Designing an Intelligent Platform for Drugs Administration

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ABSTRACT

Health is essential and can be ensured only with proper nutrition, sports, and regular visits to the physician. The correct administration of drugs has an important role in the process of healing and cannot be treated superficially. Most often, people do not read the instructions from the leaflets because these are difficult to understand or contain too much information. This paper is centered on showcasing the user interface of an intelligent platform that combines patients' clinical health data with information from drug leaflets in order to facilitate the administration of drug manufactured in Romania. First, clinical health data is extracted from wearable IoT devices and aggregated to create the patient's profile. Second, the platform aggregates leaflets from various online sources and full-text search functionalities are obtained using Elasticsearch combined with a knowledge base. Third, patients are capable to undergo extensive search through the drug database, create their own calendar, receive reminders or alerts when certain drugs contain interacting substances. The platform's goal is to increase the patients' awareness over their health data and improve their lifestyle. This is the first application of its kind available for Romanian language.

Author Keywords

User interface; Analysis of drugs' leaflets; clinical health data; full-text search; semantic search.

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION

Invariably, persons have periods when they need to undergo complex treatments involving multiple medications. When this happens, they usually are faced with several challenges. First, they need to analyze leaflets and extract relevant information, such as how to administer the drugs according to their characteristics e.g., weight, age, or side effects. Second, planning and memorizing the treatment scheme can be very complex. Third, problems and conflicts should be reported when considering personal contraindications with other medications, or with certain foods or beverages.

Our Intelligent Platform for Drug Administration (PIAM) aims to introduce a solution to these problems and to help people in Romania improve their lifestyle regarding drugs administration. First, we created a knowledge base which includes relevant information extracted from drug leaflets using Natural Language Processing (NLP) techniques. Information such as drug description, therapeutic indications, interactions with other drugs, side effects, dosage, conditions for storage, administration mode, etc., were extracted and organized to help personalize the drug administration experience, or to detect conflicts and contraindications for specific drugs. Second, we focused on creating a mobile application that together with a smartwatch, fitness bracelet, or other Internet of Things (IoT) devices can facilitate the administration process in two main directions, namely by: a) facilitating the drugs' input using the knowledge base and b) providing notifications on the mobile application when medication must be administered. For extracting the clinical health data, Apple HealthKit [1] and Google Fit [2] have been integrated, which abstract the connection to the physical IoT devices, and the measurements are persisted into the database of the platform for future analysis.

The paper is structured as follows. The second section presents some similar applications, while the third section introduces our method and the used corpus. The forth section describes the platform architecture and the mechanisms used for extracting and indexing data. Afterwards, the fifth section presents the user interface, followed by conclusions and future work.

STATE OF THE ART

Several health applications are available for the iOS and Android mobile operating systems. Their features range from generic to specialized, focusing on a few or even one type of disease.

WebMD is a website offering several applications, including Medscape [3] and the WebMD Mobile Application [4]. These offer generic features such as identifying pills using various attributes (size, pattern, shape), searching for nearby physicians or hospitals, or disease recommendation.

Glucosio [5, 6, 7] represents a popular application designed for patients suffering from diabetes, to help them keep tracking of their sugar, cholesterol, blood pressure and body weight. The application does not provide a mechanism of reading blood glucose from external devices, so these values need to be added manually. Other authors [8] have proposed a system for monitoring diabetic patient in smart hospitals.

Most specialized applications are part of packages including physical devices or wearables, in order to easily visualize their information on smartphones. As an example, the Omron Wellness App [9] enables its users to visualize their blood pressure and heart rate read from an Omron device via Bluetooth or USB.

METHOD

Our method starts with the creation of a knowledge base about drugs administered in Romania, which is used to create a mobile and web application designed to support people in the process of administering drugs.

The Intelligent Platform for Drug Administration PIAM has multiple features aimed to improve the user's drug administration experience. The functionalities presented above require several software components: First, a knowledge base is needed in order to store drugs related information and to make inferences regarding drugs interactions or symptom-disease relation. Second, a module interfacing with different wearable devices is required in order to collect data, bringing it to the same standard, and then serving it to the application. Eventually, our platform needs to integrate all this information and display it an intuitive, well-structured, and visually appealing interface.

Corpus

PIAM is based on approximately 6,000 leaflets in Romanian language which contain information about all drugs administered in Romania. We extracted the leaflets from The National Agency for Medicines and Medical Devices (NAMMD - https://www.anm.ro/en/) [10]. Different sources such as pharmacies (e.g., Helpnet – https://www.helpnet.ro/, Catena – https://www.catena.ro/prospecte) and national drugs producers (e.g., Biofarm – https://www.biofarm.ro/Portofoliu-produse-s27-ro.htm) were analyzed in order to obtain more information about drugs; however, the most complete data source was the National Agency for Medicines and Medical Devices (NAMMD), which included: drug descriptions – which contain also recommendations for administering, contraindications, ATC code (Manufacturer, Alimentary Tract and Metabolism), pregnancy and breastfeeding, therapeutic indications, interactions with other drugs, side effects, dosage, conditions for storage, and administration mode.

We used several ontologies developed by the members of the OBO Foundry (http://www.obofoundry.org), such as DINTO (The Drug-Drug Interactions Ontology) [11, 12] - https://bioportal.bioontology.org/ ontologies/DINTO, DOID (Human Disease Ontology) [13] [14] - https:// bioportal.bioontology.org/ontologies/DOID and SYMP (Symptom Ontology) [15] - https://bioportal. bioontology.org/ontologies/SYMP to gather additional information on drugs and to create a knowledge base. These ontologies facilitate more intelligent features such as: detecting whether two drugs may interfere, or predicting the disease based on a set of symptoms.

ARCHITECTURE

The PIAM architecture consists in several modules which communicate and depend each other in order to provide useful information about drugs to the users. Figure 1 presents all the modules that our platform has, as well as the dependencies between them. Elasticsearch (https://www.elastic.co/guide/index.html) stores the information about drugs from the NAMMD website. PIAM Backend represents the core of our application, it takes care of serving all the requests which are coming from the frontend, interrogates Elasticsearch and the knowledge base in order to provide complete information to users, and communicate with Authentication and Authorization Service in order to authenticate the users.

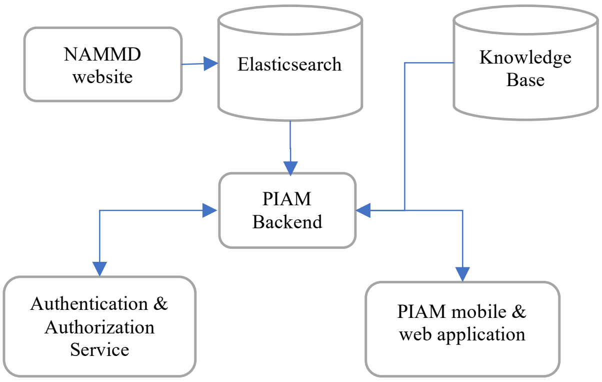


Figure 1. PIAM Architecture.

Data extraction and indexing mechanisms

Multiple Python scripts were developed in order to extract relevant information from the NAMMD website. First, all PDF files containing the leaflets were downloaded. Second, we extracted the text from each leaflet using a python script. Third, all the leaflets were split into semantically related sections (e.g., how to administer, contraindications, etc.) – for around 4,500 leaflets the split into section was done automatically, using pattern matching, while the remaining leaflets required human intervention. After all relevant information were extracted from each leaflet in a structured format, we used Elasticsearch to index the data.

After this first processing stage, every drug from the NAMMD website was connected via the name of its active substance(s) to one or several entities in the DINTO ontology, making it possible to make inferences in order to verify whether two drugs interact. Separately, the names of diseases and symptoms in the DOID and SYMP ontologies were translated into Romanian, and the two ontologies were integrated into the knowledge base, thus enabling users to search for a disease given a symptom.

USER INTERFACE

The Intelligent Drugs Administration Platform offers various functionalities to its users, namely: adding a new treatment regimen, searching for drugs, viewing heart rate, glucose, weight, medical history view, etc. In order to have the certainty that all these features are secure, the user must initially create an account or log in to the platform with an existing account. Unauthenticated users are not allowed to access the application.

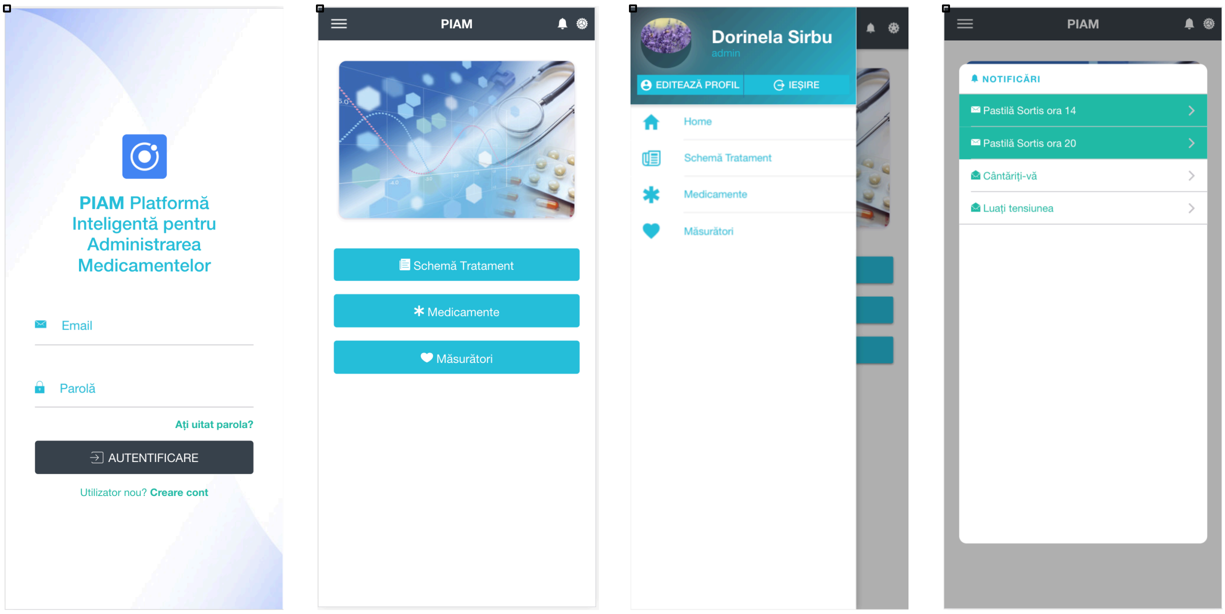
The platform is available for both mobile operating systems iOS and Android, and web. Thus, we used IONIC framework (https://ionicframework.com/) to build the application.

Navigating through the Application

Figure 2.a shows the login page of the platform where users can enter their email address and password to access the functionality of the application. All the screenshots are responsive and scalable for mobile devices, with the application being available for both mobile devices (Android, iOS), as well as the web.

Once a user logins, s/he can access the available features. Figure 2.b illustrates the home page of the platform. The page includes 3 buttons for accessing the main features: *Treatment Schedule*, *Medicines*, and *Measurements*. These features can also be accessed through the side navigation menu shown in Figure 2.c, accessible by pressing the upper left button in Figure 2.b.

By pressing the bell button located at the top right of the home page, a page with the recent user notifications is displayed, visible in Figure 2.d. The notifications are listed in descending order of their severity. Notifications provide various general information, while alerts appear when a serious deviation from treatment, or very divergent measurements from normal values were occurred.



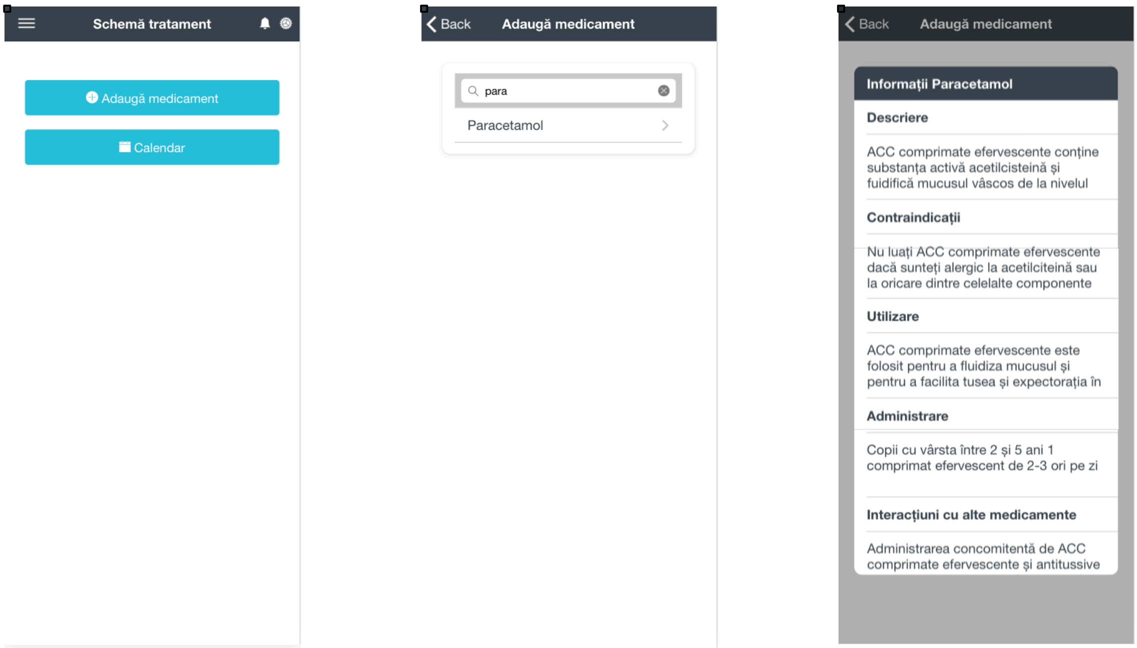
(a) (b) (c) (d)

Figure 2. (a) Login Page. (b) Home Page. (c) Side Navigation Menu. (d) User Notifications.

Drug Calendar

The Drug Calendar Module exposes the functionality through which users can add drugs to the calendar in order to have an overview of their treatment schedule. The system will also analyze the drugs to detect interferences between them. Figure 3.a shows the main menu of this module.

In order to add a new drug to the calendar, the user will first need to search for the drug in the database of the application by clicking on the "*Adaugă medicament (eng., Add Drug)*" button in Figure 3.a. By pressing this button, a new window opens through which the user will be able to search for the desired drug. This new window can be viewed in Figure 3.b and contains a drug search field by name that can restrict the results. If the newly added drug interferes with other medications from the treatment schedule, the user will be alerted. At the same time, users will be notified about other substances they are not allowed to consume during treatment with the new drug (e.g., alcohol, certain vegetables, or fruits). By pressing the name of the medicine, the user is redirected to a page that displays details of the selected drug (see Figure 3.c).

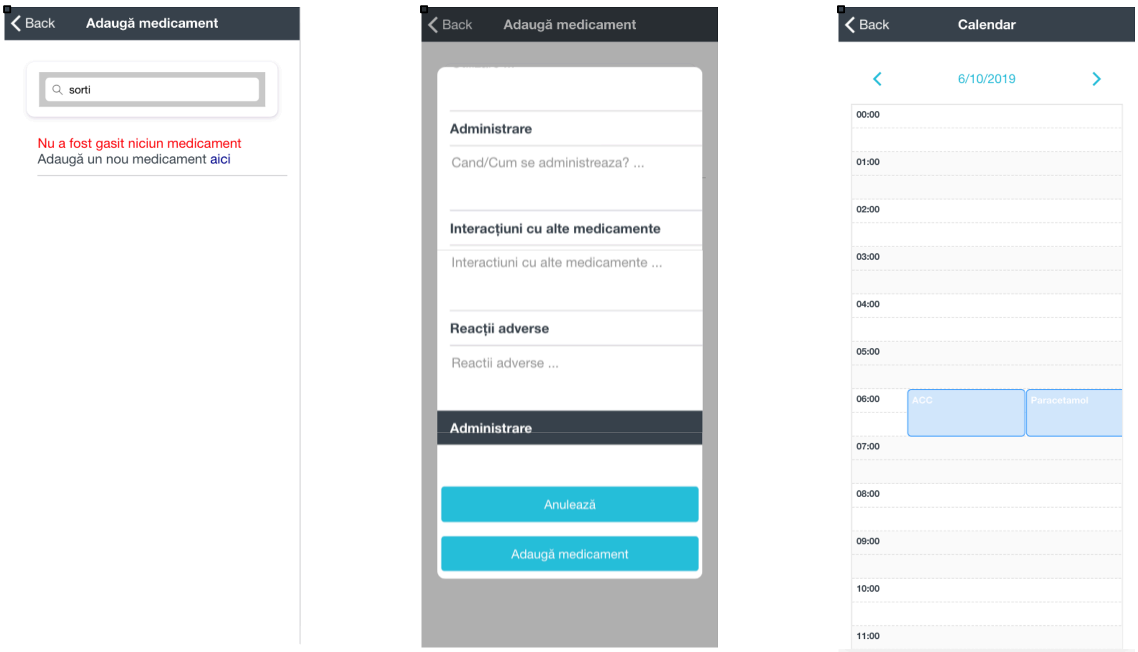


(a) (b) (c)

Figure 3. (a) Drug Calendar Module. (b) Drug Search. (c) Drug Details.

If the user enters the name of a drug that does not exist in the system, s/he can create the drug himself by pressing the button shown in Figure 4.a and add the details by filling in the inputs shown in Figure 4.b.

Once added, all the drugs can be viewed in the calendar by selecting the Calendar option in Figure 3.a. Figure 4.c shows the one-day calendar with the user's treatment scheme, offering the option to browse through the different calendar days. For each day, all events are presented chronologically.

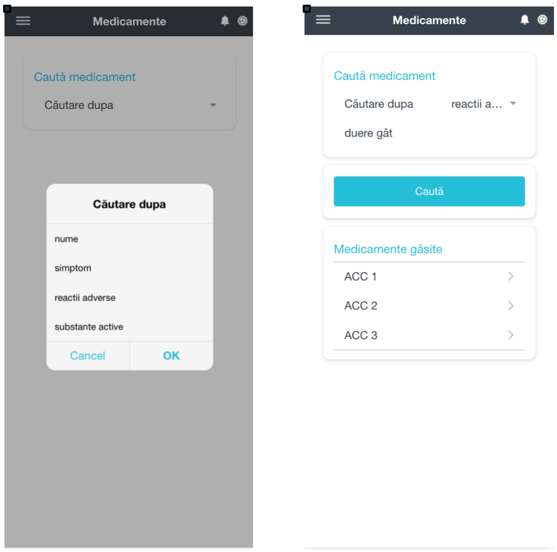


(a) (b) (c)

Figure 4. (a) Adding a New Drug. (b) New Drug Form. (c) Drug Calendar.

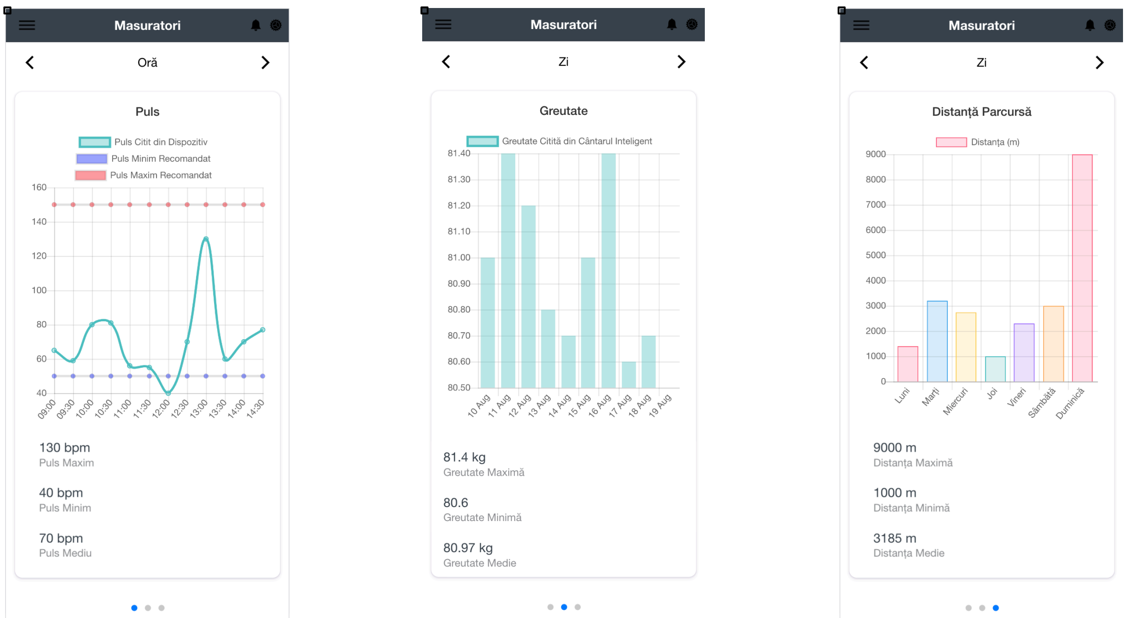
Advanced Drug Search

The advanced drug search module allows the user to search for drugs from the system using multiple search filters as seen in Figure 5.a. After adding the desired filters or combining multiple search criteria, entering the search text, and pressing the Search button, a list with all drugs matched to the criteria will be displayed, as shown in Figure 5.b. By clicking on a drug name, the application displays its corresponding details (see Figure 3.c).



(a) (b)

Figure 5. (a) Advanced Filters for Searching Drugs. (b). Search Results.



(a) (b) (c)

Figure 6. (a) Hourly Pulse Evolution. (b) Daily Weight Evolution. (c) Daily Walked Distance.

Viewing Clinical Health Data

Through this functionality, users have the opportunity to visualize their medical history. This module can be accessed by pressing the *Measurements* button from Figure 2.b or Figure 2.c. As shown in Figure 6.a, Figure 6.b and Figure 6.c, the measurements are displayed on different pages, so the user have to scroll horizontally. Measurements are displayed depending on which devices the user has entered into the system.

Figure 6.a shows a graph depicting the evolution of the user's pulse across hours. Besides the pulse evolution, three more values are displayed underneath the graph, which represent: the maximum pulse, the average pulse and the minimum pulse. Figure 6.b presents a graph showing the evolution of the user's weight across subsequent days. The chart shows below the maximum weight the user had, the minimum weight and the average weight. Figure 6.c is a graph in which users can observe the traveled distance in different days. The maximum distance traveled by the user, the average distance, and the minimum distance are depicted below the graph.

TESTING THE USER EXPERIENCE

In order to test the user experience with the application, a usability test was employed on an audience of 10 users with the ages between 28 and 55. Their first interaction with the application was during the test, when they were asked to finalize two tasks:

1) Create an account, add a drug in the calendar, and verify if it is successfully created;
2) Find three drugs that can be used for headache and track down how they can be administered by checking their leaflet.

All the ten users were able to undergo the first task successfully, but only eight of them finished the 2nd task with success. The latter two were not able to retrieve the method of administering the drugs, as the leaflet was cluttered with information.

The users' feedback was positive and, at the same time, it generated a list of useful features to include into the application:

- Add a leaflet summary for every drug with its most relevant information: method of administration and contraindications;
- Add the possibility to log in using a social account (Facebook/Instagram);
- Get rid of the page depicted in Figure 3.a; adding a drug can be done directly from the calendar screen shown in Figure 4.c, by adding a button in the page header;
- Create a new screen offering the possibility to select two or more drugs and analyze their compatibility (this is currently done only for the drugs added by the user in the calendar);
- Use the advanced search when adding drugs in the calendar - replace the screen from Figure 3.b with the one from Figure 5.a.

CONCLUSION

The correct administration of the drugs has an important role in people's life and has to be seriously treated. This paper presents an intelligent platform designed to support people in the administration of drugs. To our knowledge, this is the first application for Romanian language.

Our application makes the drugs administration process easier by offering several useful features. First, PIAM allows users to keep track of drugs and set reminders. Second, it helps users to aggregate data from multiple wearable devices so that they can have access to a clearer overview of their current health condition. Lastly, PIAM allows users to be more informed by offering easy access to drug-related details, as well as other types of medical information.

Nevertheless, we must emphasize that the application has not been designed to replace the doctor, but more as a support system targeting patients, for improving their day to day administration of drugs, and making them aware of the potential interferences between drugs. Moreover, the integration of personal clinical health data from wearables adds support for personalizing the recommendations and alerts.

Even though the initial feedback was positive, testing and acquiring more feedback remains one of the most important follows-up tasks. In order to achieve this, analytics frameworks need to be included in the application in order to detect user flows, time spent on individual screens and track individual errors that may occur.

ACKNOWLEDGMENTS

The work presented in this paper has been funded by the "Intelligent platform for drugs administration – PIAM", subsidiary contract no. 1267/22.01.2018, from the NETIO project ID: P_40_270, MySMIS Code: 105976.

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