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AUTOMATIC IDENTIFICATION SYSTEMS IN INDUSTRY APPLICATIONS

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Abstract
Automatic Identification Systems have become a cornerstone in enhancing operational efficiency and security across various industrial sectors. This paper provides a comprehensive exploration of these technologies, including Radio Frequency Identification (RFID), barcode systems, Optical Character Recognition (OCR), and Internet of Things (IoT)-based solutions. We investigate their applications in diverse industries such as manufacturing, logistics, healthcare, and retail, highlighting the transformative impact on supply chain management, asset tracking, inventory control, and personnel authentication. The paper delves into the technological underpinnings of automatic identification systems, examining the advancements in sensor technology, data processing, and communication protocols that enable seamless integration and real-time data acquisition. We discuss the implementation challenges and solutions associated with these systems, such as interoperability issues, data privacy concerns, and the need for standardized protocols. Through case studies and empirical data, we illustrate the practical benefits of automatic identification systems deployment, including improved accuracy, reduced operational costs, enhanced security, and increased productivity. Additionally, we explore the role of AI and machine learning in augmenting automatic identification systems capabilities, particularly in predictive maintenance, anomaly detection, and automated decision-making.

Key words*: supply chain management, asset tracking, authentication.*

1. Introduction

The advent of digital transformation has fundamentally reshaped the landscape of modern industry, driving a shift towards smarter, more efficient, and interconnected production environments. At the heart of this transformation lies

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the integration of automatic identification technologies, which serve as key enablers for optimizing processes, enhancing operational efficiency, and ensuring real-time data accuracy across the entire supply chain.

Automatic identification technologies, including RFID (Radio Frequency Identification), barcodes, QR (Quick Response) codes, and biometric systems, provide industries with the ability to track and trace products, materials, and assets with unprecedented precision. By seamlessly integrating these technologies into industrial processes, organizations can achieve greater visibility, reduce human error, and improve decision-making through data-driven insights.

In this context, digital transformation is not merely about automating existing processes but about reimagining and redesigning them to leverage the full potential of these technologies. As industries continue to adopt and refine these systems, they unlock new opportunities for innovation, cost reduction, and competitive advantage, ultimately creating more agile and responsive production ecosystems.

This paper explores the critical role of automatic identification in driving digital transformation within the industry, examining its impact on operational and business performance.

2. Automatic Identification Systems

Automatic identification refers to a range of technologies that enable the automatic recognition, collection, and processing of data about objects, people, or events without direct human intervention. These technologies are fundamental to modern systems that require speed, accuracy, and efficiency in data handling. They can be implemented in control and management systems (Stankovski & Ostojić, 2010; Baranovski et. al 2022), different industrial applications like traceability systems (Stankovski et. al 2009; Tarjan et. al, 2014; Ostojić el. al 2023), production systems (Stankovski et. al 2009; Vukelić el. al 2011) and in agricultural applications (Stankovski el. al 2012; Acharya et. al 2024).

Technologies that are mostly used as automatic identification technologies are: barcode, RFID, NFC (Near Field Communication), and OCR (Optical character recognition).

A barcode is a machine-readable representation of data, typically used to identify products or items. Barcodes are composed of a series of parallel lines or other geometric patterns that vary in width and spacing, encoding information that can be scanned and interpreted by barcode readers. There are different types of barcodes like linear, 2 dimensional, and 3 dimensional whereas linear is mainly used in retail for product identification and pricing, in inventory management and logistics to track stock levels and movement, and in healthcare for patient identification and tracking medical supplies. Two and three-dimensional barcodes are mostly used in industry applications (Direct Part Marking of manufactured parts commonly made of materials such as metal or ceramics, Figure 1.).

Figure 1: Direct Part Marking (HPRT, 2024)

RFID and NFC similar technologies are both wireless communication technologies that use radio waves to exchange data. However, they serve different purposes and operate in different ranges and contexts (Ostojić & Stankovski, 2012). Some types of RFID can operate over several meters, while every NFC works within a few centimeters. RFID is generally used for tracking and identifying objects, while NFC is designed for secure, short-range communication, often between two devices. RFID typically involves one-way communication, whereas NFC allows for two-way communication between devices. Both technologies are widely used in various applications like access control, enhancing efficiency, and security, whereby RFID is more often used in industrial applications (Figure 2.).

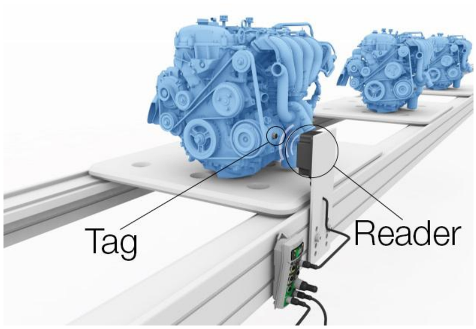

Figure 2: RFID product tracking (Balluff, 2022)

OCR is a technology used to convert different types of documents or images captured by a digital camera into editable and searchable data. OCR enables the recognition of printed text characters allowing their conversion into machine-readable text, so it is in most cases used in manufacturing for quality control since it can read and verify product labels, serial numbers, and other printed information during the manufacturing process (Figure 3.) and inventory management for automating the extraction of data from packaging and labels to improve inventory tracking and management. Also, OCR is used in logistics and transportation for package tracking and license plate recognition.

Figure 3: OCR in the automobile industry (OCR solutions, 2019)

The basic part of the Internet of Things (IoT), which enables connecting devices, systems, and processes to the Internet, allowing real-time monitoring, data collection, and automation, is the automatic identification of all connected entities. IoT is widely used in industry so a special branch of IoT is called IIoT (Industrial Internet of Things) and it differs from IoT in way that it requires higher levels of reliability, security, and real-time data processing to optimize industrial processes and operations. The processes of asset tracking within the factory, improving supply chain efficiency, and reducing waste are supported by IIoT. Often IIoT sensors monitor machinery, for signs of wear and tear, predicting when maintenance is needed to prevent costly downtime, and also can monitor and control equipment like pipelines, meters, and transformers remotely, improving reliability and reducing operational costs.

A new paradigm is Automatic Identification Systems (AIS), and they have a crucial role in navigation and safety, providing real-time information about vessels, including their position, course, speed, and other relevant data. Integrating Artificial Intelligence (AI) and Machine Learning (ML) into AIS can significantly enhance these systems' capabilities, offering benefits in several areas like trajectory prediction, where AI models can predict an asset's future trajectory based on its current and historical movement data. This can help in anticipating potential collisions or deviations from expected routes, enabling preventive actions. Also, machine learning algorithms can detect unusual asset behavior that might indicate an emergency, unauthorized activity, or other risks. By learning from patterns of normal operations, AI can flag deviations that require attention.

AIS data can sometimes be inaccurate or incomplete. AI can help identify and correct these errors by cross-referencing with other data sources or by recognizing patterns that suggest an error. AI can be used to analyze asset behavior over time, identifying potential security threats such as unauthorized entry into restricted areas or suspicious loitering.

By analyzing AIS data along with other operational data, AI can predict when a vessel might require maintenance, helping to prevent breakdowns and improve operational efficiency. Besides that, fuel consumption optimization by suggesting speed adjustments or alternative routes, leading to cost savings and reduced environmental impact, can be accomplished with AI implementation.

3. Benefits and Challenges of Automatic Identification

Implementation of automatic identification in industrial applications brings numerous benefits to industrial systems. To only name a few there is awareness of the real-time state of the system, efficiency, accuracy, security, and real-time inventory status. These technologies enable real-time tracking and monitoring, providing businesses with up-to-date information that is crucial for agile decision-making.

Automated data collection, manufacturing, and business processes can significantly reduce the time and labor required to record information, leading to faster operations and improved productivity. Besides that, automated data collection reduces the risk of human error, ensuring that data is captured accurately and consistently. In some processes, there is sensitive information about the users, like access control and identity verification which needs to be acquired, so manual activities are unsuitable. Automatic identification systems have security protocols that protect from data corruption or manipulation. The typical application of automatic identification in the industry is in inventory management. Automatic identification allows accurate tracking of inventory levels, reducing the chances of stockouts or overstocking and optimizing supply chain operations.

Automatic identification system implementors must also be aware of challenges to ensure successful system implementation. Some of the challenges can be the cost of implementation that can overtake benefits, privacy, and security of personal data, an increase in system complexity, and difficulties in interoperability.

Before implementation, businesses must make a decision to invest in the implementation of automatic identification based on weighing the costs against the potential benefits. In most cases, there are significant investments in software, hardware, infrastructure, and training. New working procedures must be adopted, for which it takes time to achieve effectiveness, essentially in complex industry processes. Also, the problem of integration of new infrastructure, hardware, and software in existing systems can arise, since an improved system should work seamlessly to maximize effectiveness. Regarding privacy concerns relating to personal data, it is essential to implement robust data protection measures.

4. Conclusion

Automatic identification is a cornerstone of modern data-driven processes, offering numerous advantages in terms of efficiency, accuracy, and security. As technology continues to evolve, the adoption of automatic identification systems is likely to expand, driving further innovation and improvements in various industries. However, careful consideration of the challenges and a strategic approach to implementation are essential to realize the full benefits of these powerful technologies.

Future research should be focused on the integration of AI and machine learning with AIS in order to accomplish a powerful evolution in the industry sector, with the potential to greatly enhance safety, efficiency, and environmental sustainability.

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