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RESEARCH PAPER

Low Cost IoT-enabled Embedded System of Smart Textile for Real-time Health Monitoring of Industrial/Agricultural Worker

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ABSTRACT

The Internet of Things (IoT) can help us better our lives in many ways by rendering real-time information over the Internet via smart network of devices. In this paper, the authors discussed about development of an IoT-enabled embedded system for smart textiles which was developed to monitor the real-time health parameters of industrial/agricultural workers. The developed system encompasses LM 35 body temperature sensor, MAX30100 pulse rate and SpO_2 module, NodeMCU ESP 8266 WiFi-enabled microcontroller, Blynk Android app development platform and mobile phone (OS: Android). The developed system was tested in the laboratory measuring the health parameters of ten persons with five replications. Test results shows that the standard deviation and standard error mean (SE mean) in the measured value of temperature were found to be 1.6 °C and 2.22 % respectively. Similarly, standard deviation and standard error mean (SE mean) in the measured value of pulse rate and SpO_2 were found as 2.68 BPM and 6.75 % respectively and 5.87 % and 4.60 % respectively. The developed embedded system is easy-to-build, easy-to-use and cost-effective (₹ 5000/-). The compactness of microcontroller as well as sensor and initial testing shows that the developed system is very much compatible to integrate with the textile product to make a low-cost smart textile for real-time health monitoring of industrial/agricultural workers.

HIGHLIGHTS

- Development of embedded system for real-time monitoring of health parameters.
- Development of GUI of Blynk Android Application.
- Integration of developed GUI with embedded system.
- Laboratory evaluation of the developed system.

Keywords: IoT, smart textile, microcontroller, sensor, embedded system

The evolution of textiles is inherently linked to the evolution of humanity. It can be charted starting from leaf-based clothing, followed by natural products such as silk and cotton that have improved well-being and comfort, until the use of synthetic materials that have gradually emerged and greatly improved our lives over the last century. The growing demand for high-quality products recently improved textile use in existing applications (Schwarz *et al.* 2010; Cherenack and Van Pieterson

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2012; Koncar 2016). Textiles that have the ability to detect and respond to external stimuli, whether they be mechanical, thermal, magnetic, chemical, electrical, or other, are referred to as smart textiles. They can detect and react in a preset manner to outside circumstances (stimuli). The growing advances in science allow for more sophisticated technologies to be developed and inserted in even more complex systems in different disciplines such as cloth manufacturing, artificial intelligence, biotechnology, information, theory of chaos, and randomizations, among others (Syduzzaman *et al.* 2015; Chen *et al.* 2020). Research and development geared towards wearable textile-based personal systems allowing for health monitoring, protection and safety, and a healthy lifestyle have gained strong interest during the last few years. These cloths are like ordinary cloth providing special function in various situations according to the design and application. Recent advancements have demonstrated the potential of smart textiles in wearable health monitoring systems.

In this segment, Shi *et al.* (2020) developed a smart textile-integrated microelectronic system for wearable applications. Shakerian *et al.* (2021) developed a microcontroller-based system for assessing the occupational risk of heat stress of workers at construction sites. Ahn *et al.* (2019) have also integrated multiple motion and physiological sensors to detect potential safety hazards and to continuously monitor a worker's health on a construction job site. Corbellini *et al.* (2008) developed a ZigBee module based low-cost wireless network of smart wearable buttons that can be applied inside the protective suits and that embed the measurement device along with a 2.4 GHz radio. Ahmed *et al.* (2022) developed an IoT-based real-time patient's vital physiological parameters monitoring system using smart wearable sensors. Similarly, Gokul *et al.* (2017), Kim *et al.* (2020), De Fazio *et al.* (2022), and Sofronova *et al.* (2023) also integrated the sensors and microcontroller in textiles for monitoring the various health parameters.

There have been quite a few research gaps regarding IoT enbled embedded system for smart textiles for agricultural workers as previous works lacked in proper integration and flexibility as many wearable systems still rely on bulky components like PCBs for signal processing, which limits flexibility and comfort. Efforts are being made to develop fabric-based circuits that maintain conductivity and reliability under physical stress, but achieving fully integrated, unobtrusive designs remains a challenge (Angelucci *et al.* 2021). Wearables for agricultural and industrial settings must endure harsh conditions like extreme temperatures, dust, and physical strain. This requires more robust materials and design strategies. Ensuring the precision of embedded sensors, particularly under constant movement or pressure, is difficult. Issues such as signal noise and motion artifacts reduce the reliability of collected data (Ahsan *et al.* 2022).

Till now most of the systems developed by researchers have either been regarding microcontroller or microprocessor-based system that only deals with monitoring of physical activities of the person, But no research has been conducted till date regarding monitoring of most crucial Parameters of health like Heartbeat, SpO2 and Body temperature for the workers who are in either industrial or agriculture sector which involves a lot of physical strain and pressure which could affect their working condition. As these sectors are labour-intensive sectors they require considerable strain and stress so the main objective of this project is to develop an IoT-based system for monitoring health parameters and making them more informative about the medical situation.

MATERIALS AND METHODS

The system presented in this paper offers a prototype implementation of smart patient health monitoring system that measures body temperature, heart rate (bpm), and SpO_2 content in blood by using various sensors and transmits the real-time information to the remotely located person using NodeMCU and IoT platform.

Electronic Components/Sensors Used

For developing the proposed system, LM-35 temperature sensor and MAX30100 sensor were used. For processing and logging the information of the mentioned sensor, IoT enabled microcontroller (NodeMCU ESP8266) was used. These sensors and electronic gadgets were selected based on measurability (higher accuracy and precision in measurement), portability, ease of programming, and availability in the market. Technical specifications of

Table 1: Technical specifications of sensors used-

Component	LM-35 temperature sensor	MAX30100 sensor	NodeMCU ESP8266
Type	Analog Temperature sensor	Pulse oximeter and heart rate monitor	Wi-Fi enabled microcontroller
Power supply	4V to 30V	1.8V to 3.6V	3.3V
Output	Analog	Analog	N/A Controller
Measurement Range	-55 °C to -150 °C	SpO_2: 0 to 100 %, Heart Rate: 30 to 240 bpm	N/A Controller
Accuracy	± 0.5 °C (from 25 °C to 75 °C)	Spo2: ±2%, Heart Rate: ±2 bpm	N/A Controller
Interface	Analog Output (A0 pin)	I2C (SDA, SCL)	GPIO, ADC(A0), I2C, SPI, UART
Resolution	10mV per °C	16-bit ADC for Spo2 and heart rate data	10-Bit ADC(A0), 32-Bit CPU

employed sensors and microcontroller are presented in Table 1.

Body Temperature measurement

For measuring the real-time body temperature, LM-35 temperature sensor was used. With this sensor, temperature can be measured more accurately than with a thermistor. The sensor is simple to use, and compatible with any kind of microcontroller board. In this research work the sensor was interfaced with NodeMCU ESP8266 microcontroller. The low-output impedance, linear output, and precise inherent calibration of the *LM35* make interfacing to readout or control circuitry very convenient. The sensor circuitry is sealed therefore, it is not subjected to oxidation and other natural processes. As the sensor gives the output in analog form, therefore, output pin of the LM-35 sensor was connected to the analog pin (A0) of the NodeMCU of the microcontroller. For proper conversion of the analog values of the sensor into digital values following relations were employed

$$V_{out} = ADC\ Value \times V_{ref} / 1023V \quad \text{...(Eq. 1)}$$

$$Temperature\ (°C) = V_{out} / 0.01 \quad \text{...(Eq. 2)}$$

By using equations 1 and 2, an algorithm was developed in Arduino IDE and uploaded on the microcontroller. The circuit diagram of the developed NodeMCU ESP8266 microcontroller based real-time body temperature measurement system is presented in Fig. 1.

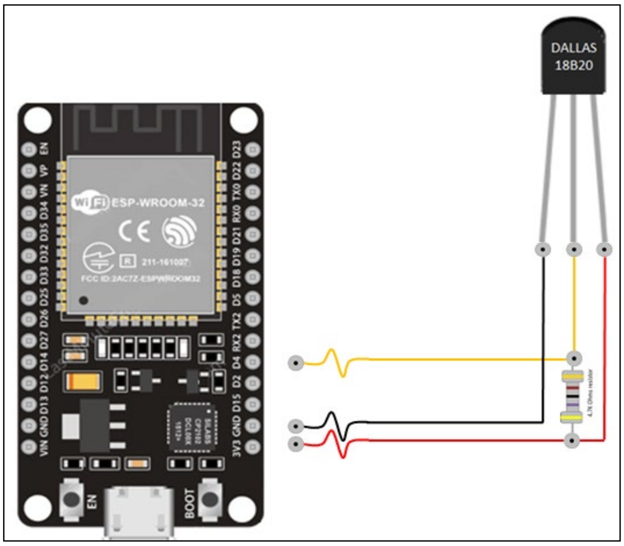

Fig. 1: Circuit diagram of the developed NodeMCU ESP8266 microcontroller-based real-time body temperature measurement system

Pulse rate and SpO_2

For measuring the real-time pulse rate and blood oxygen saturation (SpO_2) level of a person, MAX30100 sensor was used. It was used as a non-invasive method to measure oxygen saturation levels in the blood. This module has a pair of LEDs (Light Emitting Diode) that emit a monochromatic red light at a wavelength of 660 μm and infrared light at a wavelength of 940 μm. As the photodiode emits light, it falls on the finger and gets absorbed by the oxygenated blood rest light is reflected through the finger and falls on the detector. The detector detects and processes the signals and gives the output.

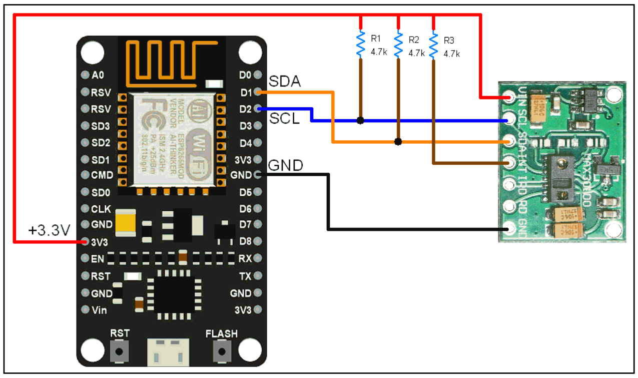

Fig. 2: Circuit diagram of the developed NodeMCU ESP8266 microcontroller-based real-time pulse rate and SpO_2 level measurement system

The MAX30100 sensor works on the I2C Serial Communication protocol. For proper interfacing of the sensor, a library (MAX30100lib) was installed and managed with the Arduino IDE platform. The sensor was connected to the microcontroller as per the circuit diagram as depicted in Fig. 2. After that an algorithm was developed in Arduino IDE and uploaded to the microcontroller to acquire the data of employed sensor.

IoT based embedded system fore real-time measurement of body temperature, pulse rate and SpO_2 level

After developing the individual embedded system for measuring the body temperature, pulse rate and SpO_2 level, both systems were integrated in one unit. The block diagram and hardware of the developed IoT-based embedded system are presented in Fig. 3 and 4 respectively.

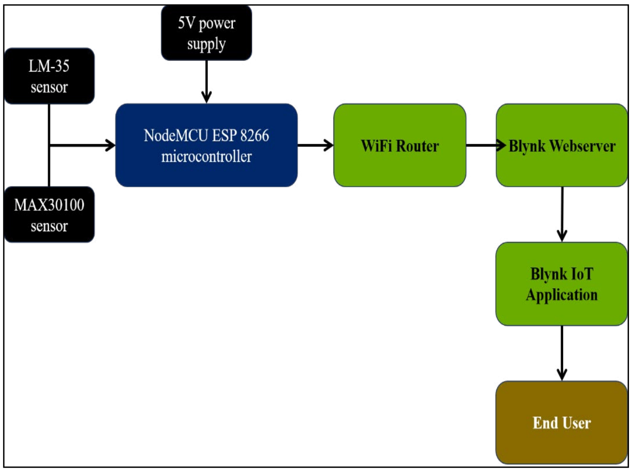

Fig. 3: Block diagram of the developed IoT based real-time body temperature, pulse rate and SpO_2 level measurement system

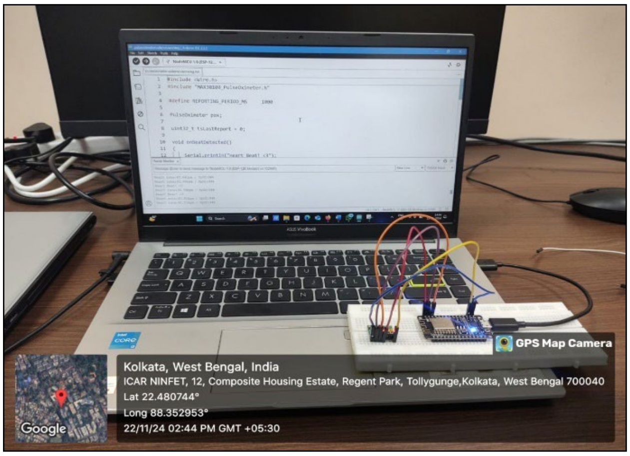

Fig. 4: Hardware of the developed IoT based real-time body temperature, pulse rate and SpO2 level measurement system

For making the developed embedded system IoT-enabled, blynk IoT platform was used. For configuring and transmitting sensors output to IoT platform and mobile application (end-user), following steps were followed (Fig. 5).

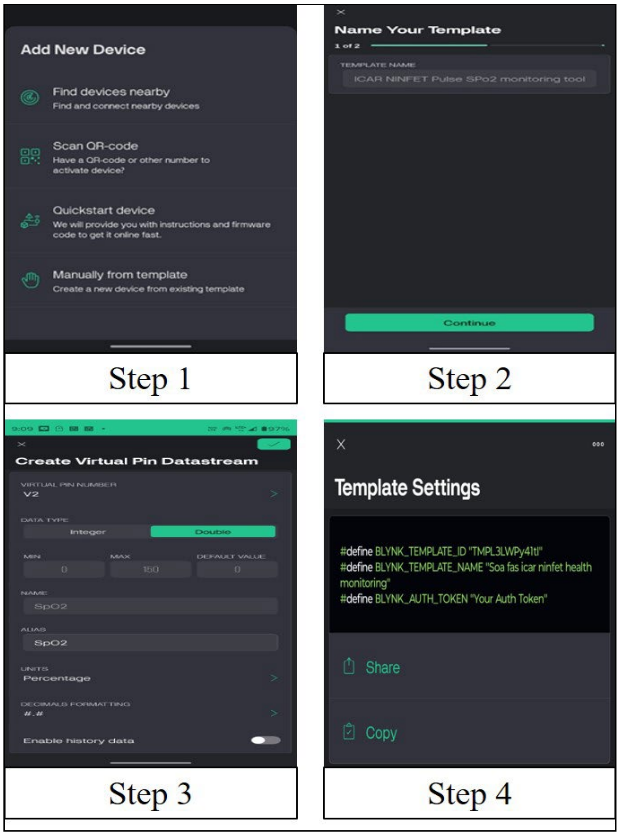

Fig. 5: Development and configuration of IoT application for measurement of body temperature, pulse rate and SpO_2 level

- ***Creation of new IoT project:*** After installing the software, a new device (IoT-enabled microcontroller) and name of the project were specified for initiating the blynk application and starting of the project.

- *Development of template of the IoT application:* for designing the template a name as "SOA FAS-ICAR NINFET health monitoring tool" was set and hardware was selected as NodeMCU ESP8266.
- ***Designing of virtual switches:*** Then gauge widgets were added for heart rate and SpO_2.; then the configuration of the virtual pins (e.g., V1 for heart rate and V2 for SpO_2) was done.
- *Configuration of the Blynk app and* NodeMCU ESP8266: Finally, after designing and configuring of Blynk app a token was generated and uploaded on the microcontroller.

Finally, an algorithm containing the measuring protocol of both sensors and IoT configuration was developed and uploaded on the microcontroller. The pictorial view of the developed algorithm is presented in Fig. 6.

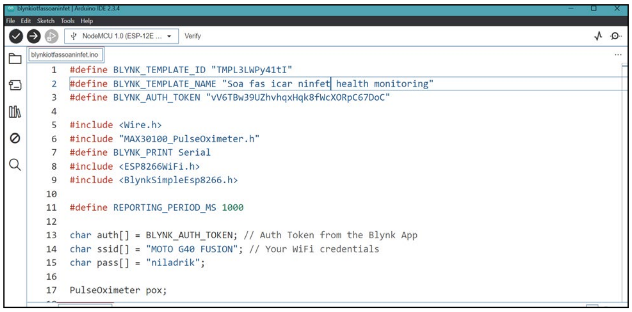

Fig. 6: Developed IoT enabled algorithm for real-time measurement of health parameter

RESULTS AND DISCUSSION

After integrating the sensor with NodeMCU ESP 8266 microcontroller the, developed system was tested in the laboratory. For testing the developed system ten healthy adults of ICAR-NINFET were randomly selected and their pulse rate, SpO_2 level and body temperature were measured with the developed system. The experiments were conducted with five replication for measuring the each parameter. The health parameters of the ten persons are presented in Table 2. Result data as presented in Table 2, informed that the developed system is able to detect the real-time values of pulse rate, SpO_2 and body temperature of a person and send to the Blynk mobile application. The pictorial of the Graphical User Interfaces (GUIs) of the developed system is presented in Fig. 7.

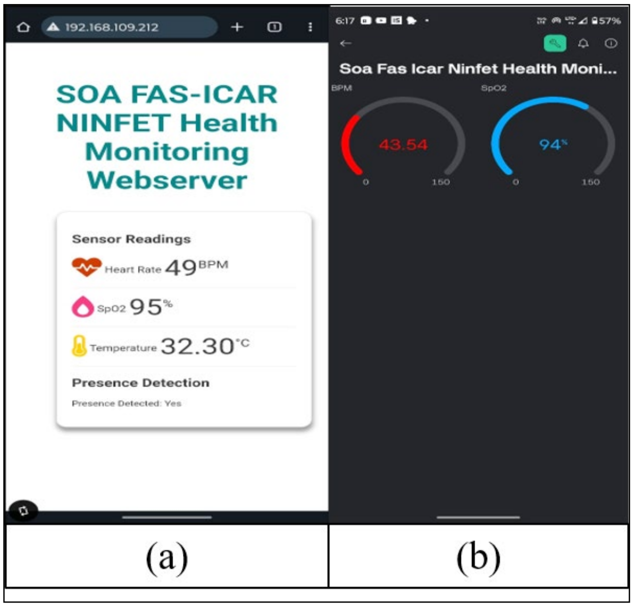

Fig. 7: GUIs of the developed IoT based health monitoring system for smart textile application

Table 2: Health parameters of different individuals

Person	Pulse rate, BPM	SpO_2 Level, %	Temperature, °C
1	56	93	39.0
2	57	94	38.0
3	99	95	32.6
4	81	92	35.2
5	77	93	35.3
6	82	93	35.7
7	43	94	35.8
8	74	95	35.3
9	78	91	36.0
10	81	92	35.9

The results as presented in Table 2, informed that the pulse rate of different persons varied from 43 to 99 BPM, SpO_2 Level varied from 91 to 95 % and body temperature varied from 32 to 39°C. The standard deviation and standard error mean (SE mean) in the measured value of temperature were found as of 1.6 °C and 2.22 % respectively. and 98 ± 21.93 PPM respectively. Similarly standard deviation and standard error mean (SE mean) in the measured value of pulse rate and SpO_2 were found as 2.68 BPM and 6.75 % respectively and 5.87 % and 4.60 % respectively. These variation in the reading were found due to the difference in body characteristic of individual. There are some variation/error in the readings was observed and further testing will be done in the future to resolve the issue. The developed embedded system is easy-to-build, easy-to-use and cost effective (₹ 5000/-). The compactness of microcontroller as well as sensor and initial testing shows that the developed system is very much compatible to integrate with the textile product to make a low-cost smart textile for real-time health monitoring of industrial/ agricultural workers.

CONCLUSION

In this modern era, IoT has become one of the brightest fields by which human life has become easier, safer and efficient through a variety of its applications. The growing advances in science allow for more sophisticated technologies to be developed and inserted into even more complex systems of the textile industry. Therefore, the present research work was executed for the development of an IoT-enabled embedded system of smart textile for real-time health monitoring of industrial/agricultural worker. The developed system encompasses LM 35 body temperature sensor, MAX30100 pulse rate and SpO2 module, NodeMCU ESP 8266 WiFi-enabled microcontroller, Blynk Android app development platform and mobile phone (OS: Android). For the present research work an IoT based application in the name of "SOA-FAS ICAR- NINFET Health monitoring system" was designed and developed. The developed system was tested in the laboratory measuring the health parameters of ten persons with five replications. Test results shows that the standard deviation and standard error mean (SE mean) in the measured value of temperature were found to be 1.6 °C and 2.22 % respectively. Similarly, standard deviation and standard error mean (SE mean) in the measured value of pulse rate and SpO_2 were found as 2.68 BPM and 6.75 % respectively and 5.87 % and 4.60 % respectively. The developed embedded system is easy-to-build, easy-to-use and cost-effective (₹ 5000/-). The compactness of microcontroller as well as sensor and initial testing shows that the developed system is very much compatible to integrate with the textile product to make a low-cost smart textile for real-time health monitoring of industrial/agricultural workers.

The integration of the developed system with textiles will make it a technological breakthrough for people involved in challenging tasks like in agriculture or any other industries for providing the medical assistance at right time and right place as per their need. However, challenges in sensing, analytics, and visualization of health data along with the flexibility of the sensors after integration with textile material need to be further investigated.

REFERENCES

Ahmed, A., Khan, M.M., Singh, P., Batth, R.S. and Masud, M., 2022. IoT-based real-time patients vital physiological parameters monitoring system using smart wearable sensors. *Neural Comput. Appl.*, **34**(22): 19397-19673.

Ahn, C.R., Lee, S., Sun, C., Jebelli, H., Yang, K. and Choi, B. 2019. Wearable sensing technology applications in construction safety and health. *Journal of Construction Engineering and Management*, **145**(11): 03119007.

Ahsan, M., Teay, S.H., Sayem, A.S.M. and Albarbar, A. 2022. Smart clothing framework for health monitoring applications. *Signals*, **3**(1): 113-145.

Angelucci, A., Cavicchioli, M., Cintorrino, I.A., Lauricella, G., Rossi, C., Strati, S. and Aliverti, A. 2021. Smart textiles and sensorized garments for physiological monitoring: A review of available solutions and techniques. *Sensors*, **21**(3): 814.

Chen, G., Li, Y., Bick, M. and Chen, J. 2020. Smart textiles for electricity generation. *Chemical Reviews*, **120**(8): 3668-3720.

Cherenack, K. and Van Pieterson, L. 2012. Smart textiles: Challenges and opportunities. *Journal of Applied Physics*, **112**(9).

Corbellini, S., Ferraris, F. and Parvis, M. 2008. May. A system for monitoring workers' safety in an unhealthy environment by means of wearable sensors. In *2008 IEEE Instrumentation and Measurement Technology Conference* (pp. 951-955). IEEE.

De Fazio, R., Al-Hinnawi, A.R., De Vittorio, M. and Visconti, P. 2022. An energy-autonomous smart shirt employing wearable sensors for users' safety and protection in hazardous workplaces. *Applied Sciences*, **12**(6): 2926.

Gokul, V. and Tadepalli, S. 2017. February. Implementation of smart infrastructure and non-invasive wearable for real time tracking and early identification of diseases in cattle farming using IoT. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)* (pp. 469-476). IEEE.

Kim, J.H., Jo, B.W., Jo, J.H. and Kim, D.K. 2020. Development of an IoT-based construction worker physiological data monitoring platform at high temperatures. *Sensors*, **20**(19): 5682.

Koncar, V. 2016. *Smart Textiles and Their Applications*. Woodhead Publishing Series in Textiles)/Woodhead Publishing.

Schwarz, A., Van Langenhove, L., Guermonprez, P. and Deguillemont, D. 2010. A roadmap on smart textiles. *Textile Progress*, **42**(2): 99-180.

Shakerian, S., Habibnezhad, M., Ojha, A., Lee, G., Liu, Y., Jebelli, H. and Lee, S. 2021. Assessing occupational risk of heat stress at construction: A worker-centric wearable sensor-based approach. *Safety Science*, **142**: 105395.

Shi, J., Liu, S., Zhang, L., Yang, B., Shu, L., Yang, Y., Ren, M., Wang, Y., Chen, J., Chen, W. and Chai, Y. 2020. Smart textile-integrated microelectronic systems for wearable applications. *Advanced Materials*, **32**(5): 1901958.

Sofronova, D., Angelova, R.A. and Sofronov, Y. 2023, July. Selecting Microcontrollers for the Creation of Intelligent Textile Systems. In *2023 3rd International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME)* (pp. 1-5). IEEE.

Syduzzaman, M.D., Patwary, S.U., Farhana, K. and Ahmed, S. 2015. Smart textiles and nano-technology: a general overview. *J. Text. Sci. Eng.*, **5**(1): 1-7.