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Integrating the Internet of Things (IoT) in SPA Medicine: Innovations and Challenges in Digital Wellness

Mario Casillo [1], Liliana Cecere [2], Francesco Colace [2], Angelo Lorusso [2] and Domenico Santaniello [1,*]

[1] Department of Cultural Heritage Sciences (DiSPaC), University of Salerno, 84084 Salerno, Italy; mcasillo@unisa.it
[2] Department of Industrial Engineering (DIIn), University of Salerno, 84084 Salerno, Italy; lcecere@unisa.it (L.C.); fcolace@unisa.it (F.C.); alorusso@unisa.it (A.L.)
* Correspondence: dsantaniello@unisa.it

Abstract: Integrating modern and innovative technologies such as the Internet of Things (IoT) and Machine Learning (ML) presents new opportunities in healthcare, especially in medical spa therapies. Once considered palliative, these therapies conducted using mineral/thermal water are now recognized as a targeted and specific therapeutic modality. The peculiarity of these treatments lies in their simplicity of administration, which allows for prolonged treatments, often lasting weeks, with progressive and controlled therapeutic effects. Thanks to new technologies, it will be possible to continuously monitor the patient, both on-site and remotely, increasing the effectiveness of the treatment. In this context, wearable devices, such as smartwatches, facilitate non-invasive monitoring of vital signs by collecting precise data on several key parameters, such as heart rate or blood oxygenation level, and providing a perspective of detailed treatment progress. The constant acquisition of data thanks to the IoT, combined with the advanced analytics of ML technologies, allows for data collection and precise analysis, allowing real-time monitoring and personalized treatment adaptation. This article introduces an IoT-based framework integrated with ML techniques to monitor spa treatments, providing tailored customer management and more effective results. A preliminary experimentation phase was designed and implemented to evaluate the system's performance through evaluation questionnaires. Encouraging preliminary results have shown that the innovative approach can enhance and highlight the therapeutic value of spa therapies and their significant contribution to personalized healthcare.

Keywords: Internet of Things; SPA; wearable; cloud computing

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1. Introduction

Using thermal resources, a medical practice that originates in ancient customs allows the beneficial properties of mineral springs to be exploited to treat various medical conditions and diseases [1,2]. This therapy, incorrectly considered a mere variant of conventional therapeutic methods, instead plays a significant element in the therapeutic framework, requiring attention and reflection to maximize clinical benefits. As part of the modernization of community health care, it merges this tradition with new technological trends, e.g., telemedicine, offering an integrated and organic contribution to patient management [3,4].

The healing characteristics of thermal water have been appreciated in ancient times, and numerous cultures have appreciated and exploited its benefits for the quality of human health. The historical and scientific literature points out that these resources, whether of natural or artificial origin, contain vital mineral substances such as sodium, calcium, magnesium, and sulfur [5]. These mineral components, injected into the skin by immersion in a thermal bath or steam inhalation, stimulate the defense system, reduce inflammation, aid arterial circulation, and soothe pain. Modern territorial medicalization and telemedicine practices can complement traditional therapies through remote monitoring and online visits for a personalized and prolonged treatment program [6].

Thermal healing water treatment is useful for a wide variety of illnesses, including, but not limited to, respiratory conditions, such as asthma and bronchitis; dermatological conditions, such as dermatitis and psoriasis; musculoskeletal problems, including arthritis and chronic pain; and stress-related disorders, such as anxiety and insomnia [7]. In addition, the above waters are found to be effective in treating metabolic dysfunction and cardiovascular diseases, including diabetes and hypertension [8]. Several interventions in various experimental laboratories testify to how effective hydroponic treatments are under such conditions, with significant increases in participants' quality of life spa treatment cycles [9]. The deployment of telemedicine solutions, e.g., telediagnosis and remote monitoring of patients, amplify these benefits, allowing permanent check-ups and integrated, personalized management of spa services [10].

In addition, thermal waters are a means of preventive therapy. Studies have revealed that regular use of mineral water can play a preventive role against certain diseases and promote optimal overall health [11]. For example, calcium-rich waters can help counter osteoporosis, while those with high magnesium levels can benefit cardiovascular function [12,13]. The evolution of community medicine and the development of new technologies in the medical field, such as advanced telemonitoring systems and remote diagnostics, make it possible to implement these preventive strategies more effectively and extensively.

However, it is crucial to recognize that thermal waters have a different chemical composition depending on the source, necessitating careful analysis before their use for therapeutic purposes. Scientific research has shown that the specific chemical composition of thermal waters can significantly affect their therapeutic effects. Different waters may be more or less helpful in treating specific diseases [14]. In this area, technological developments in territorial medicine, such as data collection and analysis through advanced sensors and telemedicine platforms, can provide additional information on the waters' composition and effectiveness, thus enabling more targeted and personalized treatments [15,16].

Integrating IoT into spa care services constitutes a quantum leap in the effectiveness and efficiency of these therapies [8,10,17–19]. The IoT, comprising an interconnected network of smart devices, sensors, and data processing systems, enables real-time data collection, analysis, and sharing, revolutionizing spa care and providing new opportunities to improve patient experience and treatment effectiveness [20,21]. The spread of IoT in the context of community medicine and telemedicine opens up new avenues for local health monitoring and management, enabling more accessible and personalized health care [22,23].

One of the most significant aspects of IoT in spa care is the ability to monitor patients, both inside and outside spa facilities, in real-time through devices such as smartwatches, wristbands, or wearable sensors that collect data on heart rate, body temperature, blood oxygen levels and other vital indicators [24–28]. These data can be transmitted to a centralized monitoring system for accurate and timely analysis [29,30]. Telemedicine, using these technologies, enables timely intervention in case of abnormalities, improving the safety and effectiveness of spa treatment [31].

In addition, IoT enables the collection of environmental data, such as temperature and humidity in spa facilities, air quality, and lighting level, which can affect the effectiveness of treatment. This information can be used to improve the spa environment, thereby optimizing the overall patient experience. Community medicine can leverage this data to create ideal treatment environments, tailoring them to the specific needs of patients and integrating them with other forms of healthcare [32].

Another critical aspect of IoT in spa treatments is the customization of treatments to the specific needs of patients. The data obtained can be used to analyze treatment progress in detail, allowing treatment to be adjusted in real time based on individual patient responses. For example, if a patient responds positively to a particular therapy, it can be continued or modified based on the data collected. This personalization is even more relevant in telemedicine, where collected data can provide remote counseling and adapt therapies to the patient's changing health condition [33,34].

IoT in spa care can also help improve communication between patients, healthcare providers, and spa managers, facilitating real-time information dissemination and increasing patient involvement in treatment decision-making. Telemedicine, in particular, can provide tools for communication and interaction between patients and healthcare providers, ensuring constant discussion and more effective sharing of treatment information.

One of the main goals, in addition to those already highlighted, is to make the system suitable and accessible to the highest number of patients, regardless of their technical abilities or their possible sensory or cognitive disabilities. For this reason, by adopting some targeted strategies, treatments can become increasingly inclusive: inclusive system design means considering different users' needs. It could be translated by implementing intuitive user interfaces, accessible multimedia supports, and ergonomic devices. Fundamental in this context is to offer customization options to adapt the devices to the specific preferences and needs of each patient: allowing settings to be adjusted through voice commands or the use of devices with tactile buttons and the Braille alphabet, for example, allows blind people to take advantage of the treatment and especially to be able to use the app. As part of the proposed system, it is also recommended to organize short training sessions aimed at users, prior to therapy, on the use of the devices in order to make them easier to use even for those with limited technological skills, as well as to increase the involvement of the patients themselves. It must be said that interdisciplinary collaboration is definitely at the heart of the proposed system: comparing and involving physicians, computer scientists, technicians, designers, and accessibility experts is necessary to ensure a holistic and inclusive approach.

In addition, the impact of IoT and ML technologies in the medical and spa treatment fields, when viewed from a different perspective, can provide a more comprehensive, deep, and holistic view of the topic. Indeed, the fields of connection with other disciplines are many and vary from psychology to sociology via health policy [35]. The psychological aspect is one of those that most influence the course of treatment: the analysis of emotions, psychological well-being, and overall patient satisfaction are just some of the parameters to be considered, which are crucial in determining the treatments' effectiveness. In addition to monitoring vital parameters, IoT and ML technologies can also effectively manage and reduce stress, for example, through collecting physiological data and implementing personalized relaxation programs, thus improving psychological and physical well-being [36]. New technologies also have a significant social impact: thanks to mobile applications, they can facilitate social connection by enabling patients to share their experiences and support each other during the course. Moreover, patients' experiences, mainly positive, can influence other users and affect the dynamics of social inclusion. As already anticipated, health policy is also closely related and mainly involves issues already widely addressed, such as patient privacy, security of data provided by the system, and medical liability in using these data [37].

This paper explores the benefits of integrating IoT and telemedicine into spa therapies as a significant step forward in innovating these treatments, offering new opportunities to increase effectiveness, efficiency, and the overall patient experience. However, it is critical to address security and privacy issues to protect sensitive patient data in the digital age, particularly in territorial medicine and telemedicine, where health data management requires strict protection and confidentiality standards.

2. Related Works

The IoT paradigm explicitly designed for the world of healthcare has still been little explored: there are still a limited number of publications on the subject; there are numerous studies on the application of IoT in the field of medicine in the general sense, healthcare and, above all, on medical devices, meaning also those that the patient could wear.

Among the medical articles that have been published in this regard, we can refer to the study [38] in which a new comprehensive smartphone-based framework called PP-SPA is proposed, designed for human activity recognition (HAR), which pays special attention to privacy protection, or to the article [39] in which a new medical communication model called "Wireless Medical Sensor Networks Protocol for Healthcare Efficiency" (PWMSN4EoCH), abbreviated as PEH, is presented, which exploits a hasty strategy and random network coding (RNC).

In the first case [38], the system devised supported real-time task execution by using a smartphone-based virtual personal assistant. PP-SPA uses a highly accurate ML model that receives data from smartphone sensors, such as accelerometer, gyroscope, magnetometer, and GPS, to recognize human activities accurately. Thus, the main goal of PP-SPA is to improve the daily routines of people with cognitive impairments. It also leverages a digital diary to provide real-time support, contributing to improving individual health. With algorithms such as Hoeffding Tree and Logistic Regression, PP-SPA achieves an accuracy level of 90%, developing models that account for variability and uncertainty in human activities.

In the second case [39], the innovative concept aims to enhance the performance of healthcare networks by rapidly analyzing the configuration of medical networks and focusing on key parameters for narrowband Internet of [38] Things (NB-IoT) systems within wireless mesh networks (WMNs). PEH effectively fits the specific requirements of wireless telemedicine applications, in which medical sensors (MS) share downlink and uplink communication resources with surrounding entities, including wireless health hubs (WHHs) and wireless base stations (WBSs) for monitoring human health status. This scheme greatly accelerates the deployment of telemedicine devices, contributing to fulfilling patients' needs: simulations conducted in the study show that PEH introduces a significant performance increase over the SoAT scheme, with an improvement of more than 64 percent. In comparison, the current state-of-the-art scheme (SoAT) does not fully embrace the principles proposed by PEH. The 'comparative analysis between the proposed PEH and the SoAT scheme is based on message size (bytes), round trip time (RTT) (ms), overall network capacity (ONC) (bytes/s), and delivery delay (DD) in ms. The results indicate that the proposed PEH significantly outperforms the SoAT scheme, with improvements of 64% for RTT, 66% for ONC, and 71% for DD.

Some other studies we can refer to onety and health monitoring are [40,41]. In the former [40], the authors present a hybrid wearable sensor network system to monitor workers' safety in outdoor workplaces. The wearable sensors have a dual purpose: on the one hand, to measure the environmental conditions around the worker, and on the other hand, to monitor the worker's vital signs. The proposed system involves a wearable network (WBAN) to collect user data and a low-power vast area network (LPWAN) to connect the WBAN to the Internet. Then, to ensure constant monitoring, an autonomous local server is designed within the network that processes raw sensor signals, displays environmental and physiological data, and triggers an alert if an emergency circumstance is detected. In the other paper [41], a medical device (MD) for narrowband IoT (NB-IoT) is implemented, and a wireless communication system is developed for the control and monitoring of hospital physicians. In summary, the proposed approach aims to improve the efficiency and performance of the polling cycle of NB-IoT MDs by reducing the response time and increasing the reliability of communications in the medical network: the polling cycle of MDs between the main station and terminal units in medical rooms is evaluated, and an end-to-end (E2E) polling protocol is introduced to reduce the polling cycle of medical devices. The proposed protocol aims to minimize the number of retransmissions, recover lost packets, and provide an overview of the medical network.

Then, in the article [42], the applicability of the IoT paradigm in the health and medical sector is discussed by presenting a holistic architecture of the IoT eHealth ecosystem. As healthcare management is becoming increasingly complex due to the shortage and ineffectiveness of healthcare services in meeting the growing demand of an ever-growing population, especially those with chronic diseases, the authors suggest the need for a shift from the clinic-centered model of treatment to a patient-centered approach, where each element, such as hospitals, patients, and services, is closely interconnected. To realize the referenced patient-centered eHealth IoT ecosystem, adopting a layered architecture, including devices, fog computing, and cloud, to manage complex data regarding variety, speed, and latency is essential. The fog-based IoT architecture is illustrated through several examples of services and applications implemented on these layers, including mobile health, assisted living, e-medicine, facilities, early warning systems, and population monitoring in smart cities. Finally, eHealth IoT challenges such as data management, scalability, regulations, interoperability, device-network-human interfaces, security, and privacy are addressed. Therefore, this paper highlights the efficiency of intelligent data analysis in different cloud and fog computing paradigms, mainly geared toward managing mobile medical devices.

Cloud analysis of information from medical devices is also highlighted in [43] as an effective element for improving medical treatments. The article develops from the idea that networked sensors, which can be worn on the body or integrated into our living environments, enable the collection of detailed information about our physical and mental health. This data, then captured continuously, aggregated, and extracted effectively, has the potential to bring about positive and transformative change in the field of health. In detail, according to the authors, the availability of data on previously unimaginable time and longitudinal scales, combined with a new generation of intelligent processing algorithms, can first foster an evolution in medical practice from the current reactive paradigm of post-facto diagnosis and treatment to a proactive approach to early-stage disease prognosis, integrated with prevention, care and overall health management rather than disease management; it can then enable personalization of treatment and management options targeted to the individual's specific circumstances and needs; and, finally, it can help reduce health care costs while simultaneously improving outcomes. So, with this article, the authors want to highlight the opportunities and challenges IoT faces in realizing this vision of the future of health care.

One of the major critical issues generally affecting the medical sector, particularly the application of the IoT paradigm to the medical field, is general patient and user data management. Since this is sensitive content, proper management of the collected big data is crucial. "Big data" represents vast amounts of information with revolutionary potential, including medical records, patient records, medical examination results, and IoT devices. In the article [44], an effective architecture for managing big data in the medical field is presented, given this background. The management and analysis of these data require advanced approaches to extract meaningful information. The challenges associated with each stage of extensive data management can only be overcome through high-quality computing solutions for analysis. Therefore, healthcare providers must have adequate infrastructure to generate and analyze big data systematically to propose solutions to improve public health. Efficient management, analysis, and interpretation of big data can change the landscape of modern healthcare. This is why several sectors, including healthcare, are taking decisive steps to transform this potential into improved services and financial benefits. Modern healthcare organizations can revolutionize medical therapies and personalized medicine with robust biomedical and healthcare data integration.

As mentioned above, numerous studies have also been conducted in the medical field regarding wearable devices: wearable health sensors can monitor the wearer's health and surroundings in real time. As sensor hardware technologies and operating systems have advanced, the capabilities of wearable devices have gradually expanded to include more diverse forms and more precise physiological indicators. These sensors are evolving toward high accuracy, continuity, and comfort, contributing significantly to the advancement of personalized health care. In this context, we can refer to the article [45] that studies just how flexible medical devices designed to monitor human vital signs, such as body temperature, heart rate, respiratory rate, blood pressure, pulse oxygenation, and blood glucose find applications in both fitness monitoring and medical diagnostics; or the article [46] that focuses on wearable biosensors used for health monitoring in different situations, exploring the technological development, commercial, ethical aspects, and future of wearable sensors for health monitoring.

Specifically, the article [45] reviews the most recent developments in flexible, wearable human life sensors, outlining and discussing the essential components needed for such sensors. This includes the sensor systems used, sensing mechanisms, sensor fabrication processes, energy requirements, and data processing requirements.

On the other hand, in the article [46], the authors focus on using wearable health sensors in the medical field, which can monitor both the user's health and surroundings in real-time. In fact, under the rapid development of IoT, some sensor chips are equipped with circuits for data reading, signal conditioning, and wireless communication modules for data transmission to computing equipment, and concurrently, for the analysis of data from wearable health sensors, most companies make use of artificial neural networks (ANNs), which enable them to effectively provide users with relevant health feedback by exploiting the physiological response of the human body. Specifically, wearable sensors can transmit data to the control unit, which analyzes it and returns health status feedback to the user through the computer. This mechanism represents the working principle of wearable health sensors.

Finally, the article [31] discusses how innovations such as big data, ambient intelligence, and wearable devices can be leveraged in healthcare. The IoT revolution significantly shapes modern healthcare, offering promising technological, economic, and social prospects. This paper examines advances in IoT-based healthcare technologies on the one hand, exploring modern network architectures and platforms, applications, and industry trends within IoT-based healthcare solutions, and on the other hand, analyzes the distinctive security and privacy features of IoT, understanding security requirements, threat models, and attack taxonomies from a healthcare perspective. In particular, the authors propose an intelligent collaborative security model to mitigate security risks. In addition, the paper addresses various policies and regulations related to IoT and eHealth in different parts of the world, examining how they can facilitate sustainable development in economies and societies. Finally, some directions for future research in IoT-based healthcare are outlined based on several open questions and challenges.

3. Proposed Approach

The development of modern medical discipline is closely influenced by the integration of IoT with telemedicine, especially regarding spa facilities. Such merging of technologies allows for a new vision to enhance therapeutic treatments' effectiveness, reliability, and individualization, enabling a revolution in monitoring treatment experiences and the quality of patient care. The so-called IoT devices, namely smartwatches, wearable bracelets, and advanced sensors, allow remote consultations and patient monitoring. Such devices enable real-time collection of essential data, such as heart rate, body temperature, and blood oxygen levels, which can be transmitted to centralized monitoring systems for accurate analysis. This approach facilitates more accurate diagnoses and consultations based on up-to-date data and decreases periodic hospital visits, improving chronic disease management, as evidenced by several studies [30,47,48]. Mobile applications connected to IoT devices are essential in integrated health management. They function as interfaces for patients, allowing them to access their health data, manage prescriptions, and interact directly with physicians. These apps encourage a proactive approach to health and help patients become more involved in their treatment, as outlined in [27,28,49]. Using IoT in healthcare, communication between patients and physicians improves significantly. Devices with real-time notification capabilities enable timely intervention in case of anomalies in patient data, while telemedicine platforms integrated with messaging and video-consulting capabilities offer direct and personalized communication. This improved interactivity allows treatments to be tailored to the specific needs of patients, adapting therapies promptly based on their responses, as noted in [23,28]. Despite its innumerable benefits, integrating IoT into telemedicine poses significant challenges regarding data security and privacy. Safeguarding sensitive patient data is paramount and requires the adoption of advanced encryption protocols and compliance with privacy regulations. These critical issues are the focus of debates and research in this area, as reported in [21,23,27].

The methodological proposal described is situated in the field of innovation and technological advancement in health and wellness. This approach is characterized by its articulation in two phases, which is essential to enabling accurate and constant monitoring of the health status of patients in the spa context. The goal of the approach, depicted in Figure 1, involves comprehensive monitoring of patients during their visit to the spa facilities and during their return to daily life. The proposed general framework is developed through a software architecture that integrates IoT objects serving both patients and expert users and can monitor patients.

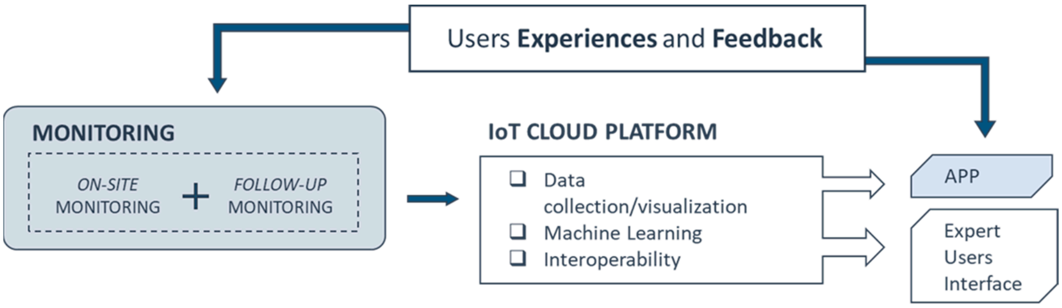

Figure 1. General framework.

The proposed architecture, represented in Figure 2, includes several layers through which the monitoring and services offered by the system are developed. In the acquisition layer are the hardware devices, which are functional for monitoring and managing patients and the facility. The devices can be wearables, such as smartwatches capable of monitoring health-related parameters during and after treatment, or passive presence sensors to monitor actual utilization and the right timing of treatments. In addition, in this context, IoT nodes include devices capable of collecting information on patients' conditions, environmental and micro-environmental conditions in the spa facility, and material and structural alterations relevant to patients' well-being. IoT nodes may also include actuators dedicated, for example, to regulating indoor climate. In addition to these data, other helpful information for the system can be integrated using external services such as repositories of medical records that can describe patients' health conditions. The second module represents the core of the architecture. This module checks, validates, and pre-processes data, making them homogeneous and available for storage. Pre-processing helps extract the information needed to preserve patient well-being, feeding the IoT platform responsible for storing the data and making it available remotely. Next, the data can be shared with the inference block, which leverages machine learning-based approaches to process the data. In the inference engine, learning models are selected and used to exploit the entire flow from the data, based on which the monitoring and decision-making applications are based. Through the services module, the knowledge and models obtained in the core architecture are made available to the application module, which deals with patient monitoring to support expert users. The implemented applications aim at patients and expert users, such as physicians and health care providers. In particular, expert users are able to access the information provided, including data and statistics on the trend of the health conditions of patients and the spa facility, capable of suggesting diagnoses and decisions to support patients and the spa facility itself (treatments to be delivered, temperature and humidity regulation, air quality control, energy optimization, etc.). Simple users, i.e., patients, can also benefit, even in real-time, by applying the treatment information to be followed. In addition, through the services module, simple users can make judgments toward the application and treatments; on the other hand, expert users can access more detailed information for monitoring patients, treatment status, and the facility, sending, if necessary, valuable notifications to patients.

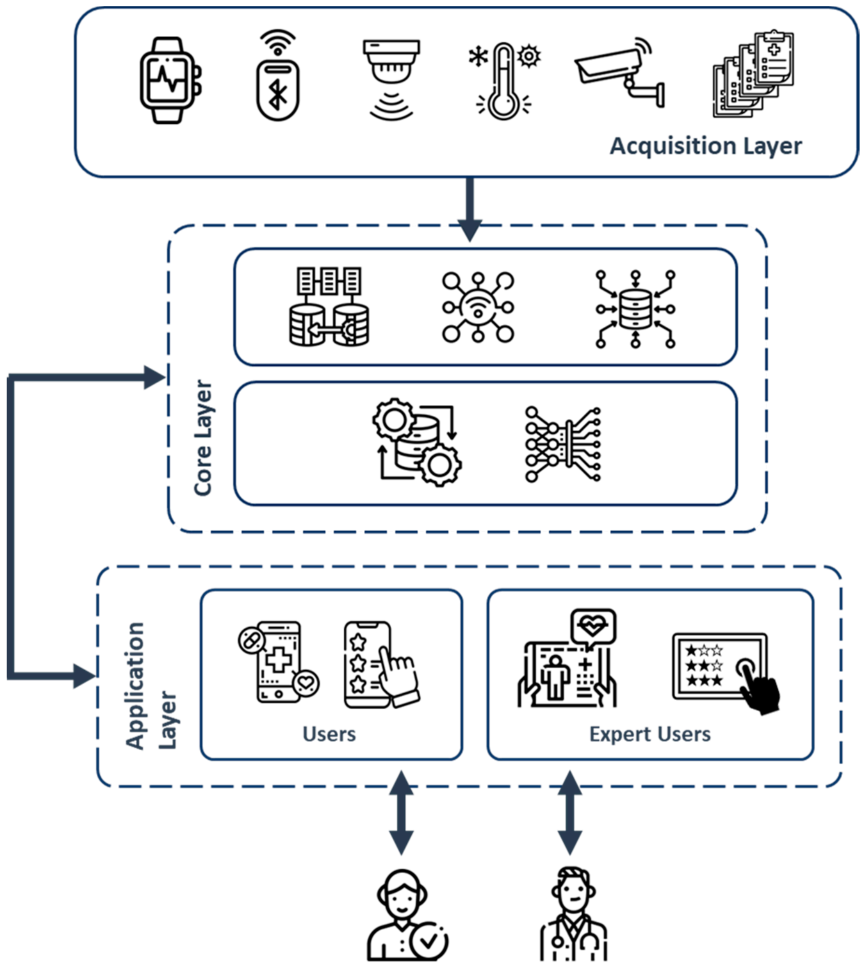

Figure 2. Proposed architecture.

For the initial development of the system, smartwatches and presence beacon sensors were relied upon, while device monitoring and management, data collection, processing, and visualization were made available with the support of the open-source IoT platform Thingsboard, from which data for the development of the first application prototypes could be derived.

Thanks to the proposed architecture, the methodological framework is developed through two main phases that lead to the timely and continuous monitoring of patient's health in spa facilities, both during the treatment period and after their departure. In the first phase, there is a focus on using devices specifically developed for monitoring patients within healthcare settings. These devices, equipped with state-of-the-art sensors and sophisticated sensing technologies, can capture various data regarding patients' physiological and clinical conditions, including heart rate, blood pressure, body temperature, motor activities, and other significant parameters. These data are captured in real-time and sent to a centralized data analysis system, which enables constant monitoring of the patient's health status and early identification of any changes or irregularities. In the second phase of the methodology, we focus on the following monitoring of patients once they have finished their treatment at the spa facility. Upon returning to their daily activities, patients can continue to be monitored through the technology of mobile devices in their possession, such as smartphones, smartwatches, or other wearable devices. With this strategy, the patient's health monitoring continues beyond their stay in the spa facility. The remote follow-up approach ensures continuous supervision of patients' health status, even after they leave the spa, so that the long-term validity of the treatment program can be assessed and any relapses or complications can be recognized early. This system also allows patients to actively monitor their health, providing up-to-date data on medical parameters and suggestions and guidance to encourage a proper lifestyle.

3.1. On-Site Monitoring

The monitoring process during spa therapy (Figure 3) is implemented through wearable devices, distributed to patients when the therapy cycle begins and returned at the end of the therapy cycle. These devices are crucial to achieving continuous, transparent, and non-invasive monitoring of vital values, including heart rate, blood oxygenation levels, body movements, and other parameters relevant to the therapy cycle. The key to these devices is their ability to operate autonomously: patients are not required to relate directly to them or other devices, as monitoring occurs fully automatically without any external intervention. Data recorded by the wearable devices are collected and conveyed through a network of Beacon devices strategically placed within the spa facilities. These Beacon devices are designed for efficient and secure data collection, thus ensuring maximum privacy and protection of users' personal information. Through this network, continuous, real-time data collection can be performed, thus providing a timely and up-to-date picture of the results and progress of the spa treatment. One of the main benefits of this approach is total clarity for the user: patients do not have to deal with handling or interfacing with the wearable or other devices during therapy. This allows them to devote themselves exclusively to treatment without distractions or difficulties related to the use of technological equipment. Monitoring through wearable devices also provides more accurate and detailed data collection than traditional methods, allowing a wide variety of parameters to be recorded continuously and in real time. This aspect is essential for comprehensive evaluation of therapy results and confirmation of the effectiveness of the treatment itself. Finally, the collected data are automatically sent to a confidential IoT cloud platform, which takes care of its storage for subsequent analysis and processing. This step is crucial to ensure that the collected information is available for in-depth analysis and to support evidence-based and reliable medical choices. In this way, thermal monitoring becomes not only a means of assessing the immediate effects of therapy but also a tool for understanding the long-term impact on patients' comfort and health.

Figure 3. On-site monitoring architecture.

3.2. Data Collection

The management and organization of medically acquired data, particularly in spa facilities, is a complex and delicate challenge that requires specific attention to the safeguarding and secrecy of patients' personal and sensitive information. This issue assumes paramount importance given the need to comply with strict privacy regulations and protect patients' rights by ensuring their privacy is protected throughout data collection and management. One of the most significant issues in this area is the association of collected data with the identity of individual patients while ensuring the confidentiality of private information. To ensure that the data collected during therapeutic monitoring comply with privacy regulations, avoiding any direct connection between the collected data and the patient's identity is crucial. This requirement implies the need to find an effective way to track the origin of data collected during treatment without using personal identifiers. Within this framework, one standard method is to produce a unique, random code for each patient upon check-in at the spa facility. Typically presented as a bar code, this code simplifies re-registration and monitoring of treatment anonymously on subsequent days without the need to match identifying data to the patient. As a result, the collected data remain anonymous, preventing the patient's identity from being traced through the monitored information. Management of this barcode system involves careful organization and tracking. It is essential to ensure that bar codes are correctly associated with the corresponding patients and recorded accurately in the computer systems. In addition, it is essential to keep detailed records of the codes associated with each patient and the treatments performed to ensure that the data are recorded correctly and can be traced back to the right patient when needed. The parameters tracked by the wearable devices were selected to monitor and evaluate critical aspects of the care pathway. These parameters include, but are not limited to, cardiac activity, blood oxygenation, movement and physical activity, and other factors relevant to the therapeutic setting. The choice of these parameters is based on the desire to obtain a comprehensive, decontextualized view of the effectiveness of the therapeutic process, thus enabling accurate assessment of the patient's progress and the overall effectiveness of the spa therapy.

3.3. Follow-Up Monitoring

Follow-up monitoring, the second key component of our methodological approach, aims to capture a comprehensive set of clinical and behavioral parameters to concretely assess the effectiveness of spa therapy, even after patients have left the facility (Figure 4). This extended monitoring phase is crucial for understanding treatment's long-term benefits and detecting early signs of relapse or post-therapy complications. In daily life, where patients may not have access to precision hardware instrumentation or complex monitoring systems, the method leverages the use of health services embedded in popular mobile operating systems, such as Android and iOS. These services serve as interface platforms with a wide range of health monitoring applications, making it possible to aggregate and analyze various health status data provided by users' mobile devices. The type and volume of data collected vary greatly depending on the user's specific hardware and software capabilities. For example, a user wearing a smartwatch or fitness tracker can produce physical activity data such as steps, distance traveled, calories burned, and even heart rate information and an initial analysis of stress levels based on fluctuations in heart rate variability.

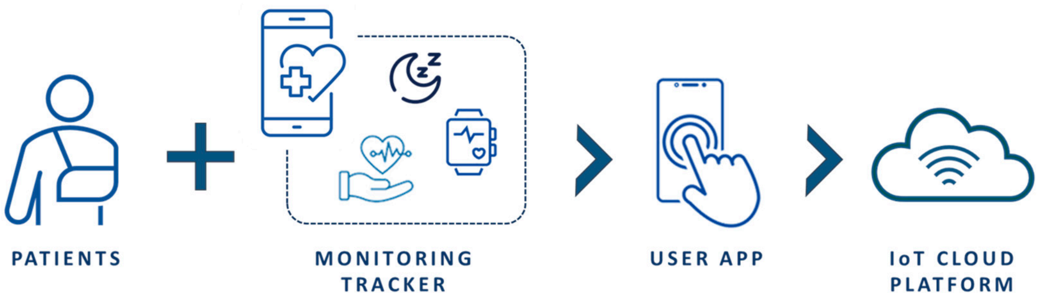

Figure 4. Follow-up monitoring architecture.

Moreover, suppose the device is equipped with suitable sensors. In that case, it can keep track of aspects such as sleep quality, noting its duration, stages, and interruptions, thus contributing to a detailed analysis of the user's overall level of well-being. In this technological scenario, one of the main challenges is ensuring the privacy and security of user data. To overcome this obstacle, we propose to adopt a specially dedicated mobile application that users can download to their smartphones. This application interfaces with the device's health services in a way that complies with privacy and security requirements.

Access to the app is via a unique code generated at the time of patient registration to ensure that the data collected is securely and anonymously associated with the user's identity. Monitoring through the app is fully automated and continues throughout the treatment period, capturing daily data from the device's health services, such as heart rate, step count, sleep data, and more. This information is then coded and transferred to a centralized cloud platform. This cloud platform acts as a data collection, storage, and analysis hub, allowing healthcare providers and researchers to access the data in a secure and privacy-friendly manner. This integrated mobile health services system and a dedicated app provide a convenient, intuitive, and secure method for extensive health monitoring, which is essential in this context. It enables the smooth integration of technology into a patient's daily life while ensuring consistent and reliable data collection, improving therapeutic interventions' effectiveness, and promoting personalized health care.

Integrating our innovative thermal monitoring system with existing electronic healthcare systems is a crucial step in optimizing the effectiveness and performance of the care process. This synergy ensures the smooth sharing of clinical information, which enhances the holistic and coordinated management of patient health. The aim is to facilitate the exchange of vital data, such as medical history and test results, between our system and health systems to give professionals a comprehensive view of the patient's health status.

3.4. Interoperability with Electronic Health Systems in the Context of the Framework for Thermal Monitoring

Interoperability reaffirms the essential role of continuous care, allowing interested specialists to consult the results obtained by a patient at a therapeutic center, especially for people undergoing treatment for chronic diseases. Moreover, we can ensure a continuous update of patient information, which makes timely interventions possible in case of need. To this end, we use standardized data exchange protocols, such as HL7 or FHIR, ensuring the security of exchanges without risk of misunderstanding. The presence of robust APIs facilitates the perfect integration of the system with the various types of platforms present in the field of health safety. Furthermore, we do not disregard transparency and security issues, introducing strict personal data security processes at the time of data reception and consultation. Intense verification activity ensures that this synergy is free of compromises in functionality or reliability, just as targeted update activity makes management procedures effective. The benefits deriving from this type of integration are evident: improving the health treatment of the individual patient by guaranteeing healthcare professionals the possibility to have a comprehensive view of their health level, enhancing performance through the saving of tests and treatments, and keeping the patient at the forefront within their care pathway, providing them with a safe and accessible approach to various clinical data. In practice, it not only increases the reliability of the treatment but also facilitates the connection of the healthcare system with that of the patient. It also contributes to creating a treatment model more suited to their characteristics, promoting greater interdisciplinarity and a greater awareness of the patient's needs.

3.5. Machine Learning

Developing an ML algorithm within the thermal treatment framework allows for exploring new potentials in the predictive analysis of health parameters. These algorithms can process historical and current information to understand dynamics and forecast potential health risks, such as heart conditions identified through heart rate monitoring or physical activity. Additionally, artificial intelligence (AI) is fundamentally valuable for customizing thermal treatment paths, as it suggests adjustments based on patient characteristics to optimize therapeutic effects. By analyzing parameters related to physical activity and rest, AI can recognize early symptoms of new diseases, such as neurological or musculoskeletal issues. This capability is indispensable for preventive intervention and addressing potential adverse complications. Thanks to its integration into our system, this functionality can assist healthcare providers in their operations, suggesting optimal patient management and identifying patient categories that require further medical treatment. The ability of AI and ML to adapt and continuously improve their performance based on received data outcomes is an essential factor. This technology, used to enhance the communication of our solution within telemedicine infrastructures, facilitates collaboration between patient and doctor and eases the home delivery of thermal services. Security and privacy guarantees are priority aspects, and AI helps to reinforce them by detecting and countering unauthorized access or anomalous data consultation pathways. The capacity of AI systems to respond in a personalized manner to patient needs through their mobile applications, offering advice on healthy lifestyle behaviors and autonomous management of health issues based on detected data, represents an additional benefit. In summary, integrating AI and ML into therapeutic disciplines improves the quality of therapeutic processes. It helps expand the patient's perception and support from healthcare providers, making the healthcare system even more integrated, organized, and attentive to the needs of each patient.

3.6. Mobile APP Integration

Developing a mobile app integrated into the advanced thermal monitoring system has been a significant advantage in realizing more efficient and pleasant patient care. Designed as a logical extension of our diagnostic tools, this new app also features an interactive and user-friendly interface that allows patients to exercise active and conscious control over their health management. Through the app, our patients have the opportunity to benefit from specific consultations, elaborated based on their data collected through the various sensors and specific interactions and lifestyle habits. Therefore, for example, if the patient has identified an increased state of stress, they can offer specific wellness or relaxation guidance to mitigate the state of stress. In addition, the program also offers its users the opportunity to achieve and control individual wellness goals, such as improving rest conditions or limiting stressors. These goals can be supported through a system-based feedback process encouraging patients to follow or correct their programs effectively. The app can be used for additional data, such as daily mood, pain-related complaints, nutritional preferences, and hydration conditions. This provides a much better and more in-depth view of the subject's health level, going beyond the simple parameters acquired independently by the sensing devices. An essential role is also played by the app's notification and reporting technology, thanks to which timely alerts can be sent following the monitoring of any abnormalities in the patient's safety parameters or the reminder of any therapies and medical examinations that need to be performed. The interface design has been carefully crafted to ensure ease of use by different users, providing graphical and grammatical explanations such that navigation and use of the app are straightforward and intuitive (Figure 5). The app's various screens allow for the integration of the subject's data with information on the medical course to be taken; a section linked to the therapy program schedule provides a view of the day's schedule and upcoming treatments that will take place in the same month. The thermal control system, fully coordinated with this app, ensures a continuous and direct passage of data through the wearable devices and the app itself. It makes the information collected easily accessible in a special section of the app to allow for real-time insights and feedback. In that section, not only are all the parameters of the monitoring system reported and represented in real-time and day by day but it is also possible to view the trend detected in previous weeks in terms of frequency or past months.

In terms of protection and confidentiality, the app uses very effective encryption protocols that ensure the security of one's health data during data transmission and storage. In addition, the role it plays in providing ongoing support to patients, even after the end of the spa treatment cycle, is crucial. In this way, subjects can follow up on their well-being and retain the correct practices adopted during their spa stay, promoting more effective management of their quality of life in the long run. Therefore, incorporating a mobile application into the spa's control device allows it to elevate the services offered further and contribute to better patient participation and awareness in managing their health condition.

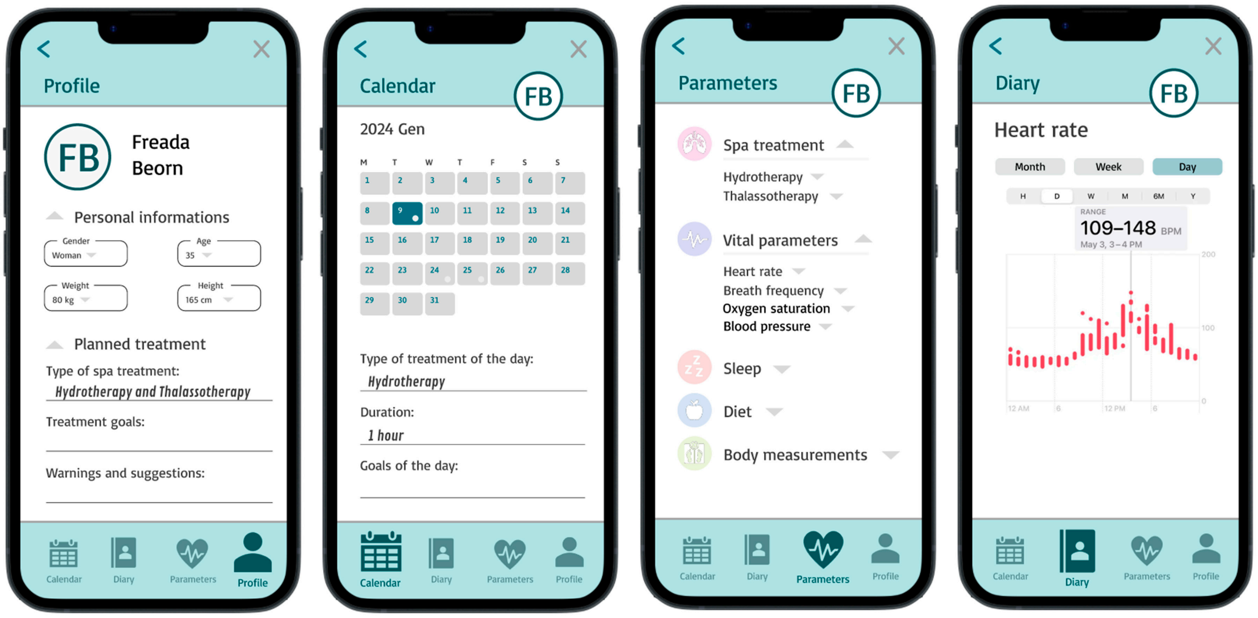

Figure 5. Example of app's interface design.

An ad hoc platform, on the other hand, would allow the physician to monitor the patient's levels in constant time during the spa treatment and in the weeks and months following (Figure 6). After logging in, he or she would identify the subject among those in treatment, select the therapeutic method, and monitor the parameters through an interactive dashboard, which can also be shared with the client himself or herself, if required. Finally, through such a platform, the physician can also decide to forward personalized and direct alerts to the patient when abnormal situations occur during treatment or at the end of therapy to correct erroneous behavior on the part of the patient. Such a significant approach constitutes a major advancement in the field of spa care, as it puts technology at the center of the patient's healing and wellness journey.

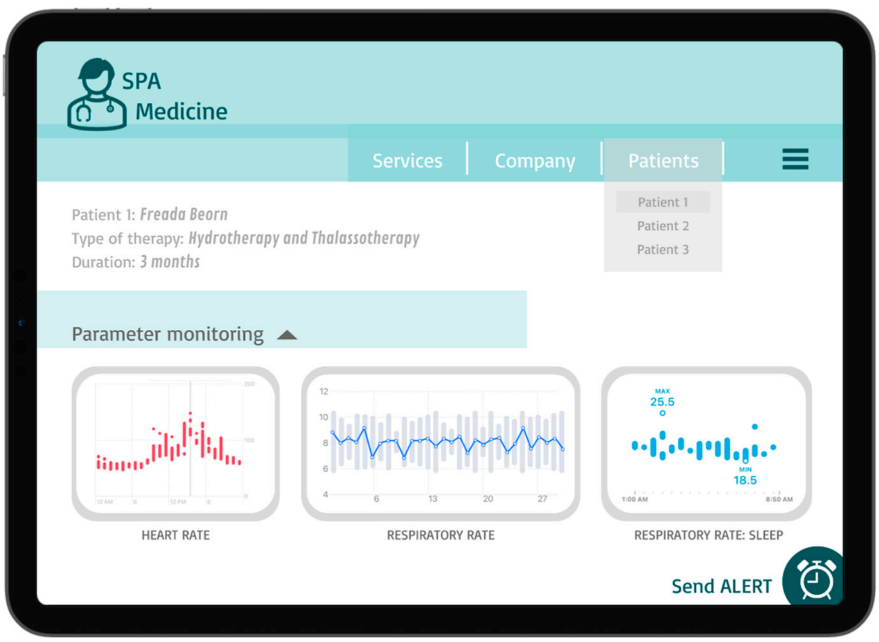

Figure 6. Example of medical platform interface.

As mentioned in the proposed system, user experience plays a key role, so it must be considered in many aspects. First and foremost is security: because the system collects sensitive patient data, it is necessary to ensure data confidentiality and include protocols for managing access permissions and respecting privacy, among which, for example, anonymization of sensitive data so that it cannot be directly linked to specific individuals, or encryption of data to protect it from unauthorized access during transmission and storage may be helpful. In addition to the issue of security, user acceptance is significant. Before treatment begins, patients are appropriately informed and trained concerning how data are acquired and used so that they are fully aware of the journey they are facing, not only medically but also informatically. Ensuring an optimal user experience balances several factors that precise rules cannot establish because they change according to the type of experience one wants to provide and the type of system created. That is why it makes sense to involve professionals from different fields who can improve the user experience from multiple perspectives.

The protection of personal health data against unauthorized and unlawful attacks plays a central role today, particularly given the consequences that could result. A multifaceted encryption strategy must be employed in the sensitive area of clinical file management within IoT and ML systems. The combination of asymmetric and symmetric encryption is undoubtedly an effective solution. Asymmetric encryption, such as RSA, can be used in cases where it is essential to exchange keys securely, and symmetric encryption, such as AES, is preferred in cases of data encryption itself, given its validity in large data sets. Encryption of deposited data must adhere to strict encryption standards, among which AES-256 is the basic standard for data protection in storage devices. Regarding data transfers, procedures such as the TLS protocol accompanied by the issuance by trusted certification bodies must be used to guarantee the passage of data over networks. End-to-end encryption is essential in situations where sensitive data are exchanged between patients and healthcare personnel to ensure that only the relevant parties can access this information. In addition to this, certain innovative features of encryption, such as homomorphic encryption, ensure, for instance, that ML applications process their data without decrypting it, preserving privacy at all times. Again, thanks to attribute-based cryptography, sophisticated access control mechanisms can be applied to medical facilities, which must strictly manage data access according to specific roles and competencies. The use of blockchain technologies in decentralized cryptography also makes it possible, for instance, to create a protected and immutable ledger that can ensure the integrity and traceability of data movements. Implementing such techniques at the cryptographic level requires a comprehensive architecture and strict adherence to standard key-handling practices, including periodic key rotation, secure storage via hardware security devices, and the choice of a zero-trust architecture to ensure controlled and authorized data entry. As mentioned, this structure must also establish stringent data management and storage procedures, anonymization techniques, and secure data exchange protocols following the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA), if applicable.

Privacy is a concern that goes beyond the technical elements of data security, as it relates to the right of individuals to exercise control over personal information. This is why we intend to explore the balance between using cryptography and using IoT and ML applications in healthcare. Implementing techniques such as data anonymization and pseudonymization are to be considered. As is the issue of consent. Indeed, patients must be informed about the processing of their data. This implies the collection of informed opinions in transparent and understandable language to ensure that the patient knows his or her rights and the destination of the health data concerning him or her. Embedding such ethical considerations within will align the practice with best practices and promote IoT and ML applications in healthcare responsibly, fostering acceptance and ensuring that consumers and the healthcare community embrace them. Furthermore, it should be emphasized that obtaining informed consent in IoT and ML healthcare applications goes beyond traditional methods. Finally, creating a supervisory body to verify compliance with the ethical use of individual health data and enforce compliance would also be beneficial.

4. Validation and Results

In order to effectively begin the search for an evaluation of an application realized within the framework of modern medicine, a methodical principle has been adopted, which consists of using a particular test; in this case, the verification criteria include a range of well-designed actions and questions directed at both patients and doctors, each of which aims to evaluate specific elements peculiar to the app.

The validation of an application in modern medicine is a crucial process involving patients and healthcare professionals. This process aims to verify the app's effectiveness, usability, and security, ensuring that it meets the needs and expectations of both parties. In the introductory phase, the main objective is to determine how the app can improve health management, doctor-patient communication, and access to health information. In addition, the validation process includes extensive testing to ensure compliance with health regulations and the protection of patient data. The app's impact on the efficiency of clinical processes and its ability to integrate with existing health information systems are also assessed. The participation of the patient and healthcare personnel in the testing and feedback phase is indispensable to verify that the application meets the requirements of the end users and contributes to a concrete increase in the quality of the service and services provided.

Key elements of this evaluation process include usability and ease of navigating the app, which is crucial to ensure that users, both patients and health professionals, can effortlessly find the information they need, e.g., data on various therapies, tips on treatment management, and more general guidance on their well-being. The app's contents' accuracy, efficiency, and transparency are also assessed, as these are decisive criteria for ensuring the availability of up-to-date and reliable elements necessary for understanding and safely dealing with the prescribed treatment. The app's clarification of therapeutic prescriptions, intake times, and management of possible unwanted reactions are also examined. Another critical point analyzed is ensuring the protection and confidentiality of health information collected with the app. This aspect of the analysis, in which privacy and data protection are paramount, aims to ensure that the app adopts precise protocols for protecting sensitive patient information. Users are asked to express their perceptions about protecting their health information while using the app, with questions about data security and concerns about confidentiality or loss of information. Finally, special attention is paid to the intuitiveness of the graphical interface. This includes assessing how easy it is for a newcomer to understand and use the program without extensive assistance, which can strongly affect its overall adoption and effectiveness in the medical context. The experimentation part was developed in the field, making the system available in the evaluation phase to several spa facilities that had the entire cycle of the spa experience itself, thus including the medical part. The experimentation was strongly desired concerning both types of development and, thus, types of users, as regards both the users of spa services and the health professionals who follow the patients. For this reason, it was decided to keep the two evaluations separate to be able to have more detail concerning the parameters taken into account by the data provided by the sensors. The accurate evaluation makes it possible to establish transparently that the product meets the requirements for proper use in wellness and health. The survey covered 128 users who had undergone a course of spa treatments during the past six months. In the context of the survey conducted among patients who used the health service with the support of the application, several questions were asked to evaluate various elements of the application, such as the usability and intuitiveness of the user interface, the accuracy of the health information reported by the application, and the ability of the application itself to contribute to the improvement of the patient's health quality. The responses were evaluated based on a satisfaction scale. In particular, a rating scale from 1 to 5 was used, where 1 indicated minimum satisfaction, and 5 indicated maximum satisfaction on the part of the patients. From the analysis of the collected results (Figure 7), the app's user interface was perceived as highly intuitive, with an average rating of 4.4. Regarding the accuracy of the health information provided by the app, patients gave a generally positive rating, with an average of 4.0. Ultimately, the survey revealed that the app significantly improved patient health management, with an average rating of 4.2. These results indicate a general appreciation and perceived application effectiveness among its users.

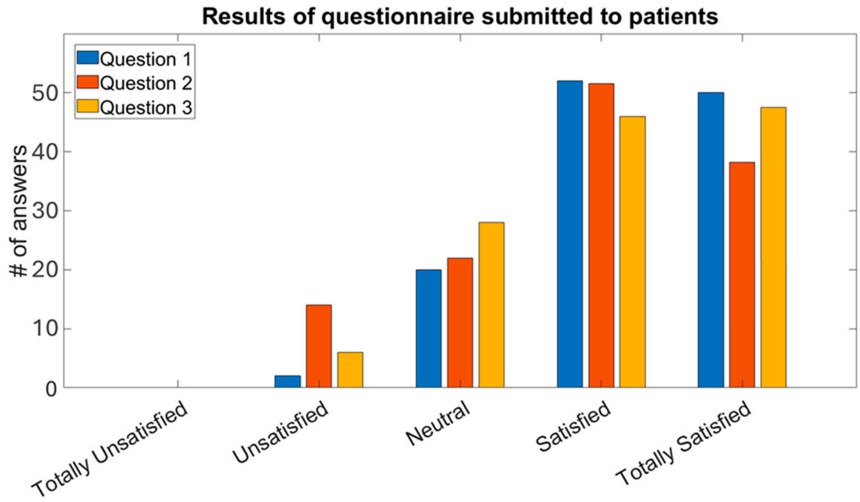

Figure 7. Results of a questionnaire submitted to patients.

As mentioned above, the experimental phase also consisted of a validation of the experimental system by healthcare professionals; in this case, the objective was to take into account the parameters of the sensors and how the patient's profile was described within the application to improve the patient-doctor relationship and the effectiveness of the proposed treatment in real-time. Using the same methods and criteria, it was also possible to evaluate the functioning of the mobile application designed for healthcare professionals. A group of 26 doctors was interviewed through the administration of the specially prepared questionnaire to assess its validity for monitoring clinical factors, both in terms of the accuracy and punctuality of the medical information provided and the ease of consulting the information relating to patients, and, above all, to verify how practical the application was in reducing the work performed, by decreasing the amount of time spent on collecting and comparing patient data. Also, in this case, the responses (Figure 8) were collected on a scale of 1 to 5, where 1 indicated the lowest degree of satisfaction/effectiveness and five the highest. The results highlighted a significant level of perceived effectiveness in using the application for patient monitoring, with an average rating of 4.4. Ease of access to patient data was rated an average of 4.2, indicating a well-designed user interface and efficient navigation. Furthermore, the application was rated positively regarding its contribution to doctors' work efficiency, with an average of 4.5, suggesting that the app facilitates more efficient time management and better organization of health information.

These findings highlight the importance of well-designed applications in the context of digital medicine, offering healthcare professionals practical tools for patient monitoring and health data management with a positive impact on the efficiency of their work. Furthermore, feedback provided by patients and healthcare professionals is essential to continuously improve the application, ensuring that it meets user needs and expectations in terms of functionality, ease of use, information effectiveness, and data security.

Therefore, from the in-depth and analytical review of the responses collected, a significant dichotomy emerges in the priorities and perceptions between the two main groups of users interviewed. From the patient's perspective, the predominant factors determining the medical application's value and usefulness are accessibility and ease of use. This group of users emphasizes the application's ability to be intuitive, easily navigable, and without complex access barriers, making the user experience seamless and frustration-free. To meet this need, a voice assistance functionality is proposed. This solution should allow users to interact with the application through voice commands, thus facilitating access even for those who may find it challenging to use touchscreen interfaces, such as old age or individuals with physical limitations.

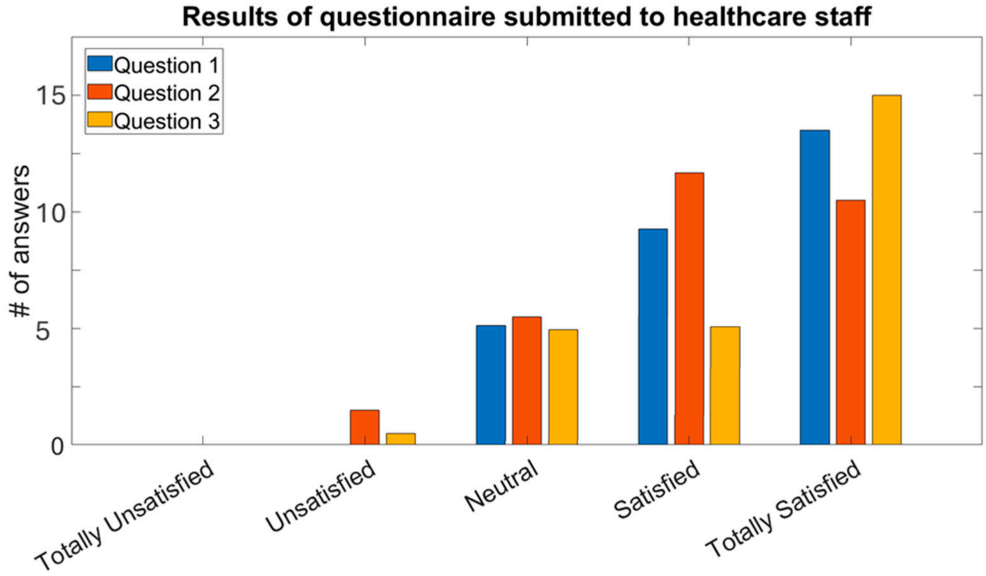

Figure 8. Results of a questionnaire submitted to healthcare staff.

On the other hand, the user segment, which consists of healthcare professionals, such as doctors, emphasizes crucial aspects such as the accuracy and reliability of the data provided by the application. This group places great importance on the correctness, accuracy, and timeliness of the app's clinical information collected and managed. In addition, there is a strong demand for application integration with other clinical tools and systems, emphasizing the need for a cohesive and interconnected digital ecosystem that supports efficient healthcare workflow and optimal patient management. Therefore, the main objective is to create seamless interoperability between the application and patient management systems commonly used in clinical environments. This could involve the development of advanced application programming interfaces (APIs) that enable secure and efficient data exchange between the app and healthcare databases, thus ensuring timely and accurate updating of patient information. Furthermore, the improved integration should make it easier for doctors to access vital data directly from the application, enabling faster and more informed clinical decision-making.

This divergence in priorities and needs between patients and doctors highlights the essentiality of a holistic, balanced, and multi-perspective approach in designing and developing medical applications. It is imperative that such applications not only meet the requirements of ease of use and accessibility required by patients but also integrate elements of high precision, data reliability, and interoperability with other systems, as required by medical personnel. This balance between usability and technical integration is critical to ensuring that the application is practical and positively impacts both individual health management and the efficiency of the overall healthcare system. Based, therefore, on the conclusions reached during the validation phase of the application, a user-centered approach was adopted, which ensures that the application not only fulfills the essential technical criteria but also responds effectively and directly to the needs specific to both patients and healthcare professionals. This orientation towards the needs of end users promotes more informative and connected healthcare management, characterized by a more fluid interaction between the different actors involved, effectively optimizing the app's functionality and ease of use.

The application validation process, therefore, turns out to be a crucial element in the life cycle of a technological solution in the medical field. Through validation, we ensure that the application is not only up to date with the latest technological innovations but also deeply integrated and responsive to the real needs of the healthcare sector. Validation, therefore, acts as a bridge between technological development and practical application, ensuring that innovations are both technologically advanced and meaningful and valuable for improving healthcare. In summary, the validation process allows the app to be refined regarding functionality, usability, and relevance, making it an indispensable tool in digital health.

Despite the positive results achieved during operational trials, several crucial points and challenges emerged while developing the IoT system prototypes for SPA and wellness applications. One of the most critical difficulties in evaluating and protecting users' data is a growing concern in an era in which data protection is highly topical. The realization of the prototype underlined the need to adopt new protection techniques to protect and safeguard personal data. New encryption and operator authentication technologies had to be implemented in compliance with current privacy protection regulations, such as the General Data Protection Regulation (GDPR) [22,23]. Such measures are indispensable for preserving valuable patient health resources that IoT devices detect. A further significant need was integrating the IoT device into the existing hardware infrastructure at the spa clinics. This integration entailed a modular and versatile design to achieve a reliable and comprehensive data collection capable of responding to the different hardware configurations at the spas. Despite the difficulties, the device integrated smoothly with standard services and equipment, ensuring the system's viability. A further period of field testing has been scheduled for a complete evaluation of all aspects of the system and the collection of direct information from the leading figures involved, allowing for a more precise definition of the system's configuration parameters. This test will improve the product's characteristics, particularly regarding the data visualization part, and introduce further innovations based on what has been learned from users and operators in the field. Therefore, in conclusion, the prototype system for IoT applications in the spa and wellness sector showed considerable potential despite some challenges encountered during the handling of personal information and integration with existing hardware. The planned extended field-testing phase will provide more information to optimize the system and make it a valuable tool in the wellness and spa sector.

At this point in the analysis of the results obtained, considerations can be made regarding the benefits and advantages of the proposed system compared with classical therapeutic spa treatments. For a proper comparative analysis, we evaluate several factors and indicators of effectiveness. Among these, the most important ones to consider are certainly treatment efficiency and clinical effectiveness, which most of all determine the success of the treatment. Treatment efficiency, for example, translates to better patient management for healthcare professionals while reducing user waiting times. This is possible thanks to new technologies and, in particular, thanks to the utilization of the mobile application that allows the optimization of treatment planning and, consequently, increases the number of patients who can be treated simultaneously due to the possibility of keeping their medical records always available and retrievable online. Clinical efficacy, on the other hand, is precisely mirrored by successful treatment, which means producing measurable and meaningful benefits for patients. With the application of the IoT paradigm, it is possible to personalize treatment to make it more effective. In contrast, ML techniques make it possible to develop predictive models, which are crucial in managing complications. Unlike traditional methodologies, possible complications or risks associated with certain medical conditions can be detected early, allowing healthcare professionals to intervene and manage them in a suitable timeframe. Implementing IoT technologies in spa treatments can enable better resource management, such as optimizing treatment schedules based on equipment or staff availability, and allows for improvement in aspects such as real-time monitoring and feedback, which are benefits closely linked to new technologies. In real-time, healthcare providers can intervene in treatment and interact with patients, even after the course has ended and outside of the spa facilities; this does not apply to traditional treatment, making the proposed method much more efficient. Overall, the use of new technologies in medical spa treatment, as opposed to traditional care, certainly allows for an improved experience for both healthcare professionals and patients.

Although promising benefits for personalized treatment, current research in the area of IoT and ML is confronted with implicit limitations and associated risks that require in-depth reasoning that takes several aspects into account. One of the most relevant limitations lies in the fact that research in this particular application area is still at a preliminary stage. This scarcity of extensive and comparative studies means that the datasets on which ML algorithms are trained may no longer be representative of the entire community or of different conditions, which may lead to biased and non-heterogeneous results.

As commented above, IoT devices in healthcare services present the concrete possibility of cyber-physical system breaches, whereby network weaknesses could be exploited to obtain sensitive health data or interfere with the devices' operations. In this context, ML applications that require continuous processing need not only robust solutions in terms of data storage but also sophisticated tools for recognizing risk situations so as to identify and mitigate possible causes promptly. The proposed integration of these technologies also poses the scenario of limited human intervention, where reliance on IT devices may reduce the contribution of professionals in the delivery of care. This change runs the risk of affecting the existing therapeutic trust relationship with the patient, a founding element of traditional healthcare treatment and one that, through a path of awareness, must also be initiated concerning innovative technological systems, as is already the case in other fields and disciplines.

5. Conclusions

As in many other healthcare sectors, spa therapies are developing and taking advantage of new technologies, especially IoT. This promising paradigm represents a valuable tool for optimizing spa treatments by actively monitoring patients both inside and outside spa facilities. Such monitoring allows for accurate and precise measurement of essential parameters such as heart rate and blood oxygenation, which are essential for tracking therapy progress. The analysis of data collected through IoT offers new possibilities for improving the quality and effectiveness of spa therapies. By identifying any problems or unforeseen events in time, treatment can be more targeted for different types of patients. In this context, integrating ML techniques into the framework has enabled more sophisticated data management and analysis, providing a more detailed and personalized view of patients' health status and their responses to treatments. In closing, it can be said that the use of IoT and ML in healthcare has proven valuable and in line with the goals of improving the management of users' personal data and personalizing care.

Regarding future developments, the prototype will be applied to a comprehensive case study to gather data and feedback from key stakeholders involved in the system. This will make a more in-depth evaluation of the method's impact on spa treatments possible and identify further areas for refinement. Ultimately, the integration of advanced technologies such as IoT and ML into the spa treatment sector has shown significant innovation power, demonstrating significant potential in facilitating the management of users' personal data and improving the personalization of spa treatments. Integrating these cutting-edge technologies offers a more specific and effective approach to therapy management, enabling more accurate and personalized care for each patient.

Future Developments

In future projections, it is expected that the application of the prototype can be expanded significantly with more extensive and more detailed studies. This implies collecting more data and feedback from a broad group of stakeholders involved in the care cycle. Such in-depth analysis will allow a more precise assessment of the real impact of the system on spa services, providing a clear view of the potential and areas that need further improvement. Expanding the prototype's integration with a wide range of health services is among the most interesting future avenues. This expansion aims to create a more interconnected and responsive care ecosystem in which different healthcare facilities can interact in a more seamless and coordinated way. In addition, developing dedicated mobile applications for patients is another high-growth area. These applications will enable patients to actively monitor their health and receive personalized treatment advice in real-time, directly on their mobile devices. Another significant planned development is implementing artificial intelligence algorithms for more sophisticated and accurate data analysis. These algorithms could significantly improve the ability to predict treatment outcomes, tailor them to individual needs, and more effectively identify health patterns. Testing the system in a wide range of spa environments will allow its effectiveness to be evaluated in different treatment settings and health conditions, ensuring that the proposed solutions are versatile and adaptable to different therapeutic demands. Finally, it is critical to conduct long-term studies to understand the prolonged effects of using IoT monitoring and ML analytics on spa treatment outcomes. These studies will provide valuable information on the long-term effectiveness of these technologies in spa treatment management, contributing to a deeper understanding of how technological innovation can improve patients' health and well-being. In sum, these future developments may lead to significant improvements in the patient experience and overall effectiveness of spa care, confirming the role of new technologies as crucial tools for improving health and well-being.

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