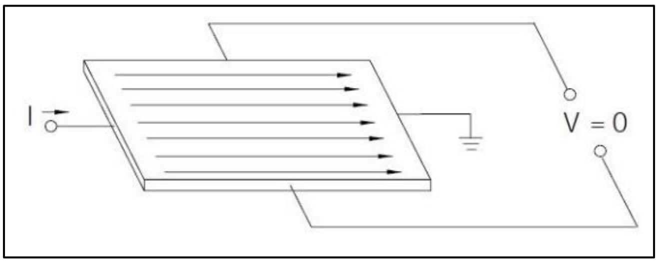

Figure 3: Hall effect principle, in case of no magnetic field.

A Lorentz force is exerted on the current when a perpendicular magnetic field is present, as shown in figure 4. This force creates a potential difference (voltage) across the output by disrupting the current distribution. That voltage is called Hall voltage. The following equation represents the interaction of the magnetic field and the current:

$$V_H \propto I \times B$$

Hall effect sensors can be used in a variety number of sensing applications and devices. The Hall sensor can perform the task if the quantity (parameter) to be sensed contains or may contain a magnetic field (Petruk et al., 2014).

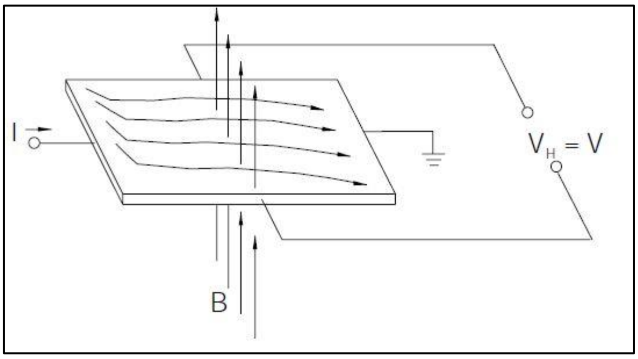

Figure 4: Hall effect principle, magnetic field present.

6. Research Method

The transverse part of the flux density passing through the sensing element is linearly proportional to the Hall voltage output signal. Lorentz forces act on charges passing through a magnetic field, creating the Hall effect (Raj & Janani, 2014).

$$F_L = q\,.(V \times B) \tag{1}$$

$$F_{hall} \propto B$$

Where:

F_{hall} = Output Hall Effect Voltage B.

B = Magnetic Field created by Magnet or Current-carrying Conductor.

6.1. Calculation of B-field

The input, output, and ground pins make a three-pin unit known as a hall sensor. In the presence of 10_4 T, the Hall sensor normally produces an output voltage of around 30 µV. An amplifier is sometimes already built into the chip to amplify it. According to the datasheet of our used DRV5053VA Analog-Bipolar Hall Effect Sensor, the sensitivity of is −90 mV/mT and specified for Vcc of 3.3 Voltage as shown in table 1, we can calculate Magnetic field in mT from all 64 sensors in real-time in addition to the position of the field.

Table 1: DRV5053VA Characteristics

	DRV5053VA		Unit
S - Sensitivity	V_{CC} = 3.3 V	−90	mV/mT

We have the following values:

V_{out} = V0 − V1 = D (Data got from the sensor)

Sensitivity = -90

We can calculate B from the equation:

$$V_{out} = 3.3 \times \frac{D}{1023} \tag{2}$$

$$B = 1000 \times \frac{V_{out}}{S} \tag{3}$$

B measured by mT

6.2. Hall Effect Sensor Modeling in MATLAB

Those sensors that are implemented in the system, are built-in Matlab / Simulink based on theory and knowledge about those sensors that are implemented in the device. Figure 1 illustrates the hall sensor blocks. The model contains Low Pass filters to remove unwanted high frequencies and demodulating the system as well. Since the model is based on theory, it is perfect and without limitations. The model consists of three (increasable) analog Hall-effect sensor components (as a sample) with filtered output signals. To create a digital output, the relays act as Schmitt triggers.

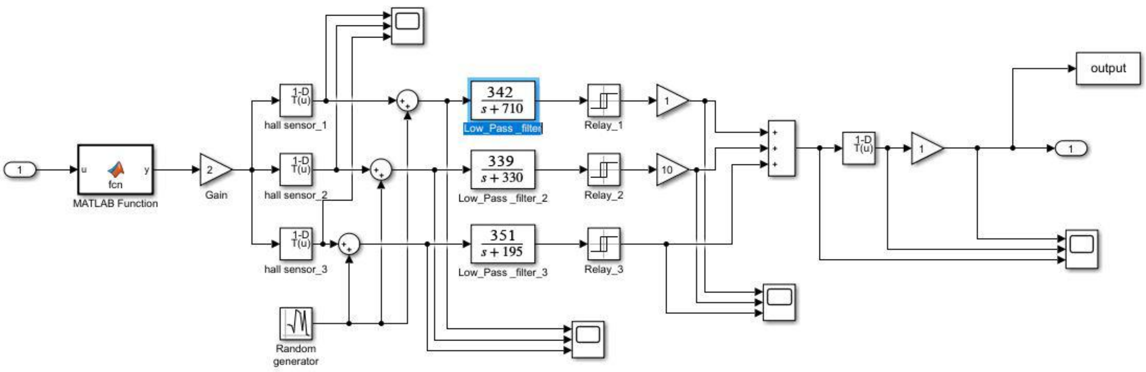

Figure 5: Hall-effect sensor model (3 sensors as a sample).

An input constant is used for the input value, then the MATLAB function contains the main function of calculating the field for just one state and one value. The gain maximizing the input signal, we used three hall sensors as a sample of 64 sensors. Then using SUMs blocks for summation with randomly generated numbers and then the signals have been filtered using LOW PASS FILTER to keep low frequencies that we need and remove unwanted high frequencies. After that, RELAYs are used to switch between signals and every switched signal has been gained with a different value. Then add them together using ADD block and put them to the last accumulated hall sensor and gain it again to show the output in workspace and scope. As we have a matrix of 64 sensors, we can model all sensors with some sample values just like those got from the sensors like the array below:

Table 2: Sensor data in volts

342	339	351	375	378	382	377	369
325	325	357	426	461	411	397	376
299	259	237	647	649	484	403	399
278	164	58	667	665	561	432	391
287	166	57	117	663	563	433	390
287	214	69	110	520	479	415	375
320	295	249	278	364	393	385	373
337	323	326	319	345	357	361	373

And they are converted according to the equations 4 and 5 into:

Table 3: Sensor data in mT

-12.2581	-12.1505	-12.5806	-13.4409	-13.5484	-13.6918	-13.5125	-13.2258
-11.6487	-11.6487	-12.7957	-15.2688	-16.5233	-14.7312	-14.2294	-13.4767
-10.7168	-9.28315	-8.49462	-23.19	-23.2616	-17.3477	-14.4444	-14.3011
-9.96416	-5.87814	-2.07885	-23.9068	-23.8351	-20.1075	-15.4839	-14.0143
-10.2867	-5.94982	-2.04301	-4.19355	-23.7634	-20.1792	-15.5197	-13.9785
-10.2867	-7.67025	-2.47312	-3.94265	-18.638	-17.1685	-14.8746	-13.4409
-11.4695	-10.5735	-8.92473	-9.96416	-13.0466	-14.086	-13.7993	-13.3692
-12.0789	-11.5771	-11.6846	-11.4337	-12.3656	-12.7957	-12.9391	-13.3692

And the combining sensors will look like figure 6:

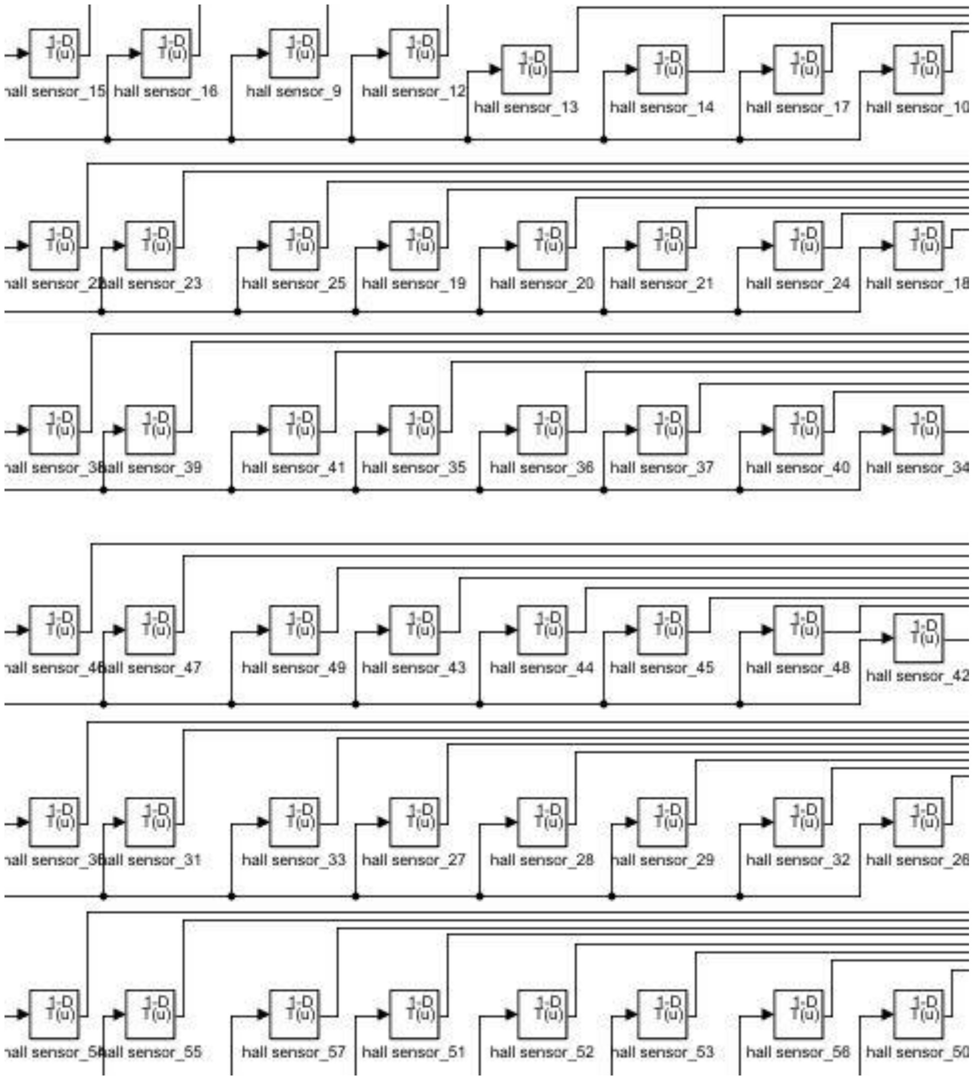

Figure 6: 64 matrix of hall sensors.

7. Experimental Results

Depending on the previous theories and equation, we can obtain an output of colors contains the magnetic field strength measured in mT by using a Hall effect sensor. We chose objects in multi positions and different speeds and get the data to compare and analyze. For example, figure 7 illustrates the object put in the middle of the tile (board).

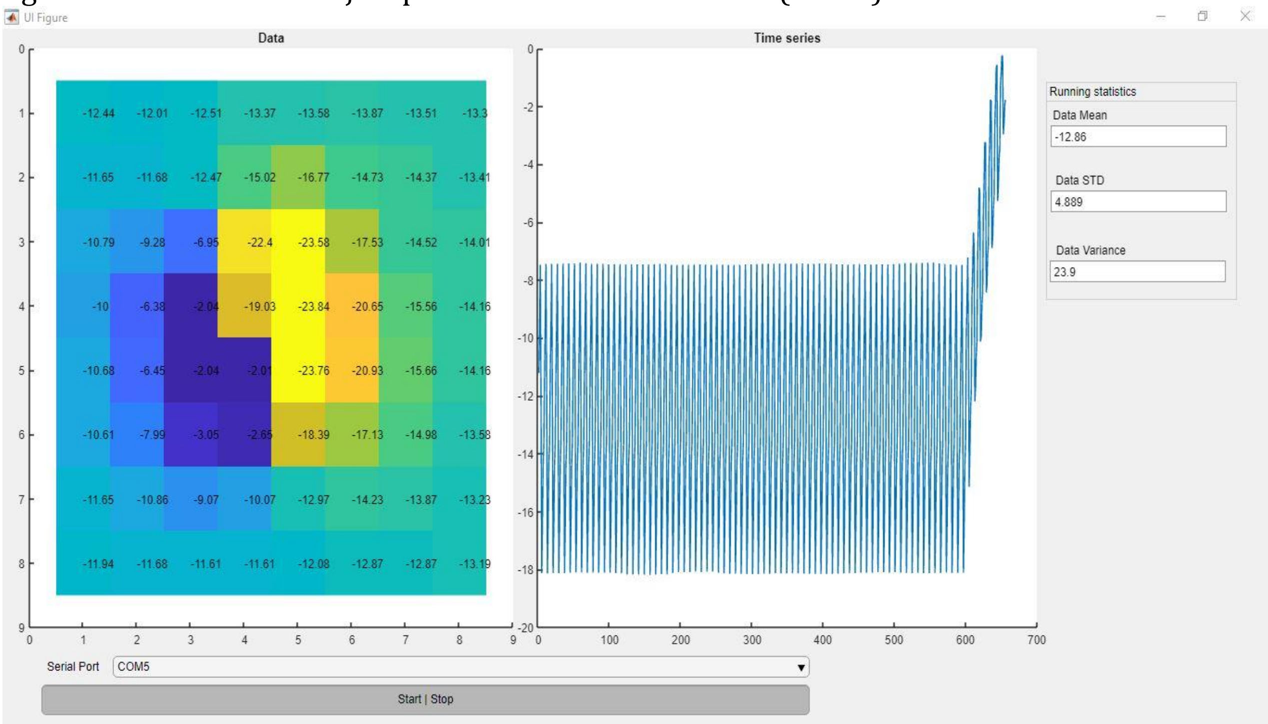

Figure 7: The object placed on the middle of the board (blue is the North and yellow is the South).

And figure 7 shows the data besides of time sequence and some statistical values such as Mean, Standard Deviation, and Data Variance of all data in real-time. And figure 8 show a smaller object comparing with the previous object, the mean and other statistical information are different:

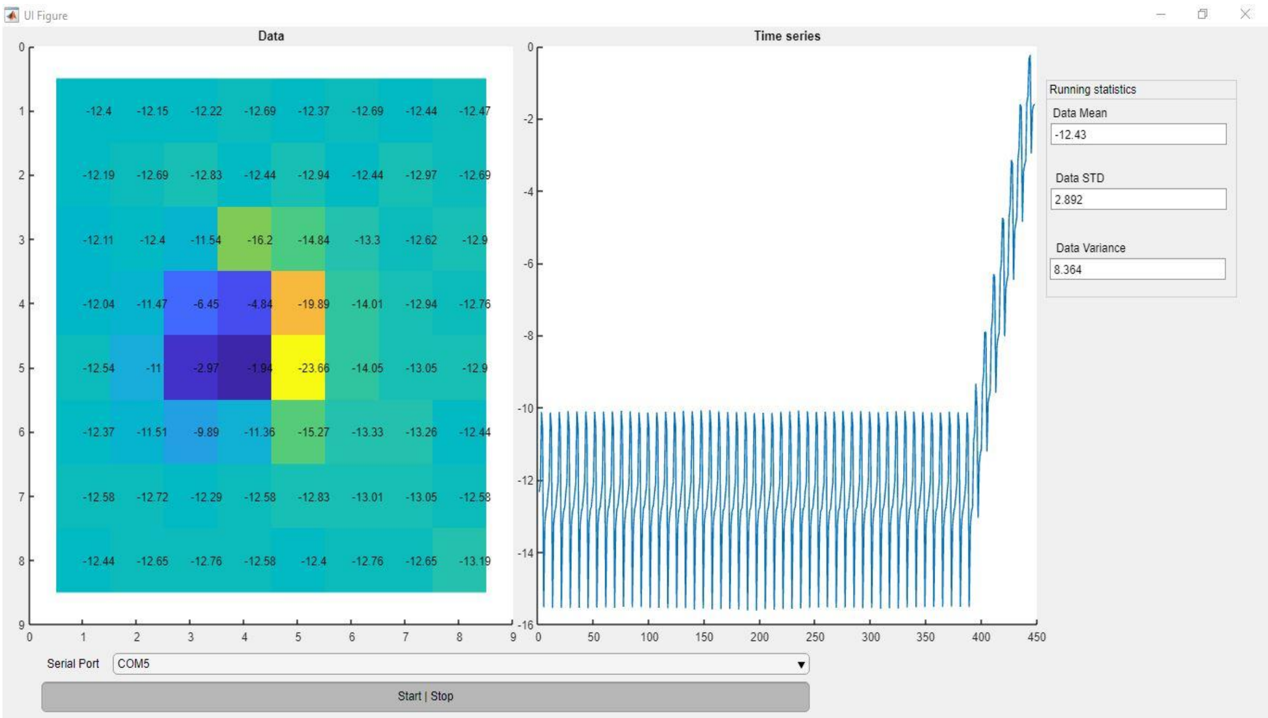

Figure 8: A smaller object placed in the middle of the board.

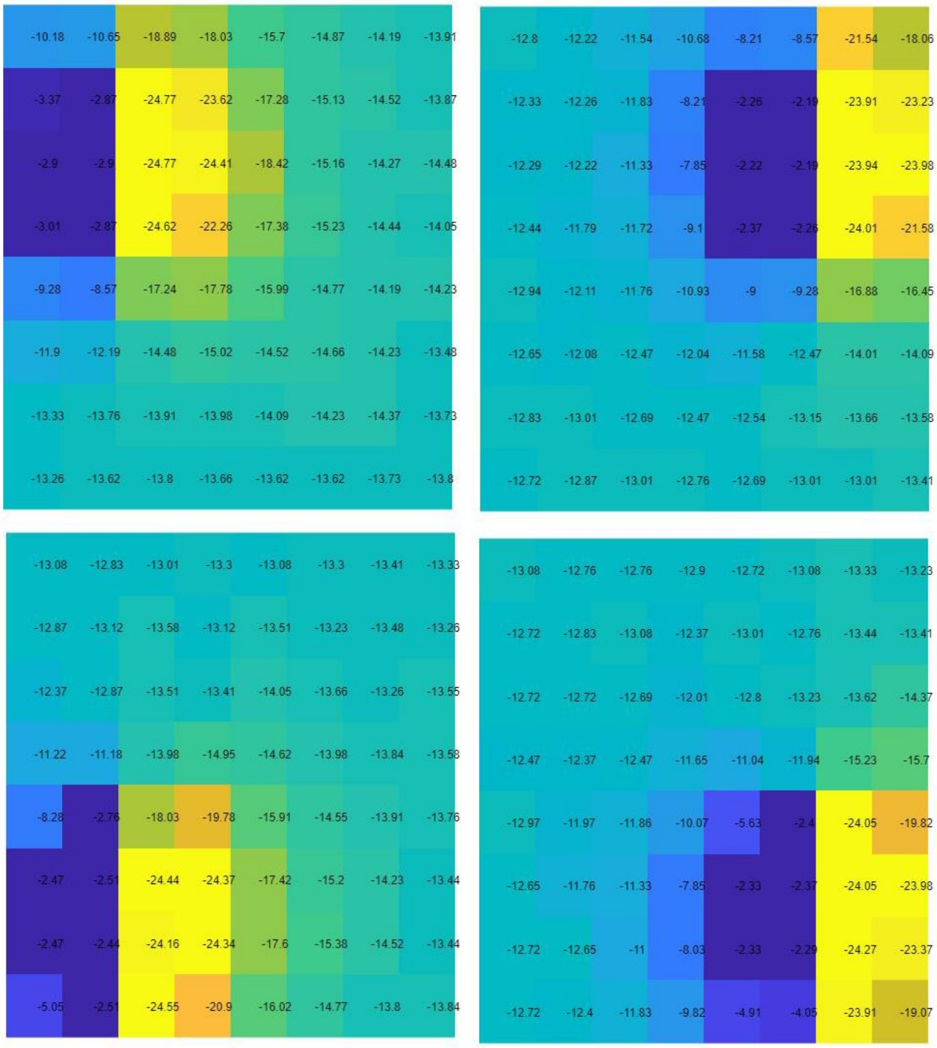

Figure 9: Different positions of an object placed on the board.

Proper quality control, magnet tests, and methods can be created by placing the sample object (used for comparison) on the board (shown in figure 9) and getting the data, then put other objects that we want to test and compare among them. We made three tests, one is the accepted state, and the other two states are not acceptable, as shown in figures 11, 12, 13, and 14.

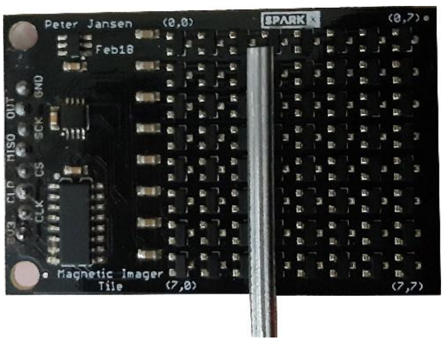

Figure 10: Sample test.

Now suppose we have the sample of figure 10 and its statistics are:

Mean: -12.72

Standard Deviation: 2.355

Data Variance: 5.548

And real-time data are shown in figure 11:

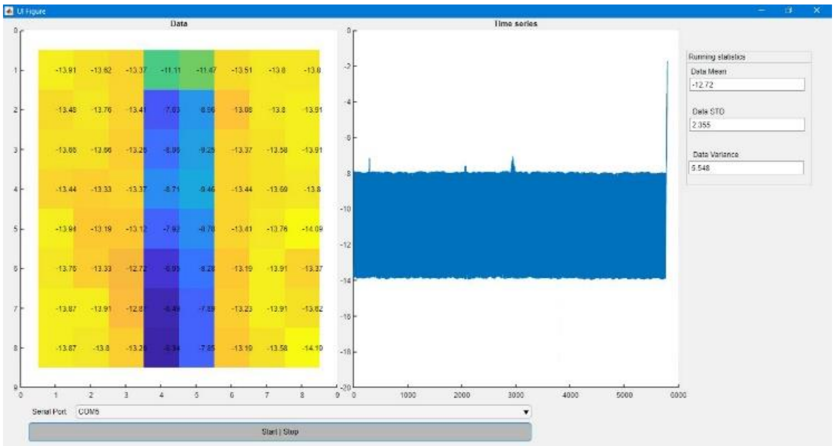

Figure 11: Sample of the test.

Now we apply three test cases and compare them with the first result (shown in figures 12, 13, and 14):

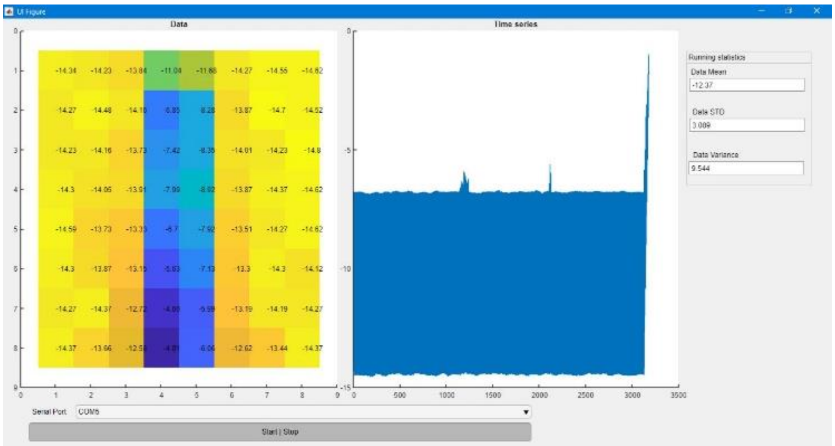

Figure 12: First test.

In figure 12, we notice that the:

Mean: -12.37

Standard Deviation: 3.089

Data Variance: 9.544

And comparing with the other sensor data, it means that this state is not acceptable.

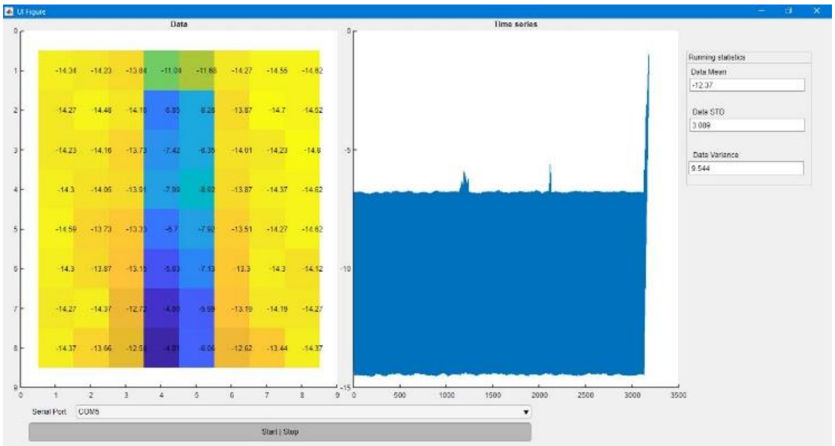

Figure 13: Second test.

In figure 13, we notice that the:

Mean: -13.27

Standard Deviation: 2.331

Data Variance: 5.432

And comparing with the other sensor data, this state is close to the sample state, so it means that this is acceptable.

In figure 14, we noticed that the:

Mean: -13.74

Standard Deviation: 0.6449

Data Variance: 0.4159

And comparing with the other sensor data, it means that this state is also not acceptable.

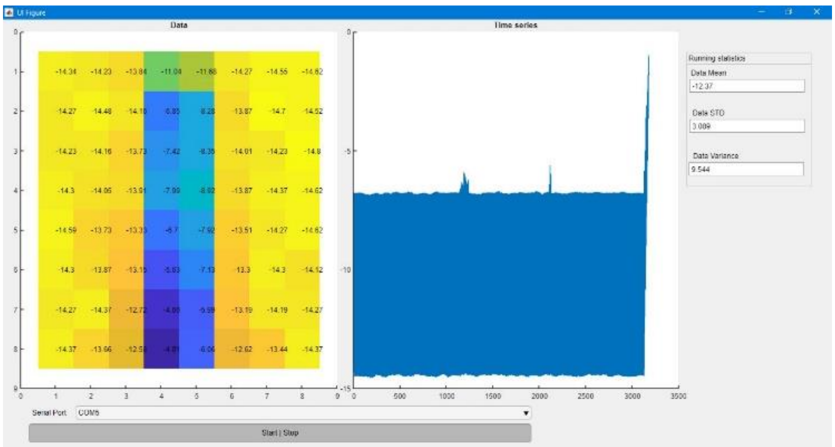

Figure 14: Third test.

Another example for testing is testing two plates, one has magnetic properties while the other doesn't contain it, shown in figure 15 and 17:

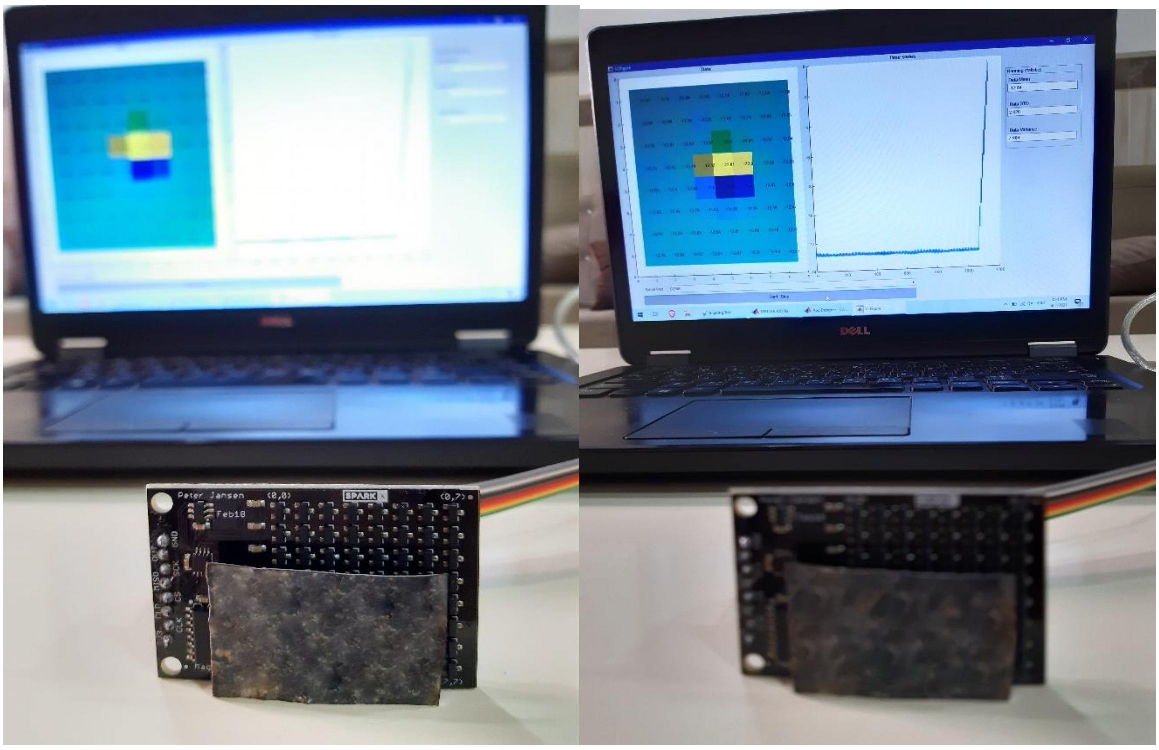

Figure 15: Testing a plate while magnetic field present.

Figure 16 shows the data of putting the plate on the board:

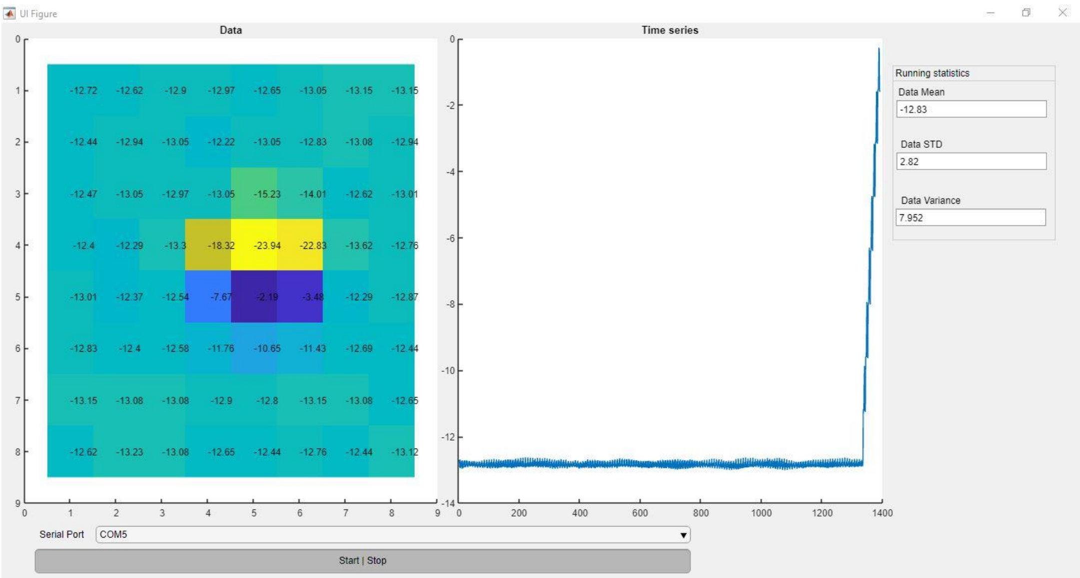

Figure 16: Data of testing plate while magnetic field present.

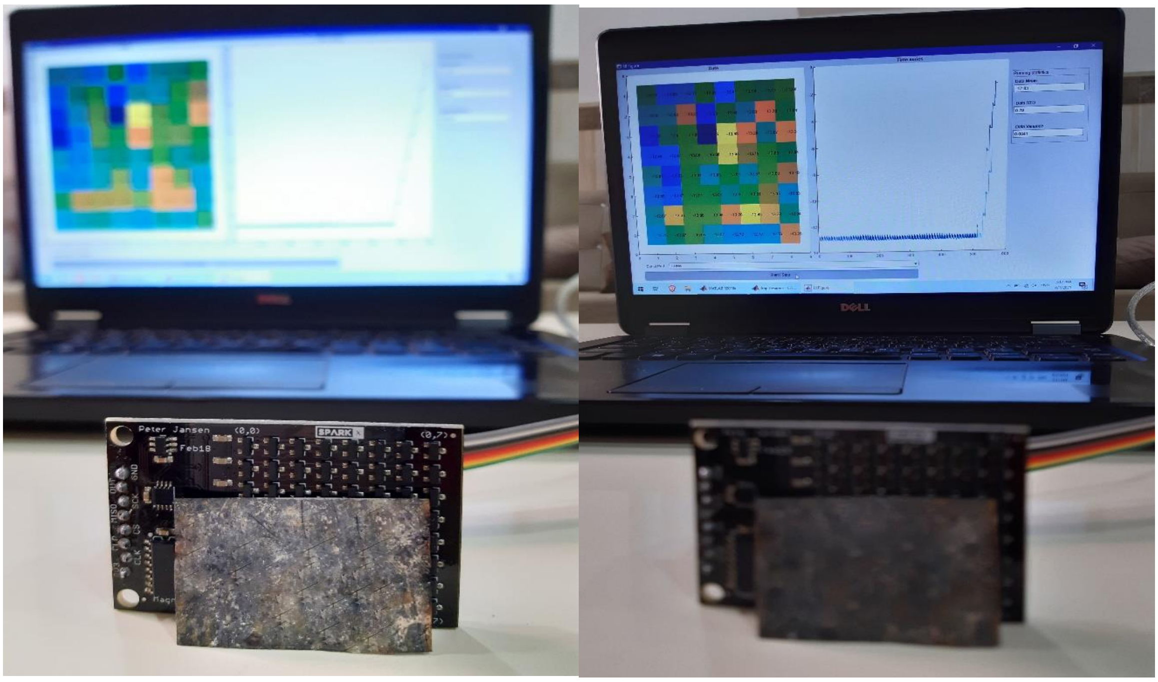

Figure 17: Testing a plate while not magnetic field.

Figure 18 shows the data of putting the normal plate on the board:

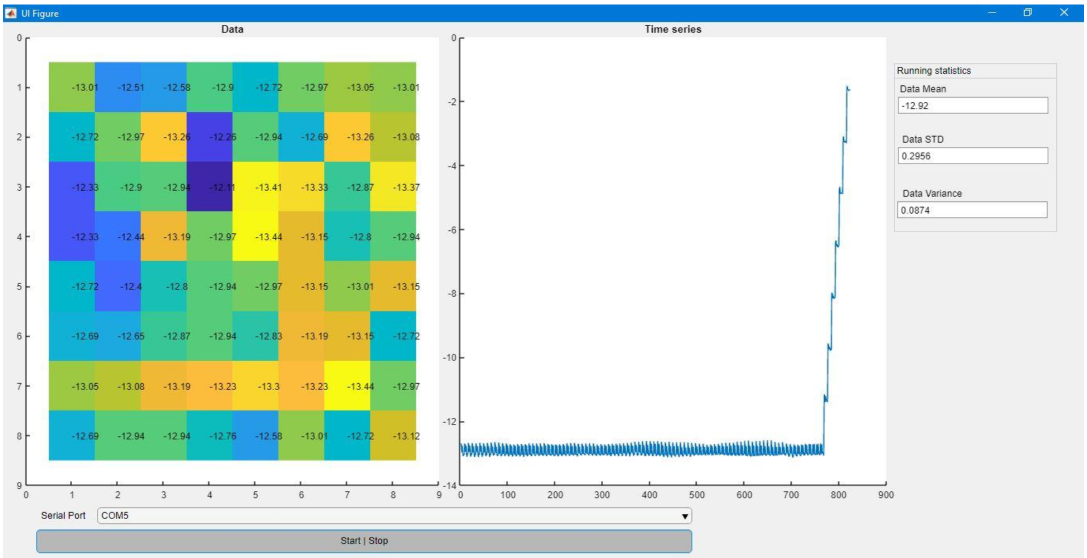

Figure 18: Data of testing plate while no /magnetic field.

8. Conclusions

There are many types of magnetic sensors and they are used daily in our life because of their safety and relatively easy to use. It is known that the Hall effect sensor is a device used in magnetic-field sensing applications in a wide range, but by combining multiple sensors and using an amplifier and an adapter (Analog to digital converter - ADC), the result will be something different and interesting to work with. In this research, it has been shown to us that magnetic field imaging is not limited to high cost and expensive sensors, which also need difficult algorithms to work well as required. We used a normal and cheap sensor as a camera for capturing the magnetic field. In addition to imaging the magnetic field, we noticed that we can see the strength and the position of the field. Not only a single image, but real and alive.

And this can distinguish magnets and minerals that demonstrate magnetic properties and sort through according to strength and colors, and even just using the human eye. However, the magnetic field appears in colors, the human eye can clearly see and distinguish the field (because it shows the field as colors). Although the sensor sensitivity is relatively not very accurate, it offers an acceptable and reliable result in inaccurate uses and cases of the weak magnetic field as the used sensor (Hall Effect sensor) depends on the principle of the voltage (Hall voltage).

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