Embedded system in biomedical applications: challenges ahead

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***Abstract*— Embedded system is a computing device with a combination of both hardware and software designed mostly for a single task and it is applied in various devices used in biomedical applications that directly involves in diagnosis, prognosis, patient management and telemedicine. Here, this mini-review addresses the embedded system technologies and their biomedical applications and discusses future challenges in designing and enhancing the functions.**

Keywords—Embedded system; biomedical application; microcontrollers; microprocessors; challenges ahead

I. INTRODUCTION

Emerging various science and engineering technologies in the twentieth century have yielded many sophisticated instruments or devices for mankind. Among them, embedded system technology is one which has various role in day to day life. An embedded system is a compact computing device for a well defined task within a mechanical or electrical system. Basically, it has embedded mechanical parts runs with real-time computing constraints. Embedded systems are used in variety of mechanical, electrical, and electronics devices that also includes various portable devices, automated cooking utensils, industrial, medical, telecommunication, military, and many other commercial applications [1].

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For example, embedded system is used in traffic lights, un-manned railway crossings, hybrid vehicles, telephone switches, mobile phones, modem, digital watches, digital camera, MP3 and DVD players, GPS, printers, microwave ovens, dish washer, washing machines, home and industrial automated indoor temperature maintenance, light, audio/visual, surveillance camera, security systems, CT (computed tomography), PET (positron emission tomography), MRI (magnetic resonance imaging) medical imaging systems, etc.

II. DEVICES USED IN EMBEDDED SYSTEMS

In general, embedded system is a combination of both hardware and software used to achieve a unified single task/performance. Importantly it monitors, responds to/or control an external environment that is well connected to a system through sensors, actuators and other interfaces and it meets timing and other constraints imposed on it by the environment. However, embedded systems require a processor that is an important unit and mostly like an heart. The processing core in the embedded system is either a microcontroller or digital signal processors (DSP).

A. Microprocessor

Microprocessor integrates the functions of central processing units (CPU) on single or some integrated circuits. It is a programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and gives as output and it is an example of sequential digital logic as it has internal memory and operates on numbers and symbols represented in the form of binary digits. It mostly uses integrated circuits (IC) for memory and peripherals. Generally, microprocessors are used in embedded systems however, it require more support circuitry than

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microcontrollers. Therefore, it is mostly used in personal computers and other general purpose applications [1].

B. Microcontroller

Microcontroller constitutes a single integrated circuit (IC) containing a processor core, memory, and programmable input/output (I/O) peripherals. The program memory is often in the form of NOR flash or OTP ROM which is included on chip and often microcontrollers are considered as small computers [1]. It uses mostly peripherals on chip and it reduces the power consumption, reduce the size of the device and minimizes the cost. Various types of microcontrollers have been developed based on the need and use. Embedded system communicates to the environment with the peripheral devices such as serial communication interfaces (SCI), synchronous serial communication (SSC), etc.

III. BIOMEDICAL APPLICATION OF EMBEDDED SYSTEMS

In the modern society, there is a consistent increase in the number of people who suffer from various illness that includes metabolic and life style related diseases, though most of the infectious diseases are under control and cured. This condition always looks for better diagnostic tools, expedited information transfer technologies, accurate prognostic devices, importantly patient management system and other alternative medicine strategies. Recently, embedded system technologies have occupied an important area in the biomedical application in diagnosis, prognosis, patient management and telemedicine that broadly includes the diseases of various kinds such as infectious, metabolic and lifestyle related disease in human beings.

1. Diagnosis

Embedded systems are used in wide range of diagnostic devices in biomedical applications that ranges from various hand held devices to big biomedical instruments. For example, blood glucose monitors, blood pressure monitors, patch detection of various disease like dengue, malaria, and portable ECG (electrocardiogram), CT (computed tomography), defibrillators, CRT-D device, digital thermometers, digital flow sensors [2], [3], [4].

2. Prognosis

Prognostication is done using various biomedical devices, for example, PET (positron emission tomography), digital X-ray, MRI (magnetic resonance imaging), etc.

3. Patient management

Wireless technology incorporated with embedded systems helps for self-management by self-testing various clinical parameters such as the blood pressures, blood glucose, body temperature, heart rhythms, etc. Embedded systems with the use of wireless technology is more beneficial to the patients and the doctors especially, the elderly and impaired. Majority of the patients with chronic illness such as diabetes and heart disease benefit from wireless technology [4]-[6].

4. Telemedicine

This employs both wired and wireless technology with embedded system to diagnose, prognoses and manage the patients. It gives both patients and physicians immediate access to important information in real time [2]-[6].

IV. CHALLENGES IN EMERGING EMBEDDED SYSTEMS IN BIOMEDICAL APPLICATION

Although embedded systems are widely incorporated into various medical devices and used in most of the biomedical applications, still lack of generic architecture make the design of this type of autonomous embedded systems a troublesome and highly expensive task. Developing a generic architecture for embedded system basically requires both the layers of hardware and software. Importantly, any prototype needs experimentation and validation and rule out the effectiveness of the architecture and finally advantages of the prototype to develop a distributed biomedical embedded systems.

Most of the biomedical embedded systems works as wireless sensor networks. It has very limited number of options to provide a constant power supply due to the small physical size and absence of wires. It is possible to have an integrated power supply using battery however, it supplies power to a limited time. It would be further complicated to replace the battery as it requires if device is implanted in the body. Alternatively, the solar and vibration provide a insufficient power for continuous operation and not feasible always. Embedded systems and their computation is also limited by the available power supply [7] that discourages continuous usage of the embedded system in any biomedical devices that incorporated into the body.

Portable invasive embedded systems are implanted within the body for various medical needs, wherein the shape and size, and materials are highly restricted as it always fit to the body. For example, a smart sensor designed and embedded to support retina prosthesis should be small and good enough to fit within an eye. on the other hand, a GI (gastro intestinal) monitor should be in the size of a pill as it needs to be swallowed. Moreover, the embedded system needs to curve around the retina, accommodate a bone or a cartilage. Therefore material constraints becomes an inevitable factor in the design of the embedded systems.

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Embedded systems are expected to last for long especially if they are invasive. Because, it is less desirable to adjust the device every week, month or even year. The idealistic life time should be in the range of decades and robustness and fault tolerance and these important factors to be most considered for any portable devices.

Scalability is also another important factor because which determines number of components should be incorporated in it that would directly decide the size of the device.

Further, as the system deals with medical information, it should be important to kept the patient information as confidential though the physician or the patient see the feedback from the sensors. This enforces to have security and interference, as any display of some false information could be fatal and dangerous, for example, appearing a false reading on a patient's glucose monitor output [7].

In general, any embedded systems for biomedical application need to be equipped with low electric power mediated communication systems. Furthermore, these embedded systems could be easily integrated to other general distributing computing platforms, in such condition, reliability and security issues needs to be significantly considered both at the computation and communication levels. Moreover, future biomedical devices with embedded systems mostly rely on the enormous diversity of sensors and especially the biomedical devices demand the development of more of general computation and communication architectures for deploying distributed embedded systems that might cover a wide range of biomedical applications in the biological and medical environments. In the forthcoming decades, a refined and a well defined embedded system would help more number of people suffering from various disease.

VI. CONCLUSION

Embedded systems are used in various diagnostic, prognostic, patient management, and telemedicine. The professionals in the biological and biomedical field are looking for emerging innovative embedded technologies for the future biomedical applications. The future challenges would be innovating a compact, constraint device with enhanced software solutions for user friendly, faster, smarter and reliable use.

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