Integrating Digital Health Strategies for Effective Administration:

Use of Mobile Phone Applications and Software for Effective Public Health Management

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ABSTRACT

The purpose of this section is to highlight the opportunities for digitizing important processes in the healthcare system to improve the efficiency of population health management. The introduction of these digital processes will increase patient satisfaction with the healthcare system, as well as provide a holistic outlook of patient health through access to data and give patients more control over their own health. Healthcare managers will also be using the developed Internet applications to conduct clinical audits and monitor health problems in the administrative district. It is proposed to develop and use free Internet applications and computer programs, namely: 1) Drug Compatibility Test online application, which is designed primarily for students. This app is designed to test knowledge of drug compatibility and certain aspects of diet and behavioral habits; 2) electronic individual antenatal drug passport for a promising way to predict, prevent and reduce the risk of allergic reactions; and 3) Medical Intelligence app using the artificial intelligence technologies to develop an individual educational trajectory for doctors and pharmacists.

Keywords: Digital Health Management, Public Health, DanyloHalytskyLviv National Medical University, Ukraine

INTRODUCTION

Functioning of the health care system at the current stage is characterized by the priority of electronic forms: both at the national level and at the level of health care institutions and patients. The development of information-communication technologies in health care promotes the improvement of the medical care

quality, reduction of the number of medical errors and improvement of the administration process. The purpose of this section is to highlight the information regarding Use of Mobile Phone Applications and Software for Effective Public Health Management.

BACKGROUND

The use of mobile applications (apps) in the pharmaceutical field is widespread, as they have a huge potential to influence the safety of medicines (Ianevski et al., 2017; Nepyyvoda & Ryvak, 2018) and therefore improve patient safety (Pavithra & Shehnaz, 2021). Mobile applications should be considered as a form of pharmaceutical intervention (Kheshti et al., 2016; Zimenkovsky et al., 2021), which will prevent the negative consequences of self-medication and help gain new knowledge about the safe use of the most common pharmacotherapeutical products (Fjeldsoe et al., 2009; Zaremba & Zimenkovskyi, 2019).

In turn, mobile applications can provide significant support in making important clinical decisions. We are talking about applications aimed at changing the behavior of patients to improve their health (Iribarren et al., 2021) and the treatment of certain diseases, such as allergies (Bousquet et al, 2017; Matricardi et al., 2020; Tan et al., 2020; Zhou et al., 2018). Thus, modern information technologies are considered as an auxiliary tool for improving the quality of medical care. At the same time, despite their ease of use, effectiveness and advantages, attention should be paid to assessing the limitations and risks of such solutions for the treatment of diseases.

Another area of the use of mobile applications is the field of health care facility management based on the results of clinical audit (Gutor & Zimenkovsky, 2022), as one of the forms of receiving feedback (patient feedback) regarding the quality of medical care. Based on the results of the clinical audit, recommendations are being developed to improve the management of medical care at the health care institution.

The use of Artificial Intelligence in medicine is a prospective vector. According to the data of Balkanyi and Cornet (2019), the number of scientific publications on the use of Artificial Intelligence in medicine has increased six fold over the past 30 years. However, further research is needed regarding the practical implications of the development, selection and use of Artificial Intelligence to support clinical decisions, as well as the assessment of its safety and effectiveness (Magrabi et al., 2019). Another field of application of Artificial Intelligence is medical education (Masters, 2019; Pinto Dos Santos et al, 2019; Waldman et al., 2022), in particular Undergraduate (Mosch et al., 2022)

It is worth noting that according to Sichkoriz, et al. (2019), information technologies that contribute to learning deserve to be used in the professional training of medical professionals, ensuring the formation of their competence in the field of computer technologies. In general, we can consider the use of information technologies as a component of precision medicine, a patient-oriented model.

MAIN FOCUS OF THE CHAPTER

Since the use of mobile applications (apps) and software in the medical and pharmaceutical fields is a relevant and promising direction, we would like to share our own developments and experience in this matter, namely:

1. Drug Compatibility Test Online Application – for testing knowledge about drug compatibility and certain aspects of diet and behavioral habits.

2. Electronic Individual Antenatal Medication Passport – for predicting, preventing and reducing the risks of allergic reactions in pregnant women and newborns.

3. "Medical Intelligence" Software Using Artificial Intelligence Technologies – for forecasting the required number of doctors and working out options for decisions regarding the need for additional professional specialization courses, internships, subject improvement of doctors / pharmacists.

SOLUTIONS AND RECOMMENDATIONS

Drug Compatibility Test Online Application

Drug Compatibility Test free online application is intended primarily for students. It is designed to test knowledge of drug compatibility and certain aspects of diet and behavioral habits. The program "Drug Compatibility Test" is designed for checking the knowledge concerning the compatibility of medications and separate aspects of diet and behavioral habits. The program is designed like a "Quiz", which offers users text and/or graphic tasks with the choice of several possible answers, and then, on the basis of the number of correct answers, calculates the overall test result. The program does not have a clearly defined target audience, except for the age limit "3+", which is characteristic of the majority of applications designed for devices run by the Android operating system and its modifications. It can be downloaded by means of Play Market by users of mobile devices run by the Android operating system of the version 4.1.0 (API level 16) or a more recent one, except for smart watches, televisions and cars. Such a choice covers about 98% of Android mobile devices, including exotic ones such as those run by MIUI (Mobile Internet User Interface) and electronic books Kindle Fire, i.e. approximately 84% of all mobile devices. It is worth indicating that the program is most suitable for smartphones with the screen size from 5 to 7 inches, which is common for the great majority of modern smartphones and phablets

The built-in mechanism of scaling fonts and distances (indicating them in Density Independent Points) makes the program windows independent from the screen resolution, which means that the program looks practically the same both on HD (720 p) and FHD (1080 p) or UHD (1440 p), and even bigger screens with insignificant differences conditioned by different ratios (normally 16:10, 16:9 and 18:9). Such peculiarities as curved display edges and the newfangled "technological" cut, which are characteristic of many devices, in particular of Chinese manufacturers, have been also taken into account.

During the development, only free and publicly accessible technologies and resources have been used such as: programming languages Java (in Android Studio 3.2) and VB.NET (in Microsoft Visual Studio 2017 Community Edition – free software for individual developers and teams of 6 members and less), the markup language XML (in Android Studio 3.2), own graphic design (graphics editor Paint.NET – free software and program graphics generation) and a sound library www.zapsplat.com, which is free on terms of attribution (indicating a reference to the source in the program). Thus, the program is free for using and sharing under any circumstances; one can be charged only for data transmission in accordance with tariff plans of one's mobile operator.

The program is composed of the database of own format, which is transformed from a file (raw data) in CSV (Comma Separated Values) format of a free meta-format of electronic tables and simple databases, although it is possible to use proprietary software during development, such as Microsoft Excel 2010 or a more recent version, if there are relevant licenses. The service part of the program forms a compressed and optimized database on the basis of the provided raw data, having previously partially checked its correctness according to the following principle: each medicine has to contain data about one compatible and one incompatible medicine, but overall not less than four interactions. Three tables serve as the basis for data: description table, the tables of compatible values and incompatible values.

For storing data, indexing algorithm is used when data is saved. Tables with data contain multiple repetitions of one and the same value; therefore, when collecting data, frequency of values is determined and corresponding indices are assigned to them, and these very numbers are saved. This algorithm has a special structure, which causes data to compress by approximately 10 times with much lower CPU time than standard compression algorithms. The generated base ensures work of the very program. Such a

choice makes it more scalable, which means that when new data appears, it is just entered into the initial file, after which the data and program are compiled and published once more. When adding 1-2 medicines, these operations last no more than 20 minutes. Furthermore, the program does not require a constant internet connection since the data is already there. The program does not take up a lot of space (approximately 600 KiB), which for modern devices is practically nothing (approximately 1 / 50,000 or even 1 / 200,000 of the total storage capacity for top devices). In some cases, for instance, when working in roaming, local data storage saves up the user's money substantially. Moreover, if necessary, the program can be easily localized into any language

After the launch of the program, the user is offered a range of functions: "start testing", "view information about the program", and "exit the program", without performing any actions by pressing a corresponding button. On the main page, one can also turn on and off the sound, haptic effects and additional animation. It should be noted that the haptic effects are not realized to the full extent because they are not related to the position of a device in space but such programs do not usually use haptic technology in full. Such partial haptic effects are called tactile feedback. This option may be unavailable on some devices due to the absence of an eccentric in the construction; some models of tablet computers (tablet PC) can have such a construction. The setting of the program is regulated by three switches located in the lower part of the window, and a stylized image of a pill is simultaneously the program logo in the main window and an indication of the selected option in the test window (Figure 1).

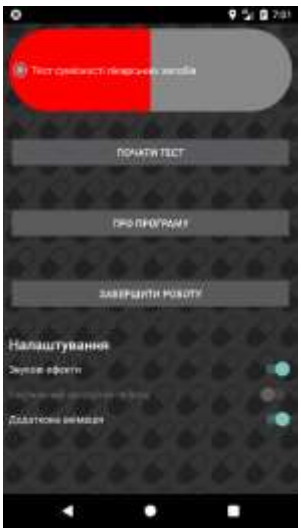


Figure 1. Main window of the program (in Ukrainian)
Source:Zaremba &Zimenkovskyi, 2019

If a user selects testing, it is conducted in the following windows shown in the Figure 2. Testing is conducted by means of showing screens with a name and short description of a medicine and the task to choose among 4 medicines one compatible or incompatible medication. When the user presses the button "Next", the program shows whether the answer is correct or not with a short explanation, which is followed by the next question. If a user chooses the button "Finish", the program shows whether the user has answered correctly, stops the testing and displays its result. In fact, the duration of testing is not regulated but considering the current amount of content in the database, the program can put about 3,000 unique questions or 12,000 with partial repetitions. According to the distribution of the standard function of random number generation, the first visibly similar questions will appear approximately in the fourth hundred questions, which is certainly sufficient for such type of testing. The final result of testing is considered positive if a user has chosen 1/2 or more correct answers.

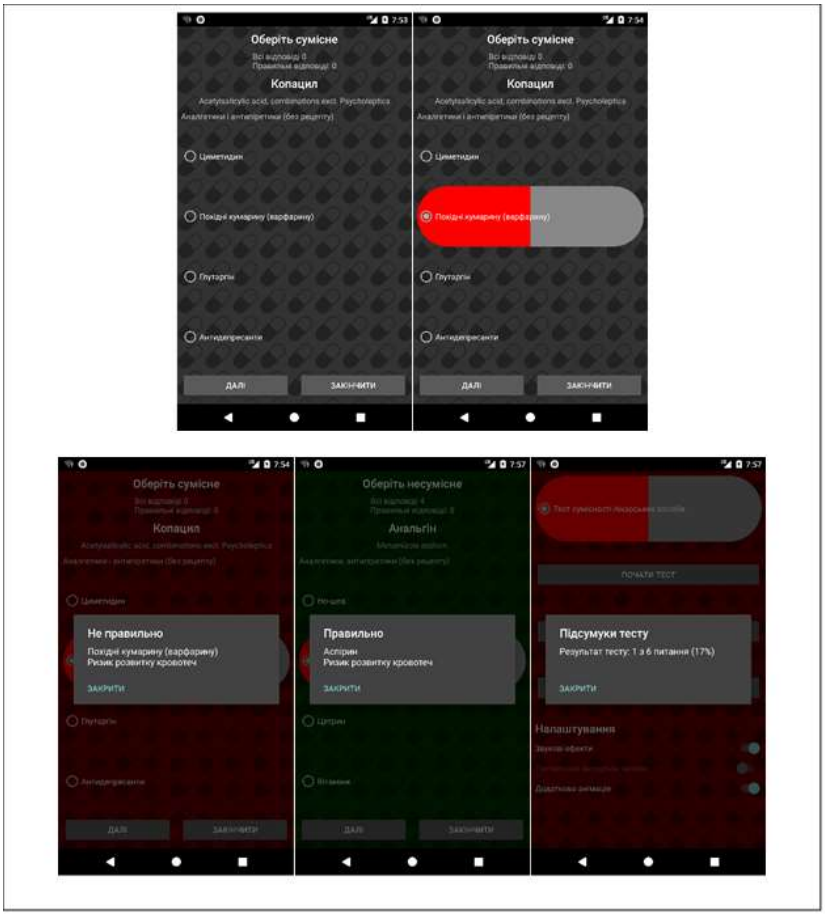


Figure 2. Some windows of the program: questions without answers; answer; a message about an incorrect answer; a message about a correct answer; a message about the end of testing (in Ukrainian)
Source: Zaremba and Zimenkovskyi (2019)

The work of the program is accompanied by so-called numerical (alpha and timeline) animation effects and transition effects if a user has turned them on in the system settings. In this case, the choice is also highlighted by a sound effect and/or haptic effects, which depend both on the program settings and the device in general. Moreover, the data, which is completely anonymous (exclusively with questions and answers without any indication of a name, phone number, e-mail address etc.), is sent for further processing and the search for medicines, the knowledge of which is insufficient. The data is sent in small packages with the help of Google forms. For the purpose of avoiding inconveniences, the data may not be sent at all, for example, if a user uses the program abroad, in places where Wi-Fi is unavailable or he or she has turned off data transmission on the device for a long time. The collected data is thus stored in the form of an electronic Google table, which is suitable for viewing and even editing directly in a web browser or downloading and converting into formats suitable for statistical processing. Main stages of work continue until a user presses the button “Finish”. Then, the next question is not put; instead test results appear and the program goes back to waiting for further commands (Figure 3).

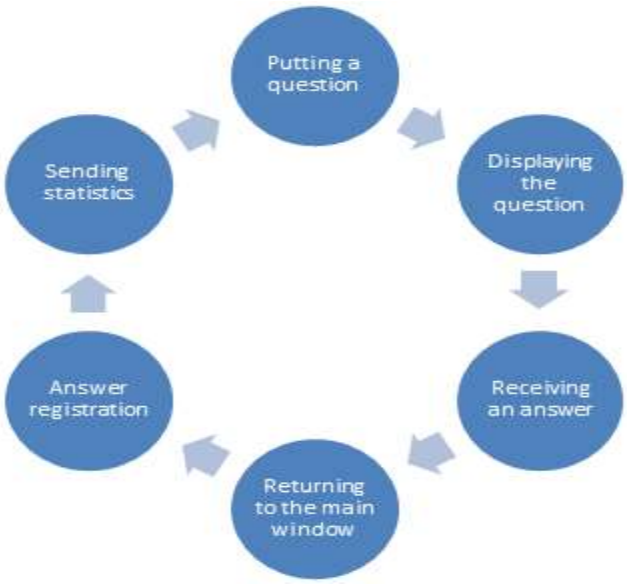
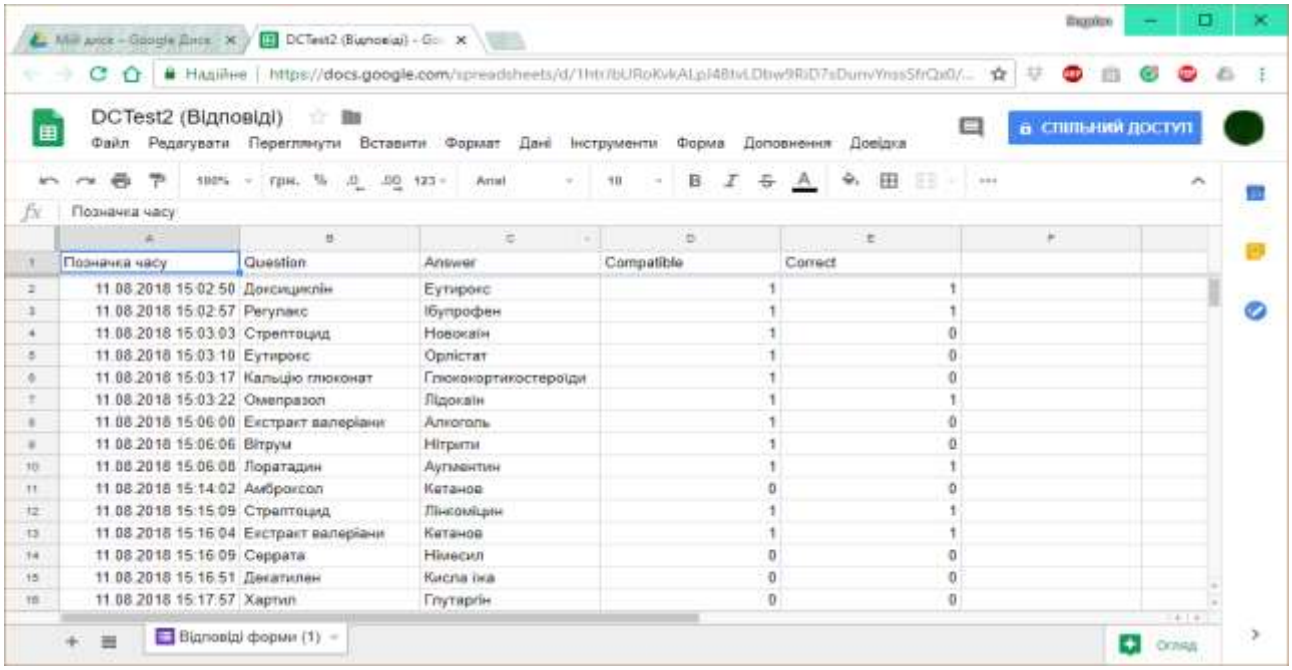


Figure 3. Main cycle of the program work
Source:developed by the authors

The table presented by Figure 4 resembles a Microsoft Excel document in its structure and appearance and contains data on one answer per a row of 5 columns.



DCTest2 (Відповіді)

Позначка часу	Question	Answer	Compatible	Correct
11.08.2018 15:02:50	Доксициклін	Еутирокс	1	1
11.08.2018 15:02:57	Регулакс	Ібупрофен	1	1
11.08.2018 15:03:03	Стрептоцид	Новокаін	1	0
11.08.2018 15:03:10	Еутирокс	Орлістат	1	0
11.08.2018 15:03:17	Кальцію глюконат	Глюкокортикостероїди	1	0
11.08.2018 15:03:22	Омепразол	Лідокаїн	1	1
11.08.2018 15:06:00	Екстракт валеріани	Алкоголь	1	0
11.08.2018 15:06:06	Вітрум	Нітрити	1	0
11.08.2018 15:06:08	Лоратадин	Аугментин	1	1
11.08.2018 15:14:02	Амброксол	Кетанов	0	0
11.08.2018 15:15:09	Стрептоцид	Лінкоміцин	1	1
11.08.2018 15:16:04	Екстракт валеріани	Кетанов	1	1
11.08.2018 15:16:09	Серрата	Німесил	0	0
11.08.2018 15:16:51	Декатилен	Кисла їжа	0	0
11.08.2018 15:17:57	Хартил	Глутаргін	0	0

Figure 4. Sample of data collected in the program test mode (in Ukrainian)
Source:Zaremba &Zimenkovskyi, 2019

Notes: A. Time indicator – is in fact not statistical data but the time of receiving an answer, and is provided not by the program but by the Google server. This column is included because it is required for the operation of the service. B. Question – essence of the question, i.e. a name of the medicine about which the question was asked. C. Answer – selected answer. D. Compatible – question mode, which can acquire 2 values: 0 (choose the

incompatible option) and 1 (choose the compatible option). E. Correct – resultcheck, which can acquire 2 values: 0 (the answer is incorrect) and 1 (the answer is correct).

In fact, “0” and “1” are generally accepted synonyms (equivalents “!0” and “0” of the Boolean algebra expression) for “True” and “False”, which are operated by machine data processing systems. Such clarification explains data structure clearly. The application of numerical analogues allows to process more data and slightly saves traffic when collecting data. Such data, practically without any changes (except for saving a file in a corresponding format), can be processed by Excel and packages of statistical data processing.

Results of testing the users of Drug Compatibility Test clinical and pharmaceutical mobile application

The analysis of the first 1500 responses to the questions randomly asked to medical students about the compatibility or incompatibility of the most common medications showed the following results. The question about drug compatibility was asked 911 times (60.7±1.3%), and about incompatibilities – 589 times (39.3±1.3%).

In the block of questions about drug compatibility, the average frequency of correct answers was 35.2±1.6%. Students usually answered the questions about compatibility of omeprazole (66.7±13.6% of correct answers), Coldflu (61.5±13.5%) and Mesaton (60.0±15.5%) with other drugs correctly. Most errors were noted in the answers regarding the compatibility of the following medications: Magnicor (91.7±8.0% of incorrect answers), rimantadine (90.9±8.7%), mefenamic acid (88.9±10.5%), loratadine (88.9±10.5%) and echinacea (88.9±10.5%).

Typical misconceptions of students were related to the possibility of co-administration of iodide with thyroid-stimulating drugs (n=11), lactovit with thiamine (n=8) and regulax with thiazide diuretics (n=7).

In the block of questions about choosing an incompatible drug, the average frequency of correct answers was higher – 48.4±2.1%. Students usually answered question about the incompatibility of deacura (100% of correct answers), glicised (81.3±9.7%), ambroxol (75.0±10.8%) and dicloberl (75.0±15.3%) correctly. Most errors were found in answers to the questions about the incompatibility of the following medications: paracetamol (83.3±15.2% of incorrect answers), analgin (80.0±12.6%), altabor (76.5±10.2%), decatylene (75.0±15.3%), dexalgin (75.0±15.3%) and bifrene (75.0±21.7%).

The most common mistakes made by students were that Altabor was incompatible with Coldrex (n=9), analgin with No-Spin (n=6), atoxyl with pancreatin (n=6), and vibrocyl with atropine (n=6). Thus, the Drug Compatibility Test application we developed is a full-fledged information application for a mobile device designed to test knowledge of drug compatibility and certain aspects of diet and behavioral habits. It covers approximately 84% of all mobile devices, including 98% of mobile devices in the Android ecosystem. The application is free of charge and free for distribution under all conditions. The database of medicines included in the app was built based on the results of a sociological survey on the medicines most commonly used by the students of higher medical education included in our study. It can be extended if needed.

In the block of questions about drug compatibilities, the average frequency of correct answers was 35.2±1.6%. Most errors were found in answers about the compatibility of the following medications: magnicor (91.7±8.0% of incorrect answers), rimantadine (90.9±8.7%), mefenamic acid (88.9±10.5%), loratadine (88.9±10.5%) and echinacea (88.9±10.5%). When answering questions about drug incompatibilities, the most common mistakes were related to paracetamol (83.3±15.2% of incorrect answers), analgin (80.0±12.6%), altabor (76.5±10.2%), decatylene (75.0±15.3%), dexalgin (75.0±15.3%) and biphenyl (75.0±21.7%).

Mobile applications to improve the safe use of medicines

In order to assess the ability to quickly find information, including information on drug compatibilities, we conducted a search for mobile applications. The search concerned the Android operating system, which is probably the most common among students, in the Google Play online store. After entering the key phrase (direct key) "Drug Compatibility Test", it turned out that this type of search has very low relevance, as we received only one application "Handbook on Injectable Drugs" developed by ASHSP, which, according to the documentation, was developed for the American Society of Health-Systems Pharmacists (a professional organization representing pharmacists; its mission is to provide care to patients in emergency and outpatient settings). However, given the technical condition and application update data, it can be reasonably concluded that it has the status of Abandonware (a specific term related to the status of software, which means that development and support of the proprietary (appropriated) software was probably, but not definitely, discontinued). At the same time, the application does not actually meet the requirements of our search, as it is intended specifically for the US pharmaceutical market. At the same time, the ASHP provides the only comprehensive, unbiased, nationally accessible resource for information on drug shortages in the United States. However, the application itself is intended for reference only and is only partially functional, as website www.interactivehandbook.com, of which it is a shell.

Our next step was to enter the words "test" and "compatibility" into the search box of the Google Play online store. The results of their separate input and especially their combination showed a very high SEO potential and were filled with completely irrelevant apps using the pseudo-scientific methods to determine psychological compatibility and mostly belonging to the prank-app category. According to Google's policy, such software cannot contain actual malicious code, but rather misleads the user to entertain rather than harm; it is inaccurate and irrelevant to the query.

To increase the relevance, we split the "test compatibility" pair and obtained the "drug compatibility" query. This manipulation increased the relevance of the search manifold and provided relevant results on the first 50 positions, after which the query began to degrade rapidly. The situation with the other related search keywords ("medicines", "drugs", "drug compatibility", "drug administration", etc.) was similar, or very similar, although with a greater dispersion and a slightly different order of results. Therefore, we further took into account the data based on the "drug compatibility" query, as approximately the same results were obtained by the other queries.

Although the results of this stage of our search were formally relevant in terms of subject matter, they did not fully correspond to the content of the app in question. As an example, here are the following apps that are the most relevant results returned by search engines, however, these are mostly reference books. The Medicines Control mobile application by Massimo Dev helps to protect consumers of medicines from counterfeiting and unauthorized prescriptions. Its functions include checking the authorization and batch of medicines, as well as displaying instructions for the same and searching for analogs, as well as monitoring the expiration date based on the batch of medicines. According to the website, the Medicines Control service is based on state data and contains all medicines registered in Ukraine (13,905 medicines, 368 medicines from prohibited batches) with instructions for their use (IFUs). Regulatory documents are monitored and the database is updated twice a day, and medicines are added to the database based on orders of the Ministry of Health of Ukraine on registration and re-registration of medicinal products. The database of prohibited batches of medicinal products is built on the basis of orders of the State Service of Ukraine on Medicines and Drugs Control. Copies of the ban orders can be viewed directly in the mobile application.

Based on the status of the app, the number of downloads (50,000+ category, i.e. between 50,001 and 100,000 downloads), high user rating (4.7 of 5 reviews), and regular updates, we can conclude that the app is in good working order. This app has an extensive database covering 100% of the medicines registered in Ukraine, but it has only a reference function and provides information on the compatibility of medicines only as part of their IFUs. Therefore, the consumer has to open the IFU, read it and find information on compatibility. Similar functionality, but to a much lesser extent (for example, there are

problems even with finding the IFU for aspirin), is provided by the Medicines Reference, First Aid Kit application developed by KB@. According to the developer, this application is "a reference book on medicines and drugs, which includes about 10 thousand items. For each medicine, it contains basic information from the description provided by the manufacturer." Still, all the data in the app is in Russian and is often outdated (the last update was six months ago). The app is also monetized by displaying rather intrusive ads. Nevertheless, its download category is 10,000+, with a review rating 4.4 of 5.

In addition to the above application, there is also a fairly extensive range of applications related to medicines registered in the Russian Federation. This is due to the often incorrect configuration of Ukrainian users' devices, which connects them to the appropriate network segment. Consequently, search results are distorted even for devices with correctly configured accounts.

The Medication Reminder & Pill Tracker application developed byMyTherapy is its Ukrainian counterpart, offering essentially calendar-schedule functions and keeping statistics on drug administration based on the data provided by the user/patient, and reminding them of the time of their use and dosage. According to the website, the app is also "a pill tracker with a log for missed and confirmed doses, supporting a wide range of dosage regimens as part of a drug administration reminder, and offers a wide range of measurements for many pathologies (diabetes mellitus (DM), rheumatoid arthritis, anxiety, depression, hypertension, multiple sclerosis)." The search returns this app because of its medical focus, but it does not take into account drug compatibilities or properties in general, which makes it a specialized organizer only and gives it a relatively low position in the results, despite the category of 1 million+ downloads and 4.7 review rating.

Particular attention is attracted by a series of "IBM Microindex" applications, in particular, part of IBM Watson Health Products, which is released by developer Mobile Microindex, owned by IBM. Although the applications are free, there is a fee for obtaining reference information through them. This batch includes the following applications: 1) "IBM Micromedex Drug Info" – a general clinical reference database "providing concise information on 4500+ search terms covering common needs such as adult and pediatric dosages, AEs (divided into 'common' and 'serious'), drug interactions"; 2) IBM Microindex Drug Int. – information on drug interactions. However, this application is recommended for physicians and allows clinicians to "simultaneously check the entire patient list for potentially harmful interactions and view severity scores ranging from contraindicated to minor. This application allows understanding why the drugs in question interact; how the results of these interactions will be manifested in a patient; recommendations for monitoring the patient's results"; 3) "IBM Microindex Drug Ref" [181] – a general reference system for medicines (with a subscription fee of USD 2.99 per year); 4) "IBM Microindex IV Comp." – information on drug compatibility and potential adverse effects of their interaction. The developers state that this application is "the largest, most comprehensive compatibility resource which improves patient safety by identifying potentially dangerous combinations; helps clinicians interpret conflicting compatibility results by identifying contributing factors such as physical compatibility, storage, study period, and chemical stability; includes compatibility results for drug solutions as well as compatibility results for drugs when creating a mixture or administering them through Y-Site"; 5) "IBM MicroindexNeoFax" [182] – PT and nutrition in neonatology (for full-term infants up to 28 days old and preterm infants up to 44 weeks old) (commercial app); 6) "IBM Microindex Pediatrics" – PT and nutrition in pediatrics (for full-term infants 29+ days old and preterm infants 44+ weeks up to 18 years old).

Thus, the above are large international, mostly commercial databases focused mainly on US medicinal products and legislation, and less on EU countries, which also somewhat reduces their value for use in Ukraine, as well as due to differences in registration and availability of medicinal products, and the fact that all information is provided in English only. Further to that, there are similar apps for different countries, some of which do not even have an English version. Such applications are hardly of any use in Ukraine.

Thanks to their aggressive marketing strategy, the app search results we analyzed also include apps for so-called fitness tracking. Although indirectly related to healthcare, such apps are actually designed to service the internal sensors of the phone and fitness bracelet, in particular, mainly to read their parameters.

Based on the analysis of the above applications, we can conclude that the most suitable high-quality domestic application for students is probably only the Medicines Control application, but it may be used as a reference only, i.e. even with a larger database, in our opinion, it is not perfect. Therefore, we believe that there is a need for an adequate mobile application on drug compatibility for students.

With the aim of expert assessment of the developed application, a survey of potential users of this software was conducted. For this purpose, 150 students of the III-VI years of study of the medical, dental and pharmaceutical faculties of DanyloHalytsky LNMU were selected. Each student was asked to download and take the test in the Drug Compatibility Test application. After completing the work, the students evaluated it according to 5 characteristics: 1) the accessibility of the application search; 2) the ease of use; 3) the design; 4) the volume of the drug database; 5) the possibility of use for educational purposes. Students graded it from 1 (worst) to 10 (best).

The highest average scores (8.7±1.7) were given for 2 criteria: the accessibility of the application search and the possibility of using it for educational purposes. At the same time, the app's ease of use was rated at 8.5±1.6 points, and the volume of the drug database was rated at 8.2±1.5 points. The application design received the lowest average score (7.4±2.0).

The developed application demonstrates obvious advantages of its use: the program covers about 84% of all mobile devices, in particular 98% of mobile devices of ecosystem of Android. Its use in everyday life can prevent the negative consequences of self-medication among users. Also, this application can be used for educational purposes among medical / pharmaceutical students as one of the tools for testing knowledge about the compatibility of medicines.

Electronic Individual Antenatal Medication Passport – as a Promising Way of Predicting, Preventing and Reducing the Risks of Allergic Reactions

The main direction of modern obstetrics is the prevention of pregnancy complications. First of all, this requires identifying women at risk of a complicated course of pregnancy. Since complicated pregnancy is a multifactorial process, an important task of an obstetrician-gynecologist is to establish risk factors before pregnancy. And precisely here the processed electronic individual antenatal medication passport plays an important role, which will prevent the occurrence of medication allergies in pregnant women and, in the future, in their children. That is why it would be most expedient to implement this Passport at the stage of pregnancy planning. This will allow predicting, preventing or reducing the risks of atypical reactions during pharmacotherapy of pregnant women and newborns.

The structure of the program of the electronic individual antenatal medication passport

The internal data of the Passport program are stored in the form of tables (that is, sets of homogeneous data), and the relationship between them is ensured by unique keys within each table. This type of data storage automatically ensures their integrity, and even if some data is deleted, the DBMS cascades data deletion from other tables related to the deleted data by checking the record keys.

The data is stored in the following tables:

- Table of users (doctors). Table records contain data about doctors: login data, user type – gynecologist/family doctor, passport data, etc., and keys that identify them in the database and those to which the corresponding records from the patient tables refer.

- Table of female patients. Table records contain data about patients: system data, namely the key and password for connecting to the record of the family doctor who will observe her after the birth of

the child, and the patient's passport data, as well as keys that point through the intermediate table to treating doctors, and keys that are identified in the database and referred to by the relevant records of the tables of children, examinations and appointments.

- Table of children. It is practically identical to the table of patients, but, unlike it, the table of children is not tied to doctors, but to the mother (it also contains a key, but direct), which allows you to observe the condition of the patient and her children in a complex manner.
- Examination and prescription tables. The records contain data on the results of examinations depending on the type of examination and purpose, respectively, keys indicating the patients and keys identifying them in the database.

There are several of the latter tables, depending on the type of examination (allergological anamnesis, serological studies, etc.). If necessary, you can also add new tables without significant modification of the program code. These data are presented in separate tables, because patients and children can have several of them at different times, and only one set of data can be stored directly in the table. All such databases are duplicated for patients and children with foreign keys referring to the corresponding tables. The possibility of adding new data without losing thr existing data is due to the fact that relative databases store the key of binding to another table (the so-called "foreign" key) in the linked table itself, and if new tables with new patients are added, then existing patients simply will not have these surveys, but the integrity of the data will not be compromised.

Prescriptions are stored in two standard tables (separately for patients and their children), which makes it possible to add an unlimited number of them for each, both for the patient and for each individual child, while practically not slowing down the work of the database, which is critical for the speed of the whole Passport programs.

Three types of relationships between tables are provided: "one-to-one", "one-to-many", and the synthetic "many-to-many" relationship. The latter is provided using an additional relationship table with two foreign keys. This type of communication is applied to the communication between doctors and patients, which allows the transfer of access from the gynecologist to the family doctor, who can read the data filled by the gynecologist and supplement it with their own data. Such transfer is carried out using a unique key and password, which is part of the patient's record data. Children, unlike patients, are bound by a direct "one-to-many relationship", because a child can belong to only one patient (mother).

A "many-to-many" relationship is essentially a pair of "one-to-many" relationships. One patient record is linked to many contact records. Each doctor record is linked to many relationship records through the corresponding foreign keys in those records and thus we end up with two-way relationships where records that are linked to one relationship record become like a relationship connected, although there is no real direct connection between them.

The doctor is identified using an e-mail address. This type of identification is generally accepted in web-based services, because it is sufficiently reliable and at the same time significantly reduces the number of unusual situations related to the human factor, because most users forget only the password, and not the login and password at the same time, as is the case with unique logins. Internal identification, which is, in essence, application, is carried out using the field of the doctor's name. Such internal identification is not technically feasible, but it allows avoiding situations when the doctor mistakenly enters data in a different login.

Built-in DBMS tools are used to provide search, selection and sorting of the received data. Extremely fast searching and sorting are also ensured, since the database contains an alphabetical index of surnames, which is replenished at the time of adding a new patient. This software solution is convenient, fast and has the ability to scale by adding new data to existing tables and / or new tables, which will make the program more informative, adapt it to future changes in the industry, and raise the level of the database used. All this will allow processing larger volumes of information and in the future will make it possible to create

reporting functions, such as the number and distribution of patients of a certain doctor or the relationship between certain prescriptions and the condition of patients and / or children, or many other generalized statistical data that can be useful in the analysis of medical practice in general and medical research based on the Passport program in particular.

Description of the functionality of the electronic individual antenatal medication passport

The Passport program provides for work in three different electronic offices for users according to the following roles: "Gynecologist", "Family Doctor" and "Patient". Let's consider how it works in stages and what functions the program performs for each of these users.

Electronic office of "Gynecologist" in the Passport program

1. A gynecologist registers in the system by choosing the role "Gynecologist" during registration. All fields are required to be filled in, but no verification is required, and in the future, at the next login, you only need to enter your email address and password (Figure 5).

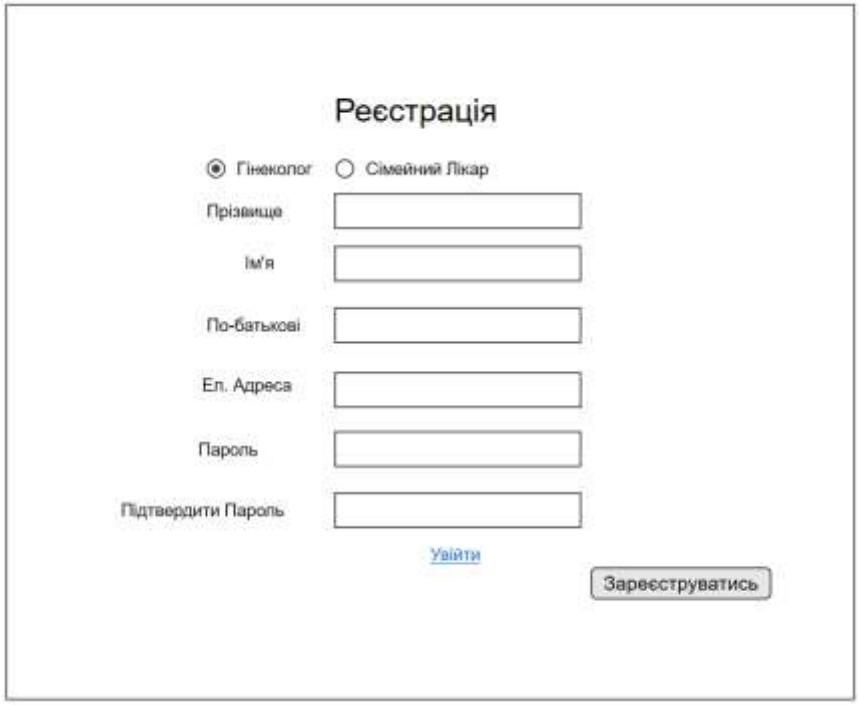


Figure 5. Registration page for physicians (gynecologist / family doctor) (in Ukrainian)
Source:developed by the authors

2. After registration, the physician goes to the List of patients page (Figure 6). When patients have been added, he sees the list sorted by last name: Surname, first name, patronymic (SFP), date of birth. You can search for the right patient by last name. By clicking on Surname, we get to the page of an individual patient, where you can add data about the patient or delete him from the system.

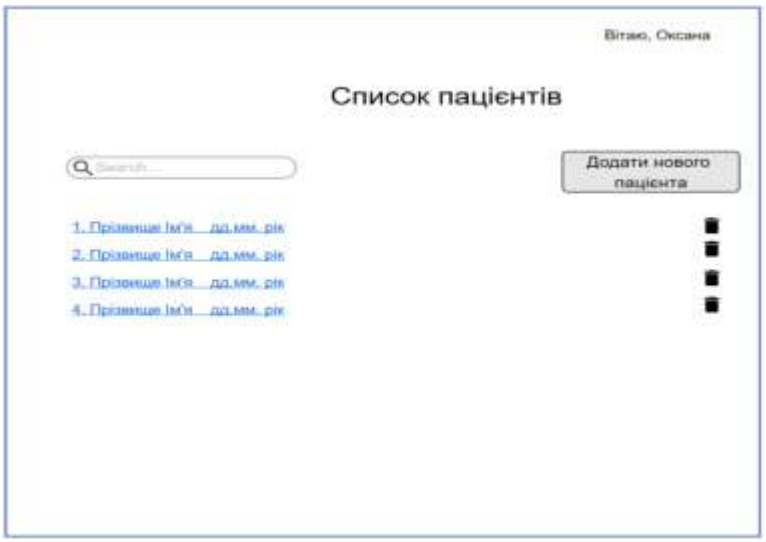


Figure 6. Patient list page physician's office in the Passport program(in Ukrainian)
Source:developed by the authors

3. In order to create a new patient's data, click the "Add a new patient" button and enter the primary data in the pop-up window: SFP and date of birth. After clicking the "Save" button, we get to the "Patient details in editing mode" page. The system must generate a unique KEY and PASSWORD for a specific patient. An example is shown in Figure 7.

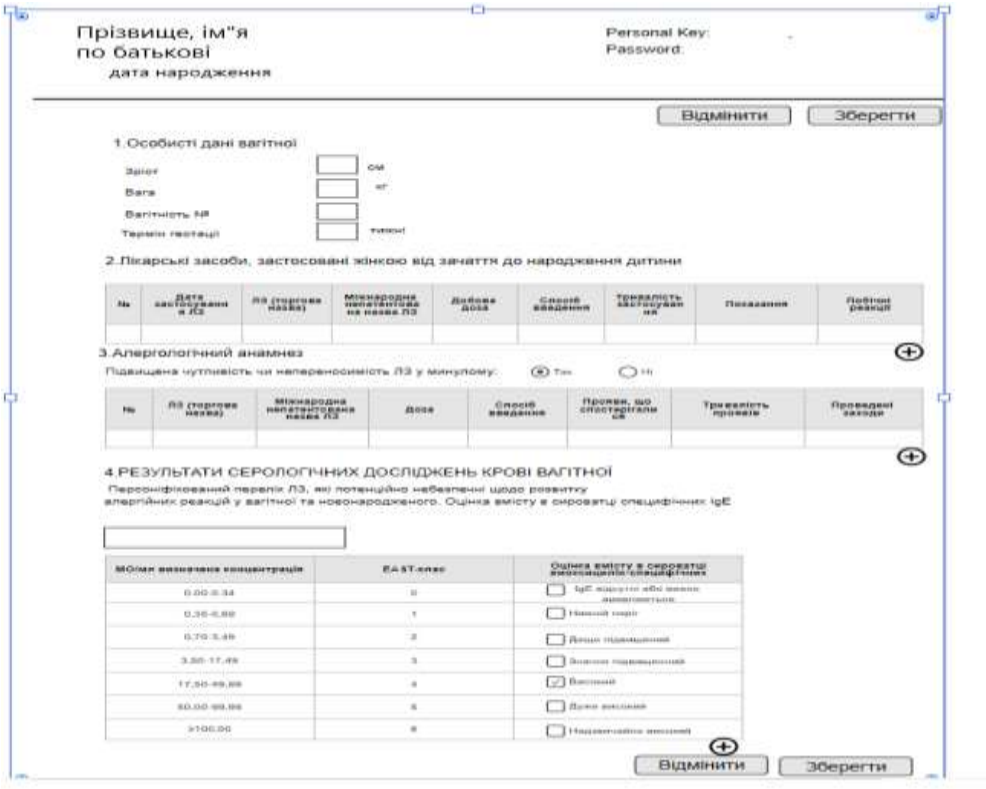


Figure 7. Patient data editing page in gynecologist's office(in Ukrainian)
Source: developed by the authors

On the patient editing page, the doctor enters the personal data of the pregnant woman (height, weight, number of pregnancy and gestation period) in numerical format in item 1.

In items 2 "Medicines used by a woman from conception to childbirth" and 3 "Allergological anamnesis" all data is entered in any format and language (words, numbers, signs). By clicking on the "+" icon, you can add the required number of lines in the table.

Item 4 "Results of serological blood tests of the pregnant woman" has a separate line for a personalized list of drugs that are potentially dangerous for the development of allergic reactions in a pregnant woman and a newborn. The number of such lines can be increased by clicking on "+". Also, in item 4 there is a table "Estimation of the specific IgE content in the serum", where it is only necessary to note the determined concentration of IgE.

4. After saving the entered parameters of the patient, we get into the patient data viewing mode (Figure 8).
If the user has selected the option "No" for item 3 "Allergological anamnesis", the table will not be displayed. In item 4, only the name of the drug entered in the line and the line with the IgE concentration selected from the table will be visible. If no row was selected, the table will not be visible.

In this window, you can choose 3 options: by pressing the "Back" button – we get to the "List of patients" page, by pressing the "Edit" button – we get to the "Edit details" page, by pressing the "Delete" button – we see the message "Do you really want to delete...", after confirming which, you can delete all patient data if necessary.

Electronic office of "Family doctor" in the Passport program

1. A family doctor (GP) is registered in the system in the same way as a gynecologist, only by choosing the role "Family doctor". Later, you log in using your email address and password.

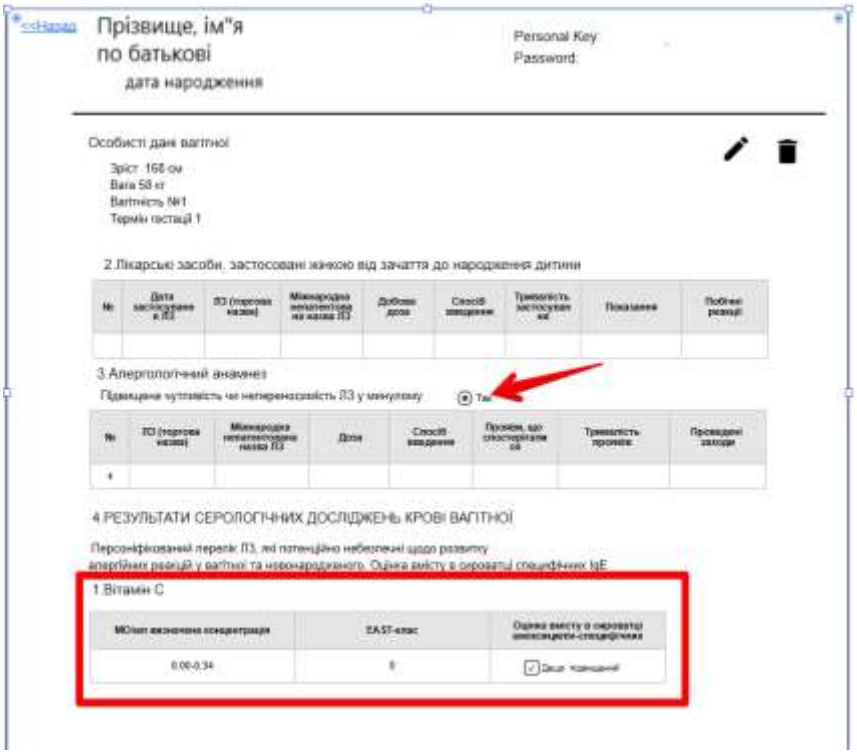


Figure 8. Patient data entry page in gynecologist's office(in Ukrainian)
Source:developed by the authors

2. After logging in, the GP gets to the "List of patients" page, which will be empty at the first login. When patients have been added, the page displays a list sorted by last name. To speed up the search, you can search for the required patient by last name in the "Search" line.

3. When adding a new patient, the family doctor must enter the patient's key and password, which were already generated by the gynecologist and given to the patient. After these data have been entered, the family doctor sees the page of the patient, which was filled out by the gynecologist, in the viewing mode, but the "Add a child" button appears for the family doctor (Figure 9).

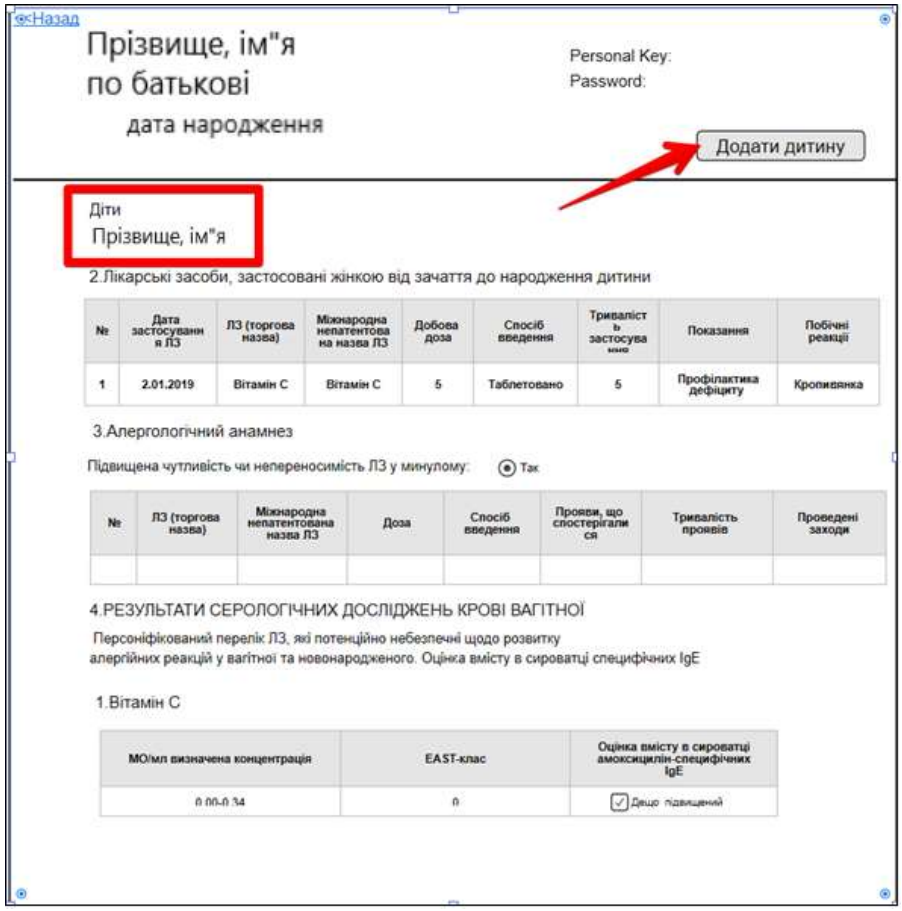


Figure 9. Patient page view window in the family doctor's office(in Ukrainian)
Source:developed by the authors

4. To add a new child, the doctor must first enter the child's social security number and date of birth. After pressing the "Save" button, the window for editing the child's data will open (Figure 10).

5. GP must enter personal data of the child: height and weight in numerical format, age will be calculated automatically. In the "Medicines administered to the child since birth" table enter all information about drugs. If necessary, the number of rows in the table can be increased by pressing "+".

6. After pressing "Save" we get to the "Details of the child in viewing mode" page (Figure 11). On this page, by pressing "Edit" – we return to editing mode, by pressing the mother's name – we get to the mother's page, while the "Back" button returns to the list of patients.

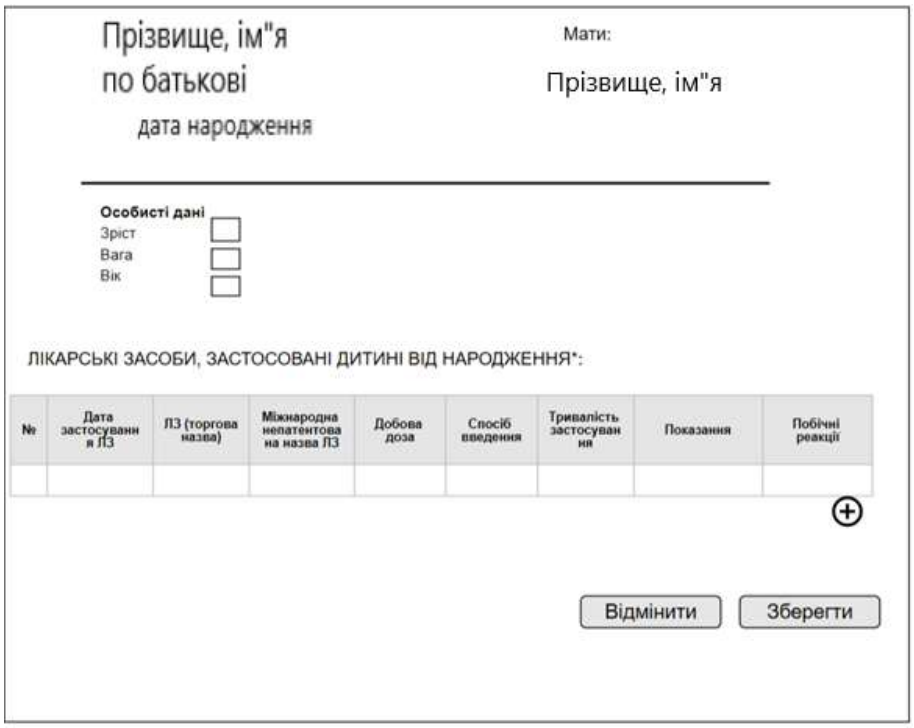


Figure 10. Window for editing the child's data in GP's office in the Passport program(in Ukrainian)
Source:developed by the authors

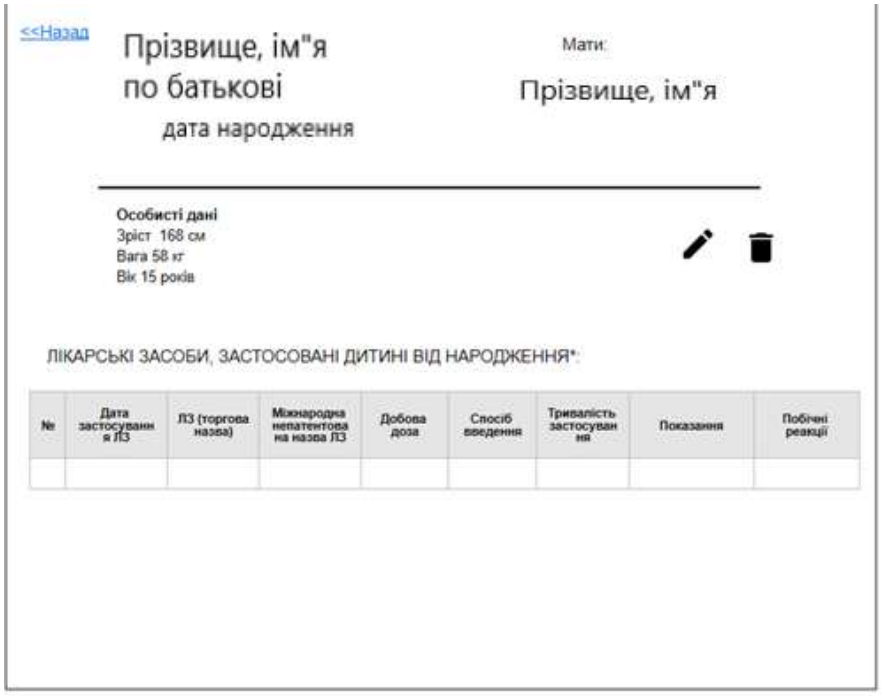


Figure 11. A child's page in viewing mode in family doctor's office(in Ukrainian)
Source:developed by the authors

7. When the child was added, the SFP and date of birth of the child appear in the patient list in the family doctor's office and on the mother's page, following her data.

Electronic office of "Patient" in the Passport program

1. The patient can enter the system using the key and password generated for him by the gynecologist.

2. After entering their office in the Passport program, the patient sees a page with information about herself and the child in viewing mode (Figure 12). Information about the patient includes 3 blocks: "Medicines administered to the woman from conception to the birth of the child", "Allergological anamnesis", "Results of serological blood tests of the pregnant woman". The child's data contains one block "Medicines administered to the child since birth".

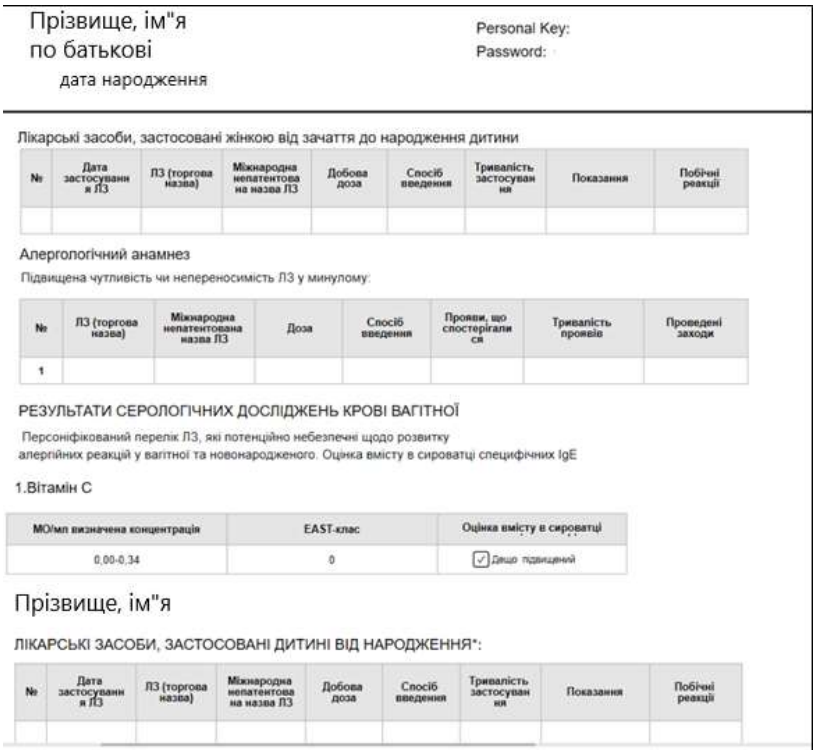


Figure 12. Window of the patient's office in the Passport program(in Ukrainian)
Source:developed by the authors

If there are several children, the patient will see the SFP and date of birth of each child, and for each there will be a table of the "Medicines administered to the child since birth" block. Thus, the introduction of an electronic individual antenatal medication passport, which contains all the information about the medicines taken by the pregnant woman during the entire gestational period, as well as the results of tests of specific immunoglobulins in the blood serum, will allow predicting and preventing the development of allergic reactions in the child. In the future, this electronic document can be used for pharmacotherapy records and can be attached to the patient's electronic medical record or function as an independent electronic document throughout life.

The use of the Electronic Individual Antenatal Medication Passport will allow one to avoid a complicated course of pregnancy by predicting and reducing the risks of atypical reactions during pharmacotherapy of pregnant women and newborns. In obstetric practice, this will allow to identify women at risk.

"Medical Intelligence" Software Using Artificial Intelligence Technologies

The concept of a medical expert system with the use of artificial intelligence technologies, which is called "Medical Intelligence" (MI) software, outlines a system for selecting optimal solutions for given tasks based on experts' assessments. This software finds the optimal solution with maximum positive consequences for the assigned tasks, at the same time, the found solutions do not have collateral negative consequences, or such consequences are minimal if the given task has a very high priority (Figure 13).

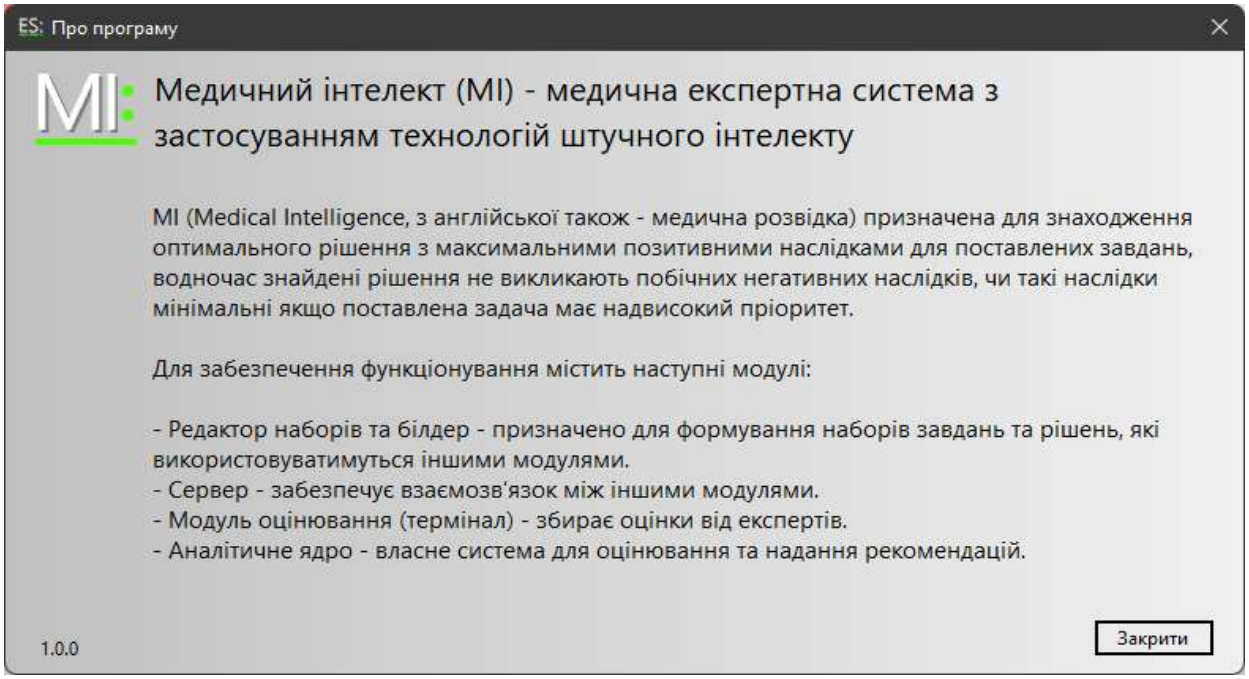


Figure 13. Modules of the "Medical Intelligence" software (in Ukrainian)
Source:developed by the authors

To ensure functionality, which is described in more detail in the second section, the following four modules are provided:

- Set editor and builder
- Server
- Evaluation module (terminal)
- Analyticalcore.

The functioning of the "Medical Intelligence" software begins with the creation of sets: left (task) and right (solution). These sets are structurally equivalent arrays of "facts". A data set of the core of the software is created from two sets via a builder (an editor/tool/system for rapid development of application software) (Figure 14).

Figure 14. The structure of sets for the MI software functionality
Source:developed by the authors

In fact, this set is not yet complete, because it does not contain evaluations. The evaluations will be added to it in the form of five-member aggregates identified by pairs of GUID structures. This approach avoids processing extremely large data sets, i.e. increasing the number of evaluations requires a fixed volume of data instead of a progressively growing one. This results in an approximate ratio of 72 bytes for the first and all subsequent evaluations of the problem-solution pair instead of 17 bytes for each evaluation without aggregation, meaning that all evaluations from the 5th onwards do not require additional resources. These calculations do not take into account the auxiliary structures required for processing, but the ratio is similar for them, and the actual sizes are dependent on the computing platform - 32 or 64 bits. Although MI is functional in 32-bit mode, it is worth giving preference to 64-bit, because due to the internal optimization of the framework used, it consumes a little more memory, but it works much faster, especially on large volumes of data.

This approach allows the processing of large volumes of evaluations ("big data") using ordinary household personal computers (PCs) instead of specialized computing machines.

Communication between parts is provided by request messages, which remain as modules in shared folders. The advantage of this type of data exchange is that it does not require additional facilities such as a database server. Within the local network, it is provided by the relevant services of the operating system, and to implement communication at the global level, you can use any tools such as Google Drive or Microsoft OneDrive without modifying the protocols or its clients. For example, the Terminal records data into a folder synchronized with the Google server, which in turn synchronizes it with another PC where the software server is located, which similarly sends it to the analytical core for further processing. At the current stage, data security is ensured by internal obfuscation (code obfuscation: bringing the source code or executable software code to a form that preserves its functionality but complicates analysis), but if necessary, you can add an encryption layer - a crypto provider.

Such data transfer allows all modules to work autonomously. If the server is inactive, then the generated requests will simply wait for it on a file-sharing server or disk in the local network. Processing of requests is carried out by the batch method when the module is launched, that is, the server performs all operations for which requests came at the time of startup, and in the future works in the mode of managing related modules. Each request has its own GUID, which eliminates the possibility of repeated processing of requests. Processed requests are mostly deleted, although any number of modules can be linked, and adequate performance can be provided for up to 200-300 modules in a single dropbox. However, with a further increase in the number of requests, a noticeable degradation of the system's performance will probably occur. In order to prevent this, it is necessary to create separate server-module groups (Figure 15).

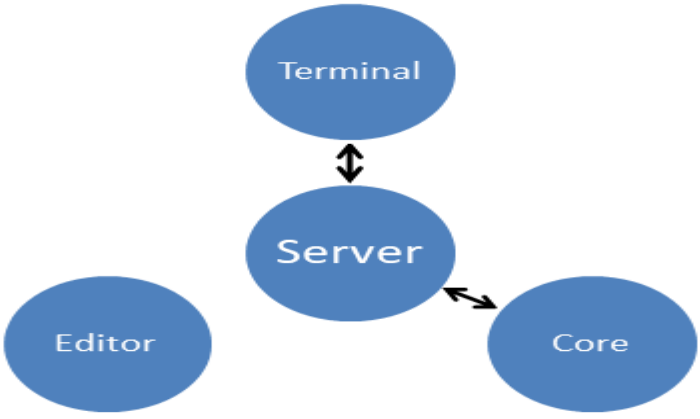


Figure 15. Server-module groups of the MI software
Source: developed by the authors

As can be seen from the diagram, the protocol operates between modules through the server but does not connect the server and the editor, the data transfer generated by the editor is a one-time process and therefore not automated in order to reduce the volume of message exchange.

Due to the uniqueness of identifiers, data can be arbitrarily merged and new ones can be added endlessly with the guarantee that there will be no conflicts between them and existing ones. Such an exchange scheme also allows exchange between a theoretically unlimited number of modules. In parallel, it is also possible to transfer data in the form of binary files, for example, to send evaluation sets and receive evaluations back via e-mail of survey services such as Google Forms.

The administrator includes the sets generated by the editor (builder) in the server data, which are then distributed among the connected terminals, the terminals in turn collect the user's evaluations and send them to the server. The server transmits the collected data to the core for further secondary aggregation, the result of which are recommendations for certain decisions.

The MI software uses DotNET 6, the current LTS (Long Time Support) version for the core libraries, and the WinForms subsystem for the user interface. PC system requirements are listed in Table 1.

Table 1. PC system requirements to work with the MI software

	Required	**Recommended**
OS	Windows 7 SP1, Windows 8.1	Windows 10 Version 1607+, Windows 11 Version 22000+
Architecture	x86	x64, Arm64
Hardware	According to the requirements of the operating system	
Optional		1080p monitor or better

Source: developed by the authors

It is possible to use Windows 7 operating system (OS), but this version may not be supported depending on the updates, so its use is not recommended. The best option is Windows 10 or Windows 11. Direct work in the "Medical Intelligence" software begins with the formation of sets in the set editor (Figure 16).

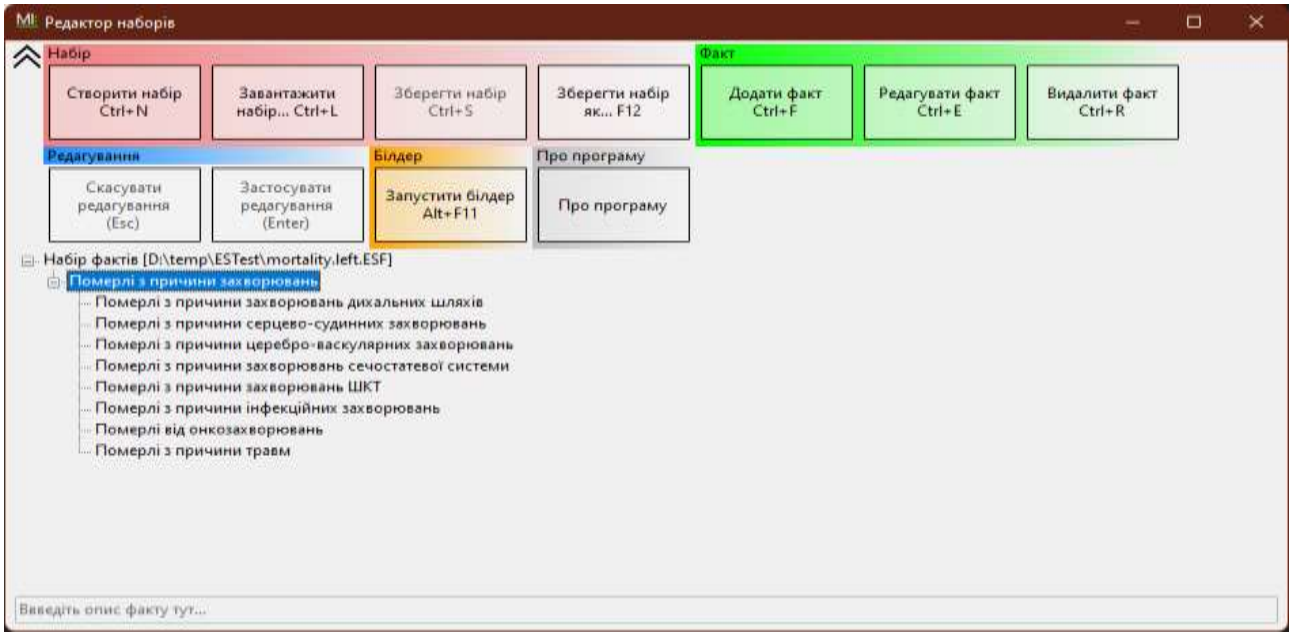


Figure 16. MI software set editor (in Ukrainian)
Source: developed by the authors

Select the necessary editor command:

- "Create a set" - designed to createanemptyset.
- "Load set" - to load thesetfromdisk.

These two commands are destructive, that is, they destroy previously made changes. Therefore, if there are unsaved changes in the current set, you will be prompted to write them to disk.
"Save set" - saves the set to disk. However, the command will not be available until the set has a file name, so the first save must be done with the "Save set as..." command.
"Save set as" - saves the set to disk after asking for a file name.
Next, we add facts to the set.
The "Add fact" function adds a new fact or facts to the selected node. We add facts from a pre-formed database. The figure shows an example of adding a set of facts "Died due to diseases".
"Edit fact" - changes the short description of the selected fact.
"Delete fact" - deletes the selected fact, or all the facts contained in it, if it is nodal.
Facts can be edited using the "Undo Edit" and "Apply Edit" functions.
After adding all the facts, the next step is "Start the builder" - a function that puts the editor into the mode of building sets (Figure 17).

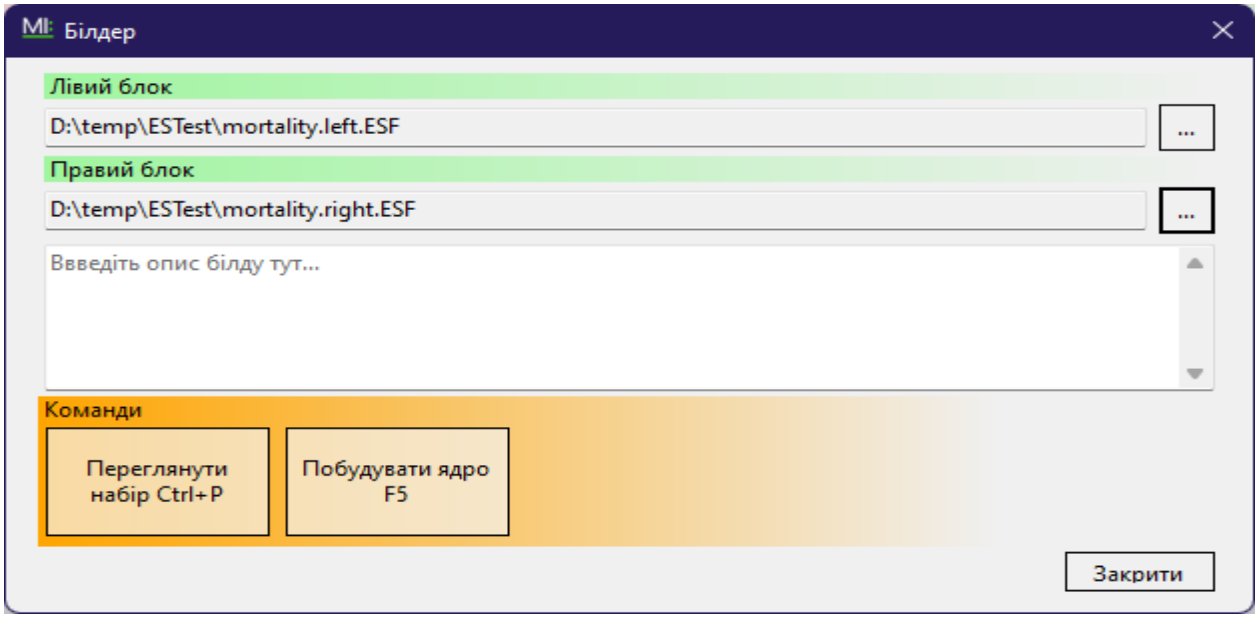


Figure 17. Mode of building sets in the builder of the MI software (in Ukrainian)
Source:developed by the authors

In the builder, you need to select the right and left parts of the set and enter a short description of the future core, and then save it, that is, "Build the core", for which the appropriate command is used.
Next, the MI software automatically switches to server commands (Figure 18).
Server commands, like all others, are divided into colored groups, each of which is responsible for its own group of tasks.
The "Set" group (red) works with datasets generated in the editor; it is activated by selecting the datasets tab.
"Load set" - loads a data set for further processing.

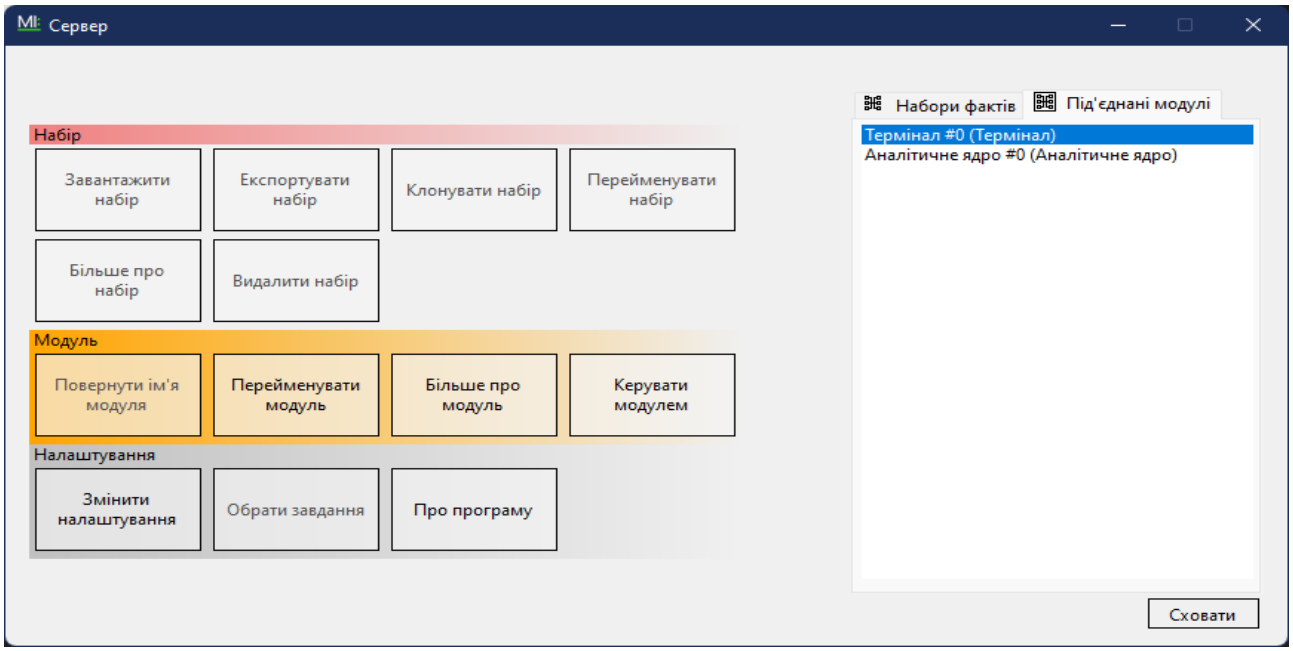


Figure 18. The server page in the MI software (in Ukrainian)
Source: developed by the authors

"Export a set" - writes an already downloaded set to disk, for example, to transfer it to another server.

"Clone set" - creates a visually identical copy, the data from which will not be mixed with the data of the original.
"Rename set" - gives the set a new name (short description), it should be noted that the renaming applies to future operations and the server interface, not already performed operations.

"Delete set" - deletes data from the server, but modules that have already received the set will continue to process it. The "Module" group (orange) works with connected modules and is activated by selecting the appropriate tab. Its main command is module management, which provides assignment and cancellation of tasks for the selected module. The "Settings" group (grey) is responsible for service settings. After entering all the necessary data on the server, you can proceed to the terminal, which shows the evaluated and unevaluated solutions to the given problem. The terminal collects evaluations and sends them to the server. Terminal commands need no further explanation.

As an example, show a part of the solution (only from the point of view of regulating the number of healthcare facilities) for the problem of reducing the number of deaths due to respiratory tract diseases. The MI software did not find significantly worse solutions (-2 points) in the "Evaluated solutions" part. Among the slightly worse solutions (-1 point) was the repurposing of healthcare facilities for other diseases, which will logically occur at the expense of healthcare facilities that treat respiratory tract diseases. So in order to solve the given problem, such a solution will lead to its deterioration. As solutions that will have no effect (0 points), the MI software indicated an increase in the number of healthcare facilities for the treatment of other diseases. A "slightly better" solution (+1 point) is to increase the total number of healthcare facilities and a "much better" solution (+2 points) is to increase the number of healthcare facilities that treat respiratory diseases and repurpose other facilities for these problems.

After the "Terminal" tab, you can go to the final page of the MI software, which is "Analytical Core" (Figure 19).

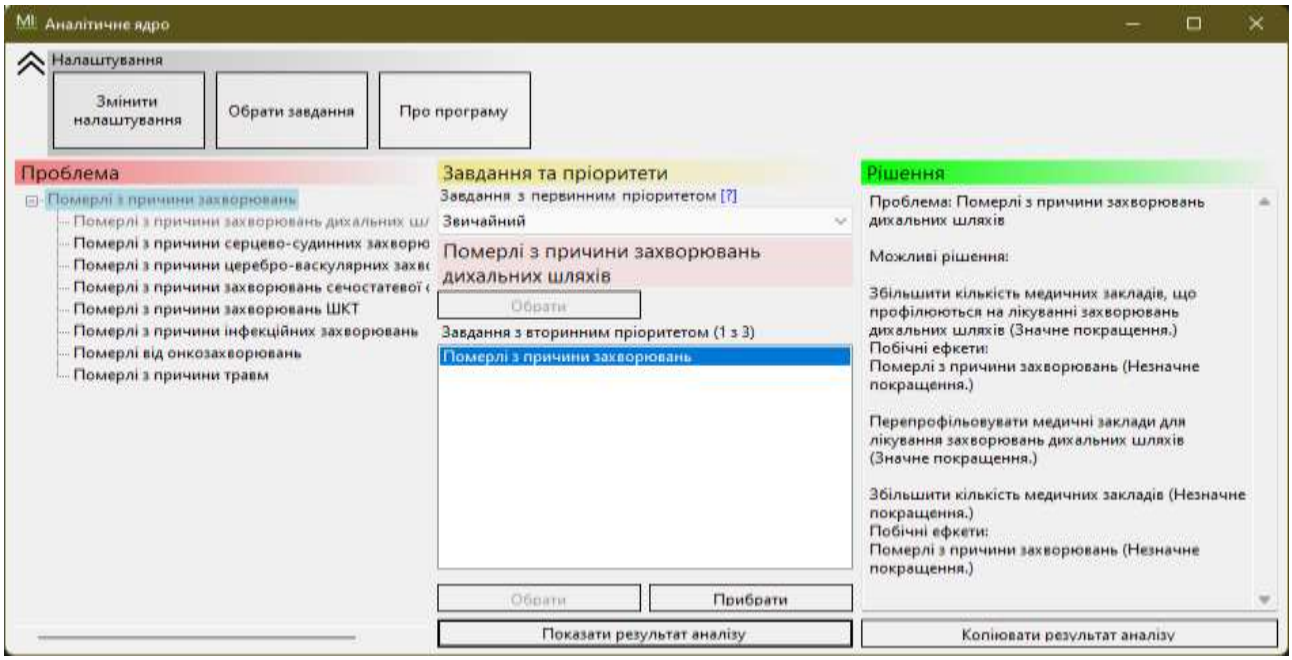


Figure 19. Analytical core of the MI software (in Ukrainian)
Source:developed by the authors

The illustration only partially reflects the operation of the analytical core, because a small amount of data is entered into the core only to display the general appearance of the results of the module.
A problem/task, its priority, and secondary priorities are selected in the analytical core, that is, tasks that should be given increased attention when solving them.
Priorities are allocated according to the damage to other related tasks if this cannot be avoided:

- "Super high" - the main task is achievedatanycost.
- "High" - minimal damage can be done to tasks with secondary priorityandanyothers.
- "Normal" - no damage can be done to tasks with secondary priority andminimaltoothers.
- "Low" - no damage can be donetoanytask.

Obtaining the results is almost instantaneous because in fact they are generated during the operation of the core itself, and only the final filtering and evaluation are carried out at this stage.

Fig. 8 shows as an example two tasks for solving the problems of mortality only at the expense of health care facilities (without taking into account other components, e.g. the number of medical workers, external factors, etc.): with the primary priority (ordinary) "Died due to diseases of the respiratory tract" and with the secondary priority "Died due to diseases". Possible solutions for the task with the priority would be:

- to increase the number of health care facilities that solve the problems of people with respiratory diseases (significant improvement), which will lead to a side effect: impact on the total number of deaths from diseases (slight improvement);

- repurpose the health care facilities for the treatment of respiratory diseases (significant improvement), which has no side effects on the second task;

- increase the total number of medical facilities (slight improvement) with the same side effect for the second task.

After receiving the results, the generated report can be copied to the clipboard for future use.

The "Medical Intelligence" software will enable to form a further individual educational developmental pattern for a doctor/pharmacist to deepen and expand knowledge in the specialty for the following years (short- and long-term). This software will allow the applicant to receive information about what exactly and why he should study, how much time and what resources he will need for this, and how the result of his studies will be evaluated. At the state level, this software can predict the future required number of doctors for each specialty and region, taking into account all force majeure circumstances, which will enable training the required number of doctors in time.

In order to study the practical implementation of the developed program, an expert assessment was conducted among scientific and pedagogical workers with a scientific degree of higher education institutions of Ukraine (n=30). According to the data of the expert assessment, 93.33±4.55% of experts consider the possibility of using the "Medical Intelligence" program when working on options for management decisions regarding the need for additional professional specialization courses, internships, training courses, webinars, conferences, etc., as well as forecasting the required number of students / doctors / pharmacists. Therefore, the use of "Medical Intelligence" software within the medical institution will reduce the burden on the administrative- management apparatus regarding the adoption of management decisions regarding the professional improvement of doctors and the calculation of the required number of medical personnel.

The effectiveness of any innovation in health care is characterized by the degree of achievement of generally recognized indicators of population health. However, like any system, it also involves financial costs, so it is important to calculate the economic efficiency of this program. To determine the general indicator of the economic efficiency of MI software, the "cost–effectiveness" method and the "cost–utility" method were used. According to the "cost–effectiveness" analysis, the use of the "Medical Intelligence" program for the implementation of an individual educational trajectory of a physician instead of the existing standard training for all will contribute to the increase of the efficiency of the physician's work, which in turn will lead to a decrease in morbidity, disability, mortality, reduction of cases and days of incapacity, lost years of potential life.

An assessment of the benefits of using the "Medical Intelligence" program at the state level using the "cost–utility" method demonstrates the growth of demographic indicators (birth rate, quality of life) that will affect GDP.

We also compared the comprehensive integral indicator of the economic efficiency of the implementation of "Medical Intelligence" software in 2 scenarios: inertial (without software implementation) and forced (after software implementation). Thus, the implementation of the program developed by us confirms the presence of economic efficiency (the value of the indicator is greater than one: 1.13), while in the absence of the introduction of changes, this indicator is 59% ($p<0.05$) lower and economically inefficient (the value of the indicator is less than one: 0.71) – *Table 2.*

Table 2. Data of the indicators of the complex integral indicator of economic efficiency in the inertial and forced scenario (%)

Indicators	Inertial scenario	Forced scenario
medical efficiency	0.87 (82%)	0.95 (95%)
social efficiency	0.82 (78%)	0.97 (97%)
cost ratio	100 (100%)	1.23 (123%)
A complex integral indicator of economic efficiency	**0.71 (71%)**	**1.13 (113%)**

Source: developed by the authors

The given indicators of both scenarios are presented under the condition of the current economic and political state of the country. If other additional elements appear, such as an economic crisis, a

default, a war, a new pandemic, etc., then there will be changes in the economic efficiency indicator accordingly. The "Medical Intelligence" program offered by us takes into account all elements of force majeure circumstances. Thus, the costs of medical education are investments into the creation of future income of the state in the form of saved funds for health care, which can be redirected to improve the quality of life of the country's citizens.

CONCLUSION

This chapter has reviewed the mobile phone applications and software to improve the efficiency of population health management, which is extremely important in the era of digitization of the healthcare system. The practical use of these applications will contribute to making informed decisions in clinical practice and management of a health care institution. In particular, Drug Compatibility Test Online Application aimed to prevent the negative influence of self-medication, can also be used for educational purposes in the training of specialists at all levels of higher medical education institutions. The program is free of charge and free for distribution under any conditions. Electronic Individual Antenatal Medication Passport will allow preventing the occurrence of medication allergies in pregnant women and newborns. This software plays an important role in modern obstetrics as preventative measure of pregnancy complications. It would be most expedient to implement this Passport at the stage of pregnancy planning.

"Medical Intelligence" Software Using Artificial Intelligence Technologies allows to form a further individual educational trajectory of a doctor / pharmacist to deepen and expand knowledge in the specialty for a short-term (1 year) and a long-term period (5 years). At the state level, this program can predict the future required number of doctors for each specialty and region, taking into account all force majeure circumstances, which allows training the required number of doctors in a timely manner.

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KEY TERMS AND DEFINITIONS

Clinical audit: A quality improvement process that seeks to improve patient care and outcomes through systematic review of care against explicit criteria and the implementation of change.

Crypto Provider: The implementation of encoding and decoding functions, which computer application programs may use, for example, to implement strong user authentication or for secure email.

CSV (Comma Separated Values): A file format that is a delimited format for representing tabular data that has fields/columns separated by the comma character and records/rows/lines separated by characters indicating a line break.

Management: A system of management subjects, management objects and management actions.

Medication Therapy Management: Management of adequate drug information flows with individual selection of the only correct one clinical decision justified on evidence-based medicine.

Phablet: A mobile device combining or straddling the size formats of smartphones and tablets.

Public Health: All organized measures (whether public or private) to prevent disease, promote health, and prolong life among the population as a whole.

Raw Data: The collection of information as gathered by the source before it has been further processed, cleaned or analyzed.