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# MORE DIGITALIZED HEALTH SERVICES: A BLUEPRINT FOR A CENTRALIZED SOFTWARE APPLICATION IN SMART CITY CONTEXT

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## ABSTRACT

This article introduces a new computerized solution designed to address the connectivity needs of a medical assistance system within the smart city context. To simulate the main developed functionalities, existing workflows from the medical system of Romania were selected as a case study. The developed information application is based on Java and Android ecosystems. It includes a desktop interface for system management addressed to medical specialists, and a mobile one accessible to patients. The platform's capabilities include scheduling and search functionalities for hospitalization and consultations, categorized by medical specialty and institutions, all managed centrally at the city level. The solution incorporates tools for both in-person and remote interactions between healthcare providers and patients. This encompasses discussion functionalities for remote consultations and the ability to monitor medical parameters collected from smart devices or voluntarily transmitted by the patients. Patient data is securely stored in a digital record containing anamnesis and medical observation details, including imaging features. These are also anonymized and labelled with the diagnosis provided by medical specialists, becoming a resource for diagnosing patients with the same pathologies, complying with medical ethics. These are analysed using Machine Learning and Deep Learning algorithms optimized to generate accurate results. The models are pre-trained with medical nature datasets from online repositories. Furthermore, the system's adaptability and resilience can become an asset in addressing health crises, such as the ongoing COVID-19 pandemic. This reinforces the city's ability to respond effectively to unforeseen challenges.

## KEY WORDS

e-healthcare, smart resilient city, medical application, data analysis

## CLASSIFICATION

JEL: I18, L86, O33

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## INTRODUCTION

In recent years, there has been a significant increase in public concern regarding urban development, public health, and technological innovation. The concepts of smart cities, digitization, Artificial Intelligence (AI), e-governance, and e-healthcare have emerged as elements that are reshaping the landscape of modern life. As cities evolve into dynamic hubs of connectivity and innovation, the integration of sensors, wireless networks, and automated data processing is emerging as a transformative force that can improve various aspects of citizens' lives. In the context of recent global events, the most significant being the COVID-19 health crisis, the critical role of modern technologies in strengthening the resilience of cities was emphasized, especially in managing the situation of the healthcare system [1] which can be seen as a complex system [2]. The adoption of smart technologies has become vital for re-evaluating and optimizing urban management strategies, providing not only convenience but also a necessary approach. The resilience and responsiveness of cities in crisis situations are directly influenced by their ability to capitalize on data, connectivity, and AI [3] to quickly respond to various challenges.

Smart cities must be regarded from a holistic perspective, where public services and physical infrastructure are coordinated and managed integratively to create a harmonious urban environment. The fundamental pillars on which the smart city is based are citizens, infrastructure, and urban planning [4], involving an integrative framework incorporating cutting-edge digital tools and data interpretation. Essential public services, such as education and health, are becoming more interactive and connected, aided by current educational approaches [5] and the use of sensors and data analysis for health assessment [6]. Related to infrastructure-the energy, and transport receive new approaches that lead to reducing consumption, optimizing the use of resources, increasing efficiency, transitioning to the use of alternative sources [7], and large-scale implementation of autonomous vehicles, and intelligent roads, traffic lights and parking systems [8]. Urban planning and management can be improved by analyzing data to anticipate city needs and making better-informed decisions by simplifying information from the city's complex network of interconnections [9].


**Figure 1.** Main pillars on which smart cities are based [10].

It has been demonstrated that health services must be brought to the forefront, particularly in light of the COVID-19 pandemic, which underscored the critical necessity for more sophisticated and interconnected health information systems [11]. Centralization of medical services within smart cities should become a priority for the authorities, changing the way medical services are provided and accessed in urban environments. Well-developed technical capabilities can: promote preventive measures, enable remotely collaborative work between teams of physicians, facilitate remote patient monitoring by medical professionals and telemedicine services, forecast the spread of diseases, monitor nutrition lifestyle, monitor vital and environmental parameters, create independence for people with disabilities by dedicated equipment, realize clinical trials helping in diseases prevention and spreading, or improve preparedness in case of calamities [12-14].

The concerns of nowadays medicine go beyond the simple diagnosis of patients and the provision of treatments. The focus has shifted more toward the prevention and integration of computer technology that facilitates the storage of medical data and monitoring of patient health status. These data can then be used for early detection and various preventative therapies. Thus, emphasis is placed on the proactive side of medicine, which promotes the early identification of risk factors and intervention in the early stages of various pathologies. Medical monitoring devices can play an essential role in the assessment of a patient’s health status. Many health facilities use devices with limited connectivity capacity, that allow only local operations. However, the data provided by these types of non-smart devices can be used by integrating them into a processing and storage infrastructure to make them accessible in a centralized manner [15]. There is also another category of semi-medical wearable tools, such as smartwatches, fitness bracelets, or various sensors, that can monitor and warn of changes in health parameters that integrate connectivity capacities. Some devices can be used to monitor physiological signals like Electrocardiography. Others provide biometric measurements like Blood Pressure, Heart Rate, Pulse Oxygen Saturation, Temperature Sensor, or the evaluation of body movements like Pedometer, Gyroscope, Accelerometer [16]. The existence of several protocols and computer systems in which semi-medical devices are integrated makes data exposure heterogeneous. Careful management of diverse data standards and formats is essential for providing accurate transfer of medical data [17]. Since these devices are used unconventionally, the obtained data are for informational purposes only.

The use of a more digitalized infrastructure in the field of health can be a real help. This is because it contributes to reducing bureaucratization, secures and stores relevant information on the health status of patients; removes redundant data from the system, avoids errors, and increases the efficiency of medical staff by improving the process of providing medical services. This allows the medical staff to focus more on the medical act and less on the preparation of documents. The implementation of new technological tools can allow better integration of patient data, leading to a reduction in the costs of services, both for diagnosis and treatment and for better monitoring and patient care [18]. Solutions must be found to meet the objectives of improving data flows between medical institutions, improving the quality of medical services, and improving the health status of the population.

Online appointment platforms for medical units are essential tools for enhancing the quality of healthcare services. These tools establish a direct connection between patients and medical service providers, enabling rapid access to programs for consultations, analyses, and investigations. This contributes to building a more accessible medical experience [19].

For the management of patients’ medical data, three types of information systems have been identified in the specialized literature: Electronic Medical Records (EMR), Electronic Health Records (EHR), and Personal Health Records (PHR) [20]. EMRs are used to optimize internal processes, at the level of a healthcare unit, providing restricted access only at its level. EHRs allow for coordinated management of data between various medical service providers. Implementing this type of system at the macro level faces challenges in managing high volumes of medical data, as well as from a technical point of view. PHRs offer patients control over their health information, as well as the ability to complete their personal medical data through platforms that are accessible to patients. The limitations of this model are represented by patient involvement and data security management challenges. However, a comprehensive solution that encompasses functionalities to meet both patient and sanitary units' requirements while promoting a centralized approach to improve interoperability between various systems is desirable.

Not only the storage of medical data is important, but also their analysis. Machine Learning (ML) and Deep Learning (DL) are powerful information technology tools with significant potential for use in the medical field. Their application can create a substantial impact. The use of ML in analyzing medical records, predicting diseases, and interpreting results enables medical professionals to make more informed decisions regarding the diagnosis and treatment of diseases [21]. For patient diagnosis, DL integration for medical image analysis enables detailed exploration of visual information, identifying complex patterns that may be difficult to detect with the unaided eye, by analyzing large data sets. [22]. This process may involve using Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Generative Adversarial Networks (GANs), or hybrid models to automatically extract relevant features from images, such as textures, edges, and anatomical structures, which are then used to substantiate the diagnosis. This approach provides greater sensitivity and specificity in the detection and classification of multiple medical pathologies, contributing to the development of more accurate and reliable diagnostic methods [23]. DL algorithms can be integrated for application on standardized image formats, such as those based on the Digital Imaging and Communications in Medicine (DICOM) protocol. This type of medical imaging file contains, in addition to a collection of images, multiple metadata that can be used to create powerful models to diagnose patients with or without certain diseases [24]. The images are automatically compared with training data inputs. Optimizing the learning models leads to high accuracy scores in fitting data into the correct classes, relative to the trained models [25]. Users who interact with the system receive predictions regarding potential diagnoses by performing minimal informatic operations [26].

Concerns regarding IT implementations to revolutionize the medical field are currently targeted by the global tech giant Google. Recently, Google introduced a model based on generative AI called MedLM [27]. This is based on Large Language Models (LLMs), called Med-PaLM, which is currently in its second iteration, and will soon integrate the new Gemini model. In the current form, the model is in the testing phase, being integrated with Natural Language Processing (NLP) tools in building systems to assist the conversation between the patient and the doctor, converting the data directly into the medical record, eliminating the need for manual transcription. Such methods of conversation-based interaction can help to extract relevant details regarding the consultation and self-completion of medical forms, generating personalized documents [28].

The aim of this paper is to introduce a health informatics solution that is useful in a smart city setting. To emphasize the main functionalities, some medical procedures and protocols at the Municipality of Bucharest sanitary system level were analyzed, and the elements that could be computerized were transposed into the informatic test application. The solution approaches functionality exploration in a manner that respects data privacy. Thus, the technical implementation focuses on testing and evaluating capabilities, without involving the capture or storage of personal data of real patients, performing simulations on fictitious data to demonstrate the potential in the medical context. The structuring of medical information respects the content addressed by other national medical programs, focusing on the flows identified in the modeling stage. This includes two IT modules – a desktop version for medical specialists and a mobile version for patients. The application offers the possibility of city-centralized scheduling of patients. In addition, it emphasizes the importance of semi-medical devices data extraction and analysis. The medical records data are analyzed through ML and DL algorithms to provide potential diagnostic suggestions and warnings.

The article is organized into four main sections. The second section provides an overview of the Romanian medical system, aiming to clarify the interdependencies and identify the main involved actors. In the third section, the methodological approach is introduced, which includes system modeling and information flow. The fourth section presents the main results and discussions. In the final section, the conclusions are outlined.

## OVERVIEW OF THE ROMANIAN MEDICAL SYSTEM

History has shown that modern medicine in Romania developed from the middle of the 19th century, when attention to this field intensified. The emphasis was initially focused on diagnosis and treatment, and many Romanian specialists and doctors achieved remarkable results in their research and were recognized worldwide. Advancements in technology, reforms, and innovations from the public and private sectors have contributed to continuous improvements and alignment with international standards.

At present, medical services are demanded by a large number of patients; therefore, healthcare involves high costs from the state. Currently, in Romania, access to public medical services is achieved through a contributory system. The health system is financed from funds collected from various sources [29]:

- For the national health system, it is made from direct and indirect taxes;
- For the social health insurance system, it is made from mandatory contributions;
- For the private system, it is made from voluntary insurance policies;
- For the free market system, it is made from direct payments by the beneficiaries;
- Other financing sources (European funds, private sources, etc.)

Funds are administered by various entities, including government departments, ministries, insurance companies, public insurance funds, etc.

The health care sector is an important branch of a smart city, and for its renewal and development as efficiently as possible, it is necessary to integrate actual informatics technologies and smart solutions [18]. In Romania, this stage was triggered by the implementation at the national level of a unique integrated system, called “SIUI”, which allows interconnection with various systems, e.g. the National Health Card, the Electronic Prescription, but also with other applications and systems of diverse medical institutions [30]. The information system allows the healthcare industry to manage and deliver medical assistance. The rapid advancement of technologies and high-speed computer connections can facilitate cost reduction and streamlining of the time allocated to medical services. Moreover, there is a need to store and rapidly analyze large volumes of data generated within the system. Thus, scaling the system is a continuous requirement.

Although the premises for an intelligent medical informatics system exist in Romania, it still requires the integration of the most recent information technologies to make better use of the infrastructure and resources to meet the needs of citizens. Expanding the system can facilitate capitalizing on data from various medical disciplines. The large scale introduction of electronic files in which each patient has stored their medical data would replace the need for archives in a physical format. These archives are difficult to manage and can be easily damaged. With an interconnected network at the city or national level, teams of specialists would be able to access the data easily and quickly. Fragmentation of medical data leads to difficulties in quick access in critical situations.

Romania's medical system is subject to national legislation and is supported by both state and private hospitals. These are equipped and operate according to the specific needs of each pathology, including general medicine, emergency, specialist, or chronic disease hospitals, more detailed in Figure 2. A hospital can include wards, diagnostic and treatment services, departments, and laboratories, and can provide specialized outpatient, hospitalization, and home care services. State hospitals are organized and operate according to territorial boundaries, ranging from regional to county, municipal, city, and communal facilities [31].

Figure 2 shows part of the existing links within the medical system in Romania and the main actors involved – beneficiaries and providers of medical services.

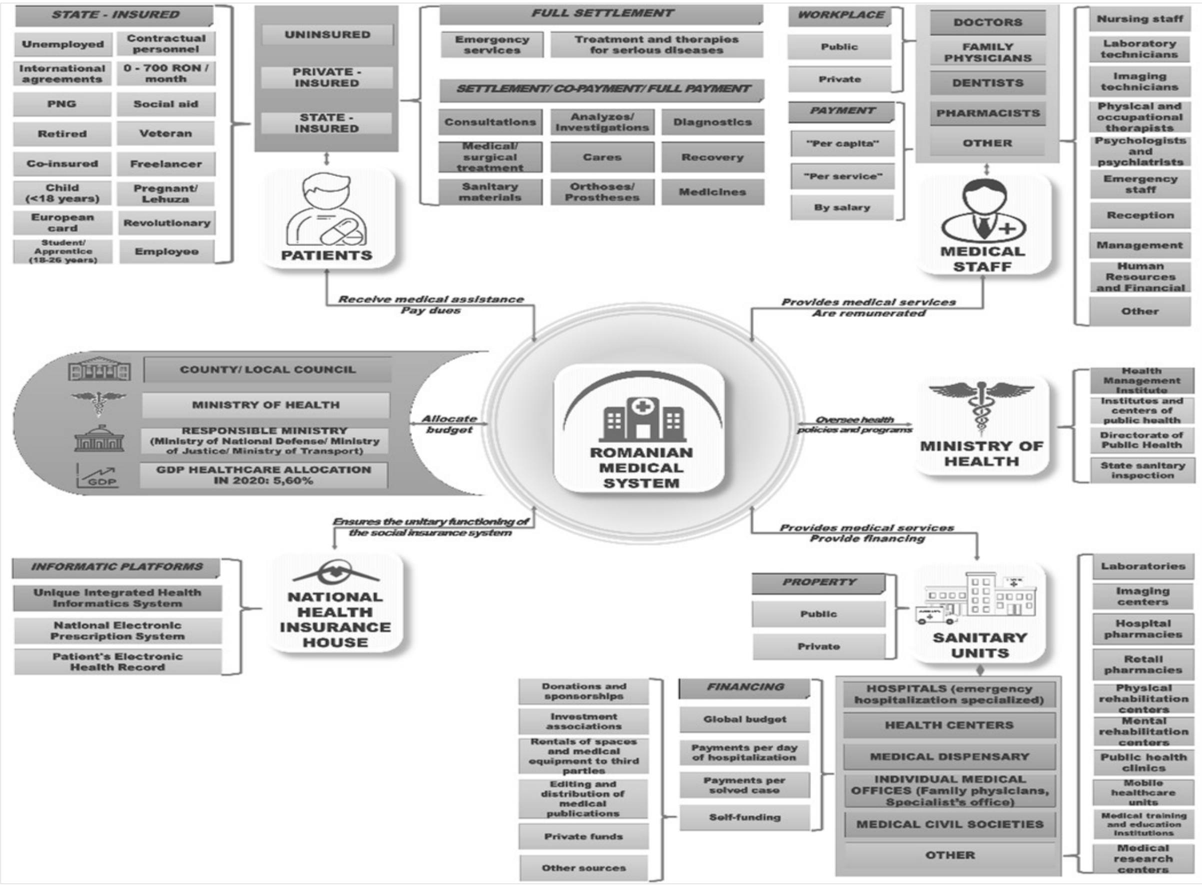



**Figure 2.** Overview of the Romanian medical system interdependencies.

In particular, this study focuses on understanding in depth the medical situation at the level of the Municipality of Bucharest. This is a complex and dynamic city, where factors such as population density, medical infrastructure, access to health services and individual behaviors directly influence the health of the community. From a statistical point of view [32], at the end of 2022, Bucharest had a total of 20 386 beds in public hospitals and 2 340 beds in the private sector. This places it at the top of the European ranking in terms of beds per 100 000 inhabitants, with 1 319 beds in both sectors per 100 000 resident population. From the perspective of the categories of medical assistance units, Table 1 shows the distribution according to the type of ownership – public or private. Out of the total of 52 state hospitals within the radius of the city, 24 hospital units are subordinate to the Ministry of Health; 19 sanitary units are managed by the Bucharest City Hall, 2 by the Ministry of National Defense, 2 by the Ministry of Justice, 2 by the Ministry of Transport, 1 by the Ministry of Internal Affairs, 1 by the Directorate of Public Health, and 1 by the Romanian Academy.

**Table 1.** Categories of sanitary units depending on the property type.

| **Categories of health facilities** | **Number of public units** | **Number of private units** |
|---|---|---|
| Hospitals | 50 | 28 |
| Hospital units with day hospitalization only | 2 | 28 |
| Specialized outpatient clinics | 6 | 24 |
| Outpatient clinics integrated into the hospital | 44 | 2 |
| Polyclinics | - | 9 |
| Medical dispensary | 6 | - |
| Health centers | 2 | - |
| Mental health centers | 7 | - |
| Social and medical units | 1 | - |
| Diagnostic and treatment centers | 4 | - |
| Specialized medical centers | - | 572 |
| Dialysis centers | 4 | 4 |
| Work points of dialysis centers | - | 5 |
| School medical offices | 477 | - |
| Student medical offices | 10 | - |
| Family medical offices | 2 | 1 388 |
| Civil medical society | - | 2 |
| Dental offices | 6 | 3 409 |
| School dental offices | 149 | - |
| Student dental offices | 13 | - |
| Civil medical dental society | - | 14 |
| Specialized medical offices | - | 2 199 |
| Specialized medical civil society | - | 24 |
| Pharmacies, Pharmaceutical points, Pharmaceutical warehouses | 62 | 891 |
| Medical laboratories | 395 | 654 |
| Dental technology laboratories | 6 | 252 |
| Transfusion centers | 3 | - |
| Other types of medical offices | 23 | 358 |

To understand the complexity of the medical system of the city of Bucharest, an important aspect is the medical personnel involved in the provision of services, both in the public and private sectors. Thus, the principal categories of professionals involved in medical assistance are summarized in Figure 3.

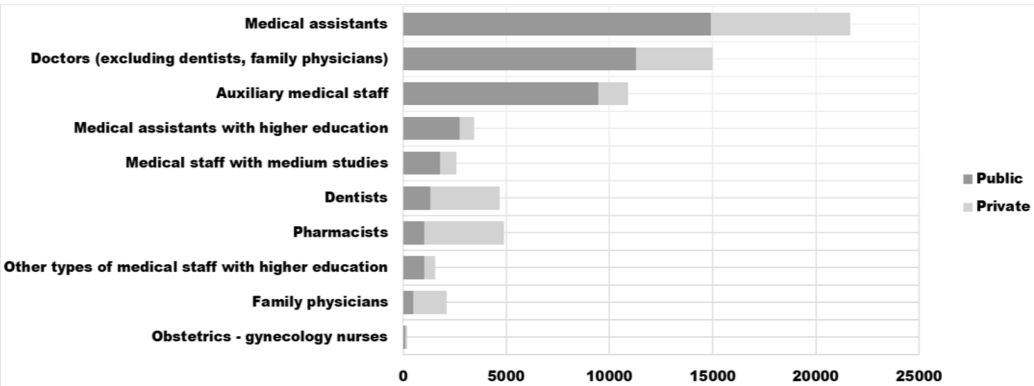



**Figure 3.** The number of medical personnel by category and work environment.

# METHODOLOGICAL APPROACH

## SOFTWARE APPLICATION MODELING

The methodological approach included the stages traditionally associated with developing an software application. The process starts with the analysis of the needs that the IT solution must fulfill, and structuring through specific diagrams. The application was modeled through the design of the architecture, database, modules, and interfaces with the user. Finally, the functionalities were effectively implemented and the proposed software application was tested.

The requirements for the IT solution were modeled using diagrams that highlight the existing links between the main identified actors that trigger various sequences of actions, called use cases. The Unified Modeling Language (UML) was used to perform modeling, allowing for the specification of the system's requirements and implementation approach. This enabled the creation of an overview prior to the actual implementation. UML can also be used to generate object-oriented scripts [33]. In the analysis stage, UML behavior diagrams, specifically use case diagrams, were utilized to identify, clarify, and organize the technical requirements, the actors involved, their roles within and external to the system, and the relationships between them. Building a use case diagram consists of using the elements from Figure 4.

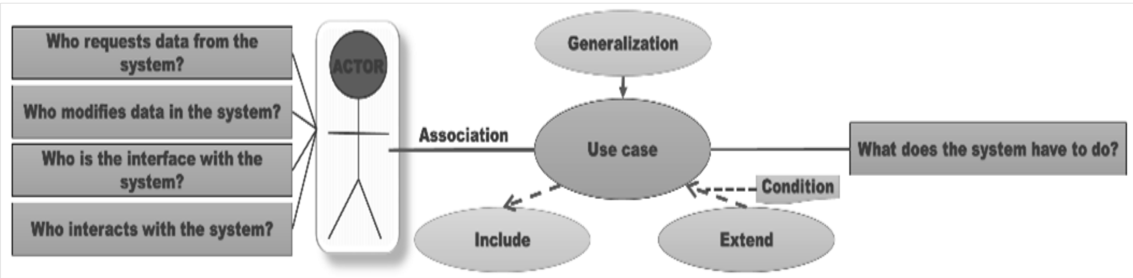



**Figure 4.** The main elements for building the use case diagram.

To successfully implement the software application, six primary actors were identified. Thus, *Patient* can use the smartphone device to create a user account (pre-verified by a healthcare specialist) to authenticate. They can schedule an appointment for a consultation or investigation with one of the medical service providers, and they can also check the medical history stored in the electronic medical record. They also benefit from medical services, according to their status in the medical system. Patients who have devices that measure fitness parameters send reports to the doctor who has them under observation. They can send feedback and read reviews given by other patients relating to the medical services offered by the medical units. The *Receptionist* manages appointments and checks insurance status. The *Medical Staff* offers consultations, analyses, investigations, or other medical procedures. Formulates diagnoses and prescriptions. Offers medical services according to working hours. The *Pharmacist* dispenses medicines according to the medical prescription with compensated payment or with full payment. The *HR/Financial* manages the schedule of doctors and the smooth running of the economic-financial situation. The *Administrator* of each medical unit and the one at the centralized level, manage the smooth running of the sanitary unit flows, respectively the real-time overview verification of the entire software application. Figure 5 shows the main requirements and the actors involved.

Sanitary units, focusing on public institutions, must have computerized records regarding medical services designed in a well-organized and efficient manner. This facilitates the management of medical documents. This approach allows the circulation of medical documents between medical units and patients in real-time. The flow of documents between the issuer of the medical document and the beneficiary – the patient – must be managed in a computerized, standardized, and unified way for all units to maximize work capacities.

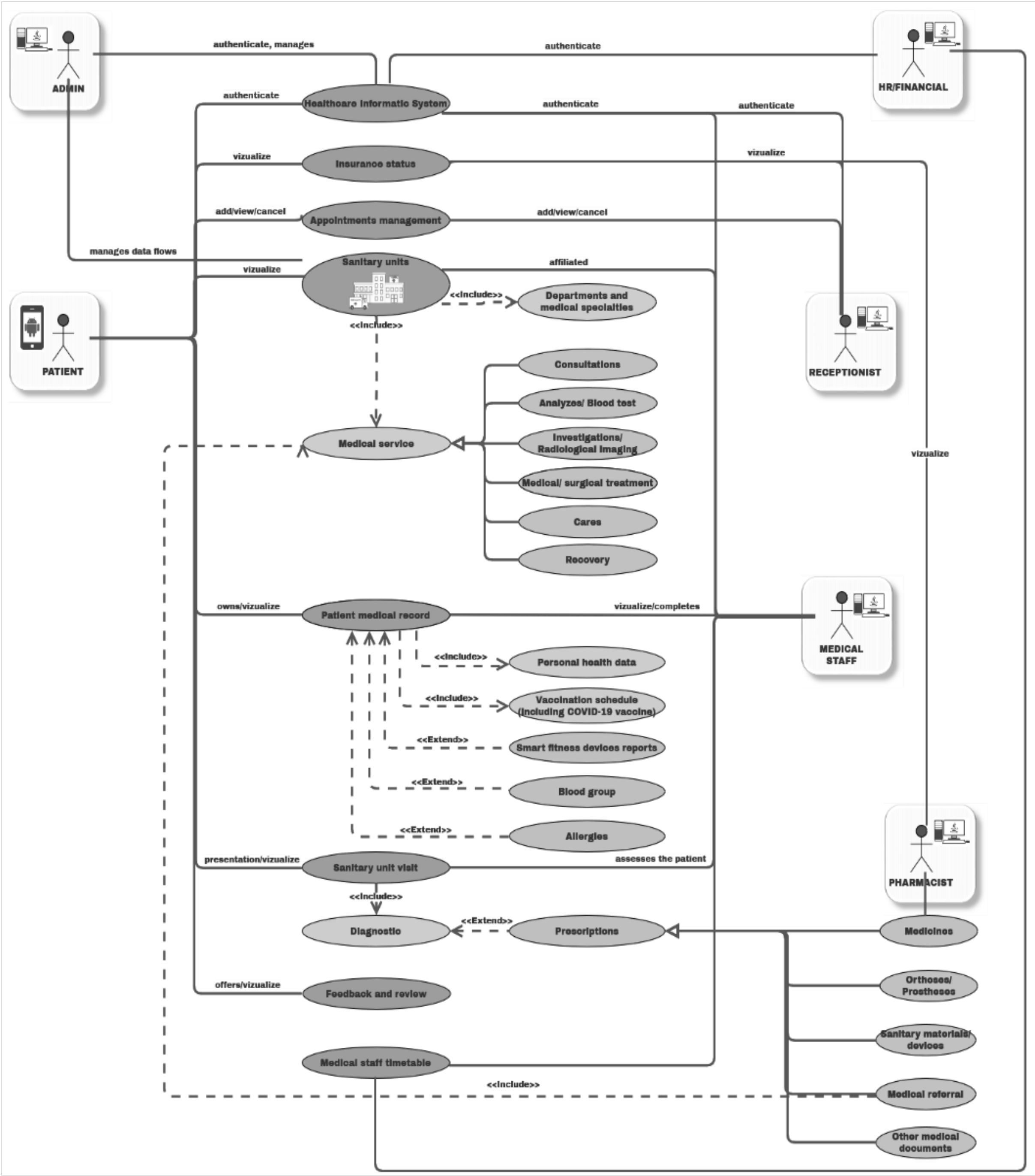



**Figure 5.** The software application - General UML diagram.

A well-structured scheduling management system can eliminate overlaps in the ambulatory consultation program, provide real-time updates on the number of beds available for hospitalization, list the services offered within each clinical specialty, monitor fund settlements, and display the number of investigations that can be supported with allocated funds.

## COMPUTERIZED FLOW

The proposed software application offers an integrated approach that considers not only the perspectives of medical units and doctors but also those of patients. They remain interconnected to the medical information application through a centralized desktop and mobile platform. In the backend, the Java API is the gateway to the main data flows. The developed API is based on REST, and has predictable and intuitive URLs organized around the resources.

Built-in HTTP functions are used to issue requests (HTTP methods). All API endpoints return content in JSON format with the HTTP header "Content-Type: application/json" encoded using the UTF-8 character set. In the case of the REST architecture, the client invokes the web service by sending a GET/POST/ PUT/DELETE request. A response is returned after the request is processed. This architecture enables the exchange of information between the two frontends, which serve as interfaces with users. Data storage is achieved using an Oracle database with multimedia capabilities, which provides persistent, secure storage and allows regular data back-ups and recovery. The ML and DL algorithms integrated in the backend provide personalized recommendations based on the integrated data. These recommendations are continuously enriched with data from newly consulted patients. This provides a proactive approach for diagnosing patients. The mobile application uses a local SQLite database in the backend to manage the data retrieved from the fitness SDK. These data are refined locally and sent to the application in the form of summary reports. Communication between medical specialists, as well as between patients and doctors, is conducted through a Firebase chat server. Firebase Realtime Database services are used to store and retrieve messages. Firebase Cloud Messaging is used to notify users when new messages are received. Figure 6 shows the workflow within the information solution:

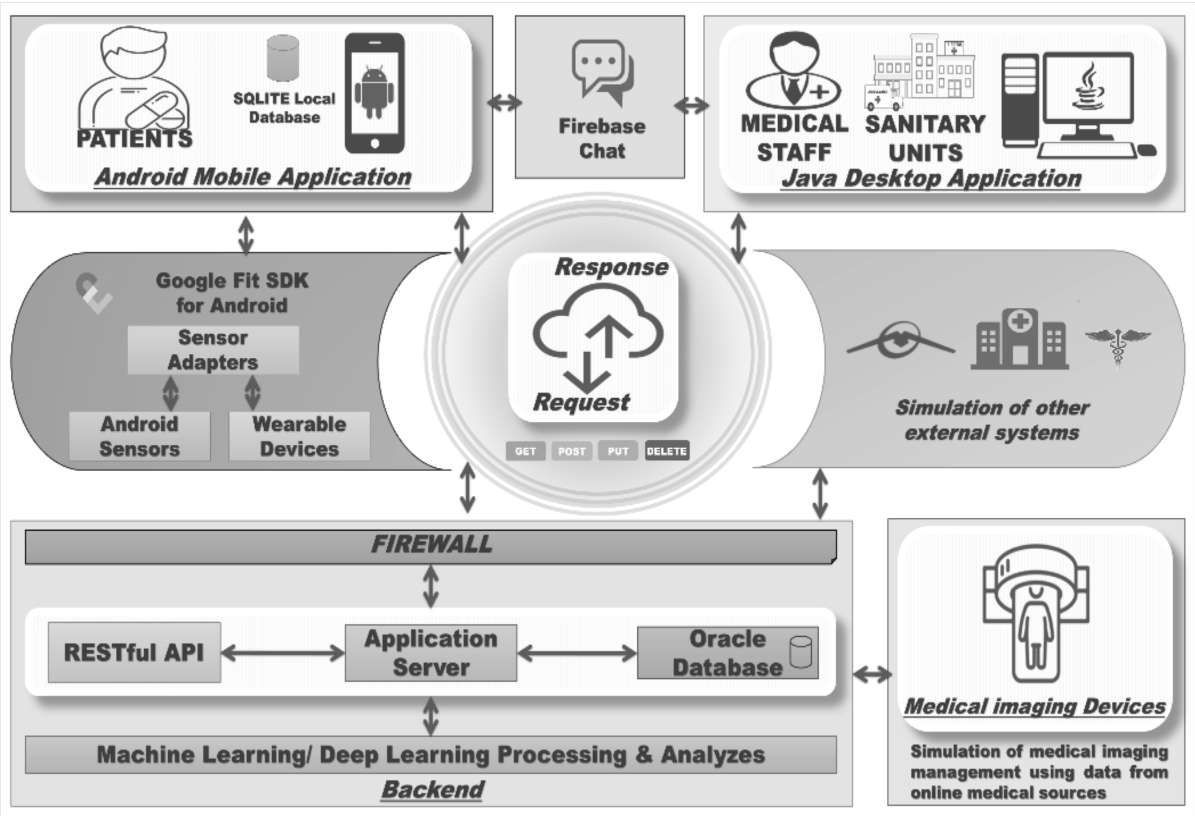



**Figure 6.** Application flow diagram.

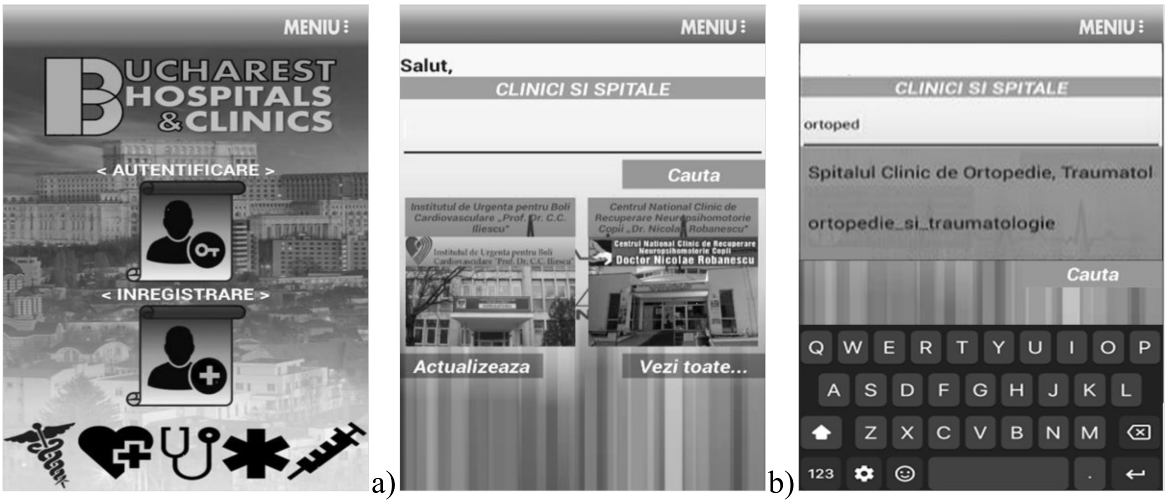
## RESULTS AND DISCUSSION

### THE TECHNICAL DEVELOPMENT OF THE PROPOSED APPLICATION

The mobile version was implemented using the Android Studio Integrated Development Environment (IDE), API version 33, which is optimized for smartphones and tablets. By studying the situation at the updated level of active devices, it was found that Android 13 is a suitable version for a very varied range of devices. It has a coverage of approximately 30,37% of active devices in Romania during the period January-October 2023 [34]. Android Studio is a flexible development environment that allows the use of emulators with various device configurations to test the behavior of the application in various scenarios.

The mobile version of the application was designed using "RelativeLayout" activities containing "ScrollView" containers to ensure visibility on various smartphone display sizes. For the same purpose, scaled and optimized backgrounds were used. Buttons have been designed to simplify the interaction between activities; also, fields limit inputs to prevent erroneous data from being entered. The existence of a network connection is verified when requests, queries, and synchronization that require an active connection are made. The local SQLite database manages the data, processes it, and then transmits simplified reports to the centralized solution to avoid overwhelming it with excessive data.

The resulting test application is fully functional and meets the initial proposed requirements. In the first activity, the patient logs in with existing credentials or creates an account as shown in Figure 7a. Creating a new user involves validating the account in the medical interface to confirm the user's identity. The patient is welcomed by the start interface, which provides a list of medical units that can be filtered by specialty or institution name, as shown in Figure 7b. Filtering enables users to quickly locate the desired medical unit, with the recommended results appearing as they type, as shown in Figure 7c. Patients can view a filtered list of hospitals that adhere to the specified restriction – hospital name/specialty.




a) b) c)

**Figure 7.** Mobile application interfaces: a) login activity, b) list of Bucharest medical units, c) cearch for a medical unit/ specialty.

By selecting the agreed hospital, its full name, direct phone call buttons, sending email, the map with the location of the hospital, the website, as well as other detailed contact data are displayed. On the same interface, the available specialties are presented and can be navigated with a scroll; a general score on the quality of medical assistance offered by each sanitary unit is presented. Selecting one medical specialty leads to a new activity that presents medical services, medical specialists, and the intervals in which they offer consultations. From here, the interval and service that the patient wants to benefit from can be selected. Appointments can be made either for in-person or remote consultations. Making an appointment is completed by exporting to the phone's Calendar the day and time slot in which the patient will receive the medical consultation. The mobile application exposes patient medical history records, general and seasonal vaccination calendars, medical records from devices connected via the native SDK or Google Fit, blood groups, allergies, and stored medical documents, such as medical imaging and prescriptions.

The authorization flow for accessing Google Fit data is realized by requesting multiple Android permissions. The connection is made through OAuth with Google credentials. Being a test application, and used for medical care purposes, it falls within the use cases provided by Google Fit. The obtained data are in the form of DataSet objects containing data points with timestamps and the fitness values, such as Steps, Heart Rate BPM, Blood Pressure Systolic/Diastolic, Oxygen Saturation, etc. Aggregate level data are requested, for example minimum, maximum, or average values over a time interval for Heart Rate. Queries are performed periodically and are stored in the local Android SQLite database. Aggregated reports are periodically sent to the centralized application.

The data transmitted by the devices undergo ML analysis, offering alerts to potential health problems by comparing them with trained data obtained from patients with certain pathologies. For example, during the COVID-19 pandemic, the integration of Heart Rate data in the determination of possible infection with coronavirus was explored [17]. However, these analyses also extend to the early detection of other pathologies, within the limits of the accuracy of the devices with the help of which the measurements are made and the conditions in which measurements are taken.

Similar to the Android version, intuitive interfaces were implemented for the Desktop application intended for medical staff. These interfaces were implemented with Java FX elements, using various types of containers and controls. The first graphical interface is the Authentication Form, shown in Figure 8a, which ensures a secure connection to the solution. The main page follows after login with a customized menu specific for the navigation of each type of user - Receptionist, Medical Staff, Pharmacist, HR/Financial, and Administrator; the receptionist interface is shown in Figure 8b.

a) b)

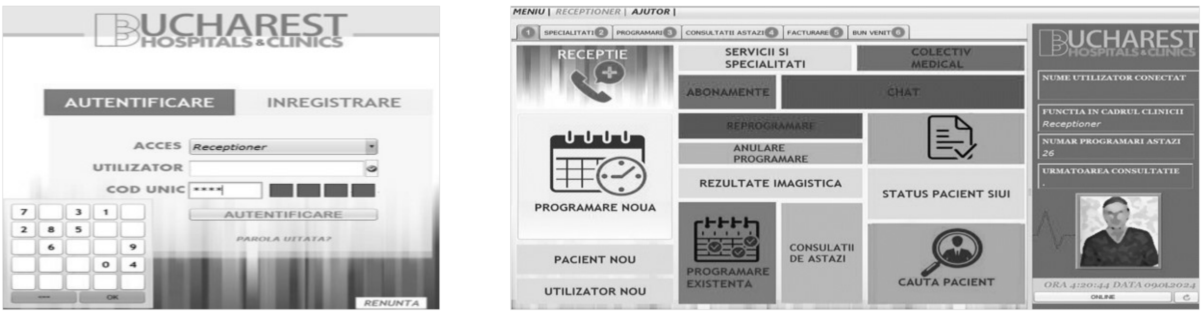



**Figure 8.** Desktop application interfaces: a) login form, b) principal menu for receptionist user-type.

All consultations are documented and stored in the patient's medical record to provide medical staff comprehensive medical information for accurate diagnoses, presented in Figure 9a. Authorized medical professionals may access these records. The doctor selects the patient from the list and opens the consultation form, which is customized for different medical operations such as consultation, investigation, collection of samples for medical analysis, etc. Detailing a patient leads to the display of a form with complete personal data, assurance status, and vital medical data such as blood group, RH and major health problems. To complete medical documents, such as the prescription – list of medicines and diagnoses are loaded in the application, being provided fields to facilitate completion of these documents. In addition, the interpretation of medical analysis contains specific application fields, for bringing to light the results outside normal ranges.A medical investigation contains specific fields such as interpretation of results, used substances, etc; the form for investigations is shown in Figure 9b. The administration of medical imaging is efficiently managed through a specialized interface, enabling integration with DICOM imaging or other formats, as shown in Figure 9c.

The medical data recorded are also stored separately and in an anonymized manner. This includes the patient's symptoms, diagnosis, and imaging results labeled with the related diagnoses. ML and DL analysis are used to offer diagnoses to other patients with similar pathologies, based on previous experience and available medical data. For testing, various datasets from online medical sources, including DICOM standard medical imagining, were loaded into the application, running multiple algorithms. Oracle automatically provides functions to anonymize OrdDicom files so that they can be safely used for research purposes [35].

a) b) c)


**Figure 9.** Desktop application interfaces: a) patient record, b) investigation, c) medical imaging.

The medical staff selects the relevant symptoms of the patient from a predetermined list. These symptoms, along with other clinical and personal data (age, weight, height), are input into an ML framework. Algorithms analyze this information to identify patterns and correlations with various medical conditions. An ML classification model from the Weka library is integrated into the application. This model was trained with a data set obtained from an online repository and helps to classify new data, represented by the symptoms of the new consulted patient and predict belonging to a certain class, represented by the potential diagnosis. This framing is done according to the input characteristics and the relationships learned from the training data. The evaluation of the models is carried out by applying standard performance metrics by testing on samples from the initial dataset. The training data set is a general one, addressed to family medicine, and for other medical specialties will require training with specific data or models. This process helps in the assessment and treatment planning; these potential diagnoses serve as guidance for the medical staff, who make the final diagnosis, considering any additional clinical factors. In the end, the data resulting from the consultation becomes a training source for establishing ML models.

The classification procedure is performed similarly for medical analyses and for the data obtained from wearable devices, using specific datasets for model training. These are represented, for medical analyses, by measurements of parameters for usual analyses such as glucose, cholesterol, triglycerides, hemoglobin, etc., and for wearable devices and fitness data, by heart rate, oxygen saturation, number of steps, etc. Classification algorithms are trained on these datasets to identify patterns and correlations, respectively, warning signals that can lead to early diagnosis. The DICOM images, obtained from radiographs from an online repository regarding a specific pathology, were converted into a format supported by the Weka – WekaDeeplearning4j extension, namely JPEG. Thus, the video-imaging to be analyzed goes through pre-processing (scaling, resizing, and normalization) to ensure the consistency and quality of the data. The training model is built using DL algorithms, more precisely neural networks suitable for image analysis, checking the performance evaluation metrics on test samples. This process of creating the model is used to analyze and interpret images obtained from new patients who present for consultation; in the test environment, simulations were made on data from online sources.

The database was built following the structure from the point of view of the entities, designing 40 tables with related relationships. The database uses the Oracle 12c Database Management System. Specific procedures for interacting with multimedia elements such as OrdImage, OrdVideo, and OrdDicom, from the OrdSys library, have been defined. Thus, the database facilitates the inclusion of medical imaging in the constitution of patients' medical files [35].

In Table 2, the main functionalities implemented at the desktop and mobile application level are detailed, together with the technologies used, the method of implementation in the backend, and the integrated models.

The Android mobile application integrates Java Files, which implements the backend part of the main functionalities of the application, and contains main source code. This manages the responses generated following API requests, deserializing and transforming JSON data into Java objects, making them available at the mobile application level. In addition to this type of file, other dependencies are added. The permission part, and the API used (version 33) are contained in the *Android Manifest*. In this, permissions were defined for "INTERNET" allowing the application to open network sockets [36]. "CALL_PHONE" access was defined to allow the application to use the phone to make calls, useful for direct calls to medical units. "WIFI_STATE" and "NETWORK_STATE" were defined for access to the state of the WI-FI and mobile data networks. When the connection to the Internet is lost, the user is notified because requests require an active connection. "BODY_SENSORS" was defined for access to fitness data measured by the mobile device, "ACTIVITY_RECOGNITION" was defined for recognizing the types of physical activities, "ACCESS_FINE_LOCATION" was defined for recognizing the distance and speed of physical activities, and for locating the patient's position relative to the medical units. "WRITE_CALENDAR" was defined to save the appointment in the patient's calendar. The other dependencies store the resources and the graphic part of the application (Res), such as figures/shapes/colors and icons (drawble and mipmap), the optimized screen format for both smartphone and tablet, and for portrait and landscape orientation (layout), the personalized menu for patients (menu) and constants utilized at the application level (values), and ensures that all elements needed by the project are available and that all dependencies and plugins are assembled (Gradle Script).

**Table 2.** Details of the functionalities and models integrated into the application setup (continued on pp.540-542).

| **Main Functionalities** | **implemented in the version:** | | **Technologies** | | **Integrated Models** |
|---|---|---|---|---|---|
| | **Desktop (Medical staff)** | **Mobile (Patient)** | **Desktop interface** | **Mobile interface** | |
| **Authentification** | | | | | |
| Login of medical staff with specific credentials to access the application. | Authentication using credentials. | – | JavaFX for the login GUI. | - Java and multiple dependencies for Android mobile version<br>- login interface. | - Strong password patterns and password encryption; use of hashing techniques to protect against cyber-attacks;<br>- Use of JSON Web Tokens (JWT) for authentication; the server generates a digitally signed token, which contains information about the user and permissions, then are included in the requests to the server. |
| Login of patients with credentials to access the application. | – | Authentication using credentials. (When the account is created, the approval is done by a medical staff user). | | | |

**Table 3.** Details of the functionalities and models integrated into the application setup (continuation from p.539, continued on pp.541-542).

<table>
<tr><td colspan="6">Patient Medical Records</td></tr>
<tr><td>Management of patients' personal data.</td><td>Inserting / viewing/ modifying/ deleting patient data depending on the access level of the medical staff.</td><td>- Inserting / viewing/ modifying personal data.</td><td rowspan="3">- JavaFX for intuitive and easy-to-use GUI (Interactive graphic interfaces are presented through which medical personnel interact with medical data, imaging results and other medical investigations of patients).</td><td rowspan="3">- Java and multiple dependencies for Android application development;<br>- SQLite for patient-level persistent data storage<br>- centralized reporting;<br>- Google Fitness SDK for integrating and monitoring fitness data.</td><td rowspan="5">- Intuitive and user-friendly graphical interface;<br>- Sensitive data security model;<br>- Medical history management;<br>- Notification for appointments;<br>- Fitness data monitoring.</td></tr>
<tr><td>Management of personal and medical documents regarding the patient.</td><td>- Uploading internal documents;<br>- Viewing/ modifying/ deleting/ existing documents depending on the access level.</td><td>Uploading personal external documents (For example, medical results from other medical institutions, proof of insurance, etc.)</td></tr>
<tr><td rowspan="2">- Management of medical records, including vaccination schedule, blood group, allergies, etc.</td><td rowspan="2">- Uploading/ viewing the medical situation of patients depending on the access level.</td><td rowspan="2">- Viewing personal medical history.</td></tr>
<tr><td colspan="2" rowspan="2">- Oracle 12C for centralized data storage;<br>- Oracle Multimedia extension for mulitmedia file management (medical Images / Video/ Dicom);<br>- API requests of the following type are made:<br>POST/records<br>GET/records/{patient_id}<br>PUT/records/{patient_id}<br>DELETE/records/{patient_id}</td></tr>
<tr><td>- Management of fitness information from wearable smart devices.</td><td>- Viewing summary reports on parameters from semi-medical devices.</td><td>- Synchronization of data from wearable devices.</td></tr>
<tr><td colspan="6">Centralized Medical Units and the Medical Program</td></tr>
<tr><td>-Management/ interactive visualization of medical units.</td><td>- Updating and managing data related to medical units, departments, specializations, medical services, and medical schedules.</td><td>- Interactive visualization of medical units (including positioning on GIS maps), specializations and medical programs.</td><td rowspan="2">- JavaFX for intuitive and easy-to-use GUI.</td><td rowspan="2">- Java and multiple dependencies for Android application development;<br>- Google Maps SDK for displaying medical facilities on the map.</td><td rowspan="2">- Interactive interface for managing and viewing medical units;<br>- Effective search and filtering of medical units according to the name of the unit or specialization;<br>- GIS system integration for locating medical facilities;</td></tr>
<tr><td>- Searching and filtering medical facilities by specific criteria.</td><td>-</td><td>- Selection of the option depending on the specifics of the pathology and availability</td></tr>
</table>

**Table 4.** Details of the functionalities and models integrated into the application setup (continuation from pp.539-540, continued on p.542).

| | | | | | |
|---|---|---|---|---|---|
| | - | in the medical schedule. | - Oracle 12C for centralized data storage;<br>- API requests of the following type are made:<br>*POST/medical_units*<br>*GET/ medical_units/{unit_id}*<br>*PUT/ medical_units/{unit_id}*<br>*DELETE/medical_units/{unit_id}* | | - Optimized management of the medical schedule. |
| - Defining the medical staff schedule for providing medical services. | - Updating and managing the schedule for consultations, laboratory analyses, radiological investigations, medical interventions, recovery programs, etc. | - | | | |
| **Medical Appointments and Consultations** | | | | | |
| - Centralized manage-ment of appointments and consultations. | - Inserting/ viewing/ updating/ deleting appointments. | - Request to change an appointment. | - JavaFX for intuitive and easy-to-use GUI. | - Java and multiple dependen-cies for Android application develop-ment. | - Scheduling and consultation management;<br>- Synchronization, optimization, and real-time updating of schedules between applications;<br>- Notifications to confirm and remind appointments. |
| - Appointment confirmation and reminder notification. | - Viewing notifications regarding new patient appointments. | - Viewing notifications about personal appointments. | | | |
| - Patient examination according to the schedule. | - Opening the consultation and offering a diagnosis, and providing prescriptions, treatments, etc. | - | - Synchronization and real-time updating of schedules between the desktop and mobile application;<br>- Oracle 12C for centralized data storage;<br>- API requests of the following type are made:<br>*POST/appointments*<br>*GET/appointments?date=YYYY-MM-DD&patient = {patient_id}&unit={unitid}*<br>*PUT/appointments/{appt_id} DELETE/appointments/ {appt_id}* | | |
| **Medical Data Analytics** | | | | | |
| - Diagnosis based on the patient's symptoms or medical analysis results and suggestions provided by pre-trained models. | - Visualization of potential diagnostics based on suggestions offered by the application. | - | - JavaFX for intuitive and easy-to-use GUI- -integrating suggestive graphic represen-tations to figure the results from the most common sensors integrated in Google Fit | - Java and multiple dependencies for Android application development.<br>- Google Fitness SDK for integrating and monitoring fitness data; | - Medical data analysis and diagnosis;<br>- Medical reports and recommendations generation;<br>- Remote physical activity and health monitoring;<br>- Sharing health data with the family physician. |
| - Diagnosis based on medical imaging and suggestions | | - | | | |
| | | | | | |

**Table 5.** Details of the functionalities and models integrated into the application setup (continuation from pp.539-541).

| | | | | | |
|---|---|---|---|---|---|
| **Medical Data Analytics** | | | | | |
| offered by pre-trained models. | offered by the application. | | synchronizable mobile devices. | - SQLite for patient-level persistent data storage-centralized reporting. | |
| - Diagnosis based on data from patient wearable devices. | - Visualization of potential alarm signals in patients' fitness scores based on suggestions provided by the application. | - Loading data from devices connected to Google Fit and synchronized with the application. | - Oracle 12C for centralized data storage;<br>- In the backend, machine learning and deep learning algorithms are implemented for modeling models to facilitate medical predictions and specific libraries for processing and analyzing medical images. | | |
| **Remote discussions between patients and medical staff** | | | | | |
| - Real-time communication between patients and medical staff. | - Synchronous communication with patients through chat. | - Synchronous communication with the medical staff through chat. | - JavaFX for intuitive and easy-to-use GUI. | - Java and multiple dependencies for Android application development. | - Real-time communication between patients and medical staff;<br>- Real-time communication between medical staff. |
| - Real-time communication between medical staff. | - Synchronous communication with other doctors through chat. | - | - Firebase for real-time chat management and notifications. | | |
| **Patient Feedback and Medical Units Review** | | | | | |
| - Providing feedback on medical services. | - | - Giving feedback regarding: professionalism of the medical team, well-being generated as a result of the treatments received, and the facilities within medical unit. | - JavaFX for intuitive and easy-to-use GUI. | - Java and multiple dependencies for Android application development. | - Collecting and managing feedback effectively;<br>-Feedback analysis and reporting. |
| - Collecting and managing feedback effectively. | - Analyzing and reporting feedback to improve medical services. | - Viewing reviews provided by other patients. | - Oracle 12C for centralized data storage. | | |

## THE CONTRIBUTIONS OF THE DEVELOPED SOFTWARE APPLICATION

The informatic solution simulates the functionalities from the point of view of medical specialists and patients to observe what facilities can be made available at the city level. From the perspective of *medical staff* and *sanitary units*, implementing a solution such as the proposed one can create a centralized solution at the city level. Thus, it will be possible to track the availability of appointments for both outpatient consultations and hospitalizations at any time. This will enable the definition of medical services available to patients within medical specialties, the distribution of doctors by specialty and services, and the list of investigations and laboratory analyses available in the medical unit. Every doctor with access to the Desktop version of the computer software, authenticated with a specific account, will be able to interact with patients requesting medical services. They will also be able to asynchronously interact with patients who are not physically present in the office by viewing reports generated based on information provided voluntarily. These data can be either received from mobile devices carried by them, or uploaded manually to the platform. These can be the results of medical tests, or various fitness parameters that can be easily measured at home, such as blood pressure, heart rate, blood glucose level, weight etc. Devices synced through Google Fit or other native SDKs on a smartphone can be connected to the application to transfer data automatically, either smart medical devices or semi-medical wearable gadgets. This minimal information can help with the prevention side, being able to early signal the appearance of some health problems.

During consultations and investigations, medical personnel will be able to provide diagnoses based on the available patient's complete medical history, and will be updated with the results of the new consultations. Medical analysis data and output from medical imaging equipment, such as images, video sequences, and DICOM imaging, will also be incorporated into patient records. These data are stored in an Oracle 12c database with multimedia capabilities. The database is natively compatible with the DICOM imaging standard and allows metadata for images and videos. Interaction with the application guarantees the security of the data exposed through REST requests. Anamnesis, symptoms, and diagnosis data are also stored separately and anonymously to become part of the learning component. This enables the automatic generation of presumptive diagnoses through ML (for text-based and numeric analysis) and DL (for imaging analysis) algorithms to assist with the final diagnosis that is formulated by medical specialists.Within the application, a chat server is also being developed for the collaboration of the medical team to address professional issues. This is accessible at the local level of each medical unit and also allows connecting with doctors from other units, which can facilitate interaction between specialists.

From the *patient's* perspective, the software application provides access at any time to the list of all enrolled medical units  and exposed through the REST service. Therefore, a patient can use a smartphone device with the Android OS app to access a variety of information, including positioning of medical units via Google Maps SDK and contact information for those. Application exposing clinical specialties and medical services provided by specialists, family physicians, dentists, assistants, etc. The application includes data on ambulatory care, hospitalization, interventions, specialized investigations, and laboratories. Once a user's credentials have been created and approved within the application, they may then schedule one of the medical services offered by the desired medical unit. Patients can read reviews from other patients regarding various aspects in the review section of the medical assistance units. This includes appreciation of the professionalism of the medical team, the well-being generated as a result of the treatments received, the facilities within the medical unit, and the general impression. They will also be able to provide feedback on these aspects after receiving the medical service. The medical record will be updated after each medical service received, so the patient will have a history of all the medical information and documents. They will be able to present historical data to other doctors, even those from the private health system.

From the perspective of the management of medical institutions and the HR&Financial staff the application will be able to centralize economic information regarding multiple aspects. These include evidence of medical documents granted by the medical and auxiliary staff and the number of hours worked for salary calculation. They will be able to define the schedule of each doctor separately, considering vacations, the number of overtime hours, etc. They will also be able to generate reports on the billing and settlement of medical services.

With each technological solution implemented in the healthcare system, the city becomes more interconnected with the needs and concerns of its citizens. The developed solution clearly brings significant improvements in patient experience, explicitly targeting the satisfaction of patients' needs. By integrating the analysis of data from the sensors of wearable devices, substantiating diagnosis based on ML and DL analysis, facilitating scheduling by listing the availability of the entire network of medical facilities in the city, as well as exposing the feedback provided by patients (which helps both medical facilities to implement improvements where deficiencies are identified, and for citizens to make informed choices about the doctor who meets their needs), the city becomes a smarter place and more responsive to its public health demands. By promoting a citizen-centric approach and using technology to improve the quality of life, cities can confidently aspire to the status of smart cities that focus on increasing well-being and health.

## CONCLUSIONS

From a global perspective, medical systems are becoming increasingly clear as complex systems, involved in an intricate network of interdependencies. To better understand this complexity, the flows from the Municipality of Bucharest, were taken as a case study. Here, there are advanced IT implementations that manage the interaction for various operations between medical service providers and patients. However, there is a constant need to identify solutions to maximize its potential and enhance its accessibility and functionality in the support of the citizens. The integration of e-healthcare technologies, wearable medical monitoring devices, centralized scheduling facilitation, the widespread use and management of personal health data recording, and the use of ML and DL technologies for the automatic processing and analysis of medical data is an important approach for the development of smarter and more resilient communities. A solution like this can also adapt to the specific needs identified during the COVID-19 pandemic.

The proposed application offers medical professionals a streamlined method of accessing comprehensive patient data, thereby aiding the diagnostic process. Facilitates an interdisciplinary medical approach based on historical data from patients' electronic files. In addition, the integration of reports sent by the patients – the transmission of medical values through the mobile application voluntarily, either from the sensors or voluntarily distributed – can offer a preventive and monitoring character, providing a more personalized medical care. Although wearable devices serve especially for informative purposes, the extracted data can be interpreted by the attending physician, creating a more accurate picture of the patient's state of health. The focus of the application is centered on the patient, being oriented to current needs, and can be adapted for scaling to real-world requirements in the context of a smart city. Being a patient-oriented solution, the aim is to simplify the process of finding a medical service provider at the centralized level of the city using the mobile application. These can be scheduled as quickly as possible for consultations, facilitating as well the management of medical documents.

The interfaces, both in the mobile and desktop versions, are simple, and ergonomic, displaying in the foreground only the information necessary for a specific operation. The solution allows users to save time and pay more attention to medical care. Quick data management is facilitated by key-combination shortcuts, logically structured menu bars, and specific work interfaces for each type of user. The software application faces limitations in the case of macro-level implementation. The most important factor being represented by the need for additional levels of data security, being susceptible to cyber-attacks. Another important limitation derives from the values obtained from mobile device sensors. Currently, there is no standardization of wearable devices, with most manufacturers indicating that the measurements taken are for information purposes. The data collected from them requires some filters to reduce anomalies and outliers, which can be generated, including by the incorrect use of wearables; in many cases, the measurements are not performed under optimal conditions. In further studies, approaches to minimize these factors will be explored. However, not all citizens have smart mobile devices and technical knowledge, or agree with the adoption of such technologies. A thorough analysis is necessary to assess the feasibility of implementing such softwares.

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