COMPARATIVE ANALYSIS OF MEDICAL EQUIPMENT IDENTIFICATION TECHNIQUES: A MULTIFACETED APPROACH FOR ENHANCED HOSPITAL OPERATIONS

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Abstract: *The quality of medical services that patients can receive in a certain hospital depends, to a large extent, on medical technologies available, more precisely on their performance and efficiency. In this context, equipping hospitals with equipment advanced technology can represent, among others, a relevant indicator in terms of the disease screening and prevention process. The primary techniques for automatically identifying medical devices in a hospital are the focus of this research work. The study examines the Barcode, RFID tags and Smart Card methods and the most efficient approach is chosen based on multicriteria analysis.*

1. INTRODUCTION

With the development of IoT (Internet of Things) technologies, industries such as healthcare seem to be turning their attention to internet-connected devices capable of collecting and acting on data [1], [2]. IoT is extremely beneficial and practical, especially in complex work environments such as hospitals. To prevent mistakes, IoT tracking devices can be used for real-time location tracking (RTLS) of medical equipment such as mobile tablets, wheelchairs, or various monitoring equipment (defibrillators, nebulizers, oxygen pumps, etc.) [3]–[5]. The deployment of medical staff at different locations can also be analyzed in real time. A busy hospital is a place where monitoring doctors, nurses, expensive medical equipment and even hospital beds can be an overwhelmingly complex and challenging task, and being able to solve this quickly and easily can optimize workflows and, sometimes even lifesaving.

IoT-based systems can be applied in a diverse range of healthcare subfields, including elderly patient care, chronic disease surveillance, etc. [6], [7]. Applications are divided into two groups: applications that related to a specific disease or infirmity and applications that relate to a number of diseases or conditions taken as whole. Below is an outline of healthcare services and applications using IoT, Fig 1. This list is inherently dynamic and can easily be enhanced by adding additional services with distinct features and numerous applications that span both groups.

IoT technologies enable a variety of healthcare services where each service provides a set of healthcare solutions [8], [9]. In the healthcare context, there is no standard definition of IoT services. However, there may be cases where a service cannot be objectively differentiated from a particular solution or application.

It can be seen that services are used to develop applications, while applications are used directly by users and patients. Therefore, services are developer-oriented, while applications are user-oriented. Along with IoT solutions, automatic identification technologies of medical devices are also rapidly evolving with innovative applications, especially in healthcare sectors [10].

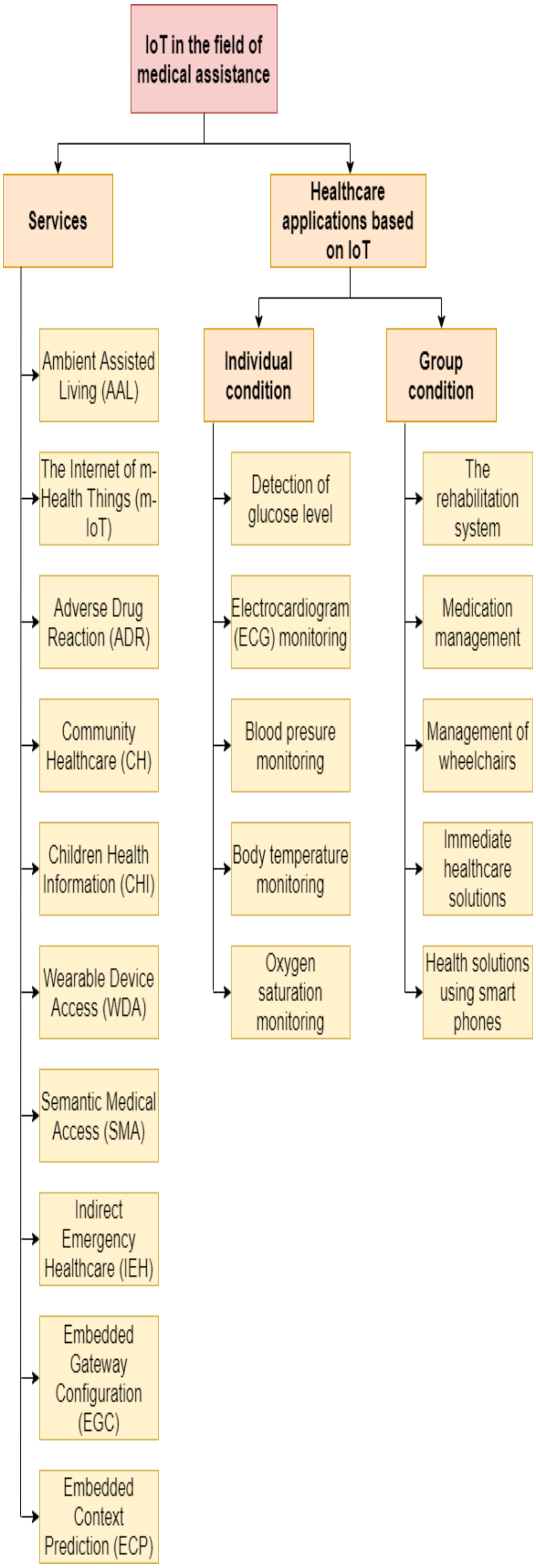

Fig. 1 IoT healthcare services and applications

These technologies can reduce medical errors, improve patient safety, and increase the quality of medical services in hospitals [11], [12]. Through the automatic identification of people (patients or medical personnel) and objects (medical equipment, medical dressing, blood transfusion bags, etc.) this technology allows the identification, detection and tracking of entities security and other specific healthcare capabilities. Automatic identification technology can be used in the medical field in the followings ways: identifying a patient in emergency situations; measurements of patients' vital signs (for example, patients with chronic diseases); recording significant medical information and transferring it to an electronic monitoring device; monitoring the elderly, even at home; asset and equipment monitoring; controlling the administration of drugs and blood transfusions, thus reducing medical errors in hospitals [8], [13].

The IMAMS research projects aims to develop a software for monitoring the operating status of the medical devices and provide an analysis of the main methods of automatic identification of medical equipment's in a hospital. Methods based on barcodes, RFID tags and Smart Cards will be analyzed. Then a multicriteria analysis will be used to determine which is the most effective method. The main contributions of the paper are:

- Description of the automatic identification methods: barcode, RFID and Smart card (Section 2);
- Analysis of the methods based on multicriteria technique (Section 3).

2. AUTOMATIC IDENTIFICATION METHODS

The operation of any automatic identification system can be summed up in the following essential aspects: on objects, patients or medical personnel, there is a tag or card considered as transponder; when this tag or card reaches the range of the reader, the data is sent; next, the data is collected and processed.

A. METHODS BASED ON BARCODE

Barcodes are visual data representation in the form of images that can be two-dimensional (2D) matrices of dots and shapes or onedimensional (1D) parallel lines [10]. The encoded information can be accessed using an optical barcode scanner that communicates with a system where the information is processed. A 2D barcode can integrate more data and is easier to scan than a 1D barcode [14]. Among the advantages of the barcode method are: low cost, high data capacity, integration of various data types and high fault tolerance. There are also some major drawbacks, including: sensitivity to the environment, low security and small storage capacity [10], [14]–[16].

B. METHODS BASED ON RFID

RFID is an identification system similar to barcode technology. Barcode systems require a reader and adhesive labels stuck on objects, while RFID requires a reader and special tags or cards attached/integrated to objects. The RFID technique uses a low-power electromagnetic field, with a working frequency in the radio frequency range, to read/write data [17]. This radio frequency field does not require a precise positioning of the object when reading, it penetrates any non-metallic material, without the need for direct contact, nor does the condition of direct visibility between the reader and the tag. RFID systems are generally composed of three components: a reader, a transponder (radio frequency tag) and a computer or any other data processing system. Unlike barcode, RFID tag is not sensitive to environment conditions, and it is also much more secure. However, the cost of reading units is quite expensive, and the implementation of such a system is time-consuming [10], [14]–[16], [18].

C. METHODS BASED ON SMART CARDS

A smart card is an integrated circuit card (ICC) which contains a microprocessor for data processing, a memory chip for operating system and temporary data and an input/output circuit for establishing communication with other devices (reader) [19]. The technical specifications of smart card technology are comparable to those of RFID, only that it comes with two major disadvantages: sensitivity to the environment and require making direct contact for reading [19]–[22].

3. MULTICRITERIA ANALYSIS

Considering the large number of criteria and the variety of options for each criterion of the comparative analysis presented in Table 1, it leads to increasing the difficulty in selecting the right automated identification method. As can be seen, there are twelve criteria that target the technical specifications of the barcode, RFID and smart card method. These technical specifications were synthesized withing the “IoT Medical Asset Management Software (IMAMS)” project.

Table 1. Characteristics of barcode, RFID and smart card method

Characteristic	***Barcode***	***RFID***	***Smart Card***
Data volume (bytes)	*1…128*	*16…64k*	*16…64k*
Data density (per surface)	*Low*	*Very High*	*Very High*
Data modifications (manual)	*Possible but limited*	*Impossible*	*Impossible*
The influence of dirt	*Very high*	*No influence*	*Medium*
The influence of non-transparent coating	*Depends*	*No influence*	*Depends*
The influence of the reading direction/position	*Low*	*No influence*	*Very high*
Lifetime	*Limited*	*Unlimited*	*Limited*
Reading unit acquisition cost	*Very low*	*Medium*	*Low*
Operating costs	*Low*	*Practically zero*	*Medium*

Unauthorized modification	*Possible*	*Impossible*	*Impossible*
Reading speed	*Low (4s/tag)*	*High (0.5s/tag)*	*Low (4s/card)*
Maximum reading distance	*0…50cm*	*0…5m*	*Direct contact*

Thus, in order to produce a single conclusion following the evaluation, or, on the contrary, with the aim of producing several conclusions adapted according to the method, in the following, the multicriteria analysis (MCA) will be used. This technique allows structuring and combining several criteria simultaneously in order to make a decision for a complex situation. So, for each individual criterion a score between 0 and 100 will be assigned, where 100 means the most favorable case and 0 the worst case. Table 2 shows the allocation of the score for each individual criterion. The weighting adopted is based on the Mean weight method, a straight forward weighting approach that considers all attributes equally important [23]. After constructing the matrix with the allocation score, the performance matrix is created, Table 3, where each criterion receives a weight expressed as a percentage, so that their sum is equal to 100%. The weights are distributed equally, each criterion having a maximum of 8.33%.

Table 2. Score matrix

Characteristic	***Barcode***	***RFID***	***Smart Card***
Data volume (bytes)	*100*	*50*	*50*
Data density (per surface)	*0*	*100*	*100*
Data modifications (manual)	*0*	*100*	*100*
The influence of dirt	*0*	*100*	*50*
The influence of non-transparent coating	*0*	*100*	*50*
The influence of the reading direction/position	*50*	*100*	*0*
Lifetime	*0*	*100*	*0*
Reading unit acquisition cost	*100*	*0*	*50*
Operating costs	*50*	*100*	*0*
Unauthorized modification	*0*	*100*	*0*
Reading speed	*0*	*100*	*0*
Maximum reading distance	*50*	*100*	*0*

Table 3. Performance matrix

Characteristic	***Barcode***	***RFID***	***Smart Card***
Data volume (bytes)	*8.33%*	*4.167%*	*4.167%*
Data density (per surface)	*0%*	*8.33%*	*8.33%*
Data modifications (manual)	*0%*	*8.33%*	*8.33%*
The influence of dirt	*0%*	*8.33%*	*4.167%*
The influence of non-transparent coating	*0%*	*8.33%*	*4.167%*
The influence of the reading direction/position	*4.167%*	*8.33%*	*0%*
Lifetime	*0%*	*8.33%*	*0%*
Reading unit acquisition cost	*8.33%*	*0%*	*4.167%*
Operating costs	*4.167%*	*8.33%*	*0%*

Unauthorized modification	*0%*	*8.33%*	*0%*
Reading speed	*0%*	*8.33%*	*0%*
Maximum reading distance	*4.167%*	*8.33%*	*0%*
TOTAL	*29.16%*	*87.47%*	*33.33%*

The barcode and smart card method obtained a total score of approximately 30%, while the RFID method has a score of 87.5%. Based on the multicriteria analysis, it turns out that the RFID method is the most suitable for implementing an automatic identification system in the hospital field. This method presents major advantages compared to the one based on barcodes or smart cards in scope of identification of medical devices. The lack of sensitivity to the environment, of positioning in the case of reading, the life span and the reading speed make this method clearly superior to the presented methods in the work environment such as the hospital one.

4. CONCLUSIONS

Automatic data acquisition increases the value of the information in the system through real-time access to it. Most identification technologies require special operating conditions, as is the case with the barcode where an environment without optical interference is required, or smart cards that needs clean contacts to carry out the data transfer and must be handled by the operator.

The RFID system based on transponders is ideal for contaminated environments, which can facilitate the transmission of pathogens found in hospital units. RFID tags and readers do not contain moving parts, the maintenance being very low, they can operate in the mentioned conditions for long periods of time without intervention. Moreover, RFID tags have extremely long lifetimes, typically exceeding the lifetime of the host object. Due to this reason, RFID system becomes the cheapest identification solution if it is evaluated in the long term. Compared to barcodes or smart cards, RFID tags are virtually impossible to copy. Therefore, they are suitable in applications with a high degree of security, such as the identification in a hospital.

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