A handheld device to monitor physiological changes using sweat

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Abstract. Sweat is a viscous, multi-parameter fluid that can be used to gain information on various functions of the body. The focus of this paper is to develop a prototype for a handheld device that considers factors such as temperature, pH, and conductivity of sweat to arrive at a conclusion about the current physiological condition of the user. Sweat is metabolite rich so it contains salts such as Sodium, chloride and potassium. The concentration of each metabolite varies the general conductivity of sweat. The prototype will contain a temperature detector, pH sensor and Galvanic Response sensor. Any abnormal change in temperature, pH and the conductivity of sweat indicates an underlying problem. Further the sensor is capable of detecting fluctuation in sodium ion concentration by measuring the changes in the voltage response. The device will use machine learning and IoT to come to a conclusion whether the user is in immediate danger or not and constantly display readings when the sensors come in contact with sweat.

1. Introduction
Sweat is a watery bodily substance produced by sebaceous glands in the human body. The function of sweat is thermoregulation. Mainly consisting of a large percentage of water, it additionally contains minute amounts of dissolved salts and other secretions. These salts are usually by products of various physiochemical reactions taking place in the body such as respiration, glycolysis and the Krebs cycle. Hence the levels of minerals can help determine which process is malfunctioning. The main chemical components include Sodium, Potassium and small amounts of Urea. Sweat analysis and study can point to various amounts of information if properly analyzed and studied. The main advantage of using sweat is that sweat production rate as well as its composition give an insight into the physiological condition. Parameters that the prototype will be taking into consideration are pH, temperature and Sodium concentration corresponding to voltage changes detected by a galvanic response sensor. Sodium is generally secreted in sweat as Sodium chloride as it reacts with chlorine ions produced as a side product after breakdown of HCL in the stomach. Therefore sweat tends to have a salty nature. An increased level of sodium in sweat has been linked to cystic fibrosis, a condition that severely affects the lungs, usually causing difficulty in breathing and eventually death. Further, changes in temperature can indicate infection as first response of the body is to increase temperature. Reduction in pH of sweat (less than 6.3) indicates acidosis, or frequent exercise. A condition caused due to accumulation of acid due to incomplete breakdown of protein. The prototype will constantly monitor the level of sodium, pH and temperature by the difference in voltage.
María Viqueira Villarejo et al. developed a sweat sensor device that is capable of detecting emotion using a specific type of sensor called galvanic skin response sensor. This sensor measures the difference in conductivity of sweat and sends sensor data via Zigbee to a processing unit [1]. Wei Gao et al. have created a prototype of a multi sensor array that is essentially a wearable. The FPCB board contains in situ glucose, lactate sensors that are capable of detecting the fluctuations in the traces of these compounds in blood [2]. Michael Chung et al. developed another prototype for a flexible sweat sensor that can be used for healthcare monitoring. Wearable flexible sensors are used with specialized electrical circuitry to measure pH and sweat rate. The sensor also contains a small Bluetooth module for transmission of data [3]. Min Zhang et al. used a CdSSe wire sensor due to its optoelectronic properties that detects moisture content in the body. The prototype is capable of detection of salts deposited on the surface and they use it to detect the perspiration capacity of the user [4]. Ali Javey et al. developed another silicon based flexible sensor to determine the concentration of metabolites in sweat for analysis of physiological conditions [5]. D. P. Rose et al., have created a prototype for monitoring sweat electrolytes [6]. Caldara et al. has proposed a prototype having a wearable sweat pH and body temperature sensor platform for health, fitness, and wellness applications [7]. Benjamin et al. have developed a wearable electrochemical sensor for the real-time measurement of sweat sodium concentration [8]. Elena Zdrachek et al. developed a wearable potentiometric sensor patch for monitoring total ion content in sweat [9]. E. K. Wujcik et al. proposed a prototype having an ion sensor for the quantification of sodium in sweat samples [10].

The prototype will consist of a pH sensor, a temperature sensor and a galvanic response sensor. All three sensors will be connected to a raspberry pi. The raspberry pi will act as a central processor and read the data. The processed data will be sent to a dashboard or to local cloud storage. Hence the user gets data directly to his phone or the data is periodically recorded and sent to the concerned. Previous studies done on sweat include stress analysis, respiration analysis as well as measurement of parameters as an integrated chip. The prototype is different in a way that it uses raw sensor data as well as a raspberry pi to process the data. IOT and Machine learning have been extensively used. The data being pushed wireless from the raspberry pi to the dashboard is IOT.

2. METHODOLOGY

2.1 Block Diagram

Figure 1 is the representation of the prototype we have developed. The main components are highlighted viz. Sensors, which collect the data, Audrino that acts as an ADC and the Raspberry Pi that is the processor capable of pushing data wirelessly to a dashboard.

![Figure 1. Block diagram of the proposed prototype.](image-url)
The pH Sensor that we use here is. It has an input supply voltage of 5V, has a pH range of 0-14 and also can measure for 0-50°C. The device consists of a pH sensor and a pH circuit board (BND Connector) that has to be interfaced with the Raspberry Pi. After programming we could easily get the pH values.

The Temperature sensor that we use here is LM75 which is best compatible for Raspberry Pi. It consists of a sensor and a circuit both together in circuit board. Same like the pH Sensor it should be first interfaced with Raspberry Pi, then after programming we could easily get the temperature values with the help of sweat when put on the sensor.

The Galvanic Response Sensor, also named Electro-dermal Activity (EDA) and Skin Conductance (SC), is the measure of the continuous variations in the electrical characteristics of the skin, i.e. for instance the conductance, caused by the variation of the human body sweating.

Arduino UNO is a microcontroller based on 8-bit Microchip CPU. It has a various set of input/output pins. It can be programmed with C/C++ language. It is much like a Raspberry Pi but performs less function and less in size & price. In our Project this is used as an ADC Converter. Without this the analog information that is sensed from the sensors cannot be show in display without any digital conversion.

As the time goes by, computers are becoming smaller & smarter. It is a low cost and small sized micro-computer that has the ability to perform various functions that a desktop computer can do. It is also used as an interactive tool to learn computing with languages like Scratch and Python. We chose Raspberry Pi for this project because of its size and ability to store details of Multi parameters which are sensed by the sensor and then which is stored in an external SD card. So, the data can be mobile and easily transferred or accessed. Raspberry Pi is also easy to program with the knowledge of Python.

Adafruit is an easy way to connect our prototype to the internet in order to display the results frequently. A dashboard will be created specifically for this purpose that will include tabular columns capable of refreshing values every 5 seconds. Further charts and graphs can also be displayed according to the requirement.

The prototype skeleton (Figure 2) Consists of three sensors namely the temperature, pH and the galvanic response sensor connected with a USB to an Audrino UNO. The audrino acts as an ADC as the raspberry pi in itself is incapable of reading analog inputs. The audrino due to its 6 input/output ports acts as a great connector between the sensors and the raspberry pi.

The sensors when exposed to the sweat will calculate the values and send the data to the Audrino. The values will be converted to digital values that can be easily read and processed by the Raspberry pi. The raspberry pi connected to the audrino through the means of another cable will receive the digitalized data from the Audrino. The coding done in audrino is in embedded C language and is primarily responsible for just collection and pushing of the data.

When the raspberry pi receives the data, its central processor that is pre coded using python segregates the data into different value ranges. This range will depend upon the values set by the designer during manufacturing. The main operating system used by the processor is called the Raspbian OS using Noobs software, that is loaded into the pi with the help of a SD card. The data is analyzed using particular programs and the data is automatically pushed to an online service called ADA fruit that creates a dashboard for the display of the data. The feed is refreshed every 5 seconds with new values being sent periodically.

3. Result and Discussions
Measurement of temperature usually gives out crucial information about the functioning of the body. High temperature indicates infection and the body’s response against it. The normal range of the body temperature 36.1-37.2 °C. The normal pH of sweat is similar to that of blood i.e. slightly acidic around 6.8 to 7. Increase in pH indicates a serious condition called acidosis caused due to collection of acid. The prototype monitors pH continuously to indicate to the user if pH has decreased so that he may take corrective measures. The conductivity will increase if there is increase in amount of salt in sweat. This increase in salt is indicative of cystic fibrosis that is a serious inherited genetic condition causing
mucilage in lungs. The normal conductivity range is 11-25 mmol\(L\). More than 700-800 ml of sweat produced in a day may lead to dehydration of lymph node conditions. This can be monitored using a sweat sensor. Alerting the user of excessive exercise.

![Figure 2. The proposed prototype.](image)

**Table 1.** Subject details and observed values.

| Subject No. | pH  | Temperature (°C) | Conductivity (G) (mmol\(L\)) | Sweat Rate (ml/hr) |
|-------------|-----|------------------|-------------------------------|-------------------|
| 1.          | 5.8 | 35.7             | 32.3                          | 680               |
| 2.          | 6.5 | 32.0             | 29                            | 570               |
| 3.          | 7.2 | 29.3             | 19                            | 200               |
| 4.          | 5.7 | 34.1             | 30.7                          | 698               |
| 5.          | 6.9 | 30.8             | 24                            | 295               |
| 6.          | 6.8 | 32.15            | 28                            | 545               |
| 7.          | 5.9 | 33.0             | 31                            | 650               |
| 8.          | 7   | 31.8             | 33                            | 345               |
| 9.          | 5.5 | 30.5             | 27                            | 400               |
| 10.         | 4.8 | 29.0             | 27.6                          | 275               |

Readings were collected (Table 1) from a sample group of 5 people, some of whom had exercised before the sample was collected. The parameters pH, temperature and Conductance were measured using the prototype. It was generally noticed that the Temperature of people who exercised was higher than those who were resting or in normal conditions. The pH was lower in people who had exercised indicating removal of CO2 that acts as a main buffer in blood, hence affecting the sweat. The
conductance was also observed to be higher in active people due to removal of excess CL- in the form of NaCl. Sweat rate was naturally very low in normal subjects.

4. Conclusion
This paper provides information on the different physiological parameters that have been tested using the prototype. Sweat rate, pH, temperature as well as general conductivity was measured from different sets of people, one who had exercised and one who were resting. The results obtained corresponded to standard values as to values obtained during other ongoing researches. Further, we will focus on reducing the size of the prototype overall and improvising the efficiency and also enabling the device to detect cystic fibrosis and other diseases based on salt level in the sweat.

5. References
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