The Consolidated Information Web-Resource about Pharmacy Networks in City

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Abstract. The main objective of this work was the development of the information system for support of pharmacy customers. This system provides information about required medicines and their analogues, medicine availability and prices. The main functions of the system and detailed workflow diagrams are described. The developed consolidated information resource allows to find the right medicine, sort pharmacies according to medicine location and price, give the necessary information about pharmacies and medicines, search for alternative medicines with the same chemical agent, view usage instructions for selected medications without internet connection.

Keywords. consolidated resource, Android, classification, clustering, content-analysis, geolocation, information search, ontology

CEUR-WS.org/Vol-2255/paper22.pdf

1 Introduction

Our free time is an incredibly valuable resource [1]. All our efforts to rationalize and optimize its usage, only lead to the more pronounced feeling of the time deficit [2]. Typically we allocate only a scant amount of time for such an important subject as caring for our health, so visiting a doctor for consultation or the prescription of medicine is often avoided and performed only in dire need [3].

According to statistics, only a third of pharmacy customers actually know what medicine they have come for. Among them approximately 10% heard about medicine from advertisement, for 40% it was prescribed by doctor, and the rest used recommendation of pharmacist or acquaintance [4]. Thus, an average customer of pharmacy needs information resources to support his decision for medicine purchase in a timely and objective manner, taking also in consideration customer location and his means.

People often need a medicine without prior planning, at need [5]. Often they cannot use the full version of pharmacy network website. Such websites typically don't provide the service of recommending purchase from other network or from pharmacy located near the customer [6]. Nowadays customers are accessing commercial services using smartphones more often than stationary computers [7]. The adaptation of web-application to mobile platform interface along with storing and analyzing information about prior searches simplifies the process of information consolidation taking in consideration the customer's needs [8]. This trend should be also followed by pharmaceutical market in our country, which is still based on antiquated solutions and needs innovations [9]. Our work aims to create a general architecture of intellectual system for customer support in Lviv pharmacy networks, which will allow to obtain the sufficient information about availability and purchase of medical medicines. This system will be able to provide such services:

1. Perform an extensive search for required medicine.
2. Produce the lists of pharmacies according to customer's location, price and comments of other customers.
3. Review the obtained information in convenient form.
4. Search for alternative prescriptions.
5. Obtain information about selected medicine.
6. Create recommendations according to customer's needs and history of his requests.

The sale of medicinal drugs by pharmacies is performed with doctor's prescriptions or without them. Medicines, which are sold without prescriptions or subsidies are sold using the rules developed for other retail goods [10].

However in average people are still not educated enough about health care and pharmaceutics [11]. The pharmacy networks have difficulties when introducing new medicines or replacing not efficient medicines [12-15]. This problem can be resolved by usage of the consolidated information resources which can provide the customer with the extensive information about pharmacies, their location and pricing, available medicines and discounts on them.

2 The current status and research perspectives

The activities of pharmaceutical networks reflect the general trends in the market of health protection services: providing information for medicinal medicines, controlling the medicine's quality and cost of services, catering to customer needs [13]. Pharmacists as a part of healthcare industry are involved in support of their customers. In some European countries, hospital based pharmacies control the safety, efficacy and profitability of medicine consumption within the hospital [14]. This started with creation of variety of therapeutic medicines usage committees co-opting different specialists with a purpose of development of the medicine consumption polices which reduces the costs while providing the acceptable level of safety and efficacy. The next step in many hospitals lead to creation of hospital reference books. Thanks to hospital based pharmacies the patient stay in hospital was reduced, medicinal medicines were used optimally and under control. Also possible errors in prescriptions were found.

The development of pharmaceutical services lead to creation of information services providing information about medicines [15]. They were initially created within hospitals, but were subsequently enlarged to municipal and national levels [16]. The providers of those services compile information into databases and collaborate with governmental and industrial organizations [17].

Ukrainian pharmaceutical market is continuing to grow [18]. According to 2017 year results, the amount of packed medicine consumption was restored to pre-war level [19]. The growth of market measured in dollars was 16,5% [20]. Lastly the number of pharmacies has stabilized [21]. The process of retail sector consolidation is continuing [22]. The leading pharmacies are pharmacies-discounters [23]. The number of such pharmacies will continue to grow [24]. However, it would be erroneous to think that only such pharmacies will remain in the market [25]. Among key factor influencing the market are the introduction of reimbursement system, medical reform, electronic prescriptions, licensing imported medicines and change of VAT rate for medicines [26]. The structure of medicine consumption will change [27]. It is predicted that part of medicines sold on prescriptions, generic medicines, medicines produced in Ukraine, and medicines supported by reimbursement system will grow [28]. In the same time the reduction of sales is expected for medicines with arguable efficacy such as homeopathic, functions enhancers, probiotics, prophylactic medicines Later the amount of sold antibiotics also will be reduced [29]. Among the actively discussed topics is the introduction of e-pharmacies. The retailers and consumers are ready to use this tool and Ukraine has all infrastructure available for it, but as of now this issue is not supported legally. There are risks of erroneous medicine consumption, the difficulties of controlling fakes, and fiscal accounting. Discussion are going only around selling medicines through Internet. However, cosmetics and dietary supplements are already successfully sold there. Thus, distribution of medicinal medicines through Internet using modern information technologies (IT) is only question of time, so we need to legally resolve all problems related to it.

3 The model of consolidated information web-resource for the networks of pharmacies in a city

The analysis of principles governing the functioning of pharmacy networks leads to conclusion that it is rather hard to implement a convenient for the customer system for exchange of information about relevant medicines and their availability in pharmaceutical network. The user often does not understand which medicine should or should not be consumed taking in consideration probable symptoms or doctor’s diagnosis, whether there are similar medicines – analogues which are cheaper, but have the different efficacy. Our formal model S of consolidated information web-resource for network of pharmacies can be represented by tuple:

$$\begin{aligned} S =< & InpDt, RqHr, OtpDt, StItCmt, StSm, CntOnt, ExtPtm, \\ & TmTrz, CndOpSt, f_{id}, f_{rh}, f_{frs}, f_{st}, f_{fr}, f_{col}, f_{od}, f_{ep}, f_{aep} >, \end{aligned} \quad (1)$$

$$\begin{aligned} OtpDt = & f_{od}(InpDt, RqHr, StItCmt, StSm, CntOnt, ExtPtm, \\ & TmTrz, CndOpSt, f_{id}, f_{rh}, f_{frs}, f_{st}, f_{fr}, f_{col}, f_{ep}, f_{aep}), \end{aligned} \quad (2)$$

$$OtpDt = f_{od} \circ f_{fr} \circ f_{frs} \circ f_{col} \circ f_{aep} \circ f_{ep} \circ f_{st} \circ f_{rh} \circ f_{id}, \quad (3)$$

where $InpDt = \{InpDt_{us}, InpDt_{pr}, InpDt_{vr}, InpDt_{md}, InpDt_{pn}, InpDt_{ad}, InpDt_{dr}\}$ – the input date from pharmacy $InpDt_{pr}$, user $InpDt_{us}$, visitor $InpDt_{vr}$, moderator $InpDt_{md}$, network of pharmacies $InpDt_{pn}$, administrator $InpDt_{ad}$, doctor $InpDt_{dr}$;

$RqHr = \{RqHr_{us}, RqHr_{pr}, RqHr_{vr}, RqHr_{md}, RqHr_{pn}, RqHr_{ad}, RqHr_{dr}\}$ – the request from pharmacy $RqHr_{pr}$, user $RqHr_{us}$, visitor $RqHrt_{vr}$, moderator $RqHr_{md}$, pharmacy network $RqHr_{pn}$, administrator $RqHr_{ad}$, doctor $RqHr_{dr}$;

$OtpDt = \{RptDt_{sh}, RptDt_{as}, RptDt_{fr}, RptDt_{rd}\}$ – output data as result of search requests $RptDt_{sh}$, extended search $RptDt_{as}$ (the name of pharmacy, network, medicine, symptoms, geolocation, price, discount), search filters applied $RptDt_{fr}$, the recommendations about filters $RptDt_{rd}$ (taking in consideration the history of requests, comments of other users, frequency of requests, statistics of usage, applicability to different groups of consumers);

$StItCmt = \{StItCmt_{ft}, StItCmt_{rs}\}$ – the internal parts of resource – facts $StItCmt_{ft}$ and rules $StItCmt_{rs}$, which are used in system's learning. This learning is based on classification and clustering. Machine learning is used for the definition of better content and ultimately for gaining new customers. In process of classification input data is grouped in two or more classes and learning system should generate the model which assign the new inputs to one of those classes. This learning as a rule assisted. The example of such classification is provided by extended search filters (popular content, last seen content), where input is the content and requests to system and classes are represented by relevant and not relevant content.

In clustering the set of inputs is divided in groups. Contrarily to classification, the groups are not known beforehand, which makes this a subject for non-assisted learning. We use also the estimates for density of pharmacies distribution in space for better location definition. The reduction of dimension number simplifies inputs by mapping them into space with less dimensions. The similar task is thematic modeling where the software obtains the list of prescriptions/symptoms for identification of similar medicines if demanded medicines are not available.

$StSm = < StSm_{gl}, StSm_{qp}, StSm_{cs}, StSm_{cc}, StSm_{ds}, StSm_{ar}, StSm_{wr} >$ – the tuple of states including location $StSm_{gl}$, request processing $StSm_{qp}$, cache lookup $StSm_{cs}$, if not found – search in cloud $StSm_{cc}$ and later – in data store $StSm_{ds}$, if not found – search in resources of other pharmacies $StSm_{ar}$ and other web-resources $StSm_{wr}$;

$CntOnt = < C, R, F >$ C – the content of system represented as ontology (the references for medicines, symptoms, pharmacy networks, and pharmacies, addresses of pharmacies,….), where C – is the finite set of concepts of subject area described by ontology O; $R : C \to C$ the finite set of mappings between concepts from selected subject area; F – the finite set of interpretation functions (axioms or constraints), defined on concepts and relations of ontology O. The natural constraints imposed on set C, is its finiteness and non-emptiness, F and R should also be the finite sets;

$ExtPtm = < E_{nrc}, E_{qrc}, E_{ncm}, E_{qcm}, E_{ntr}, E_{qtr}, E_{nfp}, E_{qfp}, E_{nfw}, E_{qfw} >$ – the tuple of external parameters used in creation of statistics describing system functioning (the quantity and quality of relevant content E_{nrc}, E_{qrc} correspondingly, comments E_{ncm}, E_{qcm}, page access time E_{ntr}, E_{qtr}, time spent on pharmacy page E_{nfp}, E_{qfp}, time spent on pharmacy network pages E_{nfw}, E_{qfw});

$TmTrz$ – transaction time (search, comments analysis, evaluating rating, sorting, symptom analysis);

$CndOpSt$ – the condition of creation of new rules and facts for machine learning;

f_{id} – the operator of analysis inputs from different sources [14];

f_{rh} – the operator of requests analysis from different sources [15];

f_{aep} – the operator of external parameters analysis for forming new facts and rules for machine learning;

f_{ep} – the operator for external parameters selection and sorting according to rating for creation of statistical data reflecting system operation (if those parameters are selected correctly system will be able to create relevant results for customers);

f_{frs} – the operator of machine learning of the system according to consolidated resource performance statistics. Statistical results are obtained from cloud, the results of last requests are stored in the cache. The cache also contains the web pages accessed recently, statistics from current period (day, or couple of hours depending on time of the year or resource load);

f_{st} – the operator of changing system into the state of data processing;

f_{col} – the operator of moderation and updating of ontology for consolidated web-resource for network of pharmacies;

f_{fr} – the operator for facts creation and rules generation for recommendation;

f_{od} – the operator for formation of reports according to analysis of requests from different sources.

The user of consolidate resource should obtain the information about the price of the medicine, possible replacements, main chemical agent, the availability of the medicine in a pharmacy, the prescription requirement, and pharmacy contact data. For pharmacy customers it important to read the medicine usage instruction before a visit to pharmacy. The main goal for our created information system is providing the support for pharmacy customers. This goal can be further divided in three sub-goals: “System design”, “Data acquisition”, “Customer support” (fig.1). For more information on fig.1 further subgoals are shown. Thus, “System design” goal is split into “Database design” (the elucidation of entities used), “The usage of modern technologies” (will allow in future to upgrade functionality and performance, new learning rules included), “Coding modules”. The subgoals “The design of server and client components, their interactions" corresponds to the main client-server design pattern used in the system. The next major goal describing the data acquisition is split in two subgoals: "Gathering data about pharmacies and networks of pharmacies" and "Gathering data about medicines". The "Customer support" goal emphasizes the importance of the usability for customer factor in system design. The implementation of this goal will allow pharmacy customers to use search functions with additional criteria, such as the price and location, medicine's chemical agent, discounts, whether prescription is required, popularity, comments, ratings, similar medicines) and also see previously selected information offline.

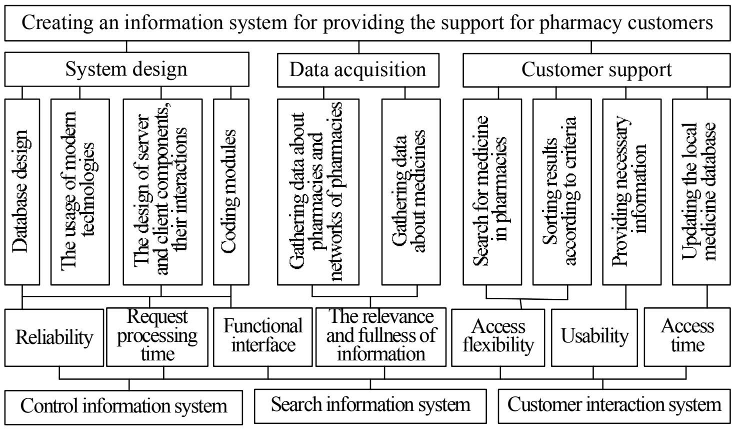

Fig. 1. Goal tree for developing our information system

The goal tree also list criteria attached to corresponding nodes. "Reliability" criterion stresses system stability in face of errors, "Request processing time" focuses on server side solutions for quick transaction processing; "Functional interface" implements the functional interactions between client and server parts; "The relevance and fullness of information" is necessary for correct execution of requests; "Access flexibility" – the ability of system to change functions in a way imperceptible for user; "Usability" – the correspondence to user needs; "Access time" – reduces the access time by storing information in customer's device.

There's also a view of our system having three parts: "Control information system" implements such functions as making decisions, distribution of information. "Search information system" realizes the storage and access of information in databases; "Customer interaction system" implements customer-oriented interface functionality.

4 Detailed view of system's functions

Contextual diagram (fig. 2) shows the interaction of system with a customer represented as an external entity. Customer creates a new session, supplies the search parameters and his location in order to provide information for better service. System if needed, interacts with customer via dialog windows. When required data from customer is obtained, server processed it and sends back results. Fig.3 shows the decomposition of this process into two intermediary processes and local data store. On session's start main page is shown with the list of medicines, stored locally.

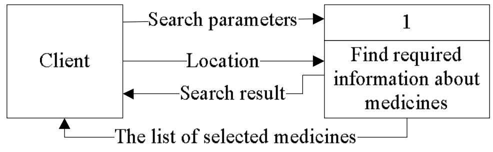

Fig. 2. Contextual diagram of our information system

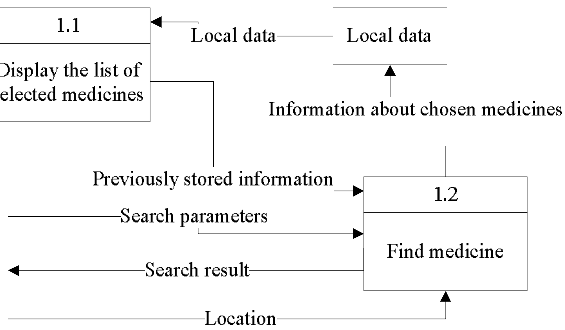

Fig. 3. Process "Find required information about medicines" decomposition (1)

The decomposition of process "Find medicines" contains the most of data flows of our designed system (fig. 4.):

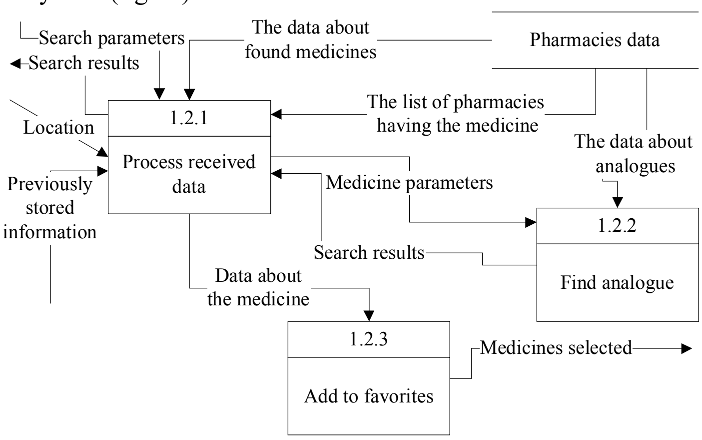

Fig. 4. The decomposition of process "Find medicines" (1.2)

– "Process received data". This process receives data about the required medicines and pharmacies from data store "Pharmacies data" and shows them to customer. This data can be also passed to process "Add to favorites" or "Find analogue".

- The process "Add to favorites" – passes data about the selected medicine to local storage.
- "Find analogue" process upon receiving the data about selected medicine, requests data store for the list of medicines having the same main chemical agent. This list is forwarded to process "Process received data" or, if there are no analogues, the system creates a dialog window with a message about no analogues available.

The decomposition of process «Process received data» (fig. 5):

- The process "Form a list for output" obtains from the remote data store the list of medicines found, checks it and transform into the format suitable for transmission between client and server subsystems.
- The process "Sort the list of pharmacies" upon receiving the information about the medicine required and location data, sorts the list of pharmacies where this medicine is available.
- The process "Check for availability in favorites" checks whether requested medicine is in the local favorites list and allows to customer to add this medicine to favorites if it is not there.
- The process "Distribute and output data" upon receiving the information for output, distribute it into corresponding fields and outputs the result in the user-convenient form.

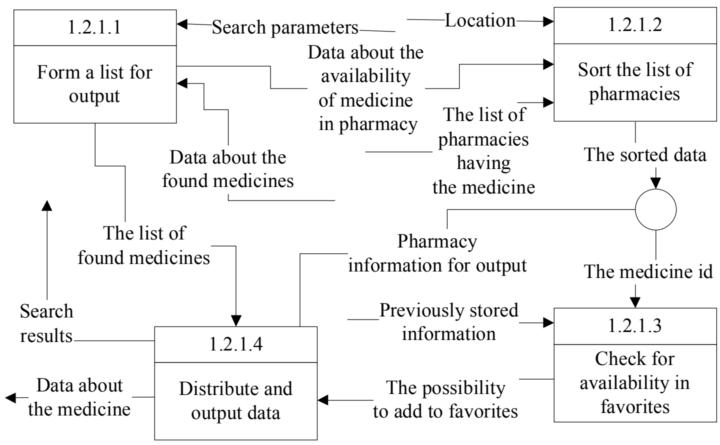

Fig. 5. The decomposition of process "Process received data" (1.2.1)

The decomposition of process "Find analogue" (fig. 6):

- The process "Find the main chemical agent" receives as input the information about medicine, identifies its main chemical agent and passes this data to further search operation;
- The process "Compile parameters for the search of analogues" obtains the list of analogues having the same chemical agent and excludes from it previously found medicines.

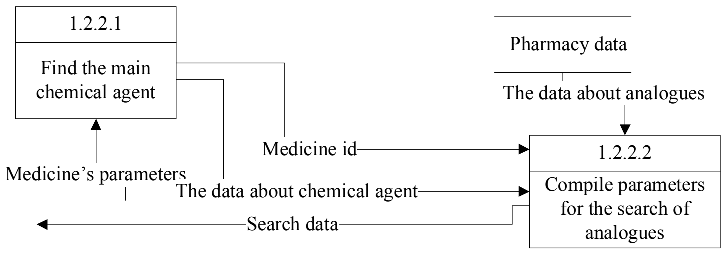

Fig. 6. The decomposition of process "Find analogue" (1.2.2)

The hierarchy of processes for designed system is shown on fig. 7.

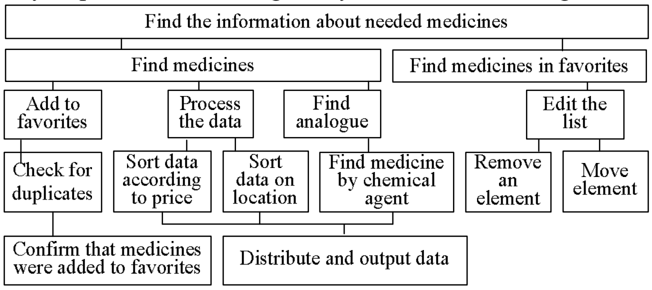

Fig. 7. The hierarchy of processes and operations of our information system

The developed system uses PostgreSQL database management system. The schema of database is shown on fig.8. The entity spatial_ref_sys is necessary for quick search based on geolocation and is created automatically by PostGIS.

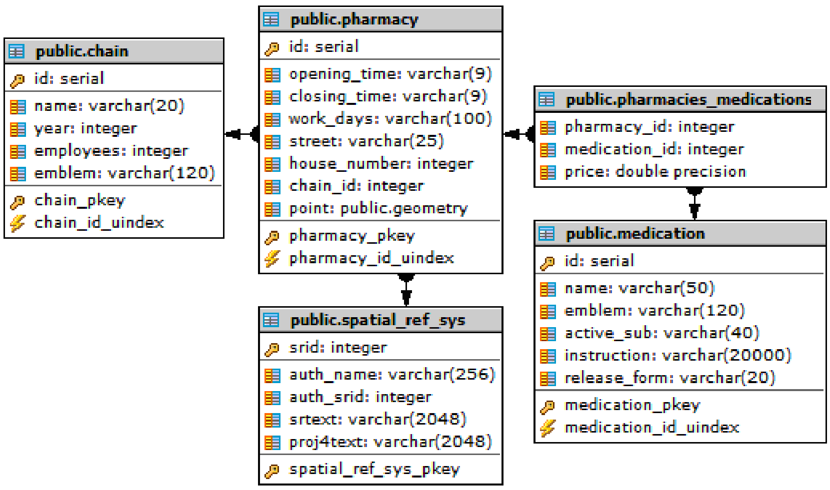

Fig. 8. The database schema in our information system

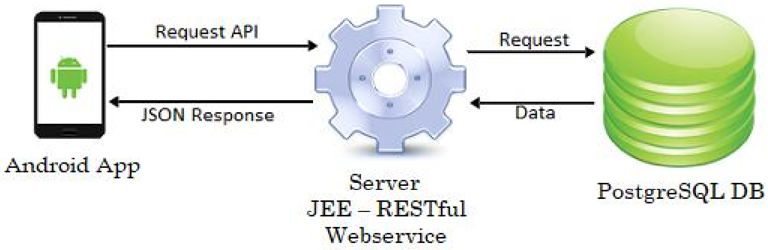

Fig. 9. The diagram of client and server interactions with DBMS

The software created was built using client-server design pattern (fig. 9). The server is represented as an abstract network service able to accept HTTP-request, process it and return the response in JSON format. The client is an android – based application able to form and send a valid HTTP request. REST interface is used for data manipulation, creating requests and corresponding reports in selected form. The structure of software is shown in further detail on fig. 10. The template, using the framework Spring MVC, defines following modules in the system: Controller, Service, DAO and their implementations. The controller analysis the user's request, creates a corresponding model, and works as a service requesting DAO module. This module performs request to database, obtains data and passes it for output.

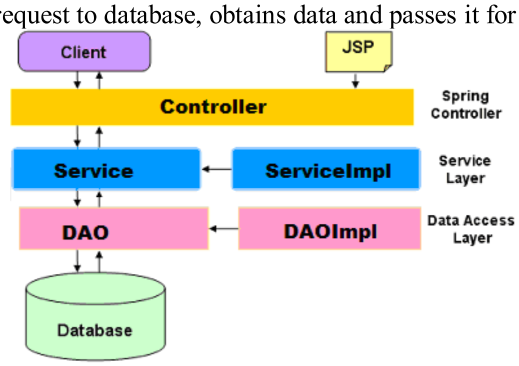

Fig. 10. The diagram of server side modules interactions in our information system

Figures 11-13 present diagrams illustrating server side module structure.

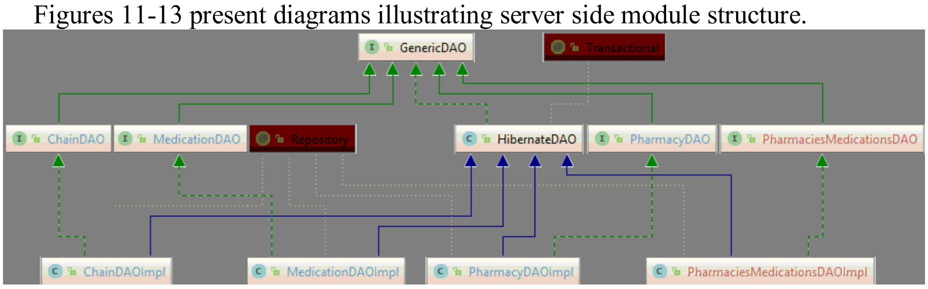

Fig. 11. DAO module of our information system

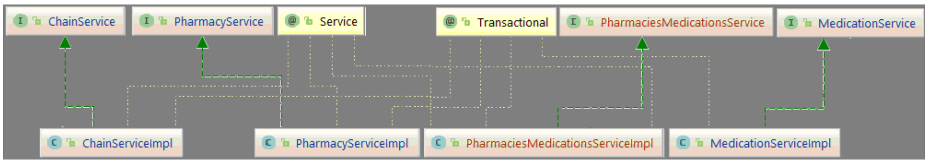

Fig. 12. Service module of our information system

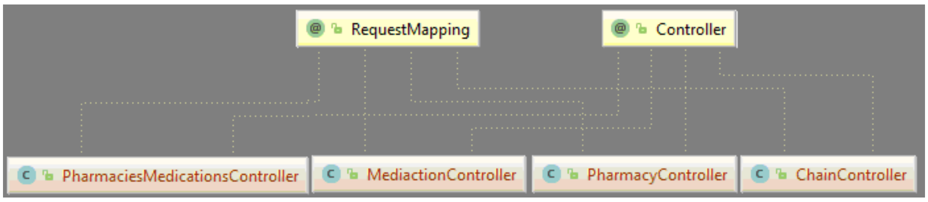

Fig. 13. Controller module of our information system

The information resource created caters for people who need to know about a specific medicine, where it is sold and analogues, helping to save time and money. The client and server parts of software are written in Java. The application works on any mobile platform with OS Android version 5.0 or higher. The Internet access is required. The application performs the search of medicines in Lviv pharmacies. The user types the name of required medicine and program provides the list of pharmacies sorted according to prices or distance from user's current location. On request the application provides the information about analogues available and their prices. User can also add medicine to the list of favorites, which will grant him the access to information about this medicine offline. Differently from similar applications, the developed resource contains the information about all pharmacies and their networks in Lviv.

5 Consolidated information resource interface and functioning

The examples of real world search for medicines using our developed information resource are shown on fig. 14- 19. Each page of the application contains an advertisement banner from Google AdMob which provides advertisement service in the context of user search history. The main application window is shown on fig. 14. It contains fields for up to four medicines and controls allowing to search the medicine in pharmacies, remove the medicine from search or show the medicine's usage instruction. Also, in the upper part of the page there are the field for the search of the medicine by its full or partial name. The user types a part of the medicine name and presses "Search" button. The application loads the search screen where the field with the name of required medicine is still present. This allows user to change the medicine name and search for the medicine again. Below the search field is a scrollable list of medicine names, which contain the text from search field. For example, if user typed "Loratadyn" in search field, the application will show the medicine names with this word. For every item displayed the application provide the search for analogues medicines or read the user instruction (fig.15).

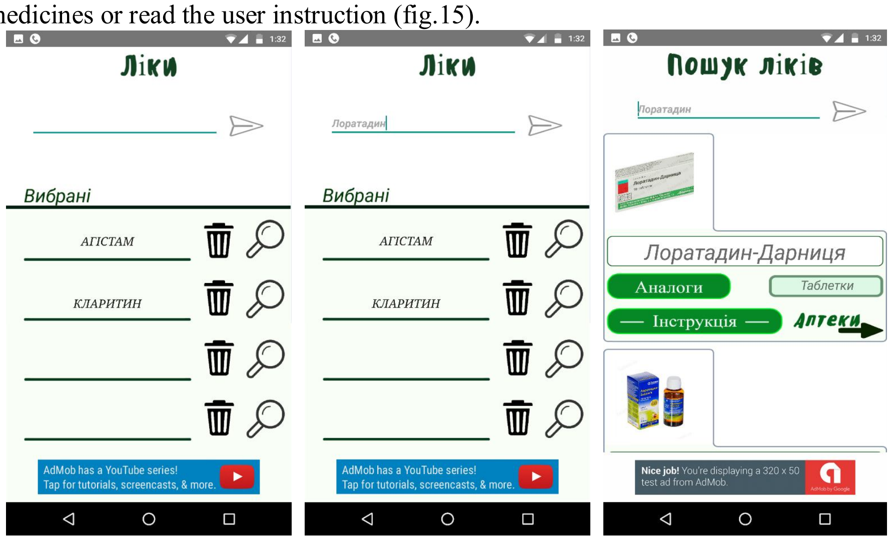

Fig. 14. The search for medicines on our information resource

The search for analogues is performed based on main chemical agents (fig. 16-17). The initial medicine is excluded from the list of analogues. After the selection of required medicines, application makes a search based on the list of pharmacies sorted by price and shows the results to user. In case if medicine is not yet included on "favorites", and this list is not full, application provides a possibility to add medicine to "favorites', and shows a corresponding button.

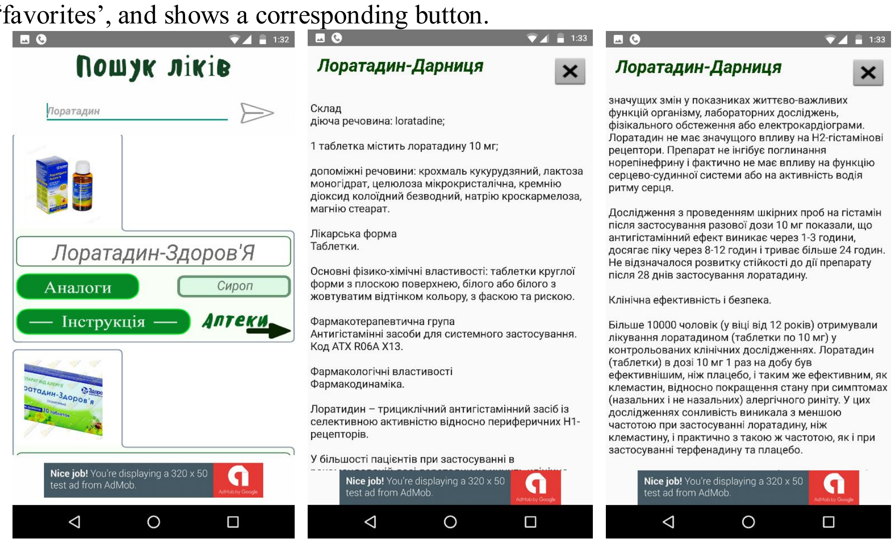

Fig. 15. The medicine search result on our information resource

Fig. 16. The search for analogues on our information resource

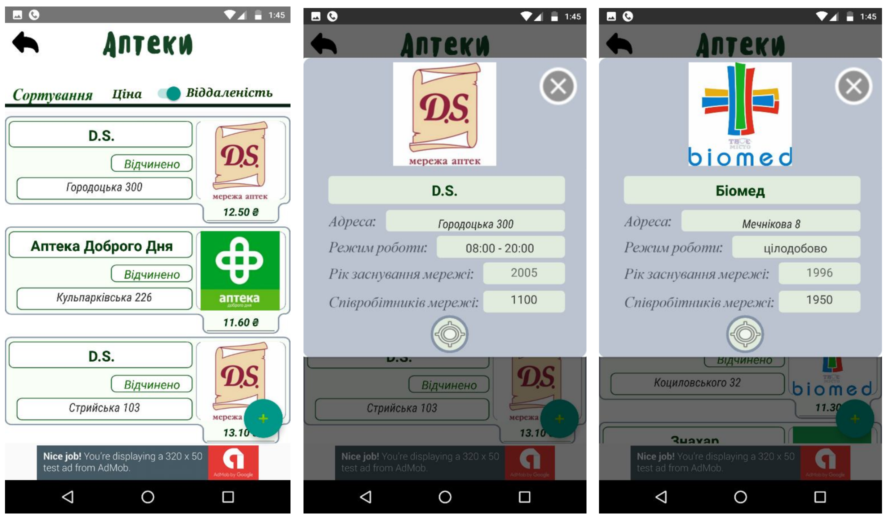

Fig. 17. The search of medicines in pharmacies using different sorting order

The slider is shown on the screen allowing for user to switch the list of pharmacies taking into account the current user location. Moreover, when user taps on the pharmacy network logo, the application shows additional information about the pharmacy network in the dialog window. Application also shows buttons allowing for a user to see the pharmacy location on Google Maps or close the application. (fig. 19).

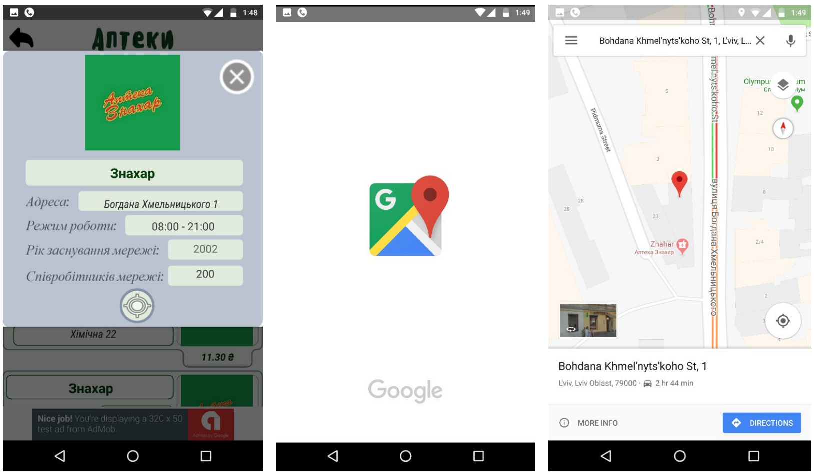

Fig. 18. Showing the location of pharmacy on our information resource

Additionally, the application can show the medicine usage instruction in offline mode (fig. 19). This information comes from the local storage, although in this mode the advertisement banner is not shown.

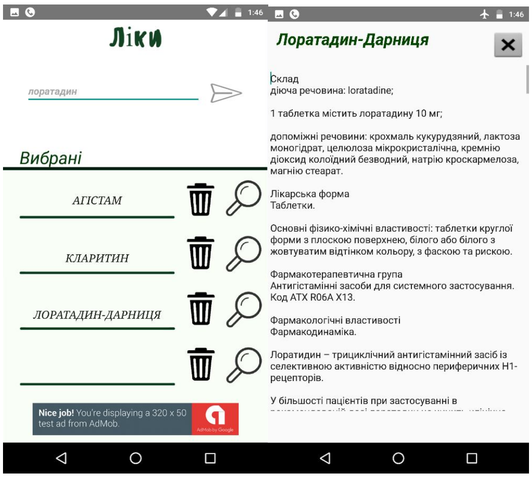

Fig. 19. Reading the medicine usage instruction in offline mode on our information resource

6 Conclusion

Our research was targeting the introduction of new mobile services in pharmaceutical market with a purpose of improving the communications between pharmacies and their customers. We address the problem of customer need for additional knowledge about available medicines and their analogues which are often cheaper than initially proposed medicine. Our developed consolidated information resource provide relevant information about medicines available in pharmacies in Lviv.

The general goal was decomposed into the tree of subgoals. The dataflow diagrams specifying processes and operations were developed. Based on them functional elements of the system, and required data transformations were defined. The software application, based on mobile platform Android and Java programming language, was created. Client and server side code was implemented and tested. In order to obtain the correct location data the technology PostGIS (part of PostgreSQL product) was used. This technology uses the system Google Geocoding to translate the coordinates of pharmacy into required format. This design solution greatly influenced the system's performance. The customers of developed service can view the information about medicines in offline mode. This service is based on using the local database, which stores data about previously selected medicines, their images and usage instructions. The developed software was built using the client-server architecture and MVC design pattern. Data from database to the mobile application are returned in JSON format. In order to have access to full set of the application's functions, the user needs a smartphone based on Android OS (with version 5.0 or later), and to have access to Internet and active geolocation service.

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