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A wearable temperature sensor network to address the COVID-19 pandemic emergency†

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Abstract: In this COVID-19 emergency, to reduce the infection risk, several types of body temperature sensors have been used to monitor people access to public enclosed spaces, e.g. thermal imaging cameras and infrared thermometers. In some buildings, the people are located for several hours, so a continuous monitoring could be useful. For this reason, in three schools, we have proposed and tested a body temperature sensor network based on wearable temperature sensors monitored via Bluetooth 5.0 by smartphones and/or custom gateways. The data are collected on a server via the Internet, and a custom software is used to control the measured temperature and to produce warnings automatically.

Keywords: wearable sensor, body temperature monitoring, security, COVID-19 pandemic emergency, School, sensor network

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1. Introduction

Following the COVID-19 emergency, face-to-face teaching activities relating to the 2019/2020 school year had been suspended throughout Italy from March 2020 while activating distance learning to protect the school staff and students' health, guaranteeing in the meanwhile the right to study.

The following school year went on between closure and reopening. Various procedures have been taken to ensure the safe resumption of classes in presence, such as physical distancing, the obligation to wear a mask, and body temperature measurement.

All these practices are used to prevent infection. In particular, body temperature detection is a parameter that can be characteristic of active infections.

To reduce the infections of the SARS-CoV-2 virus, several types of body temperature sensors are used to monitor the access of people to enclosed spaces. More specifically, thermal imaging cameras and infrared thermometers are extensively used for this aim. However, these approaches cause the concentration of the people flows in checkpoints, increasing the risk of exposure for the people. In addition, the pandemic COVID-19 risk in some buildings, where the people are located for several hours, e.g. schools, universities, or industries, could be reduced by continuously monitoring the body temperature.

In many cases, a high-precision and wearable sensors network is the only possible solution to implement a punctual (capillary) and continuous real monitoring action of one or more quantities of interest (physical or biochemical) to prevent a cluster of infections in general, to safeguard health.

Wearable sensors technology is growing as researchers and developers learn of its potential benefits and possibilities [1].

Many applications, e.g., electronics or smartphone applications, encourage physical activity by measuring the user's daily step count and other parameters. Wearable sensors can come in the form of a Wearable Sensor Network, also known as a wearable Body Sensor Network, or even a Wearable Health Monitoring System (WHMS) [2].

In a wearable sensor network, multiple sensors can communicate to one another or with a server to form a network, with great potentiality, particularly in medical and safety applications. In fact, wearable sensor networks have been successfully used to monitor the body parameters, such as fluid, ph, temperature, blood pressure, et al. leading to the opportunity to monitor our health during activity, with immediate feedback on a smartphone or a PC [3].

However, this approach is typically used only in physical activities, and it is realized exploiting a personal device (e.g. smartwatches).

It has been about ten years that numerous scientists have been bringing forward different research lines on body temperature monitoring sensors, proving that Wearable Body Sensor Networks are a potential tool for real-time monitoring of vital parameters. Their flexibility, constant, and low-cost operation make them suitable for applications ranging from medical diagnosis, patient monitoring, and disease treatment. Many branches of medical science benefit from a non-invasive and low-cost tool that enables the accurate measurement of body temperature. Body sensor networks have the potential to improve medical research [4].

Important examples of wearable sensor networks are also the applications of this technology for temperature monitoring to investigate psychological and emotional changes, in biomedical applications [5] or for the temperature measurements in different environments for several application fields, as in [6-8].

In this work, we present the exploitation of a wearable sensor network for the continuous monitoring of school staff and students' body temperature to reduce the risk of SARS-CoV-2 infection in the School and thus allow for on-site learning activities. In particular, this approach is used in three schools located in the province of Naples (Italy), and it will be extended to other schools.

2. A sensor network for body temperature detection

We have proposed and tested a wearable body temperature sensor to realize an interesting sensor network used to implement a continuous and real-time temperature monitoring of the people in schools' buildings. The used temperature sensors measure the parameter of interest and transmit it via Bluetooth 5.0 to smartphones and/or custom gateways (with a maximum of about one hundred and fifty per gateway and about fifty per smartphone). Then, the collected data are transmitted on a server via the Internet.

In detail, as shown in Figure 1, the wearable sensor system is a small-size chip with an accuracy of +/- 0.1 °C that can be inset into a specific rubber bracelet for continuous and real-time temperature monitoring and for data transmission.

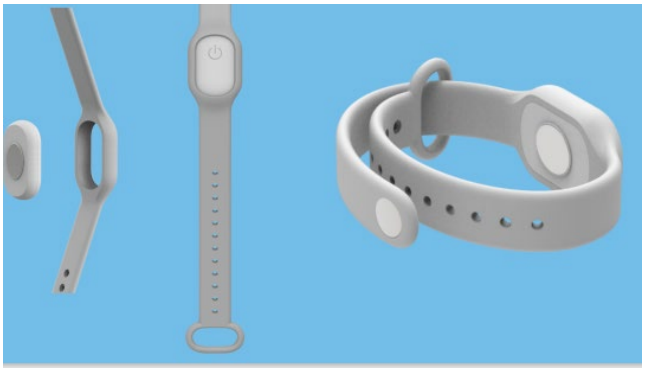

Figure 1. The packaging of used wearable temperature sensor system.

The sensor system presents a communication system and other components that are integrated onboard. More specifically, the smartphone and the gateway receive the data from the sensors by Bluetooth 5.0 protocol and then transmit the collected data to a server by TCP/IP protocols. This sensor system chip is waterproof, and it does not provide a display to reduce battery consumption. Moreover, the smartphone app (available for IoS and Android) not only transmits the data but also displays the temperature of all the sensors connected to it.

Figure 2 shows an outline of the sensor network in terms of communication architecture and capabilities, together with images of the software interface.

To obtain a body temperature sensor network, that is able to constant and safe monitoring, the developed software is used to analyse the database present on the Server, to control the measured temperature, and to produce warnings automatically.

The sensor network is provided with a web interface to view the data stored on the Server. In particular, each School can see only the data relative to its students and staff, even if the database is the same for all to allow statistic analysis, etc.

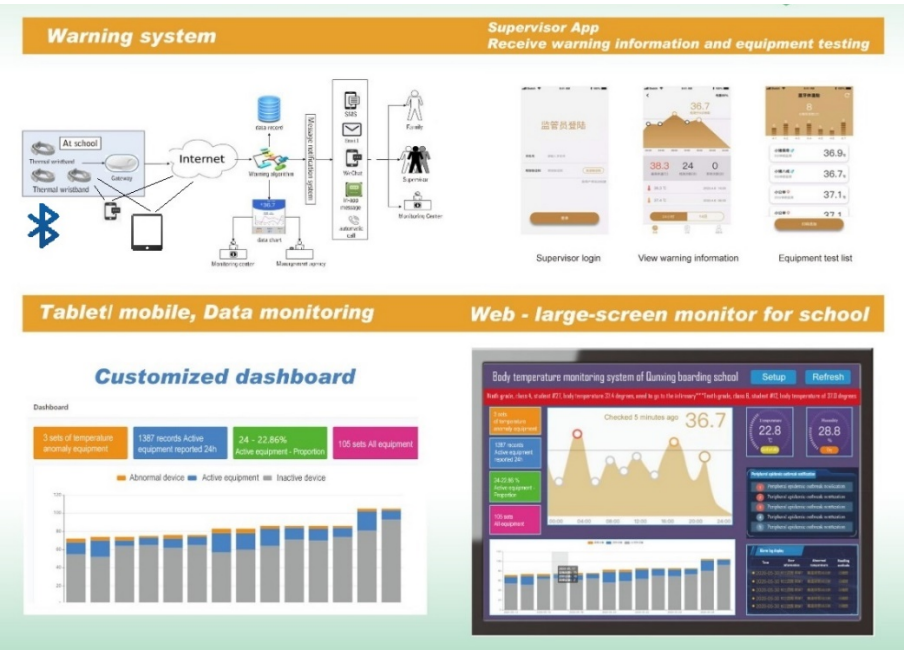

Fig. 2. Outline of the sensor network and images of the software interface.

More specifically, we are testing this sensor network in three schools: IPSEOA "C. Russo" di Cicciano (NA), IPSSAR "Di Gennaro" di Vico Equense (Na), and IS "A. Torrente" di Casoria (NA).

In each School, in addition to the installation of the App on Smartphones and Tablets, we installed a monitoring gateway covering the entire School. Moreover, we set up a background service system running in the cloud.

All students and staff members were assigned bracelets. Each wearer is a monitored object and, exploiting the smartphone app, can monitor other people connected in a range of 100 m.

3. Conclusions

We have presented an innovative strategy for continuous and real-time body temperature monitoring by a sensor network based on simple wearable sensors inserted into bracelets. This sensing approach is present to test it in three different schools. It exploits the real-time notification of the monitoring system and allows immediate isolation of the person with abnormal temperature after alert notification.

Moreover, it could be a first paradigm for monitoring body parameters in a community exploiting a sensor network; in fact, the same sensor network system can be used to measure different parameters of interest for diagnostics and health protection. In this sense, the proposed paradigm is helpful, considering effective and far-reaching "pandemic plans". Furthermore, this technology could also monitor students' health looking for congenital pathologies and/or possible infections in progress, simply by using suitable sensors to measure the markers of interest.

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