

## **UNIT 5- CYBER-PHYSICAL SYSTEMS CASE STUDIES AND PROJECTS**

**Cyber-Physical Systems Case Studies and Projects - Automotive: SW controllers for Antilock braking system, Adaptive Cruise Control, Lane Departure Warning, Suspension Control - Healthcare: Artificial Pancreas/Infusion Pump/Pacemaker - Green Buildings: automated lighting, AC control – power distribution grid – robotics- civil infrastructure – avionics – Transportation.**

### **Cyber-Physical Systems Case Studies and Projects**

#### **Cyber-physical systems: a case study of development for manufacturing industry**

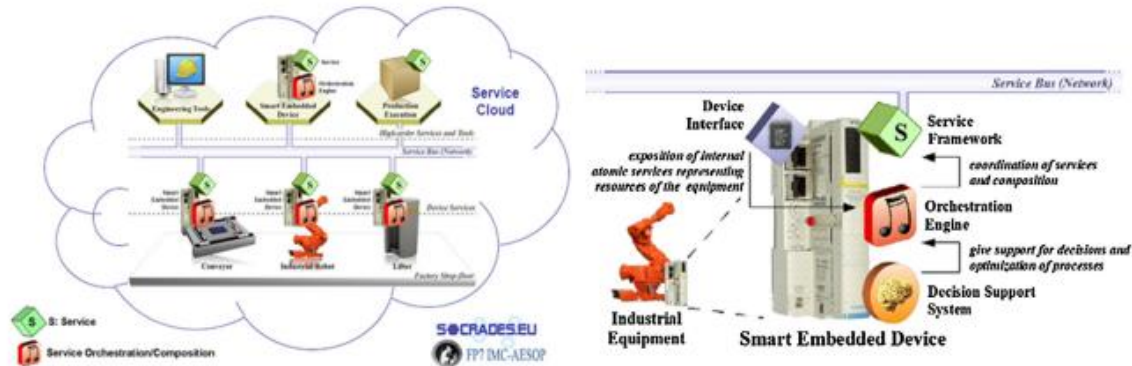
Cyber-physical systems (CPS) are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. Just as the internet transformed how humans interact with one another, cyber-physical systems will transform how we interact with the physical world around us. Many grand challenges await in the economically vital domains of transportation, health-care, manufacturing, agriculture, energy, defense, aerospace and buildings. The design, construction and verification of cyber-physical systems pose a multitude of technical challenges that must be addressed by a cross-disciplinary community of researchers and educators.

#### **Industrial automation based on cyber-physical systems technologies:**

##### **Industrial use-cases**

The SOCRADES technical approach adopted the “collaborative automation” paradigm and it is devoted to create a service-oriented ecosystem, where networked systems are composed by smart embedded devices interacting with both physical and organizational environment, pursuing well-defined automation goals. The approach takes the granularity of intelligence to the device level of an automation system allowing intelligent system behavior to be obtained by composing, orchestrating configurations of devices that introduce incremental fractions of the required intelligence as “web services”. From a functional perspective, the focus is on managing the vastly increased number of intelligent devices and mastering the associated complexity of the physical objects having their digitalized cyber-shadow in the information-communication infrastructure. From a run-time infrastructure viewpoint, the automation system engineer is confronted with a new breed of very flexible real-time embedded objects i.e. automation devices and systems (wired/wireless) that are fault-tolerant, reconfigurable, safe and secure. In this way, for example, auto-configuration management is a new challenge that is addressed through basic plug-and-play and plug-and-run mechanisms facilitated by the physical connectivity and cyber interoperability. As illustrated in Fig. SOCRADES components are a kind of CPS whose functionalities are encapsulated as web services and offered to other components through a service bus that supports forming a network of smart components/objects. The shop floor (physical components (hardware/software)) is having its cyber-shadow represented in a service-cloud. In this manner, smart embedded automation devices comprise the intelligence and logic control for the mechatronic part and are a source of automation functionalities that can be accessed from any node of the network and any other member/component of the cloud. From technological and infrastructural viewpoints, the use of the SOA paradigm implemented through Web services technologies enables the adoption of a unifying technology for all levels of an industrial enterprise, from sensors and actuators located on the shop floor to enterprise business process. Among others, this

means that low cost devices (i.e., in the range of a few Euro) can communicate and exchange data and information (represented as “services”) directly to higher-level systems like SCADA, MES and ERP. Within SOCRADES a full-fledged architecture for integration of CPS to enterprise systems and services has been designed, implemented and assessed. The building blocks of the collaborative automation system, which are built upon SOA, will then present their functionalities and production operations as Web services inside the building block network (service cloud) and form the desired production process by collaborating using the communication and information-exchange methods provided by the web technology



One very important feature of such service-oriented collaborative automation infrastructure is the capability of building ad-hoc new functionalities in any of the members of the SOA-enterprise, i.e. inside physical but also inside the cyber part of the ICPS. Under the semantic definition of Composition-of-Services, Orchestration-of-Services and/or Choreography-of-Services, it is possible to identify a SOA-based component called “Orchestration Engine” within the automation architecture. This new object is able to generate new services by composing existing/exposed services in the cloud. Represented by a “music-symbol” in Fig. 1, this orchestration engine can play the role of a monitoring component, a control component, a data-analysis-component, etc. There are different formalisms to model and implement the orchestration procedure. In SOCRADES, a kind of Petri nets [48] tailored for formalizing orchestration mechanisms was developed and prototyped, embedding the engine into smart embedded I/O devices of the SOA-technology provider Schneider Electric Automation. The biggest impact of the SOCRADES project outcomes has been the many lessons learned about how to specify, develop, commission and operate a fully distributed, smart service-oriented collaborative automation architecture, which guarantee the fulfilling of the requirements of flexibility and fast re-configurability. Although these aspects cannot be expanded in detail here due to space requirements, several examples have been published that demonstrate the benefits of the SOCRADES approach. The gist is that servicification of the infrastructure enables a wide arrange of benefits including reconfiguration, realization of more sophisticated scenarios, cross-layer integration, light-weight implementations etc. all of which have business, technical and operational impacts. The benefits of service-orientation are conveyed all the way from the upper level of the enterprise architecture, e.g., ERP/MES components to the device level, facilitating the discovery and composition of applications by reconfiguring rather than reprogramming. The dynamic self-configuration of smart embedded devices and systems using loosely-coupled services provides significant advantages for highly dynamic and ad hoc distributed applications, as opposed to the use of more rigid technologies, such as those based only on distributed objects. Moreover, applying the collaborative automation paradigm [8] typically means that all the participating groups in the automation value chain such as control vendors, machine builders and system integrators are confronted with the subject to migrate from legacy hierarchical and completely time-

synchron systems to systems composed of building blocks able to run in time-asynchronous mode. The modularization of the automation system requires the decomposition of the present “controller-oriented structure” into functional modules with a “task-oriented structure”.

### **Cyber-physical systems: A smart home case study**

With the growth in the use of Cyber-Physical Systems, such as Internet of Things (IoT) devices, there is a corresponding increase in the potential attack footprint of personal and corporate users. In this paper, we explore the potential for exploiting information retrieved from two IoT devices which, seemingly, are unlikely to store substantial amounts of data. We specifically focus on prominent smart home devices for the purpose of obtaining compromising information. We undertake a collection and analysis process, constrained by the limitations placed upon three types of adversaries, namely: forensic passive, forensic active and real-time active. The former two adversaries aim to comply with the requirements of forensic soundness, whereas the real-time active adversary does not have these constraints and therefore more closely models a malicious real-world attacker. The findings show that a variety of device data is available to even the passive adversary, and this data can be used to determine the actions and/or presence of an individual at a given time based on their interactions with the IoT device. These interactions can be both user initiated (e.g. powering on or off a switch or light) and device initiated (e.g. background polling).

The adversary model capabilities:

1. **Listen** (*Channel or Target*): Allows an adversary to (passively) monitor a communications channel or a target device.
2. **Transmit** (*Message, Target*): Allows an adversary to transmit a message to a target destination. The adversary must utilize another capability in order to obtain any replies (e.g. Listen).
3. **Modify** (*Message, Target*): Allows an adversary to modify a particular (unencrypted) message (e.g. a file, configuration, etc.) on a device. This capability may be triggered as a result of another adversarial capability (e.g. Transmit).
4. **Intercept** (*Target*): Allows the adversary to obtain all messages targeted at target device (e.g. via the use of ARP spoofing). The adversary can then choose to forward, drop or modify such messages. This adversary capability can be considered a combination of the Listen (e.g. listening to redirected messages), Transmit (transmission of poisoned ARP packets and forwarding of messages) and Modify (e.g. modifying ARP tables on devices) capabilities. An important point to note is that this capability is not considered applicable in a forensics context.
5. **Corrupt** (*Target*): Allows the adversary to obtain control of a target (e.g. a device). Adversaries that are able to employ this capability are considered some of the most powerful attackers.

### **SW controllers for Antilock braking system**

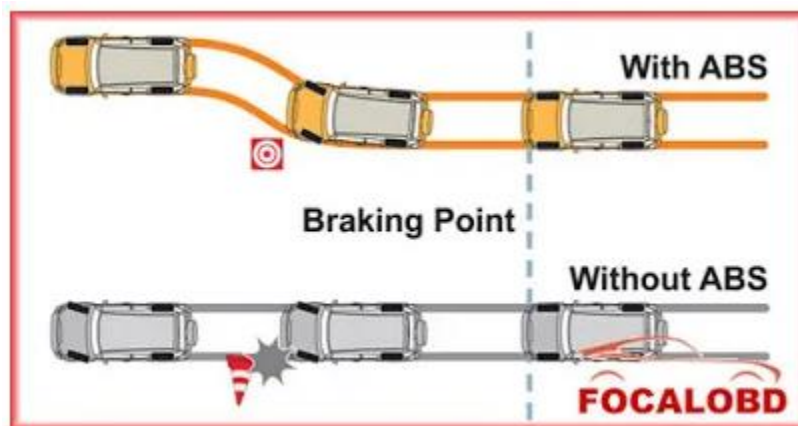
What is Anti-lock Braking System?

Anti-lock Braking System also known as anti-skid braking system (ABS) is an automobile safety system which prevents the locking of wheels during braking and avoid uncontrolled skidding. The modern abs system allows steering during braking which gives more control over the vehicle in case of sudden braking. The main advantages of using ABS system in vehicle is that it provides better control over the vehicle and decreases stopping distance on dry and slippery surfaces. Since in ABS installed vehicle the chance of

skidding is very less and hence it provides a better steering control during braking. Without ABS system, even a professional driver can fail to prevent the skidding of the vehicle on dry and slippery surfaces during sudden braking. But with ABS system, a normal person can easily prevent the skidding of the vehicle and get better steering control during braking.

Why Anti-lock Braking System (ABS) is essential in vehicles?

To understand this in a better way let's take an incident. When you are driving your car on a highway and suddenly an obstacle comes in front of you and you apply brake with full power. This will lock wheels of your car and your car will start skidding on the road and also during skidding you lost your steering control and unable to move the car in desired direction in which you want. Finally you hit that obstacle and meet an accident.



## Main Components of ABS System

It has four main components

1. speed sensors
2. Valves
3. Pump
4. Controller

### 1. Speed Sensors

It is used to calculate the acceleration and deceleration of the wheel. It consists of a toothed wheel and an electromagnetic coil or a magnet and a Hall Effect sensor to generate signal. When the wheel or differentials

of the vehicle rotates, it induces magnetic field around the sensor. The fluctuation in this magnetic field generates voltage in the sensor. This voltage generated sends signals to the controller. With the help of the voltage the controller reads the acceleration and deceleration of the wheel.

## 2. Valves

Each brake line which is controlled by the ABS has a valve. In some of the systems, the valve works on three positions.

1. **In position one**, the valve remains open; and pressure from the master cylinder passed through it to the brake.
2. **In position two**, the valve blocks the line and separates the brake from the master cylinder. And this prevents the further rise of the pressure to the brakes. Valve operates in second position when the driver applies the brake harder.
3. **In position three**, some of the pressure from the brake is released by the valve.

The clogging of the valve is the major problem in ABS. When the valve is clogged, it becomes difficult for the valve to open, close or change position. When the valve is in inoperable condition, it prevents the system from modulating the valves and controlling pressure to the brakes.

## 3. Pump

Pump is used to restore the pressure to the hydraulic brakes after the valve releases the pressure. When the controller detects wheel slip, it sends signals to release the valve. After the valve releases the pressure supplied from the driver, it restore a desired amount of pressure to the braking system. The controller modulates (adjust) the status of the pump so as to provide desired amount of pressure and reduce slipping of the wheel.

## 4. Controller

The controller used in the ABS system is of ECU type. Its main function is to receives information from each individual wheel speed sensors and if a wheel loses its traction with the ground, a signal is sent to the controller, the controller than limit the brake force (EBD) and activate the ABS modulator. The activated ABS modulator actuates the braking valves on and off and varies the pressure to the brakes.

## Working of Anti-lock Braking System (ABS)

- The controller (ECU-Electronic Control Unit) reads the signal from each of the speed sensors of the wheel.
- As the brakes are suddenly applied by the driver, this makes the wheel to decelerate at faster rate and may cause the wheel to Lock.
- As the ECU reads the signal which indicates the rapid decrease in the speed of the wheel, it sends signal to the valve which makes the valve close and the pressure to the brake pad reduces and prevents the wheel from locking.

- The wheel again starts to accelerate, again the signal sends to the controller, this time it opens the valve, increasing the pressure to the brake pad and brakes are applied, this again reduces the speed of the wheel and tries to make it stop.
- This process of applying brakes and releasing it happens 15 times in a second when a driver suddenly applies the brake harder. Due to this the locking of the wheel is prevented and the skidding of the vehicle eliminated. During braking with ABS system, the driver can steer the vehicle and reduces the risk of vehicle collision.

### **Adaptive Cruise Control**

Adaptive cruise control (ACC) is a system designed to help road vehicles maintain a safe following distance and stay within the speed limit. This system adjusts a car's speed automatically so drivers don't have to.

### **What Is Adaptive Cruise Control?**

Adaptive cruise control (ACC) is a system designed to help vehicles maintain a safe following distance and stay within the speed limit. This system adjusts a car's speed automatically so drivers don't have to.

Adaptive cruise control is one of 20 terms used to describe its functions so that you might see adaptive cruise control as the following in advertisements and vehicle descriptions:

- Active cruise control
- Dynamic cruise control
- Radar cruise control
- Automatic cruise control
- Intelligent cruise control

ACC functions by sensory technology installed within vehicles such as cameras, lasers, and radar equipment, which creates an idea of how close one car is to another, or other objects on the roadway. For this reason, ACC is the basis for future car intelligence.

These sensory technologies allow the car to detect and warn the driver about potential forward collisions. When this happens, red lights begin to flash, and the phrase "brake now!" appears on the dashboard to help the driver slow down. There might also be an audible warning.

### **Advantages of Adaptive Cruise Control**

Some key advantages of adaptive cruise control mentioned by MyCarDoesWhat.org include an increase in road safety, as cars with this technology will keep the adequate spacing between them and other vehicles. These space-mindful features will also help prevent accidents that result from an obstructed view or close following distance. Similarly, ACC will help maximize traffic flow because of its spatial awareness. As a driver, you don't have to worry about your speed, and instead, you can focus on what is going on around you.

### **Lane Departure Warning**

Lane departure warning (LDW) systems warn the driver if he or she leaves a marked lane without using the indicator, or if the vehicle is drifting out of its travel lane.

LDW is part of the ‘second wave’ of active safety measures – using cutting-edge technology such as on-board sensors, radar, cameras, GPS and lasers – that is being fitted to passenger cars.

Active safety technology can prevent accidents from happening altogether or at least actively help the driver to reduce the impact of an emergency situation. Active systems give the driver more control in dangerous situations. To that end, various safety systems constantly monitor the performance and surroundings of a vehicle. Simply put, active safety systems avoid or mitigate an accident pre-impact – so before it happens or contact is made.

## **Suspension Control**

The Suspension Control Module enables a vehicle to handle different terrain and road conditions. It's main function is to control the air suspension of the vehicle while managing passenger comfort and vehicle dynamics.

Types of suspension systems

- leaf springs
- coil springs
- torsion bars
- air springs

What Parts Make Up the Suspension System?

- Tires. These are the only part of the suspension system that touches the ground.
- Coil springs. These are the part that absorbs the impact when a vehicle hits a bump in the road.
- Shock absorbers
- Rods/linkages
- Joints/bearings/bushings.

Common examples of suspensions include:

- Mud or muddy water: where soil, clay, or silt particles are suspended in water.
- Flour suspended in water.
- Kimchi suspended on vinegar.
- Chalk suspended in water.
- Sand suspended in water

Functions of suspension systems



In a nutshell, your car's suspension system is a protective lattice of shock-absorbing components such as springs and dampers. Your car's suspension helps ensure that your drive is safe and smooth by absorbing the energy from various road bumps and other kinetic impacts.

There are three basic types of suspension components: linkages, springs, and shock absorbers. The linkages are the bars and brackets that support the wheels, springs and shock absorbers.

### **Healthcare:**

#### **Artificial Pancreas:**

Most of medical systems use cyber physical systems; they use real time monitoring and remote sensing of physical conditions of the patients. This leads to improved treatments for disabled and elderly patients and limits patient hospitalization. In future these systems will be combined into a network closed loop system incorporating a human loop to improve the safety and workflows.

The introduction of artificial pancreas (AP) has proved to be a boon for diabetic patients. This medical device has the potential to improve the conditions of people infected with type 1 diabetes (T1D). Hence, people must be aware of the working of AP in order to utilise it for maximum health benefits

Diabetes mellitus (commonly known as Diabetes) is one of the serious chronic diseases characterized by high glucose levels in the blood. The main cause of this disease is the inappropriate working of the organ called pancreas. This disease affects the ability of the body to produce or use insulin appropriately.

The pancreas is located in the abdomen behind the stomach. When we eat food, our body converts that food into energy through glucose. Therefore after a meal, when the glucose level in the blood increases, beta cells of the pancreas release insulin, which stimulates fat cells to remove excess glucose from the blood and stores it in the liver in the form of glycogen, thereby maintaining blood glucose level in the desirable range of 70mg/dL to 180mg/dL.

When the concentration of glucose in the blood gets low, alpha cells of the pancreas secrete hormone called glucagon by catabolising glycogen stored in the liver. The blood sugar level of a diabetic patient thus remains normal. The glucose drop might be due to insulin not being produced in the appropriate amount as it should be.

Artificial pancreas is a man-made scientific technology developed in order to match the working of the pancreas. It is designed to change glucose levels in the bloodstream in a similar way as the human pancreas does throughout the day and overnight.

Maintaining a balanced glucose level is important for the proper functioning of brain, kidney, and liver. Therefore it is important for T1D patients to maintain these levels when the body cannot produce insulin.

An AP system consists of three devices—an insulin delivery pump, a continuous glucose monitoring system (CGM), and a computer-controlled algorithm in order to allow real-time communication between two devices. The AP system is sometimes referred to as a closed-loop device as the patient is not in the decision-making loop, or an automatic system for glucose control.

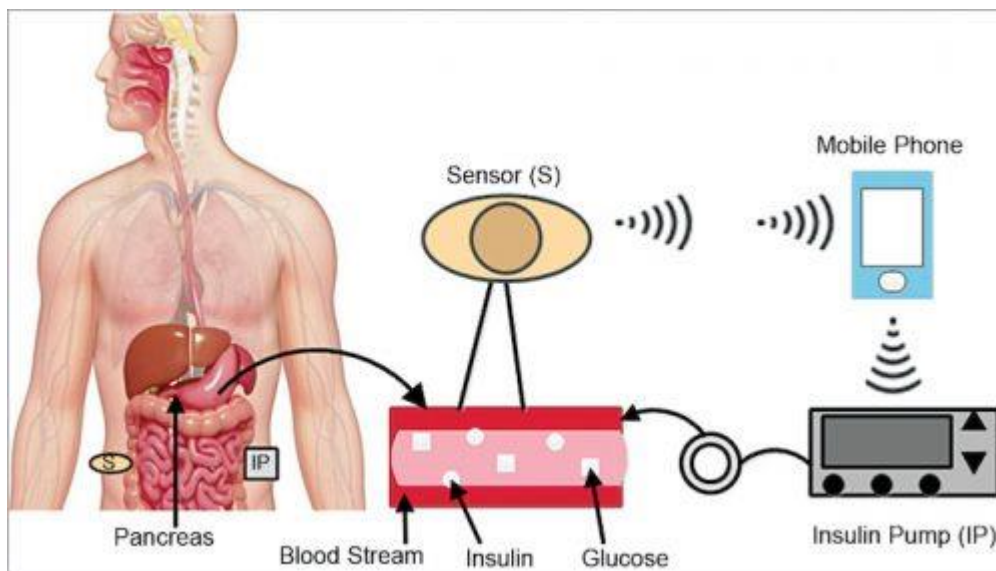
After monitoring the blood glucose levels, the AP system manipulates insulin infusion pump rates by a closed-loop controller that receives information from the sensor in order to reduce the incidence of low blood glucose due to the over administration of insulin (hypoglycemia) and high blood sugar due to failure



of enough administration of insulin or high-intensity exercise (hyperglycemia). Hypoglycemia is a short-term risk that results in drowsiness, shakiness, and even loss of consciousness. Hyperglycemia is a long-term risk that results in blindness (diabetic retinopathy), numbness (diabetic neuropathy), and kidney failure (diabetic nephropathy).

Three main types of artificial pancreas:

1. **Closed-loop artificial pancreas.** Closed-loop artificial pancreas is also called a closed-loop insulin system in which an insulin pump communicates wirelessly with a CGM inserted under the skin. The CGM measures blood sugar concentrations in patient cells and sends the result to a small computer where the control algorithm analyses the result and calculates the correct insulin dosage.
2. **Bionic pancreas.** Bionic pancreas is being developed by Dr Edward Damiano's Beta Bionics firm. It consists of two pumps that deliver insulin and glucagon, respectively, and automatically controls blood glucose levels. The pump is wirelessly connected to the iPhone that enables real-time communication between devices and calculates the required insulin or glucagon doses.
3. **Implanted AP.** Developed by researchers of De Montfort University, the implanted pancreas contains a gel that acts according to the changes in glucose level. The gel administers a higher dose of insulin if the concentration of glucose increases and decreases the amount of insulin during low glucose concentration. It can be refilled with insulin consistently.



*Fig : Artificial pancreas system*

The AP comprises following units:

#### CGM

A CGM takes ongoing blood glucose readings through a little sensor inserted into the skin and maintains a stable flow of information about diabetic patient glucose levels in the bloodstream. A sensor that is fitted under the patient's skin (subcutaneously) continuously monitors the concentration of glucose in the blood

around cells. A small transmitter sends data to the receiver. CGM provides a continuous display of estimates of both blood glucose levels and direction and rate of change of these estimates. To get the correct predictions of blood glucose from a CGM, the diabetic infected patient needs to calibrate the CGM periodically using measurements of glucose from a blood glucose device.

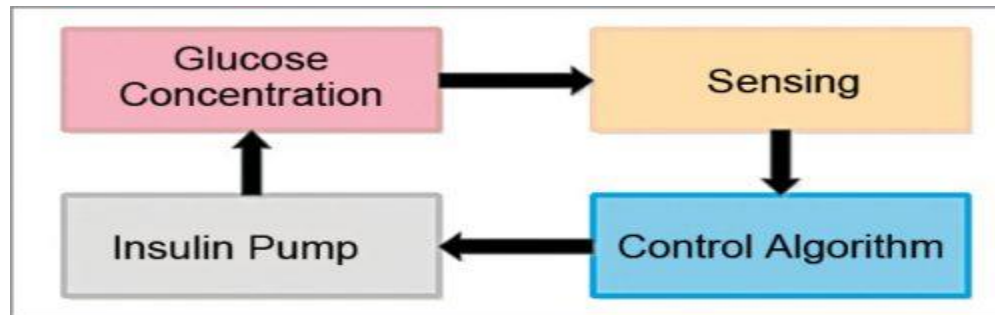


Fig. 2: Closed-loop process of artificial pancreas

Control algorithm:

A computer model or controlled algorithm embedded in an external processor, also called the controller, performs a series of mathematical calculations after receiving information from a CGM. The controller manipulates the insulin infusion rate based on these calculations.

Insulin pump :

It injects the correct dosage of insulin to the fatty tissue below the skin according to the instructions sent by the control algorithm. As a result, insulin moves throughout the bloodstream, thus lowering blood glucose levels.

Patients:

Patients are a significant part of the AP system. The amount of glucose in the bloodstream frequently changes as it gets affected by food taken by the patient, intensity of physical activity, and other substances.

### **Infusion Pumps:**

An infusion pump is a medical device that delivers fluids, such as nutrients and medications, into a patient's body in controlled amounts. Infusion pumps are in widespread use in clinical settings such as hospitals, nursing homes, and in the home.

In general, an infusion pump is operated by a trained user, who programs the rate and duration of fluid delivery through a built-in software interface. Infusion pumps offer significant advantages over manual administration of fluids, including the ability to deliver fluids in very small volumes, and the ability to deliver fluids at precisely programmed rates or automated intervals. They can deliver nutrients or medications, such as insulin or other hormones, antibiotics, chemotherapy drugs, and pain relievers.

There are many types of infusion pumps, including large volume, patient-controlled analgesia (PCA), elastomeric, syringe, enteral, and insulin pumps,. Some are designed mainly for stationary use at a patient's bedside. Others, called ambulatory infusion pumps, are designed to be portable or wearable.

Because infusion pumps are frequently used to administer critical fluids, including high-risk medications, pump failures can have significant implications for patient safety. Many infusion pumps are equipped with safety features, such as alarms or other operator alerts that are intended to activate in the event of a problem. For example, some pumps are designed to alert users when air or another blockage is detected in the tubing that delivers fluid to the patient. Some newer infusion pumps, often called smart pumps, are designed to alert the user when there is a risk of an adverse drug interaction, or when the user sets the pump's parameters outside of specified safety limits.

### **Pacemaker:**

A pacemaker is a small device that's placed (implanted) in the chest to help control the heartbeat. It's used to prevent the heart from beating too slowly. Implanting a pacemaker in the chest requires a surgical procedure. A pacemaker is also called a cardiac pacing device.

A pacemaker is implanted to help control your heartbeat. Your doctor may recommend a temporary pacemaker when you have a slow heartbeat (bradycardia) after a heart attack, surgery or medication overdose but your heartbeat is otherwise expected to recover. A pacemaker may be implanted permanently to correct a chronic slow or irregular heartbeat or to help treat heart failure.

### **What a pacemaker does:**

Pacemakers work only when needed. If your heartbeat is too slow (bradycardia), the pacemaker sends electrical signals to your heart to correct the beat.

Some newer pacemakers also have sensors that detect body motion or breathing rate and signal the devices to increase heart rate during exercise, as needed.

A pacemaker has two parts:

**Pulse generator:** This small metal container houses a battery and the electrical circuitry that controls the rate of electrical pulses sent to the heart.

**Leads (electrodes):** One to three flexible, insulated wires are each placed in one or more chambers of the heart and deliver the electrical pulses to adjust the heart rate. However, some newer pacemakers don't require leads. These devices, called leadless pacemakers, are implanted directly into the heart muscle.

### **Types :**

Depending on your condition, you might have one of the following types of pacemakers.

**Single chamber pacemaker:** This type usually carries electrical impulses to the right ventricle of your heart.

**Dual chamber pacemaker** :This type carries electrical impulses to the right ventricle and the right atrium of your heart to help control the timing of contractions between the two chambers.

**Biventricular pacemaker**: Biventricular pacing, also called cardiac resynchronization therapy is for people who have heart failure and heartbeat problems.

### **Green Buildings:**

A ‘green building’ is defined as the one which uses less energy, water and natural resources, creates less waste and a healthy environment for the people living inside, when compared to a conventional building. The need to design and construct ‘green buildings’ to conserve the precious electricity, as the green buildings can help to reduce considerably the consumption of electricity.

In general, green building is the practice of increasing the efficiency with which a building uses the various resources- energy, water and materials-while reducing its impacts on human health and the environment, during the building’s life cycle. It is better achieved through: 1) Better selection and use of site; 2) Innovation in design process; 3) Efficient use of water; 4) Accurate choice of materials and efficient construction.

### **CHARACTERISTICS OF GREEN BUILDINGS**

- Location and transport.
- Sustainable sites.
- Efficient use of water.
- Energy and atmosphere.
- Materials and resources.
- Indoor environmental quality.
- Design innovation.
- Regional priority.

Five of the green systems that are being utilized in building engineering are **radiant floors, gray water recycling, solar power, geothermal systems, and energy efficient window systems**. These systems working together can achieve an owner's energy and water conservation goals while also reducing utility bills.

### **Automated Lighting:**

Green Building is an important research area in IOT. The energy efficiency in green buildings is vital for global sustainability. However many factors affect energy consumption by the device and most of the green buildings are not really green due to static energy supply and centralized control on devices. Here we propose a design using LEDs to make use of environmental factors such as sunlight and temperature to

change power supply policy dynamically to increase energy efficiency and distributed clustering of devices for smart autonomous control.

The ways which are used today in order to light houses, offices, and most of the indoor areas are inefficient as a lot of energy is consumed unnecessarily during the day time. Mainly this problem because the interior lighting design consider the worst case when the light service is at night, which is not always valid. Also in most cases the lighting system design relies on people to control the lights switching on and off. This problem is also one of the design concerns in Green Building.

Hence, a solution to this problem and a method for people's comfort who use the indoor facilities in industrial buildings is presented. In the proposed smart lighting system, lights switch on automatically when there is somebody in the room or in the occupied space and switch off when there is no occupancy. In addition to this known technique, adjustment of the brightness level of the lights will be possible via the personal computer or any other smart device.

In this method, for the illumination level in the area, where is needed to be controlled for better energy saving, the light automatically is measured by the sensor and considering the amount of background lights coming from outside, automatically the brightness of lights is controlled to reach the preset level that determined for that room.

By means of this method, it is possible to provide better user comfort, avoid human forcedness to switch the light on and off, and hence effective energy saving. Arduino controller is used to build the controller and to demonstrate the results. Economic analysis was done to calculate the percentage of the energy saving that can be obtained by implementing the proposed smart lighting controller. As an outcome of the economic analysis, energy saving norm for an office with a standard size was calculated.

The direct advantage of an automated lighting system is to reduce energy consumption and maintenance costs. Energy consumption is reduced, because an intelligent lighting system in addition to considering the occupancy status of the room, the external daylight coming into the room is considered as well, hence reduce the amount of power consumed. And, maintenance cost is minimized, since lifetime of the light bulbs is better utilized and this factor extends the span time of light bulbs series.

In addition to this, indirect advantages of proposed solution are that it allows the country to export more oil and gas since the consumption of fuel that is needed to generate electricity will be reduced due to the energy savings caused by intelligent lighting system. Also, a reduction in pollution can be considered as another positive advantage for using the smart control for the indoor lighting system, because when less energy is consumed, the amount of carbon dioxide emission released by power generation plants is reduced.

#### **AC control – power distribution grid:**

Smart buildings use internet-connected devices so as to increase efficiency and reduce expenditure on electric appliances related to heating and lighting. These smart devices are embedded within heating,

ventilation and air conditioning (HVAC) systems, lighting systems, elevators, EV charging points, etc. in order to enhance energy efficiency comprehensively.

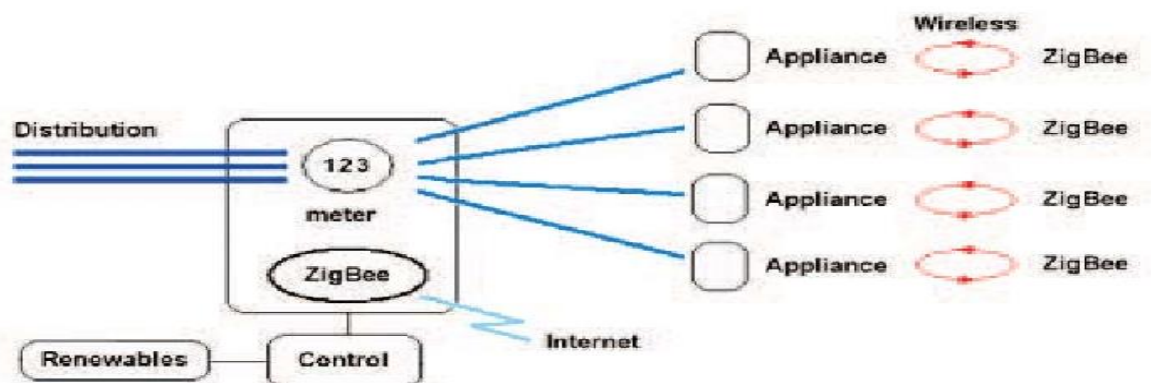
Smart home technology, also referred to as home automation, provides homeowners security, comfort, convenience and energy efficiency by allowing them to control smart devices, often by a smart home app on their smartphone or other networked device. Smart devices reduce idle running of energy consuming systems. At the household level, these devices are integrated to enable the sharing of user data related to each application and automate actions based on owners' preferences and the external environment.

Furthermore, these devices are connected to a larger network, and they send anonymised consumption data of each individual unit to the distribution utility, aiding the utility to enhance grid efficiency and reduce grid-related operations and maintenance. The exponential decline in processor sizes and cost coupled with the increase in capacity and speed is driving their adoption by households. Additionally, machine learning and AI-related advancements and the development of smartphones are providing a further fillip to the adoption of smart devices in households.

Almost all small scale renewable generators generate low voltage DC power. To supply power to the AC mains network, costly and inefficient power invertors/convertors setups are used. But ultimately, the generated power from such renewable energy sources may deliver to a DC load. A possible solution that can omit the usage of costly and inefficient power invertors/convertor setups is to install a DC network linking the DC devices to DC power supplies.

DC nano-network for a Smart Home composed of: a home area network with a Smart Meter and Intelligent Devices. The Smart Meter and Intelligent Devices manage and control the loads by group using different wireless nodes. Efficient algorithms will be developed to manage loads during peak hours, to coordinate between the Smart Meters and Intelligent Devices and to monitor the power flow.

The total load of the building will be categorized and managed. Intelligent Devices are attached to each load, monitoring and controlling the power flow individually. These Intelligent Devices can communicate with the Smart Meter and based on the decision making algorithms, the load can be managed during peak hours.



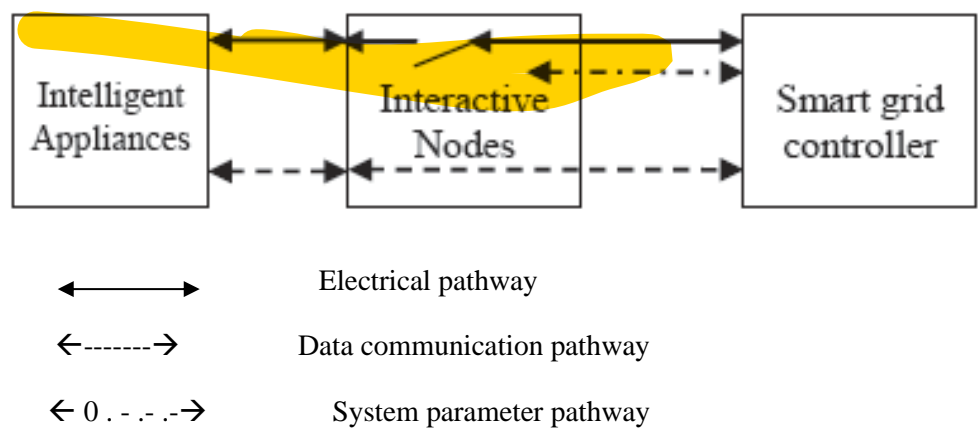
Smart Grid system architecture with consumer Premises monitoring and control

It will have

three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to communicate with each other. When an appliance is connected to the node, the switch on the electrical pathway will remain in the open position. The controller will detect that an appliance had been connected and it will send a signal through the communication channel requesting its identification data. If the controller assesses that the appliance can work properly at that node without adverse affects on any other nodes it sends a signal to close the switch and allows the appliance to operate.

It will have three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to communicate with each other. When an appliance is connected to the node, the switch on the electrical pathway will remain in the open position. The controller will detect that an appliance had been connected and it will send a signal through the communication channel requesting its identification data. If the controller assesses that the appliance can work properly at that node without adverse affects on any other nodes it sends a signal to close the switch and allows the appliance to operate.

Figure: Smart electrical system



three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to communicate with each other. Each DC appliance will need an electronic identifier which will contain its identifier parameters and have a communication channel to pass on this data to the system controller. Besides its basic voltage and current



characteristics, there will be many parameters that the appliance manufacturer will want to provide for both its' safe operation and dynamic control. At this time the use of National Instruments (NI)

Specification hardware is a tested method to provide this type of intelligence to the appliances. At this time in an ordinary AC 230V house the mode of operation is either on, power flows, or off, no power. However in the DC house it is possible that at times of low power generation, circuit overload, or if it is running on emergency generation, partial power may be lost to the system. In such a scenario, decisions have to be made as to which appliances should have priority to use the available power.

Within a conventional home system, the homeowner would have to decide on which appliances to give priority and go around the house and physically unplug those that are of low priority. However with smart control of the system this can be done automatically using a hierarchical identifier. Such an identifier puts each appliance in order of criticality to the homeowner which will be represented by a numbering system. For example general category of emergency lighting may be assigned a number 1, loads like the internet/telephony 2, refrigerator/freezer 3, other lighting 4 etc. then within each category there will be subcategories depending on importance.

A grid-connected system allows you to power your home or small business with renewable energy during those periods daily as well as seasonally like when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid.

### **Robotics:**

Robotics is a branch of engineering that involves the conception, design, manufacture and operation of robots. The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways. Robotics can take on a number of forms. A robot may resemble a human, or it may be in the form of a robotic application, such as robotic process automation (RPA), which simulates how humans engage with software to perform repetitive, rules-based tasks.

Robotics is likely to play a role in future health care delivery systems. The work that is done in hospitals by nurses, orderlies, and similar staff personnel includes some tasks that are routine and repetitive. Duties that might be automated using robots include making beds, delivering linens, and moving supplies between locations in the hospital. Robots might even become involved in certain aspects of patient care such as transporting patients to services in the hospital, passing food trays, and similar functions in which it is not critical that a hospital staff member be present. Research is currently under way to develop robots that would be capable of providing assistance to paraplegics and other physically handicapped persons. These robots would respond to voice commands and would be able to interpret statements in natural language (e.g., everyday English) from patients requesting service.

The term *robotics* is an extension of the word *robot*. One of its first uses came from Czech writer Karel Čapek, who used the word in his play, *Rossum's Universal Robots*, in 1920.

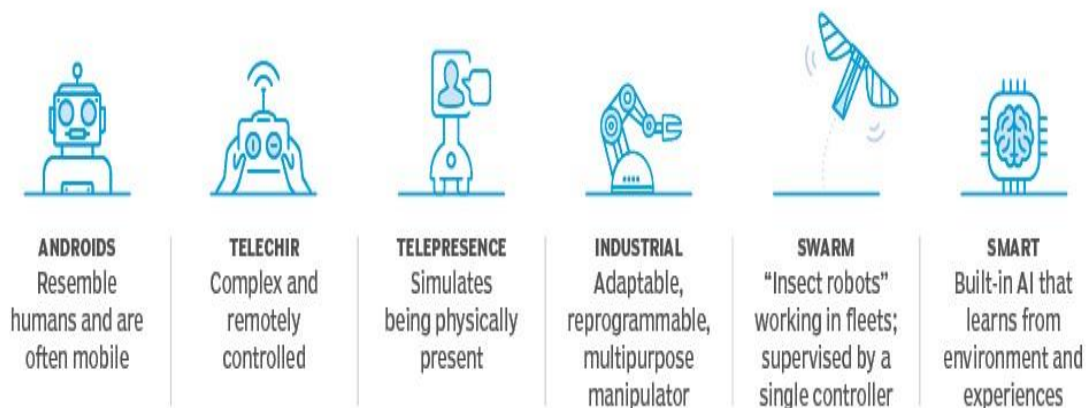
However, it is science fiction author Isaac Asimov who has been given credit for being the first person to use the term in the 1940s by *Oxford English Dictionary*.

In Asimov's story, he suggested three principles to guide the behavior of autonomous robots and smart machines.

Asimov's Three Laws of Robotics have survived to the present:

1. Robots must never harm human beings.
2. Robots must follow instructions from humans without violating rule 1.
3. Robots must protect themselves without violating the other rules.

## Types of robots



It will have three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to manage Robotics applications

Today, industrial robots, as well as many other types of robots, are used to perform repetitive tasks. They may take the form of a robotic arm, robotic exoskeleton or traditional humanoid robots.

Industrial robots and robot arms are used by manufacturers and warehouses, such as those owned by Amazon, Devo, Best Buy and more.

To function, a combination of computer programming and algorithms, a remotely controlled manipulator, actuators, control systems -- action, processing and perception -- real-time sensors and an element of automation helps to inform what a robot or robotic system does.

Some additional applications for robotics are the following:

Home electronics

Computer science/computer programming

Artificial intelligence

Data science

Law enforcement/military

Mechanical engineering

Mechatronics

Nanotechnology

Bioengineering/healthcare

Aerospace

### **Machine learning in robotics:**

Machine learning and robotics intersect in a field known as robot learning. Robot learning is the study of techniques that enable a robot to acquire new knowledge or skills through machine learning algorithms.

Some applications that have been explored by robot learning include grasping objects, object categorization and even linguistic interaction with a human peer. Learning can happen through self-exploration or via guidance from a human operator.

To learn, intelligent robots must accumulate facts through human input or sensors. Then, the robot's processing unit will compare the newly acquired data to previously stored information and predict the best course of action based on the data it has acquired.

### **Civil Infrastructure:**

Civil Engineering Infrastructure refers to the basic facilities and systems that help society function, including road construction, rail construction, tunnelling, utilities and other systems excluding the erection of buildings.

The construction industry being labor intensive requires more numbers of skilled labor, good quality of work, and increase in productivity etc. The problems associated with construction work such as decreasing quality of work, labor shortages, and safety of labor and working condition of projects can be overcome by new innovative technologies such as automation which has the potential to improve the quality, safety, and productivity of the construction industry.

The scope of automation in construction is broad, encompassing all the stages of construction life from initial planning and design, through construction of the facility, its operation and maintenance, to the eventual dismantling and recycling of buildings and engineering structures. The recent developments in the fields of computer science and robotics have helped to develop new technologies in the field of construction industry. In Japan which is a leader in robotics and automation have developed many new technologies and

machinery which have helped the construction industry to reduce human efforts, construction cost and project time period and increase the productivity.

At times construction work is conducted under dangerous condition and situation, thus there is need for robotics to optimize equipment operation improve safety and quality of work. Automated construction process leads to a continuous working time through the year. For rapid construction with less risk and good quality there should be more and more use of machines as well as equipment in the construction industry. Human efforts and risks are reduced by using machines, robots, etc. at appropriate places.

### **Advantages of automation in construction:**

Automation in construction industry may achieve the following advantages:

- Uniform quality with higher accuracy than that provided by skilled workers.
- Replacing human operators in tasks that involve hard physical or monotonous work.
- Replacing humans in tasks performed in dangerous environments such as those with heights, over a river etc.
- Making tasks that are beyond human capabilities easier.
- Increasing productivity and work efficiency with reduced costs.
- Economic improvement. Automation can serve as the catalyst for improvement in the economies of enterprises or society. For example, the gross national income and standard of living in Germany and Japan improved drastically in the 20th century, due in large part to embracing automation in construction and infrastructural development.
- Improving work environment as conventional manual work is reduced to a minimum, so the workers are relieved from uncomfortable work positions.

### **Areas of automation in Construction**

- Roads & Runways construction
- Structures
- Buildings construction
- Ports
- Tunnels
- Factories and industries

### **Avionics:**

Avionics is a blend of aviation and electronics are the electronic systems used on aircraft, artificial satellites, and spacecraft. Avionic systems include communications, navigation, the display and management of

multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions. These can be as simple as a searchlight for a police helicopter or as complicated as the tactical system for an airborne early warning platform.

The term "avionics" was coined in 1949 by Philip J. Klass. The word **avionics**, derived from the expression "aviation electronics", the development and production of electronic instruments for use in aviation and astronautics. The term also refers to the instruments themselves. Such instruments consist of a wide variety of control, performance, communications, and radio navigation devices and systems.

Control apparatus includes the attitude gyro and any number of instruments that indicate power, such as the tachometer in propeller craft, torque meter in turboprops, and exhaust pressure ratio indicator in turbojets. Performance instruments include the altimeter, Machmeter, turn and slip indicator, and varied devices that show airspeed, vertical velocity, and angle of attack.

Communications instruments include two-way radios allowing direct voice communication between the aircraft and the ground as well as other aircraft; these operate across a wide spectrum, ranging from high frequency (HF) through very high frequency (VHF) to ultrahigh frequency (UHF). Electronic radio navigation equipment ranges from radar to instrument landing systems.

There has been a progression towards centralized control of the multiple complex systems fitted to aircraft, including engine monitoring and management. Health and usage monitoring systems (HUMS) are integrated with aircraft management computers to give maintainers early warnings of parts that will need replacement. The integrated modular avionics concept proposes an integrated architecture with application software portable across an assembly of common hardware modules. It has been used in fourth generation jet fighters and the latest generation of airliners.

### **Transportation:**

Automation has been applied in various ways in the transportation industries. Applications include airline reservation systems, automatic pilots in aircraft and locomotives, and urban mass-transit systems. The airlines use computerized reservation systems to continuously monitor the status of all flights. With these systems, ticket agents at widely dispersed locations can obtain information about the availability of seats on any flight in a matter of seconds. The reservation systems compare requests for space with the status of each flight, grant space when available, and automatically update the reservation status files. Passengers can even receive their seat assignments well in advance of flight departures.

Nearly all commercial aircraft are equipped with instruments called automatic pilots. Under normal flying conditions, these systems guide an airplane over a predetermined route by detecting changes in the aircraft's orientation and heading from gyroscopes and similar instruments and by providing appropriate control signals to the plane's steering mechanism. Automatic navigation systems and instrument landing systems operate by using radio signals from ground beacons that provide the aircraft with course directions for guidance. When an airplane is within the traffic pattern for ground control, its human pilot normally assumes control.

Examples of automated rail transportation include American urban mass-transit systems such as BART (Bay Area Rapid Transit) in San Francisco; MARTA (Metropolitan Atlanta Rapid Transit Authority) in Atlanta, Georgia; and the Metrorail in Washington, D.C. The BART system serves as a useful example; it consists of more than 75 miles (120 kilometres) of track, with about 100 trains operating at peak hours between roughly 30 stations. The trains sometimes attain speeds of 80 miles per hour with intervals between trains of as little as 90 seconds. In each train there is one operator whose role is that of an observer and communicator and who can override the automatic system in case of emergency. The automatic system protects the trains by assuring a safe distance between them and by controlling their speed. Another function of the system is to control train routings and make adjustments in the operation of each train to keep the entire system operating on schedule.

As a train enters the station, it automatically transmits its identification, destination, and length, thus lighting up a display board for passenger information and transmitting information to the control centres. Signals are automatically returned to the train to regulate its time in the station and its running time to the next station. At the beginning of the day, an ideal schedule is determined; as the day progresses, the performance of each train is compared with the schedule, and adjustments are made to each train's operation as required. The entire system is controlled by two identical computers, so that if one malfunctions, the other assumes complete control. In the event of a complete failure of the computer control system, the system reverts to manual control.

## **Healthcare:**

### **Artificial Pancreas:**

Most of medical systems use cyber physical systems; they use real time monitoring and remote sensing of physical conditions of the patients. This leads to improved treatments for disabled and elderly patients and limits patient hospitalization. In future these systems will be combined into a network closed loop system incorporating a human loop to improve the safety and workflows.

The introduction of artificial pancreas (AP) has proved to be a boon for diabetic patients. This medical device has the potential to improve the conditions of people infected with type 1 diabetes (T1D). Hence, people must be aware of the working of AP in order to utilise it for maximum health benefits

Diabetes mellitus (commonly known as Diabetes) is one of the serious chronic diseases characterized by high glucose levels in the blood. The main cause of this disease is the inappropriate working of the organ called pancreas. This disease affects the ability of the body to produce or use insulin appropriately.

The pancreas is located in the abdomen behind the stomach. When we eat food, our body converts that food into energy through glucose. Therefore after a meal, when the glucose level in the blood increases, beta cells of the pancreas release insulin, which stimulates fat cells to remove excess glucose from the blood and stores it in the liver in the form of glycogen, thereby maintaining blood glucose level in the desirable range of 70mg/dL to 180mg/dL.

When the concentration of glucose in the blood gets low, alpha cells of the pancreas secrete hormone called glucagon by catabolising glycogen stored in the liver. The blood sugar level of a diabetic patient thus

remains normal. The glucose drop might be due to insulin not being produced in the appropriate amount as it should be.

Artificial pancreas is a man-made scientific technology developed in order to match the working of the pancreas. It is designed to change glucose levels in the bloodstream in a similar way as the human pancreas does throughout the day and overnight.

Maintaining a balanced glucose level is important for the proper functioning of brain, kidney, and liver. Therefore it is important for T1D patients to maintain these levels when the body cannot produce insulin.

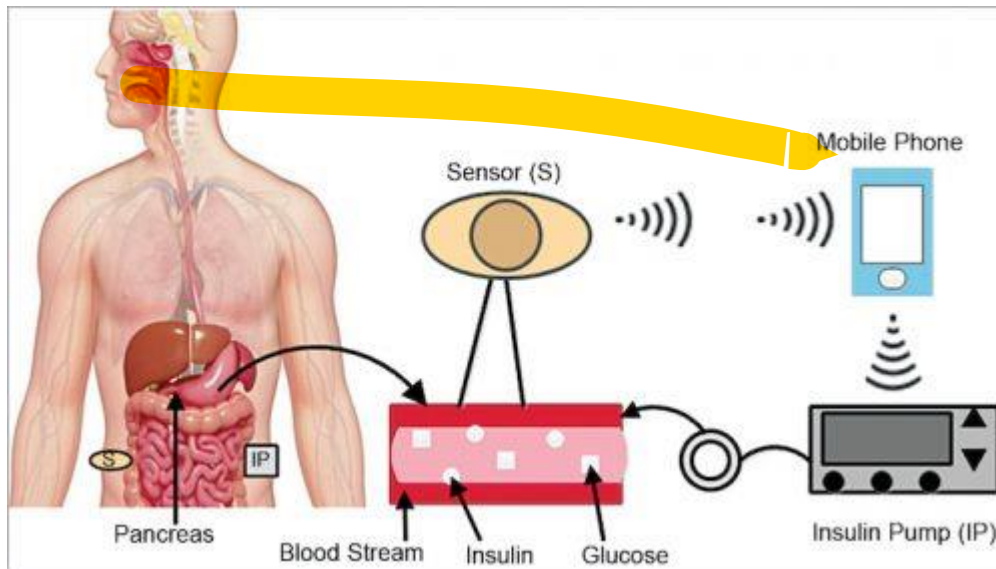
An AP system consists of three devices—an insulin delivery pump, a continuous glucose monitoring system (CGM), and a computer-controlled algorithm in order to allow real-time communication between two devices. The AP system is sometimes referred to as a closed-loop device as the patient is not in the decision-making loop, or an automatic system for glucose control.

After monitoring the blood glucose levels, the AP system manipulates insulin infusion pump rates by a closed-loop controller that receives information from the sensor in order to reduce the incidence of low blood glucose due to the over administration of insulin (hypoglycemia) and high blood sugar due to failure of enough administration of insulin or high-intensity exercise (hyperglycemia). Hypoglycemia is a short-term risk that results in drowsiness, shakiness, and even loss of consciousness. Hyperglycemia is a long-term risk that results in blindness (diabetic retinopathy), numbness (diabetic neuropathy), and kidney failure (diabetic nephropathy).

Three main types of artificial pancreas:

4. **Closed-loop artificial pancreas.** Closed-loop artificial pancreas is also called a closed-loop insulin system in which an insulin pump communicates wirelessly with a CGM inserted under the skin. The CGM measures blood sugar concentrations in patient cells and sends the result to a small computer where the control algorithm analyses the result and calculates the correct insulin dosage.
5. **Bionic pancreas.** Bionic pancreas is being developed by Dr Edward Damiano's Beta Bionics firm. It consists of two pumps that deliver insulin and glucagon, respectively, and automatically controls blood glucose levels. The pump is wirelessly connected to the iPhone that enables real-time communication between devices and calculates the required insulin or glucagon doses.
6. **Implanted AP.** Developed by researchers of De Montfort University, the implanted pancreas contains a gel that acts according to the changes in glucose level. The gel administers a higher dose of insulin if the concentration of glucose increases and decreases the amount of insulin during low glucose concentration. It can be refilled with insulin consistently.





*Fig : Artificial pancreas system*

The AP comprises following units:

#### CGM

A CGM takes ongoing blood glucose readings through a little sensor inserted into the skin and maintains a stable flow of information about diabetic patient glucose levels in the bloodstream. A sensor that is fitted under the patient's skin (subcutaneously) continuously monitors the concentration of glucose in the blood around cells. A small transmitter sends data to the receiver. CGM provides a continuous display of estimates of both blood glucose levels and direction and rate of change of these estimates. To get the correct predictions of blood glucose from a CGM, the diabetic infected patient needs to calibrate the CGM periodically using measurements of glucose from a blood glucose device.

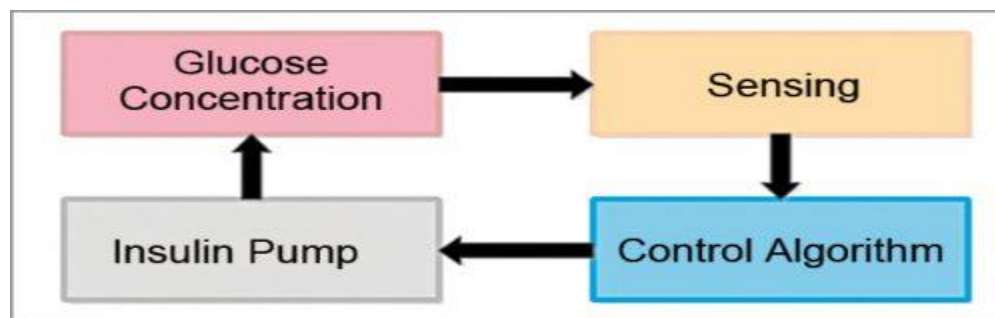


Fig. 2: Closed-loop process of artificial pancreas

Control algorithm:

A computer model or controlled algorithm embedded in an external processor, also called the controller, performs a series of mathematical calculations after receiving information from a CGM. The controller manipulates the insulin infusion rate based on these calculations.

Insulin pump :

It injects the correct dosage of insulin to the fatty tissue below the skin according to the instructions sent by the control algorithm. As a result, insulin moves throughout the bloodstream, thus lowering blood glucose levels.

Patients:

Patients are a significant part of the AP system. The amount of glucose in the bloodstream frequently changes as it gets affected by food taken by the patient, intensity of physical activity, and other substances.

### **Infusion Pumps:**

An infusion pump is a medical device that delivers fluids, such as nutrients and medications, into a patient's body in controlled amounts. Infusion pumps are in widespread use in clinical settings such as hospitals, nursing homes, and in the home.

In general, an infusion pump is operated by a trained user, who programs the rate and duration of fluid delivery through a built-in software interface. Infusion pumps offer significant advantages over manual administration of fluids, including the ability to deliver fluids in very small volumes, and the ability to deliver fluids at precisely programmed rates or automated intervals. They can deliver nutrients or medications, such as insulin or other hormones, antibiotics, chemotherapy drugs, and pain relievers.

There are many types of infusion pumps, including large volume, patient-controlled analgesia (PCA), elastomeric, syringe, enteral, and insulin pumps,. Some are designed mainly for stationary use at a patient's bedside. Others, called ambulatory infusion pumps, are designed to be portable or wearable.

Because infusion pumps are frequently used to administer critical fluids, including high-risk medications, pump failures can have significant implications for patient safety. Many infusion pumps are equipped with safety features, such as alarms or other operator alerts that are intended to activate in the event of a problem. For example, some pumps are designed to alert users when air or another blockage is detected in the tubing that delivers fluid to the patient. Some newer infusion pumps, often called smart pumps, are designed to alert the user when there is a risk of an adverse drug interaction, or when the user sets the pump's parameters outside of specified safety limits.

### **Pacemaker:**

A pacemaker is a small device that's placed (implanted) in the chest to help control the heartbeat. It's used to prevent the heart from beating too slowly. Implanting a pacemaker in the chest requires a surgical procedure. A pacemaker is also called a cardiac pacing device.

A pacemaker is implanted to help control your heartbeat. Your doctor may recommend a temporary pacemaker when you have a slow heartbeat (bradycardia) after a heart attack, surgery or medication overdose but your heartbeat is otherwise expected to recover. A pacemaker may be implanted permanently to correct a chronic slow or irregular heartbeat or to help treat heart failure.

### **What a pacemaker does:**

Pacemakers work only when needed. If your heartbeat is too slow (bradycardia), the pacemaker sends electrical signals to your heart to correct the beat.

Some newer pacemakers also have sensors that detect body motion or breathing rate and signal the devices to increase heart rate during exercise, as needed.

A pacemaker has two parts:

**Pulse generator:** This small metal container houses a battery and the electrical circuitry that controls the rate of electrical pulses sent to the heart.

**Leads (electrodes):** One to three flexible, insulated wires are each placed in one or more chambers of the heart and deliver the electrical pulses to adjust the heart rate. However, some newer pacemakers don't require leads. These devices, called leadless pacemakers, are implanted directly into the heart muscle.

### **Types :**

Depending on your condition, you might have one of the following types of pacemakers.

**Single chamber pacemaker:** This type usually carries electrical impulses to the right ventricle of your heart.

**Dual chamber pacemaker :** This type carries electrical impulses to the right ventricle and the right atrium of your heart to help control the timing of contractions between the two chambers.

**Biventricular pacemaker:** Biventricular pacing, also called cardiac resynchronization therapy is for people who have heart failure and heartbeat problems.

### **Green Buildings:**

A 'green building' is defined as the one which uses less energy, water and natural resources, creates less waste and a healthy environment for the people living inside, when compared to a conventional building. The need to design and construct 'green buildings' to conserve the precious electricity, as the green buildings can help to reduce considerably the consumption of electricity.

In general, green building is the practice of increasing the efficiency with which a building uses the various resources- energy, water and materials-while reducing its impacts on human health and the environment, during the building's life cycle. It is better achieved through: 1) Better selection and use of site; 2) Innovation in design process; 3) Efficient use of water; 4) Accurate choice of materials and efficient construction.

### **CHARACTERISTICS OF GREEN BUILDINGS**

- Location and transport.
- Sustainable sites.
- Efficient use of water.
- Energy and atmosphere.
- Materials and resources.
- Indoor environmental quality.
- Design innovation.
- Regional priority.

Five of the green systems that are being utilized in building engineering are **radiant floors, gray water recycling, solar power, geothermal systems, and energy efficient window systems**. These systems working together can achieve an owner's energy and water conservation goals while also reducing utility bills.

### **Automated Lighting:**

Green Building is an important research area in IOT. The energy efficiency in green buildings is vital for global sustainability. However many factors affect energy consumption by the device and most of the green buildings are not really green due to static energy supply and centralized control on devices. Here we propose a design using LEDs to make use of environmental factors such as sunlight and temperature to change power supply policy dynamically to increase energy efficiency and distributed clustering of devices for smart autonomous control.

The ways which are used today in order to light houses, offices, and most of the indoor areas are inefficient as a lot of energy is consumed unnecessarily during the day time. Mainly this problem because the interior lighting design consider the worst case when the light service is at night, which is not always valid. Also in most cases the lighting system design relies on people to control the lights switching on and off. This problem is also one of the design concerns in Green Building.

Hence, a solution to this problem and a method for people's comfort who use the indoor facilities in industrial buildings is presented. In the proposed smart lighting system, lights switch on automatically when there is somebody in the room or in the occupied space and switch off when there is no occupancy. In addition to this known technique, adjustment of the brightness level of the lights will be possible via the personal computer or any other smart device.

In this method, for the illumination level in the area, where is needed to be controlled for better energy saving, the light automatically is measured by the sensor and considering the amount of background lights coming from outside, automatically the brightness of lights is controlled to reach the preset level that determined for that room.

By means of this method, it is possible to provide better user comfort, avoid human forcedness to switch the light on and off, and hence effective energy saving. Arduino controller is used to build the controller

and to demonstrate the results. Economic analysis was done to calculate the percentage of the energy saving that can be obtained by implementing the proposed smart lighting controller. As an outcome of the economic analysis, energy saving norm for an office with a standard size was calculated.

The direct advantage of an automated lighting system is to reduce energy consumption and maintenance costs. Energy consumption is reduced, because an intelligent lighting system in addition to considering the occupancy status of the room, the external daylight coming into the room is considered as well, hence reduce the amount of power consumed. And, maintenance cost is minimized, since lifetime of the light bulbs is better utilized and this factor extends the span time of light bulbs series.

In addition to this, indirect advantages of proposed solution are that it allows the country to export more oil and gas since the consumption of fuel that is needed to generate electricity will be reduced due to the energy savings caused by intelligent lighting system. Also, a reduction in pollution can be considered as another positive advantage for using the smart control for the indoor lighting system, because when less energy is consumed, the amount of carbon dioxide emission released by power generation plants is reduced.

#### **AC control – power distribution grid:**

Smart buildings use internet-connected devices so as to increase efficiency and reduce expenditure on electric appliances related to heating and lighting. These smart devices are embedded within heating, ventilation and air conditioning (HVAC) systems, lighting systems, elevators, EV charging points, etc. in order to enhance energy efficiency comprehensively.

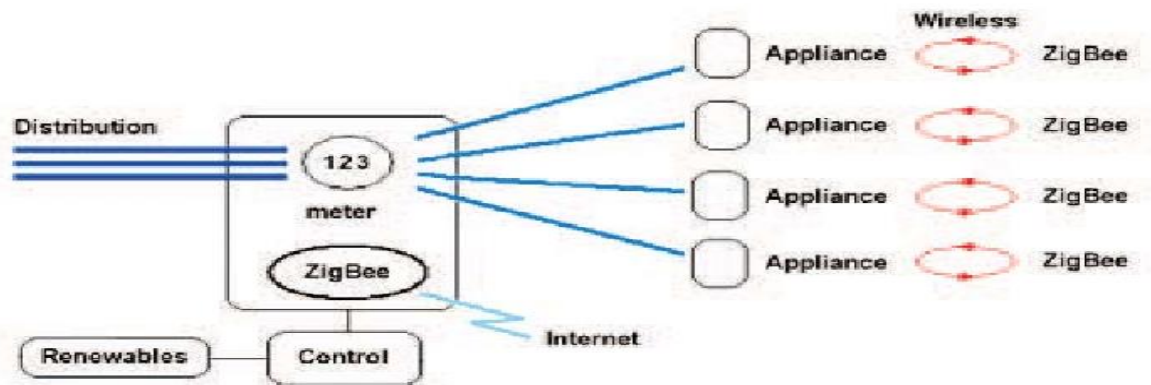
Smart home technology, also referred to as home automation, provides homeowners security, comfort, convenience and energy efficiency by allowing them to control smart devices, often by a smart home app on their smartphone or other networked device. Smart devices reduce idle running of energy consuming systems. At the household level, these devices are integrated to enable the sharing of user data related to each application and automate actions based on owners' preferences and the external environment.

Furthermore, these devices are connected to a larger network, and they send anonymised consumption data of each individual unit to the distribution utility, aiding the utility to enhance grid efficiency and reduce grid-related operations and maintenance. The exponential decline in processor sizes and cost coupled with the increase in capacity and speed is driving their adoption by households. Additionally, machine learning and AI-related advancements and the development of smartphones are providing a further fillip to the adoption of smart devices in households.

Almost all small scale renewable generators generate low voltage DC power. To supply power to the AC mains network, costly and inefficient power invertors/convertors setups are used. But ultimately, the generated power from such renewable energy sources may deliver to a DC load. A possible solution that can omit the usage of costly and inefficient power invertors/convertor setups is to install a DC network linking the DC devices to DC power supplies.

DC nano-network for a Smart Home composed of: a home area network with a Smart Meter and Intelligent Devices. The Smart Meter and Intelligent Devices manage and control the loads by group using different wireless nodes. Efficient algorithms will be developed to manage loads during peak hours, to coordinate between the Smart Meters and Intelligent Devices and to monitor the power flow.

The total load of the building will be categorized and managed. Intelligent Devices are attached to each load, monitoring and controlling the power flow individually. These Intelligent Devices can communicate with the Smart Meter and based on the decision making algorithms, the load can be managed during peak hours.



Smart Grid system architecture with consumer Premises monitoring and control

It will have

three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able

It will have

three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able

It will have

three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able

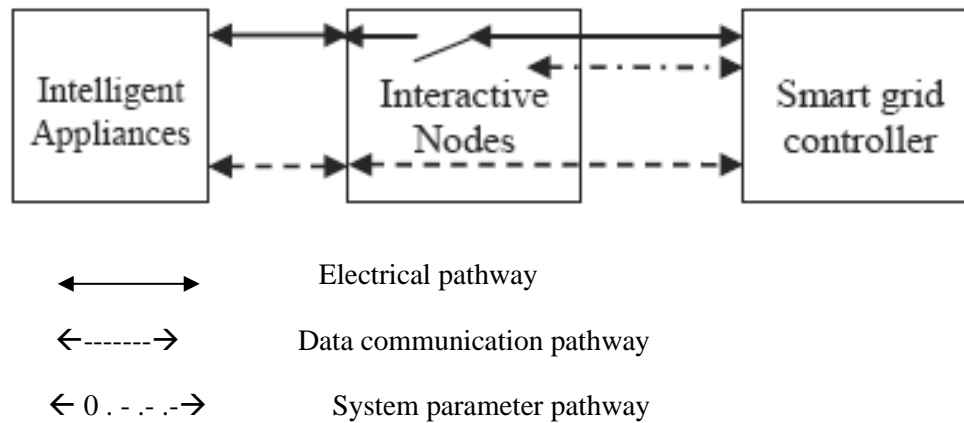
three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able

It will have

three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must b

It will have three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to communicate with each other. When an appliance is connected to the node, the switch on the electrical pathway will remain in the open position. The controller will detect that an appliance had been connected and it will send a signal through the communication channel requesting its identification data. If the controller assesses that the appliance can work properly at that node without adverse affects on any other nodes it sends a signal to close the switch and allows the appliance to operate.

*Figure: Smart electrical system*



three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able

Each DC appliance will need an electronic identifier which will contain its identifier parameters and have a communication channel to pass on this data to the system controller. Besides its basic voltage and current characteristics, there will be many parameters that the appliance manufacturer will want to provide for both its' safe operation and dynamic control. At this time the use of National Instruments (NI)

Specification hardware is a tested method to provide this type of intelligence to the appliances. At this time in an ordinary AC 230V house the mode of operation is either on, power flows, or off, no power. However in the DC house it is possible that at times of low power generation, circuit overload, or if it is running on emergency generation, partial power may be lost to the system. In such a scenario, decisions have to be made as to which appliances should have priority to use the available power.

Within a conventional home system, the homeowner would have to decide on which appliances to give priority and go around the house and physically unplug those that are of low priority. However with smart control of the system this can be done automatically using a hierarchical identifier. Such an identifier puts each appliance in order of criticality to the homeowner which will be represented by a numbering system. For example general category of emergency lighting may be assigned a number 1, loads like the internet/telephony 2, refrigerator/freezer 3, other lighting 4 etc. then within each category there will be subcategories depending on importance.

A grid-connected system allows you to power your home or small business with renewable energy during those periods daily as well as seasonally like when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid.

### **Robotics:**



Robotics is a branch of engineering that involves the conception, design, manufacture and operation of robots. The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways. Robotics can take on a number of forms. A robot may resemble a human, or it may be in the form of a robotic application, such as robotic process automation (RPA), which simulates how humans engage with software to perform repetitive, rules-based tasks.

Robotics is likely to play a role in future health care delivery systems. The work that is done in hospitals by nurses, orderlies, and similar staff personnel includes some tasks that are routine and repetitive. Duties that might be automated using robots include making beds, delivering linens, and moving supplies between locations in the hospital. Robots might even become involved in certain aspects of patient care such as transporting patients to services in the hospital, passing food trays, and similar functions in which it is not critical that a hospital staff member be present. Research is currently under way to develop robots that would be capable of providing assistance to paraplegics and other physically handicapped persons. These robots would respond to voice commands and would be able to interpret statements in natural language (e.g., everyday English) from patients requesting service.

The term *robotics* is an extension of the word *robot*. One of its first uses came from Czech writer Karel Čapek, who used the word in his play, *Rossum's Universal Robots*, in 1920.

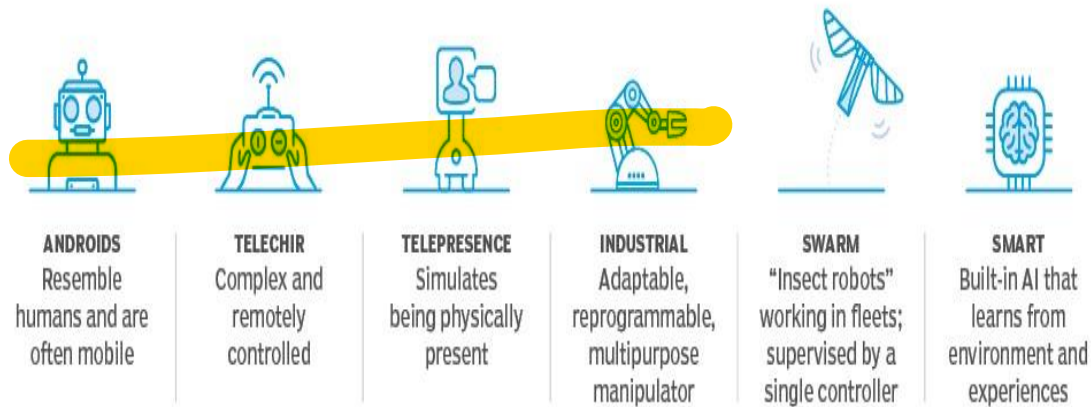
However, it is science fiction author Isaac Asimov who has been given credit for being the first person to use the term in the 1940s by *Oxford English Dictionary*.

In Asimov's story, he suggested three principles to guide the behavior of autonomous robots and smart machines.

Asimov's Three Laws of Robotics have survived to the present:

4. Robots must never harm human beings.
5. Robots must follow instructions from humans without violating rule 1.
6. Robots must protect themselves without violating the other rules.

# Types of robots



It will have three elements, the intelligent appliances, the interactive nodes and the computerized control mechanism which must be able to handle Robotics applications

Today, industrial robots, as well as many other types of robots, are used to perform repetitive tasks. They may take the form of a robotic arm, robotic exoskeleton or traditional humanoid robots.

Industrial robots and robot arms are used by manufacturers and warehouses, such as those owned by Amazon, Devo, Best Buy and more.

To function, a combination of computer programming and algorithms, a remotely controlled manipulator, actuators, control systems -- action, processing and perception -- real-time sensors and an element of automation helps to inform what a robot or robotic system does.

Some additional applications for robotics are the following:

Home electronics

Computer science/computer programming

Artificial intelligence

Data science

Law enforcement/military

Mechanical engineering

Mechatronics

Nanotechnology

Bioengineering/healthcare

Aerospace

### **Machine learning in robotics:**

Machine learning and robotics intersect in a field known as robot learning. Robot learning is the study of techniques that enable a robot to acquire new knowledge or skills through machine learning algorithms.

Some applications that have been explored by robot learning include grasping objects, object categorization and even linguistic interaction with a human peer. Learning can happen through self-exploration or via guidance from a human operator.

To learn, intelligent robots must accumulate facts through human input or sensors. Then, the robot's processing unit will compare the newly acquired data to previously stored information and predict the best course of action based on the data it has acquired.

### **Civil Infrastructure:**

Civil Engineering Infrastructure refers to the basic facilities and systems that help society function, including road construction, rail construction, tunnelling, utilities and other systems excluding the erection of buildings.

The construction industry being labor intensive requires more numbers of skilled labor, good quality of work, and increase in productivity etc. The problems associated with construction work such as decreasing quality of work, labor shortages, and safety of labor and working condition of projects can be overcome by new innovative technologies such as automation which has the potential to improve the quality, safety, and productivity of the construction industry.

The scope of automation in construction is broad, encompassing all the stages of construction life from initial planning and design, through construction of the facility, its operation and maintenance, to the eventual dismantling and recycling of buildings and engineering structures. The recent developments in the fields of computer science and robotics have helped to develop new technologies in the field of construction industry. In Japan which is a leader in robotics and automation have developed many new technologies and machinery which have helped the construction industry to reduce human efforts, construction cost and project time period and increase the productivity.

At times construction work is conducted under dangerous condition and situation, thus there is need for robotics to optimize equipment operation improve safety and quality of work. Automated construction process leads to a continuous working time through the year. For rapid construction with less risk and good quality there should be more and more use of machines as well as equipment in the construction industry. Human efforts and risks are reduced by using machines, robots, etc. at appropriate places.

### **Advantages of automation in construction:**

Automation in construction industry may achieve the following advantages:

- Uniform quality with higher accuracy than that provided by skilled workers.
- Replacing human operators in tasks that involve hard physical or monotonous work.
- Replacing humans in tasks performed in dangerous environments such as those with heights, over a river etc.
- Making tasks that are beyond human capabilities easier.
- Increasing productivity and work efficiency with reduced costs.
- Economic improvement. Automation can serve as the catalyst for improvement in the economies of enterprises or society. For example, the gross national income and standard of living in Germany and Japan improved drastically in the 20th century, due in large part to embracing automation in construction and infrastructural development.
- Improving work environment as conventional manual work is reduced to a minimum, so the workers are relieved from uncomfortable work positions.

### **Areas of automation in Construction**

- Roads & Runways construction
- Structures
- Buildings construction
- Ports
- Tunnels
- Factories and industries

### **Avionics:**

Avionics is a blend of aviation and electronics are the electronic systems used on aircraft, artificial satellites, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions. These can be as simple as a searchlight for a police helicopter or as complicated as the tactical system for an airborne early warning platform.

The term "avionics" was coined in 1949 by Philip J. Klass. The word avionics, derived from the expression "aviation electronics", the development and production of electronic instruments for use in aviation and astronautics. The term also refers to the instruments themselves. Such instruments consist of a wide variety of control, performance, communications, and radio navigation devices and systems.

Control apparatus includes the attitude gyro and any number of instruments that indicate power, such as the tachometer in propeller craft, torquemeter in turboprops, and exhaust pressure ratio indicator in turbojets. Performance instruments include the altimeter, Machmeter, turn and slip indicator, and varied devices that show airspeed, vertical velocity, and angle of attack.

Communications instruments include two-way radios allowing direct voice communication between the aircraft and the ground as well as other aircraft; these operate across a wide spectrum, ranging from high frequency (HF) through very high frequency (VHF) to ultrahigh frequency (UHF). Electronic radio navigation equipment ranges from radar to instrument landing systems.

There has been a progression towards centralized control of the multiple complex systems fitted to aircraft, including engine monitoring and management. Health and usage monitoring systems (HUMS) are integrated with aircraft management computers to give maintainers early warnings of parts that will need replacement. The integrated modular avionics concept proposes an integrated architecture with application software portable across an assembly of common hardware modules. It has been used in fourth generation jet fighters and the latest generation of airliners.

### **Transportation:**

Automation has been applied in various ways in the transportation industries. Applications include airline reservation systems, automatic pilots in aircraft and locomotives, and urban mass-transit systems. The airlines use computerized reservation systems to continuously monitor the status of all flights. With these systems, ticket agents at widely dispersed locations can obtain information about the availability of seats on any flight in a matter of seconds. The reservation systems compare requests for space with the status of each flight, grant space when available, and automatically update the reservation status files. Passengers can even receive their seat assignments well in advance of flight departures.

Nearly all commercial aircraft are equipped with instruments called automatic pilots. Under normal flying conditions, these systems guide an airplane over a predetermined route by detecting changes in the aircraft's orientation and heading from gyroscopes and similar instruments and by providing appropriate control signals to the plane's steering mechanism. Automatic navigation systems and instrument landing systems operate by using radio signals from ground beacons that provide the aircraft with course directions for guidance. When an airplane is within the traffic pattern for ground control, its human pilot normally assumes control.

Examples of automated rail transportation include American urban mass-transit systems such as **BART (Bay Area Rapid Transit) in San Francisco; MARTA (Metropolitan Atlanta Rapid Transit Authority) in Atlanta, Georgia; and the Metrorail in Washington, D.C.** The BART system serves as a useful example; it consists of more than 75 miles (120 kilometres) of track, with about 100 trains operating at peak hours between roughly 30 stations. The trains sometimes attain speeds of 80 miles per hour with intervals between trains of as little as 90 seconds. In each train there is one operator whose role is that of an observer and communicator and who can override the automatic system in case of emergency. The automatic system protects the trains by assuring a safe distance between them and by controlling their speed. Another function

of the system is to control train routings and make adjustments in the operation of each train to keep the entire system operating on schedule.

As a train enters the station, it automatically transmits its identification, destination, and length, thus lighting up a display board for passenger information and transmitting information to the control centres. Signals are automatically returned to the train to regulate its time in the station and its running time to the next station. At the beginning of the day, an ideal schedule is determined; as the day progresses, the performance of each train is compared with the schedule, and adjustments are made to each train's operation as required. The entire system is controlled by two identical computers, so that if one malfunctions, the other assumes complete control. In the event of a complete failure of the computer control system, the system reverts to manual control.