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Approved by AICTE, New Delhi, Affiliated to Anna University, Chennai
Trichy - chennai Trunk Road, Siruganur, Tiruchirappalli - 621 105, India

4.02.2019

SPEAKER : Mr.G.Rajesh Kumar

Assistant Professor

DEPARTMENT OF CSE

STAFF ATTENDED :

1.Ashok HOD/CSE

2. S.Murugavalli.

3..S.Nandhini devi

4. D.Saranya

5.Nayagan

6.Rajesh Kumar

TOPIC : Wireless Sensor Network

VENUE : PETER NORTON LAB,3.00 p.m to 4.30 p.m

**Enclosure : Report,PPT

Ashok 4/2

HOD

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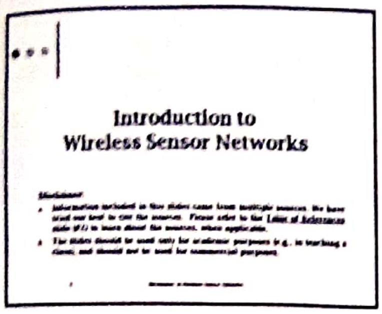
REPORT

The session was initiated by Mr.G.Rajesh Kumar Asst Prof.,where she started describing about the Ambient Intelligence

The Agenda includes the seminar on

- Introduction
- Differences with ad hoc networks
- Applications
- Characteristics
- Challenges
- Future
- Motes
- Hardware Setup Overview

Then the session came to an end with the hand on programming with Wireless Sensor Networks.



Introduction to Wireless Sensor Networks

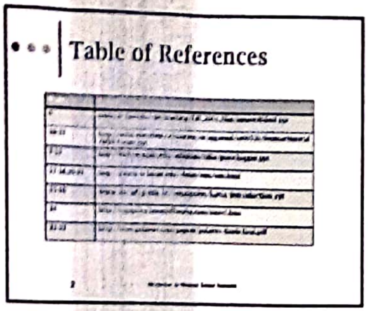
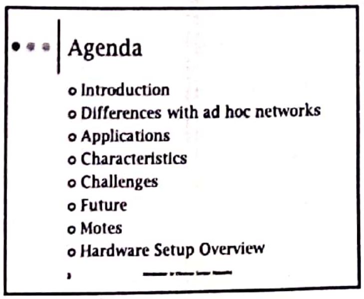
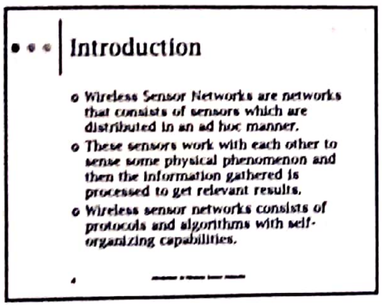


Table of References



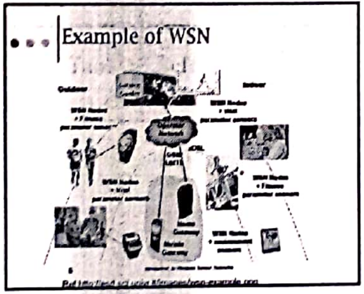
Agenda

- o Introduction
- o Differences with ad hoc networks
- o Applications
- o Characteristics
- o Challenges
- o Future
- o Motes
- o Hardware Setup Overview

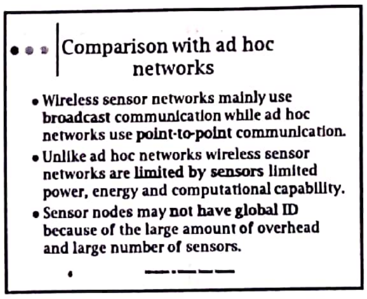


Introduction

- o Wireless Sensor Networks are networks that consists of sensors which are distributed in an ad hoc manner.
- o These sensors work with each other to sense some physical phenomenon and then the information gathered is processed to get relevant results.
- o Wireless sensor networks consists of protocols and algorithms with self-organizing capabilities.

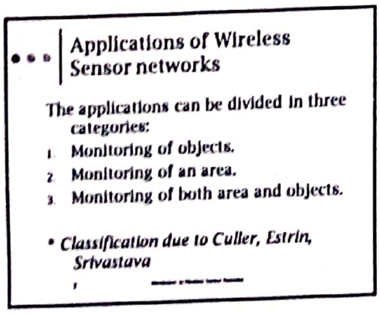


Example of WSN



Comparison with ad hoc networks

- Wireless sensor networks mainly use broadcast communication while ad hoc networks use point-to-point communication.
- Unlike ad hoc networks wireless sensor networks are limited by sensors limited power, energy and computational capability.
- Sensor nodes may not have global ID because of the large amount of overhead and large number of sensors.

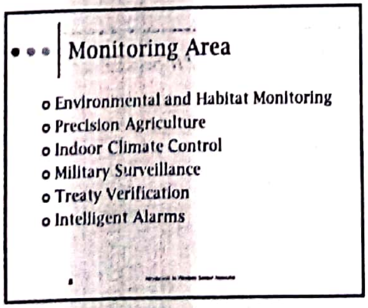


Applications of Wireless Sensor networks

The applications can be divided in three categories:

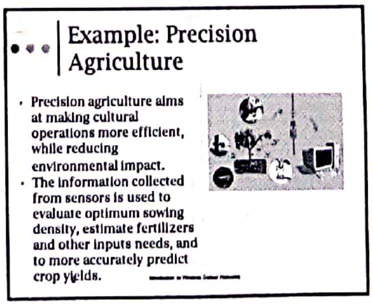
1. Monitoring of objects.
2. Monitoring of an area.
3. Monitoring of both area and objects.

- *Classification due to Culler, Estrin, Srivastava*



Monitoring Area

- o Environmental and Habitat Monitoring
- o Precision Agriculture
- o Indoor Climate Control
- o Military Surveillance
- o Treaty Verification
- o Intelligent Alarms



Example: Precision Agriculture

- Precision agriculture aims at making cultural operations more efficient, while reducing environmental impact.
- The information collected from sensors is used to evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.

Monitoring Objects

- Structural Monitoring
- Eco-physiology
- Condition based Maintenance
- Medical Diagnostics
- Urban terrain mapping

Example: Condition based Maintenance

- Intel fabrication plants
  - Sensors collect vibration data, monitor wear and tear; report data in real time
  - Reduces need for a team of engineers, cutting costs by several orders of magnitude

Monitoring Interactions between Objects and Space

- Wildlife Habitats
- Disaster Management
- Emergency Response
- Ubiquitous Computing
- Asset Tracking
- Health Care
- Manufacturing Process Flows

Example: Habitat Monitoring

- The ZebraNet Project
  - Collar-mounted sensors monitor zebra movement in Kenya

Source: Margaret Martonosi, Princeton University

Characteristics of Wireless Sensor Networks

- Wireless Sensor Networks mainly consists of sensors. Sensors are -
  - low power
  - limited memory
  - energy constrained due to their small size.
- Wireless networks can also be deployed in extreme environmental conditions and may be prone to enemy attacks.
- Although deployed in an ad hoc manner they need to be self organized and self healing and can face constant reconfiguration.

Design Challenges

- Heterogeneity
  - The devices deployed maybe of various types and need to collaborate with each other.
- Distributed Processing
  - The algorithms need to be centralized as the processing is carried out on different nodes.
- Low Bandwidth Communication
  - The data should be transferred efficiently between sensors

Continued..

- Large Scale Coordination
  - The sensors need to coordinate with each other to produce required results.
- Utilization of Sensors
  - The sensors should be utilized in a ways that produce the maximum performance and use less energy.
- Real Time Computation
  - The computation should be done quickly as new data is always being generated.

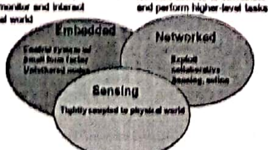
Operational Challenges of Wireless Sensor Networks

- Energy Efficiency
- Limited storage and computation
- Low bandwidth and high error rates
- Errors are common
  - Wireless communication
  - Noisy measurements
  - Node failure are expected
- Scalability to a large number of sensor nodes
- Survivability in harsh environments
- Experiments are time- and space-intensive

Enabling Technologies

Embed numerous distributed devices to monitor and interact with physical world

Network devices to coordinate and perform higher-level tasks



Exploit spatially and temporally dense, in situ, sensing and actuation

FILE NO: 5

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Date:02.02.2019

SPEAKER : Mrs.S.Nandhini Devi
Assistant Professor
DEPARTMENT OF CSE

STAFF ATTENDED :

1.Ashok HOD/CSE

2. S.Murugavalli.

3..S.Nandhini devi

4. D.Saranya

5.Nayagan

6.Rajesh Kumar

TOPIC : Ambient Intelligence

VENUE : PETER NORTON LAB,3.00 p.m to 4.30 p.m

****Enclosure :** Report,PPT

Ashok.T
02/02/

HOD

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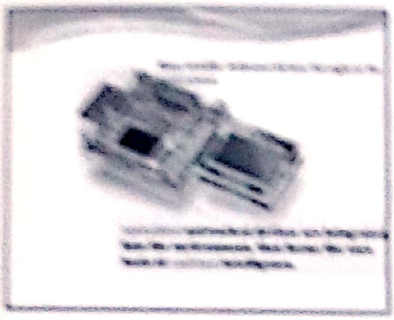
REPORT

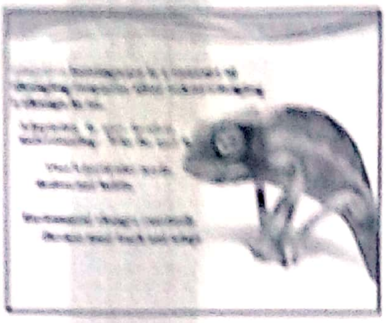
The session was initiated by Mrs.S.Nandhini Devi Asst Prof.,where she started describing about the Ambient Intelligence

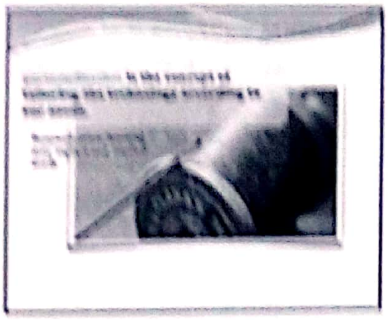
The Agenda includes the seminar on

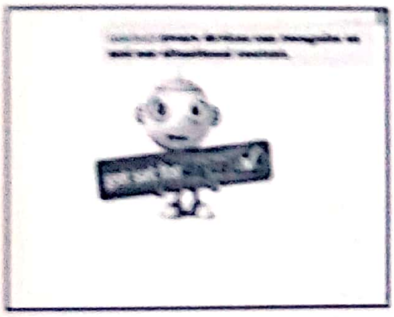
- Sensing
- Human Computer Interaction
- **Technologies Used in AmI**
- **Radio Frequency Identification**
- **Microchip implant**
- Security Risks
- Applications

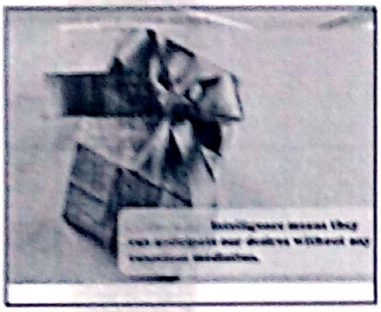
Then the session came to an end with the hand on programming with Wireless Sensor Networks.





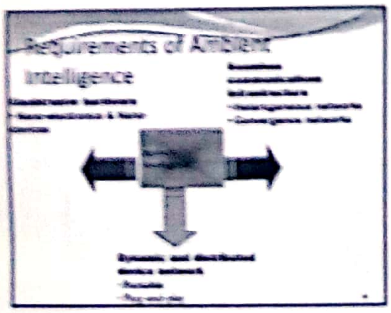




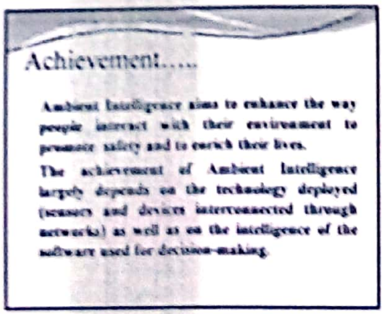


In SHORT

"…..is a vision of our future with disappearing hardware



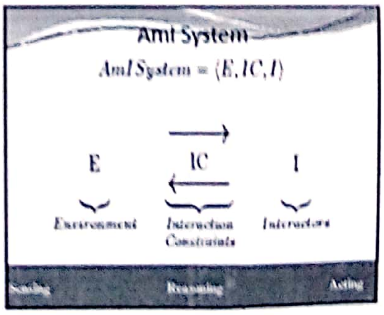
Requirements of Ambient Intelligence



Achievement…..

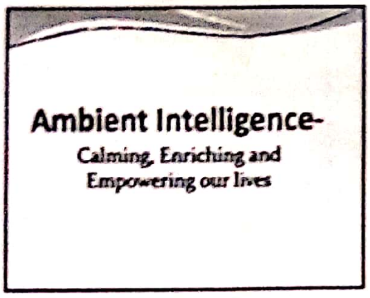
Ambient Intelligence aims to enhance the way people interact with their environment to promote safety and to enrich their lives.

The achievement of Ambient Intelligence largely depends on the technology deployed (sensors and devices interconnected through networks) as well as on the intelligence of the software used for decision-making.



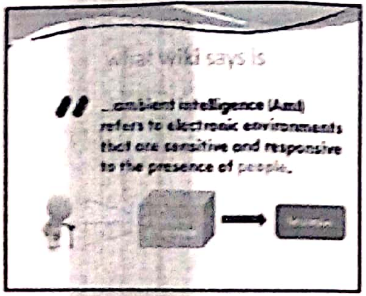
AmI System

$$AmI\,System = (E, IC, I)$$



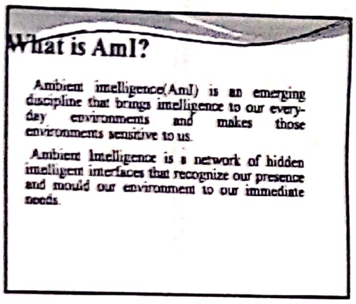
Ambient Intelligence-

Calming, Enriching and
Empowering our lives



What wiki says is

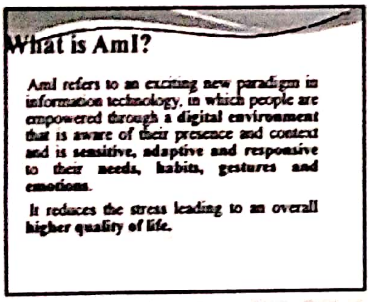
"…ambient intelligence (AmI) refers to electronic environments that are sensitive and responsive to the presence of people.



What is AmI?

Ambient intelligence(AmI) is an emerging discipline that brings intelligence to our every-day environments and makes those environments sensitive to us.

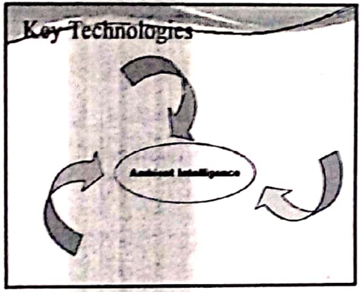
Ambient Intelligence is a network of hidden intelligent interfaces that recognize our presence and mould our environment to our immediate needs.



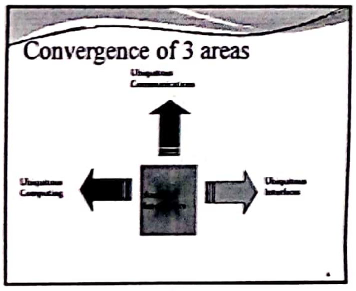
What is AmI?

AmI refers to an exciting new paradigm in information technology, in which people are empowered through **a digital environment** that is aware of their presence and context and is **sensitive, adaptive and responsive** to their **needs, habits, gestures and emotions.**

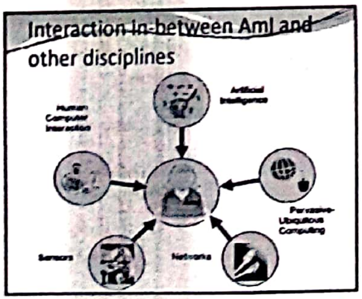
It reduces the stress leading to an overall **higher quality of life.**



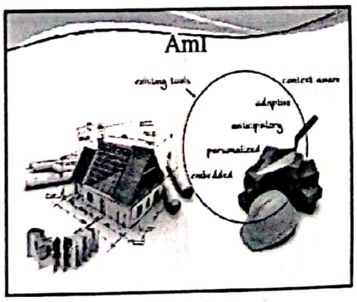
Key Technologies



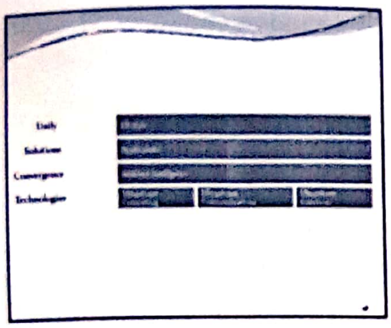
Convergence of 3 areas



Interaction In-between AmI and other disciplines



AmI



Drawbacks

- Need high finance to install and to maintain the environment.
- Technology is to be incorporated into the daily routines of different class of people.
- Makes people lazy.

Security Risks

- AmI technologies can raise other security issues. At the sensor level, sensor reliability, handling errors, and installation errors can create security risks.

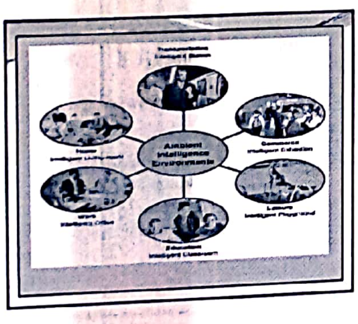
Absolutely critical for market acceptance.

Applications

- Health-related applications
- Public transportation sector
- Education services
- Emergency services
- Production-oriented services

Biggest adopters of AmI:

  - Healthcare
  - Home automation



AmI APPLICATIONS

- Health-related applications: Hospitals can increase the efficiency of their services by monitoring patients' health and progress by performing automatic analysis of activities in their rooms. (Sensing and monitoring)

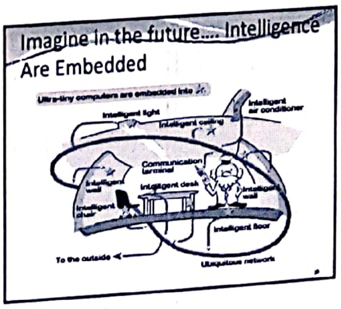
AmI APPLICATIONS

- Emergency services: Safety-related services like fire brigades can improve the reaction to a hazard by locating the place more efficiently and also by preparing the way to reach the place in connection with street services.

AmI APPLICATIONS

- Production-oriented places: Companies can use RFID sensors to tag different products and track them along the production and commercialization processes.
- It helps improving the process by providing valuable information for the company on how to react to favourable demand and unusual events like products that become unsuitable for sale.

Imagine in the future.... Intelligence Are Embedded

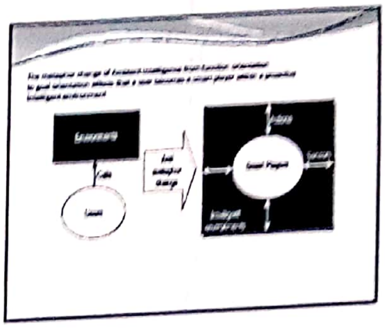


Sensing

- **Perception** is accomplished using variety of sensors
- **Software algorithm** perceives the environment and specifies the action that can be taken to change the state of the environment
- Sensors have been designed for **position measurement, for detection of chemicals and humidity sensing, and to determine readings for light, radiation, temperature, sound, strain, pressure, position, velocity, and direction, and physiological sensing to support health monitoring.**

Human Computer Interaction

- Explicit input must now be replaced with more human-life communication capabilities and with implicit actions
- Technologies : motion tracking, gesture recognition, facial expression recognition and emotion recognition, speech processing, and even whistle processing facilitate natural interactions with intelligent environments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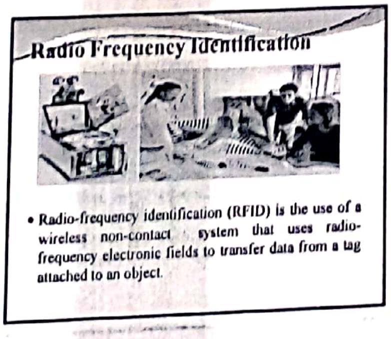
Technologies Used in AmI

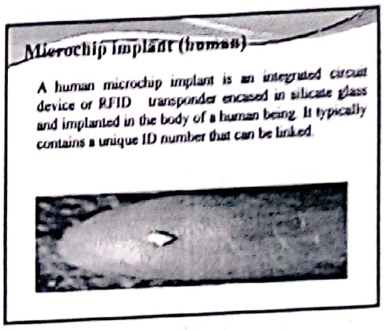
- Radio Frequency Identification
- Microchip implant (human)
- Sensor
- Affective Computing
- Nanotechnology
- Biometrics

Radio Frequency Identification



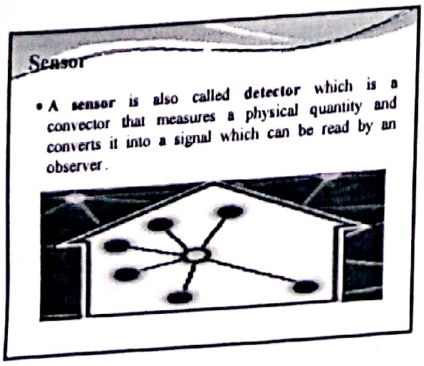
- Radio-frequency identification (RFID) is the use of a wireless non-contact system that uses radio-frequency electronic fields to transfer data from a tag attached to an object.

Microchip implant (human)



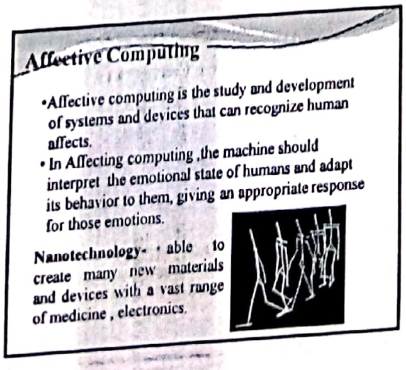
A human microchip implant is an integrated circuit device or RFID transponder encased in silicate glass and implanted in the body of a human being. It typically contains a unique ID number that can be linked.

Sensor



- A **sensor** is also called **detector** which is a convector that measures a physical quantity and converts it into a signal which can be read by an observer.

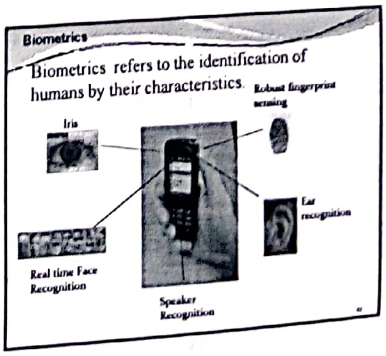
Affective Computing



- Affective computing is the study and development of systems and devices that can recognize human affects.
- In Affecting computing ,the machine should interpret the emotional state of humans and adapt its behavior to them, giving an appropriate response for those emotions.

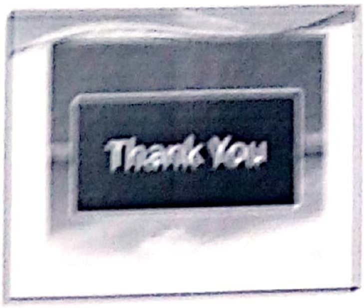
Nanotechnology- able to create many new materials and devices with a vast range of medicine , electronics.

Biometrics



Biometrics refers to the identification of humans by their characteristics.

And in Your Smart Phone......



Thank You

MAM SCHOOL OF ENGINEERING

Siruganur, Tiruchirappalli – 621 105.

Department of Mechatronics Engineering

Academic year (2018-2019) Odd semester

Date: 21th September 2018

Speaker: Mr.S.Ravichandran

Associate Professor, Mechanical Department.

Staff attended:

1. Mr.S.ManiamRamasamy
2. Mr.K.Parthiban
3. Mr.V.Jothivel
4. Mr.S.Vidhyasagar
5. Mr.K.N.Prabhahar

Topic:

Utilization of Modern Automatic Methods for increasing the Productivity.

Venue:

Smart class

Date & Time:

21th September 2018 & 1.30 P.M to 2.30 P.M

**enclosure: Report

22/9/18

HOD **PRINCIPAL**

REPORT

The session was initiated by Mr.S.Ravichandran ASP/MECH, the topic for the seminar is Utilization of Modern Automatic Methods to Increase the Productivity and discuss about the following topics

- Introduction About the traditional automatics systems
- Drawbacks of old automatic systems
- Types of modern automatic method
- Advantages over the old method
- Limitation of modern methods

The session comes to an end with the explaining the overview of Automatic System.

MAM SCHOOL OF ENGINEERING

Siruganur, Tiruchirappalli – 621 105.

Department of Mechatronics Engineering

Academic year (2018-2019) Odd semester

Date: 18th September 2018

Speaker: Mrs.K.Priya

Head of the Department, Mechatronics Department.

Staff attended:

1. Mrs. P. Sudha
2. Mr. M. Chandrasekar
3. Ms. K. Umarani
4. Ms.V. Durgadevi
5. Mr. K. Karthikeyan
6. Mr. Mahalingam

Topic:

Simplification of 5 Variable Boolean Function using Karnaugh Map Technique.

Venue:

Smart class

Date & Time:

18th September 2018 & 1.30 P.M to 2.30 P.M

**enclosure: Report

HOD

PRINCIPAL

REPORT

The session was initiated by Mrs.K.Priya, HoD/MECHT, the topic for the seminar is Karnaugh Map Simplification and discuss about the following topics

- Introduction to Karnaugh Map Simplification
- 2, 3, 4, 5, 6 variable K-Map
- Simplification of SOP and POS Boolean equations using K-Map
- Example problems
- Limitation of K-Map

The session comes to an end with the explaining the overview of Karnaugh Map.

M.A.M SCHOOL OF ENGINEERING

Siruganur, Tiruchirappalli – 621 105.

Department of Mechatronics Engineering

Academic year (2018-2019) even semester

Date: 14th March 2019

Speaker: Mrs. J. DEEPIKA

Assistant Professor, Mechatronics Department.

Staff attended:

1. Mr. M. Chandrasekar
2. Mr. K.Karthikeyan
3. Mr. Parthiban
4. Mr. S. Ravichandran
5. Mrs. K. Umarani

Topic:

ADC (Analog to Digital converter) and its types
DAC(Digital to Analog converter) and its types .

Venue:

Room no :205

Date & Time:

14th March 2019 & 1.30 P.M to 2.30 P.M

**enclosure: Report

14/3/19.

HOD

PRINCIPAL

Scanned by CamScanner

REPORT

The session was initiated by Mrs. J. DEEPIKA, Assistant Professor, Mechatronics Department,the topic for the seminar is to discuss about the ADC (Analog to Digital converter) and its types and DAC(Digital to Analog converter) and its types .

- Introduction to ADC and DAC
- Analog to Digital converter types:
- Successive Approximation technique
- Flash adc
- Digital to Analog converter types:
- Weighted resistor D/A Converter
- R-2R Ladder D/A Converter

DIGITAL TO ANALOG CONVERTER(DAC)

The process of converting digital signal into equivalent analog signal is called D/A conversion. The electronics circuit, which does this process, is called D/A converter. The circuit has „n' number of digital data inputs with only one output. Basically, there are two types of D/A converter circuits: Weighted resistors D/A converter circuit and Binary ladder or R–2R ladder D/A converter circuit.

1 Weighted resistors D/A converter

Here an OPAMP is used as summing amplifier. There are four resistors R, 2R, 4R and 8R at the input terminals of the OPAMP with R as feedback resistor. The network of resistors at the input terminal of OPAMP is called as variable resistor network. The four inputs of the circuit are D, C, B & A. Input D is at MSB and A is at LSB. Here we shall connect 8V DC voltage as logic–1 level. So we shall assume that 0 = 0V and 1 = 8V.

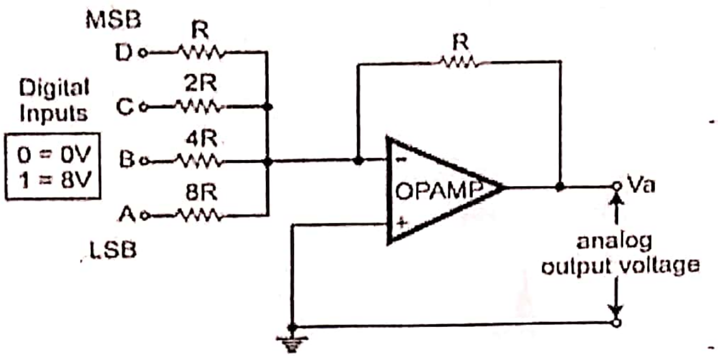


Figure: Weighted resistors D/A converter

Now the working of the circuit is as follows. Since the circuit is summing amplifier, its output is given by the following equation

$$v_0 = R\left(\frac{D}{R}+\frac{C}{2R}+\frac{B}{4R}+\frac{A}{8R}\right)$$

Working of the circuit

When input DCBA = 0000, then putting these value in above equation (1) we get

$$v_0 = R\left(\frac{0}{R}+\frac{0}{2R}+\frac{0}{4R}+\frac{0}{8R}\right) = 0V$$

When digital input of the circuit DCBA = 0001, then putting these value in above equation (1) we get

$$v_0 = R\left(\frac{0}{R}+\frac{0}{2R}+\frac{0}{4R}+\frac{0}{8R}\right) = 0V$$

When digital input of the circuit DCBA = 0010, then putting these value in above equation (1) we get

$$v_0 = R\left(\frac{0}{R}+\frac{0}{2R}+\frac{8V}{4R}+\frac{0}{8R}\right) = -R\frac{8V}{4R} = -2V$$

.... so on.

In this way, when digital input changes from 0000 to 1111 (in BCD style), output voltage (Vo) changes proportionally. This is given in the conversion chart. There are some main disadvantages of the circuit.

They are

1) Each resistor in the circuit has different value.
2) So error in value of each resistor adds up.

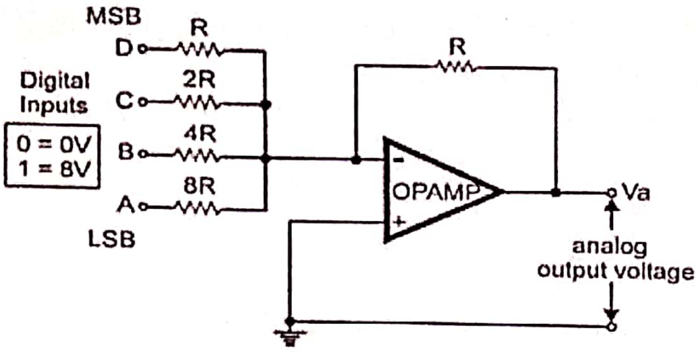


Figure: Weighted resistors D/A converter

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Working of the circuit

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$$v_0 = R\left(\frac{0}{R}+\frac{0}{2R}+\frac{8V}{4R}+\frac{0}{8R}\right) = -R\frac{8V}{4R} = -2V$$

…………… so on.

In this way, when digital input changes from 0000 to 1111 (in BCD style), output voltage (Vo) changes proportionally. This is given in the conversion chart. There are some main disadvantages of the circuit.

They are

1) Each resistor in the circuit has different value.
2) So error in value of each resistor adds up.

3) The value of resistor at MSB is the lowest. Hence, it draws more current.
4) Also, its heat & power dissipation is very high.
5) There is the problem of impedance matching due to different values of resistors.

2 R–2R Ladder D/A Converter

It is modern type of resistor network. It has only two values of resistors the R and 2R. These values repeat throughout in the circuit. The OPAMP is used at output for scaling the output voltage. The working of the circuit can be understood as follows. For simplicity, we ignore the OPAMP in the above circuit (this is because its gain is unity). Now consider the circuit, without OPAMP. Suppose the digital input is DCBA = 1000. Then the circuit is reduced to a small circuit.

$$output = \left(\frac{2R}{2R + 2R}\right) \times (+V) = \frac{V}{2}$$

Its output is given by –

Reduced circuit of R-2R ladder, when we consider that all inputs=0

Now suppose digital input of the same circuit is changed to DCBA = 0100. Then the output voltage will be V/4, when DCBA = 0010, output voltage will be V/8, for DCBA = 0001, output voltage will be V/16 and so on. The general formula for the above circuit of R–2R ladder, including the OPAMP also, will be –

$$v_0 = -R\left(\frac{D}{2R} + \frac{C}{4R} + \frac{B}{8R} + \frac{A}{16R}\right)$$

You can take (R) common from the above formula and simplify it. With the help of this formula, we can calculate any combination of digital input into its equivalent analog voltage at the output terminals.

ANALOG TO DIGITAL CONVERSION

A comparator compares the unknown voltage with a known value of voltage and then produces proportional output (i.e. it will produce either a 1 or a 0). This principle is basically used in the above circuit. Here three comparators are used. Each has two inputs. One input of each comparator is connected to analog input voltage. The other input terminals are connected to fixed reference voltage like +3/4V, +V/2 and +V/4. Now the circuit can convert analog voltage into equivalent digital signal. Since the analog output voltage is connected in parallel to all the comparators, the circuit is also called as parallel A/D converter.

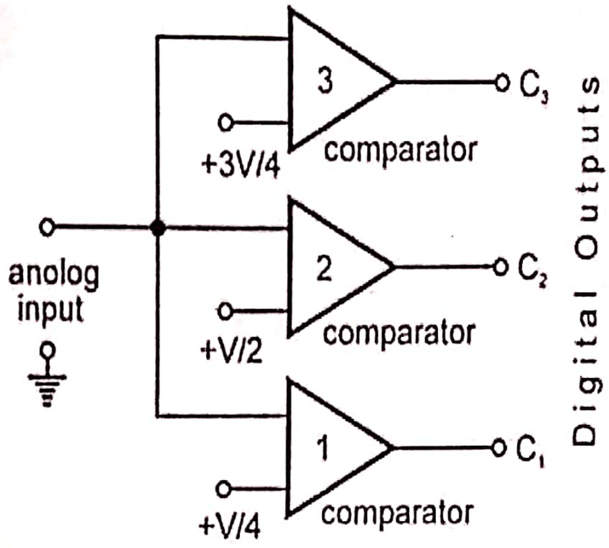


Figure: ADC Conversion

Working – Here each comparator is connected to a reference voltage of +3/4V, +V/2 and +V/4 with their outputs as $C_3C_2C_1$ respectively. Now suppose the analog input voltage change from 0 – 4V, then the actual values of reference voltages will be +3/4V = 3V, +V/2 =2V and +V/4 =1V. Now there will be following conditions of outputs of the circuit

1) When input voltage is between 0 and 1V, the output will be $C_3C_2C_1$ = 000.

2) When input voltage > 1V £ 2V, the output will be $C_3C_2C_1$ = 001.
3) When input voltage > 2V £ 3V, the output will be $C_3C_2C_1$ = 011.
4) When input voltage > 3V £ 4V, the output will be $C_3C_2C_1$ = 111.

In this way, the circuit can convert the analog input voltage into its equivalent or proportional binary number in digital style.

1. Successive Approximation Technique

The basic drawback of counter method (given above) is that it has longer conversion time. Because it always starts from 0000 at every measurement, until the analog voltage is matched. This drawback is removed in successive approximation method. In the adjacent figure, the method of successive approximation technique is shown. When unknown voltage (V_a) is applied, the circuit starts up from 0000, as shown above. The output of SAR advances with each MSB. The output of SAR does not increase step–by–step in BCD bus pattern, but individual bit becomes high–starting from MSB. Then by comparison, the bit is fixed or removed. Thus, it sets first MSB (1000), then the second MSB (0100) and so on. Every time, the output of SAR is converted to equivalent analog voltage by binary ladder. It is then compared with applied unknown voltage (V_a). The comparison process goes on, in binary search style, until the binary equivalent of analog voltage is obtained. In this way following steps are carried out during conversion.

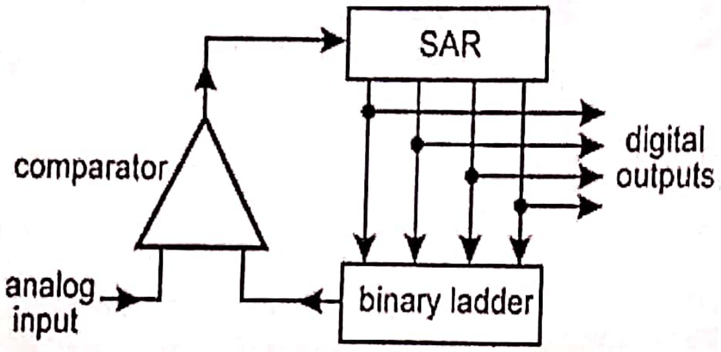


Figure: Successive Approximation Technique

Figure: Successive Approximation Technique

Now refer the following figure and the given steps -

1) The unknown analog voltage (V_a) is applied.
2) Starts up from 0000 and sets up first MSB 1000.
3) If V_a >= 1000, the first MSB is fixed.
4) If V_a < 1000, the first MSB is removed and second MSB is set
5) The fixing and removing the MSBs continues up to last bit (LSB), until equivalent binary output is obtained.

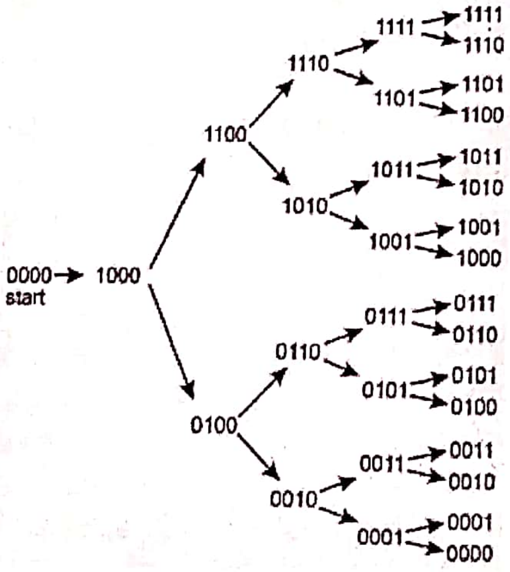


Figure 3.38 Equivalent Binary Output

Figure 3.38 Equivalent Binary Output

2 Flash ADC

Also called the parallel A/D converter, this circuit is the simplest to understand. It is formed of a series of comparators, each one comparing the input signal to a unique reference voltage. The comparator outputs connect to the inputs of a priority encoder circuit, which then produces a binary output.

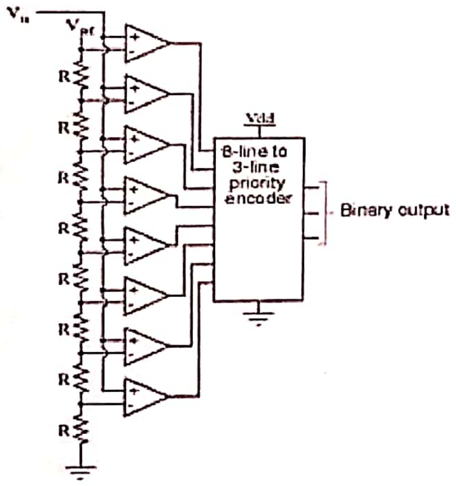


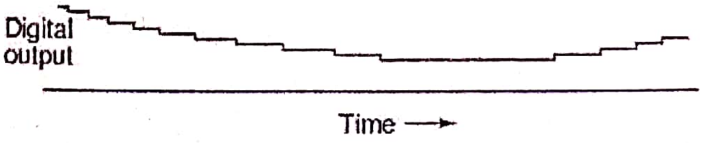
Figure: Flash ADC

Figure: Flash ADC
The following illustration shows a 3-bit flash ADC circuit:

V_{ref} is a stable reference voltage provided by a precision voltage regulator as part of the converter circuit, not shown in the schematic. As the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state. The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

When operated, the flash ADC produces an output that looks something like

igure: Outputs



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12.01.2019

Teacher Teach Teachers

Academic year (2018-19) Even sem

Speaker:Mrs.M.Dharani Devi

Associate Professor/EEE

Department of EEE

Staff Attended:

1. Mr.A.Senthamarai kannan Asso.Prof/EEE
2. Mr.K.Prasad AP/EEE
3. Mr. M.Ranjith kumar AP/EEE
4. Mr. G.Purushothaman AP/EEE
5. Ms.K.Vinothini AP/EEE

Topic:

Renewable Energy

Venue:

Circuits Lab

Report encl:

M. Dharani 12/1

HOD/EEE

PRINCIPAL

Renewable Energy Sources

Renewable Energy Sources

- Lecture Question
  - What are the renewable energy sources? Make a list, as comprehensive as possible.
  - What are the environmental impacts of these energy sources?

  - Renewable Energy Sources
    - Radiant solar energy
      - Solar heating (passive and active), solar power plants, photovoltaic cells
    - Biomass energy
      - Direct: combustion of biomass
      - Indirect: chemical conversion to biofuel
    - Wind energy
    - Hydro energy
    - Geothermal energy
      - Power plants, direct use, heat pumps
    - Ocean energy
      - Tidal; salinity-driven

Hydro Energy

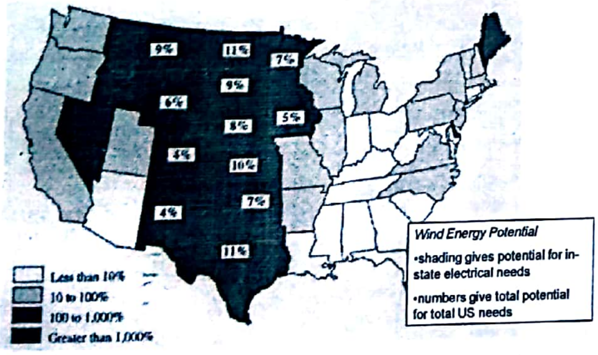
- Advantages
  - Cheap to operate
    - Long life and lower operating costs than all other power plants
  - Renewable
  - High yield
    - Lower energy cost than any other method
  - Pretty plentiful
    - Some countries depend almost entirely on it
  - Not intermittent (if reservoir is large enough)
  - Reservoirs have multiple uses
    - Flood control, drinking water, aquaculture, recreation
  - Less air pollution than fossil fuel combustion

Hydro Energy

- Disadvantages:
  - Human population displacement
  - More significant breeding ground for disease
  - Reduces availability of water downstream
  - Ecosystem impacts
    - Barriers to migrating fish
    - Loss of biodiversity both upstream and downstream
    - Coastal erosion
    - Reduces nutrient flow (dissolved and particulate)
  - Water pollution problems
    - Low dissolved oxygen (DO)
    - Increased H_2S toxicity; other DO-related problems
    - Siltation a big problem (also shortens dam life)
  - Air pollution
    - Actually may be a significant source of GHGs (CH_4, N_2O, CO_2)
  - Decommissioning is a big problem
- The Size Issue
  - Many (most) of the above problems are significantly worse for larger dams
  - However, small dams have shorter lifetimes, less capacity, and are more intermittent

Wind Energy

- How it works
  - Wind turbines directly generate electricity
  - Quite efficient (not a heat engine)



Wind Energy Potential

- shading gives potential for in-state electrical needs
- numbers give total potential for total US needs

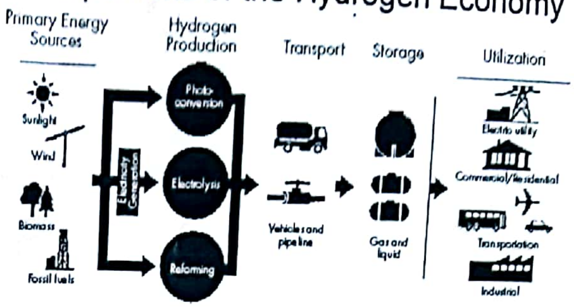
Wind Energy

- Advantages
  - High net energy yield
  - Renewable and free
  - Very clean source of energy
    - No pollution (air or water) during operation
  - Long operating life
  - Low operating/maintenance costs
  - Can be quickly built; not too expensive
  - Now almost competitive with hydro and fossil fuels
  - Land can be used for other purposes
    - Can combine wind and agricultural farms

The Hydrogen Economy

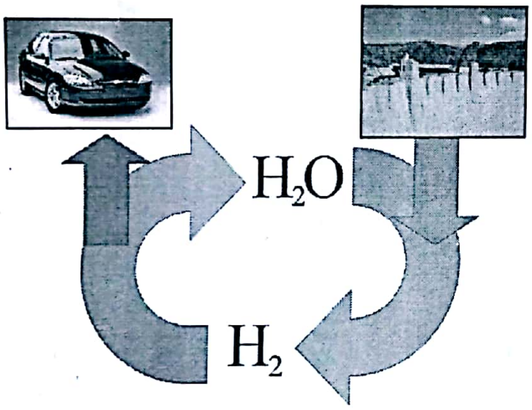
- *Lecture Questions*
  - What is the hydrogen economy?
  - Explain how the hydrogen economy could potentially serve as the basis for a renewable energy system that emits little or no air pollution
- Definition
  - *The Hydrogen Economy* is a hypothetical large-scale system in which elemental hydrogen (H_2) is the primary form of energy storage
    - Fuel cells would be the primary method of conversion of hydrogen to electrical energy.
      - Efficient and clean; scalable
    - In particular, hydrogen (usually) plays a central role in transportation.
- Potential Advantages
  - Clean, renewable
  - Potentially more reliable (using distributed generation)
- BUT many roadblocks *including potential showstoppers*
  - Poses great technological challenges for efficient hydrogen production, storage, and transport

Components of the Hydrogen Economy



- Infrastructure needs
  - Production
  - Storage
  - Delivery
  - End use

Hydrogen as a Transportation Fuel



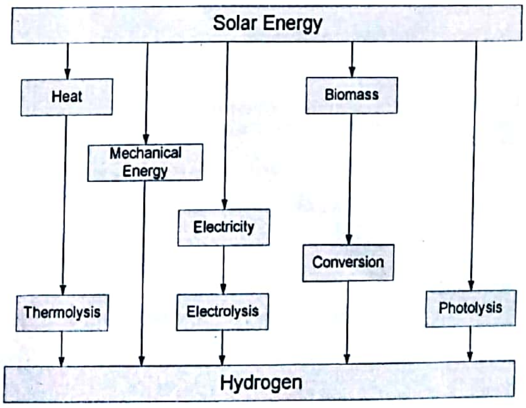
Hydrogen Production

- Fossil Fuels
  - Steam Reforming of Natural Gas
    - Combination of methane and steam produces hydrogen gas
      - Carbon monoxide is also produced
      - The "water gas shift" reaction can produce further hydrogen from the carbon monoxide. *Carbon dioxide is produced too.*
    - Most economical; main current method
      - Carbon sequestration one method to reduce CO_2 emission
  - Partial Oxidation (POX) of Hydrocarbons
    - HC partially oxidized to produce hydrogen and carbon monoxide
  - Coal Gasification
    - Gasified at high temps, then processed
    - Can also be used to get hydrogen from biomass

Hydrogen Production

- Electrolysis
  - Efficiencies 70-85%
  - Produces highest purity of hydrogen
  - Currently, the electricity consumed is usually worth more than the hydrogen produced
- Experimental methods
  - Biological hydrogen production
  - Direct photolysis
  - Thermolysis

Renewable Solar Paths to Hydrogen



Solar Energy

Heat

Mechanical Energy

Electricity

Biomass

Conversion

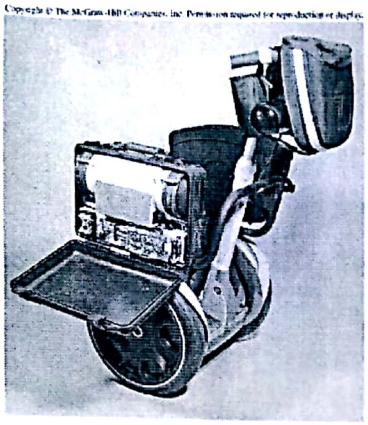
Thermolysis

Electrolysis

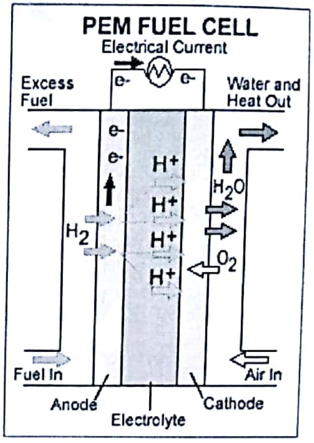
Photolysis

Hydrogen

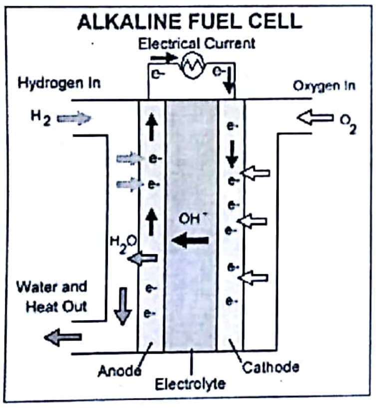
Hydrogen Fuel Cells: Scalable



Polymer Electrolyte Fuel Cell



Alkaline Fuel Cell (AFC)



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08.02.2019

Teacher Teach Teachers

Academic year (2018-19) Even sem

Speaker: **Mr. M.Ranjith kumar AP/EEE**
Department of EEE

Staff Attended:

1. Mr.A.Senthamarai kannan Asso.Prof/EEE
2. Mr.K.Prasad AP/EEE
3. Mr. G.Purushothaman AP/EEE
4. Ms.K.Vinothini AP/EEE

Topic:
Load Flow Studies in Power System

Venue:
Circuits Lab

Report encl:

M. Dharani 8/2
HOD/EEE

PRINCIPAL

Power (or) Load Flow Analysis

- Importance of load flow analysis
- Bus classification
- Load flow equation in complex & polar variable form
- Load flow methods (or) solution for load flow problems

Importance of load flow analysis

➢Load flow analysis is the backbone of PSA.

➢It is required for Planning, Operation, Economic Scheduling & Exchange of power b/w utilities . Expansion of system & also in design stage.

➢Steady-state analysis, of an interconnected PS during normal operating conditions.

Contd...

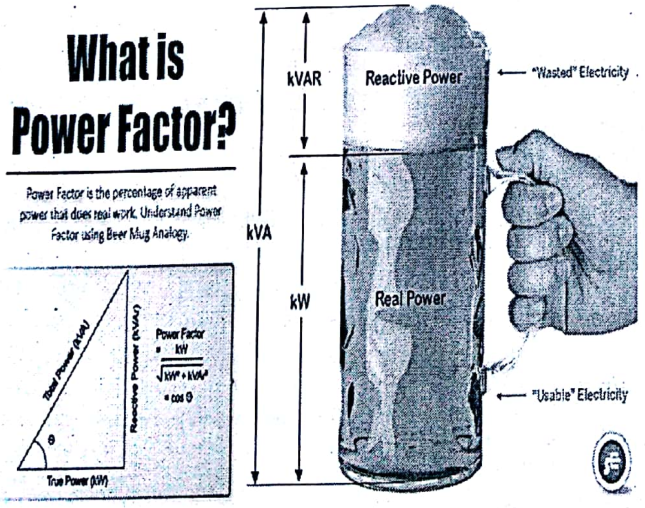
Purpose of LFA

❖Compute steady-state voltage & voltage angle b/w all buses in n/w.

❖Real & Reactive power flow in every Tr. line and transformers under the assumption of known values of generation & load.

Bus Classification

- A bus is a node at which many Transmission lines, Loads Generators are connected.
- It is not necessary that all of them be connected to every bus.
- Bus is indicated by vertical line at which no. of components are connected.
- In load flow study two out of four quantities specified and other two quantities are to be determined by load flow equation.
- Depending upon that bus are classified.



What is Power Factor?

Power Factor is the percentage of apparent power that does real work. Understand Power Factor using Beer Mug Analogy.

Static method

- The following variables are associated with each bus:
- Magnitude of voltage(V)
- Phase angle of voltage(δ)
- Active power(P)
- Reactive power(Q)
- The load flow problem can solved with the help of load flow equation(Static load flow equation).

Contd...

Check for Q limit violation.

If $Q_{i(min)} < Q_{Gi} < Q_{i(max)}$, then $Q_{i(spec)} = Q_i^{cal}$

If $Q_{i(min)} < Q_{Gi}$, then $Q_{i(spec)} = Q_{i(min)} - Q_{Li}$

If $Q_{i(max)} < Q_{Gi}$, then $Q_{i(spec)} = Q_{i(max)} - Q_{Li}$

If Q_{limit} is violated, then treat this bus as P-Q bus till convergence is obtained

8. Compute Vi using the equation,

$$V_i^{new} = \frac{1}{Y_{ij}}\left[\frac{P_{i(spec)} - Q_{i(spec)}}{V_i^{old*}} - \sum_{i=1}^{j-1} Y_{ij} V_j^{new} - \sum_{i=j+1}^{n} Y_{ij} V_i^{old}\right]$$

9. If 'i' is less than number of buses, increment i by 1 and go to step 6.

Contd...

10. Compare two successive iteration values for Vi

If $V_i^{new} - V_i^{old} <$ tolerance, go to step 12

11. Update new voltages as

$$V_i^{new} = V_i^{old} + \alpha\,(V_i^{new} - V_i^{old})$$

$$V_i^{old} = V_i^{new}$$

12. Compute relevant quantities

Slack bus power, $S_1 = P_i - j\,Q_i = V^*I = V_i^* \left[\sum_{j=1}^{N} Y_{ij} V_j\right]$

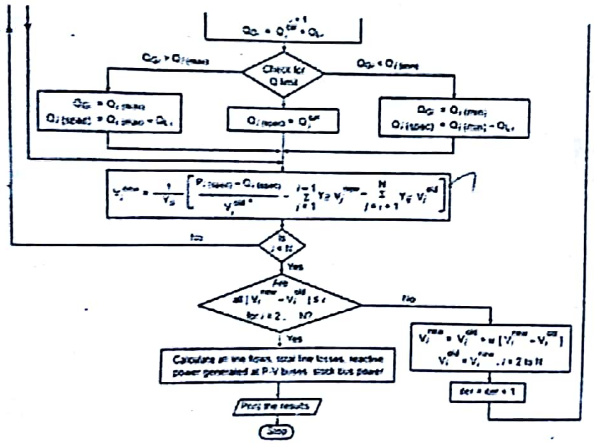
Line flow, $S_{ij} = P_{ij} + Q_{ij}$

$$= V_i\,[V_i^* - V_j^*]\,Y_{ij\,serie}^* + |V_i|^2\, Y_{ij}^*$$

$$P_{Loss} = P_{ij} + P_{ji}$$

$$Q_{Loss} = Q_{ij} + Q_{ji}$$

13. Stop the execution.



❖ **Advantage of Gauss Seidel Method**

i. Calculation are simple.
ii. Programming task is lesser.
iii. Used for small size system.

❖ **Disadvantage of Gauss Seidel Method**

i. Not suitable for larger systems
ii. Required more no.of. iterations to reach convergence.
iii. Convergence time increases with size of the system.

Newton-Raphson Algorithm

1. Form Y-bus matrix
2. Assume flat start for starting voltage solution

$\delta i^0 = 0$, for i=1,2,…N for all buses except slack bus

$|Vi^0| = 1.0$, for i=M+1,M+2,….N (for all PQ bus.

$|Vi| = |Vi|$ (Spec), for all PV buses and Slack bus.

3. For load bus, calculate Pi^{cal} and Qi^{cal}
4. For PV buses, check Q-limit violation.

If $Qi_{(min)} < Qi^{cal} < Qi_{(max)}$, the bus acts as P-V bus.

If $Qi^{cal} > Qi(max)$, $Qi(spec)=Qi(min)$

If $Qi^{cal} < Q_{i(min)}$, $Q_{i(spec)} = Q_{i(min)}$, the P-V bus will act as P-Q bus.

5. Compute mismatch vector using,

$$\Delta Pi = P_{i(spec)} - P_i^{cal}$$

$$\Delta Q_i = Q_{i(spec)} - Q_i^{cal}$$

Contd….

6. Compute $\Delta Pi(max) = \max|\Delta Pi|$, i=1,2,…N(except Slack bus)

$\Delta Q_i\,(max) = \max|\Delta Q_i|$, i=M+1….N

7. Compute Jacobian matrix using,

$$J = \begin{pmatrix} \frac{\partial Pi}{\partial\delta} & |V| \cdot \frac{\partial Pi}{\partial|V|} \\ \frac{\partial Qi}{\partial\delta} & |V| \cdot \frac{\partial Qi}{\partial|V|} \end{pmatrix}$$

8. Obtain static correction vector using

$$\begin{pmatrix} \Delta\delta \\ \frac{\Delta V}{|V|} \end{pmatrix} = [J]^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix}$$

Contnd....

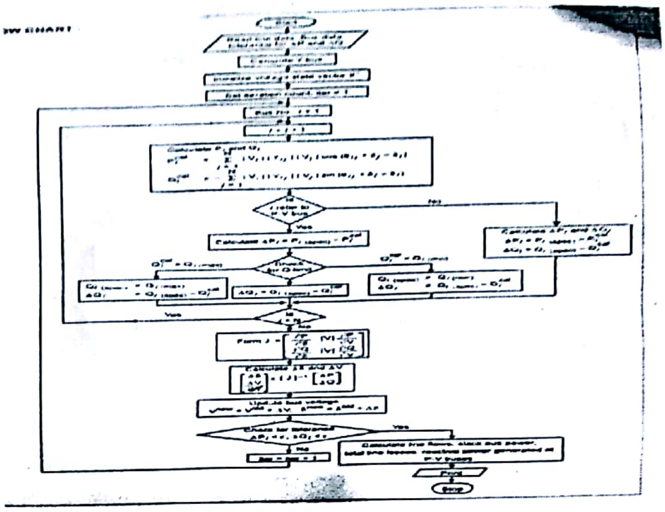
9. Update state vector using,

$$V^{new} = V^{old} + \Delta V$$
$$= V^{old} + [\,\Delta V / |V^{old}|\,]$$
$$= V^{old} + [1 + \{\Delta V / |V^{old}|\}]$$

$$\delta = \delta^{old} + \Delta\delta$$

10. This procedure is continued until,

$|\Delta Pi| < \varepsilon$ and $|\Delta Q_i| < \varepsilon$, otherwise go to step 3.



❖ Advantage of Newton – Raphson Method

i. suitable for large size system.
ii. It is faster, reliable &the results are accurate.
iii. No.of. Iteration are less to reach convergence & also iterations are independent of the no.of.buses.

❖ Disadvantage of Newton – Raphson Method

i. Programming logic is complex than GS Method
ii. Required more memory.
iii. No.of.calculation per iteration are higher than GS method

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DEPARTMENT OF MECHANICAL ENGINEERING

Teachers Teach Teacher (TTT) Programme

ACADEMIC YEAR 2018- 19 (EVEN SEMESTER)

Sl.No.	Year/Sem	Subject Name	Name of the Faculty	Syllabus	Date & Period
1	III/VI	Design of Transmission System	R.Ramanathan	Flywheel Design Aspects & Applications	23.01.2019 AN
2	III/V	Metrology & Measurements	Dr.K.Chandrasekaran	Utilization Co Ordinate Measuring Machine(CMM) in Micro Machining Elements	18.02.2019 AN

18/2/19

HoD

Quality and Inspection of Machining Operations: CMM Integration to the Machine Tool

1 Introduction

Dimensional measurement as a feedback method to the manufacturing enterprise has traditionally lain in the realm of the long term, as metrology activities on thermally stabilized parts are carried out in a controlled temperature environment away from the manufacturing activity. Incorporating true dimensional *feedback* to the manufacturing process has necessitated a transition of the metrology activity from a highly controlled remote function to an environmentally robust measurement function tightly integrated to the manufacturing activity itself.

Since measurement systems and their integration with machining systems have evolved dramatically in recent years, the primary focus of this paper is on the use of coordinate measuring machines (CMMs) in conjunction with machining. The primary research barriers to enabling this integration are highlighted in Fig. 1.

These activities establish a framework of research progress that allows the identification of needs for the near future that will enable a transition of the metrology function to a more tightly integrated feedback solution for reducing manufacturing variation and improving process control. Recent work in these areas is covered in this paper, leading to commentary and recommendations for future research needs.

The remaining sections of this paper are subdivided into the following:

- off-line CMM use
- integration of the CMM with the machine tool
- advances in sensing technology
- inspection planning and efficiency
- advanced controller feedback schemes
- machine error compensation
- on-line calibration
- the use of simulation in measurement system planning

Finally, conclusions are made with recommendations regarding immediate and long-term research needs with respect to addressing issues of integration of the disparate measurement and machining functions.

2 Measurement Assessments for the Quality Control of Machining Systems

In their comprehensive review paper on machining process monitoring and control, Liang et al. address a number of part measurement systems for monitoring and process feedback. To that end, it is noted that vision systems and advanced image processing techniques, enabled by improved software capability, have become viable options for surface measurement metrology [1]. In addition, specialized types of in-process gauging allow for dimensional measurement at the micron level. However, generalized dimensional metrology, integrated to the machine tool, still needs to be addressed.

While not initially integrated to the machine tool, the coordinate measuring machine has been in use for decades as a versatile high-precision offline measurement device. As such, the CMM has the capability of generating multiple types of measures using a single sensor head. Moreover, a multitude of measures can be made on a single program without manual intervention, making the CMM highly efficient and allowing for the evaluation of a greater percentage, or even 100%, of manufactured parts. Though "inspecting in" of quality is not condoned in this paper, research into approaches for maximum inspection ability is important. However, as stated by DeStefani [2], the benefits of measurement and machining integration must be well understood before we "invade the process."

The CMM's versatility and efficiency has led to its more recent use as an on-line measurement device, particularly as an advanced feedback sensor for machining processes and their tooling. Considering the number of advances that have recently been made in this area, this section will only present a brief review of some notable accomplishments.

Coordinate Measuring Machines. In general, the coordinate measuring machine is used to digitize a measured part for the purpose of inspection or model creation (as in the reverse engineering process). A CMM has the capability of measuring in three dimensions, but is also widely used for two-dimensional (planar) or one-dimensional (linear) evaluations. The classical configuration of the machine is the Cartesian movable bridge de-

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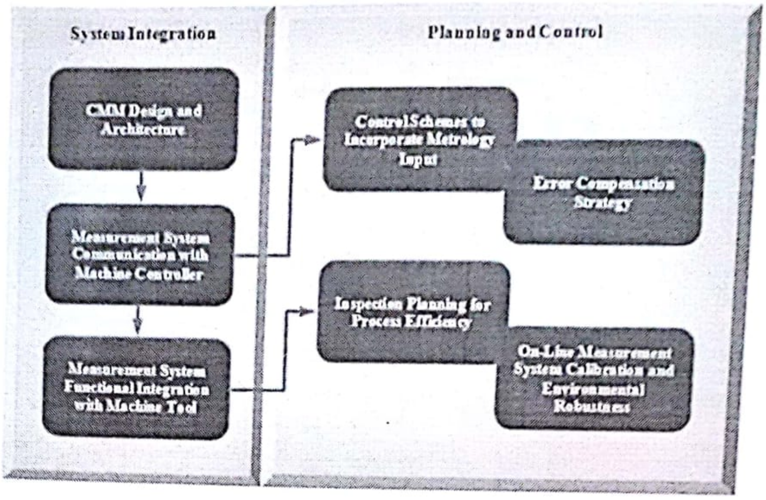

Fig. 1 Framework of research in measurement integration to machining. System integration issues between measurement and machining include functional and communication interoperability, as well as efficient planning for obtaining measurement data and its use in enhancing machine control.

sign, but some CMMs have been developed that utilize a cylindrical coordinate system for polar-specific artifact evaluation [3]. Additionally, recent developments have resulted in the design of a multijointed passive measurement device that, while requiring manual probe placement, allows greater freedom of motion and part accessibility [4]. In order to improve manufacturing efficiency, CMM operation has seen a recent evolution from a quality-based activity (driven by the organizational metrology function) to a manufacturing-based activity (driven by the operations function). This movement is beneficial in that the lag from production to evaluation is reduced and the overhead related to logistics and thermal stabilization is eliminated. This capability was enabled by recent advancements in automatic calibration and error compensation, allowing CMMs to operate in more harsh and/or temperature-variant environments.

Considering this, the next logical step is to integrate the CMM directly to the machine tool. Not only does this integration result in a further reduction in the processing-measurement lag, it also produces several other obvious advantages, including a known fixture state (the part does not need to be identified in space if the measurement device-fixture relationship is known) and the opportunity for immediate feedback to the machine controller. However, some issues emerge with the integration of inspection (or measurement) with value-added processing that should be addressed before such integration can become widespread. The first issue is the obvious loss of machine availability during the inspection, leading to a tradeoff between accuracy and inspection efficiency. This leads to the consideration that, if the part remains fixtured, if there is an opportunity to perform aligned machining activities during the inspection, or if this perceived disadvantage is outweighed by the previously stated benefits. The second issue is related to the reference plane for on-machine inspection. If the measurement platform is integral to the machine, the method for removing or compensating the machine geometric error from the measurement signal must be considered. Aside from the issues associated with the dislocation of the CMM from the controlled metrology lab atmosphere (e.g., temperature compensation), these are the major hurdles to overcome for successful integration of machining and inspection.

CMM Introduction to Machine Tool. As previously mentioned, the CMM can evaluate surfaces in one, two, or three dimensions using different coordinate systems, depending on the application and quality requirements. In addition, CMMs can generate single point data or scanned point clouds with fitting routines for characterizing part surfaces, and can measure any surface that can be reached by the probe [5]. The off-line CMM, as a quality evaluation tool, has been a manufacturing mainstay for decades. Originally designed as a modified machine tool, the CMM has been able to improve measurement accuracy and automation to a great degree [6]. However, the time lag between manufacture and off-line evaluation of a part leaves no room for direct process control. In fact, a number of defective parts can potentially be made during the wait for inspection.

In-line inspection using a CMM directly integrated with the machine tool allows for immediate inspection. Pancerella and Hazelton [7] asserted that on-machine inspection of components can reduce capital cost and reduce cycle time in a production environment because only one machine and process capability model is needed. On-machine acceptance further benefits the production cycle by promoting a design-for-inspectibility and concurrent engineering. Before switching to in-line inspection, however, it is vital to evaluate the integrated design on the basis of measurement time, quality objectives, design configuration, and integration with fixturing [8]. Such integration, coupled with the currently achievable measurement time and accuracy capability, enables 100% inspection and direct feedback to machine control or statistical process control (SPC) process evaluation [9,10].

In recent years several such integrations have been proposed. Kuang-Chao and Kuang-Pu [11] integrated a laser measurement probe directly with a computer-numerical control (CNC) machine in order to characterize freeform surfaces after machining. In this work, algorithms are developed for edge detection and the determination of shape error for on-machine mold manufacturing. In a similar work, Qiu et al. developed a spindle-referenced measurement device incorporated into a machining center for measuring 3D freeform contours with automatic following. The device is innovative in that it uses a combination of laser detector and linear encoder feedback to rapidly characterize surfaces and identify errors [12]. An additional integration development is a micromachining center adapted to be a measurement device by force feedback to the positioning servomotors [13]. The device is constructed from off-the-shelf parts and the achievable resolution is down to 5 nm. Shiou and Chen developed a process-intermittent measurement system for a milling center. The hybrid measurement system integrates a touch trigger probe with a triangulation laser probe system to measure regular geometric features and freeform surface profiles. Shiou and Chen used quadratic Bezier surfaces to approximate the measurement surface and to generate surface normals for inspection planning. The inspection system is verified with a CMM [14].

Wang et al. [15] described the error characterization of a free-form machined surface through separation of part form, part location, component movement, tool path variation, and fixture deviations from the nominal positions. Due to its multiple degrees of freedom and inherent ability to separate coordinate systems, an on-machine CMM is ideal for this decomposition analysis. Furthermore, with a CMM the primary error sources can be identified and corrected. Inspection strategy is also critical for on-machine probing. For example, Mou and Liu [16] used on-machine measurements (OMMs) of an artifact with known dimensions to complete a mathematical kinematic error model to improve accuracy of both on-machine inspection and machining. Mou and Donmez [17] proposed an inspection system that integrates on-machine and postprocess measurements to relate part errors to machine tool errors. Methods for improving the resulting geometric-thermal model are presented. Mou and Liu [18] employed state observation techniques to improve estimates of time varying machine tool errors. Mou and Liu furthered their work by developing a predictive search algorithm that increases the effectiveness and robustness of the error modeling method. The search algorithm is designed to determine the minimum number of points to measure for a given geometry [19].

However, machine reconfigurability becomes an important aspect of this process-inspection integration. The machining center must act as a material removal device in one instant (utilizing high force and controlled feed) then act as a measurement device the next instant (utilizing rapid traverse speeds and positioning accuracy). To address this new reconfigurability need, Wei et al. proposed a new programming framework designed to replace the traditional M- and G-code programming of CNCs. The software utilizes dynamic link libraries (DLLs) for rapid reconfiguration and is demonstrated on a three-axis milling machine [20].

Sensing Technology. The traditional CMM is fitted with a contacting touch probe that senses deflection magnitude and direction through orthogonal linear variable differential transformers (LVDTs). Integrating such a sensor into a machining system introduces issues such as probe wear and dynamic limitations. A number of approaches have recently been proposed to improve CMM sensing for efficiency and accuracy, enabling their use in production machining equipment.

Speed of measurements is one of the main potential benefits of on-machine measurement and significant efforts are placed on increasing this speed. Classical solutions include OMM of the workpiece using sensing probe [21] and replacing the on-machine touch trigger probe with a scanning probe to increase measurement speed as suggested in Ref. [22]. Though the precision of this system is lower than the precision of the existing CMMs, improved accuracy of the machine tool and a variety of precise noncontact sensors have made the system practical. In addition, numerous laser-based measuring devices recently became more and more available in OMM systems due to their high accuracy and increased speed compared with touch probes. Lee et al. [23] developed the OMM system with a laser displacement sensor for measuring form accuracy and surface roughness of the machined workpiece on the machine tool. Lee and Park [24] proposed an automatic laser scanner-based inspection planning algorithm for a part that has a Computer-Aided Design (CAD) model. Yoon et al. [25] combined the touch probe measuring devices and laser displacement sensor measuring devices into a 3D OMM system, which could predict the machining errors of each process much faster and accurately.

Cost is another consideration in sensor development for on-machine measurement. Liu et al. [26] developed an on-machine measurement system that enables the cutting tool itself to act as the contact probe. Setup time and machining accuracy improvements are realized at a fraction of the cost of traditional on-machine probing. Del Guerra and Coelho [27] developed a probe based on simple electrical contact to address the cost implementation barrier of OMM systems. The probe has 3 μm repeatability and addresses another traditional probe shortcoming, namely, the fact that a different force is required to actuate the probe in different directions, causing error due to pretravel distance. Probe pretravel and asymmetry error has also been addressed by Estler et al. [28] through compensation and demonstration in on-machine measurement applications [29].

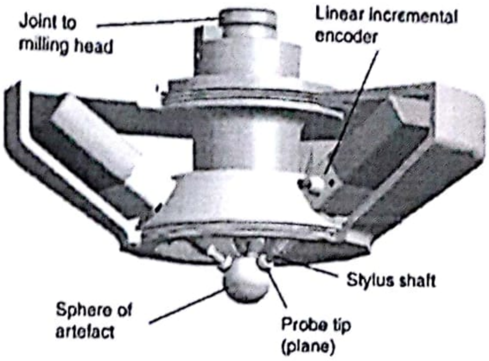

Fig. 2 Self-centering probe for rapid machine tool characterization 35

Besides advances in sensing technology, one should note accuracy improvements achieved through software. One such work is reported by Choi et al. [30], who used OMMs to define a compensation method for reduction in the machining errors of a three-axis machine tool. High levels of OMM accuracy were achieved by including both probing errors of a touch probe and positioning errors of a machine tool that are being compensated to obtain the true machining errors for the repeated machining process. An actual simple cutting test was used to prove the efficacy of the compensation method. Yin and Lee [31] presented a software method in the frequency domain for evaluating workpiece straightness using on-machine probing. It reconstructs straightness profile for smooth, nonsmooth, periodic, and nonperiodic high frequency deviations, and has been applied to on-machine error correction [32]. More recently, Cedilnik et al. [33] generated a theoretical model of touch probe stylus ball error due to contact surface slope. Such representation lends itself well to compensation.

Advances in data processing and signal analysis capability have enabled the use of new sensing technologies for measurement. Noncontact laser sensors and analog scanning probes, which require highly accurate positioning performance, are now achievable in modern systems. To demonstrate this, Chang et al. [34] retrofitted a standalone CMM with improved motion control hardware, enabling the use of alternative sensors. Such technology could be readily incorporated into the integrated manufacturing-inspection system, improving measurement performance. To this end, Kuang-Chao and Kuang-Pu [11] demonstrated this novel sensor incorporation using an on-machine laser measurement probe.

Another improvement in sensing technology is presented in the work by Trapet et al. [35] where the authors have introduced a new design of self-centering probe specifically for machine tool use that gives an efficient and rapid technique to verify machine tool performance (shown in Fig. 2).

Higher machining degree of freedom exponentially complicates error analysis and compensation. For example, traditional error modeling approaches for three-axis CNC machine tools cannot be practically applied to five-axis machines. Lei and Hsu [36] addressed this deficiency through the development of a probe-ball device, which is used to directly measure position errors in five axes. The device is used in development of a least-squares error estimation algorithm in five axes [37]. The algorithm has been successfully applied to five-axis error compensation on the machine tool [38].

Interferometry has also been successfully applied to machining, in this case, with respect to manufacturing a concave mirror by Kohno et al. [39]. However, while stable and compact enough to be applied to in-process measurement, the interferometer has limited application to the generalized machining process due to prohibitively high cost and limitations on traverse speed.

An additional advancement in sensing technology was presented in the previously described hybrid optomechanical measurement machine (OMMM) of Sitnik. As discussed in this work, the OMMM takes advantage of the accuracy afforded a contact probe with the efficiency of an optical system [40]. Moreover, the OMMM is developed for the manufacture of large parts for the automotive industry and provides for automatic process control. Suzuki et al. [41] developed a new contact-based on-machine system for measuring small aspherical optic parts. The system incorporates a SIALON slider with low thermal expansion with a high-precision glass scale for feedback. Ultraprecision on-machine measurement is also addressed by Ohmori et al. [42] in their atomic-force microscope probe integration design; a repeatability of 5.6 nm is achieved. Additional recent work in on-machine sensor development is given by Jywe et al. [43] in the development of a new measuring system aimed specifically at error compensation. In this approach, position-sensitive detectors (PSDs) are developed with 1 μm repeatability, which have a small working range but high dynamic performance for improved characterization for fast machining. The sensors are demonstrated and used for compensation of 3D high-speed cutting, and shown to significantly decrease contouring error. Kobayashi et al. [44] developed a noncontact sensing system for profile measurement using a laser probe; the system achieves equivalent performance to current state-of-the-art high-performance measurement techniques.

Inspection Planning and Efficiency. Besides improvements in sensing technology, the speed and accuracy of OMMs are improved through a careful inspection planning process. In terms of inspection planning, one can discern two main directions in the recent advances.

- advances in individual feature-based methods for inspection planning
- advances in system-based methods for inspection planning

Individual Feature Based Methods. The key to strategic inspection planning at the feature-level are methods for evaluating errors in estimation of feature parameters due to a given inspection plan. Lee et al. [45] analyzed the measurement error sources existing in the OMM system. Cho and Seo [46] proposed the error modeling scheme using a closed-loop system of the OMM for the integration of CAD/computer aided manufacturing (CAM)/ computer aided inspection (CAI). This strategy addressed inspection planning for the OMM process of sculptured surfaces through two significant factors: prediction of cutting error and consideration of cutter contact points in the measurement planning process to avoid error associated with cusps [46]. Davis et al. [47] proposed a direct memory access controller (DMAC), which closely related the CAD model, CAM system, and CMM system, and thus made it possible to utilize the measurement results from in-process inspection. Based on measurement error considerations, Yoon et al. [48] established an effective inspection system by using OMM system-based PC-NC, which optimally determined the number of measuring points, their location, and path using fuzzy logic and traveling salesman problem (TSP) algorithm. Xiong et al. [49] proposed a near-optimal probing strategy including two sequential optimization algorithms to incrementally increase the localization accuracy and a reliability analysis method to find a sample size that is sufficient to reduce the uncertainty of the localization error to a limited bound.

System Based Methods. Measurement selection for multistage machining systems (where the geometric relation between part and machine is broken at one or more points in the process flow) is addressed by Djurdjanovic and Ni [50,51]. In multistage systems, a large number of machining operations are performed across several stations, greatly increasing the complexity of inspection planning. To handle this complexity, heuristic or expert systems are frequently employed. However, in many cases these approaches result in a loss in inspection efficiency since redundant quality information is contained in the measurements. Through the stream-of-variation (SOV) analysis technique, a quantitative characterization of the generalized measurement scheme for multistation operations is employed for machining. Using SOV, the amount of quality information generated by a measurement set can be kept while minimizing the required inspection time. In a similar work, Gruget and Djurdjanovic [52] employed the method using a genetic algorithm (GA) approach to identify strongly correlated measurements and to create a scheme reduction plan to improve inspection efficiency.

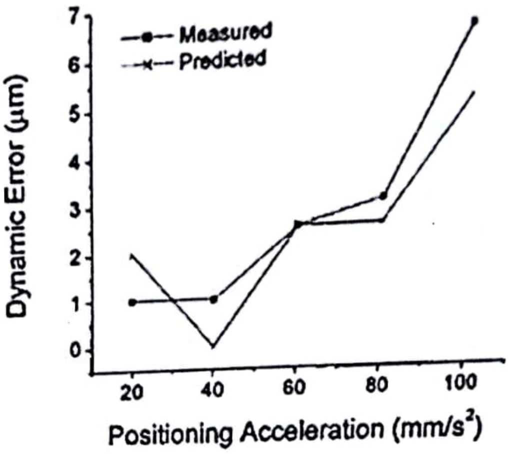

Fig. 3 CMM predicted dynamic error used in compensation [56]

Efficiency and Calibration. An immediate benefit of locating the CMM directly in the machining operation is the elimination of part transfer time and tracking logistics, and a subsequent capability to inspect a greater percentage of parts. However, some new issues also arise due to this situation, primarily: calibration of the measurement instrument, thermal influences on the measurement, and the inherent tradeoff between accuracy and measurement efficiency.

A principal disadvantage of machining and inspection integration is the logistic issues it introduces with respect to material flow through the machining process, most notably the loss of machine uptime during the part inspection. Therefore, the inspection planning process is critical for the successful integration of the CMM and the machine tool. Of most importance is the tradeoff analysis of measurement time versus accuracy (i.e., inspection efficiency). To address this issue, Vafaeesefat gave a comprehensive inspection planning process for the CMM that produces an efficient inspection result for both simple and complex parts. Furthermore, to improve computational efficiency, Mu-Chen [54] presented planning approaches based in GAs for ideal surface fitting to the point cloud, and successfully demonstrated the approaches for sphericity evaluation. With a similar goal, Jiang and Chiu [55] presents a method for determining the ideal number of measurement points to evaluate part features for rapidly closing the CAI control loop. This methodology is automated for on-line applications.

Dong et al. [56] also addressed efficiency in their treatment of probe dynamic error modeling. In this work, a neural network approach is used to predict pitch and yaw error due to CMM acceleration. The results of one predictor are shown in Fig. 3. The

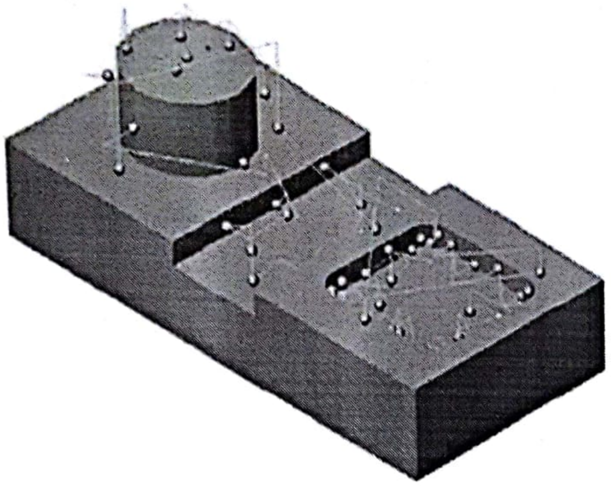

Fig. 4 Inspection path planning. The number of points, their location, and the inspection path are planned to minimize inspection time while maintaining acceptable accuracy †48‡.

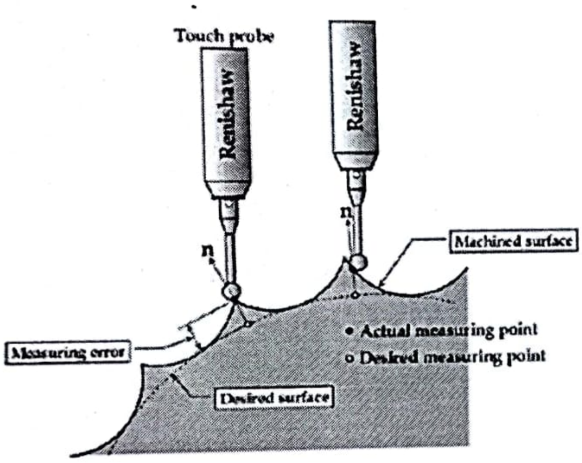

Fig. 5 Measurement error caused by machining cusp †46‡

resultant compensation improves both accuracy and efficiency of measurement.

Using a different approach, Yoon et al. [48] described a PC-based on-machine measurement system efficient enough to perform 100% part inspection. Using part geometry information, the system determines an optimal number of measurement points using a fuzzy logic algorithm. The point locations are then identified by a modified Hammersley's approach to selection on geometric primitives. Finally, the inspection path plan is minimized through off-line solution to the TSP. Minimized-path point distribution on a sample part is shown in Fig. 4.

In a different approach to implementing the TSP, Cho and Seo [46] integrated CAD data to both machining and measurement planning and minimized probe travel distance through a revised implementation of the traveling salesman problem. The result is applied to a generalized sculptured surface characterization approach, which also explicitly addresses probe error due to the machining cusp, as shown in Fig. 5.

In another recent work that integrated CAD data, Jiancheng et al. [57] developed an autonomous coordinate measuring planning (ACMP) system based on the part's CAD model to enable true interactive operation between measurement and CNC machining (see Fig. 6).

The ACMP system not only links part geometry, machining programming, and measurement, but also autonomously optimizes the probe path plan and eases the measurement programming requirement, improving overall inspection efficiency. Ng and Hung [58] also presented a measurement planning system that derives the probe path directly from the CNC machining code. However, the plan presented by Ng and Hung does not require CAD model information as an input.

Starczak and Jakubiec [59] built a classification system for different measurement tasks and classified each task through a set of potential measurement strategies. The results are applied to a software system supporting optimal measurement strategy choice. In an alternative approach, Lin and Chen [60] presented an approach to optimal CMM path planning using a cut face method to avoid probe collision. The algorithm also addresses minimization of measuring points and the desire for normality of the probe to the surface being inspected.

Cho [61] proposed a feature-based inspection plan for targeting inspection efficiency. The plan occurs in two stages: a global stage to generate an optimum inspection path for all primitive features, then a local stage to decompose each feature and determine an

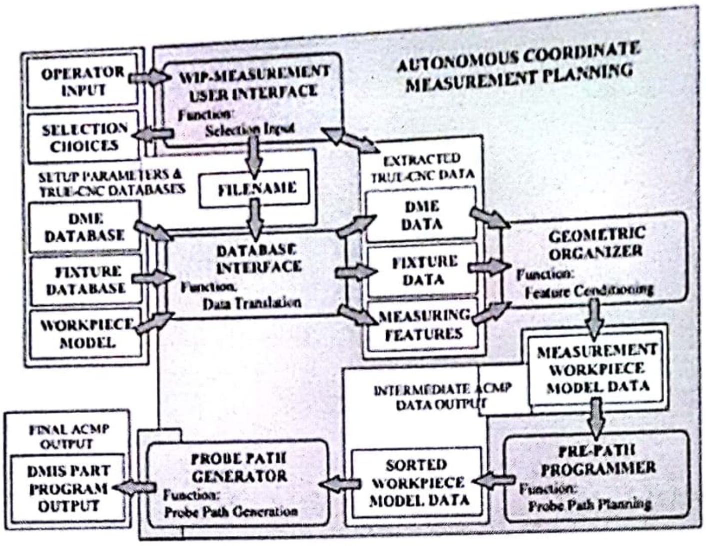

Fig. 6 Information flowchart of autonomous coordinate measuring planning ACMP system 57† ‡

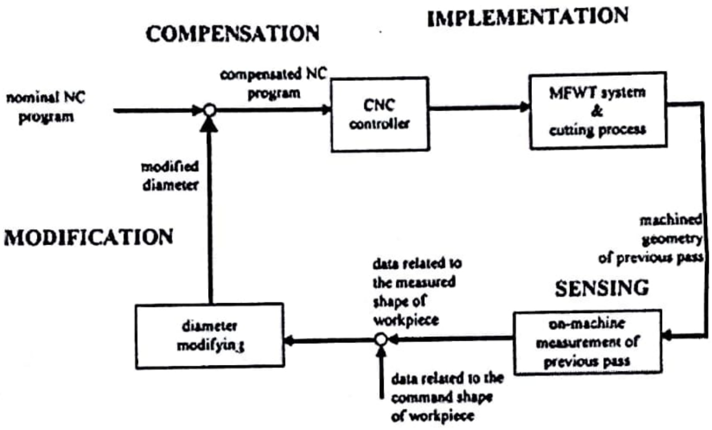

Fig. 7 Iterative error measurement and compensation system †63‡

optimal number of sampling points based on the desired accuracy.

More recently, Sitnik [40] presented a hybrid on-machine inspection system utilizing both high-accuracy contact CMM and high-measurement-speed noncontact optical techniques. The approach is in four steps: an optical measurement inspection of the entire working surface, analysis of model parts noting critical areas, remeasurement of those critical areas using CMM techniques, and a final hybrid data analysis. The system also provides for automated feedback correction.

Advanced Controller Feedback. The CMM can be used not only as a device for tracking of part quality, but on a more fundamental level as feedback directly to the process for improving process control. Utilizing measurement information in real time to dynamically update manufacturing process has the potential of making parts with better dimensional accuracy. Two approaches have been reported. Sazedur Rahman et al. [62] developed an on-machine profile measurement system, the working principle of which was based on CMM and used a touch probe to measure the coordinates on the newly ground aspheric surface. The measured surface profile was used to guide wheel wear compensation. Davis et al. [47] took a separate approach: Instead of adding measurement equipment, they used the machine tool as a CMM. The machine tool could switch between a machining process and a measuring process. Machining error was generated by the CMM software and fed back to the CAD/CAM software for compensation. That the measurement requires the manufacturing process be stopped poses a major challenge for real production application in terms of dynamically updated manufacturing process for error compensation.

One benefit of direct three-dimensional coordinate feedback is the ability to provide control actuation not to individual axis actuators, but directly to the cutting tool position itself. Along this line, Liu [63] developed a diametral on-machine measurement and compensation system for multipass lathe operations as shown in Fig. 7. In this work, measurement and compensation in situ are able to achieve less than 2 μm error over 100 mm machined length.

On-machine probing information can also be employed with advanced controllers to improve systems performance. For example, Cho et al. [64] proposed a strategy for inspecting a sculpted surface using on-machine probing. The research integrates a CNC milling machine and inspection of 3D sculpted surfaces. The proposed methodology reduces inspection errors by moving the inspection points to reduce the error caused by the cusp shape. Cho and Seo [46] also recommended locating more inspection points in the region where the largest errors are more likely to occur and use the traveling salesperson problem algorithm (the TSP is a common problem in combinatorial optimizaion) to reduce inspection time. Choi et al. developed an on-nachine measurement and error compensation system for a hree- axis milling machine. A cube array artifact is proposed and neasured using an on-machine probe in order to generate a nodel of machine positioning error. A test workpiece composed of two- dimensional curves was machined, measured using on-machine inspection, and then re-machined [30]. Choi et al. were able to reduce machining errors to less than 10 μm on the second cutting pass. Choi et al. employed a strategy for compensation similar to the strategy used by Lo and Hsiao [65], which is to apply the measured errors in the opposite direction to generate the compen- sation trajectory.

More recently, Kwon et al. [66] characterized closed-loop mea- surement error in CNC milling through a design of experiment (DOE) comparison between on-machine and off-line parts mea- surement. The results were demonstrated by a correcting feedback signal, with decreased measurement variation for more free- cutting material. Probe feedback is also applied to fixturing error by Wang et al. [15], whereby the influence of fixturing on the deviation between machined surface and defined tool path is quantified.

The movement of the CMM directly to the manufacturing floor has enabled its use for multidimensional statistical process control (SPC). SPC software specific to the CMM is surveyed by Franck and co-worker [9,67]. This technique is able to provide real-time multivariable monitoring and detection of process trends; applica- tion to limited process control is also addressed. SPC is enabled to evolve from a fixed-gauge single-variable activity to a fully- automated and flexible software-driven evaluation tool for process characterization.

The next logical step is to integrate the feeding of part measurement information to the machine for direct process control. This capability is enabled as the CMM and machine tool are integrated and the time lag between processing and evaluation is minimized. The work by Kwon et al. [66] investigates closed-loop error as it relates to integrated inspection; the authors demonstrated the efficiency and quality benefits of this information availability. However, a factor that needs to be addressed is the relative error between the machine base and the global base. Real-time feedback has been used successfully for position and dimensional control in a variety of processes such as grinding and is widespread in the industry [68–72]. However, more advanced control techniques have enabled capabilities such as force control, power control, and the direct control of subsurface damage [73,74].

Machine Error Compensation. Another inherent shortcoming of on-line inspection, besides potentially reduced process efficiency, is a reference error of the measurement. The fact that the machine reference frame is used as an input to the calibration

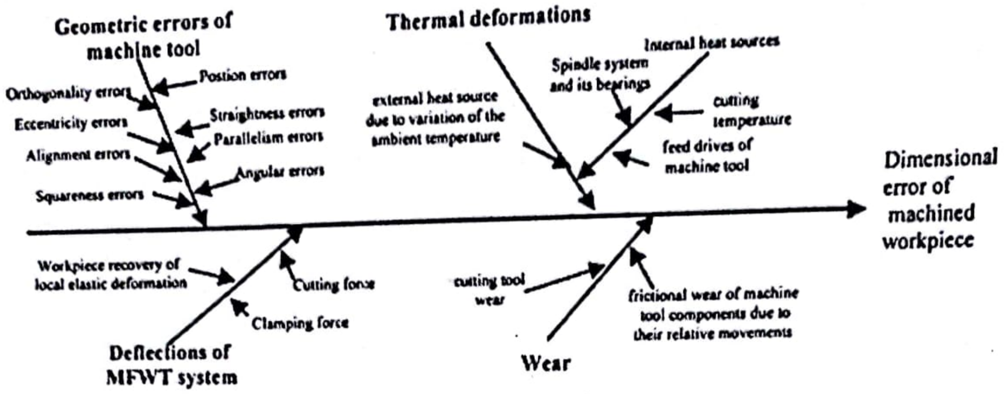

Fig. 8 Machined part error: geometry, force, thermal, and wear sources †63‡

procedure introduces an inherent error (i.e., inclusion of the machine error in the measurement). This leads to a need to understand the error deviations in the machine as a result of the departure from the ideal kinematic model, and also the error behavior with absolute or processing time. The typical machine error sources, as described by Liu, are shown in Fig. 8. Therefore, any error compensation between the on-machine measurement system and the machined part must account for these sources: geometry deviations from ideal, system deflections due to force, thermal deformations, and longer-term dimensional deviations due to wear.

Recognizing this, Choi et al. [30] approached on-machine probing through a decoupling scheme whereby probe error components are modeled as polynomial functions, which include the machine error model with backlash. The workflow and compensation algorithms are given in Fig. 9. Here, model parameters are derived through the periodic measurement of a calibrated cube array artifact. In testing, this method achieved a reduction in the general machine error to less than 10 μm.

Error components, based on the machine rigid body kinematic model, are approximated using polynomial functions by Jung et al. [75]. The application improves the absolute error of in-machine touch probe measurement, which was reduced to 5 μm for a hemispherical test part. Moreover, Huang et al. [76] improved machine accuracy for a general 3D shape by 60% using similar techniques (eight-point interpolation method).

Smith et al. [77] described a calibration system using fiducial points for improving the accuracy of large monolithic machined structures. The described fiducial calibration system (FCS) negates the need for machine thermal analysis and geometric characterization by interferometric measurement. The method flow is given in Fig. 10. In another work employing the fiducial calibration system, Woody et al. applied the method to a large machine tool and characterized the uncertainty, enabling CMM-level accuracy on a shop floor machine tool without the need for individual error source determination [78].

An approach for calibrating thermally induced machining error using on-machine probing was proposed by Chen [79]. In this work, thermal errors were quantified and calibrated through artifact analysis by on-machine probing during cutting and exposed a shortcoming of thermal calibration by a simple air cutting experiment. Chen and Chiou [80] also correlated thermal error with temperature field during the actual cutting. Weck and Herbst *[81]* addressed thermal error through thermoelastic displacement calculation rather than cooling control; this approach uses a neural net to identify significant temperature probe locations for accurate thermal deflection characterization. A generalized thermal compensation model is proposed by Attia and Fraser [82], which seeks to resolve differences between direct measurement and indirect thermal modeling compensation methods. Yang and Lee [83] ad-

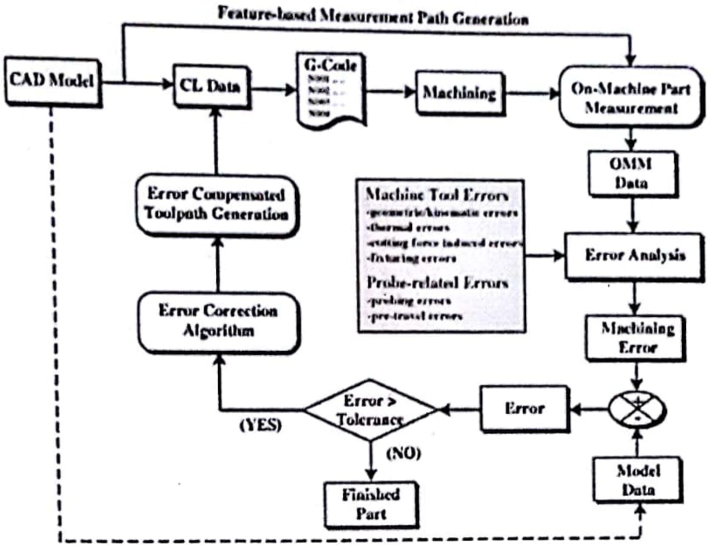

Fig. 9 Workflow for rapid on-machine probe calibration †30‡

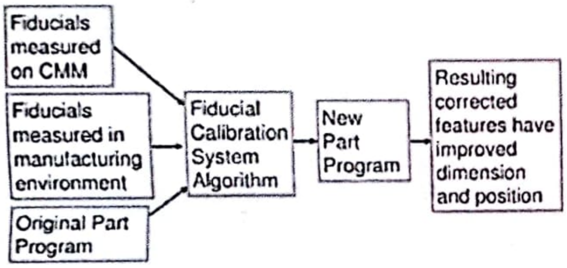

Fig. 10 Machine measurement and compensation using FCS †27

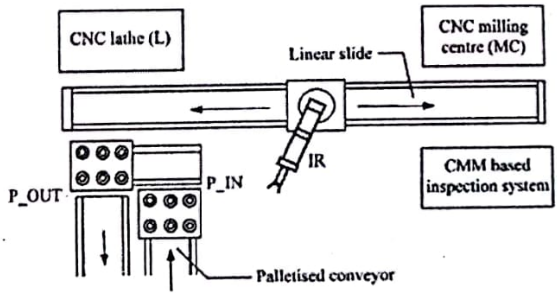

Fig. 11 Simulation of CMM integration to flexible machining line †102‡

dressed measurement and prediction of thermal error using on-machine probing with two spherical artifacts. The method is incorporated with a neural network approach for compensation. Thermal error models and compensation are addressed through artifact methods by Kim and Chung [84], where thermal transients are effectively modeled. Kim and Chung [85] also addressed pure design of a 3D reference artifact for thermal error identification. In this approach, the thermal errors of cutting tool edge, axis expansion, and machine structural C-member distortion are addressed in a single calibration step; positioning error was reduced up to 75%. Yang et al. presented a thermal compensation method dynamic thermal error modeling (DTEM), which improves both accuracy and robustness of machine tool thermal deflection models [86]. Hysteresis effects are identified as the major factor of poor robustness of the current static modeling approach [87].

Direct thermal compensation is addressed by Wang et al. [87] using 17 different thermal error components. The system was implemented on a precision five-axis machining center, improving accuracy by 50%. Lei et al. [88] presented recent developments in efficient machine path representation through an enhancement to the nonuniform rational B-spline (NURBS) method. NURBS path length calculations are undertaken through subdivision of the path to avoid the necessity of iterative derivative taking posed by point-to-point path representation. The NURBS model has been most recently applied to fast error geometric compensation [89]. Model-free approaches have also been applied to error compen- sation. Tan et al. [90] addressed geometric error modeling and compensation using a different technique involving the application of a neural network (NN) approach. A machine error map is created using interferometric measurements, and the model is then applied to compensation through a learning algorithm. This form of error map is also readily applicable to the integrated inspection process [91]. Ziegert and Kalle [92] also used the NN approach to compute error mapping using on-machine probing. Shen and Moon [93] employed the NN approach to error correction of on- machine coordinate measurement. More recently, Cho et al. [64] extended the work of inspection planning for OMM to incorporate the obtained data in an error compensation algorithm. This ap- proach addressed compensation of two machining error param- eters through a polynomial neural network (PNN) approach, and effectively reduced machining error in end milling. Additional recent work is that of Fines and Agah [94] in positioning error compensation using a neural network approach. Three different artificial neural network (ANN) architectures were studied and demonstrated, and final compensation results were shown to be comparable to current state-of-the-art systems.

On-Line Calibration. A number of theoretical calibration tools and techniques have resulted from application of the CMM directly to the machining process. Moving the measurement pro- cess from the controlled metrology lab environment to the shop floor or even to the more environmentally harsh machining pro- cess introduces numerous environmental error sources. Contami- nation, temperature fluctuations, and the potential for physical contact all result in a need for increased and, therefore, more efficient calibration methods. The telescoping ball bar used for cylindrical machine tool error mapping is adapted to the inspection process by both Curran and Phelan [95] and Jiang and Chiu [55]. This "quick check" technique replaces artifact evaluation and allows for more frequent inspection.

Calibration of probe error is undertaken by Xiong and coworkers [96,97] through a new radius compensation method. Through this method, a dual optimization of compensation accuracy and computational time is achieved. The method is implemented in an automated machine tool setup system [98]. Srinivasan et al. [99] also addressed probe radius compensation specifically for freeform sculpted surfaces using OMM. This implementation uses real-time machined surface data rather than CAD model data generation.

Simulation of Measurement Systems. As with most processes, it is important to develop accurate simulation models that are able to recreate the actual response of the system; thereby allowing process parameters to be altered such that optimal con- ditions can be achieved through off-line analysis. To this end, Zhengyi and Yonghua [101] introduced a virtual coordinate mea- suring machine (VCMM) that utilizes haptic feedback from solid part models. This device is used to provide heuristic input and immediate validation and collision prediction for measurement path planning.

Simulation is also addressed, as it relates to shop floor flow planning by Siemiatkowski and Przybylski [102]. The simulated system is shown in Fig. 11. As a part of this work, two specific issues are noted with respect to the integration of a CMM to a flexible machining cell: job sequencing and inspection planning. Through the use of their simulation, the authors demonstrated that these issues have a major effect on the overall cell performance. Considering this, alternative flow strategies are presented to mini- mize sequencing and planning issues.

The virtual machining and measurement cell (VMMC) of Yao et al. [103] also simulates the machining and measuring process (on-line or off-line) and estimates the potential machining errors of a given part form. The traditional machining process development approach is contrasted with VMMC in Fig. 12. An example of the virtual measuring simulation is shown in Fig. 13.

The output of this model provides a basis for the optimization of both the machining process and integrated measurement planning. The ability of the authors to achieve this result "virtually" allows for improved part accuracy from the first cut as well as increased development agility with respect to varying market con- ditions. Kurfess [104] also presented additional advancements by On-line evaluation of measurement performance degradation due to harsh environmental factors is treated by Franceschini et al. [100]. This work proposes a rapid on-line diagnostic procedure integrated to the normal measurement cycle that identifies mea- surement error and monitors machine performance. The method does not require additional internal or external instrumentation.

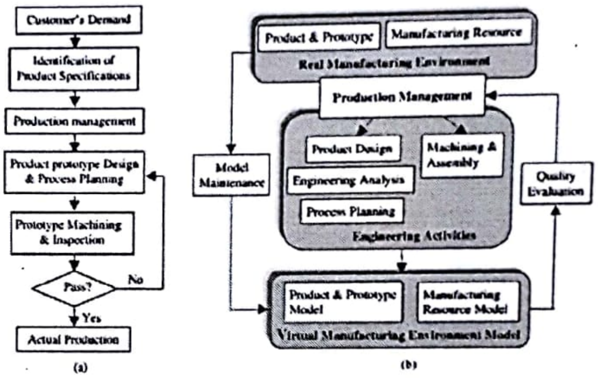

Fig. 12 Virtual machining and measurement cell architecture †103‡. „*a*… Tra- ditional development is time-consuming and expensive due to physical prototype iterations; *b* VMMC addresses optimization analytically to save time and cost.

the automotive manufacturing industry in inspection planning simulation, including solutions related to throughput and software control.

Trends and Impacts of Measurement System Integration. Fundamental issues relating to the integration of the CMM to a machining cell were treated by Wilson and Lenger [8]. The major considerations noted at the time were the following:

identifying the true quality objectives of the inspection

quantifying the part's configuration and critical attributes

coupled integration of fixture design approaches

process ownership by the implementation team

In order to successfully integrate measurement within the ma- chining environment, these considerations should all be addressed through intense preplanning, prior to attempting any integration activities.

As noted, bringing together these two previously decoupled operations, machining and CMM measurement, has revealed a number of additional issues that are directly related to the integration into a common platform or manufacturing system. In this paper, several of these issues were highlighted, including efficiency of the inspection planning, error compensation and calibration, and the ability to feed back measurement data for direct machining control. These issues are in the forefront today, recognized as vital research areas that must be understood in order to allow for measurement integration on-machine tools. However, the next hurdle for true integration will be at the machine design phase. Shelton [6] noted in 1990 that developments in-machine tool technology should be coupled with corresponding technologies in CMM research. However, so far, these technologies have not been systematically developed, leading to some of the noted shortcomings.

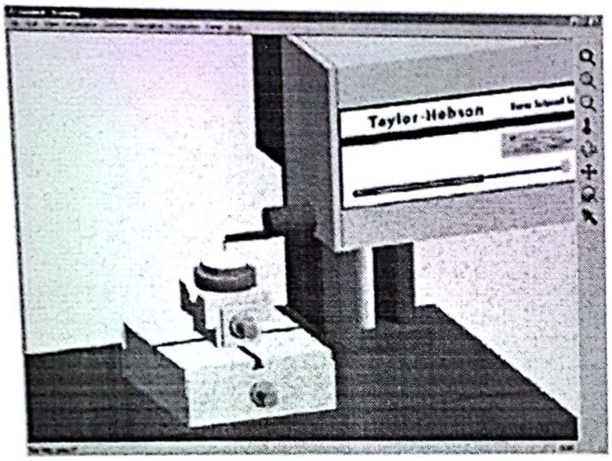

Fig. 13 Virtual measuring process of VMMC. Part measurement is simulated and the results are used to optimize the inspection efficiency.

One area later noted by Shelton and Ulbrich [105] that also remains to be adequately addressed relates to CMM data density and the diminishing accuracy returns on the time investment associated with inspection. To begin to address this, in their work, the "hyperactive woodpecker" CMM design approach is eschewed in favor of a more efficient and pragmatic approach to data analysis. This concept is also addressed by Weckenmann et al. [106] through the focus on the effect of measurement strategy planning on resultant measurement uncertainty, resulting in more efficient planning. Lin and Chen [60] addressed effective integration planning through an open architecture model using IDEF0 and STEP data models. The IDEF0 model is used to analyze measurement function requirements, while the STEP model is used to communicate measurement system commands.

Pahk et al. [107] proposed an interactive and integrated on-machine inspection planning system developed for machining and inspection planning of freeform mold geometry. The system outputs code for both CNC cutting and OMM commands for critical mold features. Limaiem and El-Maraghy [108] addressed development of robust inspection planning systems for optimum sequencing and resource allocation. This work accounts for physical probe size and attitude, and introduces the concept of *principal clusters*, groups of measurement points accessible by the given probe geometry. More recently, Oakham [109] highlighted on-machine geometric verification for process control strategies, incorporating on-machine measurement commands directly to the NC program. Quinn et al. [110] and Schuyler et al. [111] addressed communication issues between machining center and measurement system, developing a method to effectively pass information from measurement to controller for real-time error compensation. Kim and Chung [84] approached OMM integration through measurement error prediction and validation routines implemented directly in the CNC program, including the development of a set of G-code commands specific to measurement control as shown in Table 1.

However, to integrate these systems, it is also important to ad-

Table 1 Measuring G-codes †84‡

Measuring features	Measuring G-codes with arguments
1. Probe start	G100 A. D☐ H☐ T☐
2. Probe end	G100 A2.
3. Coordinate setting	G101 D☐ W☐
4. Environment setup	Ge102 E☐ I☐ J☐ K☐ T☐
5. Probe offset	G103 A1. B☐ D☐ E☐ T☐
6. Probe length	G103 A2. B☐ E☐ H☐ T☐
7. Machine tool calibration	G104 D☐ E☐ T☐ W☐ X☐ Y☐ Z☐
8. Bore	G105 A1.D☐ E☐ R☐ S☐ U☐ V☐ W☐ X☐ Y☐ Z☐
9. Boss	G105 A2. D☐ E☐ R☐ S☐ U☐ V☐ W☐ X☐ Y☐ Z☐
10. Pocket	G106 A1. E☐ H☐ Q☐ R☐ S☐ U☐ V☐ W☐ X☐ Y☐ Z☐
11. Web	G106. A2 E☐ H☐ Q☐ R☐ S☐ U☐ V☐ W☐ X☐ Y☐ Z☐
12. Internal corner	G107 A1. E☐ I☐ J☐ Q☐ R☐ S☐ W☐ X☐ Y☐ Z☐
13. External corner	G107 A2. E☐ I☐ J☐ Q☐ R☐ S☐ W☐ X☐ Y☐ Z☐
14 Plane (X, Y, Z)	G108 E☐ Q☐ R☐ S☐ W☐ X☐ Y☐ Z☐
15. Bore-bore	G109 A1. C☐ D☐ E☐ K☐ U☐ V☐ X☐ Y☐
16. Bore-Ex. Cor.	G109 A2. C☐ D☐ E☐ K☐ U☐ V☐ X☐ Y☐
17. Pocket-pocket	G109 A3. C☐ D☐ E☐ K☐ U☐ V☐
18 Web-plane	G109 A4. C☐ D☐ E☐ K☐ U☐ V☐
19. Ex. Cor.-Ex. Cor.	G109 A5. C☐ D☐ E☐ K☐ U☐ V☐ X☐ Y☐
20. Plane-plane	G109 A6.C☐ D☐ E☐ K☐ U☐ V☐

dress error separation between the process and the measurement system. Along those lines, Knapp [112] stressed the need to comprehend error sources, especially the realization that both measurement uncertainty and measuring system setup and calibration are independent sources of error, but are not considered independently by measurement standards. This analysis is especially germane in the application of measurement in a harsh environment, outside of the near-perfect domain of traditional measurement system characterization.

Total system cost is another consideration for integration. Recent research on scale reduction in-machine tools (meso- and micromachining process development) introduces additional complexity to the integration process. As noted by Lee and Yang [113], installation of traditional interferometric equipment commonly used for machine tool characterization is difficult due to system size; miniaturized measurement components are also very expensive. To address this, they proposed a simultaneous characterization setup using capacitance sensing to reduce system cost. Dornfeld et al. [114] also cited development of more precise metrology methods as a "grand challenge" to further micromachining realization.

Future CMM Development Needs. There are current efforts underway to integrate CMM inspection directly with ma- chining processes. The immediate benefits are reduced lag time between processing and inspection, and the application of on- machine inspection to multidimensional SPC and direct process feedback control (which are limited in availability when using traditional off-line CMM inspection).

However, a number of issues arise when integrating the CMM directly with the machine tool. Of particular importance are efficiency and throughput of the machining process after integration, and issues related to measurement error and calibration due to the inspection reference to the machine itself (machine errors also become integrated to the inspection). Additionally, environmental errors in the machine pose challenges for this development. These challenges are being addressed through simulation, error compensation, rapid calibration techniques, and incorporation of new sensing technologies.

3 Conclusions

This paper presents a review of the use of coordinate measuring machines in conjunction with machining. Included are advances in separate CMM designs, as well as integration of the measurement systems with machine tools and particular issues arising as a result of this integration. With the advent of more powerful processing capabilities, measurement technologies are becoming not only more efficient and accurate, but more accessible to the machine tool user as well.

The use of coordinate measuring machines in machining processes was reviewed; particularly the issue of integration of this technology as applied directly to the machine tool itself. The major points and recommendations are as follows:

- Coordinate measuring systems are accurate, highly flexible and widely used as off-line post-process evaluation tools. Recently, integration of such systems directly to the machine tool has been explored.
- There is a growing evolution of the CMM from a quality-based to a manufacturing-based activity, reducing production-measurement lag. This movement is enabled by new automatic calibration and temperature compensation routines.
- Integration of measurement directly to the machine tool is enabled by known geometric relationships to fixturing and allows for direct process feedback.
- Barriers to this integration include loss of machine availability during measurement and the inability to separate machine and part geometric errors.
- Measurement device calibration and the relation of measurement error to machine tool geometric error are primary concerns. Error compensation schemes and rapid on-line calibration routines are evaluated.
- Machine reconfigurability becomes an important aspect of process-inspection integration. The machining center must operate with high force and controlled feed for material removal, and rapid traverse speeds and accurate positioning for measurement. Control architectures have been proposed for this duality.

Overall, the fundamental issue with these measurement and monitoring technologies is proper integration of the measurement and material removal functions to result in an effective production system. As an example, Schuyler et al. [111] described the concept of a *smart machine tool system* that seamlessly integrates current process information with inexpensive and noninvasive sensors, and used models to automatically and continuously control the process; however, such an integrated system has yet to be realized.

Flywheel

A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply.

Flywheels-Function need and Operation

The main function of a fly wheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Many machines have load patterns that cause the torque time function to vary over the cycle. Internal combustion engines with one or two cylinders are a typical example. Piston compressors, punch presses, rock crushers etc. are the other systems that have fly wheel.

Flywheel absorbs mechanical energy by increasing its angular velocity and delivers the stored energy by decreasing its velocity

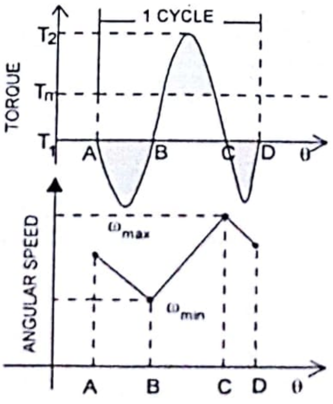

Figure 3.3.1

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Design Approach

There are two stages to the design of a flywheel.

First, the amount of energy required for the desired degree of smoothening must be found and the (mass) moment of inertia needed to absorb that energy determined.

Then flywheel geometry must be defined that caters the required moment of inertia in a reasonably sized package and is safe against failure at the designed speeds of operation.

Design Parameters

Flywheel inertia (size) needed directly depends upon the acceptable changes in the speed.

Speed fluctuation

The change in the shaft speed during a cycle is called the speed fluctuation and is equal to $\omega_{max} - \omega_{min}$

$$Fl = \omega_{max} - \omega_{min}$$

We can normalize this to a dimensionless ratio by dividing it by the average or nominal shaft speed (ω_{ave}) .

$$C_f = \frac{\omega_{max} - \omega_{min}}{\omega}$$

Where ω_{avg} is nominal angular velocity

Co-efficient of speed fluctuation

The above ratio is termed as coefficient of speed fluctuation C_f and it is defined as

$$C_f = \frac{\omega_{max} - \omega_{min}}{\omega}$$

Where ω is nominal angular velocity, and ω_{ave} the average or mean shaft speed desired. This coefficient is a design parameter to be chosen by the designer.

The smaller this chosen value, the larger the flywheel have to be and more the cost and weight to be added to the system. However the smaller this value more smoother the operation of the device

It is typically set to a value between 0.01 to 0.05 for precision machinery and as high as 0.20 for applications like crusher hammering machinery.

Design Equation

The kinetic energy E_K in a rotating system

$$= \frac{1}{\,} I\left(\omega^2\right)$$

Hence the change in kinetic energy of a system can be given as,

$$E_K = \frac{1}{2} I_m \left(\omega^2_{max} - \omega^2_{min} \right)$$

$$E_K = E_2 - E_1$$

$$\omega_{avg} = \frac{\left(\omega_{max} + \omega_{min}\right)}{2}$$

$$E_K = \frac{1}{\,} I_s \left(2\omega_{avg}\right)\left(C_f \omega_{avg}\right)$$

$$E_2 - E_1 = C_f I \omega^2$$

$$I_s = \frac{E_k}{{}_{f}\;{}^{2}_{avg}}$$

Thus the mass moment of inertia I_m needed in the entire rotating system in order to obtain selected coefficient of speed fluctuation is determined using the relation

$$E_K = \frac{1}{} I_s \left(2\omega_{avg}\right)\left(C_f \omega_{avg}\right)$$

$$I_s = \begin{array}{c} E_k \\ 2 \\ f \quad avg \end{array}$$

The above equation can be used to obtain appropriate *flywheel inertia* I_m corresponding to the known energy change E_K for a *specific value* coefficient of speed fluctuation C_f,

Torque Variation and Energy

The required change in kinetic energy E_k is obtained from the known torque time relation or curve by integrating it for one cycle.

$$\int_{\theta @ \omega_{min}}^{\theta @ \omega_{max}} \left(T_l - T_{avg}\right) d\theta = E_K$$

Computing the kinetic energy E_k needed is illustrated in the following example

Torque Time Relation without Flywheel

A typical torque time relation for example of a mechanical punching press without a fly wheel in shown in the figure.

In the absence of fly wheel surplus or positive enregy is avalible initially and intermedialty and enery absorbtion or negative energy during punching and stripping operations. A large magitidue of speed fluctuation can be noted. To smoothen out the speed fluctuation fly wheel is to be added and the fly wheel energy needed is computed as illustrated below

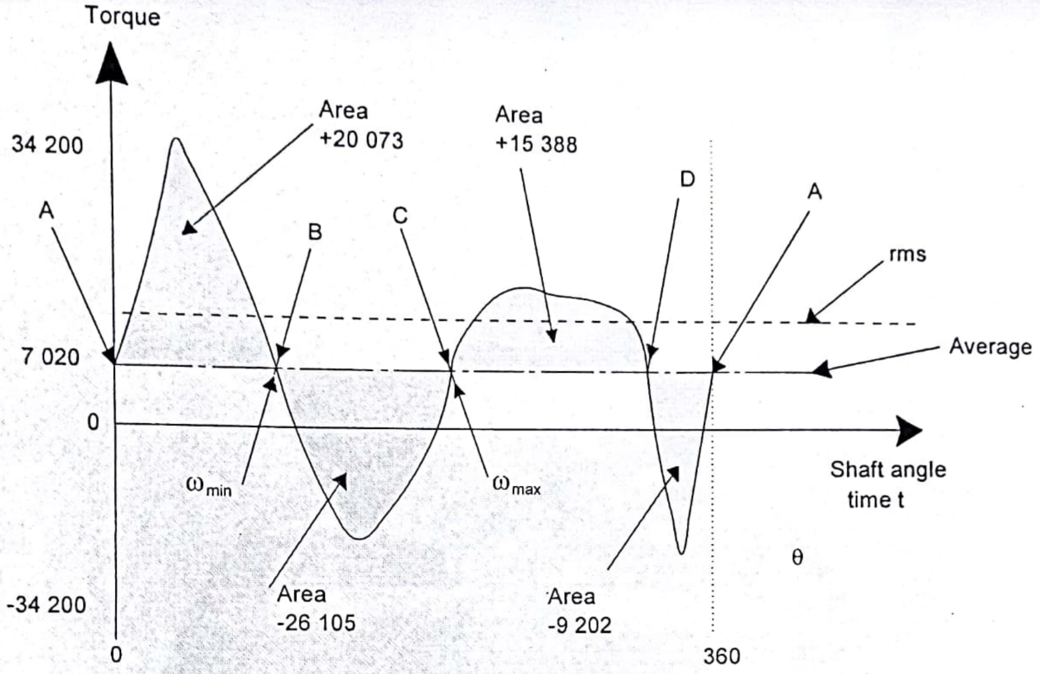


Figure 3.3.2

Accumulation of Energy pulses under a Torque- Time curve

From	△Area=△E	Accumulated sum =E	Min & max
A to B	+20 073	+20 073	ω_{min}@B
B to C	-26 105	-6 032	ω_{max}@C
C to D	+15 388	+9 356	
D to A	-9 202	+154	

Total Energy= E@ω_{min}- E@ω_{min}

=(-6 032)-(+20 073)= 26 105 Nmm^2

Figure 3.3.3

Torque Time Relation with Flywheel

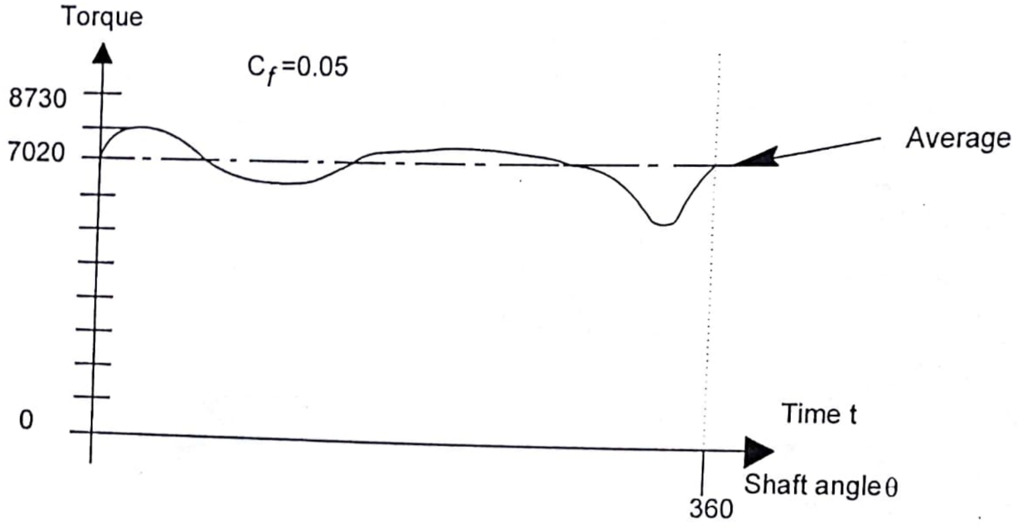


Figure 3.3.4

Geometry of Flywheel

The geometry of a flywheel may be as simple as a cylindrical disc of solid material, or may be of spoked construction like conventional wheels with a hub and rim connected by spokes or arms Small fly wheels are solid discs of hollow circular cross section. As the energy requirements and size of the flywheel increases the geometry changes to disc of central hub and peripheral rim connected by webs and to hollow wheels with multiple arms.

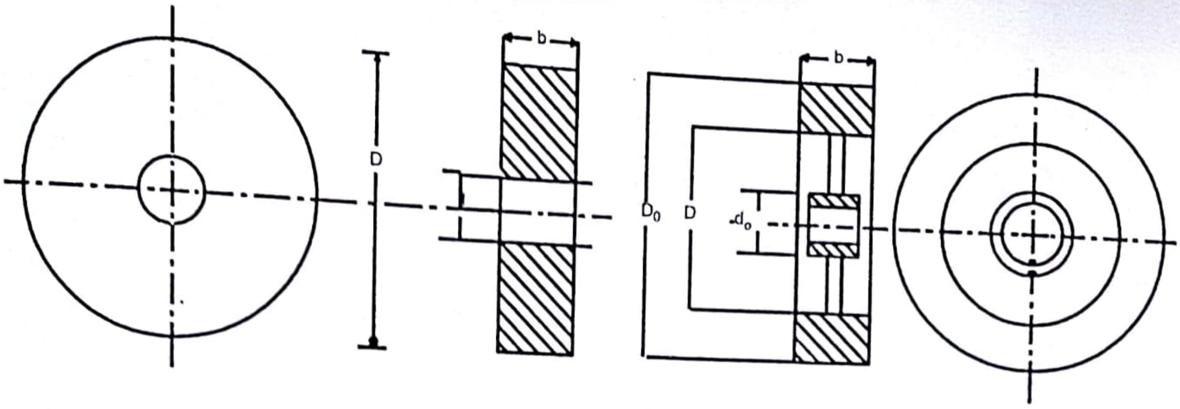
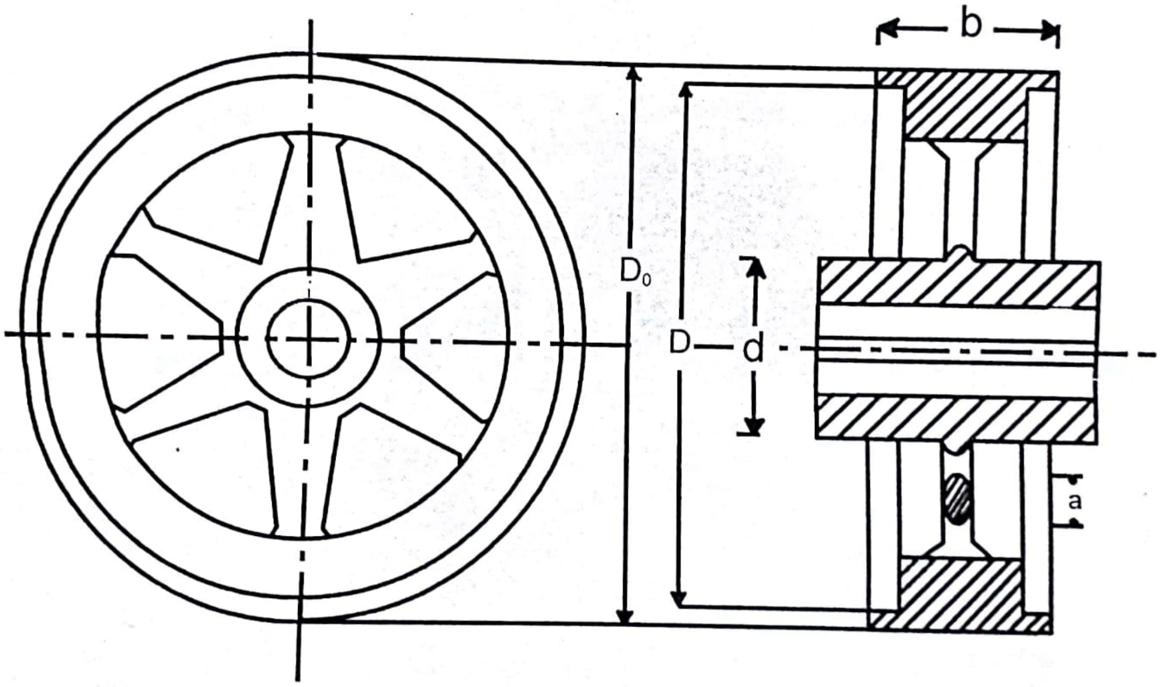


Figure 3.3.5



Arm Type Flywheel

Figure 3.3.6

The latter arrangement is a more efficient of material especially for large flywheels, as it concentrates the bulk of its mass in the rim which is at the largest radius. Mass at largest radius contributes much more since the mass moment of inertia is proportional to mr^2

For a solid disc geometry with inside radius r_i and out side radius r_o, the mass moment of inertia I is

$$I_m = mk^2 = \frac{m}{2}\left(r_o^2 + r_i^2\right)$$

The mass of a hollow circular disc of constant thickness t is

$$m = \frac{W}{g} = \pi\frac{\gamma}{g}\left(r_o^2 - r_i^2\right)t$$

Combing the two equations we can write

$$I_m = \frac{\pi\gamma}{2g}\left(r_o^4 - r_i^4\right)t$$

Where γ is material's weight density

The equation is better solved by geometric proportions i.e by assuming inside to out side radius ratio and radius to thickness ratio.

Stresses in Flywheel

Flywheel being a rotating disc, centrifugal stresses acts upon its distributed mass and attempts to pull it apart. Its effect is similar to those caused by an internally pressurized cylinder

$$\sigma_t = \frac{\gamma}{g}\omega^2\left[\frac{3+v}{8}\right]\left[r^2 + r_o^2 - \frac{1+3v}{3+v}r^2\right]$$

$$\sigma_r = \frac{\gamma}{g}\omega^2\left[\frac{3+v}{8}\right]\left[r^2 + r_o^2 - \frac{r^2 r_o^2}{r^2} - r^2\right]$$

γ = material weight density, ω= angular velocity in rad/sec. v= Poisson's ratio, is the radius to a point of interest, r_i and r_o are inside and outside radii of the solid disc flywheel.

Analogous to a thick cylinder under internal pressure the tangential and radial stress in a solid disc flywheel as a function of its radius r is given by:

Radius

σ_t

Tang. stress

Radial stress

σ_r

Radius

The point of most interest is the inside radius where the stress is a maximum. What causes failure in a flywheel is typically the tangential stress at that point from where fracture originated and upon fracture fragments can explode resulting extremely dangerous consequences, Since the forces causing the stresses are a function of the rotational speed also, instead of checking for stresses, the maximum speed at which the stresses reach the critical value can be determined and safe operating speed can be calculated or specified based on a safety factor. Generally some means to preclude its operation beyond this speed is desirable, for example like a governor.

Consequently

$$F.O.S\ (N) = N_{os} = \frac{\omega}{yield}$$

MAM SCHOOL OF ENGINEERING

Siruganur, Tiruchirappalli – 621 105.

Department of Electronics and Communication Engineering

Academic year (2018-2019) Odd semester

Date: 5th August 2018

Speaker: Ms.P.Kavitha

Head of the Department, ECE Department.

Staff attended:

1. Mrs. P. Sudha
2. Mrs. K.Umarani
3. Mr. M. Chandrasekar
4. Ms. K.Karthikeyan
5. Mr.V.Durgadevi

Topic:

Wireless Sensor Network Architecture and Its Applications

Venue:

Smart class

Date & Time:

5th August 2018 & 1.30 P.M to 2.30 P.M

**enclosure: Report

HOD

PRINCIPAL

REPORT

The session was initiated by Ms.P.Kavitha, HoD/ECE, the topic for the seminar is Wireless Sensor Network Architecture and Its Applications and discuss about the following topics

- Introduction
- Details of Wireless Network
- Applications
-

The session comes to an end with the explaining the overview of Karnaugh Map.

Wireless Sensor Network Architecture and Its Applications

In recent years an efficient design of a Wireless Sensor Network has become a leading area of research. A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing.

Wireless Sensor Networks (WSNs)

A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet.

Wireless Sensor Networks

Wireless Sensor Networks

WSN is a wireless network that consists of base stations and numbers of nodes (wireless sensors).These networks are used to monitor physical or environmental conditions like sound, pressure, temperature and co-operatively pass data through the network to a main location as shown in the figure.

WSN Network Topologies

For radio communication networks, the structure of a WSN includes various topologies like the ones given below.

Wireless Sensor Network Topologie

Wireless Sensor Network Topologies

Star Topologies

Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to a number of remote nodes. In star topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station).

Due to its dependency on a single node to manage the network, the gateway must be within the radio transmission range of all the individual nodes. The advantage includes the ability to keep the remote nodes' power consumption to a minimum and simply under control. The size of the network depends on the number of connections made to the hub.

Tree Topologies

Tree topology is also called as cascaded star topology. In tree topologies, each node connects to a node that is placed higher in the tree, and then to the gateway. The main advantage of the tree topology is

Requires minimal energy – constrains protocols

Have batteries with a finite life time

Passive devices provide little energy

Wireless Sensor Networks Applications

Wireless Sensor Networks Applications

Wireless Sensor Networks Applications

These networks are used in environmental tracking, such as forest detection, animal tracking, flood detection, forecasting and weather prediction, and also in commercial applications like seismic activities prediction and monitoring.

Military applications, such as tracking and environment monitoring surveillance applications use these networks. The sensor nodes from sensor networks are dropped to the field of interest and are remotely controlled by a user. Enemy tracking, security detections are also performed by using these networks.

Health applications, such as Tracking and monitoring of patients and doctors use these networks.

The most frequently used wireless sensor networks applications in the field of Transport systems such as monitoring of traffic, dynamic routing management and monitoring of parking lots, etc., use these networks.

Rapid emergency response, industrial process monitoring, automated building climate control, ecosystem and habitat monitoring, civil structural health monitoring, etc., use these networks.

This is all about the wireless sensors networks and their applications. We believe that the information about all the different types of networks will help you to know them better for your practical requirements. Apart from this, for additional information about wireless SCADA, queries, and doubts regarding this topic or electrical and electronic projects, and for any suggestions, please comment or write to us in the comment section below.

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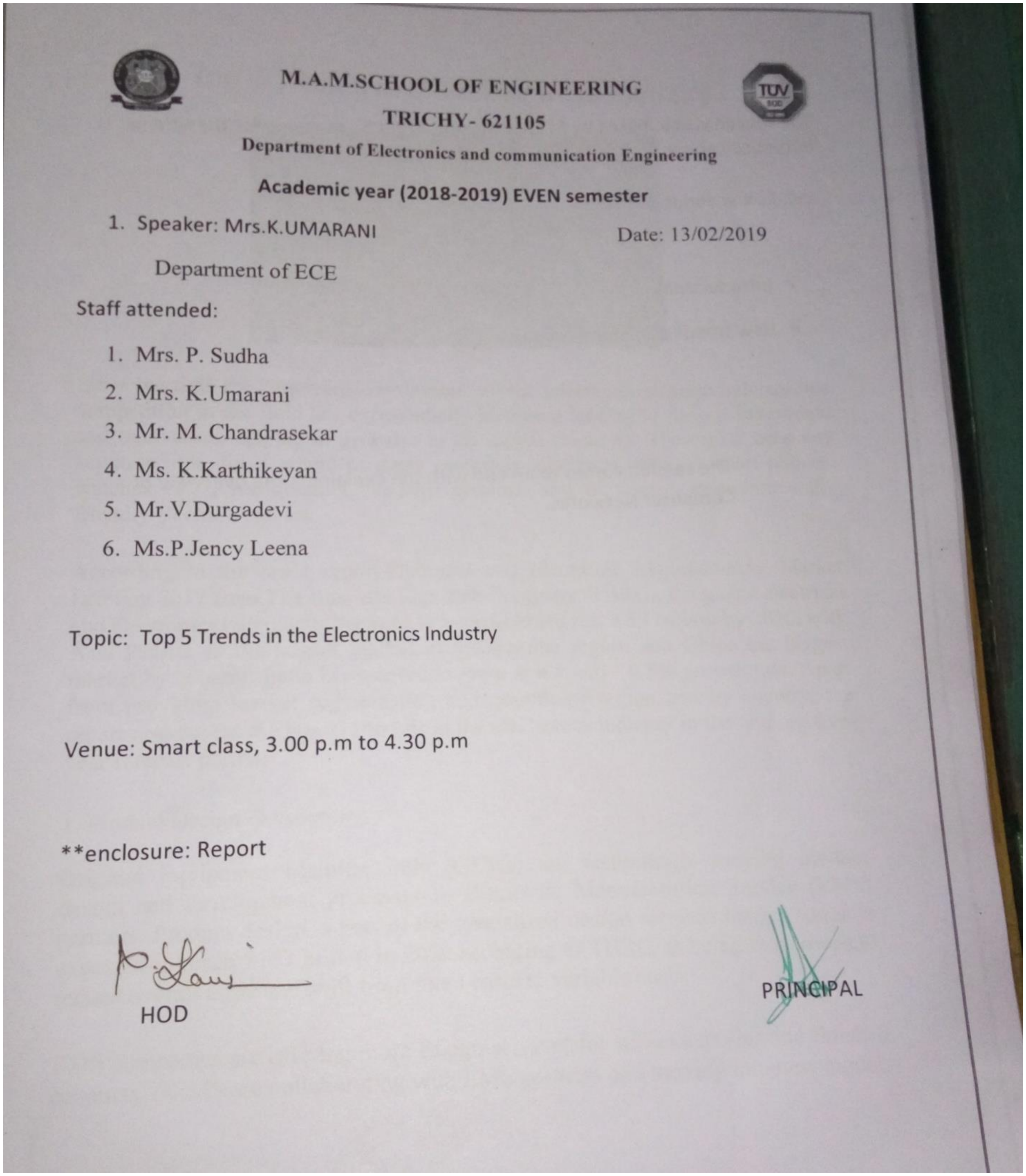
Underground WSNs by amrita

Under Water WSNs by jurdak

Multimedia WSNs by ohio-state

Wireless Sensor Networks Applications by immateriel



M.A.M.SCHOOL OF ENGINEERING

TRICHY- 621105

Department of Electronics and communication Engineering

Academic year (2018-2019) EVEN semester

1. Speaker: Mrs.K.UMARANI   Date: 13/02/2019

   Department of ECE

Staff attended:

1. Mrs. P. Sudha
2. Mrs. K.Umarani
3. Mr. M. Chandrasekar
4. Ms. K.Karthikeyan
5. Mr.V.Durgadevi
6. Ms.P.Jency Leena

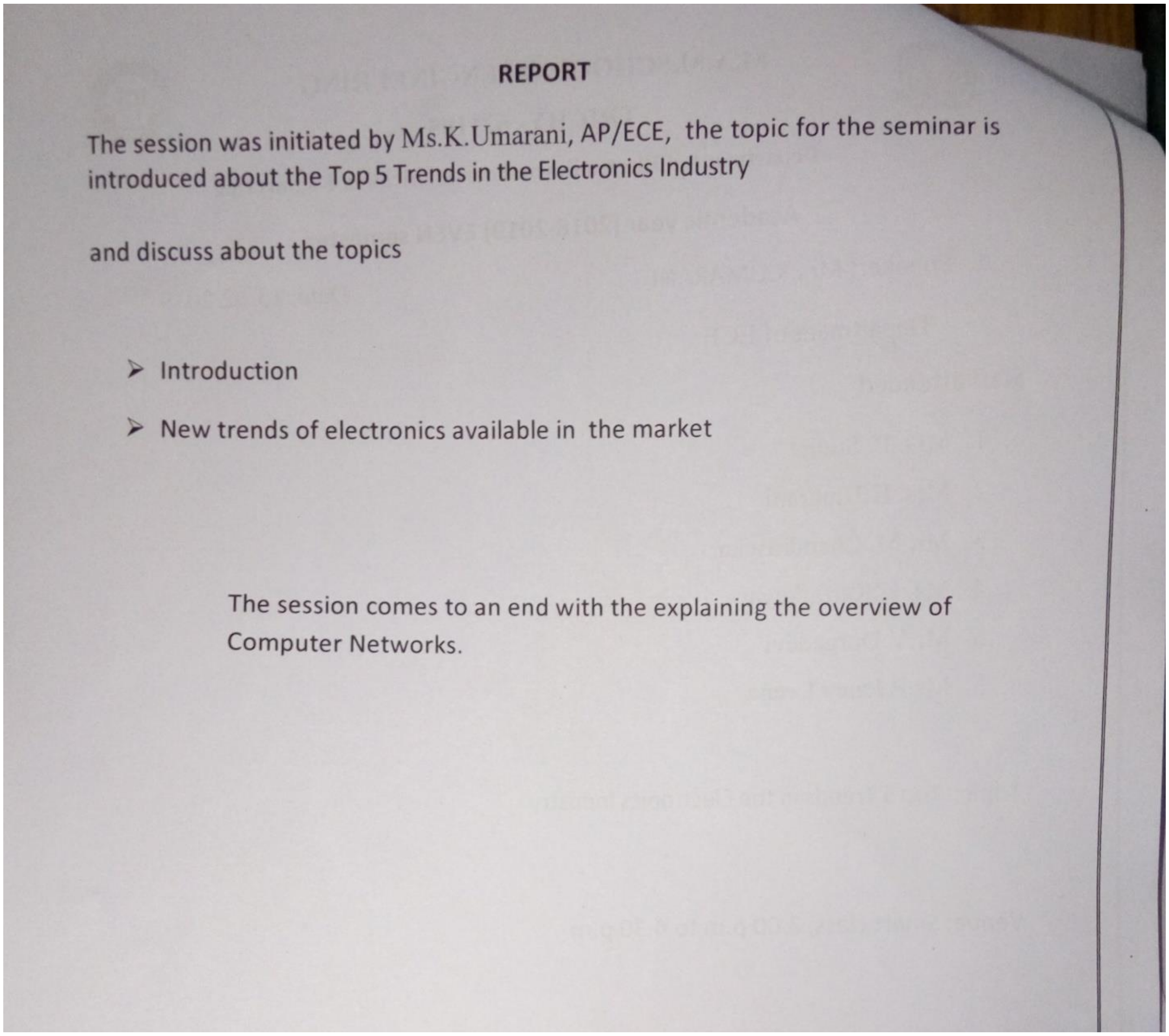
Topic: Top 5 Trends in the Electronics Industry

Venue: Smart class, 3.00 p.m to 4.30 p.m

**enclosure: Report

HOD

PRINCIPAL



REPORT

The session was initiated by Ms.K.Umarani, AP/ECE, the topic for the seminar is introduced about the Top 5 Trends in the Electronics Industry

and discuss about the topics

- Introduction
- New trends of electronics available in the market

The session comes to an end with the explaining the overview of Computer Networks.

Top 5 Trends in the Electronics Industry

Since the time the "electronic revolution" hit the telecommunication industry, the competition in the field has exponentially increased leading to furious investment and innovation, helping to give rise to the digital economy. The digital economy supported the development of many electronic appliances such as smart phones, watches, TVs, refrigerators, security systems, and of course, environmentally friendly electric vehicles.

According to the latest report Electrical and Electronic Manufacturing Market Briefing 2017 from The Business Research Company (TBRC), the global electrical and electronics manufacturing market is expected to reach $3 trillion by 2020, with Asia Pacific as the largest market by geographic region and China the biggest market by country. India is expected to grow at a heady 16.8% growth rate. Apart from providing market segmentation and growth by region and by country, the report also covers the top five trends in the electronics industry in the coming five-year forecast period.

1. Product Design Outsourcing

Original Equipment Manufacturers (OEMs) are increasingly moving product design and development processes to Electronic Manufacturing Service (EMS) partners. Product design, a part of the specialized design services market which is expected to reach $157 billion in 2020 according to TBRC, is being outsourced to reduce overall costs and shift from fixed costs to variable costs.

EMS companies are offering more design services for sub-assemblies and finished products. OEMS are collaborating with EMS partners and moving into new models such as joint design manufacturing (JDM) and outsourced design manufacturing (ODM).

2. Virtual Reality in Electronic Manufacturing

Virtual reality technology is being adopted by electronic manufacturing companies to improve manufacturing efficiency. This technology in the electronic manufacturing industry is often referred to as digital design, simulation, and integration. Virtual reality technology enables companies to inspect design objects at all conceivable scales, thereby eliminating defects in the product in the design stage. Taking into account the growth rate of electronic equipment market globally, which is 5.2% according to TBRC, virtual reality has a big implementation scope in the forecast period.

3. Robotics and Automation

Many electronic equipment companies are using robotics and automation to improve plant efficiency and productivity. Sensors are being used in various machines to access invaluable data for improving efficiencies and reducing potential breakdowns. For instance, according to a report by Boston Consulting Group (BCG) in 2016, 1.2 million industrial robots are expected to be deployed by 2025, while the electronic equipment is expected to reach $2.1 trillion by 2020 according to TBRC, thus indicating a rise in automation and robotics technology adoption to improve productivity and reduce production costs.

4. IoT Technology Driving Smart Household Appliances

Household appliance manufacturers are integrating their products with the IoT technology to make customers lives comfortable and convenient. Internet of Things technology is the interconnectivity of physical objects and devices that are integrated with sensors and software that allow them to exchange and collect data. Major technologies enabling smart household appliances include Wi-Fi, Bluetooth Low Energy, micro server and micro-electromechanical systems.

For instance, LG has created homechat, an app that enables the user to monitor their refrigerators, cookers, washing machines, and other devices from anywhere through their smart phones. The homechat technology was introduced by LG initially in South Korea and is moving to other global markets gradually.

According to report by IHS, the global smart connected electronics shipments is estimated to reach over 223 million by 2020, while the overall market of household appliances is expected to hit $471 million according to TBRC.

5. Growing Demand for Smart TVs

The demand for smart TVs is being driven by the rising consumer preference for built-in smart functions in personal devices, and increasing internet penetration. A smart TV combines the features of televisions and computers, and comprises a television set with integrated functions for internet use. Smart TV users are also offered direct access to streaming services such as Netflix and Amazon Prime Instant Video.

To capitalize on this trend, television manufacturers across the world are entering the smart TV market. According to the IHS Technology report, 48.5% of televisions shipped globally were smart TVs, and the number is estimated to reach 134 million by 2020, while the audio and video equipment manufacturing market is forecast to reach $351 billion according to TBRC.

Read Electrical and Electronics Manufacturing Market Global Briefing 2017 from The Business Research Company for information on the following:

- Market characteristics
- Market size and growth
- Drivers and restraints
- Market segmentation
- Competitive landscape
- Key mergers and acquisitions
- Market trends and strategies

that the expansion of a network can be easily possible, and also error detection becomes easy. The disadvantage with this network is that it relies heavily on the bus cable; if it breaks, all the network will collapse.

Mesh Topologies

The Mesh topologies allow transmission of data from one node to another, which is within its radio transmission range. If a node wants to send a message to another node, which is out of radio communication range, it needs an intermediate node to forward the message to the desired node. The advantage with this mesh topology includes easy isolation and detection of faults in the network. The disadvantage is that the network is large and requires huge investment.

Types of WSNs (Wireless Sensor Networks)

Depending on the environment, the types of networks are decided so that those can be deployed underwater, underground, on land, and so on. Different types of WSNs include:

Terrestrial WSNs

Underground WSNs

Underwater WSNs

Multimedia WSNs

Mobile WSNs

1. Terrestrial WSNs

Terrestrial WSNs are capable of communicating base stations efficiently, and consist of hundreds to thousands of wireless sensor nodes deployed either in unstructured (ad hoc) or structured (Preplanned) manner. In an unstructured mode, the sensor nodes are randomly distributed within the target area that is dropped from a fixed plane. The preplanned or structured mode considers optimal placement, grid placement, and 2D, 3D placement models.

In this WSN, the battery power is limited; however, the battery is equipped with solar cells as a secondary power source. The Energy conservation of these WSNs is achieved by using low duty cycle operations, minimizing delays, and optimal routing, and so on.

2. Underground WSNs

The underground wireless sensor networks are more expensive than the terrestrial WSNs in terms of deployment, maintenance, and equipment cost considerations and careful planning. The WSNs networks consist of a number of sensor nodes that are hidden in the ground to monitor underground conditions. To relay information from the sensor nodes to the base station, additional sink nodes are located above the ground.

Underground WSNs

Underground WSNs

The underground wireless sensor networks deployed into the ground are difficult to recharge. The sensor battery nodes equipped with a limited battery power are difficult to recharge. In addition to this, the underground environment makes wireless communication a challenge due to high level of attenuation and signal loss.

3. Under Water WSNs

More than 70% of the earth is occupied with water. These networks consist of a number of sensor nodes and vehicles deployed under water. Autonomous underwater vehicles are used for gathering data from these sensor nodes. A challenge of underwater communication is a long propagation delay, and bandwidth and sensor failures.

Under Water WSNs

Under Water WSNs

Under water WSNs are equipped with a limited battery that cannot be recharged or replaced. The issue of energy conservation for under water WSNs involves the development of underwater communication and networking techniques.

4. Multimedia WSNs

Muttimedia wireless sensor networks have been proposed to enable tracking and monitoring of events in the form of multimedia, such as imaging, video, and audio. These networks consist of low-cost sensor nodes equipped with micrpphones and cameras.These nodes are interconnected with each other over a wireless connection for data compression, data retrieval and correlation.

Multimedia WSNs

Multimedia WSNs

The challenges with the multimedia WSN include high energy consumption, high bandwidth requirements, data processing and compressing techniques. In addition to this, multimedia contents require high bandwidth for the contents to be delivered properly and easily.

5. Mobile WSNs

These networks consist of a collection of sensor nodes that can be moved on their own and can be interacted with the physical environment. The mobile nodes have the ability to compute sense and communicate.

The mobile wireless sensor networks are much more versatile than the static sensor networks. The advantages of MWSN over the static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on.

Limitations of Wireless Sensor Networks

Possess very little storage capacity – a few hundred kilobytes

Possess modest processing power-8MHz

Works in short communication range – consumes a lot of power

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DEPARTMENT OF AERONAUTICAL ENGINEERING

Teacher Teach Teachers Scheme (TTT)

Title: Loads of an Aircraft

Venue: Aerodynamics Laboratory

Date & Time: 10.07.2018 & 04.00 pm to 05.00 pm

Mentor Faculty	Faculty Attended
Dr.P.V.K. Perumal	Mr.K.M.Sridhar Ms.M.Suba Pradha Mr.M.F.Mohamed Hussain Ms.V.Priyadharshini

10/7/18

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DEPARTMENT OF AERONAUTICAL ENGINEERING

Teacher Teach Teachers Scheme (TTT)

Title: Optimization Techniques

Venue: Aerodynamics Laboratory

Date & Time: 07.02.2019 & 04.00 pm to 05.00 pm

Mentor Faculty	Faculty Attended
Dr.K.Chandrasekaran	Mr.K.M.Sridhar Mr.Senthil Kumar Mr.M.F.Mohamed Hussain Mr.V.S.M.Balamurali

HOD/AERO