Internet System Supporting the Work of Nurses in Long-Term Geriatric Care

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Abstract. The development of health sciences along with the continuous technological progress contribute to the emergence of web applications. There exist many applications supporting the work of doctors, whereas the market definitely lacks solutions supporting the work of nurses. This is particularly evident in long-term geriatric home care, in which the nursing specialization is developing rapidly. Care of elderly patients requires the nurse to collect medical documents from each visit. Considering the large number of diseases affecting elderly people and the number of required visits – which should exceed 4 a week – a decision was made to develop an Internet application supporting the work of nurses in long-term geriatric care. The application facilitates the process of geriatric patient description in order to eliminate the need for filling in paper medical records. This study presents the method of developing an Internet application supporting the work of nurses in long-term geriatric care. The software was developed based on an analysis of conclusions from a social study carried out in a group of 42 nurses providing geriatric long-term home medical care services in the district of Białystok, Poland. The aim of the study was to determine the features, functionality, and declarative interest in using the software. Conclusions from the analysis indicated that the attempt to develop the application had been justified. Moreover, conclusions from the social survey formed the basis for formulating the design assumptions. The web application was developed in the following technologies: HTML 5, CSS3, JavaScript, PHP 7, and MySQL. First, a prototype of the solution was tested in a XAMPP environment. After successful tests, the app was tested in a nursing practice. The obtained test results raise high hopes for potential commercialization of the application.

Introduction

According to United Nations estimates, in 2020 there were approximately 727 million people over 65 years of age worldwide (United Nations, 2020). The age of 65 is considered to be the conventional old age limit (Adamczyk, 2017). It is predicted that by 2050 this number will more

than double (United Nations, 2020). This means that by the middle of the century, every sixth person in the world will be 65 or older (United Nations, 2020). This will give the share of older people in the world population at the level of 16% (in 2020 it was 9.3%) (United Nations, 2020).

As the number of elderly people increases, so does life expectancy. Roser and Ortiz-Ospina state that the life expectancy index is a key measure of population health assessment (Roser et al., 2013). According to the researchers, the key advantage of this indicator is that it operates on mortality throughout the life cycle, rather than on infant and child mortality (Roser et al., 2013). With the use of the life expectancy index, the average age of death in the population can be determined. Life expectancy has increased steadily over the past centuries. Currently, no country in the world has a lower life expectancy than the countries with the highest life expectancy in 1800 (Roser et al., 2013). Additionally, for the first time in history, the majority of the world's population can expect to cross the age of 60 (United Nations, 2020). Inequality in life expectancy varies significantly between high, middle, and low developed countries. For example, the average life expectancy in Japan in 2021 is 84 years (28% of older people), while in the Central African Republic it is 53 years (Roser et al., 2013; United Nations, 2021; World Bank, 2020). According to the data of the Central Statistical Office of Poland, the average life expectancy in Poland in 2020 was 72.6 years for men and 80.7 years for women (Główny Urząd Statystyczny, 2021). The higher life expectancy of Polish women is in line with the global trend.

The increasing trend in life expectancy is the result of changes over the past decades. Containment of many infectious diseases, enrichment and diversification of diet, dissemination of health care, and improvement of the average standard of living have all significantly influenced the demographic structure of the world population (Adamczyk, 2017; Iwański, 2016; Stuart-Hamilton, 2006; United Nations, 2020). Changes in the age structure mean that the number of people of reproductive age will systematically decline. An aging society will require more and more care and support, which will undoubtedly translate into an increase in the demand for various types of health services, including care and treatment (Polak et al., 2007). In 2019, the average waiting time for a place in a geriatric care and treatment institution was 6 months (Narodowy Fundusz Zdrowia, 2020). Additionally, there were only 1.5 hospital beds per 100,000 geriatric patients (Główny Urząd Statystyczny, 2020). The healthcare system's response is increased funding for long-term home care, for example through the "Opieka 75+" program.

The aging of the population is a huge challenge. However, it also creates many opportunities for the development of science and technology. The dynamic development of computers and broadband Internet significantly contributed to the popularization and increase in the level of advancement of digital technologies. The medical applications market offers a number of solutions supporting the work of doctors, while definitely lacking in solutions supporting the work of other medical personnel, e.g. nurses. Moreover, the nursing sector is already struggling with staffing problems, which together with the increase in life expectancy over the decades means that there will be a need to increase the number of nurses, the financing, the technological improvement of the sector, and to modify the scope of duties of the nursing staff (i.e. nurse as an independent professional) (Cichosz, 2021). The modification of the scope of duties of the nursing staff is noticeable in long-term geriatric home care, which is a very dynamically developing nursing specialization. In view of the above, the development of a technological solution supporting the work of nurses in the area of home long-term geriatric care seems a reasonable idea.

A thorough analysis of the specific character of long-term home care made it possible to identify and distinguish areas that could be technologically developed. In fact, the work of nursing staff providing long-term home care services imposes a number of additional obligations that differ from clinical practice. Care of elderly patients requires the nurse to collect medical documents for each visit. The extent of diseases affecting the elderly and the number of visits, which should exceed 4 a week (in accordance with the Polish standards), were taken as the basis for developing a web application supporting the work of nurses in long-term geriatric care, to facilitate the process of geriatric patient description in order to eliminate the need to fill in paper medical documentation.

A Survey Justifying the Need to Create a System Supporting the Work of Nurses in Long-Term Geriatric Care

As part of the research, a social survey was carried out using the diagnostic survey method. The study was conducted in a group of 42 nurses providing long-term geriatric home care services in the district of Białystok, Poland. In order to carry out the study, an original research questionnaire was developed. The questionnaire consisted of two thematic blocks. The first block concerned the social structure of the nursing sector in long-term geriatric home care. The second block included questions checking the digital

competences of the respondents, their declarative interest, as well as the features and functionalities of a hypothetical Internet application (taking into account the specific character of the sector and the side issues of home care).

Based on the conclusions from the analysis of the collected study material, it was established that there is a need for an Internet application supporting the work of nurses in long-term geriatric care. Conclusions from the analysis made it possible to define the design assumptions of the proposed technological solution.

The mean age of the study group was 48 ± 3.8 years. The most frequently asked nurses worked in 2 centres or private institutions providing medical services.

The respondents were characterized by average technological competences. Each of them declaratively indicated the ability to use text editors and perform online payments (e.g. making a transfer from an online bank account). The respondents also indicated their basic ability to operate programs used in hospital departments or in primary health care clinics. At the same time, 92% of the respondents tried to avoid situations in which they had to perform non-standard operations in the applications used at work. Over 60% of the respondents indicated that computer programs had a positive impact on the management of medical records.

The collected survey data allowed to determine the desired features and functionalities of a hypothetical application intended to support the work of nurses in long-term geriatric home care. In terms of the questions concerning the features and functionalities, each of the respondents could choose more than one answer.

Figure 1 shows the distribution of responses regarding the features of the application supporting the work of nurses in long-term geriatric care.

Figure 1. Desired application features

The respondents almost unanimously recognized intuitiveness as the most important feature of the application (response rate: 95%). In addition, nine out of ten respondents decided that the hypothetical application should be adapted to less technologically advanced people. The fear of the application being too complicated may result from a lack of faith in one's own digital competences, being discouraged by medical Internet applications due to negative experiences with the software used in hospitals or primary care offices, or reluctance to learn new things (Kilańska et al., 2017). Nearly every sixth person surveyed indicated that they would like to have access to the web app on the phone. The respondents noticeably preferred simplicity of operation over an attractive appearance and were not in favour of a multitude of functionalities to choose from.

Figure 2 shows the distribution of responses regarding the desired application functionalities.

Figure 2. Desired application functionalities

The analysis of the distribution of answers to the question concerning the application functionalities allowed to define the detailed utilities of the hypothetical software (Figure 2). The main goal of the application is to improve the process of filling in of medical documentation. The respondents indicated their need for support with the description of the patient in accordance with the standards of the Comprehensive Geriatric Assessment (CGA) and the requirements of the National Health Fund of Poland (NFZ). In addition, the application should enable quick determination of the health of a senior in accordance with the CGA standard. The CGA tool is a fundamental procedure in the management of elderly patients (Najwyższa Izba Kontroli, 2014). It enables a precise diagnosis of

health and care problems in the elderly (Najwyższa Izba Kontroli, 2014). A module for generating reports on the health of the patient (frequency of responses: 76%) seems to be a helpful and promising functionality of the application. According to an analysis performed by the Supreme Audit Office of Poland (NIK), the lack of a standardized and transparent reporting system is one of the main problems in classifying a patient for hospital or home treatment (Najwyższa Izba Kontroli, 2014). Two out of three respondents expressed an opinion that the application should be capable of substantively supporting the nurse in difficult or unusual cases. In view of the above, it can be concluded that the combination of a report generation module and a substantive support module could be the starting point for future development of the application. In terms of communication, the respondents indicated a desire to improve communication between the medical staff and the patient’s family. According to Ferguson, deficits in communication between the medical personnel and “significant others” (family, caregivers, people without medical education close to the patient) negatively affect the final outcome of treatment (Barański & Piątkowski, 2002; Ferguson & Candib, 2002).

The vast majority of respondents (74.7%) expressed a declarative interest in using the application supporting the work of nurses in long-term geriatric care (Figure 3). Undecided and uninterested people constituted a quarter of the respondents. A complementary analysis did not reveal any correlation between the interest in using the application and age, seniority, and technological competences. The percentage of individual indications as a function of the size of town was almost uniform throughout the group.

Figure 3. Declared interest in using the application (n = 42)

Based on the obtained results of the social survey, it can be safely concluded that making an attempt to develop software supporting the work of nurses in long-term geriatric home care is a legitimate undertaking.

Design Assumptions for the Application

The design assumptions for the application were developed on the basis of the conclusions from the analysis of the conducted own study. The web application supporting the work of nurses in long-term geriatric home care should meet the following assumptions:

- have an intuitive, clear, and responsive graphic interface,
- enable registration, logging in, and password resetting to protect the medical data of each patient (according to the requirements of the Regulation on the Protection of Personal Data No. 2016/679 – Regulation of the European Parliament),
- include a module that would enable quick diagnostics of the health of an elderly person using the CGA tool without the need of adding the patient to the database,
- have a database associated with the nurse's account,
- enable the addition of a new entry about the health of a senior,
- have the option of displaying previously added entries to assist the nurse in the process of assessing the effectiveness of the implemented care plan,
- offer a specialist knowledge base in the field of prevention and treatment of the most common diseases of old age along with an overview of patient improvement activities used in long-term geriatric nursing care,
- provide a module that generates reports on the health of the patient while maintaining the description standard required by the NFZ and the CGA tool,
- offer a module enabling quick completion of medical documentation in accordance with the specifics of the description of a senior patient.

Software Development and Testing

The software was created based on the client-server model. The used software development model enables the application structure to be separated, making it possible to define tasks (assign roles) on the user and the server side (Oracle, 2009). The user interface page (Frontend, Front End Service Layers) was created in the following technologies: HTML 5, CSS 3, and JavaScript. The server side (Backend, Back End Service Layers) was created in the following technologies: PHP7 and MySQL.

In the frontend layer, it was decided to assemble individual application modules into components. Basing the architecture of the user's interface site on components made it possible to divide the Graphical User Inter-

face (GUI) into independent, reusable parts (Oracle, 2009). Each of the independent components took input values and then returned data describing what should appear on the screen. Then the request was forwarded to the server layer. After the code placed on the server processed the data, the required information was displayed in the GUI. The GUI components also determined how the content was displayed. The approach, based on JavaScript components, made it possible to meet the assumption that the application is intuitive and that the data is presented in a user-friendly manner. The graphical user interface is based on the Mobile First Design approach. As a result, it was possible to meet the design assumption of adapting the software to mobile devices.

The operation logic of the application was placed on the server side. Scripts placed on the server side received requests for data transmitted by the JavaScript language code. Each of the data requests was validated twice. The first validation was on the user's side; the second, on the server side. The code placed on the server processed the user's query. The data from the server was transferred to the user's website via JSON (JavaScript Object Notation). Ultimately, the user only received the final result of the query. All of the described activities increased the security of the application.

In the initial testing phase of the developed solution, the XAMPP (Cross-platform, Apache, MySQL, PHP, Perl) tool was used to create a local test server. After executing and testing all the test scenarios, the application was placed on external hosting, where the test scenarios were repeated. The operation of the proprietary application was tested in popular web browsers, i.e. Google Chrome, Mozilla Firefox, Opera, Internet Explorer, and Microsoft Edge. All of the listed browsers displayed both the content and the graphic and composition layout correctly. Checking the responsiveness involved verifying the method of interpretation of structure and style entries on three popular mobile devices, i.e. Samsung Galaxy Note 3, Apple iPhone 8, and Apple iPad.

Application Presentation

The graphical user interface displayed after a successful login procedure consisted of a selection of modules and a list of patients assigned to a nurse by default (Figure 4).

Modules sending a request to the server side were based on a set of forms for entering the parameters and displaying the desired data returned by the application server side. Figures 5 and 6 show the module that allows to add a new patient.

Figure 4. Appearance of the display module of patients assigned to a nurse

Figure 5. Appearance of the module allowing to add a new patient – part 1

Figure 6. Appearance of the module allowing to add a new patient – part 2

Figures 7 and 8 show the developed module for adding and removing patients. It consists of 6 cards comprehensively describing the health of the senior. The cards were developed in accordance with the CGA standards and the NFZ requirements regarding the description of a geriatric patient under long-term home care.

The screenshot displays a web application interface for a geriatric patient assessment. On the left is a sidebar with a user profile for 'Małgorzata Krasucka' and a menu with options: 'Pacjenci', 'Dodaj / usuń pacjentów', 'Baza wiedzy', 'Szybka ankieta', 'Kalkulatory', 'Twój profil', and 'Wyloguj'. The main content area is titled 'Twoi pacjenci' and features a tabbed interface. The active tab is 'Opis stanu fizycznego'. Below it are sub-tabs: 'Opis warunków lokalno-bytowych', 'Stosowana farmakologia', and 'Przeprowadź ankietę'. The 'Układ oddechowy' card is shown, containing the following sections: 'Oddech:' with a text input for 'Ilość oddechów na minutę'; 'Piwocina:' with radio buttons for 'krwista', 'śluzowa', 'ropna', 'pianista', 'obfita', 'skąpa', and 'brak'; 'Kaszel:' with radio buttons for 'suchy', 'wilgotny', 'stały', 'napadowy', and 'brak'; 'Odruch kaszlowy:' with radio buttons for 'prawidłowy', 'utrudniony', and 'brak'; and 'Duszność:'.

Figure 7. Appearance of the module for the description of a geriatric patient under long-term home care – part 1

This screenshot shows the same application interface as Figure 7, but with the 'Opis stanu psychicznego' tab selected. The 'Stan skóry' card is displayed, featuring: 'Skóra:' with radio buttons for 'Prawidłowa', 'Szara', 'Zażółcona', and 'Błada'; 'Zmiany skórne:' with radio buttons for 'Odleżyny', 'Owrodzenia', 'Wypryski', and 'Złożone zmiany skórne (np. odleżyny współistniejące z owrodzeniami)'; and a 'Dodatkowe uwagi:' section with a text area for additional notes and a 'Prześlij dane' button at the bottom.

Figure 8. Appearance of the module for the description of a geriatric patient under long-term home care – part 2

The application includes a module that allows for a quick assessment of the health of a senior without the need to add the person to the application database. The assessment was based on the CGA tool, which includes a set of standardized questionnaires to assess the health of seniors (Zielińska et al., 2018). The results obtained from the questionnaire form the basis for the selection and planning of the method of treatment (Derejczyk et al., 2003; Zielińska et al., 2018). Figures 9 and 10 show the implementation of the COG tool.

Figure 9. Appearance of the quick health assessment module based on the CGA tool – part 1

Figure 10. Appearance of the quick health assessment module based on the CGA tool – part 2

The application also offers a collection of calculators used in medicine. From the long-term nursing home care point of view, the most useful one

is that of the speed of intravenous drip infusion (Derejczyk et al., 2003). In order to implement the aforementioned calculator, formula (1) was used:

$$\text{Velocity of infusion} = \frac{\text{Volume of infusion [ml]} \cdot 20}{\text{Planned time of infusion [s]}} \left[\frac{\text{ml}}{\text{s}} \right] \quad (1)$$

Figure 11 shows the module for calculating the speed of intravenous drip infusion. The nurse enters the volume of the infusion in millilitres and the time during which the infusion is to empty. By clicking the “Calculate” button, calculations are performed and the result is returned as rounded up to a whole number.

Figure 11. Module for calculating the speed of intravenous drip infusion

Conclusions

The prototype of the application supporting the work of nurses in long-term geriatric home care was tested in real-life working conditions of nurses. The application presented in this paper was created in accordance with the adopted design assumptions. These were established on the basis of conclusions from the analysis of the results of the conducted social survey. The obtained results concerning the prototype of the application raise hopes for its practical utility. The group of nurses testing the application confirmed that it can reduce the time spent on describing the health of a geriatric patient, which – with an average visit time of one hour – results in the possibility of undertaking more nursing activities.

When developing the application, all the detailed NFZ requirements regarding the description of the health of an elderly person and the standards

of patient description required by the CGA were taken into account. As a result, the description did not differ from the adopted standards. The developed web application eliminates the problems connected with storing medical records, as all information is stored in the database. In the opinion of the nurses testing the application, the developed solution would facilitate conclusions regarding the effectiveness of the undertaken measures of nursing care and treatment, which means that there is a chance of increasing the accuracy of prediction of subsequent nursing and treatment procedures through the implementation of artificial intelligence algorithms. The developed web application is fully responsive and has an intuitive graphical interface. All its modules are protected against unauthorized access, while their operation underwent multiple tests.

It is estimated that the developed solution can be enthusiastically received in countries where the percentage of people receiving long-term geriatric home care is higher than in Poland. These countries include, inter alia, Great Britain, Germany, and the United States (Federal Interagency Forum on Aging-Related Statistics, 2016). Any attempt at commercialization in foreign markets would involve the need to adapt the solution to local standards of care of geriatric patients under long-term home care. Owing to the component-based structure of the application, the adaptation time can be significantly shortened.

Further Research Plans. In the opinion of the authors, further work on the application should focus on the implementation of artificial intelligence solutions in the field of planning further care and treatment activities. Implementation of a self-learning system presenting the patient's prognosis based on an analysis of similar cases is also planned. Moreover, there is a plan to implement a module whose task would be to automatically generate a query to the attending physician concerning the need for conducting in-depth hospital examinations. The inquiry would be generated on the basis of analysis of the patient's health status. The authors also plan to develop a module supporting the selection and evaluation of the effectiveness of pharmacotherapy.

R E F E R E N C E S

- Adamczyk, M. D. (2017). *Starzenie się społeczeństwa polskiego wyzwaniem dla zrównoważonego rozwoju*. Zeszyty naukowe Politechniki Śląskiej nr. 1981, Gliwice.
- Barański, J., & Piątkowski, W. (2002). *Zdrowie i choroba. Wybrane problemy socjologii medycyny*, Wrocław: Wydawnictwo Atut.

- Cichosz, K. (2021), *Pielęgniarka polska w XXI wieku*, Służba zdrowia, 5/2021, Warszawa.
- Derejczyk, A., Grodzicki, T., Jakrzewska-Sawińska A., & Wieczorkowska-Tobis, W. (2003), Standardy świadczenia usług medycznych w specjalności geriatry. *Gerontologia Polska*, 13(2), 67–83.
- Federal Interagency Forum on Aging-Related Statistics. (2016). *Older Americans 2016: Key Indicators of Well-Being*. Federal Interagency Forum on Aging-Related Statistics. Washington, DC: U.S. Government Printing Office.
- Ferguson W., & Candib L. (2002). Culture, language, and the doctor-patient relationship. *Family Medicine*, 34.
- Główny Urząd Statystyczny, Departament Badań Demograficznych. (2021). *Trwanie życia w 2020 roku*. Warszawa. Retrieved from: stat.gov.pl (access: 5.11.2021).
- Główny Urząd Statystyczny, Departament Badań Społecznych. (2020). *Zdrowie i ochrona zdrowia w 2019 r.* Warszawa. Retrieved from: stat.gov.pl (access: 8.11.2021).
- Iwański, R. (2016). *Opieka długoterminowa nad osobami starszymi*. CeDeWu, Warszawa.
- Kilańska, D., Gaworska-Krzemińska, A., & Grabowska, H. (2017). *E-zdrowie – wprowadzenie do informatyki w pielęgniarstwie*. Wydawnictwo Lekarskie PZWL, Warszawa.
- Najwyższa Izba Kontroli, Departament Zdrowia. (2014). *Opieka medyczna nad osobami w wieku podeszłym*. KZD-4104-003/2014, Warszawa. Retrieved from: nik.gov.pl (access: 9.11.2021).
- Narodowy Fundusz Zdrowia. (2020). *Stan faktyczny i perspektywy rozwoju opieki długoterminowej w Polsce*. Warszawa. Retrieved from: nfz.gov.pl (access: 8.11.2021).
- Oracle (2009), *Distributed application architecture*, Sun Microsystems. Retrieved from: www.java.sun.com (access: 10.05.2020).
- Polak, A., Porzych, K., Kędziora-Kornatowska, K., Motyl, J., Porzych, M., Słupski, M., & Lackowska, D. (2007). Poznawczy i praktyczny wymiar gerontologii – interdyscyplinarnej nauki o starzeniu się i starości. *Gerontologia Polska*, 15(3), 51–53, Bydgoszcz.
- Roser, M., Ortiz-Ospina, E., & Ritchie, H. (2013). *Life Expectancy*. Published online at OurWorldInData.org. Retrieved from: <https://ourworldindata.org/life-expectancy> (access: 5.11.2021).
- Stuart-Hamilton, I. (2006), *Psychologia starzenia się: wprowadzenie*. Zys i S-ka, Poznań.
- United Nations, Department of Economic and Social Affairs. (2020). *World Population Ageing 2020*. United Nations Publication.

- United Nations, Department of Economic and Social Affairs. (2021). *United Nations – World Population Prospects*. United Nations Publication, Retrieved from: <https://population.un.org> (access: 5.11.2021).
- World Bank. (2020). *Life expectancy at birth, World Development Indicators*. The World Bank Group, Retrieved from: <https://data.worldbank.org> (access: 5.11.2021).
- Zielińska, E., Guzak, G., & Syroka-Marczewska, K. (2018). *Opieka długoterminowa. Uwarunkowania medyczne i prawne*. Wydawnictwo Lekarskie PZWL, Warszawa.