

# **COMPETITION FOR THE ALLOCATION OF RESEARCH DOCTORATE SCHOLARSHIPS WITHIN THE PNRR FUNDS UNDER D.M. 352 OF 9 APRIL 2022 Academic Year 2022/2023 Cycle XXXVIII**

Ph.D. Programme in Research Methods In Science And Technology

Constrained topic: IoT and Digital Technologies for Quality-Oriented Cleaning and Integrated services

Title: Study of Quality-Oriented Cleaning through IoT and Digital Technologies

Candidate: Lorenzo Calisti

## **Proposed Research**

### **State of art**

The quality of cleaning and integrated services is a determining factor for the satisfaction of users of large hotels, shopping centers, stations, airports, and hospitals; the management of these services requires specific organizational skills that are usually offered by specialized companies to which the services are contracted out with specifications based on the type and quantity of services offered rather than on the quality of the result. Sometimes it happens that the companies involved are not able to guarantee a sufficient level of cleanliness, not only causing discontent in customers, but also bordering on legal limits; the causes of this are not attributable only to the negligence of certain companies, but mainly depend on the speed with which these services are expected to be provided which leads to an impoverishment of the work performed. Added to this is the difficulty in recognizing whether a room is clean or not.

The Internet of Things (IoT) describes all those physical objects with a set of sensors, computing capabilities, and software capable of exchanging data with other devices through the internet or a similar network [1] [2]. The term was coined in 1999 by Kevin Ashton during a presentation to automatically collect data; a few years later the term was extended to include a controller with the role of a "brain", sensors, actuators, and a network [3].

Over the years, the IoT field has evolved thanks to the convergence of numerous technologies including ubiquitous computing, more performing embedded systems, advanced sensors, and machine learning. The fields of application of the IoT are innumerable, some examples are wireless sensor networks, control systems, automation, and smart homes.

An area with increasing popularity is that of the detection of environmental physical quantities, in this case, the data collected by the sensor networks concern physical quantities related to the environment in which the sensors are located, such as the

temperature, and the amount of noise or the air quality. Usually, these data are collected to more easily study complex phenomena related to the environment.

## **Objectives**

The main objectives of this research are to study new methods to optimize the productivity of cleaning companies by improving the methods and working conditions of operators, reducing waste, and bringing a higher quality of services to end customers. To this end, the work is based on two main themes:

1. Development of methods to automate the collection of customer feedback
2. Development of IoT systems for the automatic and objective measurement of the level of cleanliness, healthiness, and comfort of environments using measurements made by operators and automatic measurements of fixed sensors

To do this, various IoT technologies are considered, such as wireless sensor networks combined with machine learning algorithms capable of extracting useful information directly from the collected data.

The data will be processed in a hierarchical manner starting from the IoT devices that represent the leaves of a tree structure, passing through edge devices, and arriving at the cloud in which the collected data will be aggregated and where the machine learning models will be trained.

The project also aims at the definition of quality standards appropriate to the case studies, the definition of intervention thresholds, and the development of semi-automatic techniques for verifying the effectiveness of the interventions carried out.

## **Methodology**

The proposed research has a total duration of three years and will initially focus on the study of the current literature in the field of IoT, sensor networks, machine learning, and more generally the guidelines on cleaning environments, outlining the limits of approaches proposed by other researchers.

In the second part, the research will focus on the development of methods for collecting feedback from customers, this can be achieved in several ways: by developing a mobile application for smartphones or a website that the customer can access to enter his opinion, or indirectly through systems placed in the areas of interest with which the customer can interface, such as tablets in kiosk mode or specially developed hardware.

Finally, the research will focus on the automatic collection of data that characterize the quality of an environment by designing the required sensor networks and training the machine learning models for proper operation.

## **Expected results**

The proposed research aims to complement the studies in the field of IoT applied to the quality of cleaning of public spaces and hotel rooms managed by cleaning companies

by creating ad-hoc solutions to semi-automatically monitor the level of cleanliness and satisfaction of customers.

In particular, with the development of monitoring systems and the definition of intervention thresholds, it is hoped to significantly improve the cleaning of places, reducing waste and bringing a direct benefit to end customers.

## **Bibliography**

1. Gillis, Alexander, *What is internet of things (IoT)?*, IOT Agenda, retrieved 22 August 2022.
2. *Internet of Things Global Standards Initiative*, ITU, retrieved 22 August 2012.
3. K. Ashton, *That internet of things thing: In the real world things matter more than ideas*, RFID journal, vol. 22, no. 7, pp. 97–114, 2009.