A Health Monitor GUI for the elder

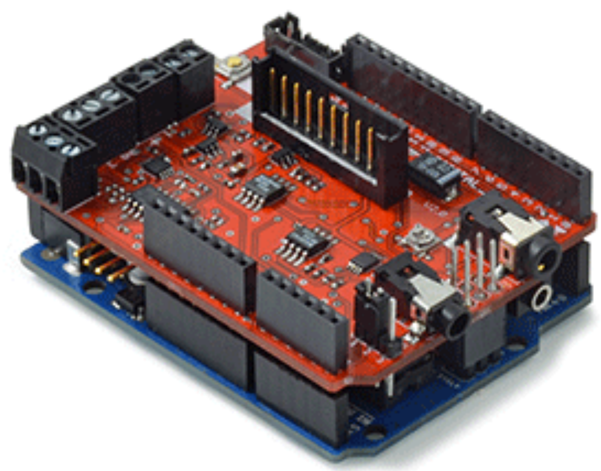

Fig. 1. The eHealth V2.0 platform mounted on the Arduino Uno R3

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A Health Monitor GUI for the elder

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***Abstract*— The latest innovations in the field of computational hardware technology integrates more the use of embedded systems in the healthcare. The aim of this project is to design an Arduino based GUI for the elder which monitors their health using three individual sensors; an ECG, EMG and respiration. After the retrieval of the data, the analysis and processing takes place. Filtering methods are being used for the attenuation of the noise in the signals with MATLAB. Appropriate metrics as the beats per minute, the QRS and PR interval, the contraction of a muscle detection, the respiration rate and volume are being extracted from the received signals. Subsequently, the results are saved in Microsoft Excel format in the patient's documents drive.**

***Index Terms*—Arduino, digital filtering, electrocardiogram, electrodes, electromyography, IIR filters, MATLAB, medical information system, microcontrollers, sensor system.**

I. INTRODUCTION

ADVANCEMENTS in the field of computational hardware technology facilitates the evolution of the medical instrumentation systems. With the age limit continually increasing globally, one could not ignore the importance and ease of using microcontrollers in the field of medicine.

After the age of fifty, the health of an individual starts declining, increasing the need for more regular check-ups. Especially for the elder, a remote health monitoring application is ideal because it allows them to monitor their sensitive health on a daily basis.

A. Aims & Objectives

The aim of this project was to design a graphical user interface (GUI) on MATLAB for the elderly, which would perform two functions: record data from three different sensors and store them in .xlc format (Microsoft Excel). The three sensors used were: an Electrocardiogram (ECG) sensor, an Electromyogram (EMG) sensor and a Respiration sensor, all provided from Cooking Hacks, Libelium Communicaciones Distribuidas S.L.. The sensors were connected to an eHealth v2.0 shield from Cooking Hacks, which was mounted to an Arduino Uno R3. The Arduino was connected to a computer with a usb type B. With MATLAB, the signals received were processed and analyzed in order appropriate metrics to be extracted and for noise reduction as well. A brief system's diagram is presented in fig. 2.

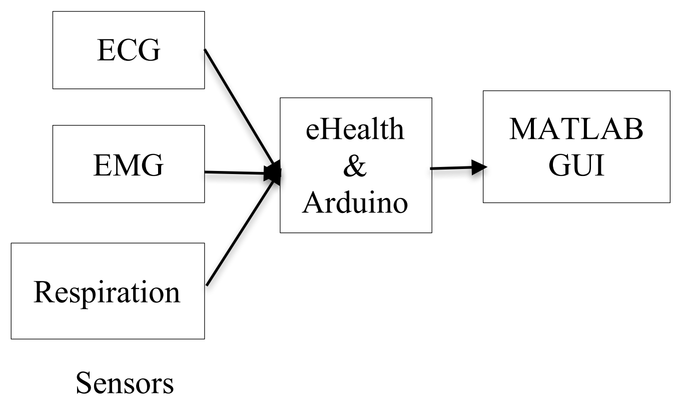

Fig. 2. System's Diagram

B. Theory Overview

In this section, a brief theoretical background will be given for the data retrieved from the sensors as also the GUI and the noise sources in the signals.

i. Electrocardiogram (ECG) [1]

The electrocardiogram is the signal that provides information for the electrical and muscular activity of the heart. One cycle of an ECG (fig. 3) consists of six different waves P, Q, R, S, T and, U. The P, T and U waves can be modeled with a sinusoid wave and Q, R and S with a triangular pulse. From the P wave information with regards to the propagation time of the impulse through the atria, can be extracted. During the PR segment, the impulse propagates to the ventricles. At the QRS complex, the atrial repolarization and ventricular depolarization occur, and it provides information about the ventricular systole. With the R and S waves, the impulse propagates to the whole tissue. At the

This 3rd year Individual Project was performed at the Department of Electronic & Electrical Engineering at the University of Sheffield, UK It was supervised by Dr. Andrew Maiden (e-mail: a.maiden@sheffield.ac.uk).

ST segment ventricles contract and the ventricular polarization happens. The U wave's origin is uncertain, and it is not detected in every ECG; some believe it represents the repolarization of the papillary muscles. Each segment and interval of an ECG must be within the normal values (Table I) for a healthy individual. Various pathologies can be detected from differences in specific segments and intervals. For example, variations in the QRS complex can indicate the pathologies of fibrillation and arrhythmia, differences in the ST segment indicate ischemic episodes and differences in the QT interval can point out hypertrophy and heart attacks. Moreover, from further analysis of the ECG an individual can detect the orientation of the heart, the thickness of the heart and the blood flow.

Heart rate	60-120 bpm
PR interval	0.12 – 0.20 s
QRS interval	≤ 0.12s
QT interval	<0.40 s
P wave amplitude	≤ 3mV
Q wave	<0.04

Table I ECG normal values [8]

ii. Electromyogram (EMG) [6]

The contraction of any muscle is associated with electrical changes called the neural stimulation. Electromyography signals measure the electrical activity of any skeletal muscle during its contraction. It is dependent on the morphological and physiological properties of each muscle. Clinical diagnosis of various pathologies as also a plethora of biomedical applications have as pillar electromyography. Management and rehabilitation of motor disability are one of the leading areas that EMG is implemented as it can be used as a control signal for prosthetic limbs. When analyzed it can detect both muscular and neurological disorders, the activation levels of a muscle and it is a way of monitoring the neuromuscular system of an individual. It is important to mention that there are two sensor types for detecting an EMG signal: the surface one and the intramuscular one. In this project for the detection, a surface sensor was used.

iii. Respiration [2]

Inhalation allows irritant particles, smaller than 10 μm, and pathogens to enter an individual's body. The vast surface area of the airways and the warm and humid environment are ideal for the cultivation of bacteria, fungus, and other pathogens. The earliest indicator of a physiological instability is the abnormal respiration rate. Thus, it is essential to track the respiratory rate of an individual and the volume of inhaled air regularly. Pathologies as hypoxemia and apnea can be diagnosed at an early stage from the respiration. The normal range for the respiratory rates and the respiratory minute volume by age can be found in Table II.

Age group	Respiration rate [breathes/min]	Respiratory minute volume [mE3/min]
Adult	12-18	$4.2\text{x}10^{-3}$-4.8 $\text{x}10^{-3}$
Elderly ≥ 65	12-28	5.0 $\text{x}10^{-3}$
Elderly ≥ 80	10-30	4.9 $\text{x}10^{-3}$

Table II Normal Range for the respiratory rates and the respiratory minute volume by age with the activity level of the patient being sedentary / passive. [9]

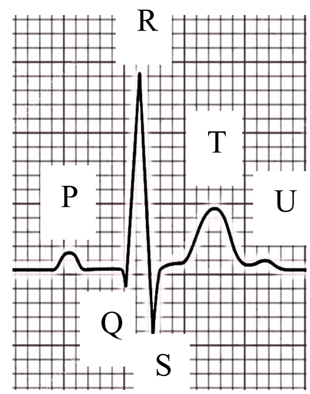

Fig. 3. One cycle of a typical ECG [7]

iv. Graphical User Interface (GUI) [5]

A graphical user interface is a computer program which uses graphical interfaces, as push buttons, toggle buttons, sliders, axes, textboxes and so on, that have the functionality of callback functions. This allows an individual to use a computer program without the need of typing the functions in a command window. Nowadays most of the operating systems for computers use GUIs.

With the elderly being the end user of this project, particular attention must be given to the design of the GUI. Vision and hearing decline as also as motor skills and short-term memory, as people get older. This is the reason that in this GUI the fonts that were used were more than 16 pixels, the diagonal distance is more than 11 mm for the interaction buttons, and in general, there was an endeavor to keep the GUI as simple as possible. [15]

v. Noise Sources

a. ECG [21]

For the ECG signal, there is muscle noise due to the electrodes motion, power – line interference, baseline wander and the high-frequency T-waves that are similar to the QRS complex. The line frequency interference occurs because the cables connected to the sensors are susceptible to electromagnetic interference from the supply lines. Also, because the ECG signal is a type of EMG signal the patient needs to be in a resting position because any given muscle contraction will lead to extra noise. The reason is that there will be potential detected from the neurons that stimulate the given muscle which will interfere with the signal's detection.

b. EMG

The use of a surface sensor can be inaccurate because the signal detection occurs by mounted electrodes on the patient's skin; where the acquired signal is a composite of all the underlying muscles of the skin, in that specific area. Therefore, this kind of detection is influenced by the depth of the tissue at the recording site, which means that it depends on the patient's weight. So, in the detected signal the noise levels will be high, and the filtering process decreases the signal to noise ratio as also the distortion of the signal will rise.

c. Respiration

The sensor used is the newest model provided by the company, which compared to the last one it does not use a two-wire lead to connect to the eHealth shield, but instead, it uses a single 3.5mm jack which requires a 3.5mm socket to be connected. The socket's connection to the board was poor even though the soldering connections were remade as also, the socket was replaced with a brand new. The results were still poor, but when held in stable position there was a decent connection were results could be retrieved. Furthermore, body discharge as sweat or mucus would interfere with the results.

In addition to the noise as mentioned above sources, there is also a random noise that occurs.

II. Economic, legal, social, ethical and environmental context

The product's end user primarily is the elderly. The requirements for successful use of the product requires a terminal which supports MATLAB; as also, the sensors, the Arduino and the shield to be obtained by an individual user. From an economic perspective, the cost of everything is as following: Disposable electrodes pack 84€, EMG sensor 48€, ECG sensor 42€, Airflow sensor 96€, eHealth v2.0 shield 240€, Arduino Uno R3 20€. In total, it is 530€that converted is £470 for the hardware.

Furthermore, for MATLAB home license the cost is £105 per year. Hence, the total cost is £575 without the price of the terminal that will run.

From a security of data perspective, in the communication link-layer there is AES encryption core for 802.14.5 (ZigBee) and WPA2 for Wi-Fi and also, in the application layer by using the HTTPS (secure) protocol, it is ensured the safe point to point security tunnel between each sensor node and the web server.

III. Methodology

In the following sections, the methodology will be discussed thoroughly. At first the design of the GUI will be analyzed; subsequently, the communication between the system's components; then, for every signal the acquisition, the filtering process and the extraction of the appropriate metrics will take place.

A. Design of the GUI

For the design of the GUI, MATLAB function guide was used to create four .fig files which were hierarchically interconnected through callback functions, as shown in fig.4.

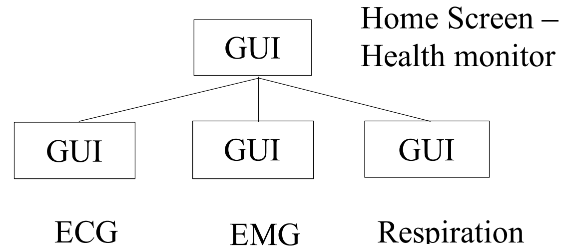

Fig. 4. GUI Hierarchical interconnection

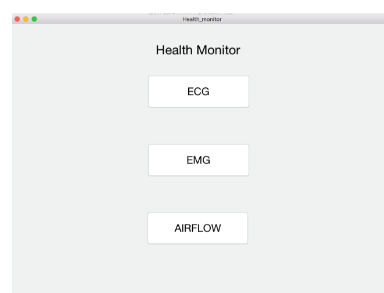

Fig. 5. Home Screen GUI

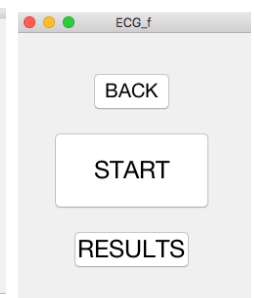

Fig.6. ECG GUI

In the Home Screen GUI, three Buttons were added as shown on fig. 5, which correspondingly were the callback functions for the three "child" GUIs the ECG GUI, the EMG GUI, and the respiration GUI. In every "child" GUI the layout was the same: three buttons Back, Start and Results as shown in fig.6. These three buttons were callback functions respectively for returning to the Home Screen, starting the collection of data and accessing the previous result for an individual patient. A minute after the Start button has been pressed a figure is being obtained with the plot of the appropriate graph as also the relevant metrics are shown. With the Results button pressed in any of the GUI's, the callback function called would open the file from the patient's Documents folder, and the Excel files would be displayed.

B. Communication between the system's components

At first, the MATLAB support package for Arduino hardware was downloaded and installed to the computer. The initial approach of the project was to use the function:
$v = readvoltage(a,'Analog\ input)$ *(1)*, which reads the

voltage at ‘analog input’ from a, the Arduino where a connection has been established by using $a = arduino('port','board')$, where port is the usb port that the device is being connected and board is the model. The analog inputs that were used to retrieve the three signals where ‘A0’, for ECG and EMG and ‘A1’ for the respiration data. But this way was not implemented finally because the maximum sampling frequency of an analog input through an Arduino Uno via (1) is approximately 100 Hz which is not enough for the filtering of the ECG or the EMG.

The method used instead was to upload on the Arduino board a script using the Arduino Ide which would run on a loop and would continuously read every 5ms a value from analog input 0 and then after 5ms a value from the analog input 1. The baud rate for both the Arduino and MATLAB was set to 9600 which is the maximum baud rate of MATLAB. Using the following function, $s = serial('port')$ for as long as the serial port would remain open inside a for loop it would acquire both data, either ECG – respiration or EMG – respiration and save them in a matrix. Afterward, to distinguish the respiration data from the ECG or EMG data, an if clause was used to determine the parity of the collected data, where the odd data were the ECG or EMG data and the even ones the airflow data. As it can be seen from the schematics (Appendix), there are three leads on the eHealth sensor called analog 1,2,3. By connecting analog 1 & 2 the ECG data pass through Arduino analog 0 port and by connecting analog 2 & 3 the EMG data pass through Arduino analog 0 port.

C. Sensors

i. ECG

For the ECG sensor three electrodes were used to obtain it. The positive was placed on the right-hand side of the chest, the neutral on top of the heart and the negative one on the lower left side abdomen. The Arduino has a built-in analog-to-digital converter which turns the detected analog voltage value to a digital one. Because the range of the digital ones is [0,1023] [4], after collecting the data; the data was divided by 1023. Afterwards it was multiplied by 5 because the range of the ECG sensor is from 0V – 5V. Then the Pan – Tompkins algorithm [3] was used for the noise reduction and QRS complex detection. A block diagram is shown in fig. 7. The sampling frequency used was 200 Hz. For the noise reduction, the raw ECG signal was passed through a digital bandpass Butterworth filter which consists of a cascaded high pass and low pass filter. The transfer function difference equation for the low pass filter is (2), and the difference equation is (3), for the high pass filter the transfer function is (4) and the difference equation is (5). The bandpass filter reduces the muscle noise, the power-line interference, the baseline wander and the high-frequency T-waves. For the maximization of the QRS complex energy, the passband must be approximately 5-15 Hz.

$$H(z) = \frac{(1 - z^{-6})^2}{(1 - z^{-1})^2} \qquad (2)$$

$$y(nT) = 2y(nT - T) - y(nT - 2T) + x(nT) - 2x(nT - 6T) + x(nT - 12T) \qquad (3)$$

$$H(z) = \frac{(-1 + 32z^{-16} + z^{-32})}{(1 + z^{-1})} \qquad (4)$$

$$y(nT) = 32x(nT - 16T) - [y(nT - T) + x(nT) - x(nT - 32T) \qquad (5)$$

The cutoff frequency for the low pass filter is about 11 Hz, and the gain is 36. The filter has a processing delay of six samples. For the high pass filter, the cutoff frequency is about 5 Hz, and the gain is 32. The filter’s processing delay is 16 samples.

Afterward, the signal was inputted to a Derivative filter to access the QRS – complex slope information. The transfer function for the derivative filter is (6), and the difference equation is (7). By differentiating the low-frequency components are suppressed to enhance the QRS complex.

$$H(z) = \frac{1}{8T}(-z^{-2} - 2z^{-1} + 2z^{1} + z^{2}) \qquad (6)$$

$$y(nT) = \frac{1}{8T}[-x(nT - 2T) - 2x(nT - T) + 2x(nT + T) + x(nT + 2T)] \qquad (7)$$

After the derivative filter, the signal is squared using equation (8). By squaring all the data points are positive, and it amplifies the output of the derivative filter enhancing more the QRS complex.

$$y(nT) = [x(nT)]^2 \qquad (8)$$

Following, implementing the moving window integration (MWI) we obtain waveform information with regards to the QRS complex as also the slope of the R wave. The equation used was (9).

$$y(nT) = \frac{1}{N}[x(nT - (N - 1)T) + x(nT - (N - 2)T) + \cdots + x(nT)] \qquad (9)$$

To obtain the QRS complex, the graph of the MWI must be plotted, and from the graph, an individual has to find the value that the curve intersects the x-axes; that’s the start of the Q signal and then the peak of the curve; which is the finish point of the S signal. To retrieve the beats per minute (bpm) the number of peaks was calculated against one minute [13]. For the PR interval, the P wave must be identified which is found again by finding the peak. The interval starts at the end point of the P wave and finishes at the start of the R wave.

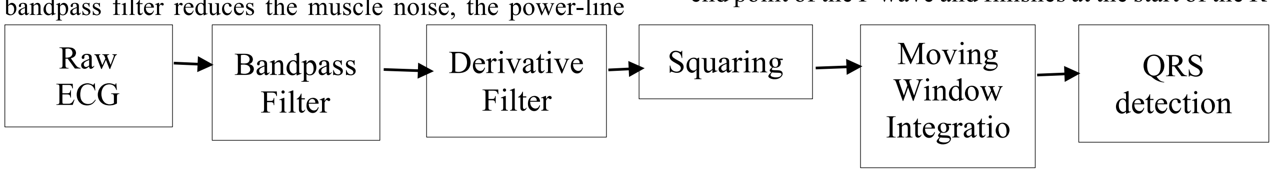

Fig. 7. Pan – Tompkins algorithm block diagram

ii. EMG

For the EMG signal, the data were collected using three electrodes which were mounted on the skin surface. The ground electrode was placed on the internal side of the elbow; the E electrode was mounted on the top part of the elbow where the veins are, and the M electrode was mounted on the bicep. After collecting the data; the data were detrended removing the DC offset of the signal and subsequently were rectified [17], [18]. Afterward, they were filtered using a low pass Butterworth filter with cut off frequency of 10 Hz. The sampling frequency used was 1 kHz. The next step was to eliminate the phase shift of the signal using the command filtfilt on MATLAB. From the obtained signal after plotting the graph the time intervals where the muscle was contracting and the time intervals where the muscle was resting can be identified.

iii. Respiration

For the Respiration sensor, a thermocouple sensor was used which consists of three leads. The two prong leads where inserted in the nasal cavity and another one that hangs midair in the middle of the mouth. The thermocouple sensor detects changes in the thermal airflow as also as alterations in the nasal temperature air. After collecting the data to retrieve the respiration rate the number of peaks had to be found in one minute from the curve, and to retrieve the inhaled respiratory volume the area had to be calculated underneath the graph.

IV. Results & Evaluation

For the ECG sensor, the fig. 8 shows the signal received from the Arduino Serial Plotter. Fig.9 shows the 1s – 5s of the raw ECG signal on MATLAB. Fig.10. shows the signal through the bandpass filter, the derivative filter, the squaring and the moving window integration. Table III shows the average QRS and PR interval detected when tested in a healthy patient.

For the EMG sensor. Fig. 11 shows the filtered and rectified signals.

For the respiration signal, fig. 12 shows the signal that was being received.

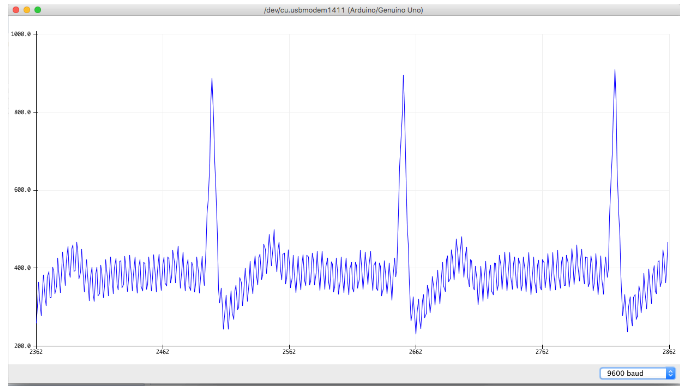

Fig. 8. Raw ECG signal received by the Arduino Serial Plotter

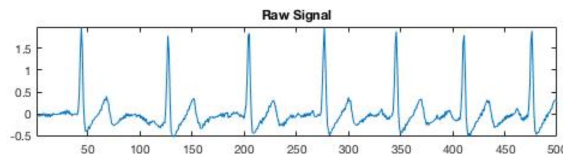

Fig. 9. Raw ECG signal detected with MATLAB

Mean QRS complex interval [s]	Mean PR interval [s]
0.20	0.22

Table III. Mean QRS and PR intervals extracted from the ECG signals detected, when tested on a healthy patient.

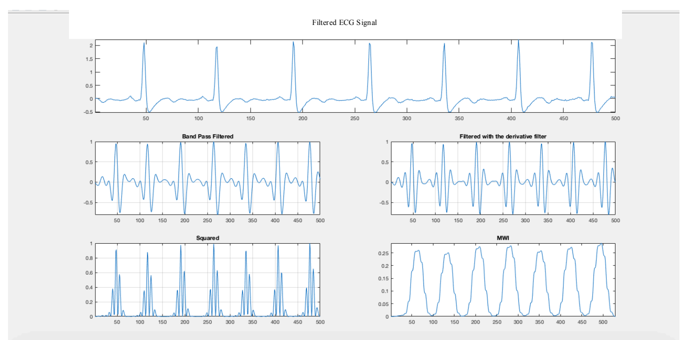

Fig. 10. Filtered ECG signal, Bandpass filtered ECG, Dervative filtered ECG, Squared ECG, Moving Window Integrated ECG

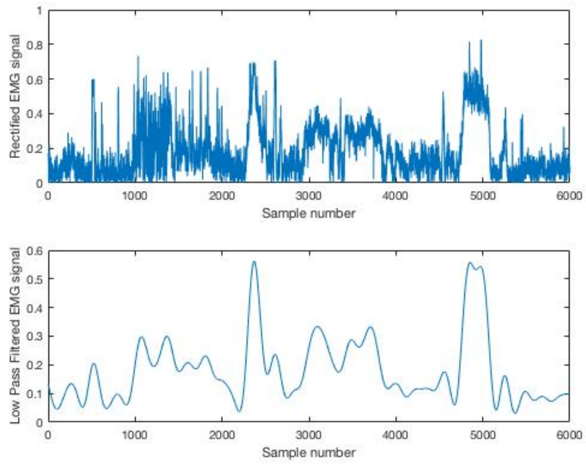

Fig. 11. Rectified and Low-pass Filtered EMG signal

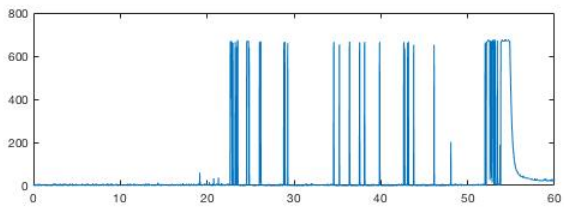

Fig. 12. Respiration signal

V. Discussion

From Table III it can be observed that the mean QRS complex interval calculated was 0.20 s and the mean PR interval calculated was 0.22s. Although it was tested on a healthy patient, both values were outside the normal values of an ECG compared to Table I, for 0.08s and 0.02s respectively. Therefore, there is still noise in the signal and the code used needs further investigation. With regards to the ECG signal comparing the raw with the filtered one it can be noticed that the majority of sound has been removed. The difference found in the QRS complex as discussed above is evidence of noise existence. For the EMG signal due to the change in methodology discussed in part III.B there was not enough time to extract more information and metrics out of the graphs apart from that around 2500 and 5000 samples the bicep muscle was contracting and around 1000 and 4000 samples the muscle was resting. For the respiratory sensor as an individual can observe on fig. 11 it was really difficult to maintain a steady connection with the sensor but in the interval [52,60] it can be seen that the inhaling and exhaling curves are visible. So there was a successful connection.

VI. Conclusions

Reflecting to the initial aims and objectives the project was set back, and some of the primary set objectives were not completed. The issue was as mentioned before, the maximum sampling frequency of the analog input through Arduino. Also, the respiration data was hard to obtain resulting to distorted data or no data at all at some occasions; furthermore, with the GUI it was noticed that while running the GUI (Matlab being busy) if the script were paused the Matlab software would crash. Therefore, there is more improvement to be done with the code. But because the main objectives of designing a GUI retrieving the signals, analyzing them and extracting appropriate metrics was completed, it can be considered as a successful project.

VII. Future Work

For future work, the remaining of the objectives that were not completed would be a priority. The feature of alerting the nearest medical center with an added GSM antenna would be investigated, as also the possibility of contacting the patient's general practitioner and an emergency contact. The connection with the computer to be wireless, providing a more accessible interference with the patient. Moreover, to provide support for other countries units and to buy a switch for the ECG/EMG junction. Furthermore, the more in-depth analysis of the EMG signal will take place as also the addition of more electrodes for the ECG signal analysis.

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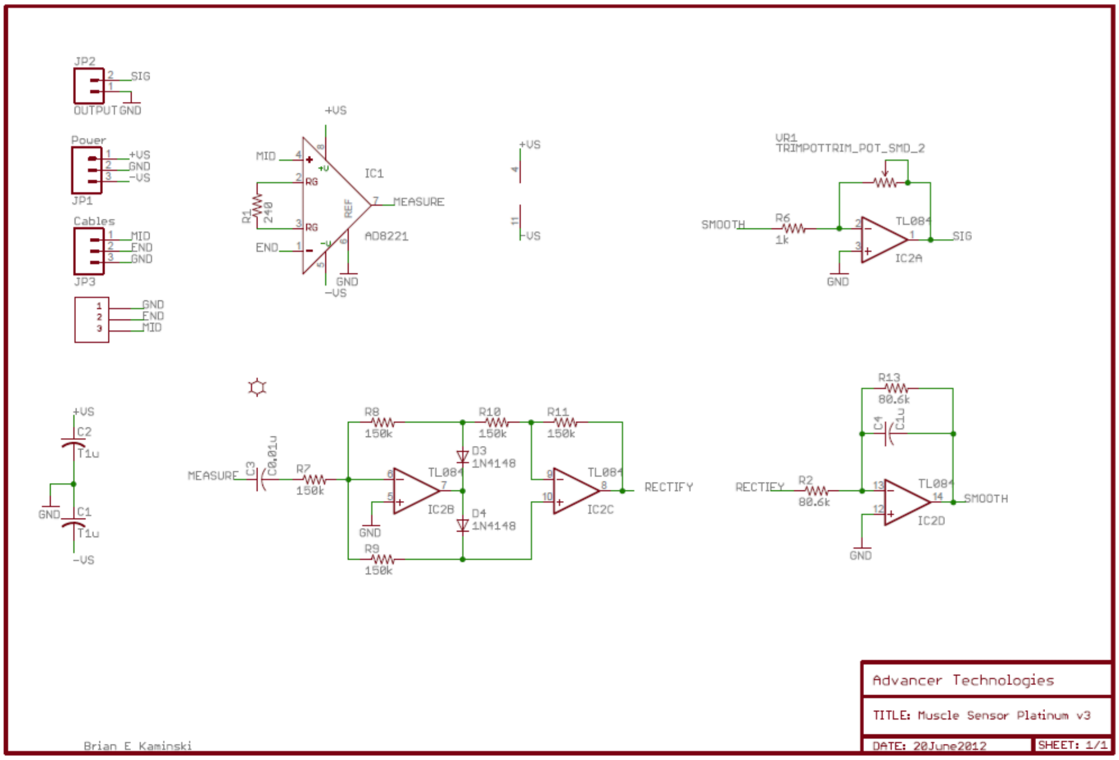
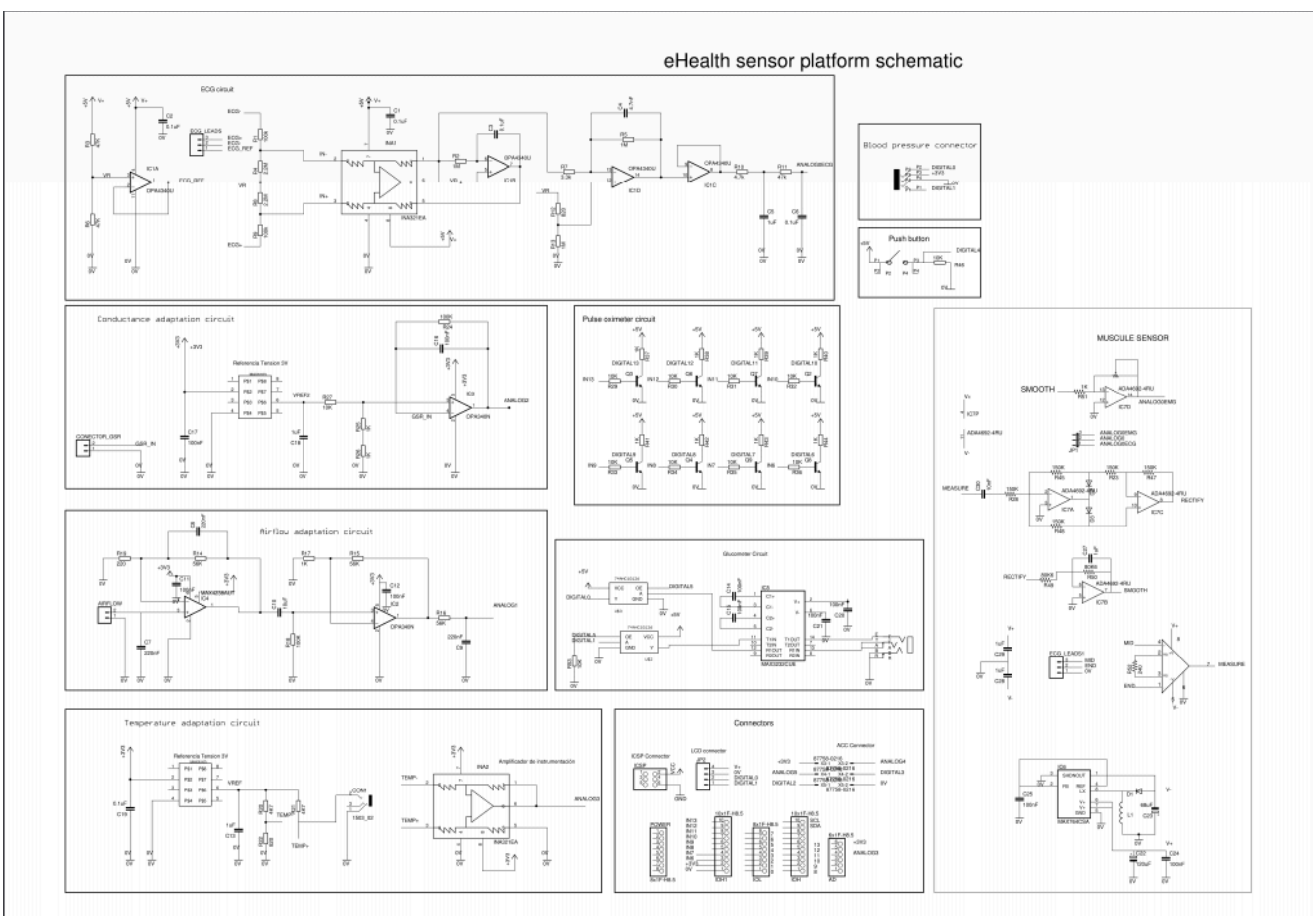
APPENDICES

The schematics of the eHealth v2.0 platform.



The "EMG v3 Sensor"



THE UNIVERSITY OF SHEFFIELD **Department of Electronic and Electrical Engineering** **3rd Year Individual Project** **Project Initialisation Document**			
Student Name	Ioannis Velgakis		
Project Title	Health Monitor		
Supervisor	Dr. Andy Maiden	**Second Marker**	N/A

Description and aims of Project:

After the age of forty the health system of an individual starts gradually to decline, increasing the need of more frequent check-ups. Especially for elder people whether they are healthy or not the possibility of a daily check-up is ideal.
The aim of this project is to develop an application which remotely monitors the health of the elderly. Using MATLAB's app developer, a graphical user interface will be built where, data will be collected using three integrated sensors to a microprocessor, an Arduino Uno. Those sensors are an electrocardiogram (ECG) sensor, an airflow sensor and a temperature sensor. After filtering out the noise, and analysing the data, the results will be presented accompanied with an estimating medical diagnosis. Furthermore, a health report will be generated which will be stored in a database for future reference. Finally, in case of an emergency the nearest medical centre will be alarmed as also the patient's general practitioner and his / her emergency contacts.

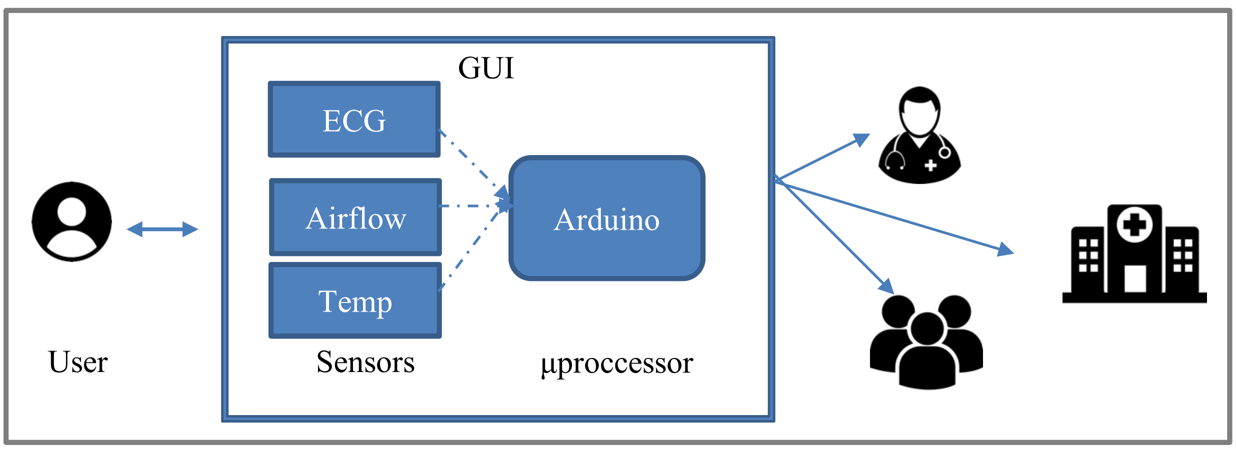


Figure 1: System diagram of the health monitor

Literature review:

This project will provide to an individual patient basic constant monitoring over his / her health, using a system of three integrated sensors which can be used with ease: the electrocardiogram, airflow and temperature sensors.
The electrocardiogram sensor can detect anomalies in the rhythm, and changes in the electrical functions of the heart. Many pathologies can be detected as: ischemia, tachycardia, bradycardia, arrhythmia and hyperkalaemia. One cycle of an electrocardiogram consists of a P wave, a PR segment, the QRS complex, the ST segment, the T wave and the U wave. From the P wave information, with regards to the propagation time of the impulse through the atria, can be extracted. During the PR

can be identified. From the QT interval, several pathologies can be pointed like hypertrophy or heart attacks. To acquire the data three electrodes will be used: a positive, a negative and a neutral. [1]

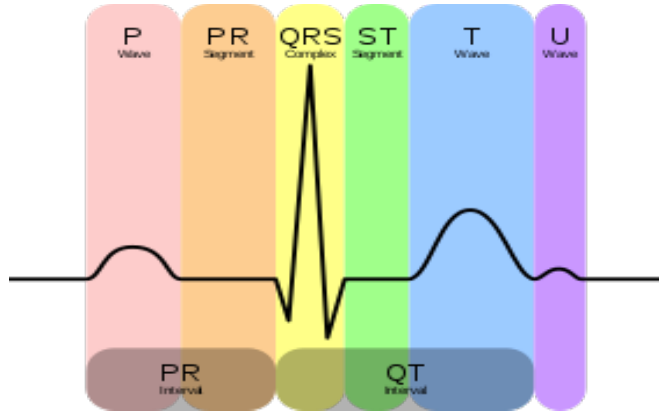


Figure 2::One cycle of a typical ECG [2]

The earliest indicator for physiological instability is the abnormal respiration rate. Using the airflow sensor an early diagnosis for both hypoxemia and apnea can be given. The sensor itself consists of three lids. The two of them have a prong shape and are inserted in the nasal cavity where the last one is hanging on the middle of the mouth measuring the thermal airflow change between the oral and nasal and also, measures the temperature of the air. A healthy adult has from fifteen to thirty breathes per minute. [3] Furthermore, respiration rate can be detected with high accuracy using a single lead ECG monitor, a 0.2-0.8 Hz bandpass filter and implementing the randomized response technique. [4]

Altering temperature is one of the first stages of the immunity system. By adjusting it higher or lower than the normal, the organism exterminates some malicious microorganisms that intruded the individual's body. Throughout the day the body temperature fluctuates and it depends upon: the place of the body that the measurement is taken, the time of the day and the activity level at that time.

The raw data collected from those sensors have been exposed to two major noises [5] during the measurements: the biological ones and the environmental. Biological noise sources, for example, are the change of the electrocardiogram's amplitude due to respiration, the exudation of mucus or sweat leading to malfunction on the airflow sensor and muscle contraction or electromyographic interference. Examples of environmental noises are the power line interference, surrounding radio frequencies, instrumentation noise and the electrode contacts.

Without the noises removed from the carrier signal some pathologies are not identifiable. For example, classification of the heart and detection of arrhythmia can only be achieved with removing almost all the noise from the signal. For ECG noise reduction, there are plenty different methodologies, who all have in common that the filtering process must be highly accurate and should ensure fast filtration. [6] For example, the following circuitry can be used for digital filtering of the ECG: a cascading zero-phase bandpass filter, an adaptive filter and a multi-band-pass filter. Another example, is replacing the filter circuits and using the microprocessor of the Arduino, which will slow it down for other real-time analysis algorithms. [7] In general, with the filtering option an individual chooses, he/she must consider the one with the highest signal to noise ratio (SNR) and also the shortest delay and calculation load.

For the temperature sensor, actually the voltage has to be measured in the area that an individual patient intends to take a measurement and then that value relates to the operating temperature there, so in order to have accurate readings the sensor needs to be regularly calibrated.

For the graphical user interface (GUI) itself because the end user will be the elderly, special attention must be given to the design. Vision and hearing decline as also as motor skills and short-term memory, as people get older. This is the reason that it is good to: avoid small fonts, use similar colors as they cannot be distinguished by them, using the color dark blue, having the option to use a screen reader and not to have a high contrast ratio with the text. [8]

Project Specification:

1. Implementation of the three sensors to the Arduino with the e-health shield.
2. Develop a GUI, easy-to-use for elder patients, with which they will retrieve the data themselves and get the results displayed on the screen.

6. Generate a health report from the extracted data and save it in a database, creating an archive for future reference. Then, if it is an emergency alert the nearest medical centre, the emergency contacts and the patient's general practitioner sending them the form.
7. Provide support for other countries' units and different thresholds, setting changing the fonts size.
8. Design & 3D print a case for the device.

Project Schedule:

A – Background research
B – Report 1
C – Connect everything together and start with learning how to interact with MATLAB's Apps
D – Start the signal processing
E – Second Marker Meeting 10/11/17
F – GUI
G – Interim Report 15/01/18
H – Report med form & emergency contacts & medical centre
I – Second Marker Viva 09/02/18
J – font size & unit's & threshold
K – 3D print the case
L – additional specs?!
M – Symposia Presentation 02/05/18
N – Public Engagement Video and Story Board 11/05/18
O – IEEE Style Article 04/05/18

Gantt chart (use as a bar chart in conjunction with the main headings above)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Component	1	2	3	4	5	6	7	8	9	10	11	12					13	14	15	16	17	18	19
A	x	x	x	x																			
B				x																			
C					X	X																	
D						X	X	x	x														
E							x																
F									x	x	x												
G												x	x	x									
H														x	x	x							
I																x	x						
J																	x	x					
K																		x	x	x			
L																				x			
M																				x	x		
N																						x	
O																					x	x	x

References:

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Risk Register:

Identify the key problems that could prevent your project from completing on time and associate a likeliness and risk level (Low/Medium/High). How can these risks be reduced?

Risk Number	**Description of Risk**	**Mitigation of Risk**	**Risk evaluation (L/M/H)**	**Chance of risk occurring (L/M/H)**
1	**Loss of data (USB key)**	**Multiple back-ups in multiple locations**	**M**	**L**
2	**Not being able to use the software on my laptop.**	**Need to contact CISC so the Arduino library for MATLAB can be downloaded and installed at a library's pc**	**M**	**M**
3	**Failing to meet the specifications**	**Follow the Gantt chart, focus on milestones**	**M**	**L**
4	**Fail to give clear instructions to the end user**	**Give clear and concise instructions**	**M**	**L**
5	**Not fully knowing how to make GUI's or interact with the Arduino.**	**practice with smaller programs to gain the knownelgde**	**M**	**L**

Interim Report

Interim Report was not submitted due to lack of results at the time. The absence of adequate documentation from the sensors in combination with the respiration sensor issue, which was outlined in the section I.v.c. of the main IEEE article, resulted to obtaining results as shown in fig. 1.

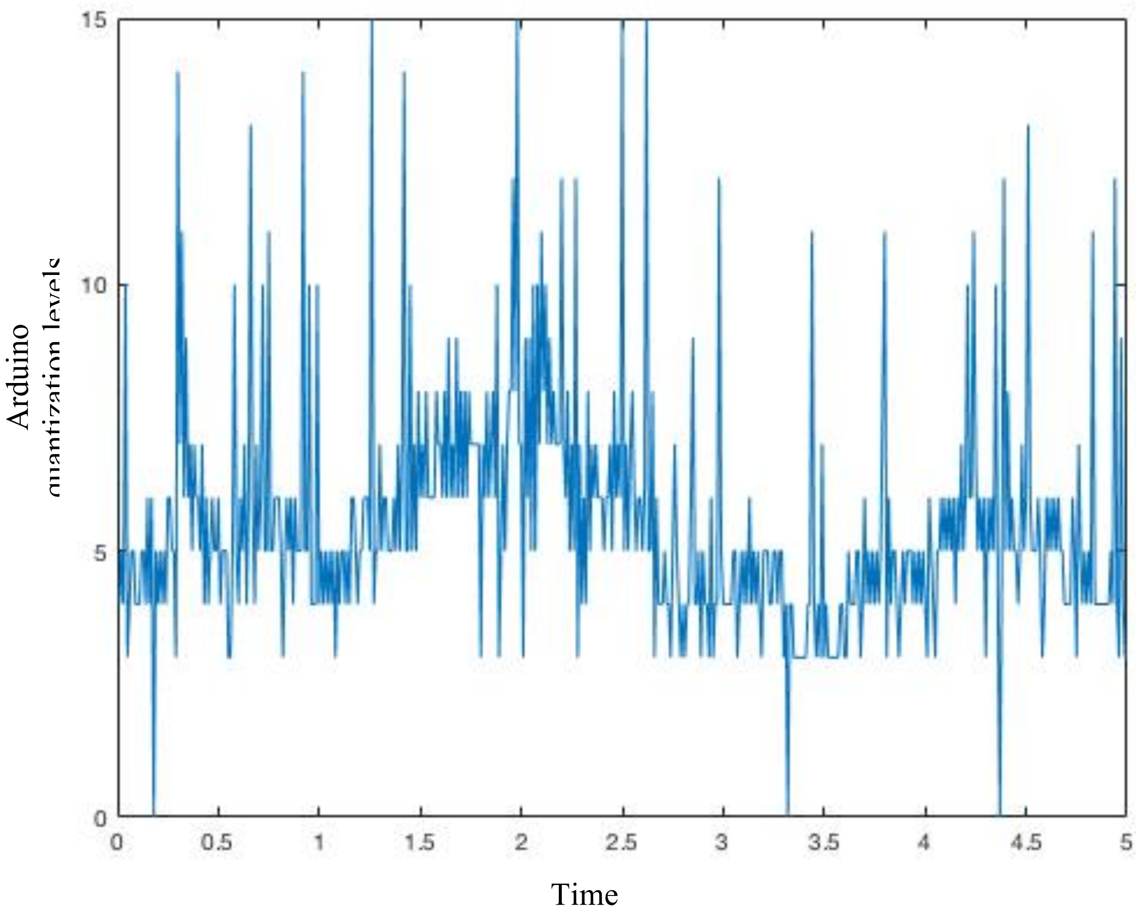

Fig. 1. Signal received from Arduino analog input 1

The range of the values obtained by the respiration sensor is [0,15], which can be considered as only circuit noise because the quantization levels in the Arduino are in the range of [0,1023]; therefore, there was no signal detected by the sensor.