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ORIGINAL PAPER

An innovative 4.0 system to prevent the spreading of the diseases which threaten the globalized world

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Abstract

Purpose The purpose of this research is to provide an effective contribution to contrast the spread of Covid19. Therefore, the authors aimed to model a new strategy (technologies and processes), using the principles made available by Industry 4.0.
Method The strategy consists in an IoT thermoscanner (developed by the authors, strategically placed throughout the settlement), and an innovative method of disinfection (achieved by redesigning the sanitization processes, using UV-C rays and gaseous Ozone produced by IoT machines, again conceptualized and developed by the authors, being capable of reproducing the Chapman Cycle and its associated benefits). This method was discussed in the article "Sanitizing of Confined Spaces Using Gaseous Ozone Produced by 4.0 Machines," which was presented at the WCE 2021 IAENG Congress (Best Paper Award of the 2021 International Conference of Systems Biology and Bioengineering).
Result The results consist in: 1. an absolute disinfection system based on a reversible cycle Oxygen-Ozone-Oxygen, with quick re-habitability of the treated rooms, at a minimum treatment costs, without expensive and harmful chemicals or moist water vapor (incompatible by nature with paper and electronics); 2. a 4.0 device for quick detection of fever; 3. clear processes for disease spread prevention.
Conclusion The target contribution was widely achieved, providing machinery, processes and procedures. The authors aim now to extend the solution proposed to any other type virus, bacteria, or pathogen agent introduced by subjects who, despite being unaware of acting as vectors, develop infection along their stay in hotels, offices or any other public place.

Keywords Thermoscanner · Surface disinfection · Surface sanitation · Pandemic

1 Introduction

This article is the extended version of a paper presented by Mosca et al. at an International Conference about "Unconventional Plants" [1] which is published in the WHO (World Health Organization) COVID-19 Research Database. The research began with a thorough examination of the literature on pandemic phenomena that have afflicted various parts of the world during the previous century. The scientists discovered that the onset of fever in Patients infected with diverse viruses was nearly consistent, regardless of viral type. As it was for yellow fever, SARS-Cov-1, and, most recently, SARS-Cov-2. Based on this assumption and considering that such an event may occur in the future for other types of viruses, the proposing team saw it as a fundamental duty to devote a portion of the research to making an effective contribution to the recognition of symptomatically infected subjects, in order to avoid them becoming vehicles of the contagion, by coming into contact with other people without taking the necessary precautions. The research given in this paper is an example of how, in the face of exceptionally complicated conditions, experts from various scientific backgrounds may obtain major achievements by combining their respective expertise. The current example is the struggle against the SARS-Cov-2, and in the future, who knows what other virus,

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bacterium, or mold may be encountered; a fight that must, in reality, be waged on several fronts. It is first important to treat the afflicted patients with medications and respiratory treatments, and then to prevent the infection from spreading further. While doctors may clearly cure the illness, the spread of the virus can be addressed and significantly controlled using ideas and approaches taken from other fields such as, in this case, Engineering 4.0. The authors of the paper focused on aspects related to infection spread, initially on the problem of recognizing symptomatic people affected by the virus who need to enter highly frequented places, and later on sanitation of paths, clothing, and environments through highly effective innovative systems, as well as monitored and controlled social distancing. Mr. Conte, the Italian Prime Minister, announced the start of a phase of easing anti-Covid19 measures on April 26, 2020, a phase in which he considered it essential that, as a precaution, all stations of any means of passenger transport, as well as places with high crowding such as supermarkets, banks, stadiums, and so on, were equipped with flow adjustment turnstiles and that each person entering was subjected to a thermoscanner to detect body temperature. The concept, while valid in and of itself, has significant objective limits. Meanwhile, the thermometer measurement must be performed individually by an employee, and so the evaluation of a big group takes a substantial amount of time, with the result that any contact between people, and hence contagion, might pose a serious risk. As a result, the team has created a column thermoscanner system that works in tandem with an access turnstile to meet this need. The thermoscanner can also recognize that the prescribed mask is being worn and that it is being used correctly, i.e. total coverage of the mouth and nose (otherwise, if the virus is transmitted airborne, the mask would be completely useless); the system notes that the person does not try to hide the part of the face dedicated to the mask with his hand; it ensures that gloves are worn by the person passing through the turnstile and measures the temperature. In the case of non-compliance, even partial compliance, with these standards, a siren sounds and a warning is sent to the operations center through IOT (Internet of Things), to take the required steps. Please keep in mind that the system is completely private, since it does not collect personal or biometric data. It also has a web site for monitoring and managing geo-located alerts and reporting them to security personnel. The suggested method therefore tries to react to the requirement to provide an effective, efficient, and cost-effective solution to the problem of viral propagation in crowded situations. The study team considered using appropriate thermal imaging cameras to conduct a mass screening as one of the possible options. This sort of solution, which looked to be theoretically legitimate for monitoring the temperature of each individual member in a group, has expenses on the order of 30,000 Euros (for each thermal camera), an unsustainable expenditure for its broad adoption. As a result, the pragmatic research group concentrated on the opportunities provided by specific Engineering 4.0 applications. The research resulted in the creation of:

- A methodology based on processes, procedures, and tools for addressing the problem of pathogen spread;
- The "Thermoscanner 4.0" device was developed; it represents a solution capable, at a relatively low cost (less than a fifteenth of the amount reported above), of providing an effective and efficient response to the problem of symptomatic people accessing confined places;
- Professional machines for sanitizing with gaseous Ozone and UVC (Ultra Violet – C) rays.

2 The work team

The operational team is comprised of highly competent Partners to ensure the presence of all the talents required to complete the project. The conceptualization was carried out in particular by DIME Researchers (University of Genoa, Polo di Savona, Prof. Ing. Roberto Revetria, Prof. Ing. Marco Mosca), the research and design by the Engineering Partner TCore (Prof. Ing. Fabio Currò), and the development by the Technological Partner mcGEAR (Prof. Ing. Fabio Currò, Prof. Em. Roberto Mosca), the dissemination and technology transfer to companies by the Partner GDR (Spin Off Unige).

3 Literature review

As the 2020 article by DiMaio et al. [2]. recalls, mankind has been attacked by various epidemics throughout history, ranging from the black plague, which killed nearly 50% of the European population in the Middle Ages, to the Spanish flu during the first part of the past century, which killed millions. Many illnesses that have spread over the world during the last century have included fever as one of their symptoms. The SARS-CoV-2 is no exception. According to INAIL (Italian Institute for Accident Insurance at Work) in the 2020 article [3], this virus produces a respiratory illness with symptoms such as fever over 37.5 °C, cough, muscular pains, and pulmonary problems. SARS-CoV-1, as the name implies, is a similar condition that, from 2002 to 2003, caused several states to begin implementing measures to regulate access at borders in order to prevent infections. During the two-year period 2009–2010, the H1N1 virus, sometimes known as "swine flu," swept around the world. Already in the early phases of the pandemic, several states have implemented methods to limit viral spread. The article by Nishiura et al. [4] discusses how Japan has adopted safeguards regarding access to foreign airports since the early stages of the epidemic. A quarantine has also been implemented, either at home or in hotels. The thermoscanners, which enable to comprehend if an individual is a positive suspect from a distance, are the most often used preventative devices. According to the scientific journal Giustizia Civile [5], thermoscanners or infrared thermometers should be used as a preventative and protective strategy. In terms of Retirement Homes, the "City of Sondrio Rest Home" announced an organizational strategy at the end of 2020 that includes the supply of thermal scanners in addition to a number of internal processes. One is installed in the main entrance and another in a different entry to measure the body temperature of those that enter the Structure. If a temperature of 37.5 °C or above is recorded, the entry door stays closed and a fresh test is taken one minute later. If the individual's fever rises beyond 37.5 °C, he or she must return home immediately and seek a doctor. Since fever is a very common symptom of both communicable and non-communicable diseases, body temperature fluctuations are even possible in a healthy individual. Therefore, a thermoscanner is not meant to diagnose a specific disease, but just to require a medical assistance to determine whether or not the subject shall be confined and treated (particularly in pandemic occasions). As a result, it is evident how an IoT system capable of measuring temperature and linked to face recognition allows in-charge operators to quickly know who is positive and to automatically alert the appropriate authorities. To ensure privacy, it is obviously required, as stated by the Nursing Home in issue, to gather preliminary staff and guest signatures on papers for the processing of personal data. INAIL (previously mentioned Italian Institute for Accident Insurance at Work) explains in the article cited above how important it is to measure body temperature using a thermoscanner because traditional methods with thermometers involve physical contact, which must obviously be avoided (with or without personal protective equipment, with a known symptomatic Patient), take a long time, and rely on the operator in charge's skills. The majority of the articles deal with exact measurements of body temperature taken at the facility's entrances. Diseases, on the other hand, have an incubation phase during which the individual remains asymptomatic. This creates the issue of granting free entry to persons who will only display the symptoms after they have already entered the Structure. This problem was mentioned by Sakaguchi et al. in a 2012 article [6] on swine fever. In reality, the authors indicate that it is hard to totally prohibit an entry into the bounds of positives, and that a surveillance system would be required to monitor the health state of patients who may acquire illness symptoms later. As a result, positive or suspicious participants are watched by phone; in fact, they are requested to measure their own temperature in the morning and evening in order to assess improvements and deteriorating. This surveillance was also taken out in Italy by the Hospital Employees. However, this approach necessitates the addition of personnel to this work, resulting in greater expenditures, including employee training. As a result, an autonomous monitoring system that detects people's temperatures without requiring intervention from public personnel or the host structure becomes far more efficient.

4 The proposed methodology

The proposed approach was broken down into two stages.

- The first relates to the surveillance of persons who entered the facilities without displaying symptoms and later became positive for fever during the stay;
- The second relates to the sanitization of the structures, both preventively and in situations of detected positive fever.

The concept entails implementing defined protocols and tight procedures that must be followed within any structure, such as hotels, healthcare facilities, offices or similar.

5 Step 1: Thermoscanner 4.0

Figures 1 and 2 depict the thermoscanner characteristics and how it works in conjunction with the turnstile. The “safe access path” designed by the team, by using of this technology, is particularly suitable for preventing people (especially if coming from areas at risk, like endemic areas for the virus, or even unknown areas) to enter the building, and for confining them, so avoiding the spread the virus. The threshold temperature, fixed in Italy by the Ministry of the Health, to allow a Visitor enter a building, is 37,5 °C. Alarm is automatically activated by the device in case of over temperature and in all the cases specified in Fig. 1.

5.1 Impact of dissemination on statistical opportunities

The thermoscanner has gained great acceptance among security officials, who are now solely outfitting the locations with such equipment. In line with the approach indicated in the preceding paragraph, it will also be feasible to have significant information on the spread of the infection among persons accessing the limited places in a short period of time, as well as to reach a limitation of the same. Finally, it is critical to remember that in a globalized world, the risk of pandemics is dramatically frequent and repetitive, so the Authors would recommend to always keep thermoscanners active in strategic points such as passenger arrival stations from other parts of the world, to be able to block virus carriers immediately before they become an unstoppable vehicle of contagion, as happened with SARS-Cov-2 in the Italian Lombardy Region.

Fig. 1 Mask and gloves control, color code

5.2 Technology adopted

A Digi-key temperature sensor (Fig. 3) approved for medical usage detects the subject's forehead temperature while in transit, with an accuracy level of 0.2 °C in the 36°-38 °C range. Particularly noteworthy is a function that the project team deemed critical for the equipment, such as face recognition, which will be used just to identify the hill person in the event of infection and not to monitor people's moods or routes. To avoid crowds near the device, it was set up such that recognition could be obtained at a medium distance (50 cm). For improved detection accuracy, the temperature sensor's viewing angle is limited to 10 degrees.

The 316L stainless steel construction was chosen and developed to be more resistant to pressure and shocks, as well as to allow for systematic sanitization with appropriate liquids (hydrogen peroxide, sodium hypochlorite and alcohol-based substances). The software was totally built in-house, both for better interface with proprietary hardware and to be able to keep up with any regulatory changes. Because the thermoscanner was created in accordance with Industry 4.0 principles, it is worthwhile to emphasize several features such as interface with other systems (for signaling on servers), autonomous operation or data network (LAN and Wi-Fi), and compatibility with IoT turnstiles. Furthermore, several additional features deemed particularly important on an operational level have been implemented, such as integration with a people counting system in and out and an audio alarm.

Fig. 2 Thermoscanner controls on User interface

5.3 Innovation compared to the most common market systems

Among the qualities outlined in this study, various constructive options for differentiating the system from others usually found on the market arise, cit. [1–6], already previously mentioned, such as:

Fig. 3 Panasonic infrared temperature sensor

- The use of a very precise sensor for measuring body temperature even in crucial settings such as backlight, perspiration, skin color, rain, and so on (this medical sensor was discovered through meticulous multi-sectoral market research);
- the materials chosen for the construction of a device housing that can work in any environment (impact resistance and dust and humidity impermeability);
- the materials used in the building of a sturdy and readily sanitized column;
- the adaptability of use for other critical security applications (limiting access of persons to the numbers needed by law and by distancing regulations), as well as commercial (statistical surveys), such as people counters;
- face recognition for the identification of the hill Person and its confinement pending rescue, as well as criminal prevention in other circumstances (theft, robbery or assault).

In addition to the characteristics purely attributable to hardware and software design choices, the device is accompanied by ad-hoc use processes, depending on the sector of application, with the goal of maximizing the impact generated by the thermoscanner (e.g., the hotel case study reported above), with clear procedures to be followed, easily manageable by appropriately trained staff and customers. This is also due to the training provided and the project documents, which contain clear instructions and forms that guests of the structure must sign at the entrance.

6 Step 2: Sanitization

The authors' technique obviously demands that once the infected subject has been separated, a careful sanitation of the locations frequented by the same is carried out (room, hallways, offices, public spaces), which is performed by utilizing the 4.0 machine described in the article by Mosca et al. [1, 8, 9]. The 2021 International Conference of Systems Biology and Bioengineering, World Congress on Engineering 2021, IAENG, awarded as Best Paper of the Section. The 4.0 machines (Figs. 4 and 6) sanitizes by producing gaseous Ozone, which is then removed by the same machine at the end of the treatment, by retracing the phases found in Nature, in the Ozonosphere, as described by the Chapman Cycle cit. [8, 9] by Mosca et al., thus ensuring the deactivation of any microorganism as described by Muzhi et al. [7], and by Martinez-Sanchez et al. [10]. Tseng et al. observed in [11] that surfaces are dangerous because they can host viruses and ozone is considered to be a promising method to inactivate. Also [12] Cristiano identifies ozone as a possible effective disinfection measure against coronavirus, as in [13] Zhou and again in [14] Shin and Sobsey. This papers induced the Authors to prefer the use of gaseous ozone to chemicals, being harmful to People and dangerous for the environment (e.g. chlore, bleach, alcohol,..) cit. [15–21] in particular in [15] Govindaraj et al. explain that disinfection can eliminate microbes, but not necessarily all microbial forms (e.g. bacterial spores) from the inanimate object of interest; [16] Burkhart declares that ozone has been proven to kill bacteria, fungi, viruses and protozoa; [17] Ruttala et al. state that cleaning should always precede high-level disinfection and sterilization; in [18] Ebihara et al. explain that DNA or RNA genome contained in bacteria and viruses is oxidized and destroyed by ozone under appropriate treatment conditions; in [19] Edelstein et al. treat the effect of pronation of supply water for hospitals subjected to positive cultures of Legionella; in [20] Joret et al. observe how the presence of residual ozone and contact time may inactivate population of bacteria and in [21] Farooq et al. propose the results of disinfection studies performed using five cultures of organisms. Or, as well, other pathogens such as viruses [22] Haraken et al. To ensure a correct sanitization, in literature, do appear different studies like in [23] Kawamura et al. explain what indicators to use for an efficient process of disinfection; other Authors treat the inactivation of infectious agents and viruses like Cutler et al. in [24] and Tseng et al. in [25]. Specifical disinfectants against SARS coronavirus are then tested by Rabenau et al. in [26]. Italian Ministry of Health itself, already in 1996, issued a guideline for air treatment with ozone in the environments dedicated to cheese maturing, to determine an efficient sanitization. And finally, in [28] Martinez-Sanchez et al. propose a study about the potential cytoprotective activity of ozone

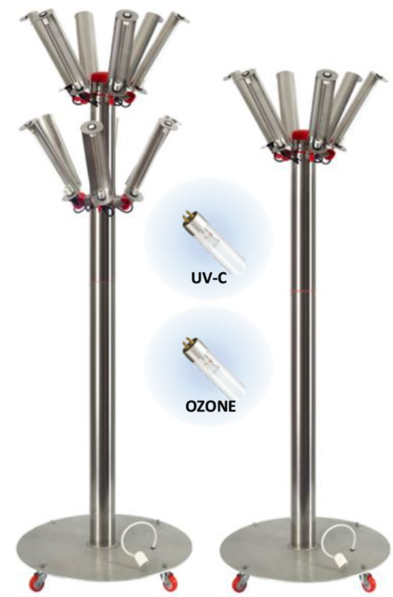

Fig. 4 UV-C and Ozone Sanitization machines

Fig. 5 UV-C and Ozone Sanitization machines

therapy in SARS-CoV-2/Covid19. Moreover, the machines reported in Fig. 4, do operate at low cost (because of the negligible consumption of energy). Here below is reported a UV lamps detail (Fig. 5).

In paper Mosca et al. [9] demonstrate how an operator, through the use of a simple interface (Fig. 6) may control two or more machines installed in neighboring rooms at the same time (Fig. 7), disinfecting a 100m3 environment in 20 min using a UVC-Ozone machine equipped with 12 14W/each lamps. Otherwise linking more machines to increase the light pressure needed for sanitizing wider environments (Fig. 8). The key activities are positioning, turning on, and turning off. Cleaning personnel is often assigned these activities as part of their normal duty (it takes about 20 min at the end of each shift). On the same paper, a case study of a structure with four floors of 250 square meters each is given (15 rooms, 5 bathrooms, and an entrance hallway per floor). To sterilize each level, two machines will be used, each costing €4,000, for a total cost of €32,000 (8 machines: 2 per floor, on 4 levels).

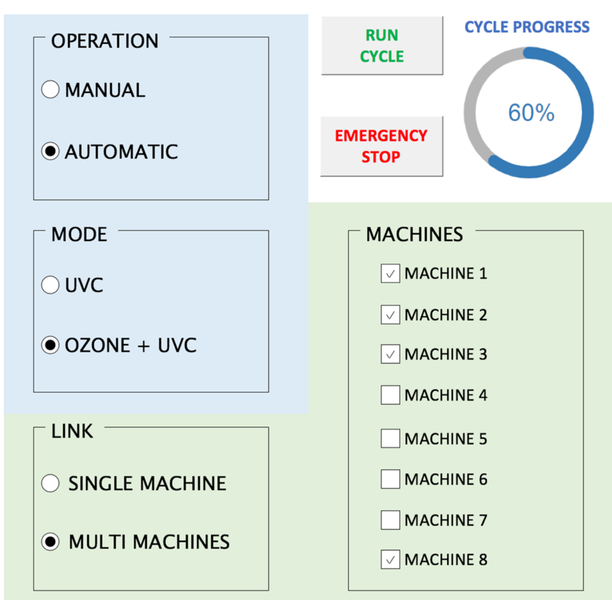

Fig. 6 Machines control interface

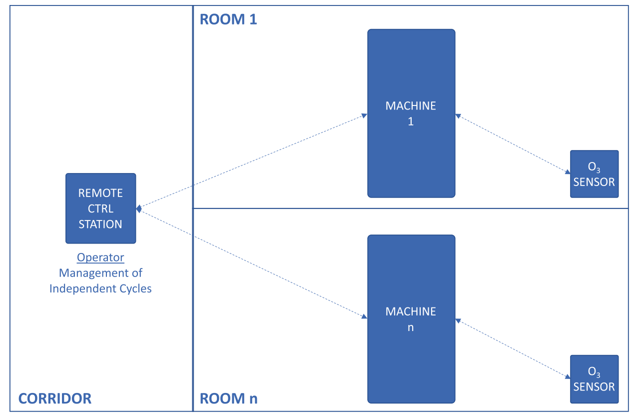

Fig. 7 Machines operating in automatic mode, UVC+O3, single link

For each sanitization completed, the total cost of treatment for the entire block is €27. It also appears that the machines require a single maintenance duty of changing the bulbs and other accessories after 12,000 h of operation, which will cost €9,600 (total cost for 8 machines). The life cycle of a machine is 20 years. The average cost of maintenance in this example study is 4€ per treatment. The figure below (Fig. 9) illustrates an application of UV-C lamps to sanitize, inside the ducts, the air shared among different rooms. IoT controllers make each device visible and controllable by the Web.

7 An application (case study)

Given their distinctive features of usage by hotel guests, it was required to build a specific anti-contagion process for these locations, which employs numerous thermoscanner devices for the reasons that will be detailed below. The team's method undoubtedly has a favorable influence

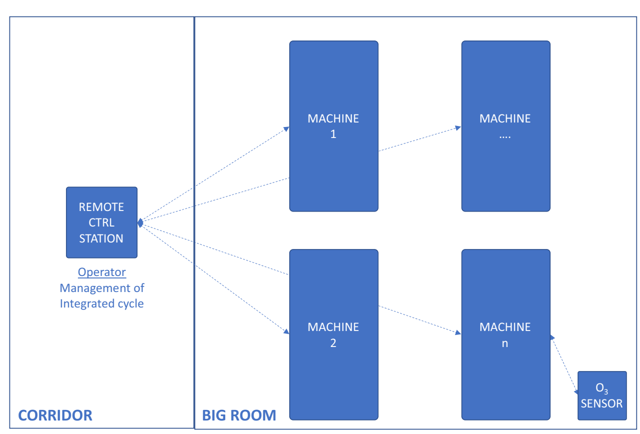

Fig. 8 Machines operating in automatic mode, UVC+O3, multi-link

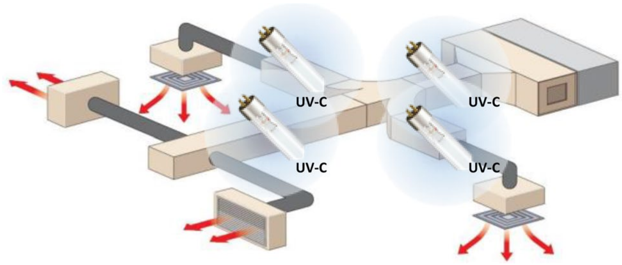

Fig. 9 UVC rays lights installed inside the ducts

on preventing the spread of infection by persons arriving from outside locations and who may be unwitting carriers of the virus. The instance of that worker of a firm (located in Bergamo) who arrived from China and stayed in Italy (in Codogno) and became the first vehicle for the spread of the virus in Lombardy Region and from there throughout Italy is emblematic in this regard. Based on this incident, the team devised a technique that calls for the systematic use of the thermoscanner in areas of prospective contagion in order to prevent extreme events like this from occurring again, both now with Covid19 and in the future with any other virus or disease agent. The team's approach envisions, as a first step, the submission of an informed permission for writing approval to the Customer of the facility who presents himself for acceptance, by signing which he fully acknowledges the safety procedure related to the thermoscanners present in the Structure. In utmost regard for privacy, these devices use face recognition and combine it solely with the room number that has been issued to them. Except for the positive temperature detection, no biometric data will be saved or provided by the facility to the outside (exclusively to the local Body for Health surveillance). The guest is also advised that more thermoscanners have been installed in the restaurant and the corridor (Figs. 10 and 11) where the room allocated to him is positioned, close to the elevator. Moreover, a form of informed consent is required to be signed at the entrance.

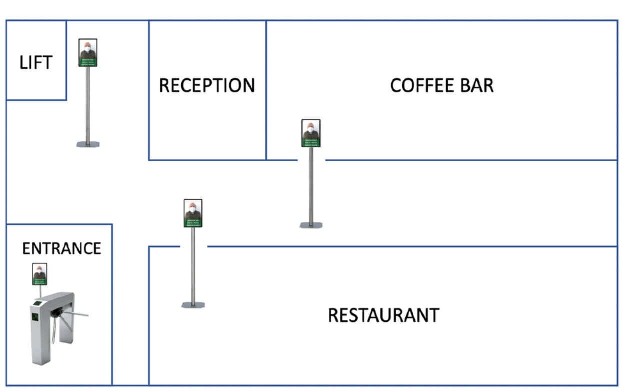

Fig. 10 First step of the Methodology applied to the Ground Floor

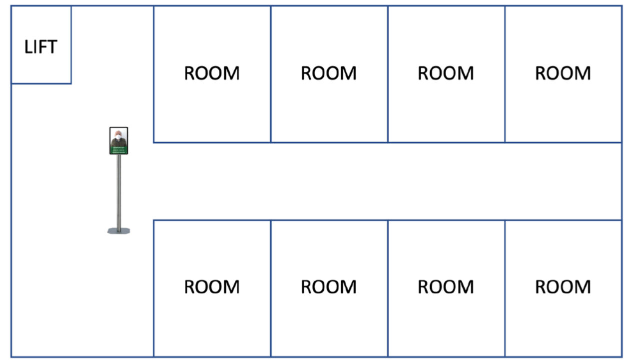

Fig. 11 First step of the Methodology applied to the Upper Floors

The reason for these additional thermoscanners is that in places where people temporarily stay, whether hotels, hostels, motels (etc.), they spend a significant number of hours (8–12 in general) in which they could develop infection symptoms, including fever, with all that would follow in terms of infection spread, by subjects who may not have perceived having been affected by the virus. Obviously, in these instances, placing an equipment at the reception desk and/or in the restaurant will not solve the problem of detecting a positive during the incubation phase. The crew chose to install the thermoscanners in the corridors listed above after analyzing the problem and looking for a viable solution. This installation ensures that those who develop feverish symptoms of infection during their stay in the room are required to return to the room they came from and wait for the Government Medical Staff notified by the Reception (alerted by automatic system notification) who will arrive appropriately equipped anti-contagion to pick up the unfortunate and, possibly, his guests in the room. The next step is to do a thorough sanitization using the 4.0 machines (described above) in every place visited by the diseased person. In this regard, it is advised that the regular sanitization operation be carried out daily in all frequently visited places, regardless of the detection of aberrant temperatures, especially given that these devices do not utilize chemicals or contaminate the environment.

8 Conclusions

The suggested methodology, based on innovative IoT monitored and controlled devices, completely accomplishes the aim for which it was developed, namely:

- First, the thermoscanner allows for the safe management of subjects accessing certain surroundings. The term "safe" refers to both the avoidance of waiting-people gatherings (which normally occur around the detector used for manual temperature control, with frequent bypasses of the same), with the risk that subjects carrying the virus will spread it among those who are waiting, while carrying out the formalities required for access, and also the precision with which the temperature is controlled, including the recognition that gloves and masks are worn correctly, where required;

- Second, move to a professional sanitization of the environs employing proprietary 4.0 machines adequately conceptualized, designed and built by the authors to provide comprehensive and accessible cleanliness of all Structures.

The project team feels that the methods, procedures, and 4.0 devices described have contributed significantly to prevent the dissemination of Covid 19. Because of the methodology developed by the authors through appropriate notifications, those subjects positive for fever will suddenly provide to self-isolate and, in short, will be taken over by the Health authorities in charged, who, in case of positive pathologies, will urgently provide them with appropriate treatment, including, if necessary, hospitalization in the intensive care Hospital wards, with the added benefit of slowing down the spread of the virus and to provide for Patient care. It has made a substantial contribution to the identification of symptomatic persons who can frequently accidentally spread the virus and, as a result, to their isolation in order to avoid them becoming a hazard to those who come into touch with them unknowingly. The methods outlined was originally intended to combat the spread of Covid 19 by people who contracted the virus while staying in "healthy" hotels, motels, or residential constructions of any sort. Such technique may be fully adapted and implemented with the same efficacy to any location where people spend an acceptable amount of hours. Offices and workplaces in general are classic examples, where they spend up to 12 h in the same day between various types of breaks (coffee machines, canteens, meetings and overtime). Finally, the purpose of this work is to emphasize the critical role that the devices hypothesized, theorized, and produced by the authors play in the technique. The Authors feel that the residual limitation of the system consist in the level of integration of the same in the hosting structure management software (ERP or similar), as currently is is not foreseen a standard interface, which is the goal set for a future development. It should be noted that sanitation is currently used in conjunction with the thermoscanner to neutralize the effects of symptomatic subjects, but that it should become a daily practice to ensure the avoidance of who knows what other pathogens, a real danger in a globalized world, as Bill Gates hypothesized in 2015 at the Ted Talk "The next outbreak?" "We are not ready."

Author contributions All authors contributed to the study conception and design. Conceptualization, material and images preparation, data collection and analysis were performed by Roberto Mosca and Marco Mosca. The first draft of the manuscript was written by Roberto Mosca and Marco Mosca and all Authors commented on previous versions of the manuscript. Engineering solutions were designed by Fabio Currò. Accurate review and consulting was provided by Roberto Revetria. Literature review was conducted by Federico Briatore as well as final editing. All authors read and approved the final manuscript.

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Declarations

Ethics approval, consent to participate, consent to publish No study was conducted on Humans or Animals. The study regards exclusively processes and technologies to protect Humans.

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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