Application Of Real-Time Operating Systems in the Design of Medical Devices

Wilver Auccahuasi [1], Sandra Meza [2], Emelyn Porras [3], Milagros Reyes [4], Oscar Linares [5], Karin Rojas [6], Miryam Inciso-Rojas [7], Tamara Pando-Ezcurra [8], Gabriel Aiquipa [9], Yoni Nicolas-Rojas [10], and Aly Auccahuasi [11]

[1, 3, 4] *Universidad Científica del Sur, Lima, Perú*
[2] *Universidad ESAN, Lima, Perú*
[5] *Universidad Continental, Huancayo, Perú*
[6] *Universidad Tecnológica del Perú, Lima, Perú*
[7] *Universidad Privada del Norte, Lima, Perú*
[8] *Universidad privada Peruano Alemana, Lima, Perú*
[9] *Universidad Tecnológica de los Andes, Apurímac, Perú*
[10] *Escuela Superior la Pontificia, Ayacucho, Perú*
[11] *Universidad de Ingeniería y Tecnología, Lima, Perú*

Abstract

Medical equipment plays a very important role in the care of people, for this they must be designed with the functionality to ensure the operation and performance, these teams are characterized by being integrated by hardware and software, through which govern all resources, one of the requirements that are asked to these teams, is the reliability, understanding as perform certain tasks when necessary, to ensure the continuity of the patient's life. In this paper we recommend how to use a real-time operating system, based on the FreeRTOS distribution in its version to be used in embedded devices, the results are related to how to be used with which we can describe the advantages we can achieve using these systems when we are in the design stage of medical equipment, the method presented can be scaled and applied depending on the requirements of medical equipment, which can be used in embedded devices as well as in desktop processor architectures.

Keywords

Programming, FreeRTOS, Real time, algorithms, tasks, Execution time.

1. Introduction

The current conditions originated by the COVID-19 pandemic, allow the increase in the development of medical equipment, many universities and research institutions are directing their efforts to develop medical equipment, according to the level of complexity. The main unit related to the control of the equipment is related to a data processing unit, which can be a processor or a microcontroller, the choice will depend on the level of complexity of the equipment and the processes to be performed. The main problem is the execution of tasks according to priority levels. Reviewing the literature, we found works where real-time operating systems and the various applications that require them are applied.

We found works referred about the development of medical equipment which must have clear

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EMAIL: wilver.auccahuasi@upn.edu.pe (Wilver Auccahuasi)
ORCID: 0000-0001-8820-4013 (Wilver Auccahuasi)

processes in order to obtain the safety of both the user and safety, so it is proposed the systematization of good practices for the development of medical equipment, developing a method to systematize the activities of the process in 5 phases with 9 functional groups where each group works has its activity and tools used to perform their work [1].

We found works referred about the development of an IRB system and expects the system develops to be used for the development of medical devices, smart, accesses and fast to IRB certification and for easy follow-ups, which has provided a mechanism for communication and cooperation between both researchers and manufacturers generated through an online conferencing system [2].

In the development of medical equipment, energy consumption is a very important factor, we describe a work where we present a methodology for the development of medical equipment in order to change the types of approaches being increasingly energy efficient where the ECG is the most used, In the case of any equipment with a lower energy consumption compared to traditional equipment is considered as a greener or more efficient equipment reducing the count so it is proposed to design and implement an efficient ECG machine using I / O standards LVDCI (low voltage digital control impedance), SSTL (Stub series terminated logic) and HSTL (high-speed transistor logic) [3].

Telemedicine services are on the rise, therefore a work is described where it provides health service in remote locations for which a tele-assistance system with GSM functionality is implemented with an architecture, processes and procedures included in the development where the design scientific research (DSR) has been used during the development, for which each block has been designed separately and then integrated, at the end they have been compared with calibrated medical instruments where it was shown that the system worked as proposed after calibration [4].

In the use of real-time operating systems, we found works referred to the development of catheter OS used in medical applications, for which a high precision remote control system is developed with the use of a master-slave system with which security is guaranteed with a design of a simple micro force sensor, then the experiment on the operational simulation "in vitro" has been carried out, where the results indicated that the proposed catheter OS works perfectly to control the teleoperations which can improve the effectiveness, operability within aneurysm with force feedback for intravascular neurosurgery [5].

When designing medical equipment, we are not alien to the design of algorithms, we present a work where we consider the design of algorithms for complex electronic medical equipment, which has an element of biotechnical system considered as a variant of cyber-physical system which contains a biological object, an electronic medical equipment and a potential user, where the design of medical equipment is considered as complex according to the characteristics of the biotechnical system where each development of 1 piece leads to an individual approach, where the analysis of the structures of these systems and their characteristics allows a systematization of the sequence of operations used for the creation after the tests it could be demonstrated that the design of the algorithm has improved during the design of biotechnical systems for therapeutic purposes [6].

In the industrial environment we find different real-time operating systems, with characteristics depending on the type of industry. In the medical field we find the QNX MEDICAL OS [7]. These systems perform control processes of all the devices that are connected to the equipment, through the various communication ports, the most important being the GPIO port [8]. One of the distributions of real-time operating systems is RTOS, which has in its different versions, including 32 bits and 64 bits, can also be configured multiplatform as in microprocessors, microcontrollers of different architectures [9]. One of the advantages of these operating systems is the security against failures, because they are designed exclusively for the intended tasks, that is why it is configured according to the design of the equipment [10]. One of the most widely used and free versions is FreeRTOS, with the features described above [11].

Among the different applications that medical equipment is used, we find those related to telemedicine, where medical data is transmitted through different communication networks, for the purpose of remote diagnosis [12]. In the sending of signals is another of the most used mechanisms, we find solutions where EGC, EMG, EOG, EEG signals are transmitted, among others, using different communication networks [13]. Another signal transmitted is related to the fine movements of the body through inertial systems [14].

In this paper we present the benefits of working with real-time operating systems in most processor and microcontroller architectures, we present the advantages of their application with emphasis on embedded systems.

2. Materials and Methods

For a better understanding of the methodology presented, we describe in Figure 1, we present a block diagram, where we describe the organization of this work, based on describing the needs in the design of medical equipment from the conception of the problem, then we describe the main features of real-time operating systems and end with the advantages of using these operating systems in the operation of medical equipment.

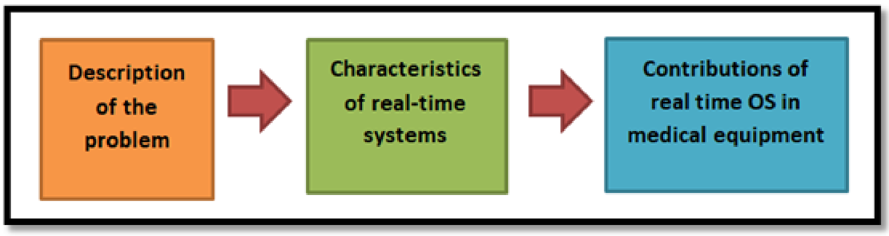

Figure 1: Block Diagram of the Proposal

2.1. Description of the problem

In the design of medical equipment, the execution of tasks is one of the most critical processes, due to its nature and complexity of use, these tasks can activate alarms and actuators that guarantee the continuity of patients' lives. In order to design reliable equipment, it is necessary to consider times and priorities of execution of critical tasks, in many cases exclusive processing units are used for these tasks, having as a consequence the increase of the physical size of the equipment, as well as the increase of energy consumption. It is necessary to have a small, reliable and low power consumption equipment, as a basic requirement of the equipment, so it is necessary to work with embedded hardware that meets the functionalities, which have processing units, signal acquisition, digital analog conversion units, among other processes, these devices are usually programmed with its proprietary SDK, which in the algorithms we do not find functions to plan the priorities of operation, leaving the SDK kernel this function.

2.2. Characteristics of real-time systems

One of the requirements that design engineers are asked to meet is the reliability of the equipment, for which tasks are designed and given execution priorities, leaving the designation of priorities to the kernel. This programming mode can work in conventional situations, but in situations where it is required to activate alarms or activate actuators in the shortest possible time, we solve these problems when we design the algorithms using concurrent programming logic and in real time, thereby giving execution priorities, in execution mode when one of these tasks related to activate alarms or activate actuators to ensure the continuity of the patient's life. This programming mode is achieved thanks to real-time systems, which have an architecture that makes it possible to communicate directly with the hardware.

In the case of medical equipment. The real-time programming mode, allows to meet the reliability requirement, then, we describe the main features of real-time operating systems, applied to the design of medical equipment.

1. Sensitive: The equipment is sensitive to the execution time, meeting the start time,duration time and process time.
2. Deterministic: this characteristic is important because the tasks are executed in adetermined time.
3. Control by user: the algorithms are designed according to the design needs, with which the programmer indicates the order of priorities.
4. Reliable: the designed algorithms are reliable, because they only exist in the system for the duration of their execution time, using memory only as long as necessary.
5. Tolerance to failures: it is guaranteed that the algorithms do not fail when their life cycle is shorter.
6. Priority planning: algorithms are designed in the form of functions and a main algorithmthat defines the execution priorities of the tasks found in the algorithms.
7. Interprocess communication: this programming model ensures communication between processes, thanks to the shared memory mode.
8. Interrupt handling: priorities are defined in execution mode thanks to the interrupt, which allows to pause certain tasks when a task with a higher priority level is activated.
9. Input and output support: this programming mode is designed to perform control tasks using various types of inputs such as serial ports, parallel ports, GPIO ports, among others.

2.3. Contributions of real time OS in medical equipment

To be able to work with the operating systems in real time, it is first necessary to perform processes with the kernel, which is commonly called, patch the kernel, or install the operating system in real time, in this way you have the operating system in real time working directly with the hardware, which ensures that the tasks are executed as scheduled, at the time of installation the resources to be used in real time are configured, this task is very important because the programming is customized to the hardware you have.

Figure 2 shows the block diagram of the architecture of real-time operating systems, where they can exist alone or coexist with the conventional operating system, when we say that they can coexist it means that both are installed in offline mode, but in execution mode only one of them is executed. We must consider that the real-time operating system is directly linked to the hardware, without any other program or system to help manage, this model has its advantages and disadvantages, the biggest advantage is that it can be programmed directly in the availability and access of resources such as processor, memory, input and output units, etc.. But it has as a disadvantage, the programming level, because you must define the tasks to be executed. In this sense, the systems have to be updated and programmed in a personalized way according to the characteristics and work levels of the equipment to be developed, there is no general development mode.

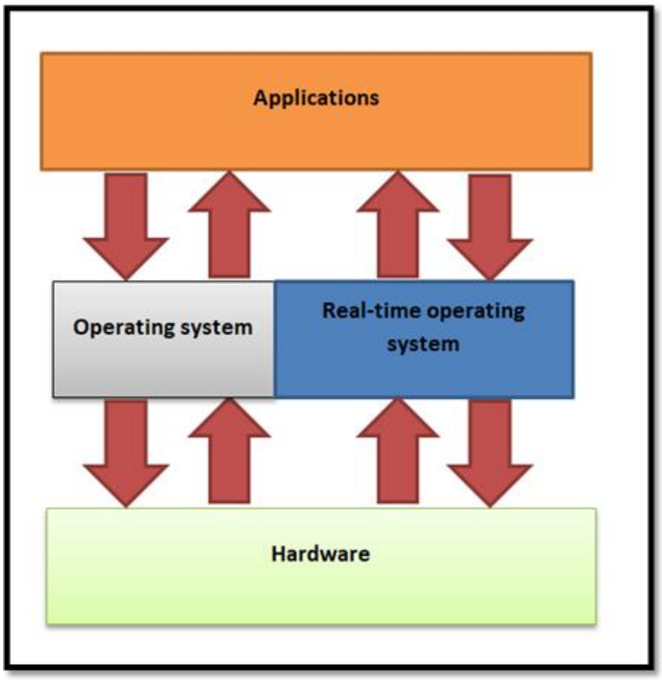

Figure 2: Real-time systems architecture

3. Results

The results that we present, is dedicated to present the working model with an embedded hardware, PIC-IoT of the Microchip, which has as processing unit the PIC24FJ128GA705. It has in its architecture a digital analog conversion unit, digital input units, analog input, memory, this device can be configured using a real-time system for embedded systems, we can work with FreeRTOS, so we continue working with all the capabilities of the hardware in addition to a definition of their tasks, a particularity of this model, that the programming of the tasks are performed using the C language, and working with Microchip's own SDK.

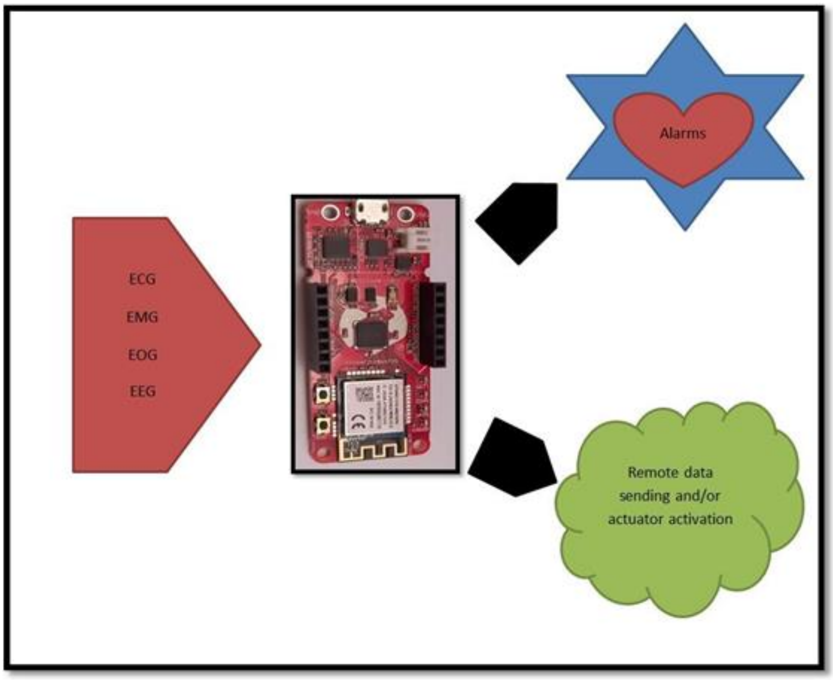

Figure 3: Architecture of an implementation model

Figure 3 shows an implementation architecture of medical equipment, as a prototype, where you can connect EEG, ECG, EMG, EOG sensors, among others, which are acquired by the analog inputs of the device, the processing that can be performed, will depend on the functionality you want to implement, such as recognition of characteristic patterns of a signal, such as the QRS segment in an ECG signal, in the execution mode of the tasks first the process of recording the signal is performed, Then the QRS segment is analyzed, and depending on the result, alarms can be turned on or signal transmission mechanisms can be activated, the real-time task can be executed if in a second recording the signal is being recorded again, if the algorithm detects a different pattern of the QRS signal, this task activates the alarm that alerts the equipment and automatically activates the necessary actuators, in this programming model, the alarm has a high priority and short duration time, to ensure that the next signal is analyzed.

4. Conclusion

The conclusions that we reached, is dedicated to present the benefits that provides us to design medical devices, under the real-time programming approach, under a FreeRTOS kernel, the results show that you can have an embedded system running a real-time system, with exclusive application in tasks to analyze biomedical signals, under the concept of medical equipment, the operating system chosen can be installed on different models of embedded devices, for which it is necessary to know the microcontroller that has and verify if it is compatible with the FreeRTOS operating system.

Analyzing the characteristics of the operating systems in time, and performing an analysis of the advantages in the performance of the medical equipment, we describe below these advantages that allow to obtain a higher performance:

1. Sensitive: at the sensitivity level, we can indicate that the programmed tasks must be performed for a specific task. We can indicate sensitive tasks such as signal acquisition,analog to digital conversion, among others.
2. Deterministic: at the programming level, the tasks are programmed with a specific time.
3. User control: characterized by the programming mode, where algorithms are customized, depending on the hardware and functionality of the medical equipment.
4. Reliable: in development mode this feature is achieved, because the task uses resourcesfor a certain time, then releases the allocated resources.
5. Fault tolerant: in execution mode this feature is achieved due to the short lifetime of thetask.
6. Priority planning: at scheduling time a priority list is created, where each task has apriority assigned by the scheduler.
7. Interprocess communication: in scheduling mode when a task is finished, it returns the execution to the next task with the best priority, so that each task knows which task continues the process.
8. Interrupt handling: interrupts are also scheduled, each task has its own interrupt, whichcan be configured in emergency situations.
9. Input and output support: depending on its architecture, we can configure serial, parallel,GPIO and other ports.

Finally, we can indicate that in the design of medical equipment, standards must be considered to ensure patient safety, therefore the proposal presented helps in terms of hardware performance, in order to demonstrate in design mode, if you want to take it to a commercial level, you should consider the corresponding standard IEC 62304 called software for medical equipment.

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