www.dergipark.gov.tr
ISSN:2148-3736
El-Cezerî Fen ve Mühendislik Dergisi
Cilt: 6, No: 1, 2019 (868-880)

El-Cezerî Journal of Science and Engineering
Vol: 6, No: 1, 2019 (868-880)
DOI :DOI :10.31202/ecjse.570593

ECJSE

Research Paper / Makale

Incubator Automation and Medical Thermal Image Control System Design for Newborns

Mustafa YAZ, Kadir Caner KILIÇARSLAN

Bozok Üniversitesi, Mühendislik Fakültesi, Elektrik-Elektronik Mühendisliği, Yozgat / TÜRKİYE
mustafa.yaz@bozok.edu.tr

Received/Geliş: 15.05.2019 **Accepted/Kabul:** 09.07.2019

Abstract: In 1891, Following the first baby incubator developed by Alexandre LION in France, for many years incubators help babies (premature) born as early or problematic to hold on to life. Incubators ensure that premature infants are kept in a transparent and sterile environment, keeping heating, ventilation and humidification conditions at their optimum level so that they can continue their lives. In designed incubator control model, incubators that are usually utilized in Newborn Intensive Care Units, in addition to controlling the appropriate environmental conditions for premature infants physiological and biological signals (ECG, SpO2, pulse and body temperature) can be monitored. The entire measurement and control system is integrated into the user interface program designed in C # in the Microsoft Visual Studio environment. In addition, on C # program, through using the image processing program designed using the Aforge.Net library, on thermal imaging of premature infants using color filtering techniques, body heat changes can be analyzed. In this way, for internal bleeding, circulatory system and diseases, neuromuscular system and diseases, muscle, joint and skeletal system diseases, etc. diseases It is thought that diagnosis and treatment procedures can be done faster through earlier radiological and ultrasonographic examinations. The purpose of this study is to design these systems and a user interface that is easy and convenient to control and monitor with all the mentioned systems and to ensure that the relevant personnel work more comfortably and efficiently.

Keywords: Incubator control systems, vital parameters, medical thermography, thermal image processing.

Yenidoğanlar Için Kuvöz Otomasyonu Ve Tıbbi Termal Görüntü Kontrol Sistemi Tasarımı

Öz: 1891 yılında Dr. Alexandre LİON tarafından Fransa'da geliştirilen ilk bebek kuvözünün ardından, kuvözler uzun yıllardır erken ya da sorunlu olarak dünyaya gelen bebeklerin (prematüre) hayata tutunmasına yardımcı olmaktadır. Kuvözler, prematürelerin hayatlarına devam edebilmeleri için ısıtma, havalandırma, nemlendirme koşullarını optimum seviyede tutarak, şeffaf ve steril bir ortamda korunmasını sağlar. Tasarlanan kuvöz kontrol modelinde özellikle Yeni Doğan Yoğun Bakım Ünitelerinde sıklıkla kullanılan kuvözlerde, prematüreler için uygun çevre koşullarının kontrol edilmesine ilave olarak fizyolojik ve biyolojik sinyaller (EKG, SpO2, nabız ve vücut ısısı) izlenebilmektedir. Bütün ölçüm ve kontrol sistemi Microsoft Visual Studio ortamındaki C# programında tasarlanan kullanıcı ara yüz programına entegre edilmiştir. Ayrıca yine C# programında, Aforge.Net kütüphanesi kullanılarak tasarlanan görüntü işleme ara yüzü ile prematürelerin termal kamera görüntüleri üzerinde renk filtreleme teknikleri kullanılarak, vücut ısı değişimlerinin analizi yapılabilmektedir. Bu sayede vücut iç kanama, dolaşım sistemi ve hastalıkları, nöromuskuler sistem ve hastalıkları, kas, eklem ve iskelet sistemi hastalıkları vb. rahatsızlıklar için ön teşhis konularak, daha erken yapılacak radyolojik ve ultrasonografik tetkiklerle daha hızlı teşhis ve tedavi işlemlerinin yapılabileceği düşünülmektedir. Bu çalışmanın amacı bahsedilen tüm sistemler ile bu sistemlerin kontrol ve monitörizasyonunu sağlayan kolay ve kullanışlı bir kullanıcı ara yüzü tasarlayarak, ilgili personellerin daha rahat ve verimli çalışmasını sağlamaktır.

Anahtar kelimeler: Kuvöz kontrol sistemi, vital parametreler, medikal termografi, termal görüntü işleme.

How to cite this article
Yaz M. Kılıçarslan K. C., "*Incubator Automation And Medical Thermal Image Control System Design For Newborns",* El-Cezerî Journal of Science and Engineering, 2019, 6(3); 868-880.

Bu makaleye atıf yapmak için
Yaz M. Kılıçarslan K. C., *"Yenidoğanlar Için Kuvöz Otomasyonu Ve Tıbbi Termal Görüntü Kontrol Sistemi Tasarımı",* El-Cezerî Fen ve Mühendislik Dergisi 2019, 6(3); 868-880.

1. Introduction

Babies born with premature and / or health problems cannot keep their body temperature stable at the required level. As the body defence systems are not sufficient, they need continuous care and treatment in a sterile environment. Incubators provide a quiet and sterile environment in which sleep cannot be interrupted by providing constant temperature, a certain amount of moisture and fresh air filtered through antibacterial filters in order not to deteriorate health conditions of premature. Built to meet this requirement, the baby incubators consist mainly of the cabin section with transparent lid, micro controller unit and body sections that carry out the functions of the incubator such as heating, ventilation and humidification [1].

Conventional incubator control systems are designed to provide and control the optimum and stable environmental conditions for the survival and the correction of health problems of prematurity. Vital parameters indicating the vital functions of premature children who are generally born with health problems should also be measured and monitored. Body temperature, pulse, respiration, blood pressure and oxygen saturation, which are expressed as vital signs, provide information about the physiological functions of the individual. If there is any change in physiological functions, this is reflected in the values of vital signs [2]. Monitoring of body temperature, pulse, respiration, blood pressure and oxygen saturation values plays an important role in monitoring the patient and identifying health problems. The vital values of the premature cases in the incubator are measured and displayed by the bedside monitors which are external devices by means of sensors placed on the body. Also, many devices and systems such as injectors or infusion pumps, phototherapy devices used for the treatment of jaundice, ventilators providing respiratory support for premature delivery of drugs or solutions to the premature are used outside the incubator for disease diagnosis and treatment of premature. Considering all these, healthcare personnel in charge have to monitor many systems and devices separately.

In addition to heating, ventilation and humidification parameters in the incubator control system, the vital parameters such as pulse, ECG, SpO_2 and body temperature are measured by sensors and electrodes placed on the body surface. Thus, the environment and vital parameters of the premature in the incubator can be monitored and controlled with a single user interface.

In addition, the designed program has also designed an interface to perform premature body temperature analysis with the thermal imaging method, which has become widespread in medicine in recent years. The temperature map of the human body has a symmetrical structure. So the temperature data on the right and left sides of the body are very close to each other. Therefore, asymmetric temperature values can be easily noticed. Infrared thermography is highly diagnostic because it can detect initial deviations from ideal health status [3]. The thermal imaging method is a non-invasive diagnostic technique because the practitioner does not require the application of an extra catheter, contrast agent and ionizing radiation to the patient, where the practitioner can see changes in the skin surface temperature [4].

Designed in this model; with the user interface program, the environmental parameters (temperature, humidity and O_2 concentration) can be controlled as well as vital parameters of the premature (ECG, pulse, SpO_2 and body temperature). In addition, body temperature analysis can be done with thermogram module and kept under premature continuous thermal examination. In this way, an integrated system was created to provide an easy and convenient interface for the doctors and nurses in charge.

2. Material and Method

Arduino Uno R3 is used as microcontroller board. The Arduino project is open source and many development libraries are available for free. Many libraries needed for basic operations are included in the Arduino project [5].

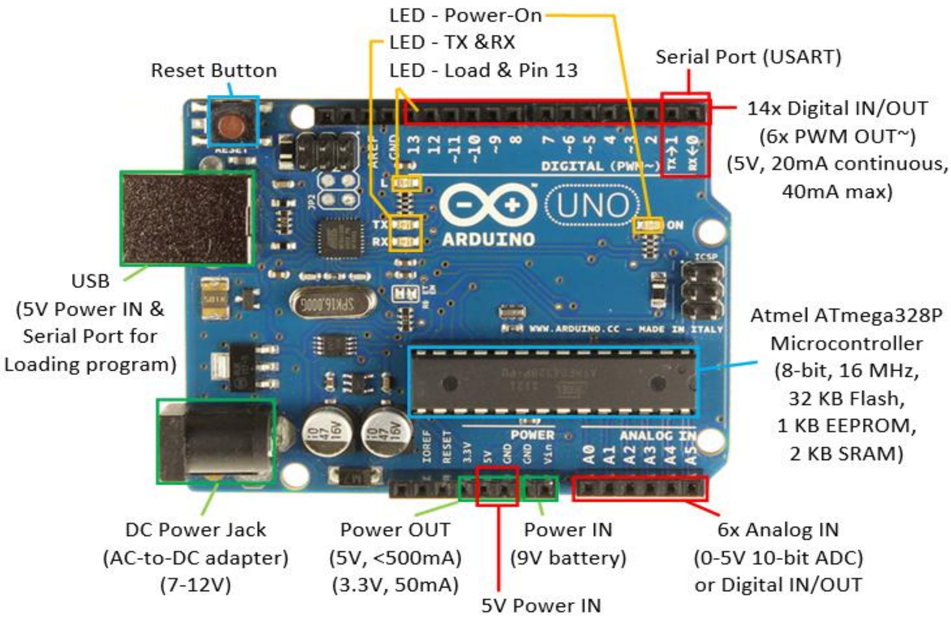


Figure 1. Arduino Uno and basic units

In the designed system, Arduino Uno R3 card which is shown in Figure 1 measures the environmental parameters of the incubator, heat, humidity and O_2 concentration data and the vital parameter values of the premature (pulse, ECG and SpO_2) via related sensors and sends commands to the user interface and the commands coming from the user interface (fan, heater, O_2 source).

In addition, temperature distributions and variations on the premature body surface can be analyzed with the thermogram module on the user interface. A detailed description of these modules is given below.

2.1 Environmental Parameters

The temperature, humidity and oxygen concentration in the incubator are measured by the sensors described below.

2.1.1 Temperature and humidity measurement

Temperature and humidity values in the incubator are measured with DHT22 integrated. The DHT22 is a calibrated digital output signal for measuring the temperature and humidity of the environment. +/- 0.5% accuracy. The open source DHT22 library is compiled and loaded on the Arduino card.

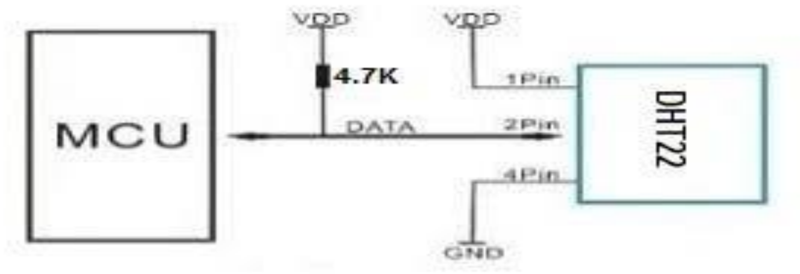


Figure 2. DHT 22 connection diagram

The microcontroller and the DHT22 sensor communicate and synchronize via a single data line as shown in Figure 2. A communication process takes about 2ms as illustrated in Figure 3 [6].

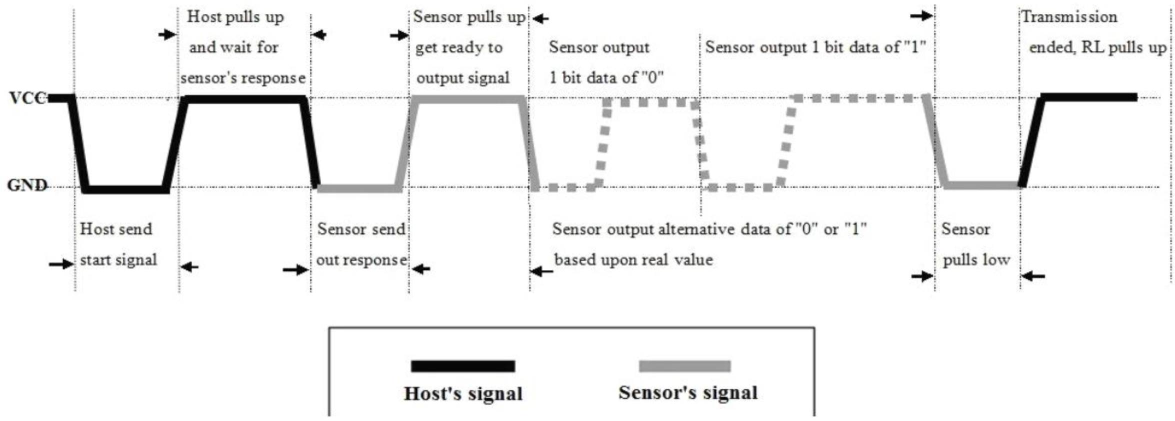


Figure 3. DHT22 communication diagram [6]

The DHT22 sends temperature and humidity information in a 40-bit data packet. The structure of this package is as follows in Figure 4 and connection diagram is shown in Figure 5:

Figure 4. DHT22 data packages [6]

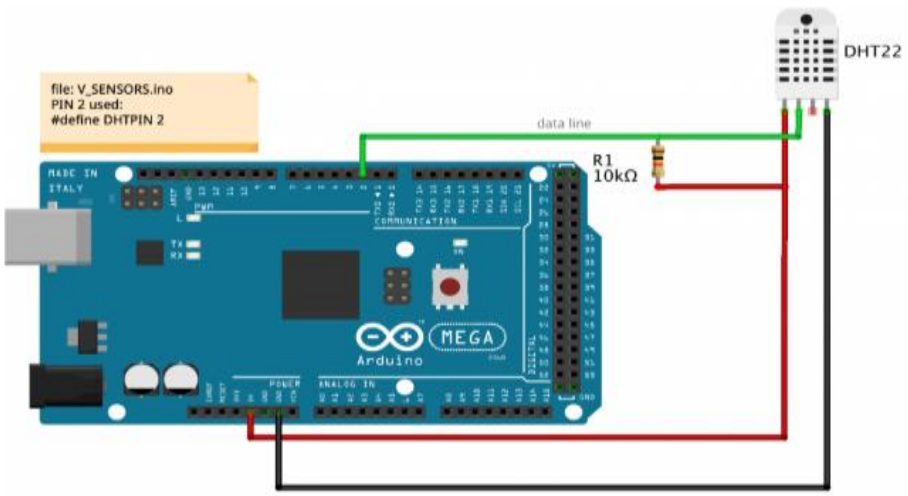


Figure 5. Connection of Arduino Uno card with DHT22

2.1.2 Oxygen Concentration Measurement

Itg / M-04 medical oxygen sensor was used to measure the oxygen concentration in the incubator. The sensor has a 3-pin (VDD, Earth, analog output pin) structure and delivers an analog output voltage in the range of 12.5 - 16.5 mV depending on the amount of oxygen in the environment.

The data pin of the sensor is connected to the analog pin (A1) of the Arduino board. The Arduino board is programmed to determine the amount of O_2 in the environment based on the amount of voltage from the O_2 sensor in Figure 6.

Figure 6. O_2 sensor

2.2 Vital Parameters

SpO_2, pulse and ECG data of the prematures are measured by the sensors introduced below. Body temperature values can be seen in detail with the designed thermal imaging interface.

2.2.1 SpO_2 Oxygen saturation and pulse measurement

The MAX30100 integrated was used to measure the pulse and oxygen saturation values of the premature. The MAX30100 combines pulse oximetry and pulse sensor. It works by emitting light from the red and infrared LEDs it contains and taking measurements from the reflection of this light. In this study, oxygen saturation and pulse values were measured by compiling the open source library of MAX30100 integrated for Arduino.

The MAX30100 integrates data with the I^2C communication protocol. Arduino card and MAX30100 integrated connections are shown in Figure 7 to provide data flow.

According to this communication protocol, the ground line between the master and slave must be common and the SDA (serial data, data line) and SCL (serial clock, clock pulse line used for data synchronization) pins must match. While data synchronization is provided on the SCL line, bidirectional data flow occurs on the SDA line [7].

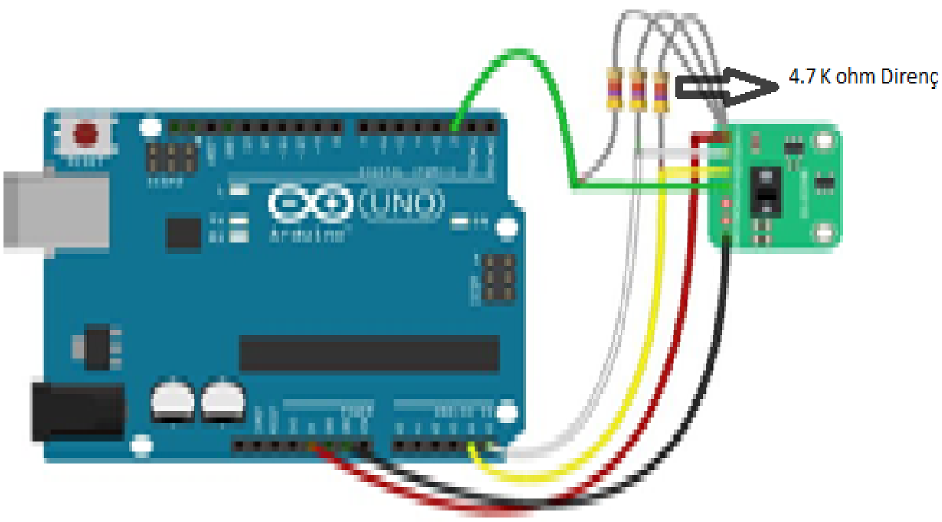


Figure 7. Arduino connection with MAX30100

2.2.2 ECG measurement

In order to measure the ECG (Electrocardiography) values of premature, AD8232 integrated circuit is used on board which is shown in Figure 8 as a heart rate sensor. AD8232 can be used in ECG and other bio-potential measurement applications. This component is designed to extract, amplify and filter small, noisy bio-potential signals. AD8232 detects bio-potential signals via electrodes placed in the body.

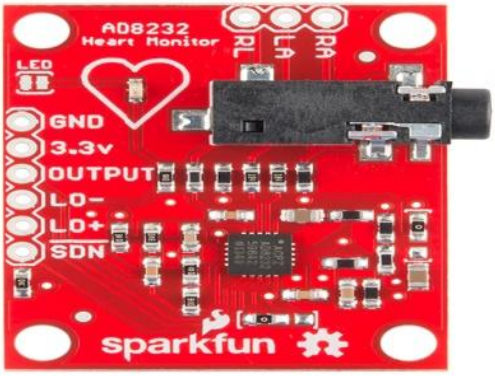


Figure 8. AD8232 heart rate sensor

A simplified circuit diagram of AD8232, which generally has 4 separate functions, is shown in Figure 9. It includes an instrumentation amplifier, an amplifier step that supports low-pass filtering, a right leg driver (RLD) amplifier, and a reference buffer [8].

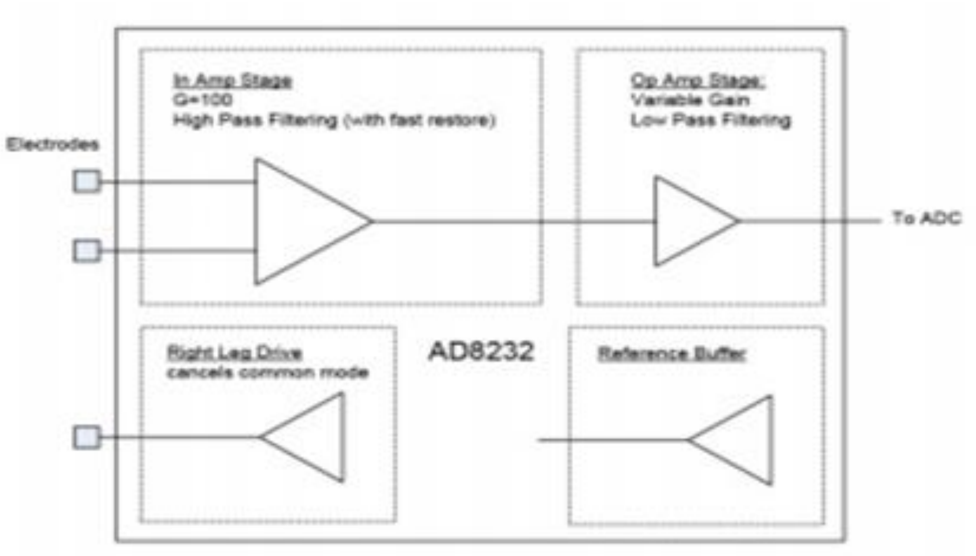


Figure 9. Simplified block diagram of the AD8232 [8].

The open source library of the AD8232 sensor for Arduino is edited and ECG data of the premature is obtained.

2.3 Premature Thermogram Analysis

All objects emit energy at the absolute zero temperature (-273.15 °C) in the form of electromagnetic radiation, also called thermal radiation or infrared radiation. The amount of energy emitted by the body is within the infrared region of the electromagnetic spectrum [10].

In the thermogram analysis interface, the images of the premature from thermal imagers are used. Figure 10 shows Arduino, AD8232 integration and body electrode connections. Normal cameras form the image by light, while thermal cameras form the image by heat [11]. In thermal imaging systems, all objects above -273 degrees Celsius appear in color. Thermal cameras convert these coloring tones into our visual spectrum according to the thermal radiation the device detects.

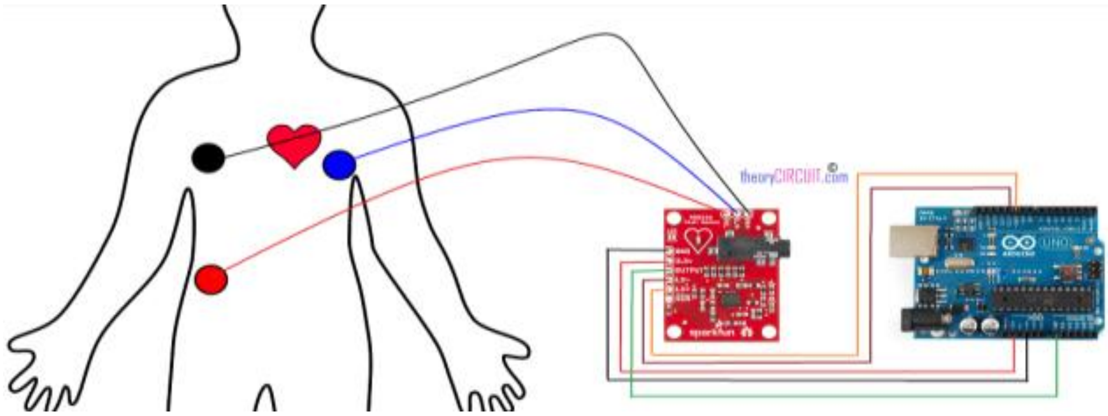


Figure 10. AD8232 and body electrode connection with Arduino [9]

As is known, each image in a computer environment consists of pixels. For each pixel, there is brightness and color information at that point [12]. All colors in nature are formed by the combination of red, green and blue color channels in different shades of RGB (Red, Green, Blue). These intonations are expressed in computer language with HEX or Decimal code as follows in Table 1.

Table 1. RGB color space decimal and HEX code information

RENK	HEX KODU	DECİMAL KODU
Red	#FF0000	255, 0, 0
Green	#00FF00	0, 255, 0
Blue	#0000FF	0, 0, 255
Yellow	#FFFF00	255, 255, 0
Cyan	#00FFFF	0, 255, 255
Purple	# FF00FF	255, 0, 255
White	#FFFFFF	255, 255, 255
Black	#000000	0, 0, 0

That is, the color shades of each pixel value of the images generated by the thermal imagers give us the thermal radiation, ie the temperature information in that region.

The designed interface program algorithm matches each temperature value with the difference of both RGB and gray hue in step intervals of 0.1 ^{o}C for premature body surface temperature analyzes (For example; 37.8 ^{o}C temperature value RGB (153,153,255), Gray (153,153,255) 209,209,209).

Premature thermograms are filtered by RGB color filtering method, and pixels with RGB color tones matched to the set temperature values are filtered and the other pixels are dimmed. Thus, the set temperature locations can be easily seen on the premature body surface. When converting premature thermal images to gray level gradations, each pixel takes values in the range of 8 bits 0-255 according to the RGB color tone ratios. Warm regions are white and cold regions are black. The gray color filtering method can also be used to determine the temperature value locations on the analyzed image.

In the designed thermogram interface program, median filtering technique is used to improve the image, improve the image and reduce the environmental / noise factors. The ability of the median filter to reduce the noise on the image while preventing the loss of details in the image has been an important factor in its preference.

3. User interface

3.1 Environment and Vital Parameters Interface

In this study, the Arduino Uno board receives both the environmental parameter of the incubator and the vital parameter data of the premature by means of the sensors mentioned above and sends it to the user interface designed in Microsoft Visual C # program via serial communication. The data flow between the Arduino and the interface program is performed via serial communication at a bandwidth of 115200 kb / s. This allows users to view temperature, humidity and O_2 concentration data of the incubator and ECG, SpO_2, pulse values of premature at a single interface. The environment parameters in the incubator are controlled via the user interface. User commands received from the interface as shown in Figure 11 are sent to the Arduino card. Arduino is programmed to evaluate incoming command data, send and control data to the relevant unit (fan, heater, O_2 source) to ensure that the incubator environment parameters reach the desired values.

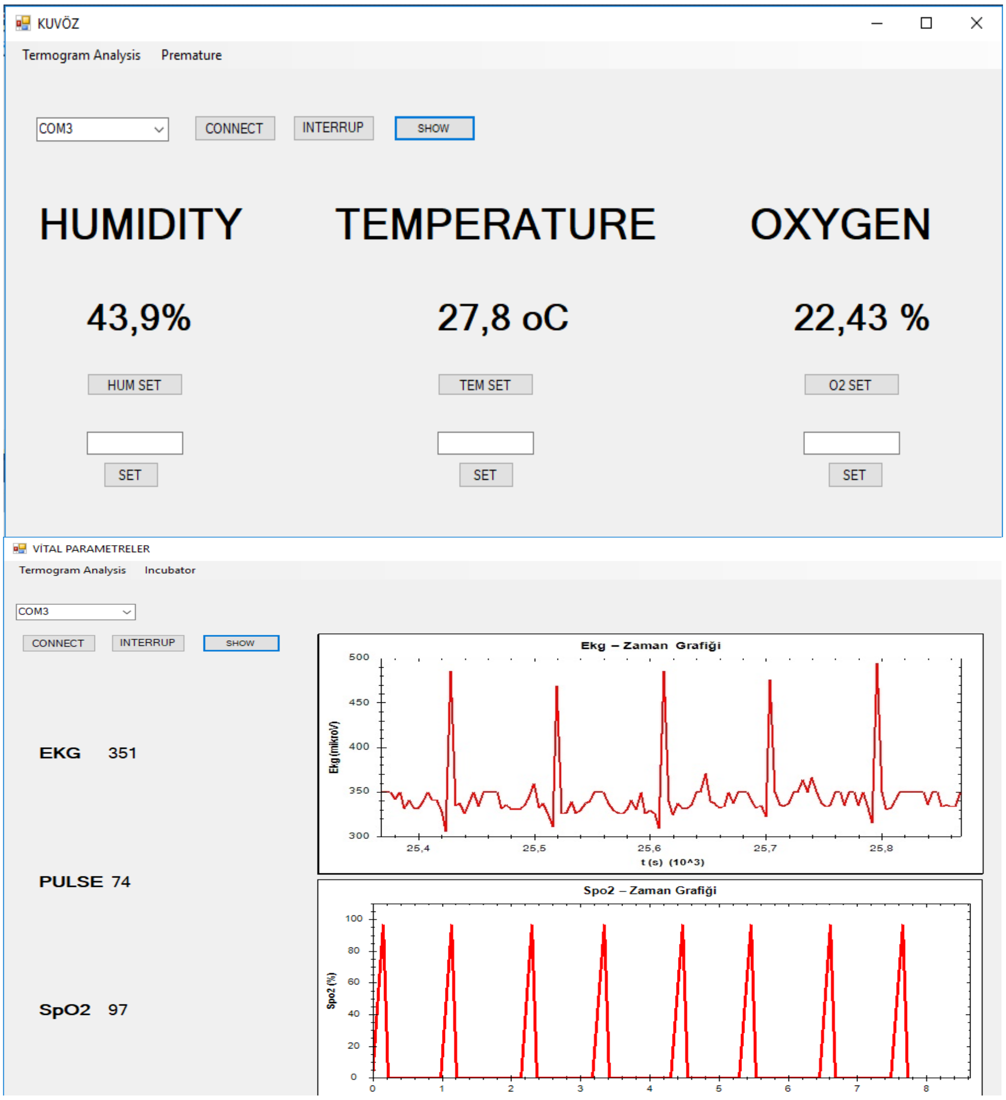


Figure 11. Media and vital parameters user interface screen

3.1 Premature Thermogram Analysis Interface

In this section, C # form tools are used for premature image-temperature analysis and Aforge.Net library designed for C # is used.
The main image section is selected by selecting the desired image from the file where the thermal images as illustrated in Figure 12 are stored. The commands on the form are described below.

Filtering command (RGB); Filter the pixels in RGB color values corresponding to the temperature parameter set from the TrackBar object, dim the pixels outside this value, and display it on the RGB **Filtering** screen. This is done through the Euclidean function in the Aforge.Net library.

Filtering command (GRAY);The gray tones corresponding to the temperature parameter set from the TrackBar object are displayed. This is done through the Threshold filter from the Aforge.Net library.

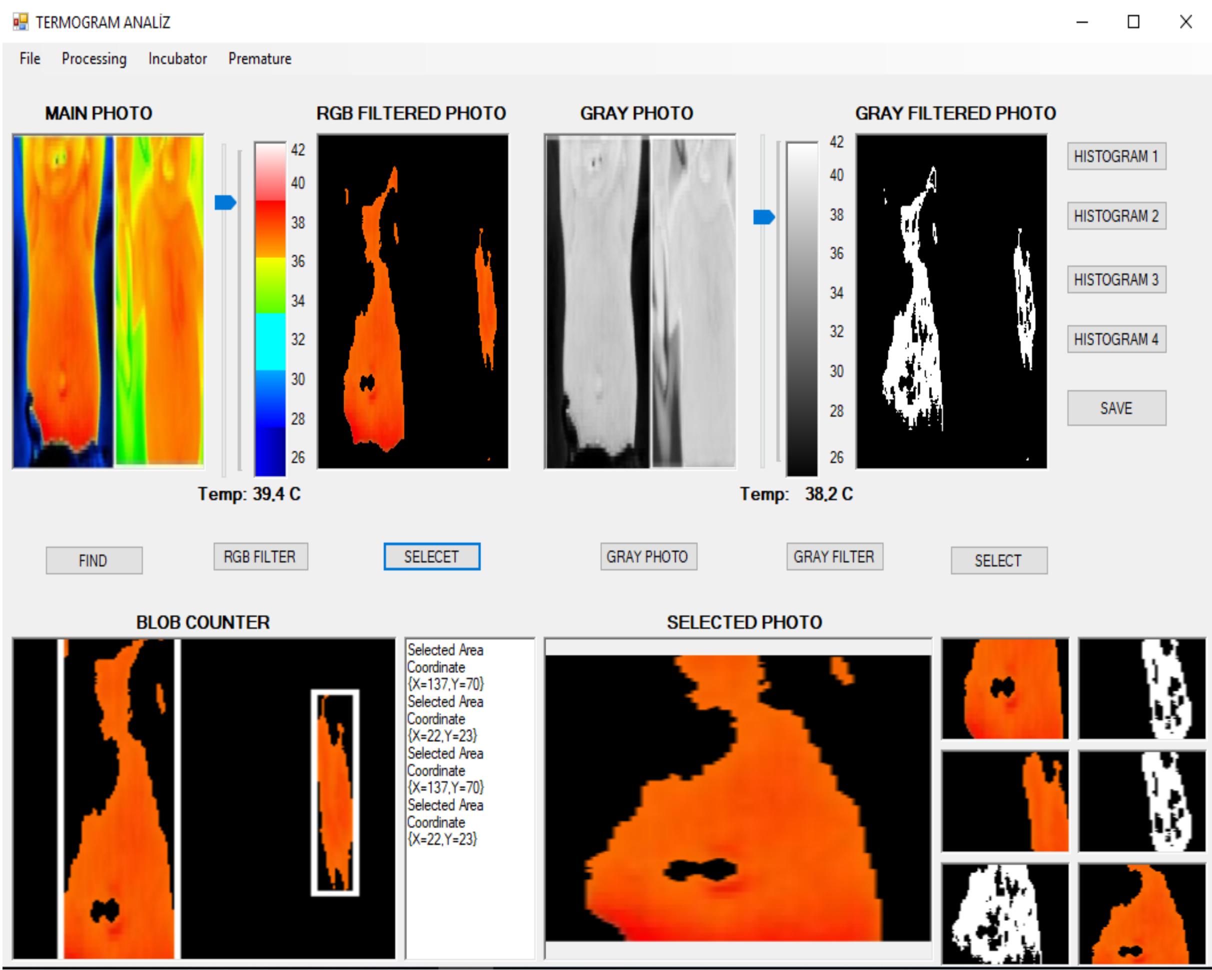


Figure 12. Thermal Imaging Interface Screenshot

Find Command; The filtered pixels are displayed on the **Find Screen** by enlarging the frame with the Blob.Counter function in the Aforge.Net library. The coordinates of these locations are also printed on the TextBox.

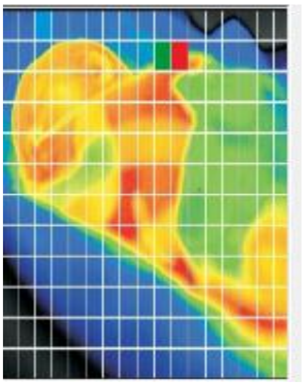
Select Commands; Allows you to select an area on the image in the RGB and Gray Filtering screens and magnify them to the **Select Screen**. The selected fields are also listed on the small screens at the bottom of the Select Screen.

Save Command; Allows you to save the processed image to the specified file.

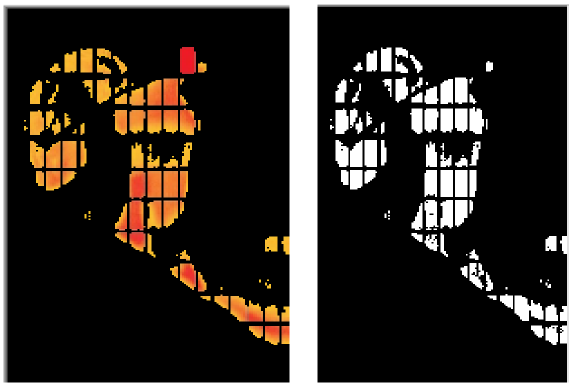
Thermal cameras can show temperature values in different color spectra according to software differences. For example, for a thermal imager with a temperature measuring range of 10-40^o C, the 10^o C zone is displayed in the darkest, the 40^o C zone is displayed in the lightest colors, or it can define temperature values in different shades. The color filtering algorithms in the study can be updated according to the color scale scale of the thermal imager to be used.

4. Results

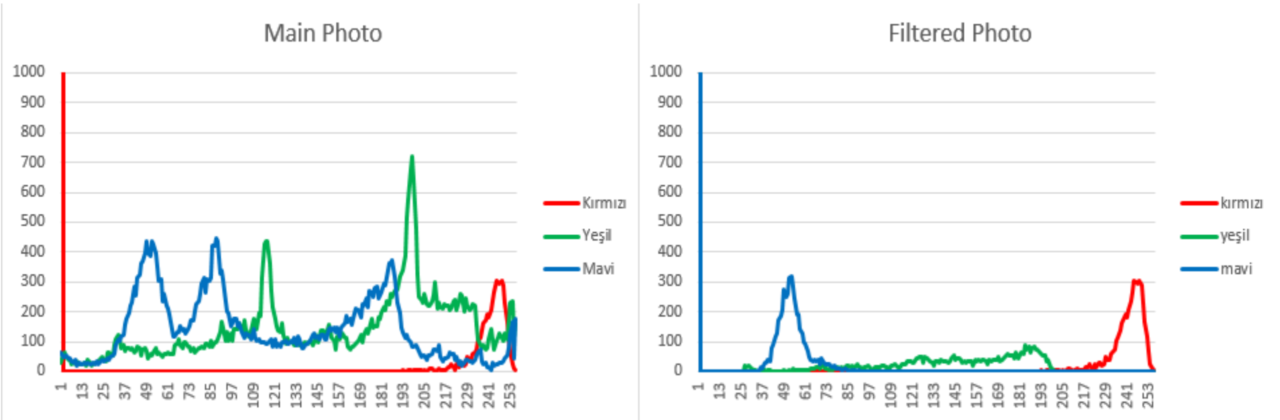
In the designed thermogram analysis interface program, successful results were obtained by studying both premature and adult thermal images used in previous studies in this field. It was seen that the locations of the desired temperature values on the thermograms according to the color-temperature scale set, emerged as a result of filtering operations. The filtered images obtained on some thermal images studied and the histogram graphs showing the pixel color-tone distributions of infant's infrared images are shown in Figure 13.



(a)

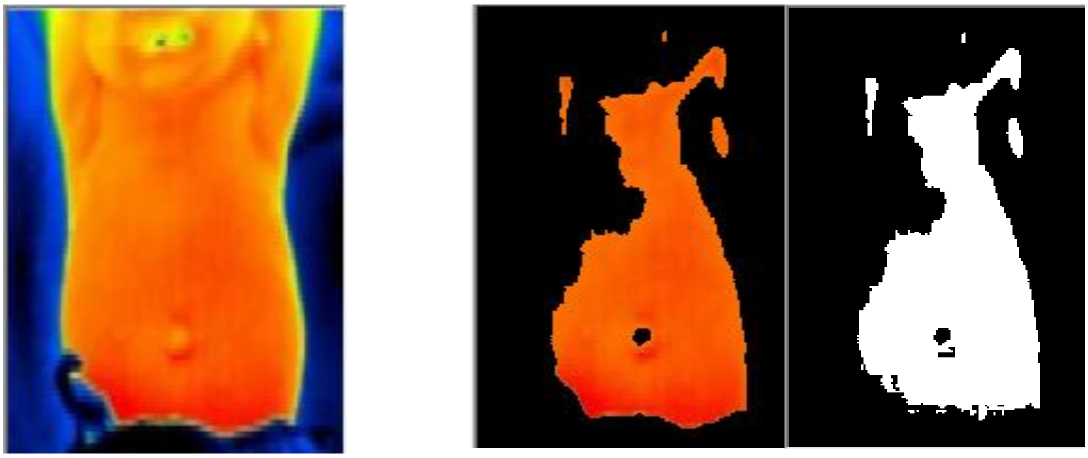


(b)

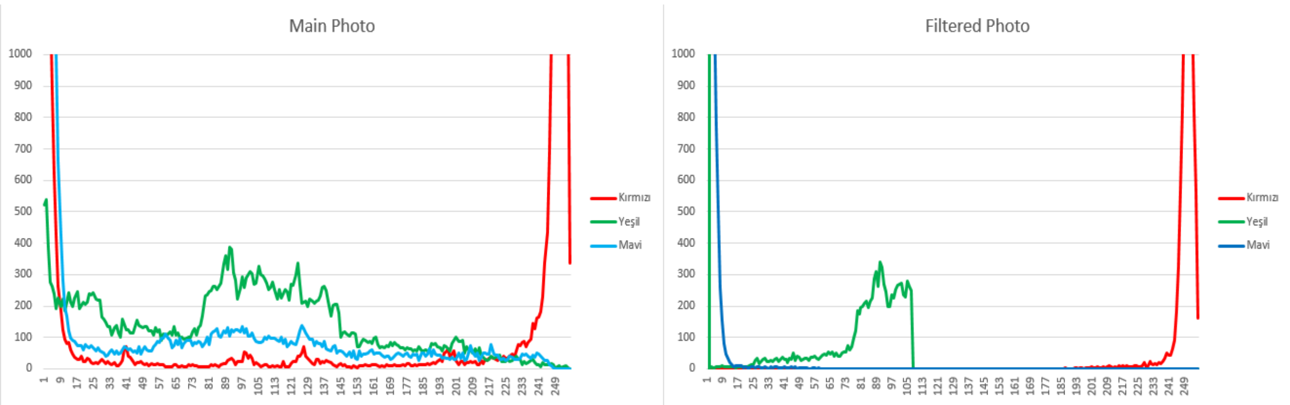


(c)

Figure 13.a) Infrared image of baby b) Filtered images c) Main and filtered image's histograms



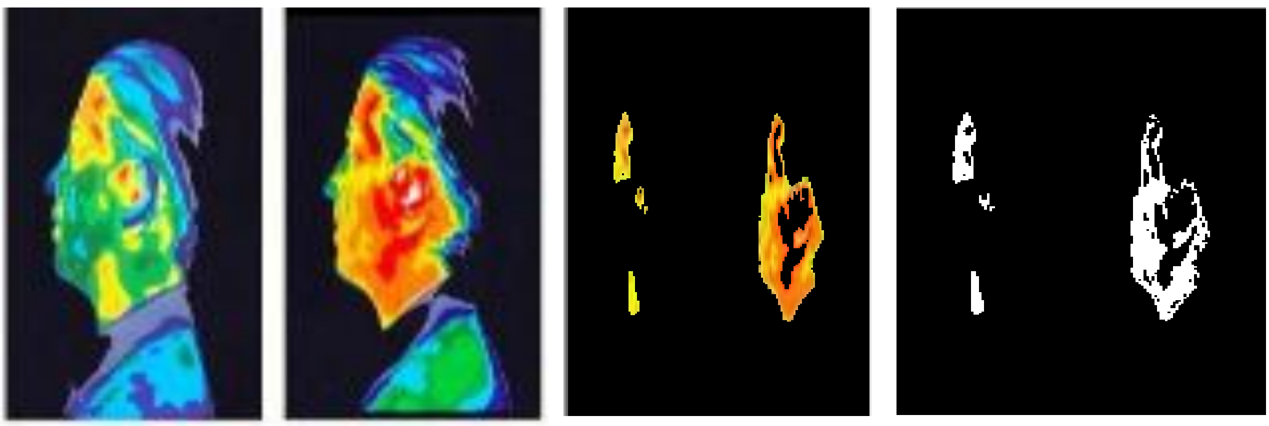
(a) (b)



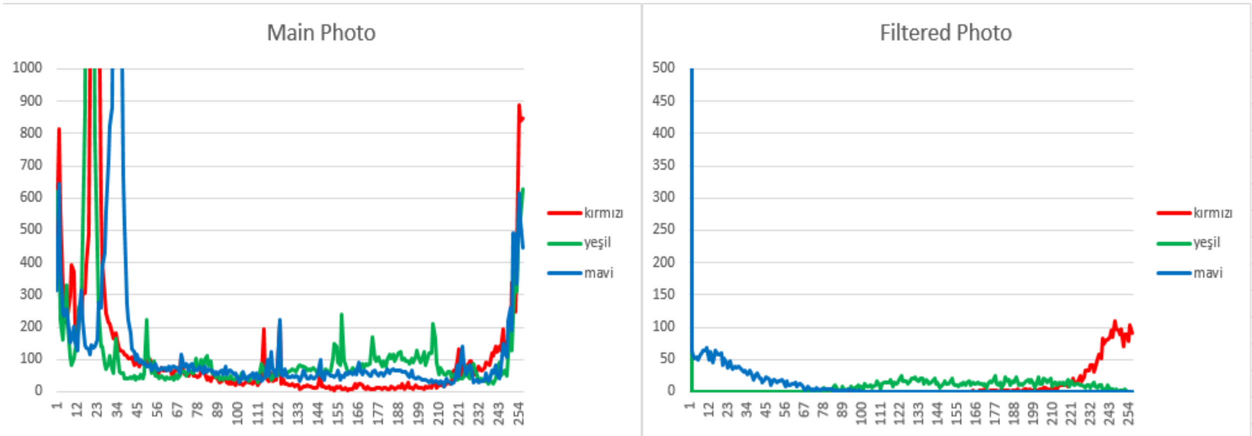
(c)

Figure 14.a) Infrared image of body b) Filtered images c) Main and filtered image's histograms

In figure 14, body of a child has been shown and temperature threshold value filtering is applied and both main and filtered image's histogram is illustrated. In figure 15, images of a person who monitored before and after a 15 minutes phone call is illustrated.



(a) (b)



(c)

Figure 15.a) Infrared image of cell phone effect b) Filtered images c) Main and filtered image's histograms

In addition, environmental and vital parameters were measured by sensors and transferred to the user interface designed in C #. Figure 16 shows the vital and environmental parameter data transferred from the Arduino card to the user interface. It was determined that the commands given through the interface can be evaluated and controlled by giving commands to the appropriate sources (fan, heater, oxygen source, etc.).

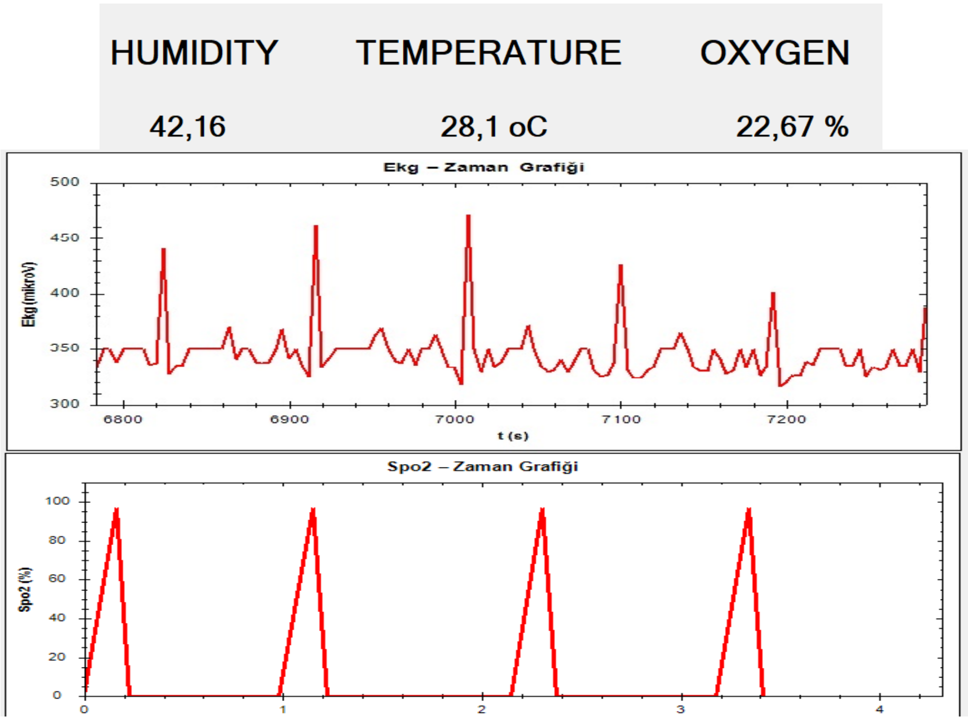


Figure 16. Vital parameter findings

5. Conclusion and Discussion

In the designed model, the thermograms used in the previous studies in this area have been studied and the locations of the temperature determined by the algorithms adapted to the thermal camera color scale from which the image is taken can be obtained. In this way, it is thought that premature children may be under continuous thermographic examination.

In addition, both vital parameters (pulse, body temperature, ECG, SpO_2) and ambient parameters (temperature, humidity and oxygen concentration) of prematurity can be measured and monitored on a single user interface. In this way, with a single interface program, it is thought that health personnel can control, diagnose and treat their premature children more easily, quickly and effectively.

This model, which is designed as an advanced stage of the study, includes infusion pump, injector, ventilator, etc. which are used in the treatment of prematurity. algorithms and systems that can control devices can also be designed and integrated. Using artificial intelligence techniques, however, the use and control of all these devices and systems can be carried out by means of the control system of the model within a certain reference range. In this way, the solutions and decisions made by artificial intelligence algorithms can be applied to premature very quickly. This may lead to the retention of premature life, and the faster and more effective treatment of health problems can be resolved faster.

References

[1] Megep, Biyomedikal Cihaz Teknolojileri, Kuvözler, http://www.megep.meb.gov.tr/mte_program_modul/moduller_pdf/Küvezler.pdf, 2012, Ankara, p 3-4, Date of Access 09.03.2019

[2] Megep, Anestezi Ve Reanimasyon, Vital Bulgular, http://megep.meb.gov.tr/mte_program_modul/moduller_pdf/Vital%20Bulgular%201.pdf, 2011, Ankara, p 3, Date of Access 09.03.2019

[3] http://www.3eelectrotech.com.tr/arsiv/yazi/129-kizilotesi-goruntuleme-ve-tibbi-termografi/, Date of Access 05.04.2019

[4] Susam. M, "Koroner Arter Cerrahisinde Termal Görüntüleme Kullanılarak Greft Değerlendirilmesi", Uzmanlık Tezi, 2005, p 9-13

[5] Karakücük H., "Zenom Benzetim Ortamı İle Arduıno Kontrolü, Yüksek Lisans Tezi", Teknoloji Enstitüsü Mühendislik Ve Fen Bilimleri Enstitüsü, 2014, Gebze.

[6] DHT22 Datasheet, https://cdn-shop.adafruit.com/datasheets/Digital+humidity+and+temperature+sensor+AM2302.pdf, Date of Access 12.03.2019

[7] Aydın G.B ve Özhan O., Pulse Oksimetre Tasarım Ve Analizinin Yapılması, Ubictüs, 2017, p. 46-48

[8] AD8232 Datasheet, https://www.richardsonrfpd.com/docs/rfpd/Predicting-and-Finding-Your-Limits-MS-2385.pdf, Date of Access 18.03.2019

[9] Heart Rate Monitor AD8232 Interface Arduino, http://www.theorycircuit.com/heart-rate-monitor-ad8232-interface-arduino/, Date of Access 19.03.2019

[10] Abbas, Abbas K. & Heimann, Konrad & Blazek, Vladimir & Orlikowsky, Thorsten & Leonhardt, Steffen, Neonatal infrared thermography imaging: Analysis of heat flux during different clinical scenarios. Infrared Physics & Technology. 2012, p 538–548.

[11] Günyel, B., Bala, E., Akar, G.B., Uzun ve Orta Dalga Boylu Kızılötesi Görüntü Kaynaştırılması, Signal Processing and Communications Applications, SIU, 2007, Eskişehir.

[12] Karakoç M., Net Platformunda Emgu Cv ve Aforge.Net İle Görüntü İşleme Tekniklerinin Uygulanması, İleri Teknoloji Bilimleri Dergisi, 5(3), 2016, Antalya.