Real-Time Systems

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Module No. # 01

Lecture No. # 01

Good morning and welcome to this course on real time systems. Today, we will have some introductory discussion on real time systems and we will see what the topics are and so on, possibly in the subsequent lectures we will discuss in more detail.

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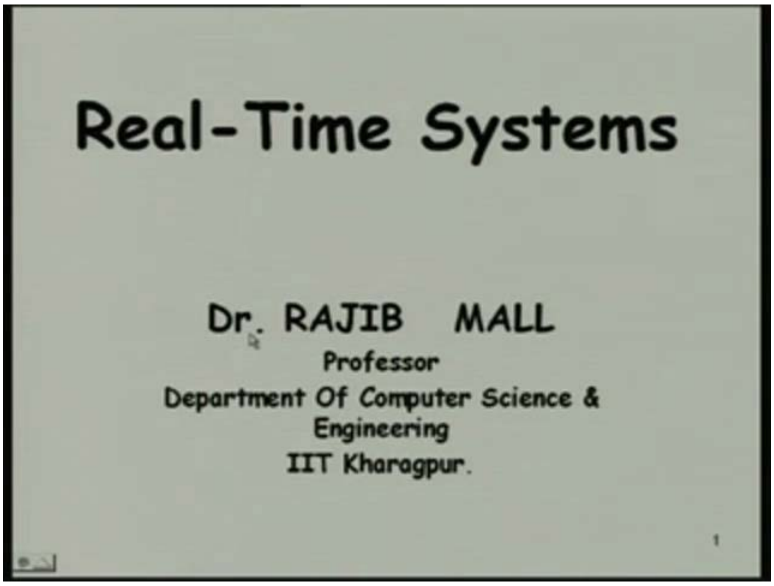

So, let me just introduce myself, because some of you, I am teaching for the first time. So, I am a professor at the department of computer science and engineering IIT Kharagpur, been with IIT Kharagpur for last about 16 years and before that worked with a Motorola India and completed all my education bachelors, masters and Phd from Indian institute of science Bangalore. And as the course proceeds, possibly based on the questions you ask, just later get to know you about you your name and so on. So let us start, let us look at the plan of the course.

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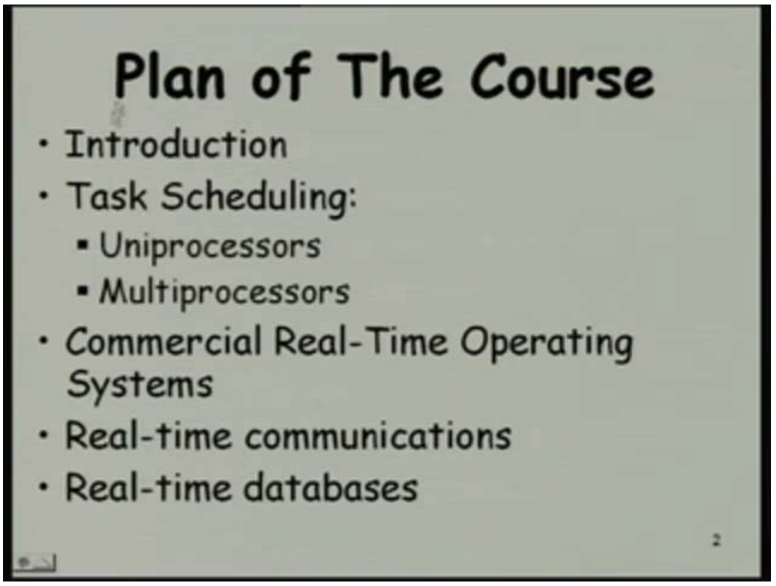

It will have a one or two or maximum threes lectures on introduction and then we will look at some very basics of real time operating systems, because that is the major emphasis of the course real time operating systems. And as you will see that, scheduling tasks is one of the major issues in many real time operating systems, we will look at uniprocessors, how tasks are scheduled. There is a quite a bit of theory developed over the years for tasks scheduling in uniprocessors.

Possibly, you have done in a operating system course basic operating system course, how tasks are scheduled in traditional operating system, we will see that here, different we will we will observe the difference and we will look at multiprocessor and distributed system. We will look at resource sharing issues and after that we will look at commercial real time operating systems, some of the operating systems there are actually used in different organizations. And then, will look at real time communications, because now a days, most of the real time systems they have they communicate with other devices or may be on the internet.

So, we will see how real time communication can be supported and then we will look at real time data bases, because increasingly more and more the systems are using data bases to store data about their environment process them in real time. Whereas, you can see the plan of the course, it is mostly deals with a software issues, we will restrict the hardware issues to minimum, we cannot really avoid in such a course some hardware issues, but will restrict that, otherwise the course will be too large.

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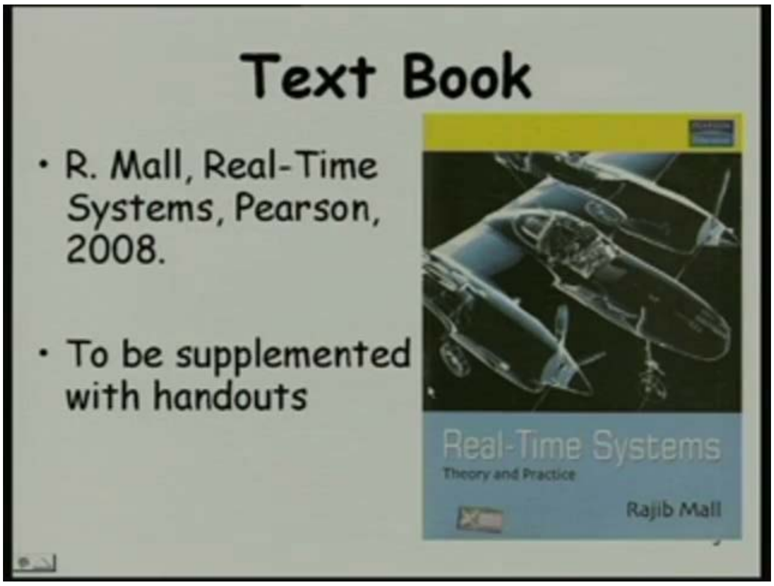

So, the text book, will be a book I wrote on real time systems in 2008, Pearson publication and the book will be supplemented with some handouts that, I will give you periodically.

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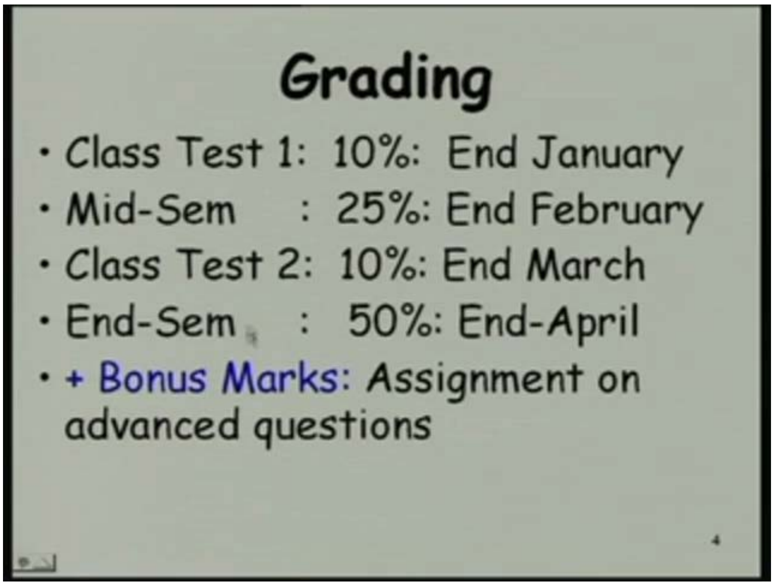

Now, let us look at the grading issues, because in any course grading is important, class test one will have 10 percent weightage, which will occur sometime end January, mid semester will have 25 percent weightage, sometime around end February. Class test two will have 10 percent weightage, sometime end march and the end semester will have 50 percent weightage, sometime in the end April. So, as you can see that almost every month end we have one test or other just to keep track whether you are following the course or if there are any specific difficulties will give you feedback on your performance.

And another thing that we will follow here is that how is the course proceeds will pose you some problems, the problems are not there, I mean the answers are not there in the book, neither can easily get them on a Google search or something, basically will have to think. So, those who are able to do those problems will have additional mark more than this, whatever is displayed here, so that will be added to the total more than this 100 percent.

So, based on the 100 percent and the IT grading scheme like all of you are familiar 90 (( )) etcetera will follow that. But one thing is yes yes.

(( )).

Yeah, I think he as pointed out good thing, that we have only 10, 25, 10, 50 is 95 and he says that 5 percent are not mentioned, yes 5 percent is on attendance, possibly I should have written here, that just to encourage you to attend every class will have 5 percent weightage given to attendance. If you attend all classes 5 percent is assured. Actually grading, as you know that grades are not really an indicator of the intellectual capability or something, because even the best students can score poorly, that do not study, do not attend classes. As long as you are putting effort on this course, keeping track with the lectures should be able to get good grades.

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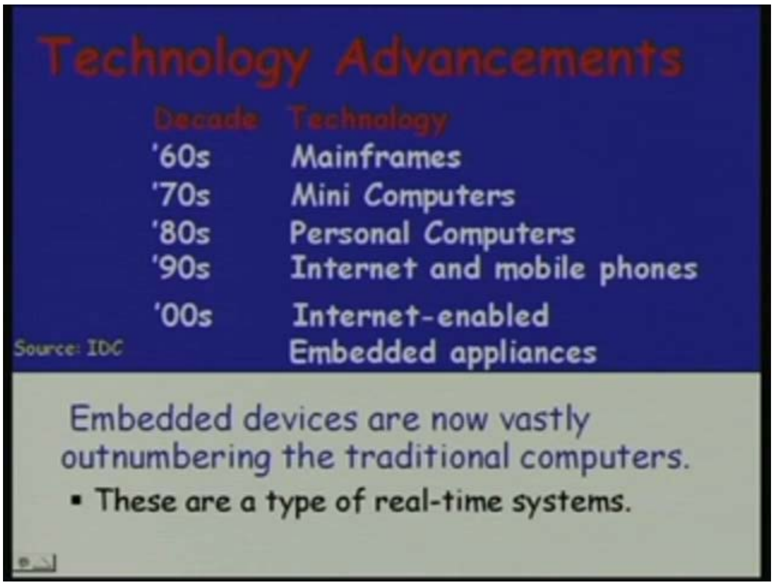

So, let us look at how the technology as advanced over the years, we will see where the real time systems coming. In the 1960's, the computers were basically main frames, extremely expensive computers, hardly an organization or an institute own one and the students or the employees will use that. And these real time systems and embedded systems did not exist those days, because they were extremely expensive for everyday use.

And then we in the 1970's we had mini computers, these were also expensive and in 1980's we had the personal computers, where the cost dropped dramatically and computers got used accuracy various domains and this is the period where the embedded and real time systems they use started to increase. And in 1990's, we had the mobile phones and internet, this was the revolution in 1990's, suddenly everybody started using internet and mobile phones as you know appeared around in India 1995 or something. And then now you know everybody owns a mobile phone, students or shop keeper or even the rickshaw pullers in Kharagpur they own a mobile phone.

And now, one thing that is clear now is that embedded devices that are after 2000, these are vastly out numbering the traditional computers. So, if you look at the number of processors manufactured world wide, the number of processors being deployed in embedded devices is about 70 percent of the processors manufactured. And we now have internet enabled embedded devices, for example, through the internet you can download code on to your devices, they are connected, you can control them on the internet.

So, we will look at these as we proceed, we will look at several examples of this. So, the embedded devices are basically we use real time operating systems, they are a time type of real time systems, we will see what are these real time systems, real time operating systems, some basic concepts about that.

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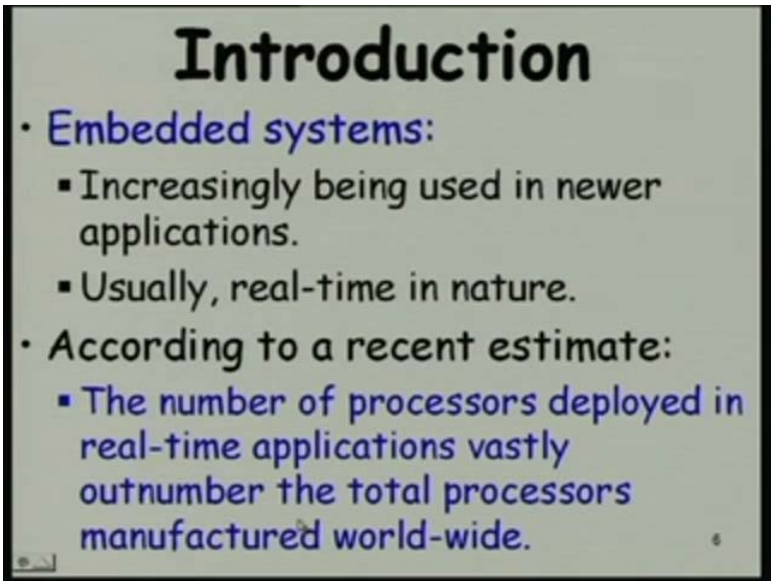

So, as we just saw that the embedded systems are being increasingly used in new applications and all this have real time in nature in the sense that based on some events the action must take place within certain time. The numbers of processors that are manufactured worldwide, now outnumber, vastly out number I think, I said about more than 70 percent that is the statistics published out of the total processors manufactured, more than 70 percent being used for embedded applications.

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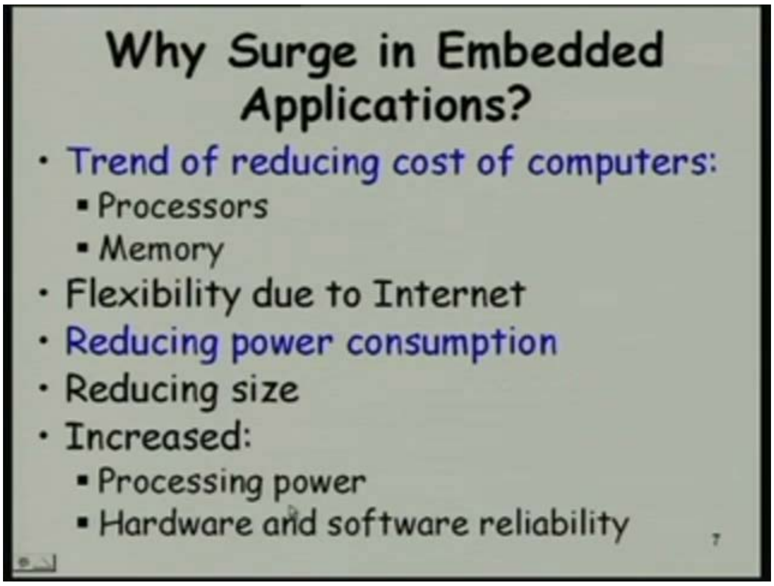

But over the years, why there is a surge in use of embedded applications, there are many reasons actually which have contributed to this trend of increasing use of embedded applications. One is of course the cost of the computers as decreased over the years, from million rupees to few 1000 rupees over about 30 years or so. The processor cost has decreased, memory cost as decreased dramatically, both the semiconductor memory as well as the magnetic memory. And as we will see that in real time systems actually the magnetic memories are not used that much, we have the flash memory's, they are being used. And then the flexibility that has come about due to the use of internet, the embedded devices, even though they are small and many in number, but you can easily configure them and you can maintain them through internet.

And another important factor that has helped, increase the embedded application is the reducing power consumption that is seen over the years. Actually many of these embedded applications, they are battery powered and unless they consume less power, you know they would not be usable and size has reduced from the size of a room to the size of a very small size and we have not only that, we have increased processing power, and the reliability of both hardware and software has increased considerably over this period of time.

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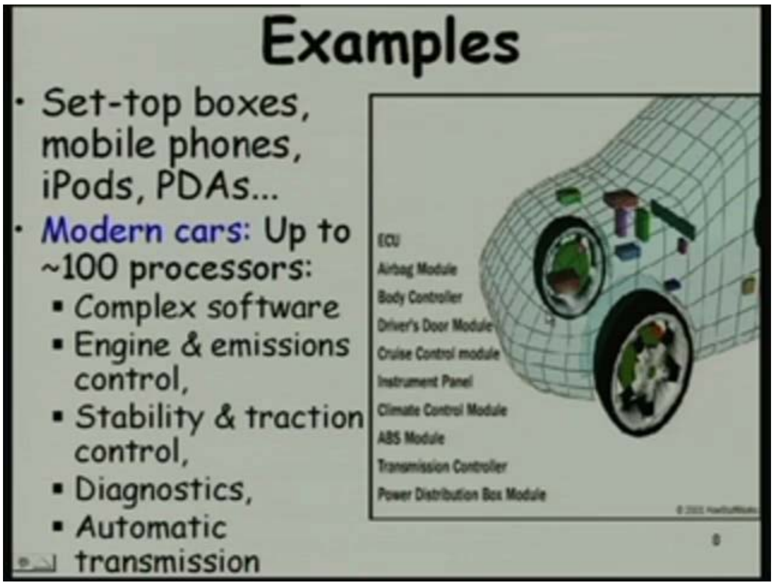

Let us see some examples of these applications, so that our later discussions will fall into place like when we say say that some kind of applications, we use a time based scheduling and in some other applications, we use a event base scheduling, why, etcetera that will become clear and even data bases communication and so on.

We have large number of examples, we examine actually a few examples here, the set-top boxes, mobile phones, ipods, PDA‘s, etcetera are all examples of embedded systems and will see that they use various types of real time operating systems. One example is the modern car, a high end car can use more than 100 processors which are embedded in various parts of the car and complex software run on this and some of the high end cars have code up to a million lines.

Now, what do these processors do? They do engine and emission control, traction carrying out, some diagnostics and giving early warning of problems, automatic transmission and so on. So, as you can see here that there are processors at various places in a car, which do various activities, even I I think it would not be wrong to say that in the present time you would not find a car in the road, which a does not have processors in that.

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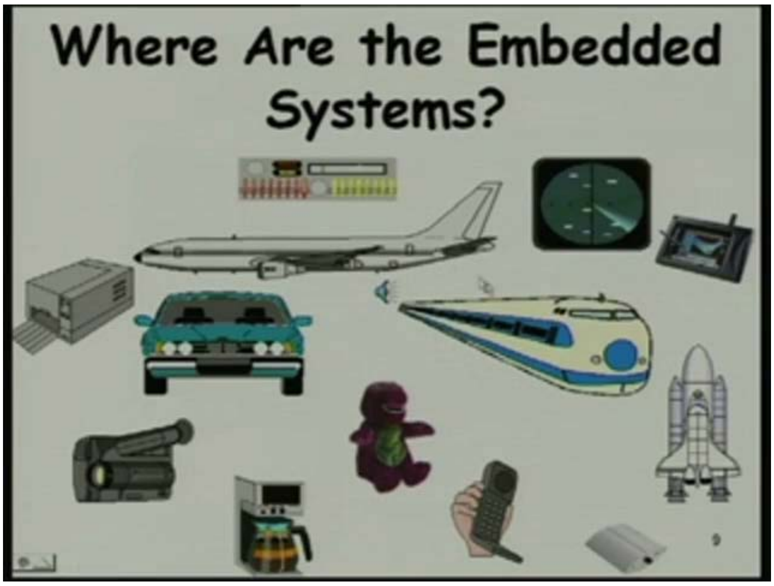

There are large number of embedded systems and the once that run this real time operating systems, some of them are difficult to, I mean unless we say that these are devices which have computers, which have processors and software real time operating system, you would not really notice them. For example, look at this laser printer, use it every day, but there is a processor which does some activities, we will we will look at that.

For example, let us say this toys or a coffee machine or a phone, hand held phone or radar or an internet router all have all use… yes please. What is a difference between a processor in a computer and a processor uses devices, what the process, why is this called a real time systems? Yeah, see, your question is that, let me just get the question, all right, that there are even in a p c or something we have a processor and we have software running on it, which are computers basically. So, what is special about these devices, why do we call this as real time systems, ok.

So, that is a very basic question and we have some slides coming upon that, because that is the fundamental question we must answer, that what is the basic difference between a PC or a mini computer or a work station versus a real time system. We we have some slides, so let us try to answer this with the help of slides, just have patience for a minute or so.

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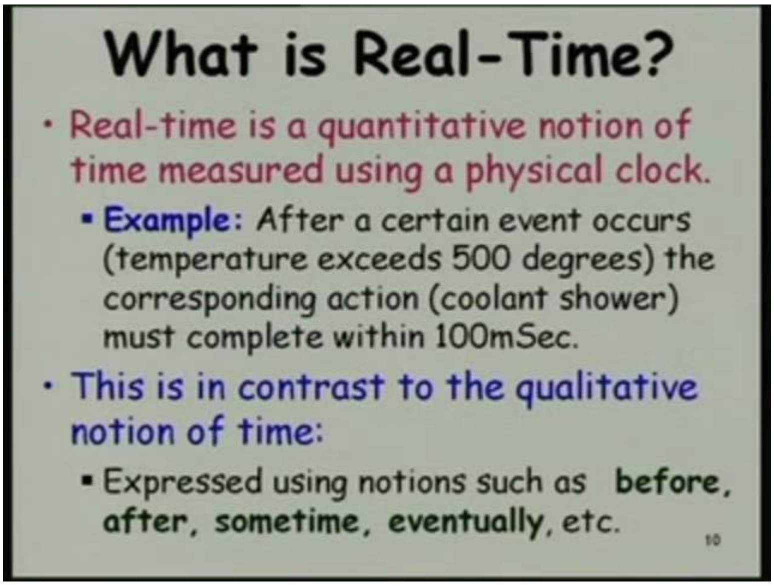

Now, let us see what is this real time and then we look at what is real time system. One is that in a real time is one where we quantitatively measure time using a physical clock. In the contrast, we have a qualitative time, where we say that something occurred before something, do not know how how much before or something occurred after or something will occur sometime, something will occur eventually, if you use these terms to describe a system, it will be a non real time.

Whereas, if you say that certain event occurs, for example, in a a chemical plant, that when the temperature exceeds 500 degree centigrade, the corresponding action, that is a coolant shower should complete within 100 mille second of the temperature exceeding. So, we have a notion of time here with respect to a physical clock, which measures this 100 mille second. We will see more examples and we will also contrast this with a traditional computer.

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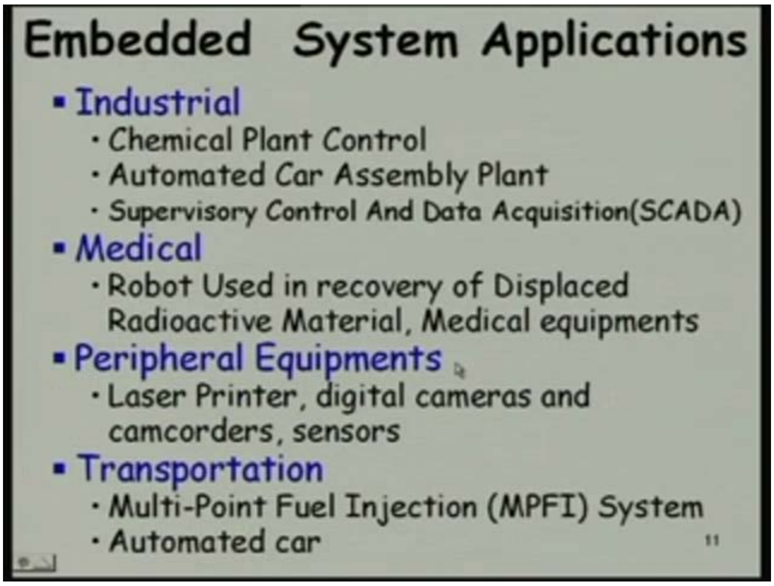

Now, let us look at some of the applications, we have a large number of applications. We will not mention all of them, it will consume all over time if we just try to discuss this applications. We will just give some example applications in each area and possibly in later slides, we will just look at couple of them in some detail. The idea is that we will try to find out what kind of tasks they run and what the timing constraint on those tasks is.

Let's look at the industrial applications. A chemical plant control, as you are saying that a chemical plant has many parameters, rate of chemical reaction depends on the chemical concentration temperature and the pressure. And based on these parameters changing, the rate of the reaction might vary, so to control the reaction will have to monitor these parameters and then also control these parameters for the chemical plant to operate.

Let's look at automated plant, lets a let us take an example of a car assembly plant. I do not know whether you would have gone to a modern car assembly plant where many of the activities are automated. You you find, you go to a car assembly plant and find that you know there are very few persons there visible, but there are systems, there are partly completed parts of the car moving on a conveyor belt and there are work stations where the work stations are doing work on these partly completed parts of the car.

So, here, there is a computer control of this various work stations and also the synchronization between these various work stations. Supervisory control and data acquisition, this is a very important industrial application, where you monitor various parameters of a system which is distributed. Lets us give an example, would be a energy management system, where you try to balance the load in electrical system, because the consumption by the customers is unpredictable and unless the electrical power is balance the line will trip, right. So, you will have to monitor the power consumption and apply load shedding and also give this feedback to the generator possibly to keep up with the power generation.

In medical, most of the medical equipments actually use processors and software medical electronics is an important area for real time systems. Another use may be use up robos to do, a there were reports in news paper that robos are even able to do some operations precision and some activities which is difficult by human beings being done by robos.

For example, let say radioactive treatment and sometimes the radioactive material gets displaced from the machine, human can go and put it back, it will be a robo, which a sets the material in its right position. Different peripheral equipments now we see that are attached to a computer, most of them have embedded applications, for example, laser printer use them every day, but do not what we do not see is that the processor that is there and the activities it does to give us this nice print, we do not see that.

Similarly, digital cameras gets signals and processes them and stores, then later transfer to computer; camcorders some types of sensors. Similarly, in the transportation, these are used heavily, the MPFI system, now I think all the cars to be road worthy, they have to use an MPFI system, because they reduce the pollution. Here, the idea is that when a computer controls the exact fuel quantity and the time of injection of the fuel, the car will run at maximum efficiency. Say at multiple points the fuel is injected, depending on the values of the car speed, the acceleration and the the other conditions like temperature and so on.

Compare to a corroborator based system, here the efficiency of petrol, efficiency of combustion is much higher and this has made the corroborator system absolute, this we will see little bit about that. And then the automated car, where a car is driverless and being driven based on the sensed signals on specific roads, so there are reports that the automated cars are able to cover distances up to 60 kilo meter, I mean there is every year a competition for automated cars and the even on crowded streets they are able to drive. So, possibly in few years we will have them in our streets as well.

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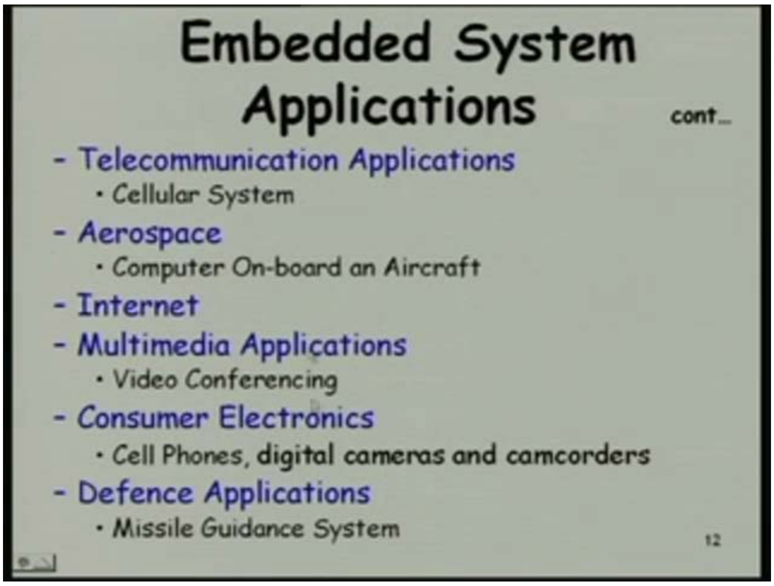

Telecommunication applications, example, important example is the cellular system, mobile phones that we use, the base stations that are there are which receive signal from the mobile phone and give signal to the mobile phone, they use real time operating systems, they handle many tasks at any time. For example, handling SMS messages, handling call establishment, keeping track of billing, hand off to other base stations and so on.

Similarly, the mobile phone itself has a real time operating system, we will have a quite some discussion on that, later on the different activities that are occur inside a mobile phone and how these are handled and the kind of real time operating systems used in this mobile phones. Most of the aerospace applications now indispensably have computers on board, because these reduce the botherence of the pilot, let they help them and sometimes even without piloted they can fly the aircraft. The internet also uses many embedded systems; I was just giving an example of a router.

Multimedia applications, for example, video conferencing, handling the signal compressing, transmitting, receiving it another other side real time, because in video conferencing if there is a one frame to another frame, if there is a the time delay is not proper, usually glitches and you will say that it is not working, so these are also real time systems. Then consumer electronics like phones, digital cameras, camcorders, defense applications, in defense also these are used heavily including the wireless sensor networks.

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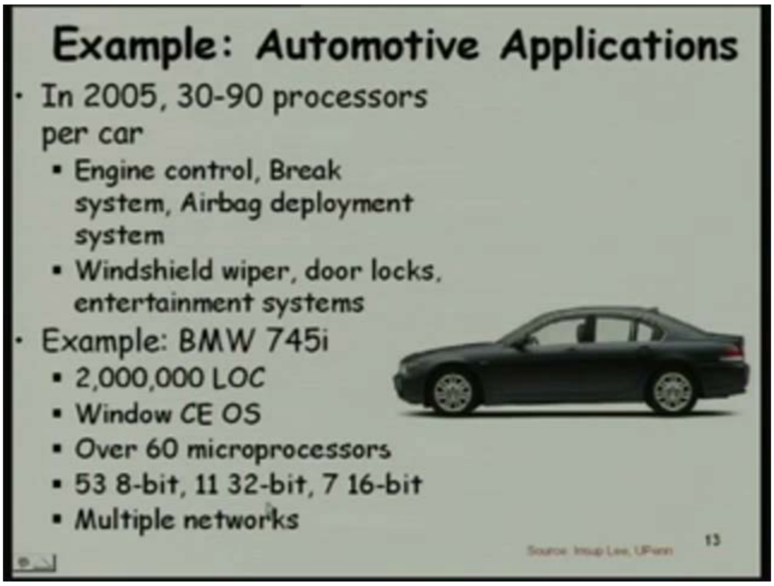

Now, let us look at couple of them in slightly more detail just to know the kind of time constraints under which they will have to work and the kind of tasks that are involved. Let's look at the automotive application. So, 30 to 90 processors per car is nothing unusual that was in 2005 and the kind of activities they do is engine control; I was saying that the fuel injection is one important work. The breaking system, airbag deployment, because in case there is an accident within fraction of a second, airbag has to be deployed, it has to be inflated and it as to be deployed, otherwise it is of no use.

Even the windshield wiper, these are even use processors depending on the rain intensity, they can manage themselves without the driver intervening. The door locks, the entertainment systems, the diagnostics that run on this, for example, measuring the tyre pressure and giving early warning, measuring the health of the other critical parts, so these are done by various processors.

One example is a high end car, the BMW 745i, which has 2 million lines of code, uses the windows CE operating system, we will discuss this operating system in some detail later as we look at the commercial operating systems, commercial real time operating systems. It has a various types of processors, 53 8 bit processors 11 32 bit processors and 7 16 bit processors and inside the car there are many networks.

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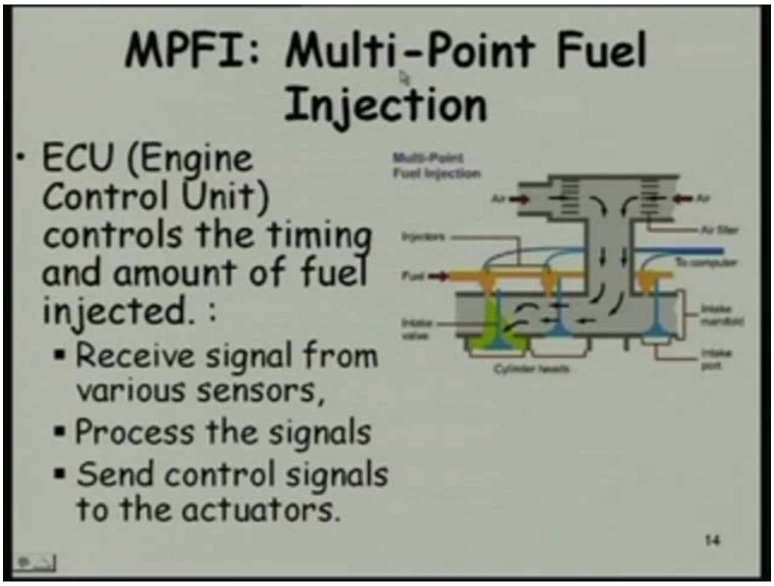

Now, this is another automotive application, almost every car has this, a multipoint fuel injection system just see here, there are different points at which the fuel is getting injected and the quantity of the fuel and the time at which the fuel is to be injected is controlled by the computer. These are determined based on various signals received from different types of sensors, we are saying that the sensors are the speed, the rpm revolutions per minute, the temperature, the acceleration and so on.

Earlier the mechanical system in a corroborator, know, you need to tune the car every once in a while, so because that use to go out of a tune and it was inefficient, you cannot really do whatever is done by sampling various events and then taking action based on that and quickly computing how much fuel to be injected and time to be injected and the different places, see here multiple points where how much will be injected.

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A laser printer, use them, we have used them many times, but there is a processor inside and it does some activities, there is a horizontal strip of dots that needs to be composed. It the basic capability is to print a dot and if you have a post script file or a text file or files in some specific, I mean, for different laser printers, they have specific languages in which the fonts are specified.

So, depending on the font that has to be translated to dots and this is done by an image processor and then these are transferred on to a rotating drum inside the laser printer. The image is transferred in the form of charges and a laser beam is used to neutralize charge from the black parts of the image leaving only the static electric negative image on the photoreceptor surface.

So that when the ink powder is a spread, it is a it gets attached only to the charged parts and then this a transferred to a paper through a again through electric deposition, because there will be a opposite polarity electric charge which will attract the electricity from the drum and it will get deposited on the paper. And then the next thing is to fusion where you have this temperature, know, you see their paper coming out, printed paper is hot because after the ink is deposited, the ink powder is deposited, these are fused through heat on to the paper.

The mobile phone, I think we did not talk about the timing here, the timing if depends on the speed of the laser printer, but typically most of these tasks need to be completed in millisecond. So is the case for a fuel injection system, milliseconds is the time for different tasks, 10s of milliseconds to 100s of milliseconds.

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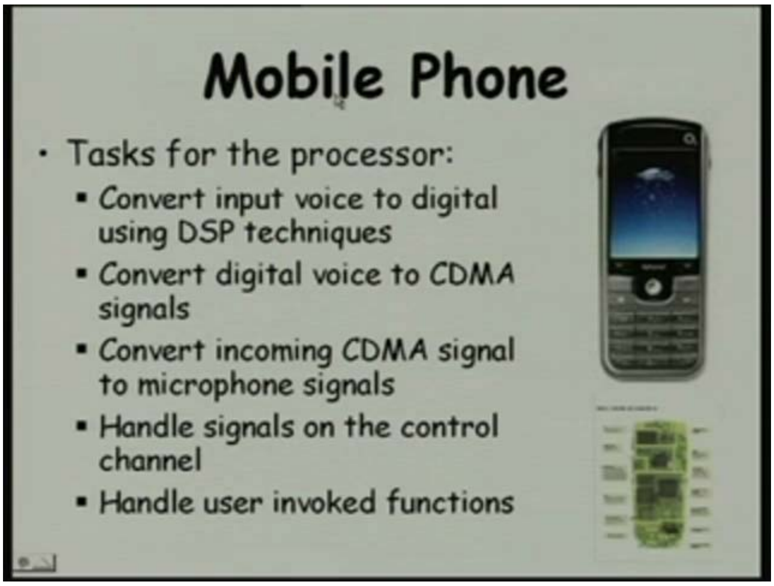

A mobile phone all of us have used it, so why do we need a operating system and a processor in that, one is that to convert the voice to digital using DSP techniques and then convert the digital voice to signals that can be transmitted. It is the CDMA modulated signals code division multiple access and also once the signal comes, these has to be converted to the microphone signals and also see these are the signals which are the voice signals, but there are also some control signals that are received from the base station.

For example, the position and when you or mobile, the base station needs to register mobile phone or when you switch on a mobile phone, there is a transmission on the control channel. Similarly, to send an SMS or to handle user invoked functions, the user might do like set an alarm or do several of the provided operations on a mobile phone, so all these are handled by a processor. So, if you look at these different parts, you are there is a memory, there is a processor here, unless I enlarge this image, you cannot see this, but as I said later part will discuss in more detail.

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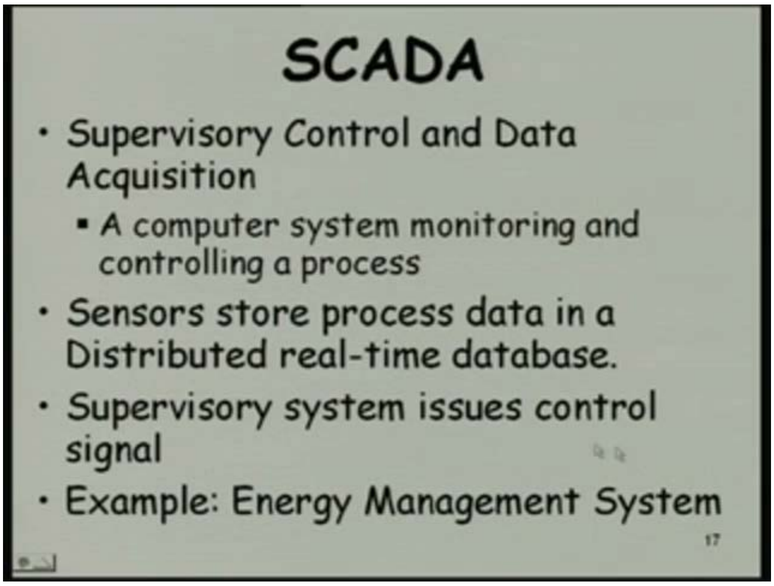

SCADA is an important industrial application stands for supervisory control and data acquisition. So, the data arise at various places geographically and these data are collected a different places and even they might be stored at different places by a real time data base. So, these form a distributed real time data base and then the required information only is transmitted to the supervisor and the supervisor can give comments to the different local monitors to take certain corrective actions.

As you are saying that one is an energy management system, where you try to balance the load in electric lines or may be a building management system where the timing at which the various lights are switched on and managing the power inside a large building is also a SCADA application.

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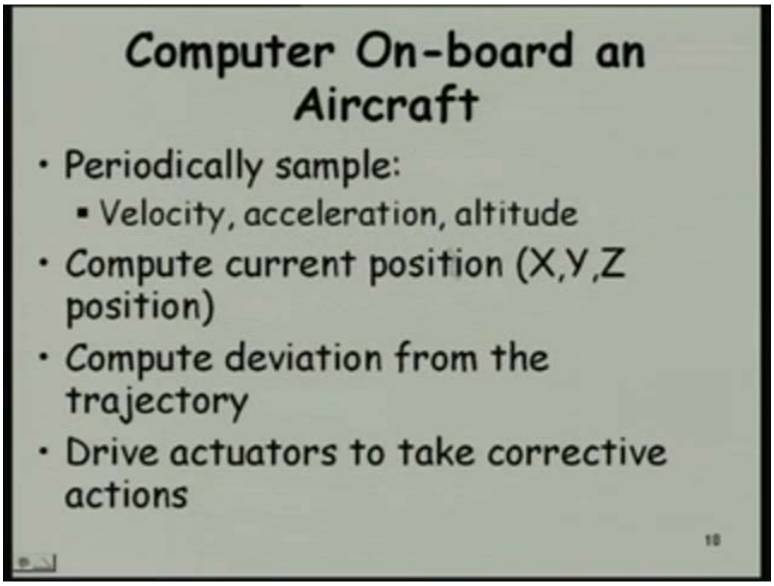

Computer on board an aircraft, so as we are saying that the velocity, acceleration and altitude, these need to be sampled by using some sensors and based on these values of velocity acceleration and altitude, the position of the aircraft is computed and the deviation from the required trajectory is computed. Based on the error in the trajectory, planned trajectory and the current trajectory, some corrective actions need to be taken through the actuators. And again here, the rate at which, I mean the constraints and the tasks will be again in the form of milliseconds, the rate at which these are sampled, the rate at which the tasks need to be completed of the order of milliseconds.

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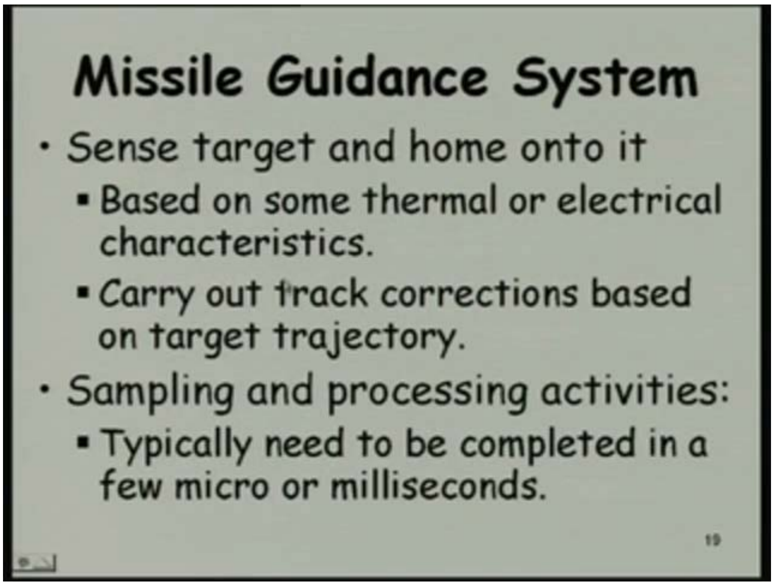

A missile guidance system, this is a defense application, where lets a difference system senses a missile from an enemy and then send an antimissile that is guided, it just tracks that missile and destroys it. It tracks it based on some thermal and electrical characteristics and once it tracks that, the trajectory of the track device is computed and then the track corrections are based so that it will directly meet that and destroy that.

So, here, the constraints are of the order of micro to few millisecond, because this travel at, varies large speeds, so the time also needs to be that much smaller and the activities must occur in microseconds. So, we saw some of the applications and found that in each of those applications there are many tasks that need to be completed, multiple tasks running at the same time and the constraints are of the order of milli to microseconds.

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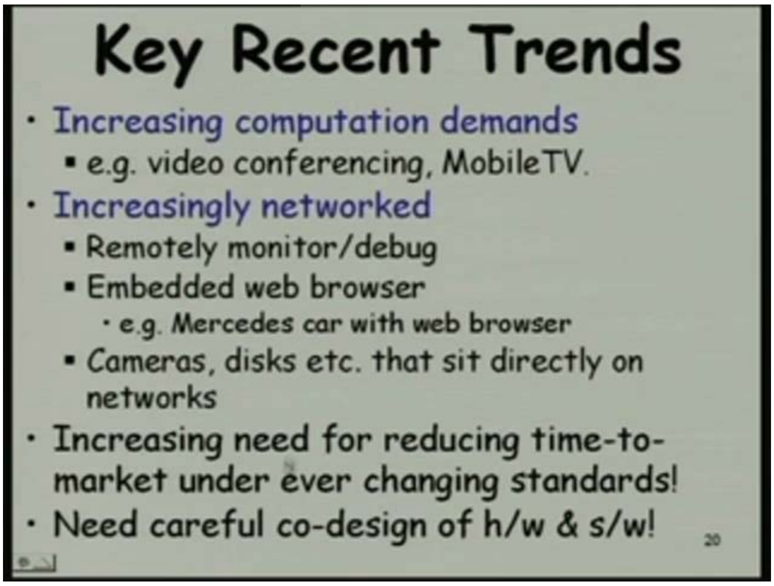

Now, let us look at the trend in these kinds of devices. So, one is that the computational demand on many of these devices is increasing rapidly, just to give an example is a video conferencing, where you want good quality picture and also voice among multiple participants to be transmitted and heard, which is a very large compute intensive. Because, all these image and data had to be transmitted at a very fast rate to give good quality and similar is mobile TV or on your mobile phone let say you want to see TV, the mobile phone processor must be capable of processing the signals and be able to show it.

So, one is an increasing computation, demands need more powerful processors, the other is, most of the devices now are networked, so that we are able to remotely monitor and debug these various devices. We can see whether these are working in proper condition or failed, we can know the reason they have failed, they can have even web connectivity, web browsers, for example, some cars have web browsers.

We can have cameras discs that are networked, you do not have to really plug them into transfer data, they directly sit on the network and you can download the data or get data from computers. And not only that, we have another constraint which we will also discuss while discussing about the real time operating systems, is a commercial issue that because of the increased competition. The different companies want to market their products the quickest possible and also specific hardware and software needs to be designed for some of the applications, we will just see shortly about that.

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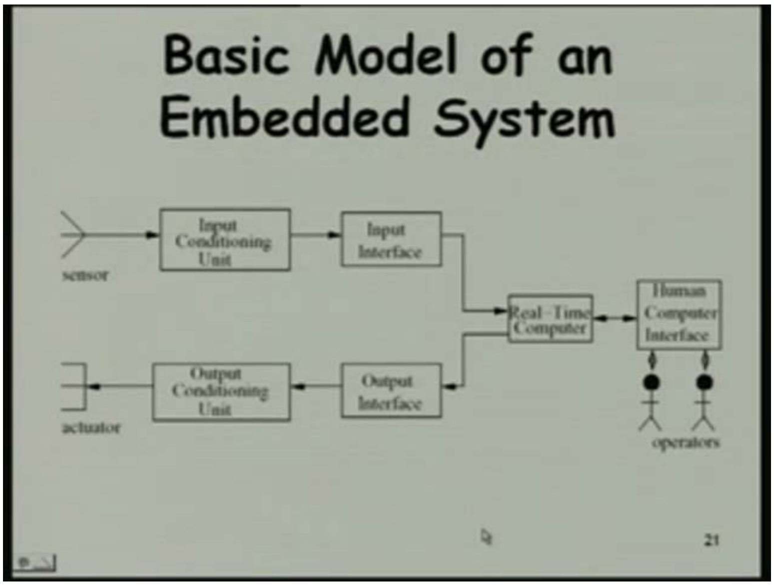

Now, let us see a basic model of an embedded system, because we we just said that embedded systems are a major category of application for real time operating systems. There are other applications of real time operating systems other than the embedded systems, even certain large computers might use real time operating systems, but let us look at an embedded system, because unless you have some idea of them, later discussions would not be very meaningful.

So, what we every embedded system does is, it has sensors which it samples some signals, different sets of signals and the signals are either very low voltage, low current or this may be a direct current, direct voltage or this may be a alternating. So, there are various types of voltage and signals that are sampled and therefore, we need a conditioning unit.

Because our computer recognizes voltage and current at certain values, so the input interface does that, connects this sampled voltage and current to the input interface. And the real time computer, they process this signal and of course, there is a human interface where these are monitored configured and so on, but normally the human interface is not used very frequently unlike in a traditional computer. Here, the operator only intervenes only if there is an extraordinary situation or to initial configuration and so on.

And the actions of the computer are carried out by the actuators, again these require different amounts of voltage current has is produced by a computers, so we need conditioning units voltage scaling, we able to drive a motor and so on.

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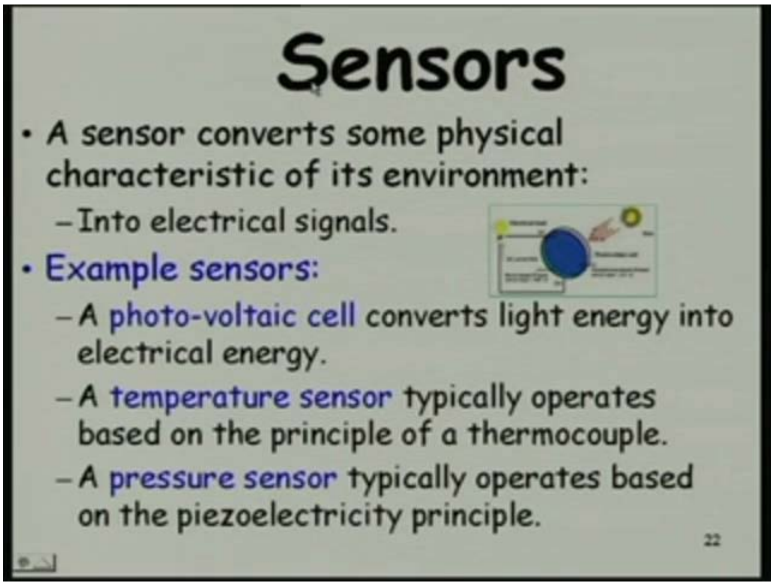

So, let us have some idea about the sensors, because even though these are not crucial to real time operating systems or real time systems by themselves, but unless we have some idea, we do not know what kind of signals, what kind of voltage levels, etcetera we are taking of.

As you are saying that the sensors convert physical characteristics into some electrical signals, one example is a photovoltaic, photovoltaic cell which converts light energy into electric energy; the electric energy is in terms of millivolts, milliamperes or may be microamperes. We can have temperature sensors which sense the temperature based on the thermo couple principle, there can be pressure sensor which operates based on the piezoelectricity principle. Again, all these generate some electric energy and the typically millivolts.

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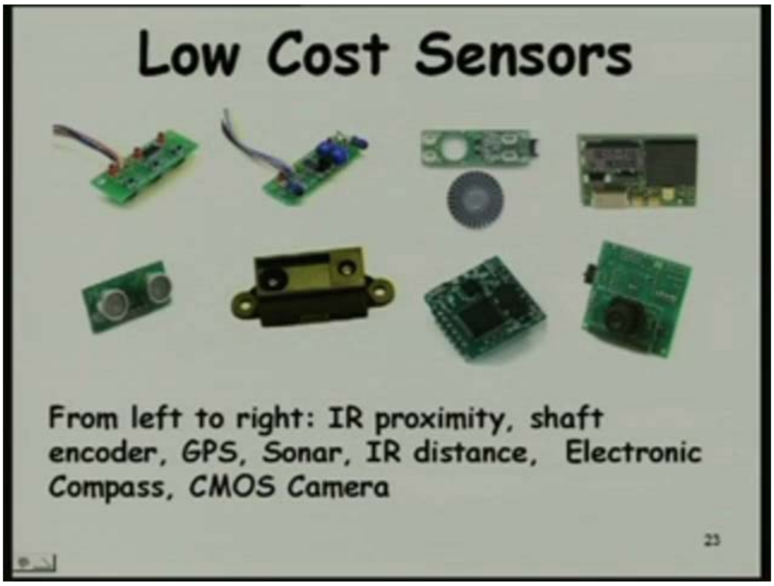

We can have, we know commercially have several low cost sensors that are available, the IR proximity server, the IR proximity sensor, the shaft encoder, GPS, SONAR infrared distance sensor, electronic compass, cmos camera, see the camera mounted here. So, these are various types of sensor you can buy of the self from shops and these are used to build the embedded systems.

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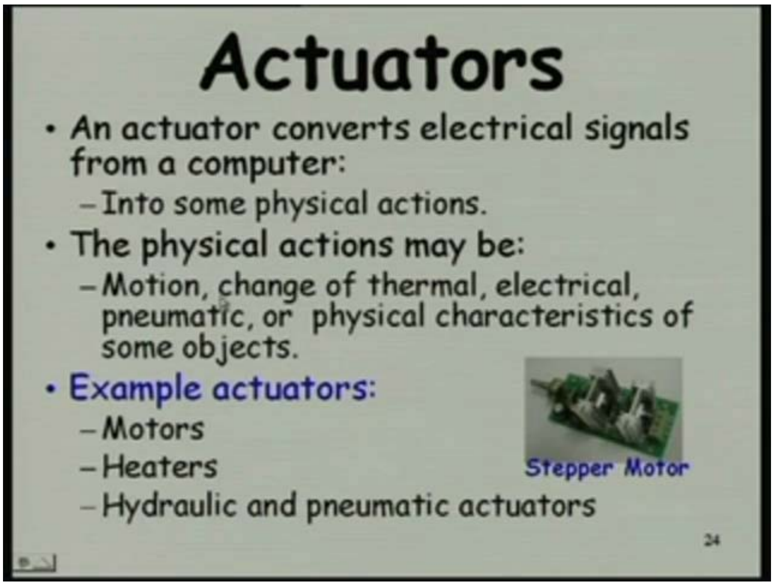

These are some of the actuators which convert electrical signals from the computer into actions, the actions can be in the form of a motion, changing the thermal characteristics or electrical characteristics, pressure, physical characteristics, so on.

Some of the popular examples are motors, heaters, hydraulic and pneumatic actuators. So, there is no depth of examples for sensors and actuators, there are many of them, if you examine any device, let say camera or let say a laser printer or let say a mobile phone, you can see the different types of sensors, actuators that are needed.

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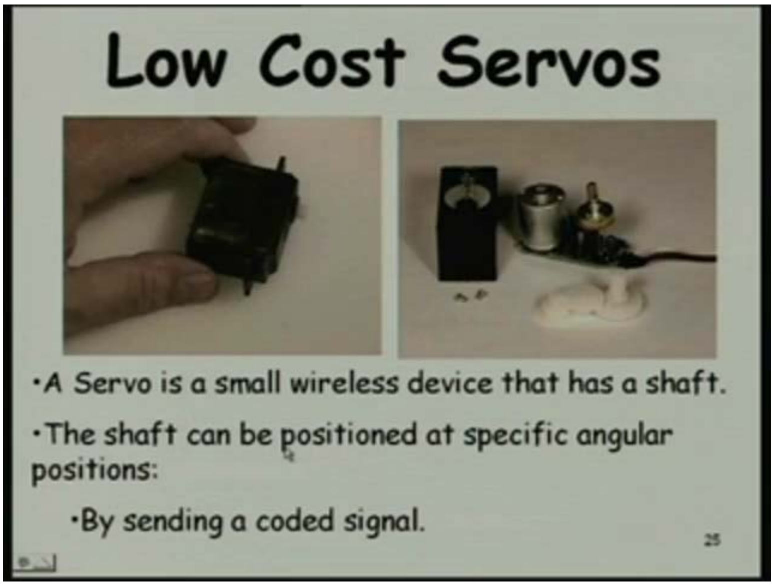

So, this is low cost servo used in many applications including the robos, it is a small wireless device that has a shaft and this can be positioned at specific angular positions by sending a coded signal very popular in robos.

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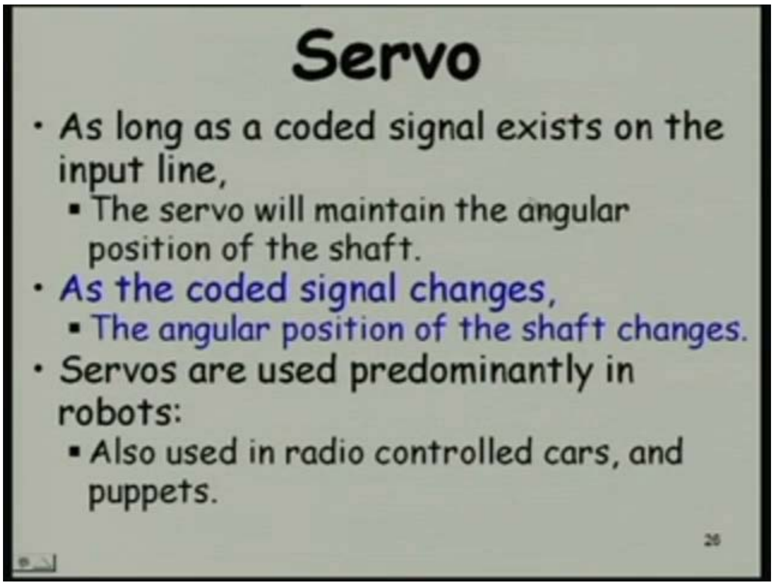

So, as a signal exists, it will maintain a position, otherwise it will change the position, not going to details of this. These are beyond the robos, it are used in controlled cars, some toys.

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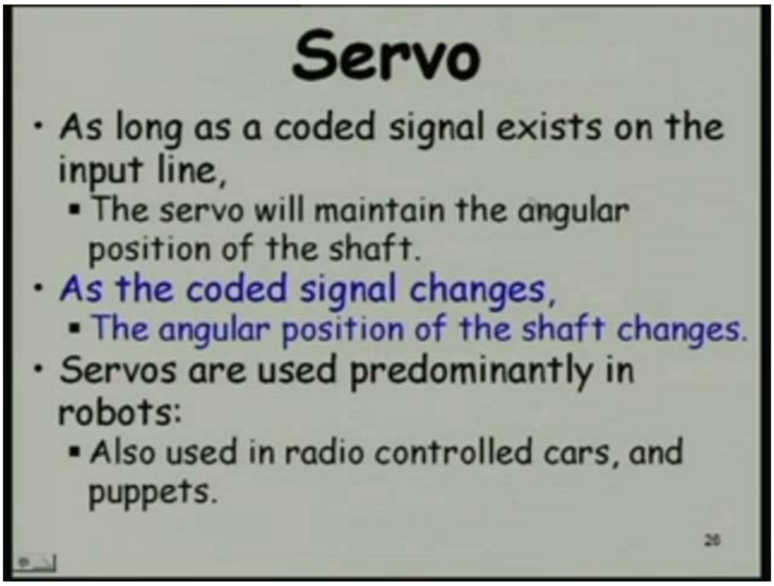

Now, let us have some small idea about signal conditioning, even though not really a crucial part of the course, but just to have the idea about what this sensor signals are done before they are processed in the computer or the computer signals, what happens to them before these are given to the actuator.

So, signals in mille volts are need to be scaled up, so we need voltage amplification and sometimes we need voltage level shifting, because the level of the voltage is lets say between 10 to 20, what we need is minus 5 to plus 5 or something. So, in not only need amplification, might need level shifting, you might need frequency range shifting and filtering and the mode conversion AC to DC and so on.

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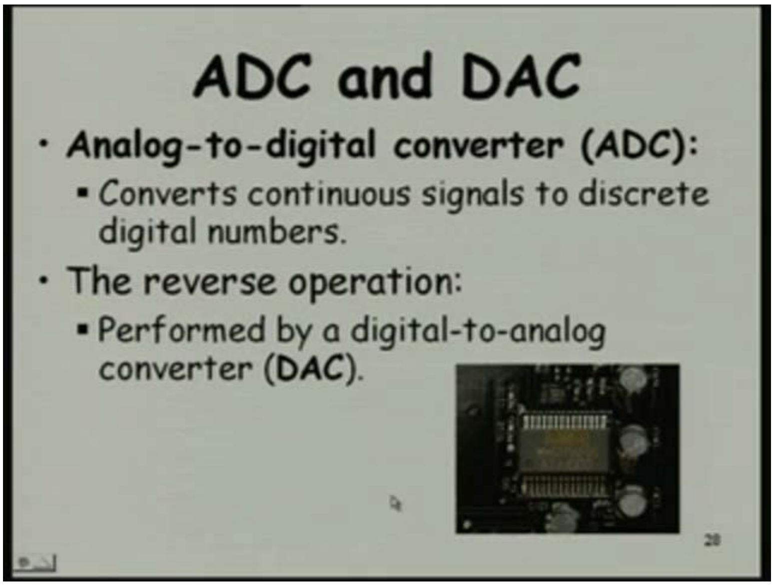

And off course most of these devices they use analog to digital and digital to analog converter, because most of the sensors they generate analog signals, where as our computer needs digital signals and similar is the case with respect to actuator. Most of the actuators they need analog signal, so a digital to analog converter needs to be done. Again these are available of the self; see here a small chip here is doing analogs to digital and digital to analog.

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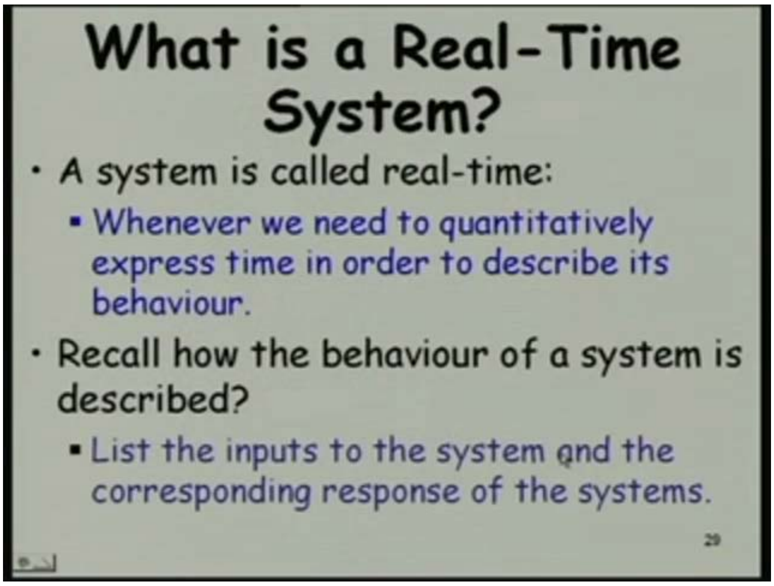

So, with that basic introduction to various areas, where these real time devices are used and the basic definition of what is real time that where we the actions need to takes place based on some physical clock events generated by a clock or and also the other events generated in the system, so let us look at what is a real time system. If you have a system where to describe its behavior, you need to re set to some real time description, need to implicitly or explicitly use timing aspects, that is a real time system, but just remember that we do not have to really use in every behavior, even if some of the behavior of the system requires some timing description, that is a real time system.

Actually most of the real time systems that will discuss not all tasks are real time, for example, we have a logging task, you know which keep tracks, keeps track of different events that occurred, actions that are taken, these occur non real time, no constants on that, they can completed as and when required.

So, one issue we need to, we just mentioned here, that we said describes the behavior of the system and if you need a timing issue there, we need to be measured using physical clock, say real time system. But what exactly is a behavior and how do you describe. A behavior is the input output processing, when you give a input, how does the output, what output occurs and how does that input gets transformed to the output, that is exactly is the behavior.

So, to describe the behavior of a system, will have to find out what are the input to the system, what signals or what data was input and what did the system do to generate the output, that is the behavior and to describe that if we need timing, is will then that is a real time system.

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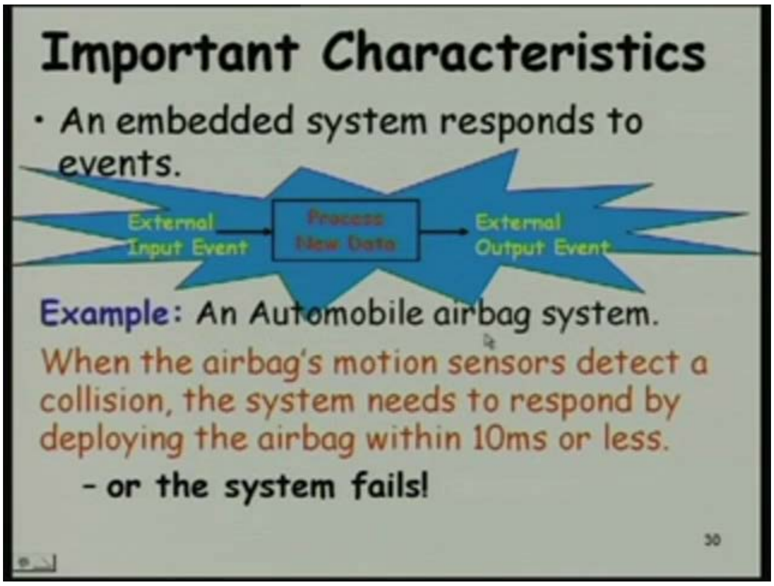

Now, in the next one hour or so, we will try to find out some input and characteristics of these systems, because based on these characteristics, we will have to design our operating system. Because the operating system must facilitate that these devices, they stick to their characteristics, otherwise they will fail. One of the important characteristics is timing, handling, I mean responding to event in certain time.

So, the events are obtain through the sensors, reported to the computer, these are the input event and somehow they need to be processed and some output produced before a certain time expires. For example, if a robo senses an obstacle and the robo is progressing, I mean moving and unless it changes its track, it will collide and the system will fail.

Another example is a automobile airbag system, I think we were just mentioning about it, that once the sensors detect a collision, the system must respond, the bag must be inflated, must be deployed within 10 millisecond or less. Otherwise, it will serve no purpose, because the vehicle is typically in speed and the damage will be done even within a fraction of a second.

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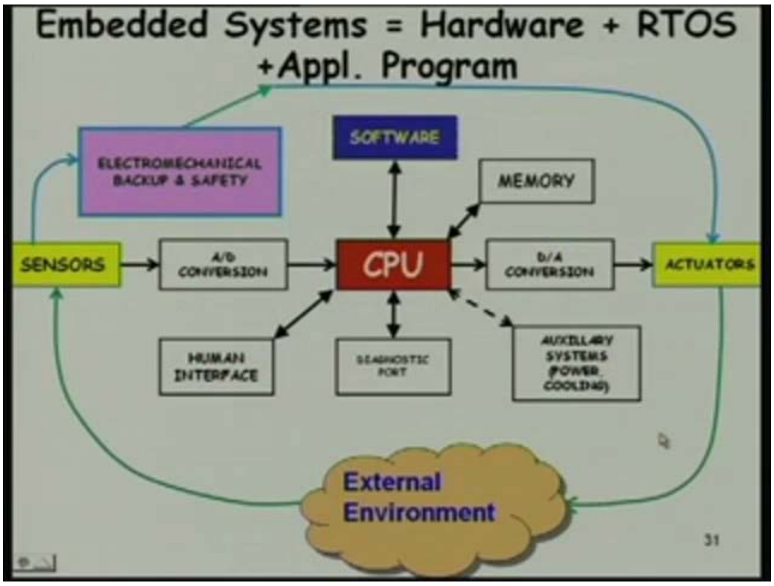

So, there are some discussion left on this different characteristics and also this the basic configuration of a embedded system, which need to have some idea about the CPU, the kind of memory, the kind of sensors and actuators, diagnostics human interface, etcetera. So that we will be able to appreciate our real time operating systems and when we mention that event occurred, millisecond interval will have idea about what kind of events and how actions takes place, what are constraints in the memory, constraints on the CPU, constraints on the software. So, we will continue from this diagram in the next class, will stop here.