IoT (Internet of Things)

IoT Introduction

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IoT (Internet of Things)

- IoT provides networking to connect people, things, applications, and data through the Internet to enable remote control, management, and interactive integrated services
- IoT Network Scale
  - Number of mobile devices exceeds the number of people on Earth
  - Predictions are made that there will be 50 billion 'things' connected to the Internet by 2020

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IoT Service Support

- Some advanced IoT services will need to collect, analyze, and process segments of raw sensor data and turn in into operational control information
  - Some sensor data types may have massive sizes (due to large number of IoT devices)
  - IoT databases will need Cloud Computing support
  - IoT data analysis will need Big Data support

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Influence of IoT

- **People: More 'things' can be monitored and controlled ➔ People will become more capable**
- **Process: More users and machines can collaborate in real-time ➔ More complex tasks can be accomplished in lesser time**
- **Data: Collect data more frequently and reliably ➔ Results in more accurate decision making**
- **Things: 'Things' become more controllable ➔ Mobile devices and 'things' become more valuable**

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Economic Impact

- Predictions have been made that IoT has the potential to increase global corporate profits by 21% (in aggregate) by 2022

Asset Utilization	$2.5T	$19 Trillion Market
Employee Productivity	$2.5T	
Supply Chain & Logistics	$2.7T	
Customer Experience	$3.7T	
Innovation	$3.7T	

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Economic Impact

- **M2M (Machine-to-Machine) connections are increasingly important**
- **P2P (Person-to-Person) as well as P2M (Person-to-Machine) & M2P (Machine-to-Person) still represent the majority of IoT's economic value**

M2M	$6.4T	45%
M2P or P2M	$3.5T	55%
P2P	$4.5T	

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IoT Applications

- **Security**: Surveillance applications, alarms, real-time object/people tracking and monitoring
- **Transportation**: Fleet management, road safety, emission control, toll payment, real-time traffic monitoring, and many more ITS (Intelligent Transport Systems) applications
- **Healthcare**: E-health, personal security, body-sensor based customized healthcare systems

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IoT Applications

- **Utilities: Measurement, provisioning, and billing of utilities (e.g., gas, water, electricity, etc.)**
- **Manufacturing: Monitoring and automation of a production chain**
- **Supply & Provisioning: Freight supply, distribution monitoring, and vending machines**
- **Facility Management: Home, building, and campus automation**

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IoT & M2M Ecosystem

Segment	Description	Companies / Organizations
Services	BSP (Business Service Providers / Business Solution Providers)	Jasper wireless, KORE, ECHELON, Axeda, ei 3
	System integrators and IoT solution providers for enterprises	hp, QUALCOMM, Deloitte., IBM, accenture, CSC
Network	Network operators, communications service providers, and transport infrastructure providers	verizon, Sprint, at&t, CISCO, vodafone, Deutsche Telekom

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IoT & M2M Ecosystem

Segment	Description	Companies / Organizations
Software	Software manufacturers, middleware and application infrastructure vendors, IoT OS providers	
Hardware	Manufacturers of GPS chips, wireless sensors, wearable devices, actuators, and embedded hardware devices	

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IoT

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IoT (Internet of Things)

IoT Architecture

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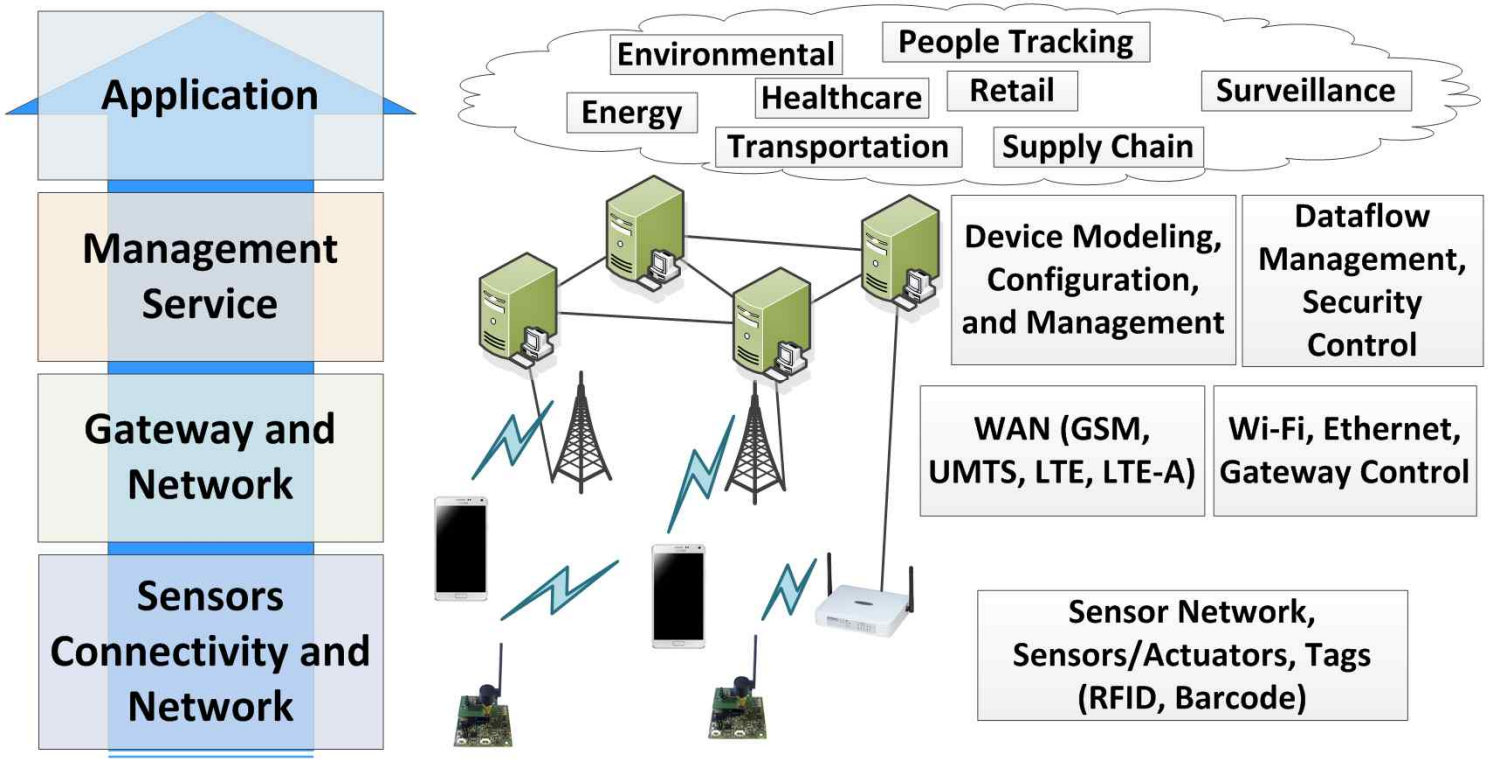
IoT Architecture Layers



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- **Sensor Layer**

Sensors Connectivity and Network

LAN

Wi-Fi | Ethernet

PAN

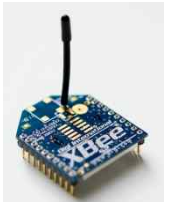
UWB | ZigBee | Bluetooth | 6LoWPAN | Wired

Sensors / Actuators

Solid State	Catalytic	Gyroscope
Photochemistry	GPS	Photoelectric
Infrared	Accelerometer	

Tag

RFID | Barcode (1D, 2D)



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Sensor Layer

- Made up of sensors and smart devices
- Real-time information to be collected and processed
- Sensors use low power and low data rate connectivity
- WSN (Wireless Sensor Network) formation
- Sensors are grouped according to their purpose and data types (e.g., environmental sensors, military sensors, body sensors, home sensors, surveillance sensors, etc.)

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Sensor Aggregators (Gateways)

- LAN (Local Area Network): Ethernet and Wi-Fi connections
- PAN (Personal Area Network): ZigBee, Bluetooth, and 6LowPAN
- Sensors which do not require connectivity to a LAN gateway can be directly connected to the Internet through a WAN (Wide Area Network) interface

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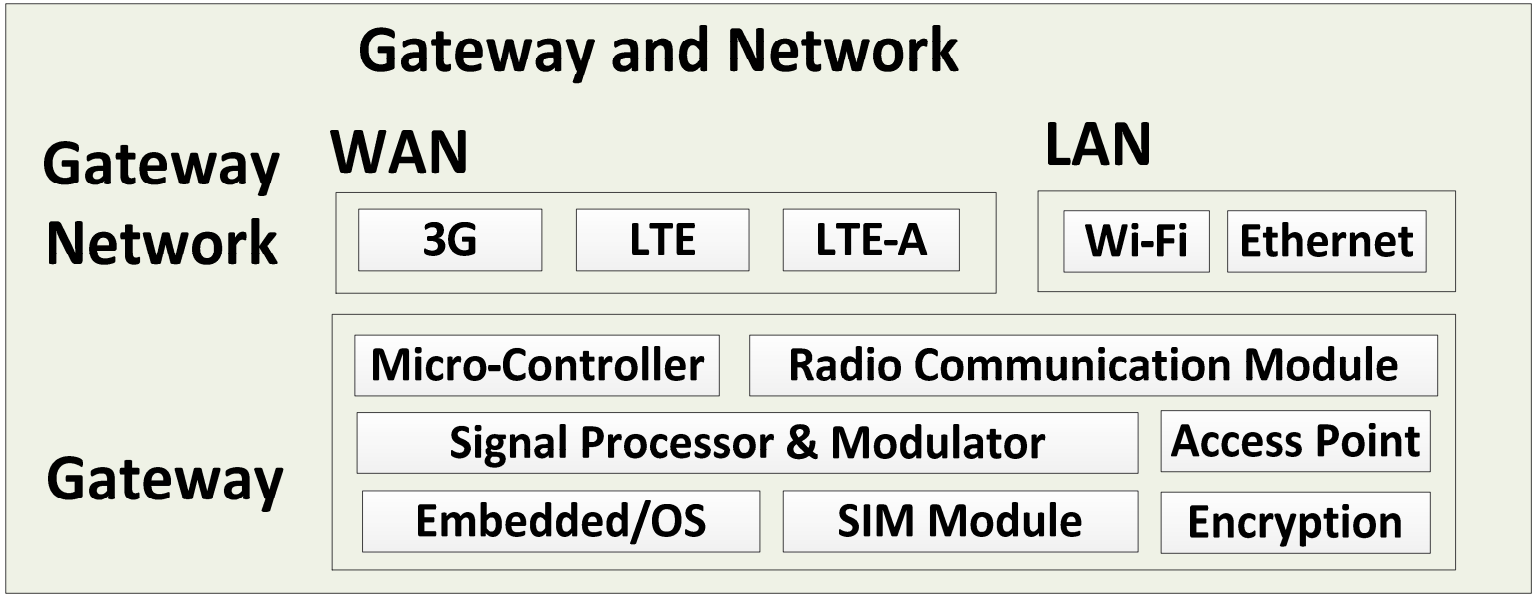
Gateway & Network Layer



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Gateway & Network Layer

- Must support massive volumes of IoT data produced by wireless sensors and smart devices
- Requires a robust and reliable performance, regarding private, public or hybrid network models
- Network models are designed to support the communication QoS requirements for latency, error probability, scalability, bandwidth, security, while achieving high levels of energy efficiency

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Gateway & Network Layer

- It is important to integrate different types of networks into a single IoT platform
- IoT sensors are aggregated with various types of protocols and heterogeneous networks using different technologies
- IoT networks need to be scalable to efficiently serve a wide range of services and applications over large scale networks

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Management Service Layer

Management Service

OSS (Operational Support System): Device Modeling / Configuration / Management, Performance Management, Security Management

BSS (Billing Support System): Billing Reporting

Service Analytics Platform: Statistical Analytics, Data Mining, Text Mining, In-Memory Analytics, Predictive Analytics

Security: Access Controls, Encryption, Identify Access

BRM (Business Rules Management): Rule Definition / Modeling / Simulation/ Execution

BPM (Business Process Management): Workflow Process Modeling / Simulation / Execution

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Management Service Layer

- Management Service Layer is in charge of
  - Information Analytics
  - Security Control
  - Process Modeling
  - Device Management
- Data Management
  - Periodic IoT sensor data requires filtering
  - Aperiodic event triggered IoT sensor data may require immediate delivery & response
    - Example: Patient medical emergency sensor data

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Management Service Layer

- Data Management
  - Manages data information flow
  - Information access, integration, control
- Data Abstraction
  - Information extraction processing
  - Used as a common business model

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Application Layer

Applications

Sector

Environmental	Energy	Transportation	Healthcare	Retail	Military

Horizontal Market

Fleet Management	Asset Management	Supply Chain	People Tracking	Surveillance

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Application Layer

- Various applications from industry sectors can use IoT for service enhancement
- Applications can be classified based on the type of network availability, coverage, size, heterogeneity, business model, as well as real-time or non-real-time requirements

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Application Layer

- **Personal and Home: IoT at the scale of an individual or home**
- **Enterprise: IoT at the scale of a community**
- **Utility: IoT at a national or regional scale**
- **Mobile: Devices are usually spread across other domains mainly due to their mobility**

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Application Layer

Smart Environment Application Domains

	Smart Home	Smart Office	Smart Retail	Smart City	Smart Agriculture	Smart Energy & Fuel	Smart Transportation	Smart Military
Network Size	Small	Small	Small	Medium	Medium /Large	Large	Large	Large
Network Connectivity	WPAN, WLAN, 3G, 4G, Internet	WPAN, WLAN, 3G, 4G, Internet	RFID, NFC, WPAN, WLAN, 3G, 4G, Internet	RFID, NFC, WLAN, 3G, 4G, Internet	WLAN, Satellite Comm., Internet	WLAN, 3G, 4G, Microwave links, Satellite Comm.,	WLAN, 3G, 4G, Satellite Comm.	RFID, NFC, WPAN, WLAN, 3G, 4G, Satellite Comm.
Bandwidth Requirement	Small	Small	Small	Large	Medium	Medium	Medium~Large	Medium~Large

- WLAN: Wi-Fi, WAVE, IEEE 802.11 a/b/g/p/n/ac/ad, etc.
- WPAN: Bluetooth, ZigBee, 6LoWPAN, IEEE 802.15.4, UWB, etc.

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Application Layer

Smart Environment Application Domains

Service Domain	Services
Smart Home	Entertainment, Internet Access
Smart Office	Secure File Exchange, Internet Access, VPN, B2B
Smart Retail	Customer Privacy, Business Transactions, Business Security, B2B, Sales & Logistics Management
Smart City	City Management, Resource Management, Police Network, Fire Department Network Transportation Management, Disaster Management
Smart Agriculture	Area Monitoring, Condition Sensing, Fire Alarm, Trespassing
Smart Energy & Fuel	Pipeline Monitoring, Tank Monitoring, Power Line Monitoring, Trespassing & Damage Management
Smart Transportation	Road Condition Monitoring, Traffic Status Monitoring, Traffic Light Control, Navigation Support, Smart Car Support, Traffic Information Support, ITS (Intelligent Transportation System)
Smart Military	Command & Control, Communications, Sensor Network, Situational Awareness, Security Information, Military Networking

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IoT (Internet of Things)

IoT Technologies

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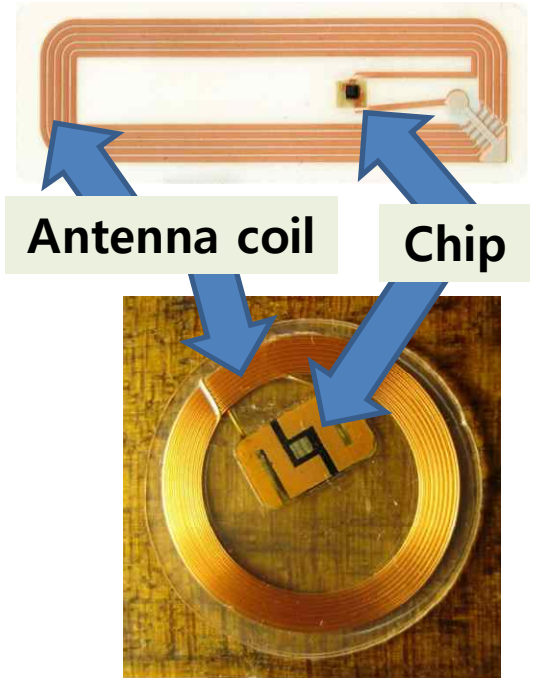
RFID (Radio Frequency Identification)

- RFID chip holds information about the 'thing'
- RFID chip is attached and transfers data to the reader
- Antenna is used to receive energy that is used to operate the RFID device and transmit information back to the reader



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RFID (Radio Frequency Identification)

- RFID enables efficient management, tracking, and monitoring processes
  ➔ Logistics and supply chain applications
- RFID R&D
  - Streams of data support
  - Chip design
  - Energy usage optimization
  - Automatic meter reading
  - Home automation applications
  - Vehicle & transportation applications

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WSN (Wireless Sensor Networks)

- Efficient, low cost, low power devices for use in remote sensing applications
  - Low power integrated circuits and wireless communications
- A large number of intelligent sensors collect raw data, and create valuable services by processing, analyzing, and spreading data
- Challenges are related to limited processing capability and storage, and sensor data sharing for multiple device/system cooperation

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IoT Cloud Computing Support

- For Advanced IoT services, IoT networks may need to collect, analyze, and process segments of raw data and turn it in into operational control information
- Advanced IoT services will need support of cloud computing
  - Numerous IoT connections will be made to various devices and sensors
  - Many IoT devices will not have (PC or smartphone level) sufficient data processing capability or interoperability functionality

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Cloud Computing

- IoT applications will need support from a reliable, fast, and agile computing platform
- IoT devices can overcome lack of Software, Firmware, Memory Storage, Hardware, Data Processing capability through Cloud computing
- Cloud service models
  - SaaS (Software as a Service)
  - PaaS (Platform as a Service)
  - IaaS (Infrastructure as a Service)

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IoT R&D (Research & Development)

- Many IoT devices have small memory and limited processing & communication functionalities and are also battery operated
- IoT requires integration of multi-technology networks to a common IP network platform
  - IPv4 & IPv6 protocols support addressing, management, and scalability requirements
  - IoT will have significant influence on the future Internet architecture

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IoT R&D

- IoT services must guarantee the security, privacy, integrity of information and user confidentiality
- Key Features
  - ‘Thing’ Authentication & Authorization
  - User Authentication & Authorization
  - ‘Thing’ to ‘Thing’ Access Control
  - IoT Public & Private Key Management
  - IoT Low Overhead Protocols
  - IoT Low Complexity Processing

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IoT R&D

- Mobility Support
  - Mobility support increases the applicability of Internet to new areas
  - Mobile platform based IoT enables an enormous range of future applications
    - LBS (Location based Service)
    - Social Networking
    - Environment Monitoring & Interaction

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IoT R&D

- Energy and Resource Management
  - Energy issues are related to optimization of energy harvesting, conservation, and usage, and are essential to the development of IoT
  - It is important to consider resource restrictions such as wake-up delays,
    power consumption and limited battery,
    and packet size

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IoT R&D

- Identification Technology
  - IoT devices produce their own contents, and the contents are shared by any authorized user
  - Identification and authentication technologies need to be converged and interoperated at a global scale
  - Management of unique identities for ‘things’ and handling of multiple identifiers for people and locations

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IoT (Internet of Things)

IoT Networks

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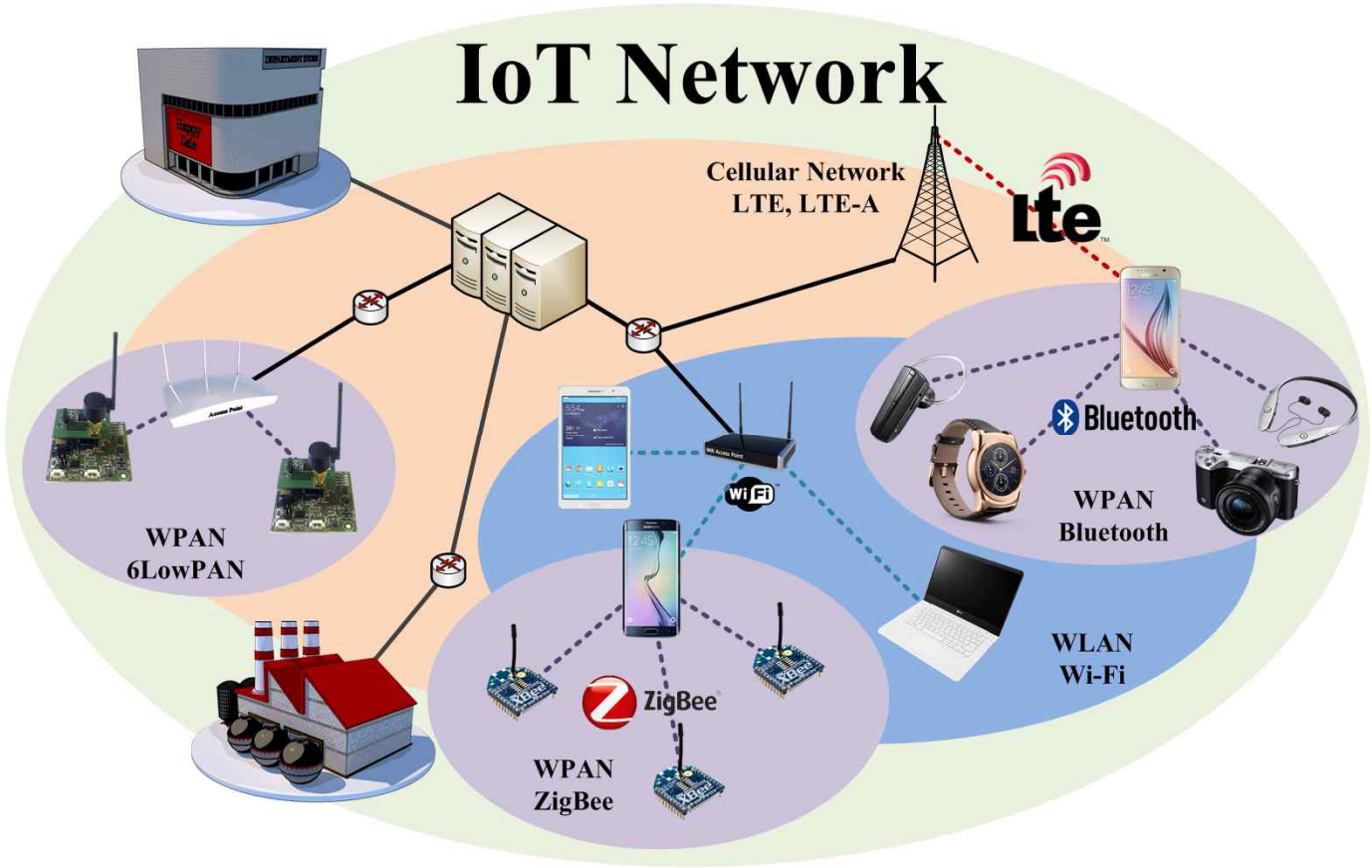
IoT Network



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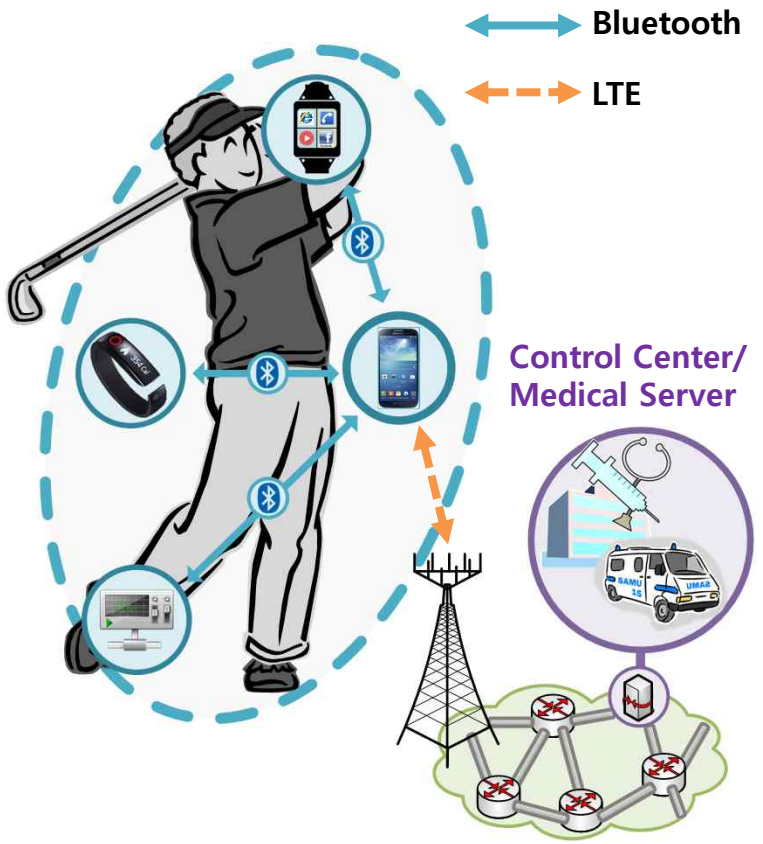
Wearable IoT Network

Wearable IoT Network

- **Wearable devices** (e.g., shoes, watch, glasses, belt, etc.) can be used to detect **biometric** information
- **Smart device** collects the information and communicates with **control center** and/or **medical server** through the **Internet**



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Wi-Fi

Wi-Fi

- Wi-Fi is a WLAN (Wireless Local Area Network) technology based on the IEEE 802.11 standards
- Wi-Fi Devices
  - Smartphones, Smart Devices, Laptop Computers, PC, etc.
- Applications Areas
  - Home, School, Computer Laboratory, Office Building, etc.

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- **Wi-Fi**
  - **Wi-Fi devices and APs (Access Points) have a wireless communication range of about 30 meters indoors**
  - **Wi-Fi data rate is based on its protocol type**
    - **IEEE 802.11a can achieve up to 54 Mbps**
    - **IEEE 802.11b can achieve up to 11 Mbps**
    - **IEEE 802.11g can achieve up to 54 Mbps**
    - **IEEE 802.11n can achieve up to 150 Mbps**
    - **IEEE 802.11ac can achieve up to 866.7 Mbps**
    - **IEEE 802.11ad can achieve up to 7 Gbps**

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Bluetooth

Bluetooth

- Bluetooth is a WPAN (Wireless Personal Area Network) protocol designed by the Bluetooth SIG (Special Interest Group)

- Replaces cables connecting many different types of devices
  - Mobile Phones & Headsets
  - Heart Monitors & Medical Equipment

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Bluetooth

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Bluetooth

- Bluetooth's standard PAN range is usually 10 meters (50 m in Bluetooth 4.0)
- Bluetooth Low Energy (in Bluetooth 4.0) provides reduced power consumption and cost while maintaining a similar communication range
- Bluetooth 2.0 + EDR can achieve up to 2.1 Mbps
- Bluetooth 3.0 + HS can achieve up to 24 Mbps
- Bluetooth 4.0 can achieve up to 25 Mbps

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IEEE 802.15.4

IEEE 802.15.4 Standard

- Low-cost, low-speed, low-power WPAN (Wireless Personal Area Network) protocol
- IEEE 802.15.4 applications
  - ZigBee, 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks), WirelessHART (Highway Addressable Remote Transducer), RF4CE (Radio Frequency for Consumer Electronics), MiWi (Microchip Wireless Protocol), and ISA100.11a

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IEEE 802.15.4

IEEE 802.15.4 Device Types

- FFD (Full Function Device)
  - Equipped with full functionality (i.e., send, receive, route data, cluster formation)
  - Can serve as the PAN (Personal Area Network) coordinator
- RFD (Reduced Function Device)
  - Reduced functional protocol
  - Can only communicate to FFDs
    - Cannot serve as a PAN coordinator
    - Serves role of simple sensor or switch
    - No routing functionality

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IEEE 802.15.4

IEEE 802.15.4 Definitions

- Network Topology
  - Star network
  - P2P (peer-to-peer) network
  - Mesh network (P2P extension with FFDs)
  - Cluster Tree network
- Coordinator
  - Controls the IEEE 802.15.4 network
  - Special form of FFD
    - Typical FFD functions and network coordination & services features

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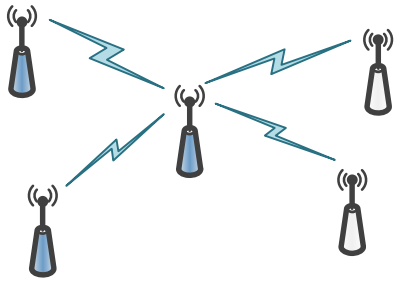
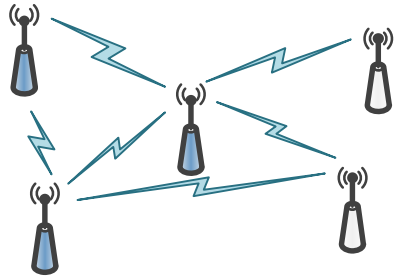
IEEE 802.15.4 Network Topologies

Star Topology		• Nodes communicate via the central PAN coordinator
P2P Topology		• Nodes can communicate via the PAN coordinator and via point-to-point links • Extension of the star topology

 : FFD  : RFD

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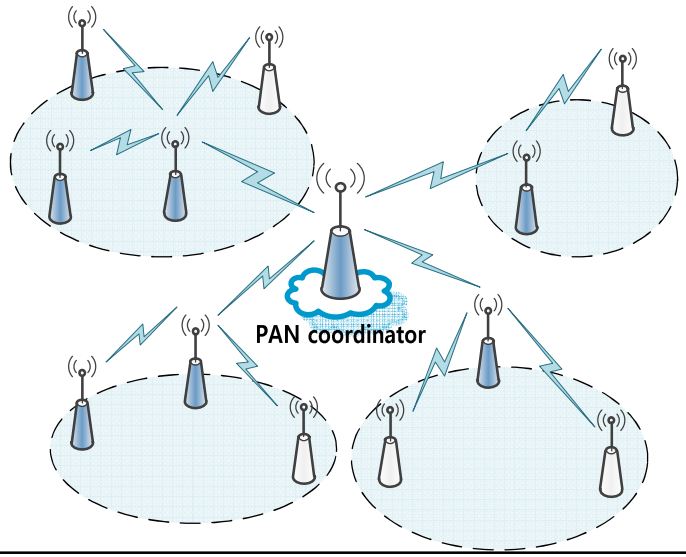
IEEE 802.15.4 Network Topologies

Cluster Tree Topology	
	• Cluster trees are similar to stars, though RFDs are only allowed to connect as the outer most branches • Diagram shows that the FFD connect to the coordinator, and a FFD can have connections to multiple end devices

 : FFD  : RFD

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IEEE 802.15.4 General Frame Format

Octets: 2	1	0/2	0/2/8	0/2	0/2/8	variable	2
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Frame Payload	Frame Check Sequence

Bits: 0-2	3	4	5	6	7-9	10-11	12-13	14-15
Frame Type	Security Enabled	Frame Pending	Ack. Requested	Intra PAN	Reserved	Destination Address Mode	Reserved	Source Address Mode

- Max. frame size: 127 octets
- Max. frame header: 25 octets

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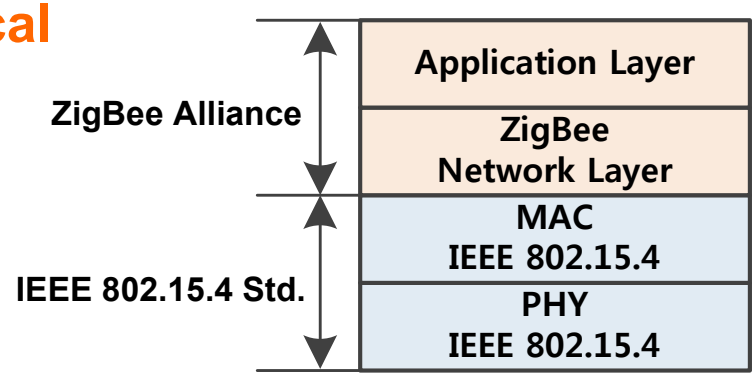
ZigBee

ZigBee

- Supported by the ZigBee Alliance
- Provides IEEE 802.15.4 higher layer protocols required for low powered radio system
  - IEEE 802.15.4 defines the physical and MAC layers
  - ZigBee provides the application and network layer protocols



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ZigBee

ZigBee 

- ZigBee works well in isolated network environments
- ZigBee Network Topologies
  - Star, Mesh, Cluster Tree or Hybrid Network
  - Star network is the basic common topology
  - Mesh & P2P networks can provide high reliability (via multiple routes between nodes)
  - Cluster tree network is a combination of Star and P2P topologies

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6LoWPAN

6LoWPAN (IPv6 over Low power Wireless Personal Area Networks)

- Supports IPv6 packets over IEEE 802.15.4 WPANs
  - Enables IPv6 IoT wireless network support
  - Low power design aspect included
    - Good for battery operated IoT devices

- 6LoWPAN is an IETF (Internet Engineering Task Force) standard that uses the IEEE 802.15.4 WPAN technology

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IPv6 Advantages of 6LoWPAN

- WPAN direct connection to IPv6 Internet
- IPv6 features can be used to support the WPAN
  - Can use IPv6 security (i.e., IPsec, Encapsulation, Authentication, Access Control, Firewall Protocols, etc.)
  - IPv6 naming, addressing, translation, lookup, and discovery function can be used

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6LoWPAN Characteristics

- Small packet size that supports 16-bit short or IEEE 64-bit extended MAC (Medium Access Control) addresses
- Low data rates of 20, 40, 250 kbps
- Star & Mesh topologies (based on IEEE 802.15.4)
- Good for low power battery operated nodes
- Relatively low cost devices

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HC (Header Compression)

- 6LoWPAN & IPv6 packet size matching required
  - IPv6 minimum packet size is 1280 octets
  - IEEE 802.15.4 has an MTU of 127 octets
  - IPv6 Header has a 40 octet minimum length
- Compress IP address when it can be derived from other headers (i.e., IEEE 802.15.4 header)
- Compress Prefix for Link-Local Addresses
- Completely omit 128 bit IPv6 address when it can be provided from the link-layer address
- Compress common headers ➔ TCP, UDP, ICMP

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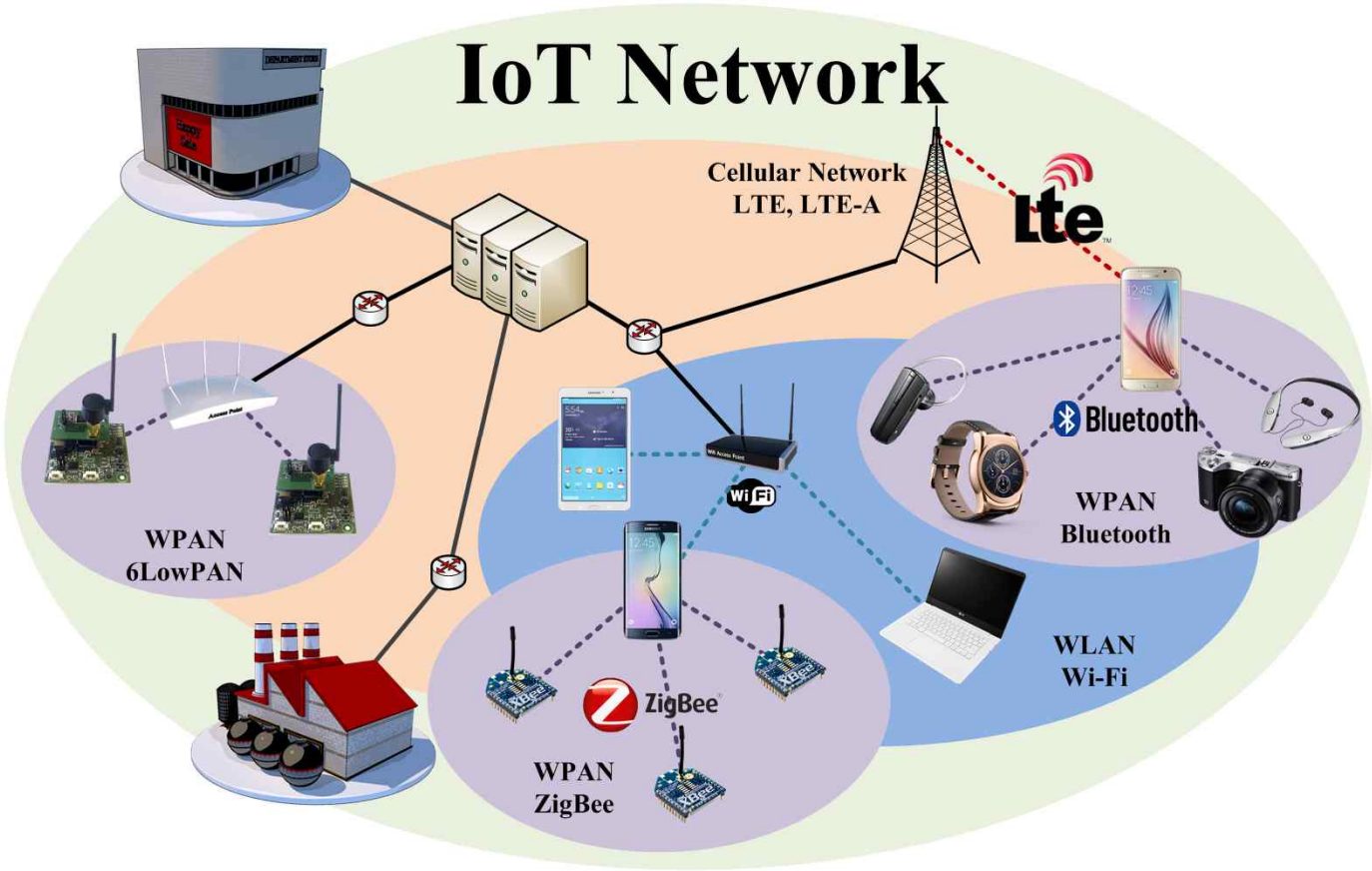
IoT Network



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IoT

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AR (Augmented Reality)

AR Introduction

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AR (Augmented Reality) Definition

- AR is a technology that superimposes a user's real world view with (computer-generated) virtual text or image on the user's viewing screen, monitor, helmet facemask, glasses, goggles, HMD (Head-Mounted Display), window, windshield, etc. in real-time!
- Virtual text or image can be superimposed on selected objects in the real world view of the user, where the virtual text or image is about the selected object

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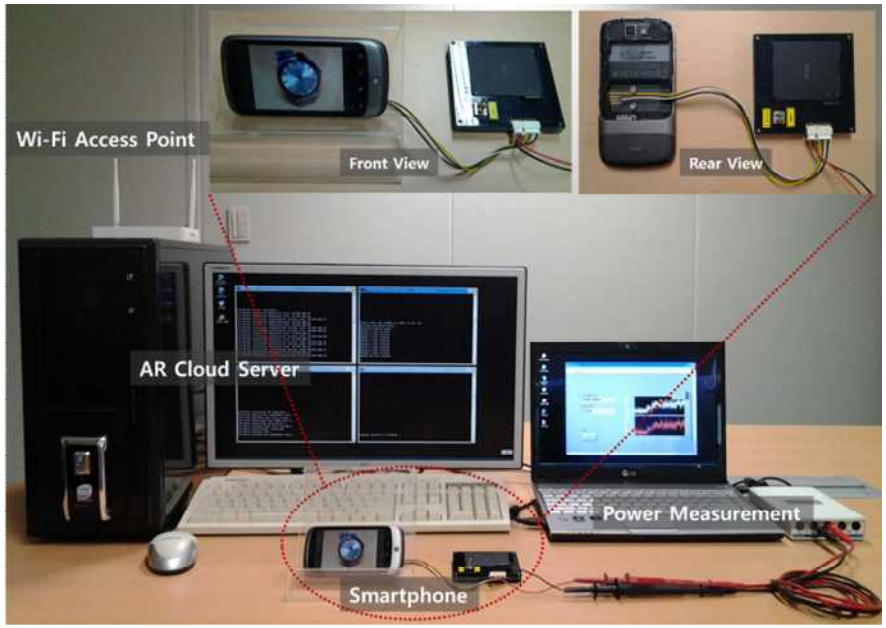
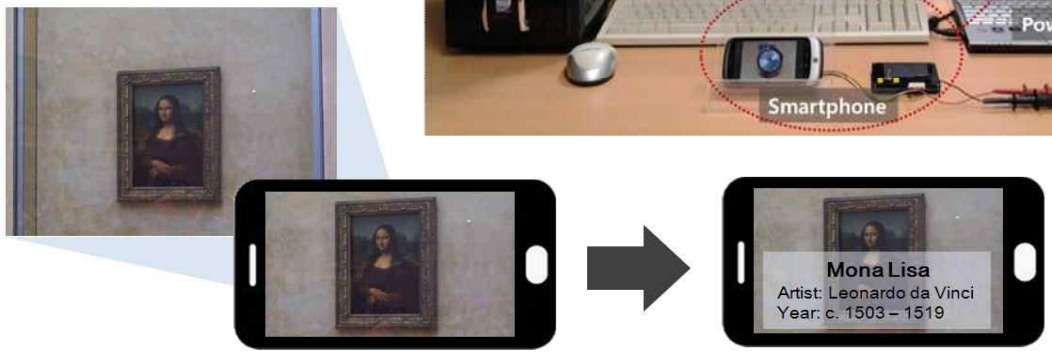
AR

AR Definition

- AR is based on **Context Aware Computing**
- For an AR user, the **Real World** & **Virtual Objects** coexist on the same view





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Short History of AR and VR

- In 1901, author L. Frank Baum first mentions the idea of 'character marker' which is an electronic display overlaying on real life (people)
- In 1989, Jaron Lanier coins the phrase 'Virtual Reality' (VR) and its concept model
- In 1990, Thomas P. Caudell creates the concept and phrase 'Augmented Reality' (AR)

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Questions on AR and VR

- What is the difference of
  VR (Virtual Reality) and AR (Augmented Reality)?
- AR (Augmented Reality) seems like a very old technology.
  So why learn about it now?

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AR

YONSEI UNIVERSITY

Why is AR important now?

- The concept of AR is old, but only recently it became fully implementable and reliable!
  Let see why!

- Higher resolution cameras on smart devices enable accurate image and object identification

- Enhanced processing capability of CPUs and GPUs on smart devices enable fast and reliable image processing, object identification, and feature extraction

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AR

YONSEI UNIVERSITY

Why is AR important now?

- Large memory and fast input/output memory access enables large amounts of AR object information to be stored and quickly used
- HD (High Definition) displays on smart devices enable sharp virtual text and images to be superimposed in an elegant and easy-on-the-eye fashion
- Broadband wireless and wired networking enables AR servers/database information to be quickly retrieved

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Future of AR

- New AR Platforms ➔ More Smart Device Types
  - Smartphones, Smart Devices, Smart Glasses, Smart Watches, Wearable IoT Devices, etc.
- AR will only get better!
  - Faster, More Accurate, More Informative, Lower Power Consuming → Longer Lifelines, Easer to Use, More Portable, Cheaper,
    More Functions/Features, More Reliable,
    More Durable, etc.

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AR vs. VR

- VR (Virtual Reality) Characteristics
  - VR user will be fully immersed into an artificial (animated) environment
    - Game playing spaces are commonly VR spaces
    - User/player will commonly use an avatar to exist and interact inside the VR space
    - User's view in VR is different from the real environment ➔ Fantasies & illusions are easy to create in the virtual world

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AR vs. VR

- **AR (Augmented Reality) Characteristics**
  - **AR is a mixture of real life and virtual reality**
  - **AR users are able to obtain useful information about location or objects, and can interact with virtual contents in the real world**
  - **AR users can distinguish the superimposed virtual objects**

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AR vs. VR

YONSEI UNIVERSITY

- **AR (Augmented Reality) Characteristics**
  - **AR users may be able to turn on or turn off selected AR functions (which may be related to certain objects)**
  - **In comparison to VR, AR users commonly feel less separated from the real world**
  - **Fantasies & illusions can be created and superimposed on a real world view**

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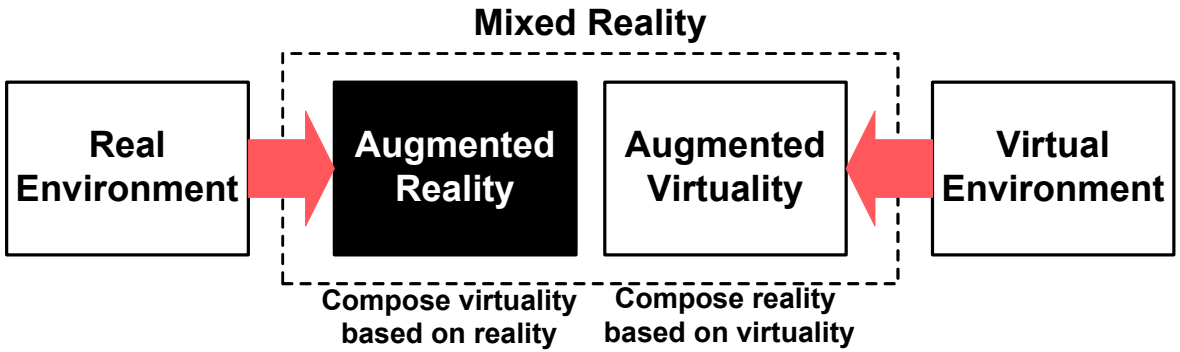
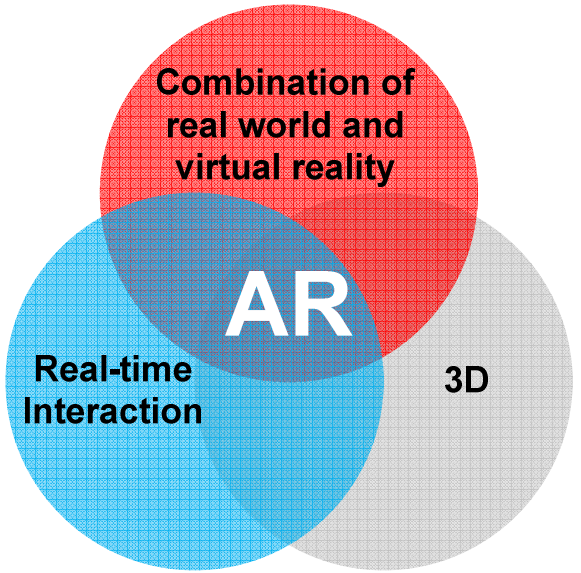
AR vs. VR

AR Definitions

- Definition by Paul Milgram



- Definition by Ronald Azuma



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AR Classifications

- Sensor based AR
  - GPS, Gyro sensor, Accelerometer
    - Example: Layar, Wikitude, Sekai Cam
- Vision based AR
  - Computer vision, OpenGL (Open Graphics Library)
    - Example: Vuforia, Metaio,
      Total Immersion ARToolKit
- Hybrid Tracking based AR
  - Vision + Sensor
    - Example: Outdoor AR

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AR (Augmented Reality)

REFERENCES

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AR (Augmented Reality)

AR Technology

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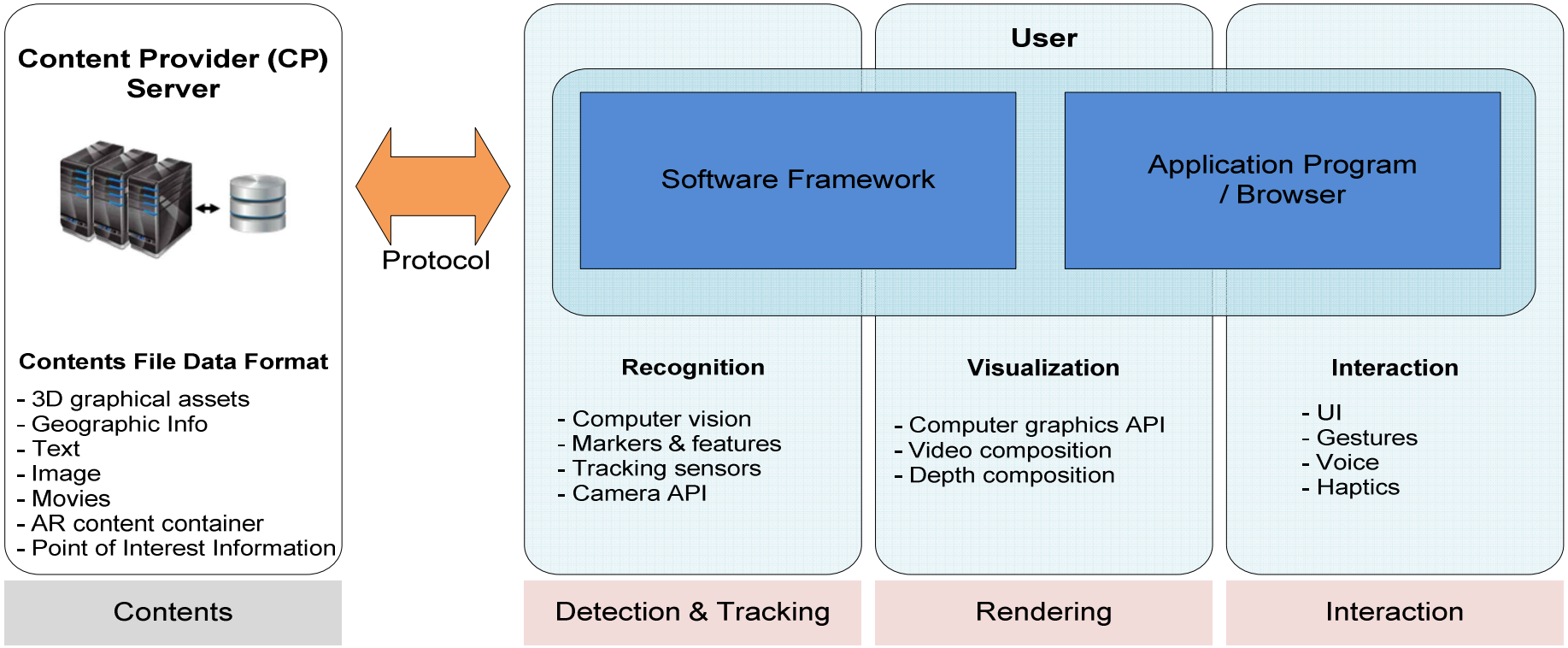
AR Technological Components



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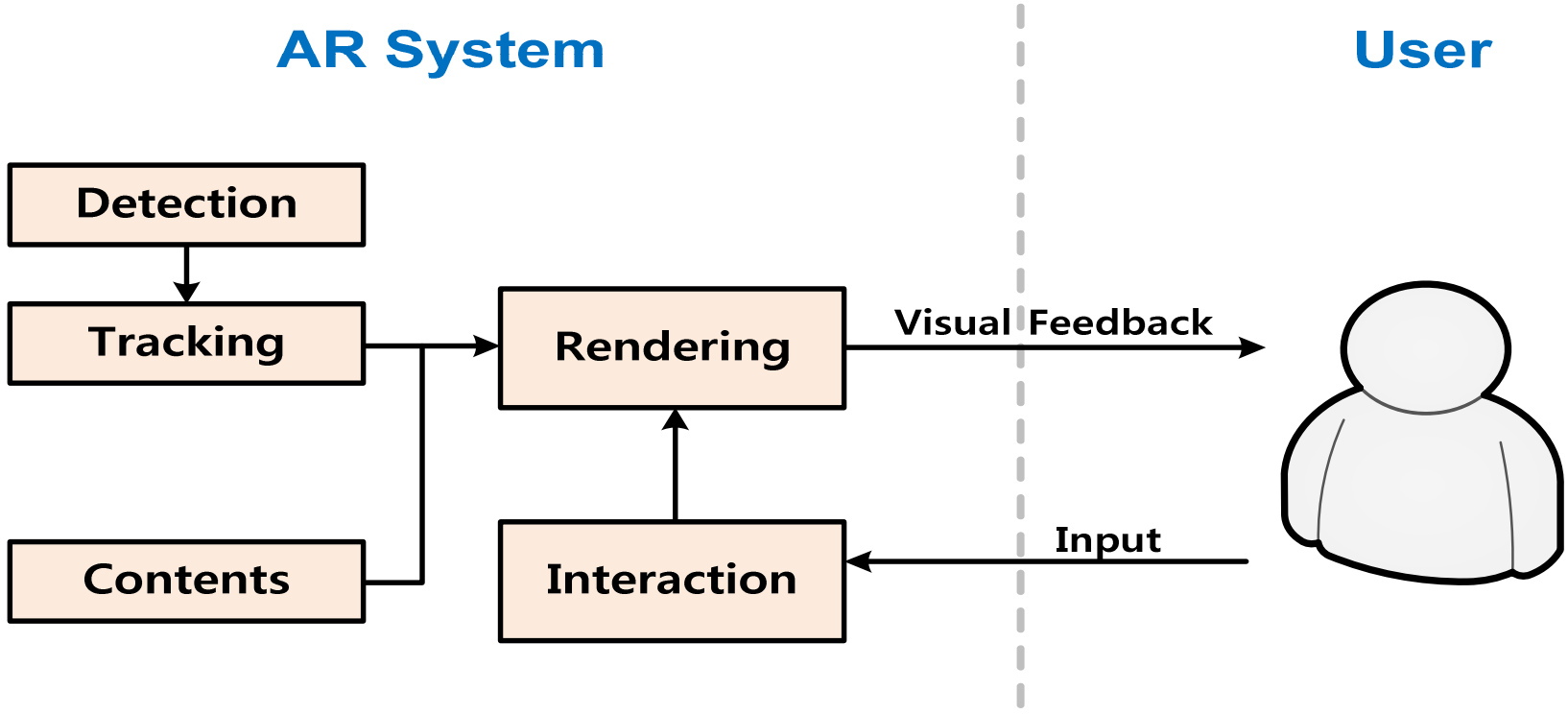
AR Workflow



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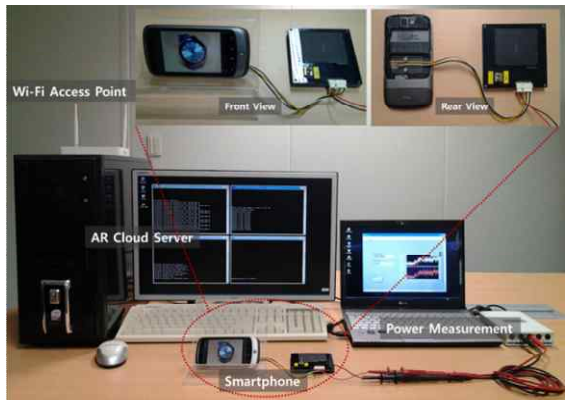
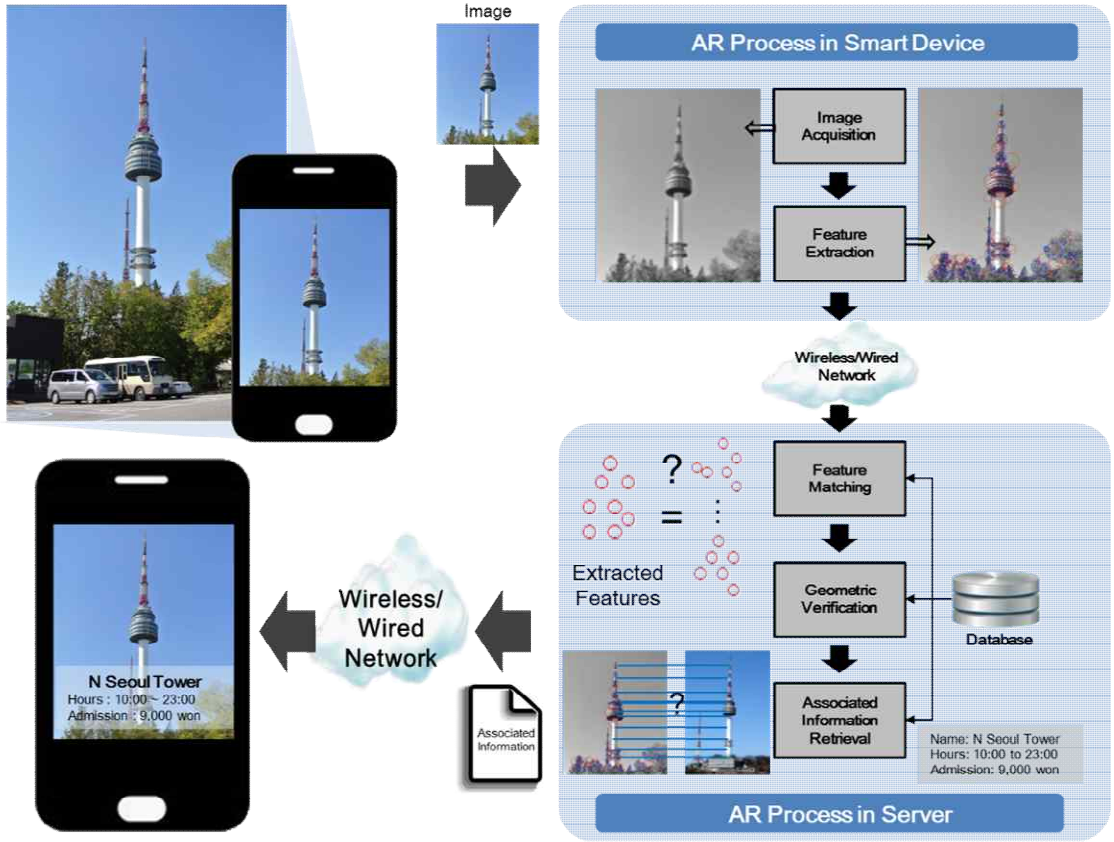
AR Process

1. Image Acquisition
2. Feature Extraction
3. Feature Matching
4. Geometric Verification
5. Associated Information Retrieval





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AR Process

1. **Image Acquisition**
   - Process of retrieving an image from the AR camera

2. **Feature Extraction**
   - Based on an initial set of measured data, the extraction process generates informative non redundant values to facilitate the subsequent feature learning and generalization steps

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AR Process

3. Feature Matching
   - Process of computing abstractions of image information, and to make a local decision if there is an image feature (or not), which is conducted for all image points

4. Geometric Verification
   - Identification process of finding geometrically related images in the image data set (which is a subset of the overall AR image database)

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AR Process

5. **Associated Information Retrieval**
   - **Process of searching and retrieving metadata, text, and/or content-based indexing information of the identified image/object**
   - **Associated Information is used for display on the AR screen near the corresponding image/object.**

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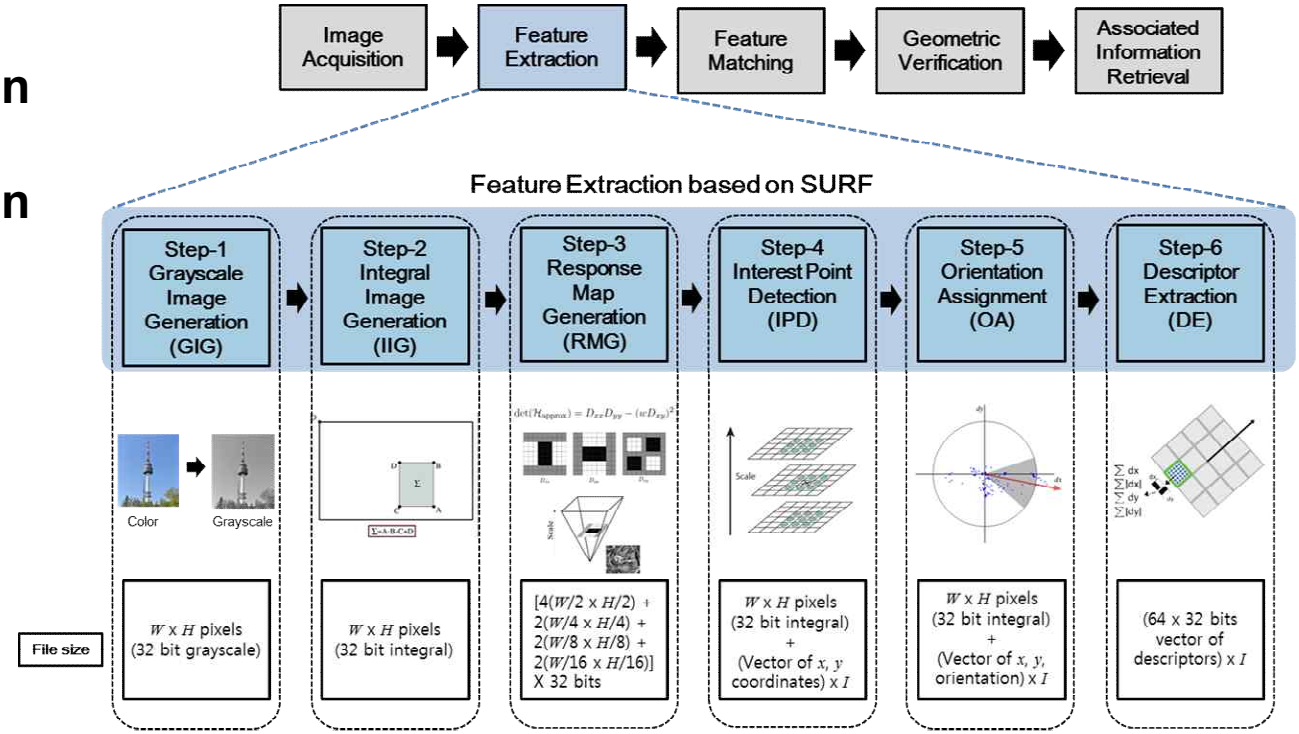
AR Feature Extraction Process

1. GIG: Grayscale Image Generation
2. IIG: Integral Image Generation
3. RMG: Response Map Generation
4. IPD: Interest Point Detection
5. OA: Orientation Assignment
6. DE: Description Extraction



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Feature Extraction Procedures

1. GIG (Grayscale Image Generation)
   - Original image captured by the AR device is changed into a grayscale valued image in order to make it robust to color modifications

2. IIG (Integral Image Generation)
   - Process of building an integral image from the grayscale image. This procedure enables fast calculation of summations over image sub-regions

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Feature Extraction Procedures

3. RMG (Response Map Generation)
   - In order to detect IPs (Interest Points) using the determinant of the image's Hessian matrix, the RMG process constructs the scale-space of the image

4. IPD (Interest Point Detection)
   - Based on the generated scale response maps, the maxima and minima are detected and used as the IPs

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Feature Extraction Procedures

5. OA (Orientation Assignment)
   - Each detected IP is assigned a reproducible orientation to provides rotation invariance (i.e., invariance to image rotation)

6. DE (Description Extraction)
   - Process of uniquely identifying an IP, such that it is distinguished from other IPs

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- **Feature Extraction**
  - Finding the Interest Points from the image/video
  - Detecting the Descriptors from Interest Points and compare the descriptors with data in the database

Original Image

Gray Scale

Interest Points

Descriptors

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Feature Extraction

- Qualification for Descriptors
  - Invariability from Noise, Scale, Rotation, etc.
- Kinds of Descriptors
  - Corner
  - Blob
  - Region

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Blob Detection

- LoG (Laplacian of Gaussian)
- Hessian Matrix (H): 2nd derivative
  - Hessian (determinant of H)
  - Laplacian (trace of H)
- Blob Detection

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- Blob Detection
  - Blob Detection
    - Process of detecting blobs in an image
  - Blob
    - Region of an image that has constant (or approximately constant) image properties ➔ All the points in a blob are considered to be similar to each other
    - These image properties (i.e., brightness, color, etc.) are used in the comparison process to surrounding regions

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Typical Feature Extraction Techniques

- Haar feature
  - P. Viola, et al., 2001.
- SIFT (Scale Invariant Feature Transform)
  - D. G. Lowe, 2004.
- HOG (Histogram of Oriented Gradient)
  - N. Dalal, et al., 2005.
- SURF (Speeded Up Robust Features)
  - H. Bay, *et al.*, 2006.
- ORB (Oriented FAST and Rotated BRIEF)
  - E. Rublee, *et al.*, 2011.

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- **SIFT (Scale Invariant Feature Transform)**
  - **Most widely used Feature Extraction algorithm**
  - **SIFT extracts features from images accurately and efficiently**
  - **SIFT overcomes various adverse effects of extraction, such as transformation, noise, and lightness**

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- **SIFT (Scale Invariant Feature Transform)**
  - **4 Step Algorithm**
    1. **Scale-space extreme detection**
    2. **Keypoint localization and filtering**
    3. **Orientation assignment**
    4. **Descriptor construction**

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SURF (Speeded Up Robust Features)

- SURF improves the speed of SIFT
- SURF algorithm is based on the same algorithmic principles as SIFT, but uses procedures that require less computation to enhance the processing speed
- SURF made it possible to carry out feature extraction in a (near) real-time manner

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- SURF (Speeded Up Robust Features)
  - 3 Step Algorithm
    - Interest Point Detection
      - High-speed detection of Interest points
    - Local Neighborhood Description
      - Descriptors using response of Haar-wavelet
    - Matching
      - Faster matching algorithm by using Laplacian operator

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AR

- **Handheld AR Displays ➔ Smartphones**
  - **Initial commercial success of AR models**
  - **Powerful computing capability, good camera & display, and portability make smartphones a great platform for AR**
    - **Example: Retailers Affinity Boosts Mobile AR**

Source: Flickr: UAR NAi Best Practice Poster

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AR Displays

AR Eyeglasses

- Example: Google Glass, Vuzix M100, Optinvent, Meta Space Glasses, Telepathy, Recon Jet, Glass Up
- Google Glass example

Source: Flickr: Loïc Le Meur on Google Glass

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AR Displays

AR HMD (Head-Mounted Display)

- HMD is a mobile AR device that can provide an immersive AR experience
  - Example: Aircraft Maintenance & Aviation

Source: Creative Commons Attribution-Share Alike 3.0 Unported

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AR Cloud Cooperative Computation

- All object information can NOT be stored on the AR device ➔ AR database needed
- AR requires a large amount of computation to complete its task ➔ The amount of AR processing directly influences the battery power consumption of the AR device
- To reduce the processing load and overcome AR database limitations of the AR device, AR Cloud Computation Offloading can be used

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AR Cloud Offloading

- Virtualization allows cloud server vendors to run arbitrary applications (from different customers) on VM (Virtual Machines) ➔ IaaS
- Cloud server vendors provide computing cycles ➔ AR devices can use these computing cycles to reduce their computation load
- Cloud computing (offloading) can help save energy and enhance the response speed of the AR service

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Adaptive Cloud Offloading

- Unconditional offloading may result excessive delay
  ➔ Adaptive Control needed
  - Cloud server load and networks congestion status monitoring needed

- Adaptive Cloud Offloading parameters
  - Network condition
  - Cloud server status
  - Energy status of the AR device
  - Target QoE (Quality of Experience) level

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AR (Augmented Reality)

REFERENCES

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AR (Augmented Reality)

AR Applications & Business Models

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AR Applications

YONSEI UNIVERSITY

- **Architecture**

  - **Planning of buildings and landscapes**
  - **Rebuilding of ruins**
  - **Archaeological information overlaid landscape scanning**

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AR Applications

YONSEI UNIVERSITY

- **Arts & Performances**
  - **Holographic & 3D design assistance**
  - **Animation design assistance**
  - **Musical note assistance**
  - **Sound coordination services**
  - **Image & sound coordination services**

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AR Applications

YONSEI UNIVERSITY

- **Commerce**
  - **Help select products in a catalog**
  - **Finding product information about a product or object**
  - **Real-time stock & sales information**

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AR Applications

YONSEI UNIVERSITY

Education

- Student customized assisting text, graphics, video, and audio support
- Interactive computer simulated experience of historical events and exploring

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AR Applications

- **Medical Science & Engineering**
  - **Health scanning of patient vital signs**
  - **Medical image processing**
    - **CAT scan, MRI, etc.**
  - **Robotic surgery support**
  - **Anesthesia procedures support**

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AR Applications

YONSEI UNIVERSITY

Military & Disaster Management

- Military combat training
- Situational awareness assisting information
- Theater C2 (Command & Control) planning and evaluation
- Disaster management procedure and location guidance

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AR Applications

- **Sports & Entertainment**
  - **Game play assisting information**
    - **Football first down line**
    - **Tennis ball line crossings**
  - **Game rules guidance information**
  - **Team objectives guidance information**
  - **Commercial advertisements overlaid in real-time onto the users view**

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AR Applications

Tourism & Sightseeing

- Guidance of historical events, places, and objects
- Tour course (hotel/motel, restaurant, and restroom) navigation information
- Translation and interpretation of foreign language voice, text, signs, and menus
- AR supportive voice translation sound output (speaker) into foreign languages

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AR Applications

YONSEI UNIVERSITY

- **Transportation**

  - **Navigation information display on automobile windshields**
  - **Accident prevention information and alarms**

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AR Business Models

Segment	Description	Companies / Organizations
AR Platform	• Provides AR foundation & Tool Boxes • Provide custom services	vuforia by Qualcomm, metaio
AR Product & AR Game	• Develop and market their own exclusive AR products • Product types: Books, Games, etc.	sphero, SONY, POPAR (Read It. See It. Be It.), Microsoft, Nintendo

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AR Business Models

Segment	Description	Companies / Organizations
Custom Branded App Development	• Work directly with brand marketers and agencies • Allow marketers to combine one-of-a-kind custom AR experiences • Service 3D modeling, integration with other software or platforms, etc.	((appshaker)) gravity jack MARXENT®
Industry-Specific Vertical AR Solution	• Serve niche business verticals • Examples: Luxury retails, medical services, pharmaceutical companies, and cosmetic companies	blippAR HOLITION AUGMENTED RETAIL adornably

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AR Business Models

Segment	Description	Companies / Organizations
Self-Service DIY (Do it Yourself) AR	• Offer content management tools • Provide simple experiences like launching a single video or simple animation • Provide the environment to test or create a simple AR experience • Offer AR viewers customized services and white label options.	layar, AURASMA, DAQRI, zappar AUTHORIZED RESELLER

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AR (Augmented Reality)

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