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DEVELOPMENT OF AN AUTOMATED SOURCE PORT IN IoT FOR APPLICATION IN INDUSTRIAL PROCESS TOMOGRAPHY

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ABSTRACT

Computed tomography technology uses an electromagnetic radiation source or particulate radiation source, to analyze / study different samples that can range from living organisms to the most diverse objects (rocks, phantoms, etc.). The use of the radioactive materials may cause harm to the operator if he is exposed to the source of radiation, so aiming at the safety of the operator, the objective of this work is to develop an Internet of Things automation system for the opening of the Industrial Process Tomography source port for industrial tomography applications. Thus, this system can drive the stepper motors through this platform can be opened at a safe distance to the operator, avoiding the operator to take radiation dose to perform this operation. For the IPT project, five source ports were made so that each was positioned diametrically opposite each array of detectors. In this project we used ^{192}Ir sources that have activity of 18,500 MBq and that were produced in the reactor IEA-R1, from the neutron bombardment of the pellet containing stable isotope ^{191}Ir. The main characteristics of ^{192}Ir are: half-life of 74.2 days; radiation energy from 0.13 to 0.65 MeV. For the safety of the operator during the opening of the sources, an automated opening system with IoT that can be activated with software installed on the tomography or by a smartphone application by the MQTT protocol, which makes it possible to be monitored in real time at long distance showing the opening and closing status of each source port.

1. INTRODUCTION

This work aims at the design and manufacture of a trunk to be used in industrial computed tomography scanner of the tomography of industrial process in real time (tomography) Thus, this system can be used as a method of comparison between a model and a system remote control. Safe for the operator, avoiding the user to take a dose of radiation to perform this operation via Wi-Fi communication.

It was used sources of ^{192}Ir that have activity of 18,500 MBq (500 mCi) and that were produced in the reactor IEA-R1, with approximate power of 4.5 MW to 5 MW, from the neutron bombardment of the tablet containing isotope stable ^{191}Ir, to a flow of approximately $3.45 \cdot 10^{13}$ n.cm^{-2}.s^{-1} [1]. The main characteristics of ^{192}Ir are half-life of 74.2 days; radiation energy from 0.13 to 0.65 MeV [2].

For operator safety during opening of sources, an automated IoT opening system that can be activated with software installed by a smartphone application (.app) by the Message

Transporting Telemetry Transport (MQTT) protocol, which enables the monitoring in long-distance real time, showing the opening and closing status of each source holder.

This work has not been possible to have many previous work references because the IoT technology is relatively new compared to other communication technologies and in the field of nuclear technology in machine control applications has not been found so far, seeing that it is a technology which can be highly developed due to the communication being made at safe distances for operators.

2. METHODOLOGY

2.1 Source holder

With the geometry of the detector arrangements defined, a detailed study was carried out for the development of the source holder project. Studies to establish parameters (distance, geometry, collimation angle) for making a source holder capable of obtaining the best detection efficiency were performed.

To determine the material to be used in the production of the source holder, some code routines were performed in C #, which calculated the required shielding thickness based on the density of the material to be used as shielding and the radioactive isotopes to be used. With this, the source holder was produced using forged tungsten (W) due to its high density and attenuation to gamma radiation [3].

Five fountain holders were designed and built to be positioned diametrically opposite each detector array. Figure 1 shows the drawing of the detailed font holder, and Figure 2A shows the sectional view of the font holder, in which the positions where the two radioactive sources can be placed simultaneously can be observed, Figure 2B an image of the holder, sources with its stepped motor coupled and Figure 2C image of the ^{192}Ir inserts that were placed for use in this projects.

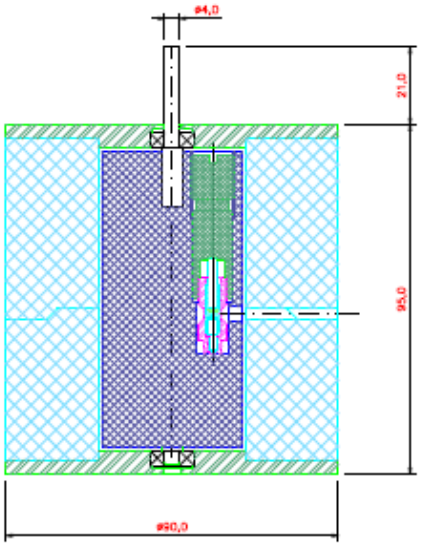


Figure 1: Technical drawing of the source holder with tungsten shield for the tomography assembly portable industrial real-time processes.

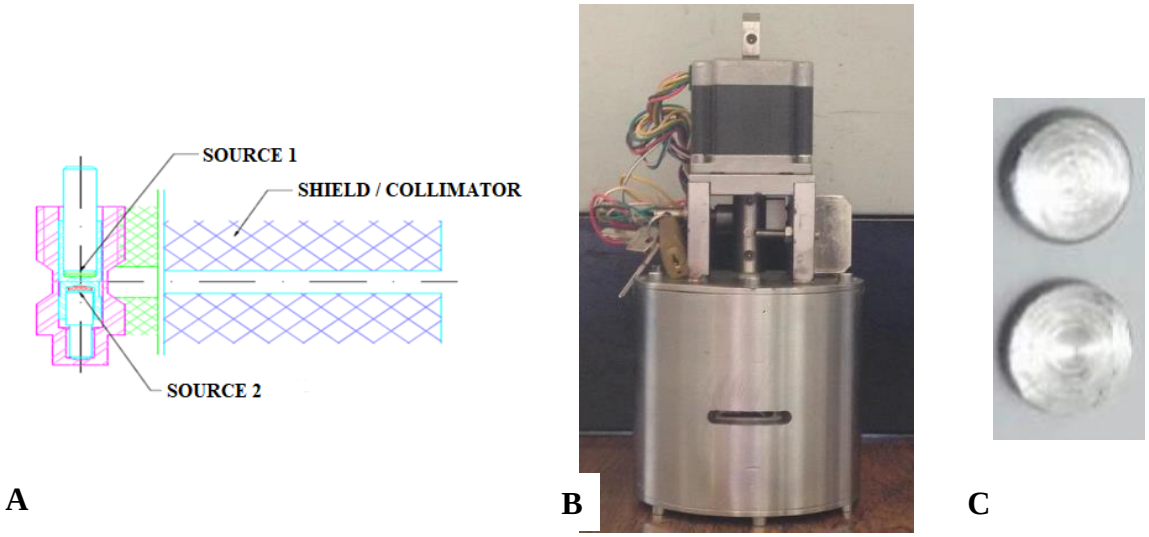


Figure 2: Sectional view of the source holders. (A), the photo of the source holder made with capacity for two sources (B) and photo of radioactive sources (C).

2.2 ESP32s

In this work the NodeMCU-32s version is a development board based on the ESP32s Wi-Fi module, which is a highly technological electronic component specially developed to connect robotic projects or residential automation and small industrial projects to the Internet, easily and mainly low cost.

In this module, besides the ESP32s, it has a crystal of 40MHz in addition to the crystals of 160MHz and 240MHz, built-in antenna and micro USB port for power and programming, plus 36 pins General Purpose Input / Output (GPIOS), Digital Analog Converter with 12 bits of resolution, 2 Digital Converter and Analog with 8-bit resolution, Wi-Fi 802.11 b/g /n, Bluetooth V4.2 and dual core 32-bit LX microprocessor [4].

2.3 Programming of the motors of opening / closing of the sources system

Targeting a security operator during the opening port-sources, an automated opening system, the Internet of Things (IoT), which can be triggered via software installed on the scanner computer or by an application (app) smartphone by the Protocol Message Queuing Telemetry Transport (MQTT) [5] [6] [7], which enables the stepper motor to be monitored in real-time and long-distance, showing the opening and closing status of each source port. Programming codes that were written in the Arduino Integrated Development Environment (IDE) [8].
The MQTT protocol and the application design platform, MQTT DASH for smartphone, communicates between the ESP32s module and the smartphone via the internet using a broker, web data manager [6] [7], which enables opening and closure of the power supplies, either simultaneously or separately, and perform all status checks.

The software for managing the opening and closing system of the sources was developed on an app free platform, available on the internet. In MQTT DASH applications, the data manager is handled by the CloudMQTT server.

From the data provided by CloudMQTT is set up the application so that it makes communication with the cloud, which in turn communicates via the Internet, through the MQTT protocol with ESP32s, for the control and monitoring of the motors of the step of the source holders [6].

3. RESULTS AND DISCUSSION

3.1 Engine control module

The stepper control module was developed with the same standard of the pre-drilled plate, as can been seen in the Figure 3, ESP32s is coupled using a ULN2803 drive controller for each motor of its respective source holder. This whole system uses a voltage of 5 volts [9].

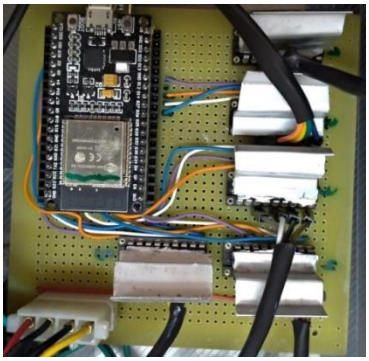


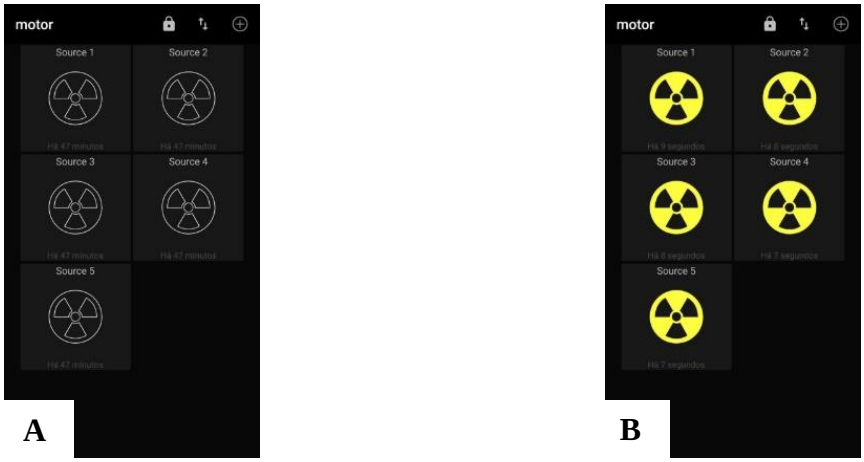
Figure 3: Stepper motor control module.

The motor module had an effective control, but some heat on the drive ULN2803 was observed. This may be due to the current that flows through this drive, once the system and motor run on 5 volts and approximately 1.5 amps for each motor [9]. This problem was solved an aluminum sinks on top of integrated circuits and a cooler.

3.2 Opening and closing source holder system software

From the data provided by CloudMQTT the application is configured so that it can communicate with the cloud, so the communication through the internet through the MQTT protocol with the ESP32s for the control and monitoring of the stepper motors of the source port is initiated.

The software interface for managing the system is shown in Figure 4. As can be seen in the application screen, there are symbols representing each holder. Figure 4A indicates that the source holders are closed, and Figure 4B, containing the highlighted symbols, represent that the radioactive sources are exposed, so the source holders are opened [10].



A **B**

Figure 4: Screenshots of the app showing closed font holders (A), open font holders (B).

4. CONCLUSIONS

The use of the MQTT protocol is a form of communication with easy programming that allow fast access for the transference of data between the smartphone, clouds through the internet and ESP32s.

The motors module has an effective control but with a heating in the ULN2803 drive was noted, probably due the voltage and current in the system, but this problem was easily solved adding aluminum sinks on top of integrated circuits and a cooler.

The automatization of the source-holder system for industrial process tomography, as performed in this work was effective, but major studies and developments for the whole tomographic system will be necessary.

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REFERENCES

1. E. Y. Toyoda, *Evolução das doses no ambiente do reator IEA-R1 e tendências com base nos resultados atuais* . **Dissertação de mestrado**. ed. São Paulo: IPEN, 2018.
2. M. E. C. M. Rostelato, *Preparação de fontes de irídio-192 para uso em braquiterapia* . **Dissertação de mestrado**. ed. São Paulo: IPEN, 1997.
3. D. V. S. Carvalho, *Efeitos do colimador na qualidade de imagem em tomógrafo industrial de terceira geração* . **Dissertação de mestrado**. ed. São Paulo: IPEN, 2014.
4. ESPRESSIF, *Espressif Systems.com*. Espressif , 2019. Disponivel em: <https://www.espressif.com/en/esp-wroom-32/resources>. Acesso em: 04 Juny 2019
5. MQTT DASHBOARD, HiveMQ Enteprise MQTT broker . Disponivel em: < http://www.mqtt-dashboard.com/index.html >. Acesso em 29 Juny 2019
6. BARROS, M. MQTT - *Protocolos para IoT*. Embarcados, 2015. Disponivel em: <https://www.embarcados.com.br/mqtt-protocolos-para-iot/>. Acesso em: 16 Março 2019.

7. CLOUD MQTT, *Documentation Getting started*. CloudMQTT, 2018. Disponivel em: <https://www.cloudmqtt.com/docs/index.html>. Acesso em: 16 Março 2019.
8. ARDUINO, *Arduino IoT Cloud*. Arduino.cc, 2019. Disponivel em: <https://www.arduino.cc/en/IoT/HomePage>. Acesso em: 02 junho 2019.
9. D. V. S. Carvalho, *Desenvolvimento e análise de um sistema multical e multiufontes para tomografia de processos industrial em tempo real* . **Tese de doutorado**. ed. São Paulo: IPEN, 2019.
10. F. Souza, Use o MQTT DASH para contorlar uma lâmpada remotamente. **Embarcados**, 2018. Disponivel em: <https://www.embarcados.com.br/mqtt-dash/>. Acesso em: 16 março 2019.