Technical University of Varna Annual Journal
https://doi.org/%2010.29114/ajtuv.vol7.iss1.283
Vol. 7 Issue 1 (2023)
Published: 2023-06-30
ISSN 2603-316X (Online)

Design and development of a system for processing drug prescriptions

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Abstract. *The paper describes a system for processing and issuing electronic medical prescriptions for drugs. The developed system facilitates the medical staff in writing prescriptions quickly, easily and effortlessly, displaying relevant references and an ability to aid patients in their medication consumption. The quality of medication intake is expected to improve with the implementation of a notification system.*

Keywords: electronic medical prescriptions, notification, medicines, patient, doctor

1 Introduction

Electronic prescribing (e-prescribing) systems are computer applications designed for use by clinicians to generate paper or electronic medication prescriptions. They offer the clinician and the patient the promise of safer prescribing and advanced office efficiencies, which are major drivers for the adoption of such systems **(Robert S. Gerstle; Christoph U. Lehmann, 2007**). E-prescribing systems enable electronic transmissions of prescriptions to pharmacies from the provider's office, greater patient safety by reducing the time gap between point of care and point of service, medication errors, and improved quality of care. (**Kannry J. MD, 2011**). The information system is a combination of information technology and the actions of medical personnel who prescribe treatment (medical prescriptions) according to the patient's needs. This type of system is mainly used by hospitals, providing the possibility to store the data in databases. Evaluation of electronic prescribing systems (EPS) can contribute to their quality assurance, motivating users and policy-makers to implement these systems, directly influencing the health of society **(Samadbeika M., Ahmadib M., Sadoughib F., Garavandc A.)**. The system provides an opportunity to process, analyze and extract useful information about a patient or a group of patients with similar diseases, identifying the causes, factors affecting different diseases and the way they should be cured or their development retarded. Proposed and validated benefits of e-prescribing include increased patient safety, reduced drug costs, increased access to patient prescription records, and improved pharmacy workflow.

The main advantages of electronic prescribing systems are:

- Patient Safety: The main priotiry is to ensure greater patient safety and prevention of prescription-related errors, selection of the wrong or out-of-stock drug, dosage errors, duplication of therapy, misinformation, and misinterpretation of the medication order due to illegible handwriting. Identifying these types of errors prior to the electronic prescription processing requires additional correspondence between the pharmacist and provider, which can delay patient care. Failure to identify drug allergies or drug interactions increases the likelihood of medication errors. There is a feature in e-prescribing software with on-site decision support that notifies physicians of potential errors and prompts the provider to check for allergies, confirm dosage accuracy, and identify drug-by-drug interactions before submitting the prescription **(Ducker, Sanchez, Taylor, 2013)**. Medication errors are an important factor that influences the quality of patient care. According to Barach et al., nearly 100,000 individuals per year in the US die of preventable medical errors (**Emmenwerth E., PhD, Schnell-Inderst P., PhD, Machan Ch., MSc, Siebert U., PhD, 2008**);
- Access to previous prescriptions: Electronic storage of prescription records is invaluable in situations where patient safety is at risk, such as natural disasters and drug recalls. Clinical benefits of e-prescribing have also been reported, including improved cholesterol goal attainment in a retrospective

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study of 796 patients. **(Ducker, Sanchez, Taylor, 2013)**. Moreover, the e-prescribing software can provide further information on the availability of lower cost medications and medically appropriate treatment alternatives **(Samadbeik M., Ahmadi M., Asanjan S. 2013, October 5)**;

- Improved workflow: Advantage for pharmacies. Electronic prescribing has been proved to optimise prescription processing and decrease waiting times as patients no longer need to be attended before their prescription is filled, and there is no need for manual entry of the prescription into the computer. Calls to the provider's office to clarify illegible orders have been eliminated, giving pharmacists more time to consult closely with patients. Available evidence confirms that increased pharmacist time spent counseling patients leads to a reduction in preventable adverse drug reactions. Additionally, extra safety, shorter wait times, expanded pharmacist counseling services, and reduced medication costs provide greater patient satisfaction with pharmacy care, resulting in patient retention and increased income. **Ducker, Sanchez, Taylor, 2013)**;
- E- prescribing enhances pharmacy efficiency. Undoubtedly, electronic delivery of the prescription eliminates the age-old problem of deciphering doctors' scribbling and enables the pharmacist to prepare the prescriptions with ease for patient pickup (**Salman J., Jiang R., 2012**).

Advanced in the present paper is an innovative design of a system for drug prescription, called Medican, which is originally developed by the authors. The main purpose of the system is to decrease the administrative work for pharmacists, doctors, and patients, with a mobile application providing easy access to patients' electronic medical prescriptions and notifying them to take their medicines from the active medical prescriptions. Each app is designed with the latest trends in UI and UX, and the system architecture consists of a database system, API, mobile application, doctor application, admin application, and notification system.

2 Exposition

Purpose: The present comprehensive database information system assists physicians in issuing electronic medical prescriptions and enables patients to receive timely updates about their medical prescriptions and notifications via their mobile devices. Users can access all their medical prescriptions, including the active ones, and receive notifications based on the prescribed intake. The development of this-information system was implemented with the help of essential program tools, means, and resources.

The information system includes the following levels of access:

– System Administrator;
– Medical person (doctor) to write medical prescriptions;
– Patient.

The information system contains information about:

– Patients;
– Medical prescription;
– Doctors;
– Medicines.

Conceptual model (see Fig. 1):

The system under consideration operates through a relational database comprised of seven tables, which is utilized by all the applications. The visibility and permissions for each table are built in a hierarchical way, with privilege levels being determined by the users currently logged into the system. The designed applications contain a common database that allows communication between different applications. The server, desktop, mobile application, application programming interface (API), and notification generation system uses the same database.

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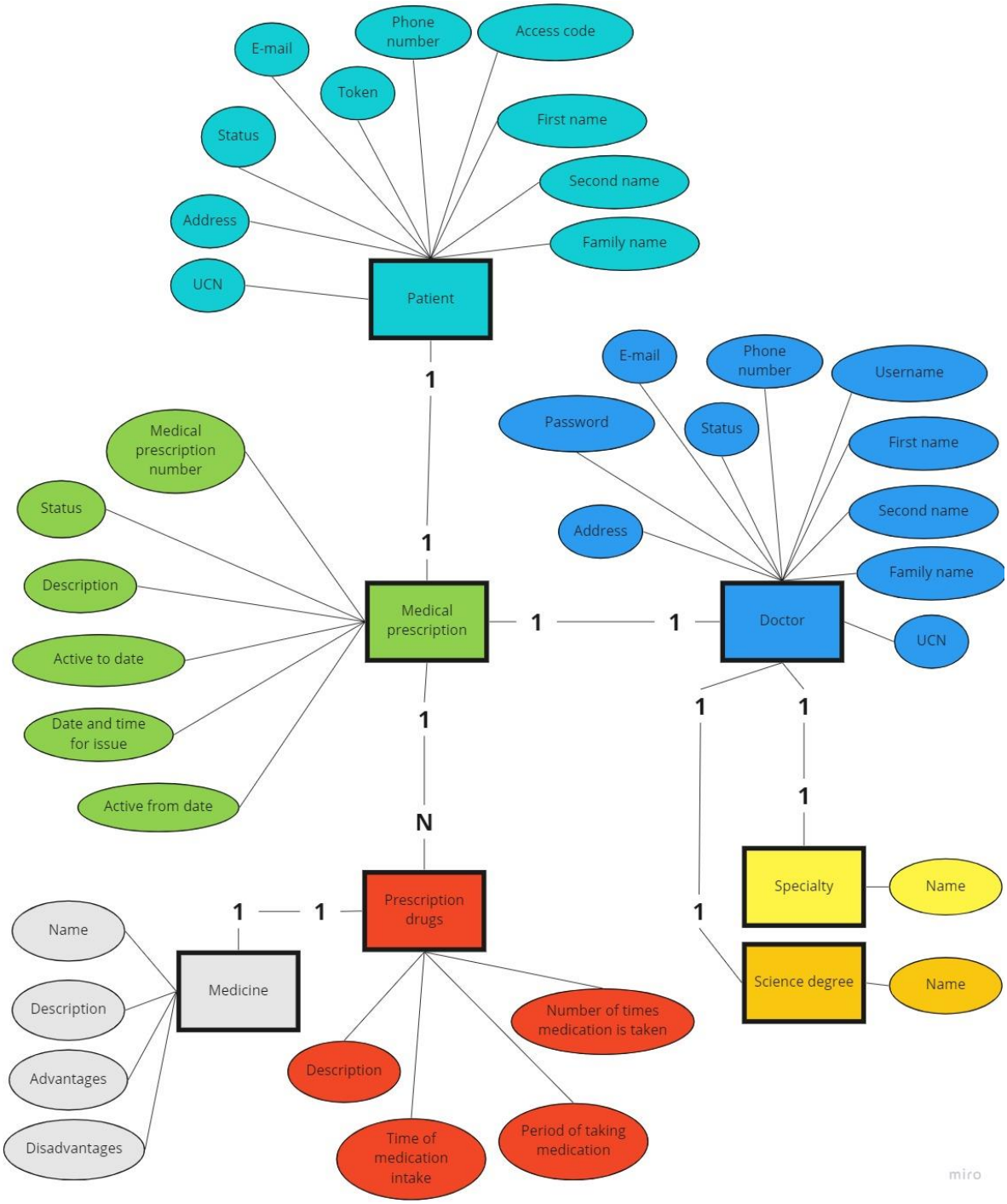

Fig. 1. Conceptual model

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The system is made up of five applications:

– Admin panel (Desktop application)

The administrator is the user with the highest level of privileges and for him all the functionalities of the system are available. This is the only user who can create a doctor profile and activate or deactivate the profiles of medical persons (doctors).

– Doctor application (Desktop application)

Once a doctor has been authenticated, they are able to issue electronic medical prescriptions. However, they have access to add new patients only. In the event that an existing patient forgets their key, a new one is generated to allow access to the mobile application.

– – Patient App (Mobile App)

The mobile application, provides patients with access to their currently written electronic medical prescriptions once they have successfully logged in. Patients are able to filter their electronic medical prescriptions using a variety of criteria, and can also edit their personal data such as their address, phone number and e-mail. The mobile application provides a notification function to remind patients when it is time to take their medication.

– Application Programming Interface (API) (**see Fig. 2**)

Since there is communication between patients and their mobile devices with the data that resides on the server, it is necessary to implement a server application, API, so that they can view and filter medical prescriptions, as well as edit their personal information.

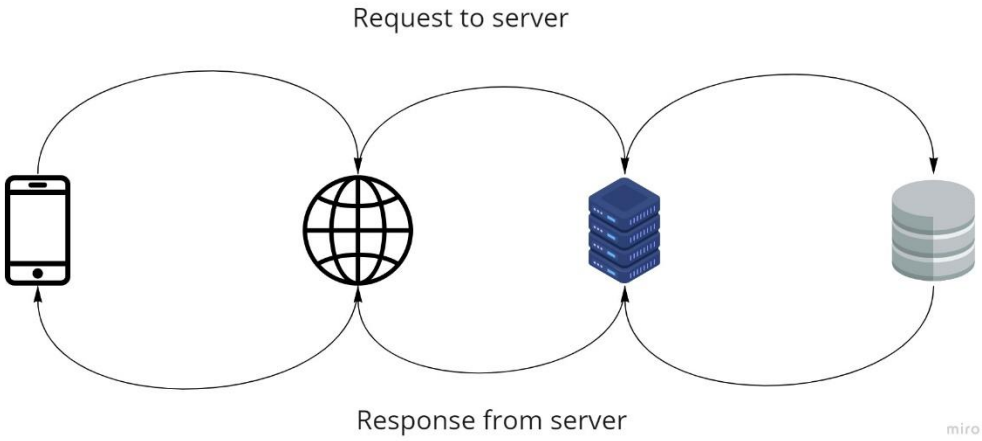

Fig 2. API action

– Notification generation system (**see Fig. 3**)

The notification generation system sends patients personalized medication reminder notifications for all their active prescriptions as of the current date. The sending of notifications is initiated by a server application (Fig. 3), which enables patients to receive notifications on their mobile devices, reminding them to take their medication at the exact time and minute set by the medical professional who issued the medical prescription. These notifications are received and processed by the dedicated Medican medical mobile application and more precisely by a dedicated class (Service). To utilize this system, patients must install the mobile application on their smartphone and log into their personal profile. Once logged in, the app sends a special token to the server to identify the patient. The notification system verifies that the patient is logged in and has an up-to-date token before initiating an action to send a notification to Google's Firebase system **(https://firebase.google.com/docs/cloud-messaging, 2022)**.

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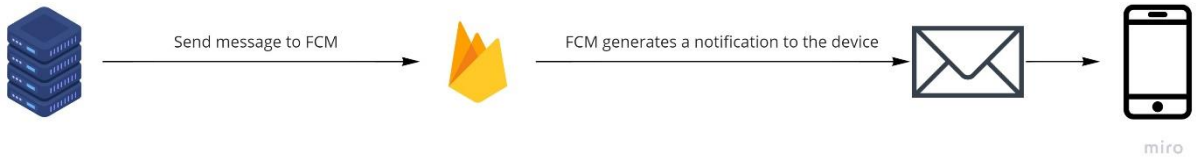

Fig 3. Notification system

Libraries used to implement the system:

– PHP Data Object (PDO) **(Mitchell, Lorna, 2016) (https://www.phptutorial.net/php-pdo/)**;

Data Sql Client **(https://docs.microsoft.com/en-us/dotnet/api/system.data.sqlclient?view=dotnet-plat ext-6.0) (Petkovic D., 2020) (Jones D., 2014)**;

– Country Validator **(https://github.com/anghelvalentin/CountryValidator, 2021)**;
– Font Awesome Sharp**(https://github.com/awesome-inc/FontAwesome.Sharp, 2022) (https://font-awesome.com/)**;

Icon8 Pichon **(https://crozdesk.com/software/icons8-app, 2022) (https://icons8.com/)**;

– Firebase Cloud Messaging (FCM) **(https://firebase.google.com/docs/cloud-messaging, 2022)**;
– Firebase Admin **(https://github.com/Firebase/firebase-admin-dotnet, 2022)**;
– Gson **(https://github.com/google/gson, 2022)**;
– Firebase Messaging Service;
– Volley **(https://google.github.io/volley/, 2022)**.

3 Experiments

Data validation

Data validation is performed in all applications:
- Administrator application
- Doctor application
- Mobile application for patients

In each data filling form, validation is performed according to the necessary criteria such as:
- Maximum length of the fields according to the lengths defined structurally in the database tables;
- Data validity check;
- Business logic.

API response rate

Another type of experiments after the implementation of the system was to check the response speed from the application programming interface (API), and the requests were generated using the mobile application.

Methods	Query to the database server	Response time, ms
GET	Request to the server to retrieve a list of active medical prescriptions	58.00 ms
GET	Request to server to retrieve medical prescription data	42.80 ms
GET	Request to the server to retrieve medical prescriptions for a specified period	195.40 ms
GET	GET request to the server to retrieve the patient's personal data	58.50 ms
POST	POST request to the server to set the patient's personal data	63.40 ms
POST	POST request to server to set patient token	40.10 ms

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Data protection

Protections such as SQL-injections **(https://portswigger.net/web-security/sql-injection, 2022)** brute-force attacks **(https://www.datto.com/blog/cybersecurity-101-intro-to-the-top-10-common-types-of-cybersecurity-attacks, 2022)** and others are implemented using additional software protection tools **(Fritchkey G., 2014)**.

Data security is a very important system because it stores personal data of patients and doctors. Data such as:

- Unified Civil Number (UCN);
- Password;
- Special key for access.

This type of data is not stored in its pure form.

App Testing with Feedback (User Survey)

Table 1. Feedback for Doctor's desktop application

Gender, Age, Specialty	Smartphone and computer technology skills	Feedback
Male, 23 years old, Medical student "Cardiologist"	Yes	The program is well designed. It is quite intuitive and provides quite good options. Everything becomes clear from the first opening of the medical prescription section. As a recommendation, it may be helpful to include the form in which the medication will be taken (example: tablets, liquid, injections, etc.)

Tested by people at a younger age (15-44 years)

Table 2. Application feedback for mobile application for young patients.

Gender, Age, Specialty	Smartphone and computer technology skills	Feedback
Female, 23 years old, Water Transport Management student	Yes	"The design is clean and every user can easily and pleasantly navigate their choice. The status of the recipe is clearly and distinctly expressed, by means of a bright color that attracts attention and gives a clear answer to the question of whether the recipe is "Active" or "Inactive". The window that pops up while loading is a great idea. It provides the user with visual information about what is happening and that they need to wait for a while to be able to continue with the next action. In the "Profile" section, the different fields are well demarcated, which provides clarity as to which field is for which purpose."

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Male, 21 years old, Student in Computer Sciences	Yes	Pretty well structured interface. Minimalistic design providing quite intuitive actions. I don't think there will be a user who gets confused about what to do regardless of their age. The module with the generation of notifications is a very good idea and the notifications are quite well designed, as content they carry quite a lot of information. The recipe review is pretty clean and informative. The description is hidden, but it is colored like a link and it is visualized quite well, and only when you want to view it, you click on it so that it does not fill the screen with unnecessary information, which is quite clever. Well done!
Male, 22 years old, Student in Cyber security	Yes	I have no remarks and recommendations. Everything is just presented in a very good way.
Male, 23 years old, Medical student "General Practitioner"	Yes	Everything is very useful as an idea and we like it very much, only the only recommendation is that when the medical prescription is opened, it should show in detail with a picture or text what form the medicine will be taken in (tablets, liquid, syringe, etc.)

Tested by people of middle (mature) age (45-59 years)

Table 3. Application feedback for a mobile application for middle-aged patients.

Gender, Age, Specialty	**Smartphone and computer technology skills**	**Feedback**
Female, 51 years old, Unemployed	Yes	The phone app is very convenient. Medication reminder is very convenient for everyone regardless of age. Editing personal data is good because the patient will be able to keep it up to date. The filtering part of medical prescriptions is very convenient, you can look through old prescriptions, which is great.
Male, 56 years old, Driver of a special fire truck	Yes	The colors are pleasant and soft, not obtrusive. It's nice to have a contact for feedback in case of a problem. It's nice that you can see exactly which medicine can be taken when, and what its description is.

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Tested by old people (elderly age) (75 - 89 years)

Table 4. Application feedback for mobile app for elderly patients.

Gender, Age, Specialty	Smartphone and computer technology skills	Feedback
Female, 82 years old, Pensioner	No	There aren't many buttons. There is a contrast in the colors. It was easy to navigate where to click and find the recipes. The thing where it sends notifications is really nice, especially for people like me who forget to take their meds.

4 Conclusions

Advanced in the present paper is an information system for processing drug prescriptions. The system is designed to provide robust information security against known cyber-attack methods. The software allows for easy visualization of references of medical prescriptions for both patients and medical professionals (doctors). The mobile application provides a medication notification feature, which is very convenient for all age groups, and especially useful for patients with memory- related illnesses.

One of the primary objectives of the e-prescription system is to simplify the process for patients with chronic diseases who no longer need to visit their health center every time they require medication renewal. This has reduced the number of administrative appointments by as much as 60% and has also centralized all the medications received by patients in a single health card, thus, enhancing safety by avoiding duplication, incompatibility and possible allergic reactions, while also reducing errors since prescriptions are now perfectly legible, complete and in a standardized format **(Guijarro A., Guijarro E., Bailén M., Hernando A., 2022)**. The Estonian e-prescription service has very high usability and user satisfaction scores. From a public administration perspective, the implementation of e-prescription has led to potential efficiency gains (**Parv L., Kruus P. Motte K., Ross P. 2014**). In 2010, in Bulgaria the first pilot for E-Prescription system took place in two villages where 10 GPs were linked with pharmacies; however a larger scaled pilot was not followed up. In 2011, the Bulgarian Ministry of Health received approximately €5 million for the project to develop an Integrated Health Information System (IHIS) which involves the creation and implementation of an electronic prescription and an electronic patient record over a period of 27 months (**Kierkegaard P. 2012**).

Despite the available functionalities, the system can be improved and developed with the following developments:

1. Doctor application:

- Patient reference output in PDF format;
- Chat with a patient;
- Send notifications by headings for better health;
- When creating a prescription, send a notification to the mobile application, email, electronic prescription (QR code to scan and output a PDF copy of the prescription);
- To indicate an incompatibility for a medication.

2. Mobile application

- To show incompatibility for a medication, if for some reason the medical person missed or did not pay attention when issuing the electronic medical prescription;
- Icon of the type of medication (pill, injection, etc.);
- Chat with a doctor, consultation type;

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- Blog "How to take care of our health?", which contains useful tips and exercises tailored to each patient's specific diagnosis or disease;
- Different views of the mobile application for different age groups in order to make it easier for patients to use the mobile application, and the age group will be identified by the patient's Unified Civil Number (UCN) or the feature will be optional and can be selected by the user of the mobile application;
- Ability to monitor medication intake by caregivers, relatives and other persons;
- - Reserving an appointment for an examination in a hospital facility.

3. Integration of an Artificial Intelligence (AI) module

- The model will allow for the prediction of possible diseases based on all patient examinations, enabling early detection and prevention of diseases with appropriate types of therapies. The module has been developed to enhance patient care and improve health outcomes.

Acknowledgement

The research, the results of which are presented in this publication, were carried out on a project NP3 "Research of models for management of processes for effective transition to an economy, based on 6G networks" within the framework of the scientific activity at Technical University of Varna, financed by the state budget.

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