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IoT Instrumentation Device for Digital Data Acquisition and Remote Virtual Monitoring of Ionizing Radiations in Radiology and Medical Imaging Media

Sandrine Emvoutou Ndongo[1], Jean Mbihi[2], Jacquie Thérèse Ngo Bissé[3] and Célestine Nguemgne Malongte[4]

[1, 2]Laboratory of Computer Science Engineering and Automation, ENSET, Douala, Cameroon
[3]Higher Technical Teachers Training College, University of Ebolowa, Douala, Cameroon
[4]Department of Radiology and Medical Imaging, Douala General Hospital, Cameroon
mbihidr@yahoo.fr (corresponding author)

ABSTRACT

This paper presents a new remote virtual instrumentation device for ionize ng radiations in IoT radiology and medical imaging media. The main parts used in the local medical medium consists of: an ionizing radiation sensor (GB51 component), an ESP32-Based core for DSP (Data Signal Acquisition) and WiFi server, and a 4G WiFi modem. In the remote side, a Labview virtual monitoring system is used for the visualization and analysis of received ionizing radiation data. A sample of experimental results obtained and visualized on the remote Labview monitor screen, show the feasibility and high quality of the proposed innovative instrumentation device, dedicated to radiology and medical imaging media.

Key words: Radiology and medical imaging, ionizing radiations, ESP32-based core, remote Labview monitor, IoT instrumentation

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INTRODUCTION

The presence of ionizing radiation in the medical imaging environment has become indispensable in the rapid diagnosis of body anatomy [1]. However, the main cause of disease related to exposure to ionizing radiation is in the imaging environment and is a risk worldwide [2]. This exposure to ionizing radiation sources results from the uptake of a dose by the contacted subject that can induce short-term and long-term biological effects [3, 4, 5]. The short-term effects linked directly to cellular lesions for which a threshold of appearance has been defined [6], whereas the long-term effects deal with either cancers or genetic anomalies, which might become harmful from many hours to several years [7].

The International Commission on Radiological Protection (ICRP) and some governments have developed a set of standard measures, in order to protect people exposed to these sources of radioactivity [8, 9]. A few examples of theses standard measures are as follows: a) ISO 20553 protects workers, exposed to the risk of internal contamination; b) ISO 27043 estimates the internal dose in the context of monitoring; c) ISO 80000-10 estimates the atomic and nuclear physical quantities and their units. On the other hand, the safety thresholds of harmful ionizing radiation dose, are outlined in the aforementioned standards [10, 11]. Given these thresholds, scientific tools contribute to the improvement of instrumentation devices to be used for detecting, preventing and analyze ionizing radiation doses in exposed sites, including medical imaging media.

As an implication, existing instrumentation tools such as personal dosimeters and topographical counters, allow health care workers to assess the doses absorbed by the most exposed parts of the body [12, 6]. The disadvantage of these tools is that the dose assessment is done after a long period of time. In [13], a qualitative and quantitative study on different types and topologies of sensors that support the detection and evaluation of ionizing radiation is conducted. The work in [14] proposes a device for measuring ionizing radiation in hospitals that can be used as a personal dosimeter for specific areas and also as a surface dosimeter with a Geiger-Müller tube, involving wireless Internet communication. In [15], a digital radiation meter based on a Geiger Muller tube detector LND7121 and using an

Atmega328P microcontroller, is presented with the aim of facilitating data collection and analysis. Many equivalent similar instrumentation tools for ionizing radiation dose, are also available in the following biomedical engineering literature [16, 17, 18, 19]. In **[**20**]**, a new ESP32-based instrument involving a BG51 sensor, for ionizing radiation dose measurements is developed. Unlike most aforementioned instrumentation devices, it involves lower size, lower building cost, higher operating flexibility under a Labview virtual monitor. However, beside these merits, it is a local device requiring the physical presence of radiologist in the medical imaging room, where the virtual monitoring screen to be visualized is located.

Therefore, the aim of this paper is to study an IoT based model of the local ionizing radiation dose instrument initiated earlier in [20]. The next sections of the paper deals with study tools and methods, results and discussions.

BUILDING TOOLS AND STUDY METHODS

Building tools

Fig.1 shows the block diagram the proposed IoT Based instrumentation device, for ionizing radiation doses involving in a medical imaging environment. It consists of a Radiation Click module that integrates a BG51 sensor for measuring x-, beta- and gamma-rays, whose operation is based on a custom PIN diode array. The measurement principle of this sensor is centered on a number of pulses that corresponds to an evaluated radiation dose with a sensitivity of 5 cpm/µSv/h. The ESP 32 WROOM server module through a program written as described in the flowchart in Fig. 2 sends the logical state (0 or 1) of the output of the Radiation Click module to the modem through a Wifi link. The data is sent on request from the client (Labview PC interface) and if necessary, no data will be sent from the server. The modem relays the data from the server to the PC through a WiFi link and is the response from the client. In the PC, an interface designed in the Labview environment allows to bring back the pulses in radiation dose while taking into account the sensitivity of the sensor. The main technical characteristics of building modules are given in table 1. The characteristic of the local building tools are available in [20].

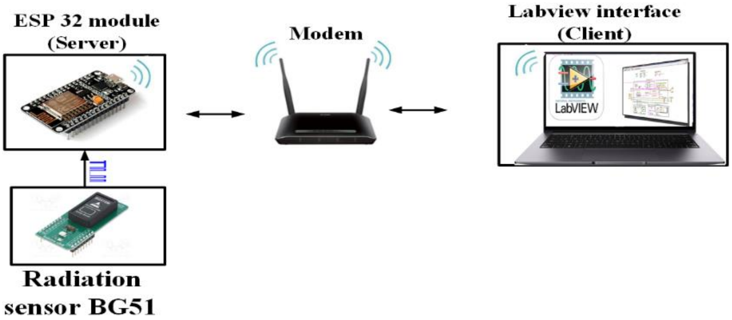


Fig. 1 Block diagram of the IoT based instrumentation device for Ionizing radiation

Study methods

The data acquisition and analysis when an individual is subjected to x-ray, beta or gamma radiation is usually done by a biomedical imaging technician or expert. Excessive radiation on the body can lead to the risk of cancer or other diseases. Given that a human expertise can be slow under unpredictable conditions, an expert system based on the CIRP recommendations that proscribe the radiation dose levels to be respected, is established according to the flowchart given in Figure 2.

The proposed system analyses and renders information based on the data collected. Thus, the operator or technician at the beginning enters the information that allows the system to connect to the server. When the system is connected to the server, the biomedical imaging technician clicks on the "started" button, which changes colour immediately. The system enters the automatic operation area and begins to instruct the server to send the BG51 sensor logic states and counts the number of *pulses per minute* (cpm) and then calculates the corresponding radiation dose. When one minute has passed after an evaluation, the required biomedical information to be visualized and analysed are monitored as follows:

- dose in *µSv*;
- energy to the body in *keV*;
- number of counting pulses per minute in *cpm*;
- plot of number of pulses versus doses per hour
- plot of energy versus dose per hour

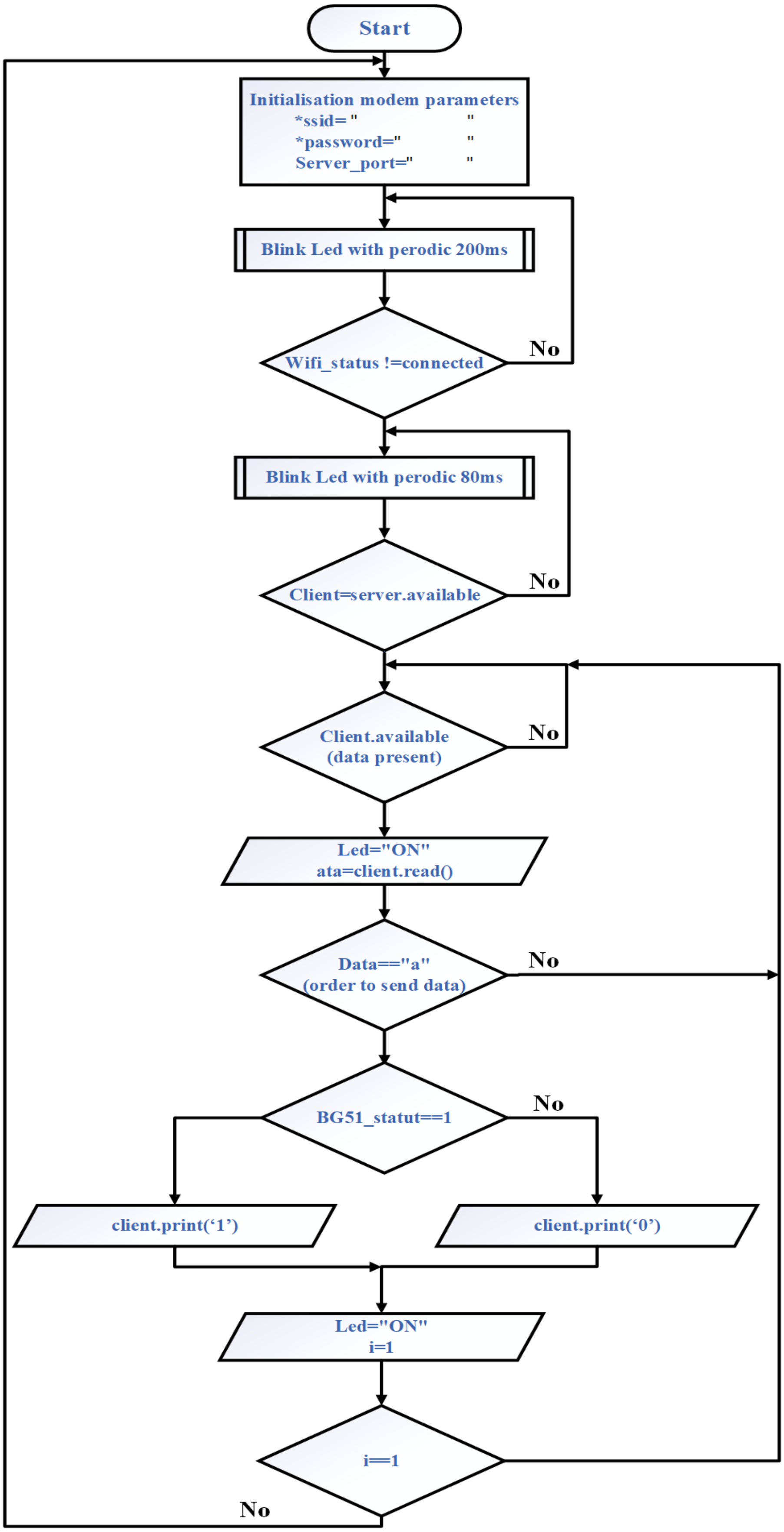


Fig. 2 Flowchart of the web server tasks

The qualitative analysis of the dose to which an individual is subjected is based on the CIRP restrictions. Each calculated dose is compared with the normalised quantities as described in the last condition of Figure 3 and in all situations the expert system makes a quick decision which it reports directly to the medical imaging technician.

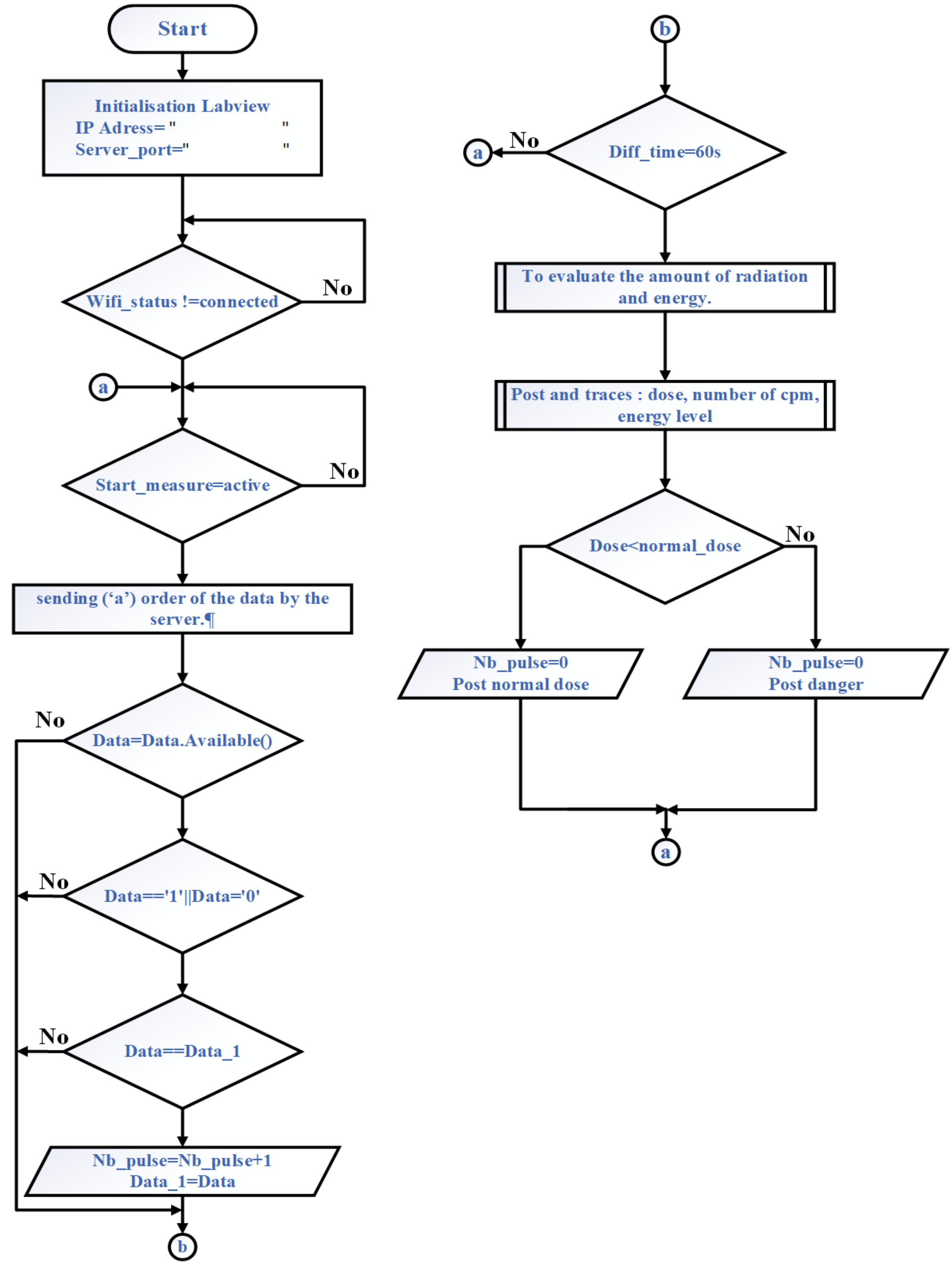
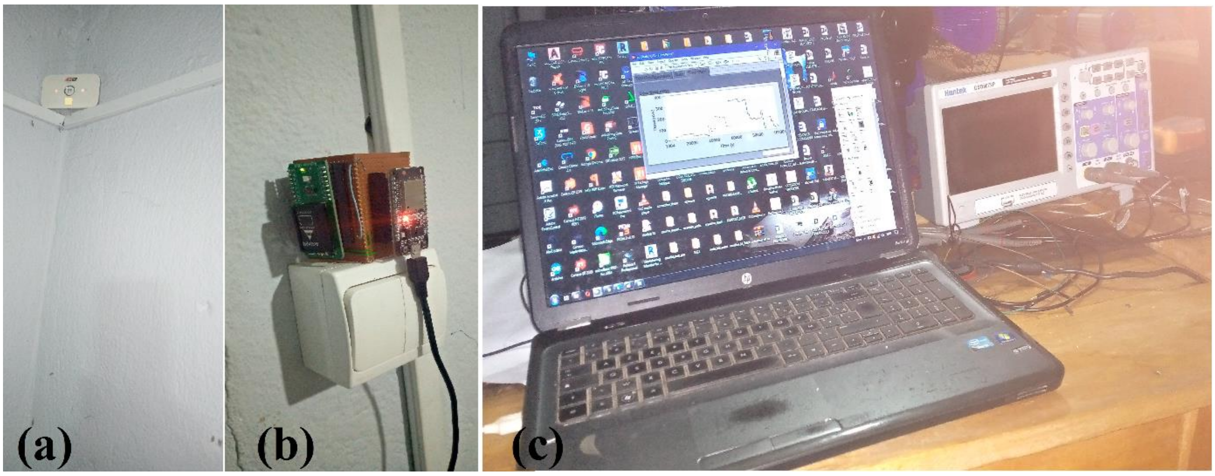


Fig. 3 Flowchart of measurement, analysis and feedback in Labview

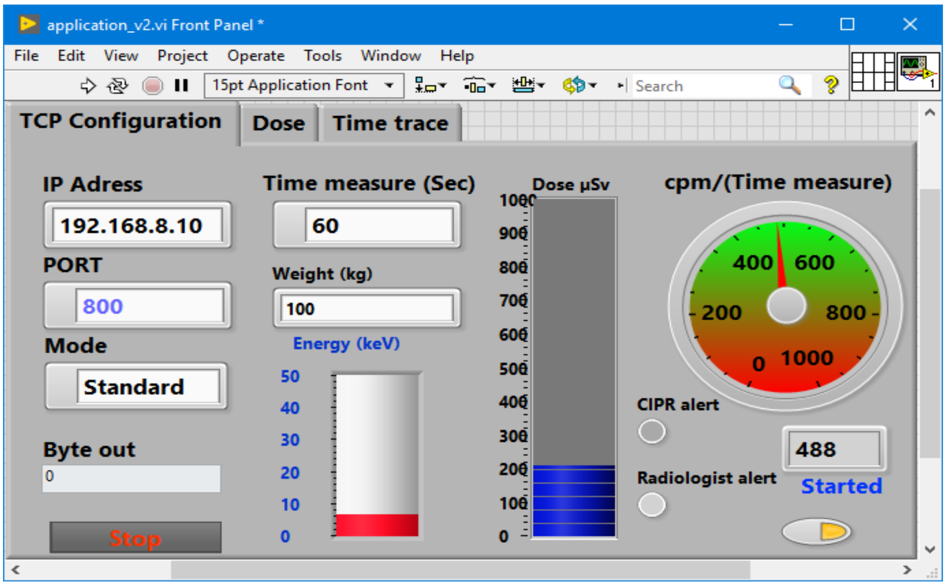
RESULTS AND DISCUSSIONS

The main results obtained during laboratory experiments are presented from figure 4 to figure 8. Figure 4 shows a workbench built and used for conducting experimental tests. Figure 5 presents a screen sample of the Labview monitoring panel. The measurement procedure starts as soon as the application is switched on, but the collection of dose information starts when the "started" button is pressed (i.e., turns orange).



(a) WiFi data relay module; (b) ESP32 based module

Fig. 4 Experimental workbenck



application_v2.vi Front Panel *

IP Adress: 192.168.8.10
PORT: 800
Mode: Standard
Byte out: 0
Time measure (Sec): 60
Weight (kg): 100
cpm/(Time measure): 488
Started

Fig. 5 Home tab of the interface

It is worth noting that numerous instrumentation characteristics as well as interactive visual tools are provided on the main virtual instrumentation panel, e.g. IP address input control and connection port of the Wi-Fi box, measure time, ionizing radiation dose (uSv), energy (keV), number of pulses per unit time (cpm). In addition, the graphs of *cpm (dose)* and *energy(dose)* are provided in Figure 6, while that of *dose(time)* is given in Figure 7.

The moment the dose is higher than 20mSv as recommended by the ICRP the "ICRP alert" button turns red and an alert signal is triggered. For additional protection, an alert is given to the radiologist whenever the dose exceeds 5mSv through "Radiologist alert". The number of pulses is displayed through a digital display (cpm/ (time measure)).

A few comments and discussions arise from experimental results as described above. In Fig. 6a, a linear evolution of the pulse number as a function of the dose is observed with a slope *given by*:

$a = \frac{\Delta(nomber\ cpm)}{\Delta\left(\mathrm{Dose}\left(\mu\frac{\mathrm{Sv}}{\mathrm{h}}\right)\right)} \cong 5cpm/\mu Sv/h$ (**Error! Reference source not found.**(a)).

(1)

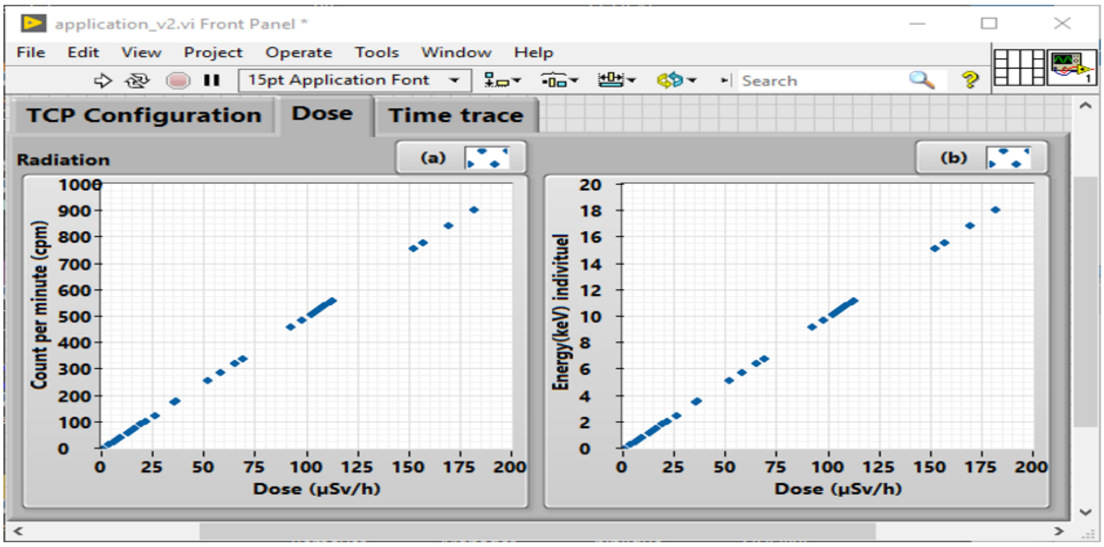


Fig. 6 Linear trend of Ionizing radiation doses under cpm and energy variations

This result is quite realistic and reliable according to the characteristics of the BG51 sensor as provided by the manufacturer in its user manual.

On the other hand, the energy absorbed by the radiologist during the test is presented in Figure 6(b), and this energy evolves according to an estimated slope $a' = 0.12keV/\mu Sv/h$. Therefore, the dose and energy can be computed as given in equation (2),

$$\begin{aligned} x &= a_1 * y \\ y' &= a' * x \end{aligned} \qquad (2)$$

where x is the dose in µSv/h, y is the pulse number (*cpm*) and $a_1 = \frac{1}{a}$ is the slope of the equation, y' is the energy in *keV*. During the measurement, the maximum dose is estimated to be 312 *µSv/h* for an energy of 37.44 *keV* for the radiologist with a mass of 100 kg.

Fig. 7 shows the evolution of the radiation dose over time during the test phase. It is clear that the radiation level is not constant in the test environment. However, this level is below the recommendations. The phases where we have considerable radiation levels in the room are the moments when the X-ray equipment is in operation.

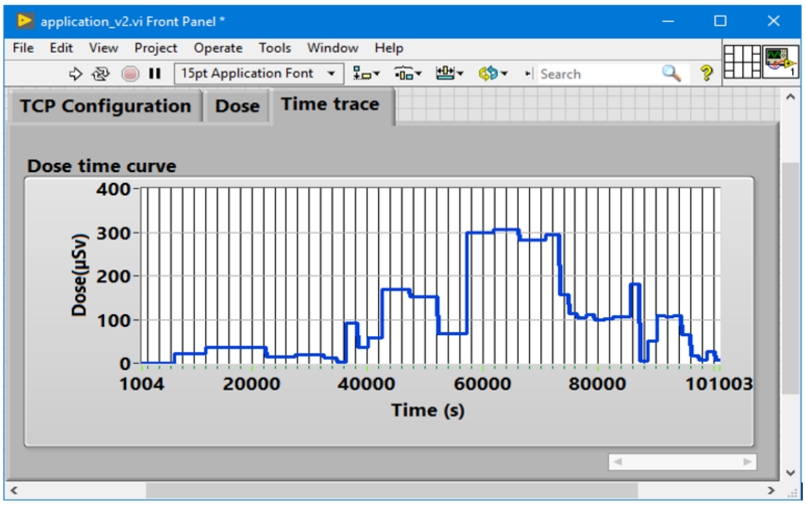


Fig. 6 Evolution of the ionizing radiation dose during the test phase

The proposed prototype has a good measurement performance and best informs the technician or radiologist about the radiation level but also alerts in case of danger. Moreover, the visual user interface data can be saved in a ".text or .scv" file.

CONCLUSION

The research work presented in this paper has outlined an innovative IoT Labiew instrumentation device, for ionizing radiation, under emission in radiology and medical imaging media. It offers a comfortable visual user interface, with numerous ionizing radiations data involved in radiology and medical imaging media. In addition, real time tests conducted using a prototyping realization device, have pointed out relevant technical characteristics and high qualities. Following these advances, a complete study of an industrial prototyping model for the biomedical engineering market, will be a relevant target of our future research work. It would be important also to develop an artificial intelligence model, to be used as an IoT instrumentation expert system, which is able to behave as a human radiologist expert, i.e. read as well as collect and analyse data, taking smart decisions or alert.

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