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Recent Trends, Future Perspectives and Career Options of Embedded Technologies

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Abstract – Due to rapid advances in the field of electronics, robotics, wireless communications, and networking, devices around us with a small processor/sensor embedded within them (called embedded systems), communicate with all other devices around, making our lives much more connected and easily accessible than ever before. Embedded systems are controlled by instructions stored on a chip, and are also known as real time systems since they respond to an input or an event within a guaranteed time to produce the result. Today's embedded technologies and systems are becoming more intimate and control to human lives. There are a number of challenges encircling the use of embedded technology like energy consumption, security, privacy, and human-computer interaction. With the latest advances in health monitoring and other related applications, we expect that, it is the time to reveal the extent to which embedded system developments might offer a paradigm shift in this context. This paper will bring together the recent trends in embedded technology, real-world applications, future perspectives, and various career options of embedded technologies.

Keywords- Embedded Systems, Real Time Systems, Firmware, Microprocessor, Pervasive Computing.

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1. INTRODUCTION

Embedded systems have become an integral part of daily life. Be it a cell phone, a smartcard, a music player, a router, or the electronics in an automobile- these systems have been touching and changing modern lives like never before [1,2].

An embedded system is more than the electronics as most people perceive it. It is a combination of computer hardware, software, and additional mechanical or other technical components, designed to perform a dedicated function. The major building blocks of an embedded system are micro-controllers / digital signal processors (DSP), integrated chips, real time operating system (RTOS), industry-specific protocols, interfaces, and printed circuit board assembly [1-4]. Embedded processors are the heart of modern electronic devices such as DVD player, smart card, remote control, air conditioner, router, microwave oven, television, or cell phone. Firmware is the software for embedded system [1-3]. Design challenges of embedded systems are space, cost, weight, and power consumption. Low power, real-time response, rugged in design, low thermal dissipation, small physical form factor / footprint, and low radiation/emission etc are important characteristics of embedded systems [1-5].

In order to achieve key requirements, embedded systems are generally restricted to limited resources such as memory and display size. A lot more functionalities are being pushed into embedded devices that were once part of traditional computing platforms by the virtue of continued convergence of other technologies that adds a major 'decision challenge' for architects and product managers on the selection of processors, operating systems, and standards of usage [2-3].

2. REAL LIFE APPLICATIONS OF EMBEDDED SYSTEMS

Embedded systems are deployed in various applications and span all aspects of modern life. In almost all facets of human endeavour, its presence is virtually unavoidable. Figure 1 details the main application areas of embedded systems [6]. Important application spaces of embedded systems are discussed below.

A. Embedded Multicore

The need for high performance in embedded systems has become inevitable with a large number of functionalities being added to it. Hence, a large number of developers are increasingly attracted towards multi-core processors. Today smart phones

are indeed getting 'smarter'. These smart phones and most of gaming consoles are multi-core [6-8].

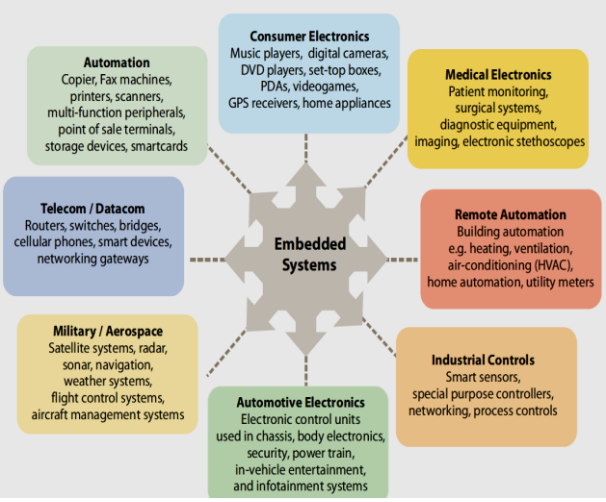

Fig.1 Application space of embedded systems

B. Embedded Operating Systems

Traditionally embedded system did away with an operating system (OS), it had lightweight control program / monitor to offer limited I/O and memory services, however, as the systems became complex, it was inevitable to have OS which offered a low latency real-time response, low foot print both in time and space and give all traditional functionality such as memory protection, error checking/report and transparent inter-process communication, which can be applied to communications, consumer electronics, industry controls, automotive electronics and aero-space/ national defence [1-2].

C. Healthcare

Electronic medical devices, sensor technologies, other technological advancements, and innovations with the convergence of biotechnology, nanotechnology, manufacturing technology, and communication techniques are making breathtaking transformations in medicine, health care delivery and creating new health care paradigms. Bio-medical devices technology is being applied into a wide variety of analytical problems including medicine, surgery, and drug discovery [1].

Wireless cardiovascular solutions have been developed to offer unprecedented visibility into a patient's health status anytime, anywhere across the world. All these happened because of the advancements of sensor, computing, and wireless communication technologies.

D. Automotive

Embedded systems are clearly the ways and means of achieving multiple objectives in automotive industry taking it from engine control unit, car-area-network, fuel management, safety systems all needs to be embedded in it. Traffic management and prediction systems are being developed for larger cities across the world today with the support of communication networks that, form adhoc networks, seamlessly gather information from multiple sources, fuse and make decision that not only help the car users but also city traffic managers.

E. Entertainment

Mobiles, handhelds, ipods etc have changed the landscape of the personal entertainment in the world in the recent past. The emerging trend is adding more intelligence in the personal entertainment communication devices by converging the social networks, city information, location based services, choices and profile of the users. All these are going to be delivered through the continuous gathering of intelligence, users and recent transactions. The devices are becoming multimodal, iPod, other new androids offer gesture recognition, and the new devices are offering augmented reality applications that are going to be future killer applications for smart phones.

3. FUTURE OF EMBEDDED SYSTEMS

Since their inception, embedded systems have come a long way. The future of embedded systems lies in advancement of technologies that enable faster communications, how faster people adapt to the changes offered by convergence of communications, heavy data storage capacities [1, 8-9]. Following is the description of seven important features that will define the future of embedded systems.

A. Ubiquitous computing

A branch of computing that focuses on interconnected and communicating devices carefully integrated into the objects we interact with in our daily lives is termed as Ubiquitous Computing. These objects can be anything right from our clothes to toasters and coffee mugs. Currently the smart phones and tablets are obvious targets for applications aiming at ubiquitous computing, but in the near future; 'if our game console talks to our smart phone's calendar about how 'busy' we are today' it is not surprising. Applications of ubiquitous computing got a real boost with the advancement of cloud computing [1, 4-5].

B. Intelligent device

Intelligent devices or 'things that think' are the devices with the ability to think. These devices use a combination of technology, algorithms and embedded hardware to replicate what was once thought to be an

activity exclusive to living beings with brains. Today, there are machines that can do your thinking for you. MIT Media Lab is working on this 'Things that think' idea and aims at creating environments that enable this way of thinking [1, 8-9].

C. Internet of Things

The Internet of Things (IoT) is a technology revolution introduced in 1989. It is gradually sneaking into our lives and will soon be a reality. IoT is a concept that involves connecting the internet to physical devices such as home appliances and manufacturing machines [1].

With the internet of things, our smart phone communicates with the chair on which we are sitting and lets us know about our sitting posture, the satellite receivers provide the right temperature, and our cooking gas alerts us to whether the dish we left to simmer on it is burning; in case of a fire hazard, it will communicate with the respective fire control agency in our zone. Businesses have also realized the importance of IoT and there many are specialized consultancy firms helping us to apply IoT at our organization [1, 9-10].

D. Cyber physical systems (CPS)

Cyber physical systems (CPS) focus at integrating the physical and cyber world into one. The backing to CPS is powerful computation and the fast communication. CPS can be used for a highly precision-based task such as in the implementation of robotic arms, creating and deploying energy efficient systems, exploration-based tasks in areas inaccessible to humans, for easing daily life activities, as well as in exploring the outer space. Cyber physical systems are challenging to implement as they involve a combination of advanced hardware and software needs. Privacy, security, and flexibility due to their high level of complexity are some of the issues relating to these systems. Somewhere some great minds are working in a lab to make all this happen for us [1, 8-10].

4. APPLICATIONS OF FUTURE EMB-EDDED SYSTEMS

In the near future, embedded systems will come with a lot of cool stuff in its bag and a variety of applications in different verticals and are discussed below.

A. Smart agriculture

One of the primary fields that require assistance of something awesome like embedded systems is agriculture. In the field of agriculture, many complexities are involved such as a farmer has to understand the climatic conditions, sometimes predict the conditions, and change the farming practices accordingly. According the soil conditions of that specific area the farming practices also change and hence some computational assistance can help a lot. With this in mind, scientists have come up with what they call as Precision Farming/Precision Agriculture that optimizes the whole farm management by maximizing the output while keeping the input minimum. Kerala Agricultural University (KAU) and International Centre are presently implementing precision farming in Kerala where they are trying to setup a technology-assisted system called 'Smart Agriculture' which would provide real-time data about the soil with the help of sensors to a cloud-based platform [1,9-10].

B. Intelligent transport systems

Autonomous transport systems developed by the organizations such as Google, Audi, and Toyota focus at increasing the safety and comfort of drivers and are in the plans of releasing them for commercial purposes in near future.

Autonomous vehicles are designed to drive on their own by understanding their surrounding and act accordingly. Implemented with technologies like GPS, advanced Computer Vision, LIDAR; these vehicles can identify the correct paths and lanes in a city and navigate without colliding obstacles and follow proper traffic rules. BMW Company has been doing R&D since 2005 and is all set to release an autonomous vehicle in 2013- 2014. Google has already released some videos of the driverless car system that they have been working on since 2005 and has some positive reviews. These autonomous vehicles are also equipped with Anti-Lock Braking System that is triggered when the vehicle is in a potentially dangerous situation. Inter- Vehicular Networks are being established which maintains communication between the vehicles. This reduces the risk of potential accidents, as generally accidents happen due to humans not being aware of 'Blind Turns' and 'Steep roads. Therefore, the objective is to ultimately make a Context aware Information System (CAIS), which maintains information about the context of roads and paths. These systems will definitely help in the reduction of accident rates as the systems aimed to have an increased reliability and lower reaction time when compared to humans. Some New technologies are used in airplanes these days, which send data about how each component in the aircraft is doing to a central computer for better tracking and management [1, 9-10].

C. Smart healthcare systems

This feature revolutionizes the way the medication at present. To the people living in rural areas, doctors can provide remote medication that is estimated to reduce more than 15% of medical expenditure in the country and to save a number of lives. Recently, telemedicine has gained a lot of importance and

practically being implemented in countries like France, and Spain.

With the development of Remote Patient Monitoring (RPM), telemedicine will take a step forward. With advanced mobile technology, a doctor can monitor the status of a patient; get real-time reports on his/her medical status like Heart Rate, and Blood Pressure. Even internal-body examinations can be done with the help of pill-shaped micro cameras that can travel inside the digestive system and can send image that helps in a better diagnosis.

Embedded systems are also used to create artificial human organs. Many organizations are into research and development of artificial organs. America's San-Diego based company already has a working 'mini-liver', which almost functions like the real one [1,8-10].

D. Smart architecture

With highly context aware and connected systems, Smart Homes have become a reality. These homes have electronic circuits, sensors embedded into their walls floors, and everywhere else, they allow us to operate our entire house from just a one-point contact such as a smart phone/tablet application. Presently days many companies are working on assistive homes that can help elderly and disabled people lead a quality life without the help of institutional care. These homes are equipped with a set of wireless systems connected with central context aware systems for monitoring daily schedules of the elderly people and using machine-learning algorithms to learn and recognize behavioral patterns [1,9].

E. Personal assistants

Future embedded systems will see a wide range of applications in the area of personal assistance devices. Google already is working on GLASS, a glass shaped head mounted display that is just a hands-free ubiquitous computer that lets us interact itself using voice commands such as "Glass, Where am I?" and 'Glass, Take a picture'. Such devices act as smart and intelligent personal assistants. Hitachi has developed an office assistant robot EMIEW 2. It acts as your workmate and follows you voice instructions such as 'follow me'. Whenever it sees an object, it takes picture and compares it with an online database of images [1].

F. Smart retail

Today smart phones allow consumers to be connected to the brand and communicate with it in variety of ways. Today it has become imperative for consumer brands to understand the importance of Internet of Things concept and context awareness and apply them in business. With social media applications such as twitter and face book, consumers stay connected to brands all the time. Using location meta-data, many brands are working on dynamic pricing of their products [1, 8].

G. Security and defense

This feature prevents unauthorized Photography /Videography by using projectors and cameras that make any such photo/video blurred. This enhances the security of areas, which do not allow photography. Complex embedded systems are used to develop high-end reliable devices for the use of military and defense department [1].

5. CAREERS IN EMBEDDED SYSTEMS

Embedded systems are going to be everywhere in the near future-On every floor, every wall, our coffee mug, public transports, cars, homes, offices, aero planes. Looking at the numerous possible applications it has and the awesome projects that are already in pipeline, it is safe to say that Embedded Systems will be one of the most sought after fields of study and hence would require a lot of talented minds, and dedication. Choosing this field as a career option to young Electronics and Electrical engineers would be a smart option [1, 8-10].

A. Study and pre-requisites

Embedded systems is more like an amalgamation of almost all latest technology of today-Software Programming, Digital Electronics, Mobile Computing, Wearable Computing, Augmented Reality and hence would require a base knowledge of all the above mentioned fields, especially Digital Electronics [1,10-11].

Top Universities around the globe including MIT, Carnegie Mellon, Stanford, Cornell, University of Tokyo, University of Cambridge provide both Undergraduate and Postgraduate courses on Embedded systems. Major technological institutions like IITs, NITs, and IIITs in India provide Post-Graduate courses on embedded systems with a pre-requisite knowledge/ degree in Digital Electronics/ Electrical Engineering. These Institutions provide top-notch facilities, research laboratories and have many on-going projects, which can give a deep insight into the study of this field [1, 11].

Many Institutions also provide short-term Certification courses in embedded systems such as Sastra University, University of Pune, CDAC, IGNOU and a lot of training institutions like Vector, Miracle Technologies and Think labs. However, these institutions lack the research facilities and environment, as they are short-term /certifications courses [1,8-11].

B. Specializations

Embedded Systems itself is a specialization in Electronics/ Electrical Engineering. One can work on Robotics, Automobiles, Mobile Technology, Wearable Computing, and Augmented Reality. Although, there are no specialization courses (like Embedded Systems in Robotics) in the above-mentioned fields, one can do research / self-projects in these fields and quote it as their area of interest and apply in the respective organizations [1, 9-12].

C. Career paths

Unlike the IT industry, the entry barriers in this field are quite high, due to the high level of expertise and experience required. Many of the current embedded systems engineers in India confess that the first major practical learning they had was in their first job. So, it is important for young engineers to work on cutting edge technology. For this, one needs to have an open mind to learn and be very passionate about technology and innovation.

Samsung, LG, HCL, IBM, National Instruments, and Texas Instruments companies recruit embedded systems engineers. These also companies facilitate innovative research laboratories. Many technology-consulting firms like persistent technologies also recruit embedded systems Engineers at entry and senior levels. This field has endless opportunities in terms of growth and research and as the parallel technologies such as wireless communication and Artificial Intelligence keep growing, embedded systems will witness a complete overhaul in coming years [1, 8-12].

6. CONCLUSIONS

Embedded systems are ubiquitously related to our everyday life. The development of embedded systems greatly facilitates the comfort of human life, changes the thinking views, and has a significant impact on the society. Although the embedded systems technologies are becoming mature, still there exist several challenges to meet the ever-growing speed and reliability demand from the market. In the near future, we expect more innovative and enlightening researches in this area.

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