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# EVOLUTION OF RFID APPLICATION IN CONSTRUCTION

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## ABSTRACT

In the last two decades, RFID technology was used widely in construction. In essence, during different phases of a building project, RFID enables control over a wide variety of procedures, from its construction to its ecosystems. In order to demonstrate recent trends, weaknesses and differences, this paper aims specifically to examine RFID implementations in the construction industry. The paper presents the use of RFID technology in tracking and monitoring of material and resources in construction work. In addition, RFID is integrated with different systems like PDAs (Personal Digital Assistants) and Vision technology to enhance its capability. In this later step an RFID application is presented aimed at facilitating the identification of furniture parts in scanned habitats. At the end of the paper are discussed future progress.

**KEYWORDS**: Construction, Monitoring, RFID, Tracking, Vision technology.

## 1. INTRODUCTION

Philips suggested the idea of an intelligent world, which first appeared in the 1999 literature [42],[44]. A smart environment is characterized as a place for the users to have invisibly and unobtrusively various technical devices (sensors, readers, computers, etc.) with which to interact [25], simple and easy. For instance, an elementary proposal for an intelligent environment is the space in which lights are enabled if light value is below a limit, and people inside it need it. This description gives rise to many lines of research concerning the automation of human or human-to-machine interactions. The theory of communicating with technology devices presupposes a major shift. Other types of devices less challenging to the consumer replace keyboards or mice (remote controls, wireless sensors, touch-sensitive screens, etc.).

Radio Frequency Identification (RFID), a technology that is focused on information exchange through electromagnetic signals, is one of the most costly and promising wireless contactless systems in the world [39]. RFID is used for a variety of uses, including aviation, building and facilities management, healthcare, retail, logistics or protection because of its capacity for object detection and tracking.

The location of the components is tracked by means of RFID technologies in a manufacturing chain. The incorporation of an RFID system into the manufacturing process, for example, allows information on the following tasks in robot construction [20]. Infineon Technologies, one of the world's largest semiconductor producers, has developed an RFID and ultrasonic sensor detection and location system for improving logistics in wafer production [34].

## 2. INTRODUCTION TO RFID TECHNOLOGY

The system of RFID (see Figure. 1) consists mainly of an antenna and a series of transponders or tags that are attached to the transceiver (called the reader) with data being stored [17]. The transceiver works with an application to handle the information contained in the tags with a computer.

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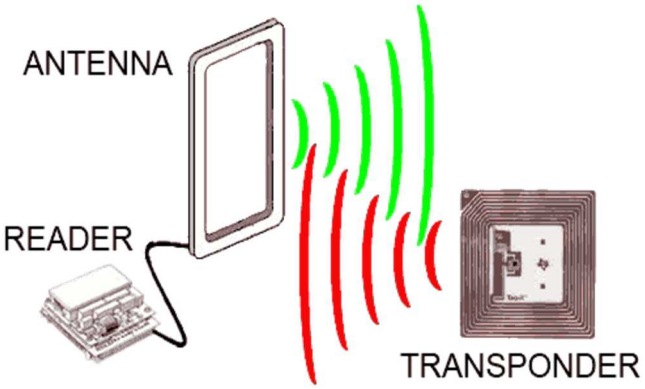


**Figure. 1. Example of RFID system [45]**

The transceiver and transponder are conveyed by antennas. Depending on the distance between the system and the objects on which the Tags are fixed, different types of antennas and tags are available. The various service bands and area of action are presented in table 1.

***Table. 1. Operation Band for RFID Technology***

| **Band** | **Frequency Range** | **Range** |
|---|---|---|
| 125-150 kHz | Low frequency | <2 m |
| 13.56 MHz | High frequency | <20 cm |
| 433-928 MHz | Ultra-high frequency | 433-864 MHz <100 m |
| | | 865-928 MHz <2 m |
| 2.45-5.8 GHz | Microwave | <1 m |
| 3-10.5 GHz | Ultra-wide band | <10 m |

In a construction, some details about components or even individuals that are scarce in the area needs to be monitored. The distances are therefore in the range of several dozen meters. The antennas used to track materials or staff are in the majority of cases UHF antennas, as shown in table 1.

As already explicit, the knowledge being shared via RFID is keep in tags. The vary of actions of the device is additionally supported the kind of tags hooked up to the objects. These devices embrace 2 parts: an integrated system to store, process and modulate the signal and if required the transceiver gathers power; and a signal transmitting and receiving through antenna.

Three types of tags are available: active, passive, and semi-passive [29],[7]. Active tags are supplied with power and signal is transmitted to the transceiver. Passive tags, on the other hand, obtain the necessary reader energy. There is a restricted range of action on passive tags (15 m), while active ones can be used up to 100 m distances. Finally, semi-passive tags may be distributed, but reverse dispersion is used. Furthermore, the tags must be activated by a signal. The variations between various types of tags can be seen in table 2.

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*Table. 2. Types of RFID Transponders*

| | **Active Tags** | **Passive Tags** | **Semi-Passive Tags** |
|---|---|---|---|
| **Distance range** | Up to 100 m | Up to 15 m | Up to 60-80 m |
| **Power** | Power supply (Battery) | Inducted from readers | Turned on by a signal |
| **Data storage** | Extendible | 512 bytes to 4 KB | Extendible |
| **Data transfer rate** | Up to 128 KB/s | Up to 1 KB/s | Up to 16 KB/s |
| **Lifetime** | Up to 10 years | Unlimited | Over 6 years |

## 3. RFID IN TRACKING SYSTEM

**Material**

The RFID technology provides the ability to rapidly update and accurately locate materials in construction applications, from one to several meters. Since the 1990s, there has been a possibility to take RFID technologies into account for the management of essential resources, equipment, and vehicles [27].

To identify the materials in a scene and estimate their position RFID may be incredibly helpful to find or even to place wireless sensors [20] on a construction site. In recent years, several techniques for this purpose were developed in order to improve position precision [1].

One solution is to incorporate a Global Positioning System (GPS) of RFID devices for search in a real 3D scenario for tagged items, to boost the precise locations of RFID [10]. The proximity of an object to other known locations is identified as other techniques to estimate the position of the materials at a working site [11]. The combination of ultrasound technology and RFID system [2] will enhance positioning efficiency in order to avoid limitations in RFID- and GPS-based systems.

The structural components are numerous and often distributed throughout the workplace, making them truly complex in real-time monitoring. Structural steel elements, such as beams and precast concrete panels [36], are equipped with RFID tags in order to track their position in the construction field. Using metal tags increases the reliability of the method of data collection.

**Resources**

It is not only the materials that must be monitored at the construction site, but also other resources, such as workers or equipment. A supervisor must carry out the assessment of work on several occasions. However, several workers travel about the office concurrently. In order to monitor work done by workers, RFID tags can be used [6] to record movements of labour and working time.

The low number of tools or their place of work is due to unnecessary interruptions. Their use is unwanted. Staff must check for the correct tool for the scene, a task that takes time. The number of equipment exceeds the quantity to prevent delays in other building scenes. But applying RFID tags to the equipment [4] is a useful technical technique for budget optimization.

One of the major causes of deaths in construction is vehicle and heavy machinery, which accounts for almost 36% [14]. The creation of a personal alert system [43] will alarm staff with work area information to the dangers of hazards. Wu et al [35] have analyzed and classified a ZigBee RFID Device to track and regulate the location of materials and labor force for struck-by-fall-object accident.

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The proposals referred to in Section 3 are presented in table 3, which indicate that authors combine various technologies.

***Table. 3. Use of RFID Tags for Locating Resources***

| Authors | Material | Workers | Equipment |
|---|---|---|---|
| Yagi et al. [5] | ✓ | | |
| Jaselskis et al. [11] | ✓ | ✓ | ✓ |
| Su et al. [13] | ✓ | ✓ | ✓ |
| Cai et al. [14] | ✓ | | |
| Song et al. [15] | ✓ | | |
| Skibniewski et al. [16] | ✓ | | |
| Kim et al. [17] | ✓ | | |
| Chae et al. [18] | | ✓ | |
| Goodrum et al. [19] | | ✓ | |
| Chae et al. [21] | | ✓ | ✓ |
| Wu et al. [22] | ✓ | ✓ | ✓ |

## 4. RFID IN CONSTRUCTION SITE MONITORING

The Monitoring is a vital activity in order for progress in construction sites to be correctly calculated. This control technique also supports the management of work, protection, and equipment. The RFID systems are used to analyze each of these factors separately, as shown in Section 3. However, a number of works occur in the management of an overall project with various approaches. For instance, Yoon et al. [15] suggest that each part should be regulated in ordering, manufacturing, transport, storage, Jobs to install and inspect.

The ongoing movement of materials and staff in the workplace, together with progress in work, make it truly difficult to track the resources in the building environment. Not all procedures carried out in the workplace can be regulated by RFID technologies. The combination of several technologies will nevertheless automate the monitoring systems to assess the progress of each operation. RFID and bar codes, laser scanning and photogrammetry are then used for the visualization of locations in order to capture actual working time and model information and update planned data [5].

The status of materials at work sites is regulated using RFID technology, a useful tool to view and compare the planned model with the designed model of the 4D CAD building in development [37]. Other authors [28] suggest the incorporation and enhancement of Building Information Management (BIM) models to visualize construction progress in real time. They recommend the use of RFID to monitor various components.

Liu et al. [3] propose a combination of technologies (RFID, GPS, PDA and GPRS) in one of the publications in this area to document watering activities in the construction of earth-rock dams. The trucks are fitted with RFID tags to ensure that the vehicles are placed.

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These works, which lead to integrating RFID with other construction site control technologies, are compared in table 4.

***Table. 4. Combination of Technologies and RFID for Construction Site Monitoring***

| Authors | Computer Vision | Barcodes | CAD/BIM | AR | GPS | GPRS |
|---|---|---|---|---|---|---|
| El-Omari et al. [24] | ✓ | ✓ | | | | |
| Montaser et al. [25] | | | ✓ | | | |
| Wang et al. [26] | | | ✓ | ✓ | | |
| Liu et al. [27] | | | | | ✓ | ✓ |

## 5. INTIGRATION OF RFID SYSTEM WITH DIFFERENT TECHNOLOGIES IN CONSTRUCTION

Form the last five or six years the concept of integrating different technologies has been consolidated in RFID applications. The use of the RFID enables a range of activities in this area. However, if various technologies are combined, a method may be even more efficient and complete. To simplify and increase the performance of work, some systems requiring the use of various technologies will automate them. There are a number of publications currently in existence, which combine many systems.

Two of the most common forms of RFID-based technology combinations: personal digital assistants (PDAs) and computer vision.

**RFID Integrated with PDAs**

Several users are supposed to connect with the RFID system in a multitude of activities. As a result, users have a device that allows them to bind to the RFID targets placed at a wide distance. Wireless and PDAs are most widely used. Both different innovations are combined from construction to habitat over the life cycle of a home.

Before the construction process began, RFID and PDA technologies were merged, in particular during the manufacture of concrete components [32]. The employees track and produce a portable data set for the inspection tasks in the test laboratories. The management of the elements can be managed once produced. In order to submit and share with the manager office or the workplace details relating to the inventory or the transportation phase [33].

Another point to remember is that in the last few years work for the renovation of the habituated facilities has decreased [23]. There are buildings that are able to reuse or alter parts. Therefore. These constructions are referred to as open buildings [41]. The elements of this style of construction have been handled by the RFID and PDA system [28] to help architects and engineers re-analyze and re-design the building components.

When the building is occupied, a number of components are available that need maintenance. These elements may be part of the structure of the building or machinery. RFID tags are mounted in these modules so that information about the items to be restored or checked in the building is handled. Thus, a scheduling method for the coordination of the different activities may be developed [9],[12].

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As previously mentioned, RFID technology can be useful in building disasters management and prevention. Sending fire-related details via the PDA would save valuable time during emergency operations [45].

**RFID Integrated with Computer Vision**

A scheduling and budgeting process model may be developed to record progress on the construction project [5]. Barcodes or RFID systems may be implemented to manage the staff, the material, and the positioning of the instruments. The complete representation can be performed via laser scanners and photogrammetry on the site under construction. This allows identification of potential defects in building components [18]. Finally, the laser scanner-based 3D models produced by the data update the details contained in the plans and compare the designed and constructed model [21].

As mentioned in the last section, a number of identification or repair operations take place in various scenarios during the life cycle of a project. In these works, vision systems may be useful. The role of the object recognition could however become very complex if the sensed objects are not fully visualized. In these instances, some information on the elements can be made accessible through a collection of RFID tags. The knowledge obtained from the RFID tags enables you to understand what artifacts are present in the scenario under study amongst those stored in a database [31]. A visualization system can consist of cameras providing two-dimensional images with extracted several object parameters [24] or laser scanners that provide scene 3D information [31],[40].
RFID and Laser Scanning Combination for the Development of BIM Models

As stated in the previous sections, RFID's work focuses primarily on the development process and the management of the position of the different resources at the workplace. However, the use of this technology for monitoring sites or sites under construction, in particular together with other technologies, has expanded over the last few years (see table IV and V).

A combination of RFID technology and laser scanning is required to generate a 3D model from a populated environment in this subsection. To date, several authors have worked with Terrestrial Laser Scanners (TLS) to create synthetic models of various types of installations and the automated development of these 3D representations is at the heart of construction research. However, TLS data consists of millions of unstructured 3D points to be processed.

A RFID system is adapted to a laser scanning system [40], in order to reduce the computational processes in this mission. RFID offers valuable details on the scene being analyzed, as is seen in this work. Stored in RFID tags, this information applies primarily to the design of simple furniture components where tags are applied to. Figure. 2 offers an overview of this framework.

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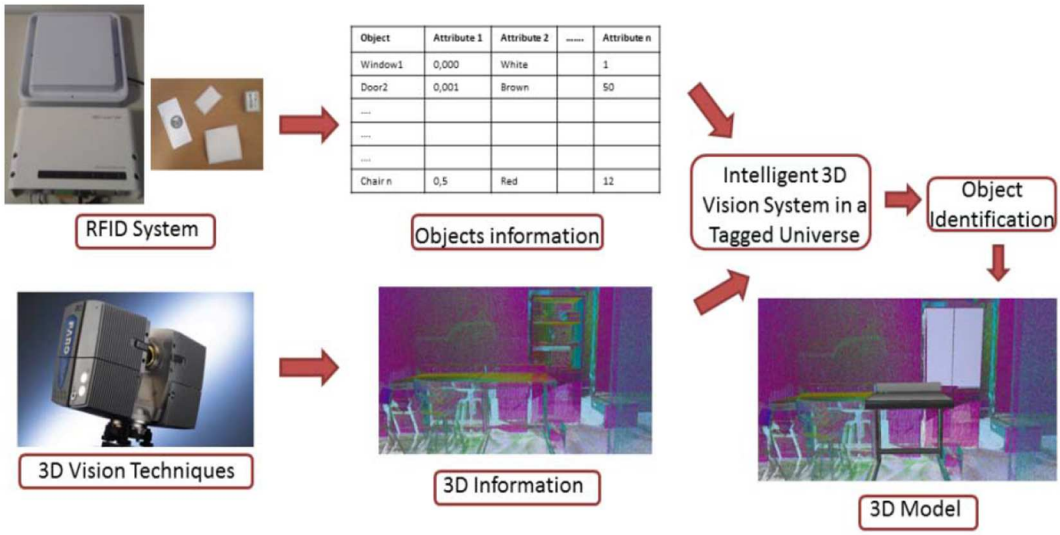


***Figure. 1. Overview of the System [36]***

The framework has been evaluated in a number of furnished situations and can differentiate common pieces of furniture, chairs, tables, and wardrobes in detail. While the intention of this paper is not to provide further information about the proposed method, the reader is referred to [40].

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*Table. 5. Characteristics of Different Combination of Technologies*

| Authors | Accompanying Technology | Purpose |
|---|---|---|
| Yin et al. [33] | PDA | Sending information to the manager's office or the site under construction |
| El-Omari et al. [5] | Laser Scanner | Calculating quantities and site representation |
| | Photogrammetry | Calculating quantities and site representation |
| | Barcode | Collecting working hours |
| | CAD | Information / updating planned data |
| Kiziltas et al. [18] | Laser Scanner | Condition assessment |
| | | Quality control defect detection |
| | | History capture / Heritage |
| | Embedded Sensors | Bridge footing inspection |
| | | Building inspection |
| Cheng et al. [16] | PDA | Maintenance management |
| Ko et al. [9] | Tablet PC | Data management, scheduling and data transfer between workers |
| Shiau et al. [45] | PDA | Sending drawings and information to the rescue teaming fires |
| Rebolj et al. [21] | Camera | Image recognition |
| | Mobile Computing | Communication support and information consistency checking |
| Cerrada et al. [31] | Laser Scanner | 3D information from the scene |
| Hontani et al. [24] | Camera | Initial pose estimation of object |
| Valero et al. [40] | Laser Scanner | 3D information from the scene |
| Wang et al. [32] | PDA | Monitoring and control of inspection progress |
| Cong et al. [12] | PDA | Maintenance management |

## 6. FUTURE PROGRESS

Radio Frequency Identification technology has helped simplify a variety of works, increase their production, and lower the costs from the design to its application, whether as the only technology or in conjunction with others.

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There are various shortcomings and discrepancies after an analysis of the state-of-the-art in this system that drive contractors to select other available technologies.

1) Accuracy: Regarding the analysis of the location of various subjects in the scene, it checks not very accurate to measure the position of RFID systems [22].
2) Interferences: Metals and concrete, which are very common in the building sector, can interfere during the exchange of information [8]. In reality, a further surface between the tag and the object in several instances must be put. Moreover, if tags are surrounded by metal, reading problems may arise.
3) Standardization: There may be some supposed difficulties in the trade in tagged parts due to the variations in the law around the world about RFID antennas. EPC global is currently engaged in the establishment of RFID standards, such as UHF 1 Generation 2 [13].
4) Safety: One benefit of RFID is that it does not require a clear view of a tag for the user to detect and receive the stored information. Although a range of works are available in connection with fire support [19], the issue is still not adequately addressed. The monitoring of structural components that are not accessible to users, such as piping spools or the electrical supply may contribute to a potential improvement of the protection of buildings.
5) Building Information Management (BIM): In order to change the building industry, this phase would play a critical role in the physical and functional characteristics of the facilities. In a description of Section 5.2.1, we presented a laser scanning and RFID combination method for the generation of BIM models for the inhabited interior [40]. In this context, we presented the system for this area. In addition, RFID-based work related to user localization monitoring in BIM model was published in the recent past [26],[30].

Integration of RFID with Other Technologies: The proposals for combining RFID with personal digital assistants or other wireless gadgets, as the demand is growing and prices of this kind of gadget are one of the stronger research lines in the future. During the past five years, the majority of work carried out in this field of research has concentrated on integrating technologies, particularly in the monitoring of building sites.

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