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Internet of Things for Smart Ports: Technologies and Challenges

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***Abstract*—**The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data.This paper reflects the main requirements and the key ideas foreach ports, sensing solution and also the challenges related to the calibration and testing of distributed sensing systems associated with the main equipment that compose the world largest ports, such as quayside cranes, automated guided vehicles for container handling and yard cranes.The Internet of Things is making the fabric of the world around us more smarter and more responsive, merging the digital and physical universes.

I. Introduction

According to the IEEE, the Internet of Things (IoT) is a network of goods, such as sensors and embedded systems, that are connected to the Internet and allow physical objects to collect data.and data exchange [1]. Sensors are becoming increasingly important as the Internet of Things (IoT) gains traction.are essential for determining the physical properties of objects and converting them to numerical values.This in- formation can be read by another device or by the user. In recent years,Year after year, the worldwide sensor industry has grown, and It is likely to continue to grow at a rapid pace in the future. If we work together, we can such as Industry
4.0 of Germany and Made in China 2025 of China, the key to these projects is the data provided by sensors. Sensors are widely applied in different fields such as smart power grids, smart buildings, smart industries, smart cities, and smart ports

II. IoT in Smart Ports

The smart port's essential infrastructure includes devices and data centres, allowing port officials to operate more effi- ciently.to provide key services in a more timely and effective manner. Productivity is one of the most important factors in smart ports.as well as advances in efficiency Inertial sensors, ultrasonic sensors, eddy current sensors, radar, and lidar are some of the sensors used.To transform the "port" into a "port," imaging sensors, RFID readers, and tags are utilised to collect

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the necessary data a so-called "smart port"Kaloop et al. pre- sented steel container crane movement analysis and assessment based on structural health monitoring, in which accelerometers were used to monitor the dynamic crane behavior, and a 3- D finite element model was designed to express the static displacement of the crane under the different loads [4]. Carullo and Parvis presented an ultrasonic sensor to measure the distance from the ground to selected points of a motor vehicle [5]. Fu et al. proposed a computer vision-based procedure with image sensors to determine the position of one container in the horizontal plane [6].

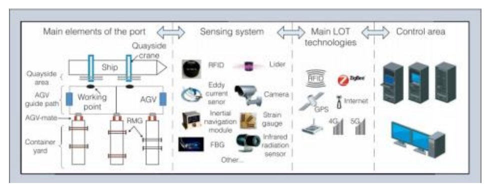

Fig. 1. The layout of an automated container terminal.

III. Port Architecture and Operation

The quayside berthing area, the AGV transit area, and the storage yard make up an automated container terminal. The berthing area, in particular, is outfitted with quay cranes (QCs) for unloading and loading containers.AGVs use the travelling area to transport containers from one location to another.the berthing area to the storage yard, the storage yard, the storage yard, the storage yard, the storage yard, the storage yard, the storage yardImport and export containers are stored here until they are delivered to their final destination Trains or trucks.For the loading and unloading of containers, an automated container terminal primarily employs equipment such as QCs, AGVs, and yard cranes (YCs). QCs are thus used to discharge containers from the ship to the terminal.AGVs or for loading containers onto ships from AGVs. AGVsbuild horizontal transportation between the beach and the pier YCs are in responsibility of placing the containers in the appropriate areas in the yard during operation and yard operation.

Table 1 - The comparisons between the traditional and automated container terminal

Characteristics	Port	
	Traditional Port	Automated Port (e.g., Xiamen Port)
Operating subjects	People and machines	Automatic systems and equipment
Quayside operations	Quayside cranes	Semi-automatic/automatic Quayside cranes
Horizontal transportation	Container trucks Straddle carriers	Container trucks Straddle carriers Automatic Guided Vehicles
Yard operations	Rubber-tired gantry cranes	Automatic rail mounted gantry cranes
Operation efficiency	Labor based operation Limited efficiency Low dispatching efficiency	Techniques/information based operation High automation and intelligence High and improvable efficiency Intelligent and coordinated dispatching
Economic efficiency	Low construction costs Low maintenance costs High labor costs High transportation costs Low economic benefits	High construction costs High maintenance costs Low labor costs Low transportation costs High economic benefits
Security supervision and control	Low reliability Slow response High labor cost	High intelligence High reliability Fast response More safety
Environmental protection	High energy consumption Heavy pollution	Sustainable development Low energy consumption Little pollution
Sustainability	No	Yes

Fig. 2.

IV. Sensing Systems for Smart Ports

The construction of an automatic container terminal neces- sitates the use of sensing systems that are used in duties such as quayside crane structural health monitoring and container tracking.Positioning and handling, AGV localization, naviga- tion and control, and so on. The state of the art in the field of optical fibre sensors, magnetic sensors with high sensitivity, and MEMS inertial measurement units, including the latest advances, that enable interoperable wireless protocols 4G and 5G that will permit the extension of the Internet connectivity of the sensing systems, represent big opportunities for new developments in the field of smart ports. Thus, new smart sens- ing architectures for container identification and management, vehicle identification and management, location and navigation services, and the safety of port terminals equipment related to structural health monitoring are based on contact and remote sensing solutions.Table 2 lists the key sensing technologies utilised in smart ports for SHM. The strain gauge is the most often used sensing element among these technologies. The metre It is both cheap and stable to convert structural strain into resistance change. Fiber Bragg Grating (FBG) is a type of grating that is used to A frequency shift can be used to detect the impact of strain.The strain monitoring technology is more expensive than the magnitude change of the reflected beam and is a more expensive long-term monitoring technique than the strain monitoring technology.gauge. Eddy current probes and ultrasonic probes are also used.Probes and on-line defect detection are two on-line defect detection technologies. During the Electromagnetic fields, fractures, and other flaws will all have an impact.the eddy's dimensions and shape.Eddy current probes that incorporate just coils or coils and magnetic sensors such as huge magneto resistors [10] are used to detect materi- als. The presence of faults in the uniform material will cause the ultrasonic sensor to malfunction.the material's discontinu- ity, which can lead to inconsistency in acoustic impedance The reflection theorem states that It is well understood that the ul- trasonic wave will be reflected.The magnitude of the reflected energy is related to the difference in acoustic impedance at the interface of two different acoustic impedances.the inter- face's acoustic impedance, the orientation, and he interface's dimensions .The proximity, level and distance measurement sensors are mainly for anti-collision monitoring and location applications of cranes, RMG and AGV in smart ports, where the ultrasonic, inductive, laser and IR sensors are the most common, as detailed in Table 3. Navigation sensors for AGV and unmanned container trucks, which are the main container handling equipment in smart ports from shore area to container yard,mainly include RFID-based navigation systems (HF and UHF RFID solutions),differential GPS systems, laser-based navigation systems, inertial navigation systems and encoders, compared in Table 4 [12].

Table 2 - Main sensing technologies used for structural health monitoring in smart ports

Type	Parameter			
	Relative Cost	Working Range	Environmental Adaptability	Applications
Strain gauge	$	Long-term monitor	Sensitive to water, humidity and electromagnetic interference	Stress and strength reserve of the metal structure in cranes and RMG
FBG	$$$	Long-term monitor	Resistant to dust, water, humidity, and electromagnetic interference	Stress and strength reserve of the metal structure in cranes and RMG
Inductive eddy current sensor	$$	Short-time monitor	Resistant to dust, water, and oil interference; Sensitive to surface roughness, surface coating and material	Flaws detection, such as micro-cracks, weld cracks and plastic deformation
Ultrasonic sensor	$$	Short-time monitor	Sensitive to reflection problem, noise with the same frequency and cross problem	Flaws detection, such as micro-cracks, weld cracks and plastic deformation

Fig. 3.

Table 4 - The comparison between the navigation sensors in smart ports

Type	Parameter			
	Relative Cost	Accuracy	Measurement of the position	Environmental adaptability
HF and UHF RFID solutions	$$	High	Absolute position	Sensitive to foundation settlement
Differential GPS systems	$$$	Very high	Absolute position	Sensitive to metal and other shelter
Laser- based navigation systems	$$$	Very high	Absolute position	Sensitive to dust, water, humidity, oil, sun and reflector interferences
Inertial navigation systems	$$	High	Relative position	Sensitive to cumulative error, vibration and slip
Encoders	$	Low	Relative position	Sensitive to cumulative error, vibration and slip

Fig. 4.

V. Communication Standards for Smart Ports

Because of its flexibility in implementation, the trend to

"go wireless" in automated ports is becoming more apparent. However, there are various concerns that must be addressed throughout the implementation of wireless transmission. The most difficult aspect is that these wireless gadgets are vulnera- ble to large metal objects.components and electrical appliances with a lot of power To address this problem,Anti-jamming antenna technology is being developed.Antenna gains can be self-adjusted based on the environment.the condition of interference With the advancement of anti-jamming technolo- gies, the use of wireless communication has become more widespread will continue to expand. ZigBee protocol: One of the most widely used protocols in wireless sensor networks is the ZigBee communication protocol. It has been frequently used as part of IoT [1] infrastructures due to its ease of deploy- ment and ad-hoc capabilities. In terms ofWhen it comes to an automated port, the use of ZigBee orWSN primarily monitors the structural health of buildings. In this case, in the event that the ZigBee nodes have a strain gauge sensorand placed on critical port equipment components (e.g.,crane in the yard). The sampling data is transmitted to the ZigBee sensors.multi-hops to the base station on a regular basis The ad-hoc paradigm is supported by the ZigBee protocol.Wi-Fi protocol: In the field of automated ports, Wi-Fi protocol appears to be the most welcoming wireless technology. Wi-Fi protocol is primarily utilised for video surveillance and AGV remote control due to its wide coverage and vast bandwidth benefits [14]. For example, the front-facing camera on theA yard crane will use Wi-Fi to offer a continuous video stream to the surveillance centre. The coding is done by visual recognition.RF data communication over long distances: RF data communication over long distances is a point-to-point wireless communication technique. RF communication has two distinct advantages:1) RF wireless transmission can reach a distance of 5 km, which is significantly longer than conventional wireless transmission techniques; and 2)Users communicate with each other using RF's point-to-point feature.other directly using RF terminals, without the need for additional infrastructure supportHowever, there are several drawbacks to RF.RF's anti-jamming ability is poor, and data transmission speed is slow.only has a bitrate of 9.6 kbps

4G and 5G solutions: As the fourth generation of mobile telecommunications technology, 4G is becoming increasingly significant in automated ports. When compared to Wi-Fi, it has two advantages: 1) the infrastructural costsis lower because infrastructure is frequently developed by national governments.2) Its coverage and versatility are far superior to that of its competitors. Most locations, with the exception of a few extreme circumstances, can be covered by base.

VI. Implementation of Smart Port Sensing Systems

In this section, details are provided about the identifica-tion, localization, tracking and quayside crane health structure monitoring applications in smart ports. Identification of stress and the strength reserve of the metal structure in cranes and RMG is a very important aspect of SHM. Yao et al. developed a portable wireless strain monitoring system with some IoT technologies such as ZigBee and WSN (Fig. 4a) [9]. This system combines self-organization, self-recovery and low power consumption and aims to improve the monitoring efficiency and meet the serious challenges within SHM of quayside cranes (Fig. 4b)

VII. Computer Vision Application for Container Identification

Serial numbers serve as the foundation for container man-agement in ports, yards, and customs (Fig. 5a). Computer vision can be used to identify objects automatically. container

Fig. 5. 4. Wireless Sensor Network for strain monitoring on a quayside crane: a) the wireless sensor network kit for strain monitoring, b) the distribution of the WSN nodes on the level of the metallic structures

number, and to gather this data as part of theAutomated real- time logistics, addressing the crucial issue The issue of auto- mated container management, which has been implemented in some Chinese ports [15]. The container number, seal integrity, condition of the door handle, lock, and door orientation can all be automatically identified with this vision system. The system architecture is depicted in the diagram.Fig. 5b. Information on the packing position and door location.are also crucial for container transportation via automated means.which the cam- era and laser sensor have been watching.The packing position and door location are provided by this method.Container infor- mation on AGVs or trucks for port transport operations, which can help with automated management Reduce the number of people on the job and enhance the container operation.

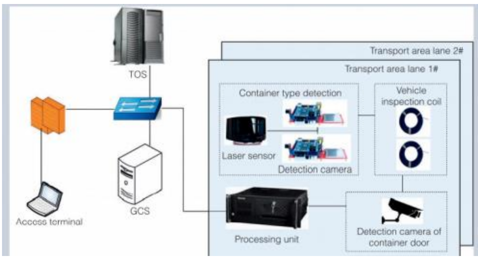

Fig. 6. Automatic identification of container in a smart port. container ID and camera system, distributed container identification system.

CONCLUSIONS

Currently, smart ports represent a reality where automatic container terminals deploy smart sensing systems to improve the performance associated with different terminal tasks. Mod- ern remote sensing technologies such as RFID for identifi- cationand localization and cameras and embedded computer vision algorithms may contribute to safer and reduced time handling operations compared to classical container terminals.

Safety conditions are improved using several possible solu- tions for structural health structure monitoring for quayside cranes. Robust wireless networking and Internet connectivity present important challenges in the port terminal scenario, considering the metallic obstacles present. Different communi- cation solutions that are currently used in automated terminal were mentioned, giving special attention to the ZigBee WSN for strain monitoring. Besides the sensing solutions that we presented that currently are part of the option.

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