Industrial IoT for the Circular Economy

Lecture 07: IIoT
SS-2024

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NEWS/UPDATES

Course Evaluation – QR Code and Link

- **For the course: *„Emerging Technolgoies for the Circular Economy”***
- Link: Click Me

Course Evaluation – QR Code and Link

- **For the course: *„IoT and Digitalization for Circular Economy”***
- Link: Click Me

Lecture 07: Industrial Internet of Things

Content

- An introduction to the IIoT
- Comparison of IoT and IIoT
- Advantages of IIoT
- How to use the IIoT?
- Challenges and the future of IIoT

INTRODUCTION

Defining Industrial IoT

Results

"Industrial internet of things or industry 4.0 is a combination of IoT technology and data with production and other industrial processes, which is often done with the aim of increasing the automation of efficiency and productivity."

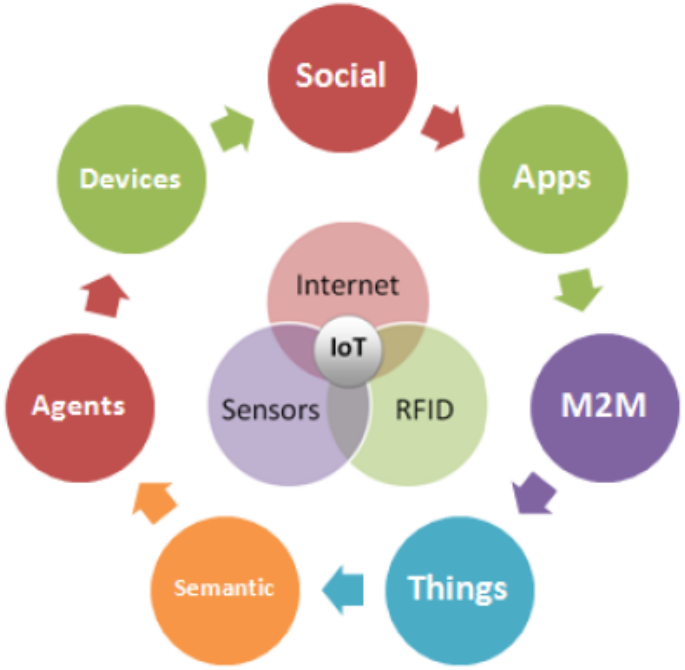
"IIoT also refers to connected sensors, tools and other devices related to industrial applications of computers, including connected manufacturing and energy management. This connection enables data collection, data exchange and data analysis and it potentially leads to improvements in productivity as well as other economics benefits."

Alasdair Gilchrist (auth.) - Industry 4.0_ The Industrial Internet of Things-Apress (2016)
Sudip Misra, Chandana Roy, Anandarup Mukherjee- Introduction to Industrial Internet of Tings and Industry 4.0

What do we mean with “ things “ in IoT and IIoT

The classification of objects in IoT and IIoT

- Those that collect and send information
- Those that receive and act on information
- Those that do both



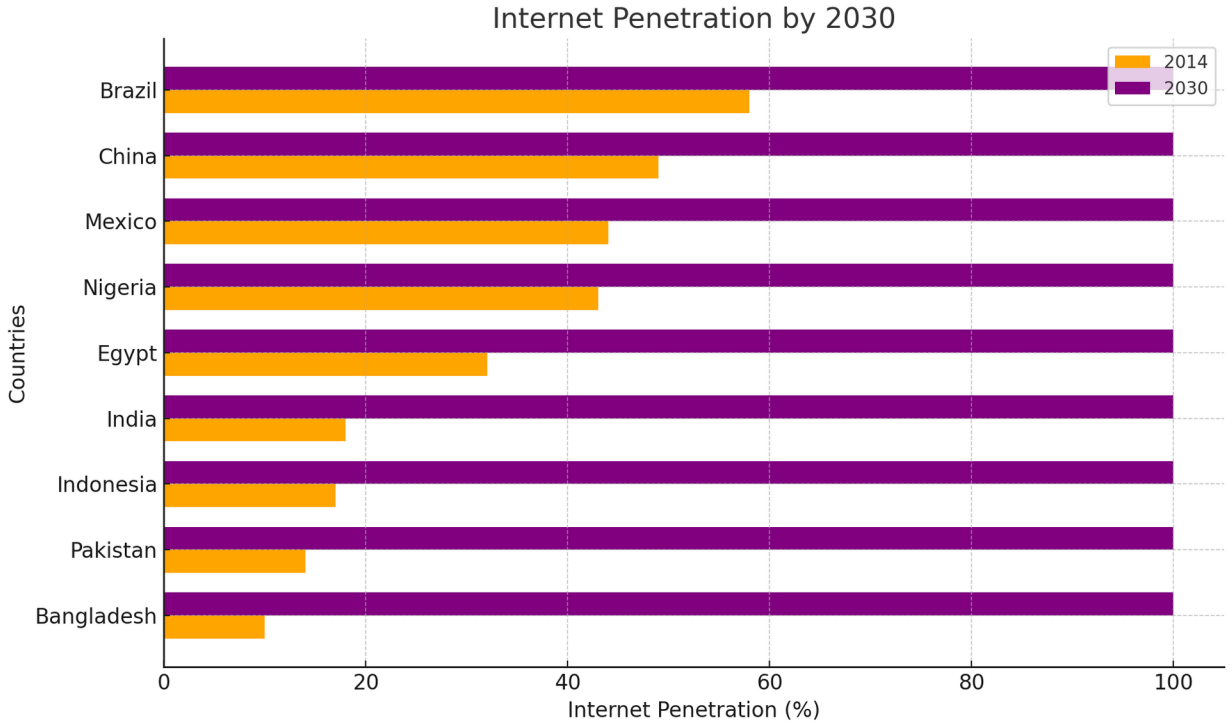
Evolution of IIoT

The Industrial Internet of Things(IIoT) has its roots in the field of industrial automation and has evolved over the years to become a prominent technology that is transforming industries globally.

- Industrial Automation
- Advancements in sensors and connectivity
- Cloud computing and big data
- Edge computing
- Convergence of IT and OT
- Industry-specific IIoT solutions

Alasdair Gilchrist (auth.) - Industry 4.0_ The Industrial Internet of Things-Apress (2016)

Evolution of IIoT



Timeline of internet of things

Image based on → https://commons.wikimedia.org/wiki/File:Corrected_2030_internet_penetration.png

The components of an IIoT system

- Sensors / Devices
- Ability to connect
- Cloud computing
- Data processing
- User interface

“Remember, the IoT and IIoT are not sensors and equipments but an ecosystem based on information which is ecosystem of communication base.”

Based on The Industrial Internet of Things Volume G5: Connectivity Framework, Rajive Joshi, Paul Didier, Jaime Jimenez, Timothy Carey, 2017

Comparison of IoT and IIoT

- Security
- Interoperability
- Scalability
- Precision and accuracy
- Programmability
- Low latency
- Reliability
- Resilience
- Automation
- Serviceability

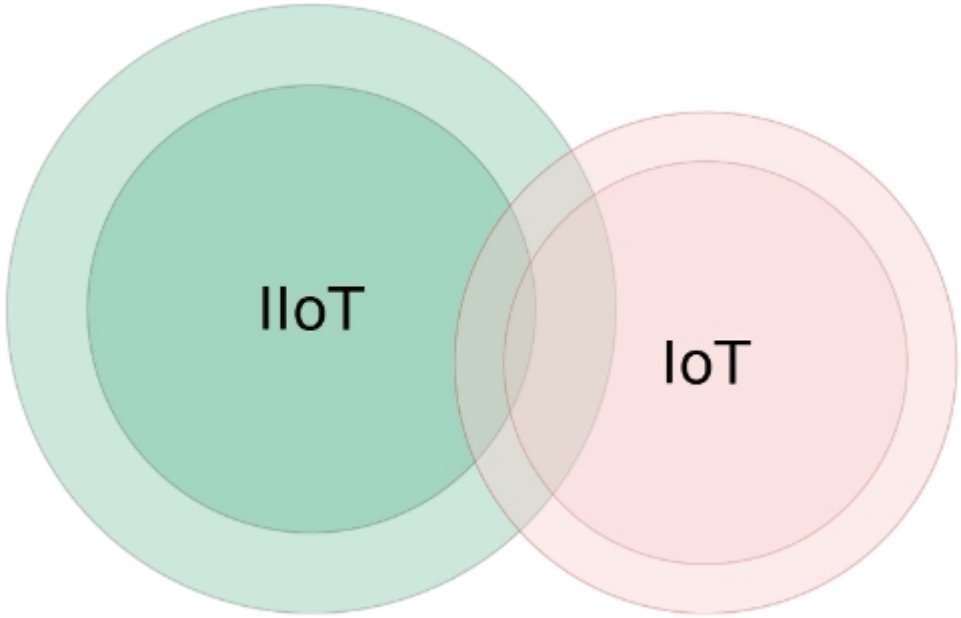


Image adapted from:https://web.stanford.edu/class/archive/ee/ee392b.1186/lecture/apr3/ee392b_2018_Lecture1_Overview.pdf

Based on UTPOwerElec, @utpowerelec7705

Comparison of IoT and IIoT

Security in IIoT

Cloud	Using multiple cloud providers and adhering to cloud standards and certifications to support regional data laws. Mapping to the Cloud Security Alliance Cloud Controls Matrix and complying with national, international, and governing body regulations
Authentication and authorization	Securely enroll edge devices using PKI for authentication before data is collected. Authenticate connections from edge to cloud. Have precise control over who can read and write data.
Encryption	Encrypt data during transit using the strongest security (TLS). Establish secure tunnels and VPNs from edge to cloud. Allow traffic only from specific IP addresses. Encrypt data at rest, keeping it isolated from other tenants' data.
Code security	Implementing code signing, conducting code reviews, and prioritizing a security-focused approach.

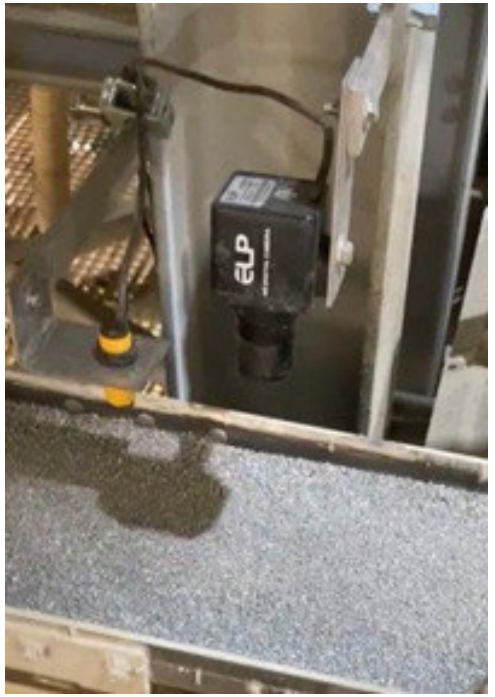
Comparison of IoT and IIoT

Examples

- Interoperability
- Scalability
- Precision and accuracy
- Programmability
- Low latency
- Reliability
- Resilience
- Automation
- Serviceability

Eddy current separation machine

Materials on conveyor belt



Integrating IIoT

Other benefits of IIoT

- Real-time information on the state of the supply chain
- Automatic timely decision-making during the production process
- Predictive maintenance
- Cost reduction
- Increased safety of the environment and employees

Let's do more with less always

Why Industrial Internet and Why Now?

- Need for Efficiency: Complexity of systems and economic pressure demand innovative solutions.
- Technological Maturity: Advancement in sensor technology, analytics, and cloud computing make IioT feasible and beneficial.

Alasdair Gilchrist (auth.) - Industry 4.0_ The Industrial Internet of Things-Apress (2016)

Other benefits of IIoT

Use cases

- Manufacturing
- Energy
- Smart Office
- Transportation
- Agriculture
- Healthcare
- Recycling
- Logistic
- Retail
- Aviation
- Space Travel
- Smart Factory
- AND → Smart city

Optimization and Sustainability

- Resource optimization
- Energy management
- Waste reduction
- Environment monitoring

Use cases
Manufacturing

- Predictive maintenance
- Condition monitoring
- Supply chain management
- Asset tracking and management
- Energy management
- Remote monitoring and control
- Quality control

Use cases

Oil and Gas Industry

Challenges in oil and gas industry

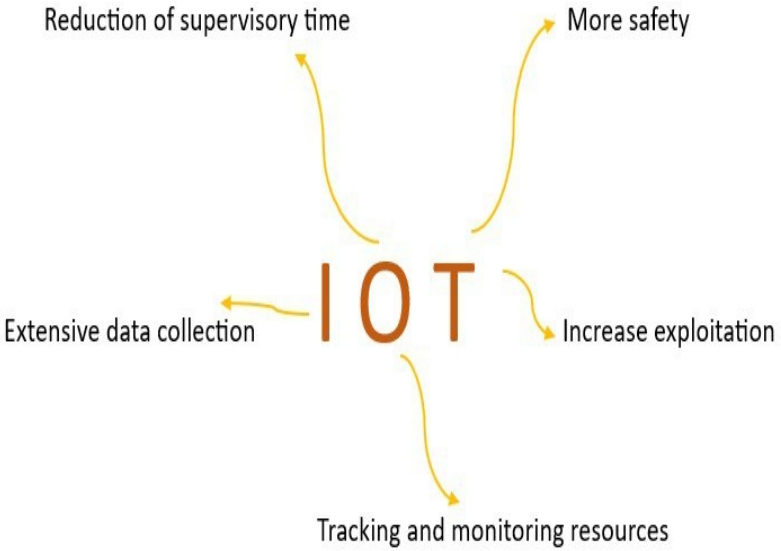
- Natural disasters
- Oil and gas pipeline leaks
- Communication and regulatory restrictions

They can cause a lot of financial and life damage.

Use cases

Oil and Gas Industry

- Reduce cost of extraction
- Creation of a fast and reliable platform for collecting extensive data in the refinery
- Increase the speed of system
- Being able to monitor and check information in short time
- Monitoring the level of tanks
- Real-time checking thickness of pipes
- Real-time checking rate of flow and pressure of pipes



Use cases

Oil and Gas Industry

- The use of IoT in this industry provides:
  - Close monitoring of harmful gases, pressure, and other important factors
  - Minimization of possible risks for employees
- IoT enables monitoring of oil and gas production in seas and areas with low access to communication networks
- Ability to measure water salinity and monitor employee's health
- Monitoring of pipelines and quick notification of leaks
- Prevention of financial damages and environmental destruction
- Creation of a platform to check different parts of energy-carrying ships
- Remote accessibility for employees to check difficult-to-access ship parts

Use cases

IIoT integration in solar and wind farms

- Enhances operational efficiency
- Reduces downtime
- Improves maintenance practices
- Maximizes energy production

Use cases

Agriculture

- Precision Agriculture
- Livestock Monitoring
- Automated Farming
- Weather Monitoring and Forecasting
- Supply Chain and Traceability
- Smart Greenhouse

Use cases
Agriculture

Use cases

Healthcare

- Remote Patient Monitoring
- Smart Medical Devices
- Asset and Inventory Management
- Telemedicine
- Patient Safety and Security
- Health and Wellness Monitoring

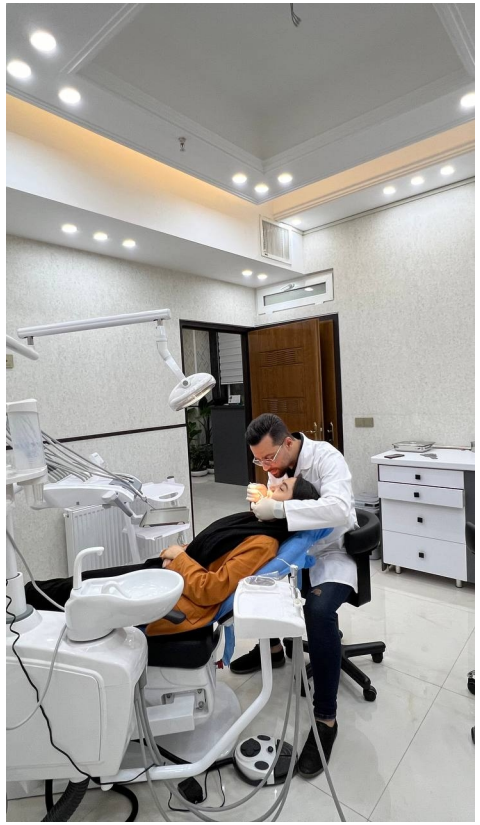


Image by Shohreh Kia

Healthcare

Examples

Giraff Robot

- Automation
- Supervision
- Communication

All in remote.

https://link.springer.com/article/10.1007/s12369-021-00843-0

Check the image from the above link.

Healthcare

Examples

Baymax

A robot with a soft synthetic skin that can detect medical conditions.

https://www.awn.com/animationworld/roy-conli-talks-production-disneys-big-hero-6

Check the image from the above link.

Use Cases
Recycling

- Smart Bins
- Sorting and Separation
- Predictive Maintenance
- Energy Management
- Supply Chain Management

Recycling

Examples

Separation in Recycling

Hand picking
Separationsp [1]

Mixed metals [2]

Monitoring [3]

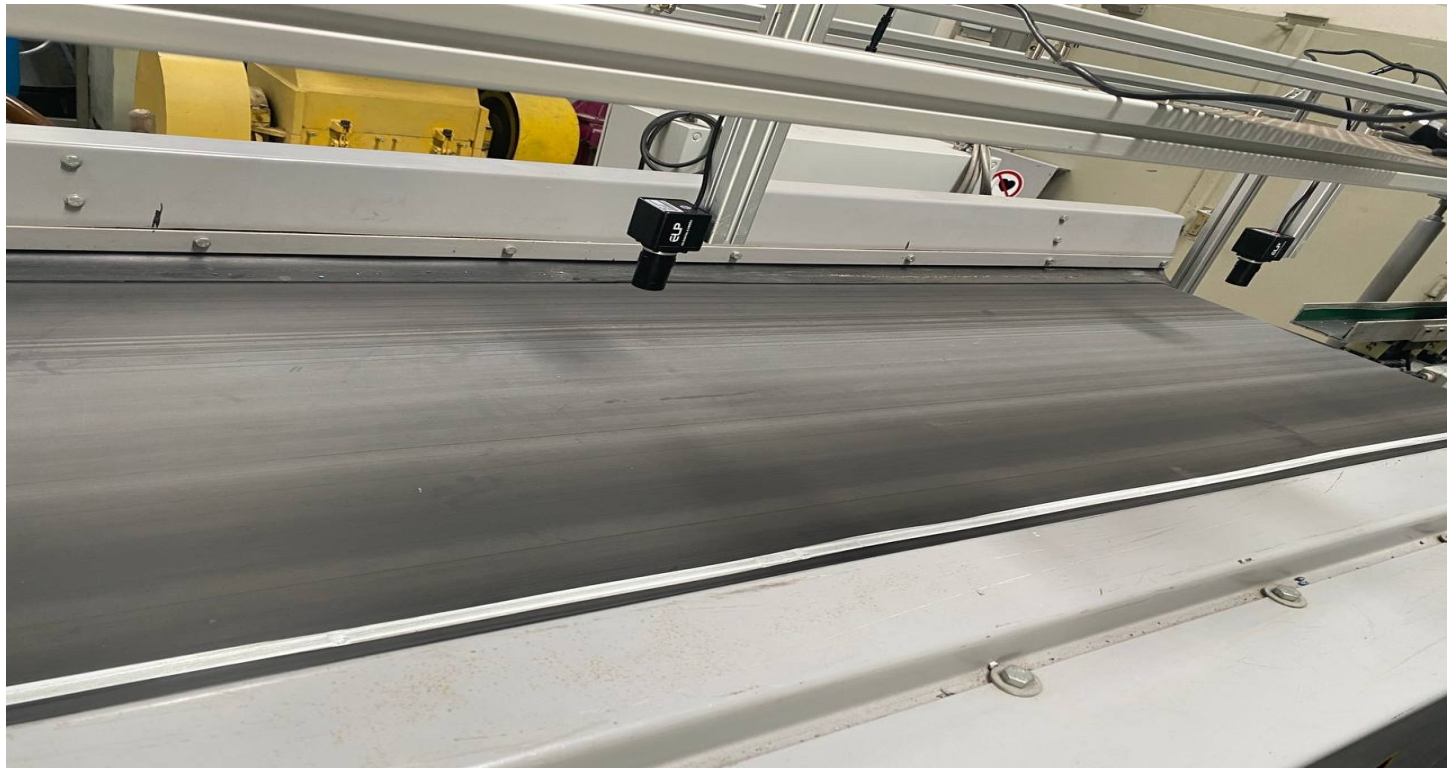
Digitalizing[4]

Digitalized separation
[5]

Recycling

Examples

Separation in Recycling



Set up of monitoring the belt

Recycling
Examples
Monitoring

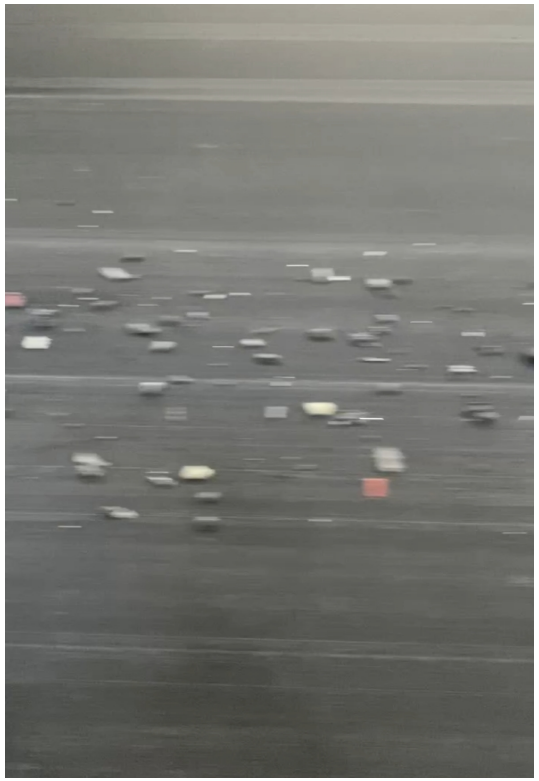


Image of original material

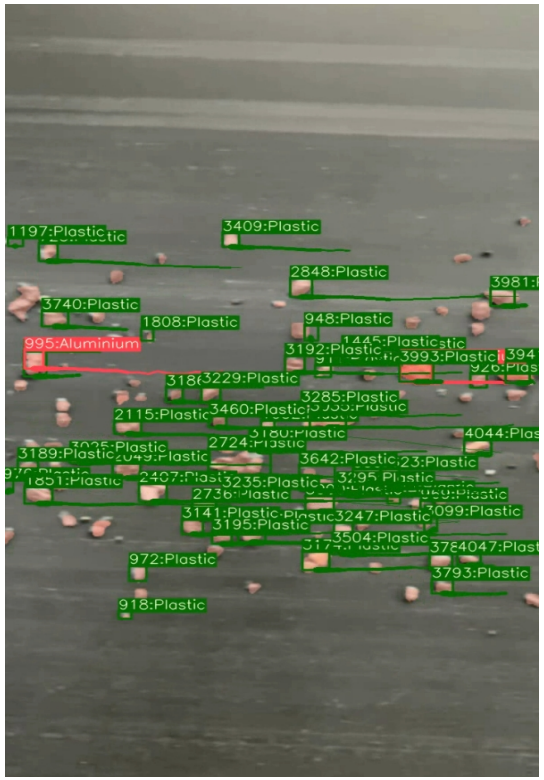
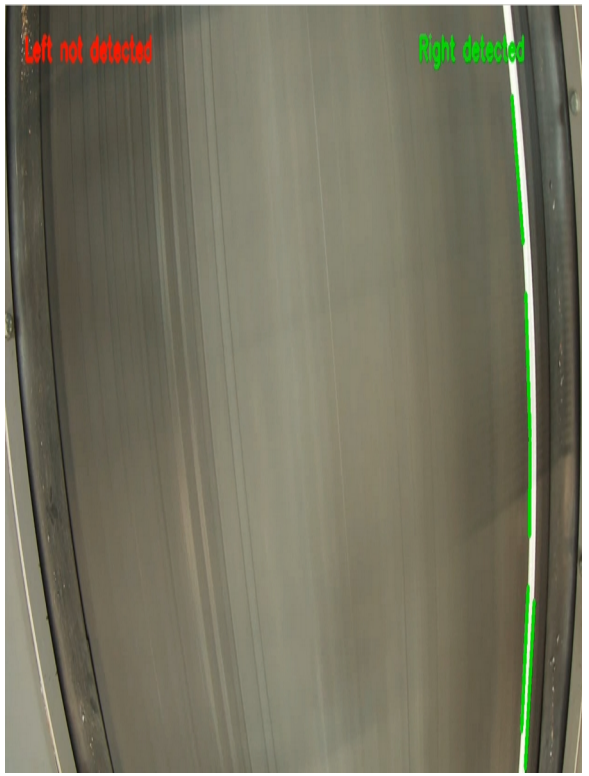


Image of predicted material

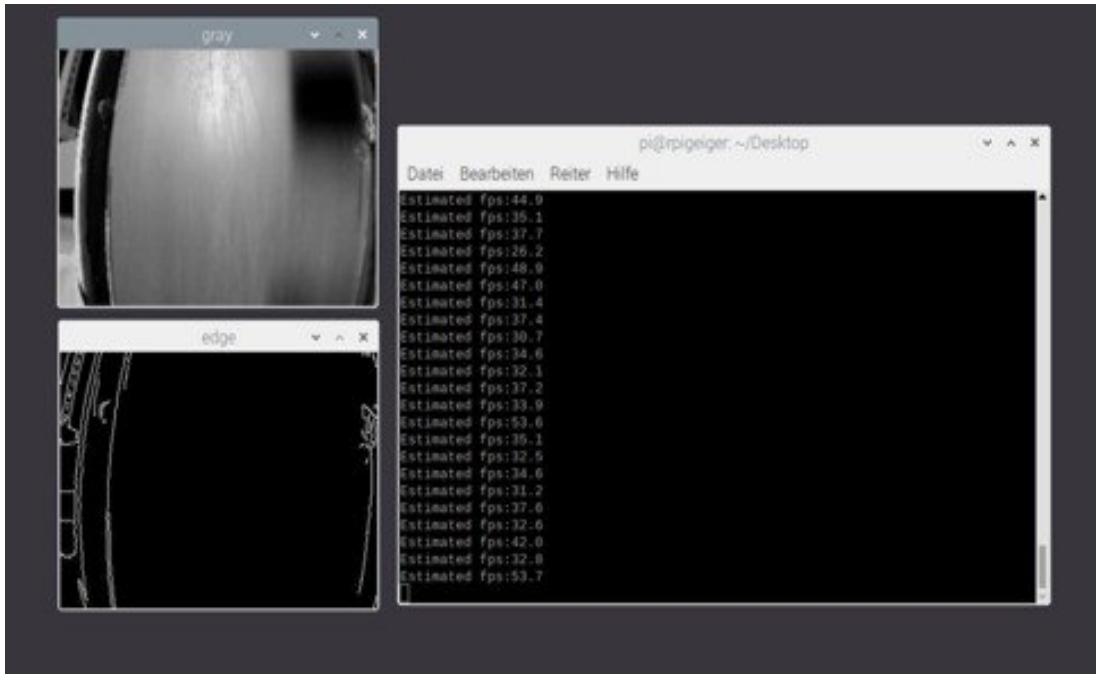
Recycling
Examples
Monitoring

Belt at the center



Belt has moved

Recycling
Examples
Monitoring



Monitoring the absence of materials

Informing to human forces

Use cases
Logistics

- Data driven decision making
- Improved safety and security
- Enhanced product quality and innovation
- Sustainable operations

Use cases
Mining

Image based on mining department at TU-Clausthal

Use cases
Mining

- Continuous health monitoring
- Detection of hazardous gases
- Environmental monitoring
- Smart alert systems
- Workers position tracking

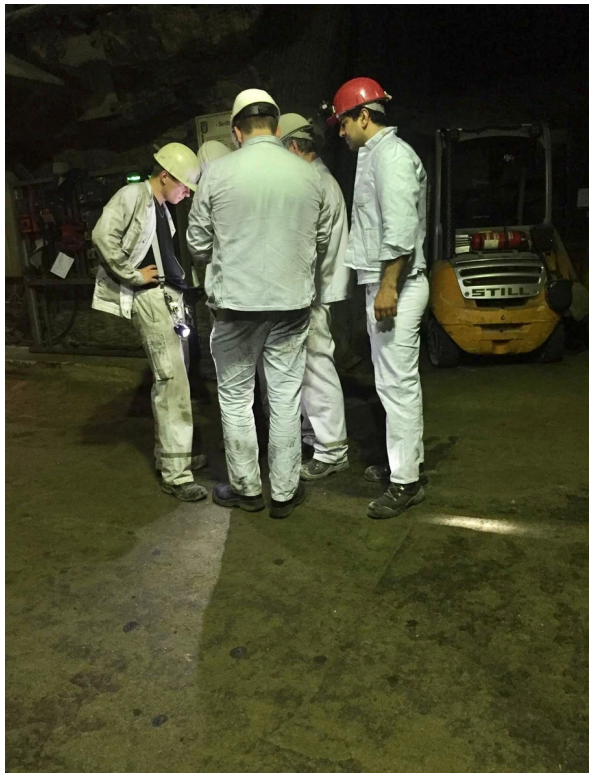


Image based on mining department at TU-Clausthal

Use cases
Aviation

integration of IoT technologies and data analytics in the aviation industry.

- Real-time monitoring of aircraft systems
- Predictive maintenance
- Optimized fuel consumption
- Enhanced safety measures

By collecting and analyzing data from various aircraft components and systems

- Improves operational efficiency
- Reduces downtime
- Facilitates proactive decision-making for airlines and maintenance crews

Use cases
Space Travel

- Enables enhanced communication
- Monitoring
- Control of spacecraft and space systems
- Real-time tracking of spacecraft
- Remote diagnostics and maintenance
- Predictive analytics for equipment performance
- Efficient resource management

It enables astronauts and mission control...

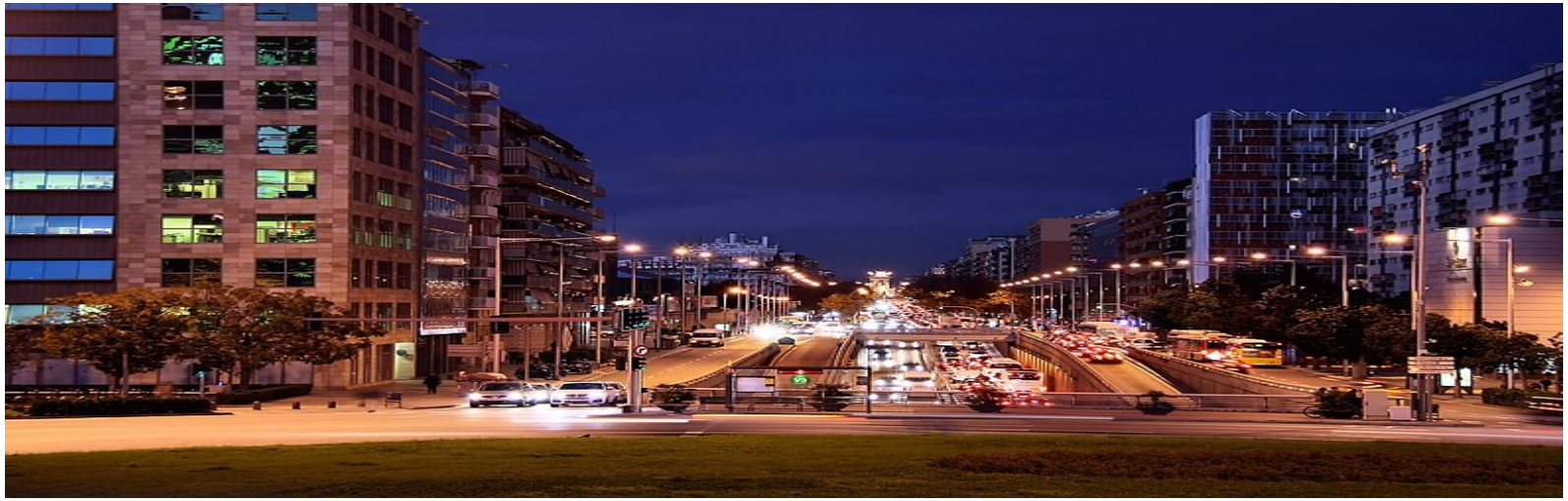
- To gather valuable data
- Make informed decisions
- Optimize mission operations for safer and more successful space exploration

Opportunity and Spirit

Use cases
Smart city

what is smart city?

A smart city means a city where all data and information are connected and easily available to citizens.



Smart city(specific example)

Examples

Barcelona city

- Barcelona has implemented a new approach to managing traffic flow in its busiest zones.
- Instead of using sensors for general parking spaces, the city has installed sensors targeting high-importance spaces.
- This includes parking areas for tourist buses near the renowned tourist attraction, La sagrada Familia.
- The new approach also extends to areas outside the city to support the “ Low Emission Zone” initiative.
- Urbiotica and world sensing offer additional insights into this strategic shift.

Tuba Bakici. Esteve Almirall. Jonathan Wareham- https://link.springer.com/article/10.1007/s13132-012-0084-9

Use cases
Examples

- Easy communication is a key feature of a smart city.
- Buses in Barcelona are equipped with solar panels to store solar energy as a clean fuel source.
- Solar panels were implemented in Barcelona starting from 2008, serving as a successful model for other Spanish cities.
- The city has a total of 30,000 solar panels, capable of producing 550,000 kilowatts of electricity per hour.
- The electricity generated by these panels helps prevent the emission of 440 tons of greenhouse gases annually.

Tuba Bakici. Esteve Almirall. Jonathan Wareham- https://link.springer.com/article/10.1007/s13132-012-0084-9

Use cases

Examples

Media Tech

- The Media tech building in Barcelona is recognized as one of the smart buildings globally.
- ATFT metal coverings are utilized in the building, incorporating lightweight cushions filled with low-pressure air.
- These coverings provide both resistance and heat insulation for the building.
- The heat insulation contributes to approximately 20% of the building’s energy consumption savings.

Image by Fred Romero- https://commons.wikimedia.org/wiki/File:Barcelona_-_Edifici_Media-TIC_%281%29.jpg- CC BY 2.0
https://www.youtube.com/watch?v=2ejzrZaD-PI

How to use the IIoT

What issues should we pay attention in designing and implementing an industrial system?

- Equipment
- Communication
- Protocols
- Big data
- Robotics
- Cyber security
- Digital twins
- Cloud computing
- Security (has been covered in previous slides)

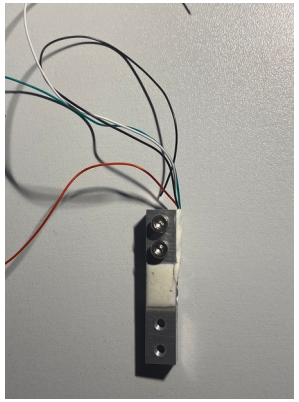
Introduction to Mining Sensors

Mining sensors are an essential component of modern mining operations, providing crucial data that ensures the safety, efficiency, and productivity of the industry.
These sensors are designed to monitor various environmental parameters and detect potential hazards, allowing for proactive measures to be taken. From detecting toxic gases to monitoring temperature and pressure, mining sensors play a pivotal role in the overall management of mining sites.

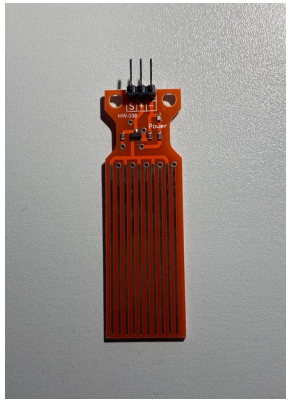
How to use the IIoT

Equipment

Home used sensors

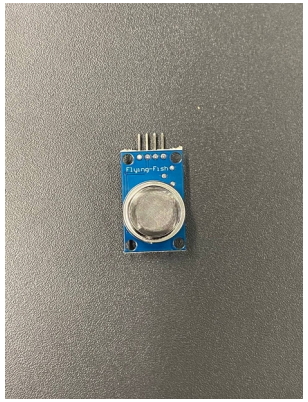


Weight sensor



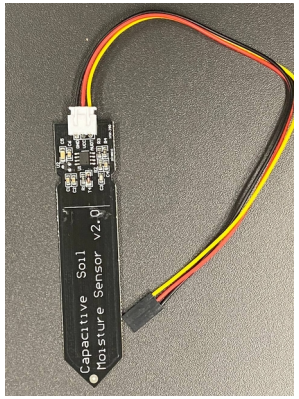
Temperature sensor

Sound sensor



Gas detection

Movement sensor



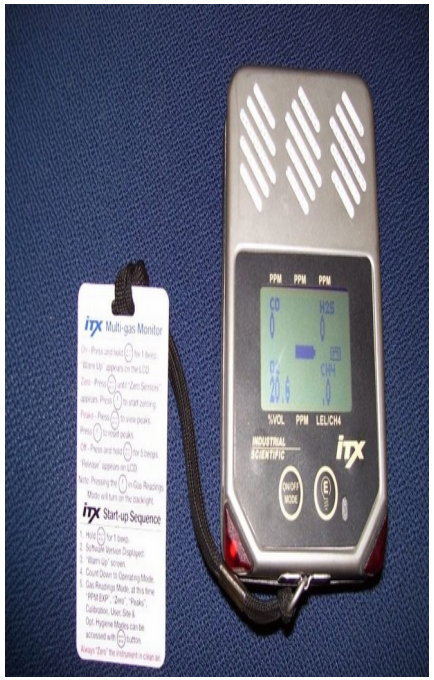
Moisture sensor

How to use the IIoT

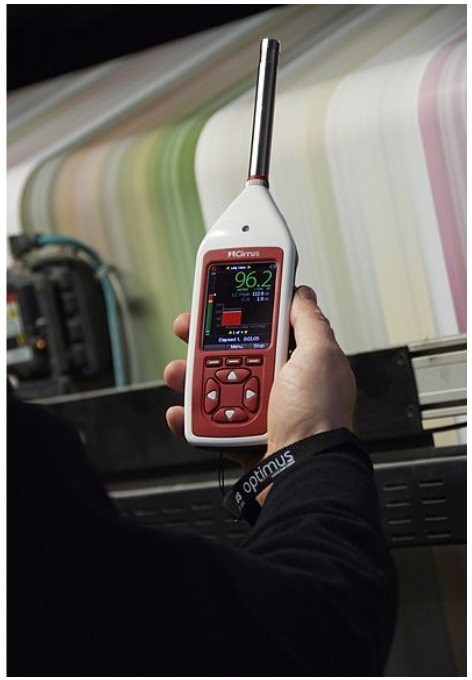
Equipment

Industrial used sensors

Velocity [1]



Gas detection [2]

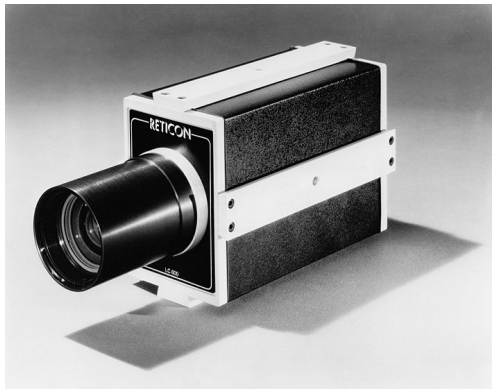


Sound detection [3]

How to use the IIoT

Equipment

Industrial Cameras



Line scan camera [1]

PMDCamCube camera [2]

Introduction to Network Protocols in IIoT

The Industrial Internet of Things (IIoT) represents the use of smart technology within various industries to improve efficiency, productivity, and safety.

Industrial Internet of Things and Communications at the Edge, by Tony Paine, Kepware Platform President, PTC

Importance of Network Protocols in IIoT

- Efficient Data Transfer
  IIoT network protocols enable efficient data transfer, crucial for real-time monitoring and process optimization in industrial settings.

- Interoperability
  Network protocols allow devices from different manufacturers to communicate seamlessly, forming a unified network.

- Security and Privacy
  Robust network protocols protect IIoT data from cybersecurity threats and unauthorized access.

How to use the IIoT

Protocols

And what is protocols?

A set of rules for communication between two or more than two systems.

IIoT Protocols:

- IP (Internet Protocol)
- TCP (Transmission Control Protocol)
- MQTT (Message Queuing Telemetry Transport)
- CoAP (Constrained Application Protocol)
- HTTP/HTTPS (Hypertext Transfer Protocol/Secure)
- Wifi
- Bluetooth
- NFC
- Satellite

How to use the IIoT

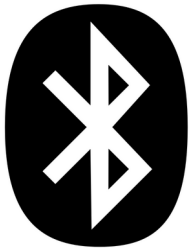
Communications

- Communication Protocol
- Wi-Fi → belongs to OSI layer → 1-2
- Satellite Communication → belongs to OSI layer→ 1-7
- Bluetooth → belongs to OSI layers→ 1-7
- NFC → belongs to OSI layers → 1,2,7
- RFID→ belongs to OSI layer → 1,2,7

[1]

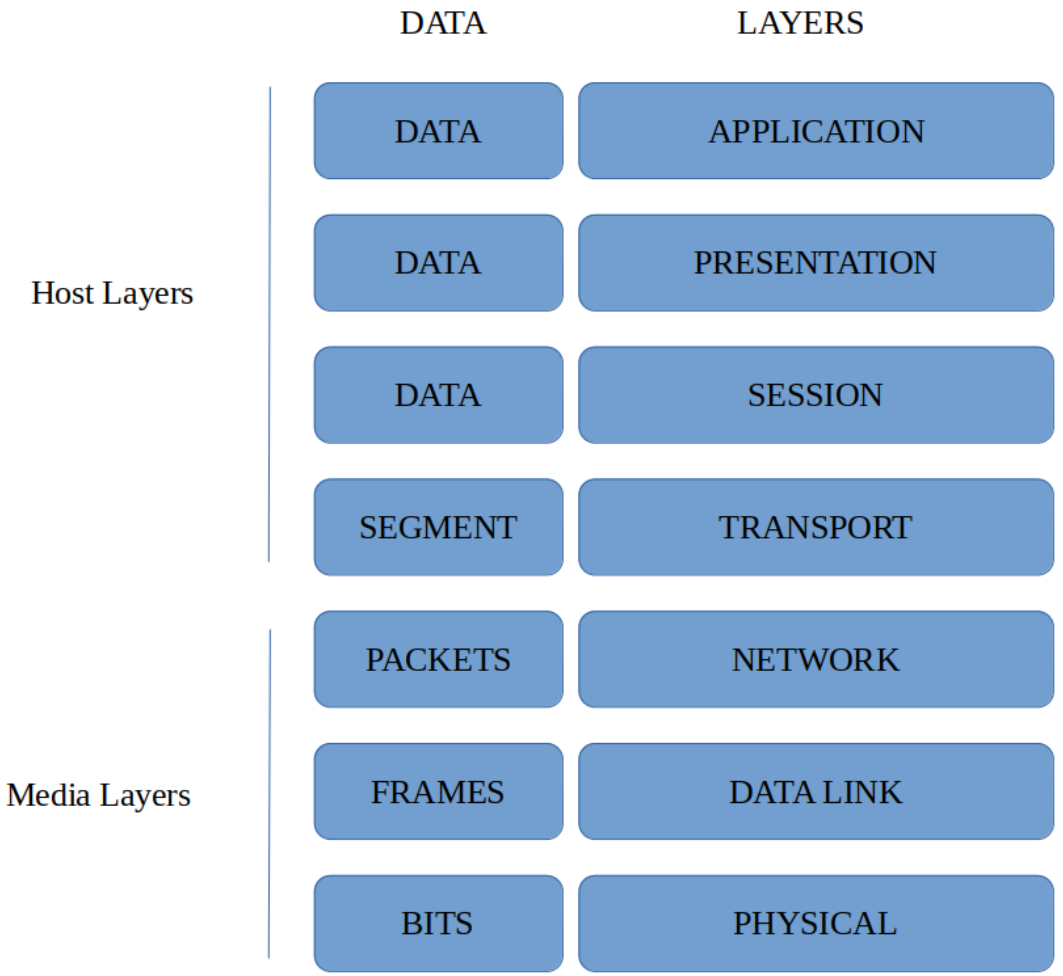
[2]

[3]



[4]

OSI Layers



Based on → https://commons.wikimedia.org/wiki/File:Osi-model-jb.png- CC BY-SA 3.0

IIoT Protocols

IP (Internet Protocol)

IP → OSI layer → 3 (Internet layer)
(host-to-host and end-to-end)

- Fundamental protocol/ serve as the backbone of internet communication
- Responsible for routing packets across network boundaries
- Provides addressing and packet forwarding functionalities
- Facilitating the delivery of packets from the source host to the destination host based on their IP addresses.

IIoT Protocols

TCP(Transmission Control Protocol)

TCP → OSI layer → 4 (Transport layer)
(host-to-host and end-to-end)

- Provides reliable, ordered and error-checked delivery of data
- Uses acknowledgments to confirm of data packets
- If a packet is lost or corrupted during transmission, TCP will retransmit the packet.
- Data is broken into smaller segments for the transmission.
- Each segment contains a sequence of numbers which make it more secure and accurate to track.

IIoT Protocols

MQTT(Message Queuing Telemetry Transport)

MQTT → OSI layer → 7 (Application layer)
(machine to machine)

- Message Queuing Telemetry Transport
- Lightweight
- Efficient Messaging Protocol
- Ideal for low-bandwidth

IIoT Protocols

MQTT(Message Queuing Telemetry Transport)

MQTT → OSI layer → 7 (Application layer)
(machine to machine)

- MQTT specifies **topics, messages, publish/subscribe** machanism.

  Used by applications to communicate.
- Relies on other protocols to handle the transport of messages.
  - Transport layer (layer 4)
  - MQTT uses TCP as its transport layer protocol.
  - TCP ensures reliable delivery of the messages MQTT sends between client and brokers.

IIoT Protocols

CoAP(Constrained Application Protocol)

CoAP → OSI layer → 7 (Application layer)
(machine to machine)

- Low-power networks needed
- Offers simple and effective way to enable communication in IIoT ecosystems.
- Provides web-like interaction using a **request/response** model
- Support methods such as **GET,POST,PUT**, and **DELETE**
- Uses UDP (User Datagram Protocol) as its transport layer protocol(4)

Comparison

TCP/IP	Known for its reliability, extensive usage. Is a top choice for applications requiring assured data delivery within IIoT.
MQTT	Popular in IIoT for its efficient, low-bandwidth message distribution, where minimal network resource use is crucial.
CoAP	CoAP provides a lightweight messaging solution for IIoT devices requiring minimal data exchange overhead.

How to use the IIoT

Big Data

The community's collection of data and information from various production lines and equipments, will be used to make real-time decisions.

"BigData represents the information assets characterized by such a high volume, velocity and variety to require specific technology and analytical methods for its transformation into value"

Based on previous lecture in IoT

How to use the IIoT

Robotics

- Enhance system flexibility and collaborate with humans.
- Capable of working in challenging environment where human access is limited.
- Equipped to make intelligent and safe decisions.
- Able to carry out the tasks with precision and within specified time limits.

How to use the IIoT

Digital twins

" A virtual representation or digital replica of a physical objects, process, or system."

" Digital twins are created by collecting data from sensors, devices and other sources that capture information about the physical object or system. This data is used to build a dynamic model that reflect the state, performance, and behavior of the physical asset."

" Digital twin is not just a static model but is continuously updated with real-time data from the physical object or system. It enables monitoring, analysis, and simulation of the asset's performance, allowing for predictive and proactive maintenance, optimization, and decision-making."

How to use the IIoT

Digital twins

- Creating a virtual replica of a physical asset or system.
- Utilized for real-time monitoring, predictive maintenance.
- Optimization of industrial processes.
- Through simulation, digital twins provide an understanding of system functionality before constructing the actual physical system.
- Reduce design time
- Minimize failures
- Leading to improved quality
- Better decision-making

How to use the IIoT

Cloud computing

- Industry 4.0 connects information technology platform to the cloud for communication.
- Data sharing in industry 4.0 has increased significantly among companies.
- Internal communication in industry 4.0 occurs at millisecond or microsecond speeds.
- Cloud computing enables different devices to connect to the same cloud.
- Devices in cloud computing share information that is beneficial for the entire factory.

Internet of Things in Industries: A Survey, by Wu He, Shancang Li

IIoT and Artificial Intelligence(AI)

- Convergence of IIoT and AI technologies.
- Use of machine learning, deep learning, and other AI techniques.
- Advanced analytics employed in IIoT applications.
- Predictive maintenance facilitated by AI in IIoT.
- Autonomous decision-making enabled through AI in IIoT.

IIoT and Blockchain
Definition

"Blockchain is a decentralized and distributed digital board technology that records transactions across multiple computers or nodes. It provides a secure and transparent way to store and verify data, enabling trust and eliminating the need for intermediaries."

More simple?!

" Blockchain can be thought of as a chain of blocks, where each block contains a list of transactions. These transactions are validated, encrypted, and added to the chain in a chronological order. Once a block is added to the chain, it is extremely difficult to alter the information it contains.

Blockchain, A practical Guide to Developing Business, Law, and Technology Solutions by Joseph J.Bambara, Paul R.Allen

IIoT and Blockchain

The potential of blockchain technology in IIoT, including its applications in…

- Data security
- Privacy
- Trust
- Decentralized government of IIoT networks.

Challenges and future of IIoT

Current challenges:

- Privacy concerns
- Secure data storage and management

The upcoming challenges

- Data management and processing (cloud, fog and edge computing)
- Security

Internet of Things in Industries: A Survey by Wu He and Shancang Li, November 2014

How to make IIoT more secure?

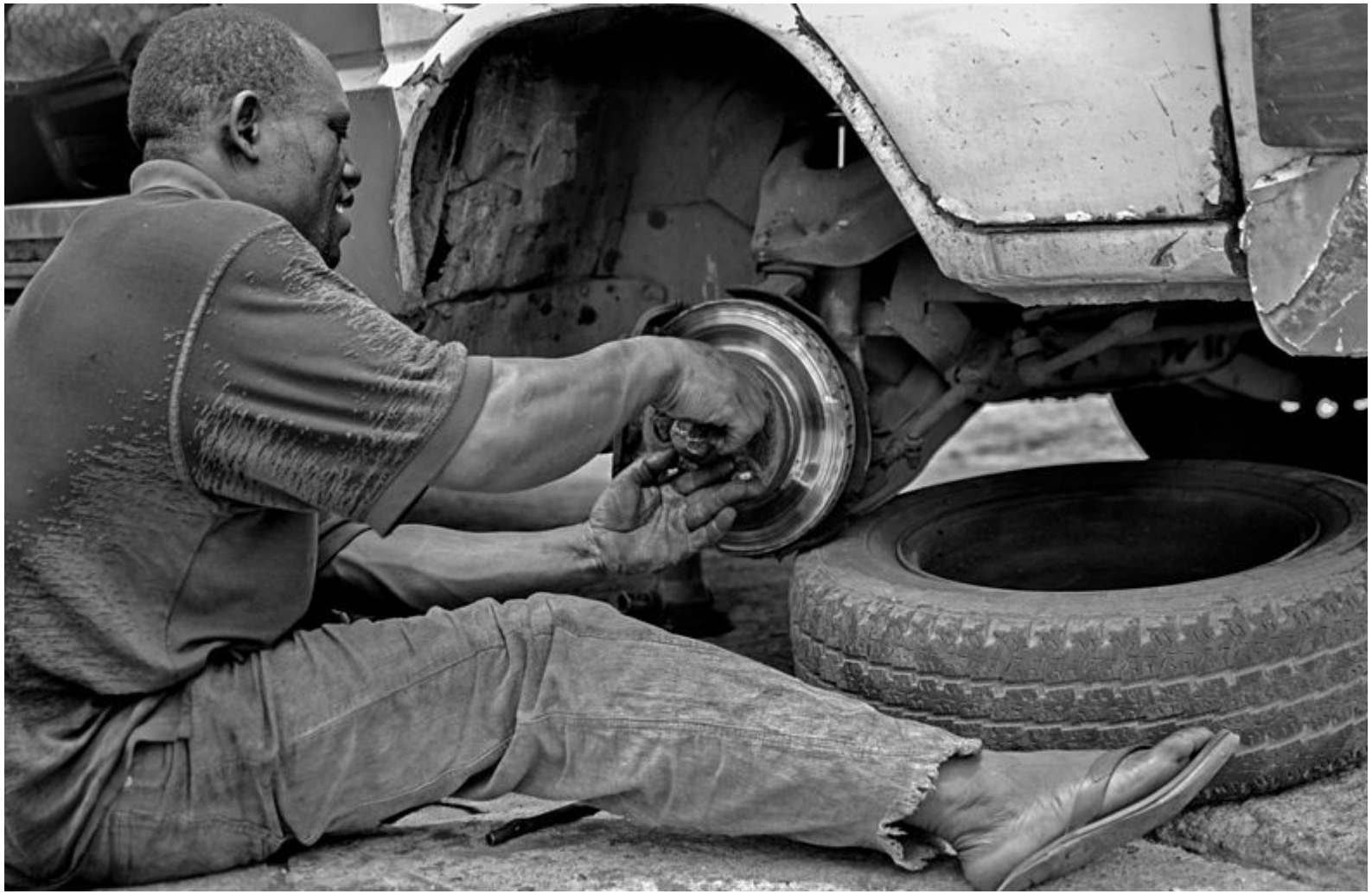
Some techniques

Lets start with a lot of donot's

- Using default passwords
- Storing hard-coded passwords
- Protocols that have no encryption protocols (for ex. HTTPS instead of HTTP)
- Giving a public IP address
- Turn off certificate verification
- Physical security ignorance

X If its easy for someone to plug an Ethernet cable from the IT network to the plant control network **X**

Isn’t it the time for humans to say bye to some jobs?!!



CONCLUSION

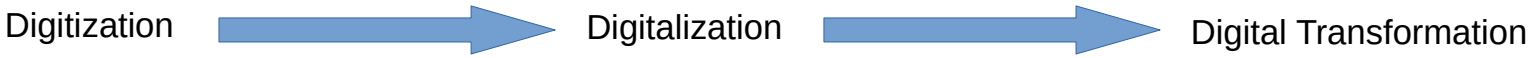


Image based on → https://medium.com/@everlynsalt/what-is-digitization-in-education-6b697bcfb38b-

- An introduction to the IIoT
  - IIoT is transforming industries such as manufacturing, energy, and infrastructure.
- Comparison of IoT and IIoT
  - IIoT leverage connected device, sensors, and advanced analytics for industrial applications.
- Advantages of IIoT
  - Real-time data enables informed decision-making and operational optimization.
  - Remote monitoring, predictive maintenance, and enhanced safety measures are facilitated by IIoT.

- How to use the IIoT?
- Challenges and the future of IIoT
  - Address the challenges associated with interoperability, scalability, data privacy.
  - Highlight the potential of IIoT to revolutionize industries and drive efficiency

Thank You!