FACULTY
OF INFORMATION
TECHNOLOGY
CTU IN PRAGUE

Assignment of bachelor's thesis

Title:	Hospital Information System
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Supervisor:	Ing. Jiří Dostál, Ph.D.
Study program:	Informatics
Branch / specialization:	Information Systems and Management
Department:	Department of Software Engineering
Validity:	until the end of summer semester 2022/2023

Instructions

Pro potřeby nemocnice navrhněte a implementujte informační systém (IS). Systém by měl podporovat registraci a správu pacientů a pracovníků nemocnice.
1. Seznamte se s problematikou IS v oblasti zdravornictví. Zaměřte se na právní problematiku, požadavky národních regulátorů a standardy zejména s přihlédnutím na kybernetickou bezpečnost a uchování citlivých zdravotnických informací.
2. Analyzujte funkční a nefunkční požadavky na nový IS.
3. Na základě analýzy navrhněte konceptuální model systému.
4. Implementujte navržený IS.
5. Proveďte finanční analýzu návrhu, vyčíslete náklady na provoz a tvorbu systému.

Electronically approved by Ing. David Buchtela, Ph.D. on 14 February 2022 in Prague.

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Bachelor's thesis

Hospital Information System

Elisavet Nafanailidou

Department of Software Engineering
Supervisor: Ing. Jiří Dostál, Ph.D

June 20, 2022

Acknowledgements

I would like to thank my bachelor thesis supervisor Ing. Jiří Dostál, Ph.D for his guidance during the creation of this thesis. Last but not least, I would like to thank my family for their moral and psychological support throughout my studies.

Declaration

I hereby declare that the presented thesis is my own work and that I have cited all sources of information in accordance with the Guideline for adhering to ethical principles when elaborating an academic final thesis.

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In Prague on June 20, 2022 . . . . . .

Czech Technical University in Prague
Faculty of Information Technology

Citation of this thesis

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Abstrakt

Tato práce nabízí řešení projektu "Hospital information system". Hlavním cílem práce je přispět ke zvýšení efektivity nemocnice a k přechodu na novou úroveň péče a léčby pacientů. V teoretické části práce se čtenář bude moci seznámit s tematickou oblastí související s oborem zdravotnictví a zaměřit se na právní problematiku národních regulátorů a norem s odkazem na kybernetickou bezpečnost a ochranu citlivých zdravotnických informací. Kromě toho bude podrobně popsán proces návrhu informačního systému, včetně analýzy požadavků, koncepčních modelů. V praktické části práce bude implementován informační systém pro zdravotnická zařízení založený na webové platformě.

Klíčová slova Nemocniční informační systém, backend, frontend, citlivé údaje, finanční efektivita, analýza požadavků, webová aplikace, JavaScript, UML

Abstract

This thesis offers solution for project "Hospital information system". The main aim of the thesis is to contribute to improving the efficiency of the hospital and to transit to a new level of care and treatment of patients. In the theoretical part of the thesis reader will be able to explore a subject area

related to the health field and to focus on legal issues of national regulators and standards with reference to cybersecurity and the preservation of sensitive health information. Besides, the process of designing the information system, including analysis of requirements, conceptual models, will be described in details. In the practical part of the thesis the information system for medical institutions based on a web platform will be implemented.

Keywords Hospital information system, backend, frontend, sensitive data, financial efficiency, requirements analysis, web application, JavaScript, UML

Contents

List of Figures

List of Tables

Introduction

In recent years developments in all kinds of industries have been accelerating. The success of any organisation increasingly depends on the effective use of information technology. Its rapid growth makes it possible to introduce it into various spheres of human activity.

In addition, one of the current problems of any human activity is the problem of handling the increasing flow of information. A promising way of solving this problem is to automate the handling of information, in particular the creation of computer databases that enable data to be stored, systematised and processed.

The history of hospital information systems goes back more than 50 years, but in spite of this, many medical institutions still face a high time-consumption of medical records due to the lack of automated systems at doctors' and registrars' workplaces. The quality of medical services now heavily depends on the use of new medical technologies and modern medical equipment. Recently, there has been tremendous interest in information technology as a tool that determines the dynamics of the effectiveness of a medical organization. In this connection, the design of information systems for various health care structures is an urgent task. The creation of HIS[1] makes it possible to use a convenient software product specialized for the needs of a particular institution. A hospital is an organization that works with a huge amount of information about both employees and patients. The accumulation of patient data will solve the problem of obtaining up-to-date and detailed information about them. Also, the use of such systems facilitates greater interaction between medical institutions. Especially, this innovation can reduce the time resources that are usually spent in the preparation of various kinds of documents.

[1] HIS – Hospital information system

Chapter 1

The aim of the thesis

The aim of the thesis is to design an automated information system for medical organization, the use of which will contribute to improving the efficiency of the hospital, the transition to a new level of care and treatment of patients, research business processes taking place in the medical organization and the reception of the doctor.

The aim of the thesis will be achieved by addressing several interrelated objectives:

1. Analysis of the subject area required to create the software.
2. Focusing on legal issues, requirements of national regulators and standards with particular reference to cybersecurity and the preservation of sensitive health information.
3. Analysis of functional and non-functional requirements.
4. Design and implementation of the system.
5. Calculation of the economic viability of the project.

Chapter 2

Subject area analysis and methodology

2.1 Methodology

The theoretical part of the thesis is based on the study of professional literature on the development of HIS, the life cycle of information systems, methodologies of software development and software tools, UML[2], and legislation. All UML diagrams are modelled in the Enterprise Archictect from Sparx Systems version 14, which is a complex tool for system analysis and system design.

The practical part of the thesis deals with the design of HIS, to manage patient's and doctor's data and make appointments with the doctors.

2.2 Information systems

An information system is a formal, socio-technical, organisational system designed to collect, process, store and disseminate information.IS [3] can be defined as the integration of components for collecting, storing and processing data, from which data is used to provide information, knowledge inputs, and digital products that facilitate decision-making. [9]

2.3 General description of the subject area

The health care facility that was taken as the basis for the project is a private clinic. It is staffed by specialists and deals with patients by appointment. Information about each patient is stored in the hospital's database, so it is possible to keep track of all visits to a selected patient at a given clinic. he

[2]UML–Unified Modeling Language
[3]IS–Information System

Hospital Information System makes it possible to trace a patient's path from reception to appointment with a doctor, diagnosis and treatment. The system is designed to process data on doctors, patients, appointments and treatment. Before a patient is admitted to a hospital, he or she is registered. If the patient has already had an appointment at the hospital, a search will be carried out and the patient will be booked in and given an outpatient record. The outpatient record indicates the time and day of the appointment, the specialist (specialty, doctor's name) and the cabinet where the appointment is to be made.

2.4 SWOT analysis

SWOT analysis is a methodological tool designed to help workers and companies optimize performance, maximize potential, manage competition, and minimize risk. It can help to determine the efficacy of something as small as introducing a new product or service or something as large as a merger or acquisition. SWOT consists of four components organized into two categories - internal(Strengths and Weaknesses) and external(Opportunities and Threats).[8]

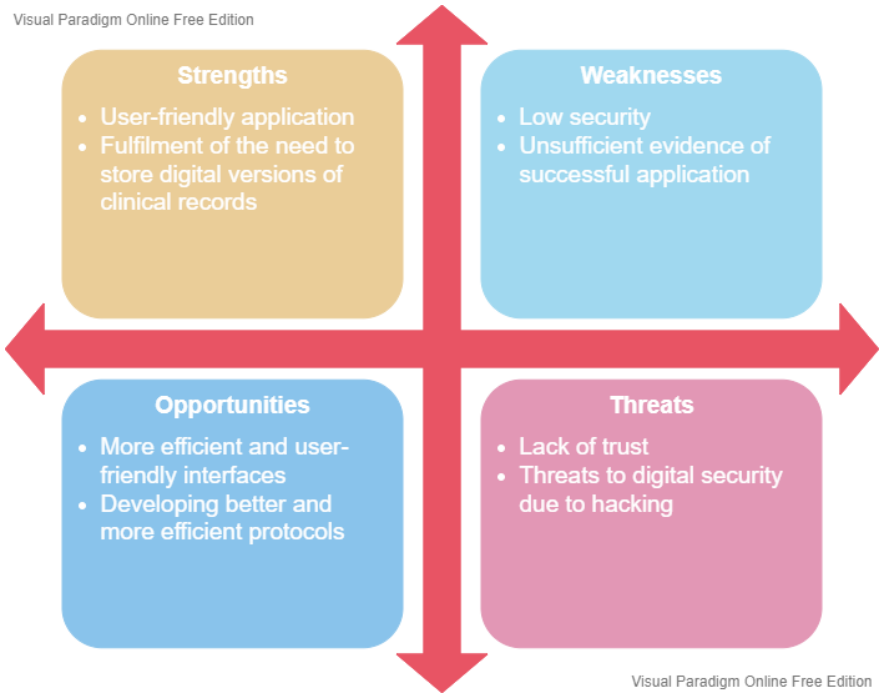

Figure 2.1: SWOT

Chapter 3

Legal issues of the area

Information security is a pivotal aspect of many industries, and healthcare industry is not an exception. According to the Charter of Fundamental Rights of the European Union, everybody has the right to respect for their private life and the protection of personal data. A number of European and National Laws are in place to enforce these fundamental rights.

Medical public bodies and commercial organisations have an access to a large amount of personal data on a daily basis, including names of patients and staff, date of birth and marital status. The issue of security is particularly acute for medical institutions where data such as diagnoses, examination results and case histories are collected and stored. The introduction of new technologies in healthcare increases the likelihood of information leakage and theft.

3.1 The processing of patients' personal data

When a health care provider fills in an outpatient card or concludes a contract for medical services, the provider receives the patient's personal data, such as name, surname and patronymic, date of birth, residential address, sex, weight, height, health status and test results, and must comply with certain requirements.

The processing of patients' personal data consists of the following steps:

1. collection and recording of information;
2. the systematization of the data obtained;
3. storing the information in the database;
4. specifying the details (if necessary);
5. destruction of irrelevant information.

3.1.1 Purpose of processing personal data

The main purposes of processing personal data in medical facilities include:

1. health services and health care;
2. clinical trials;
3. the supply of services or goods containing personal data;
4. employment relationships or applications for inclusion in a selection procedure;
5. follow-up services and activities containing personal data;
6. contractual relationships involving personal data.

3.1.2 Special categories of personal data (sensitive data)

Some personal data are of such a nature that they may themselves cause the data subject harm in society. For this reason, an exhaustive list of the categories of data which are considered sensitive for the data subject and which are afforded enhanced protection during processing is defined. Special categories of personal data are those personal data that reveal an individual's racial or ethnic origin, political views, religious or philosophical beliefs, health status, genetic and biometric data.[2]

Sensitive data in healthcare industry include patient data such as PHI [4], stored medical and payment records, payer and provider employee data, data in container environments, and data related to wired and wireless IoT [5] medical devices which are ubiquitous in healthcare environments. [3]

3.1.3 Possible threats

Informational privacy is, "a state or condition of controlled access to personal information", is infringed whenever another party has access to one's personal information by reading, listening, or using any of the other senses. Such loss of privacy may be entirely acceptable and intended by the individual, or it may be inadvertent, unacceptable, and even unknown to the individual. [1]

Attackers may use personal information in the following cases:

1. medical cards may be used on the black market to obtain medical care for the uninsured;

[4]PHI–Protected health information
[5]IoT–Internet of Things

2. the card may be “damaged” by adding thief’s information to it, what puts the patient at risk of receiving care based on someone else’s medical history;

3. insurance limit can be exhausted by fraudsters what will prevent the rightful owner from receiving medical care;

4. prescriptions for medicines may be abused, what will deprive the cardholder of this opportunity, and prescriptions are usually limited.

3.2 Protection of personal data in the healthcare organisation in Czech Republic

Let’s look at the topic of personal data processing in particular of sensitive data, using Hospital ”Horažďovice” as an example.
Personal data and special category data are processed by NNP [6] Horažďovice, s.r.o., hereinafter referred to as the ”Hospital”, in accordance with Regulation (EU [7]) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC [8] (General Data Protection Regulation; hereinafter referred to as the ”Regulation”) and in accordance with national data protection legislation.

The Hospital maintains a database of the patients’ personal and sensitive data and are the data controller of the following data:

- personal data and special category data that the Hospital collects and processes in connection with the provision of health services (medical records),
- personal data enabling the Hospital to contact you,
- personal data used to protect our rights and interests;
- personal data for unambiguous and unmistakable identification,
- personal data related to the relationship between the Hospital and the patient.

The Hospital processes personal data in the case of compliance with legal obligations for the period of time specified by law; in the case of processing necessary for the performance of a contract, for the period of time necessary

[6] NNP–Net national product
[7] EU–European Union
[8] EC–European Commission

to ensure mutual rights and obligations arising from the contract, i.e. always for at least the duration of the contract; in the case of processing based on the consent of the data subject for the period of time specified in the consent or until its revocation.
After the end of the period of legitimate processing, the Hospital shall cease to process your personal data and shall ensure their destruction in accordance with the relevant legal regulations. [4]

3.3 Protection of personal data in the healthcare organisation in Russian Federation

Legislation strictly defines the status of personal data. They are defined in Federal Law No. 149 of 27.07.2006 "On Information, Information Technology and Information Protection", which describes them as "restricted information". A separate legal act deals with the issue of interaction with personal data. The key document here is Federal Law No. 152 of 27.07.2006 "On personal data". The law contains basic definitions and requirements that relate to the processing of personal data - in particular, it requires the protection of human rights and freedoms. Also the Federal Law strictly regulates this process: for example, it states that personal data processing operators must ensure certain security levels established by the RF Government Resolution No. 1119 of 01.11.2012. These levels refer to a set of requirements that neutralise certain security threats. Protection measures are defined in more detail by Federal Service for Technical and Export Control of Russian Federation: Order No. 21 of 18.02.2013 approves the composition and content of organisational and technical measures to ensure the security of personal data, while Order No. 17 of 11.02.2013 regulates requirements for the protection of information in state information systems, including personal data. The Russian Federal Security Service issued Order No. 378 of 10.07.2014, which describes measures to ensure the security of personal data when using cryptographic information protection means. The Ministry of Health also refreshed personal data legislation by issuing Order No. 911n of 24.12.2018 "On Approval of Requirements to State Health Information Systems of the Constituent Entities of the Russian Federation, Medical Information Systems of Medical Organisations and Information Systems of Pharmaceutical Organisations". [5]

Today, experts assess the level of personal data security in public and private medical centres in Russia as low. This is due to insufficiently qualified personnel, the lack of a unified information security system, and insufficient control. Solving these problems requires clear state regulation and the introduction of new software. [6]

Chapter 4

Analysis of requirements

Requirements analysis is a crucial part of the software development process, which sets the direction for the rest of the work and helps to identify the real needs of stakeholders. It is a rather long and time-consuming process, which consists of three main steps. The first one is information gathering, which includes subject area research and communication with the customer and the end user. The second one is analysis of the collected information, which consists of searching for inconsistencies and inaccuracies, their solution and linkage search. And the last one is documentation of information.
Good requirements are clear and concise. This means that they cannot be overwhelmed by managerial vocabulary, empty prose, and confusing jargon.

4.1 Ways of analysing requirements

The requirements analysis phase is the structuring of previously collected requirements. The purpose of the stage is to provide a clear list of unduplicated requirements to the system which should be highlighted from redundant and partially redundant scenarios and user stories that were obtained in the previous stage Properly grouped requirements will help to make do with the minimum amount of functionality to meet as many goals as possible.

Requirements analysis methods are primarily needed to map the business process so that you can analyze, understand, and make necessary changes to the workflow.

There are various methods of requirements analysis that can be used in the software development process, for example:

1. Business process modeling notation (BPMN)

2. Unified Modeling Language (UML)

3. Role Activity Diagrams (RAD)

4. Data flow diagram

[10]
In my project i have decided to make the analysis of requirements using UML method. In my opinion, that gives quite a clear and obvious view of the processes taking place within the system. A UML diagram can be of two types: a behavioral model and a structural model. I decided to draw an activity diagram, which belongs to behavioral class and a class diagram from the group of structural models.

4.2 Activity diagrams

Activity diagrams are graphical representations of workflows of stepwise activities and actions[1] with support for choice, iteration and concurrency. In the UML, activity diagrams are intended to model both computational and organizational processes, as well as the data flows intersecting with the related activities. [7]

In order to show, how that UML method works, i decided to consider a process of logging in the system in details.

4.2.1 Logging in

Main flow of events:

1. The system asks for a user name and password.

2. The user enters a name and password.

3. The system confirms that the name and password are correct, identifies the type of user (doctor/administrator) and displays the main menu which gives access to system functions according to user type.

Alternative streams:

1. The system detects that the name and password combination is not correct.

2. The system reports an error and prompts the user to either re-enter the name and password or refuse to log in.

3. The user informs the system of their choice.

4. According to the user's choice, either execution moves to the beginning of the main thread or the use case is terminated.

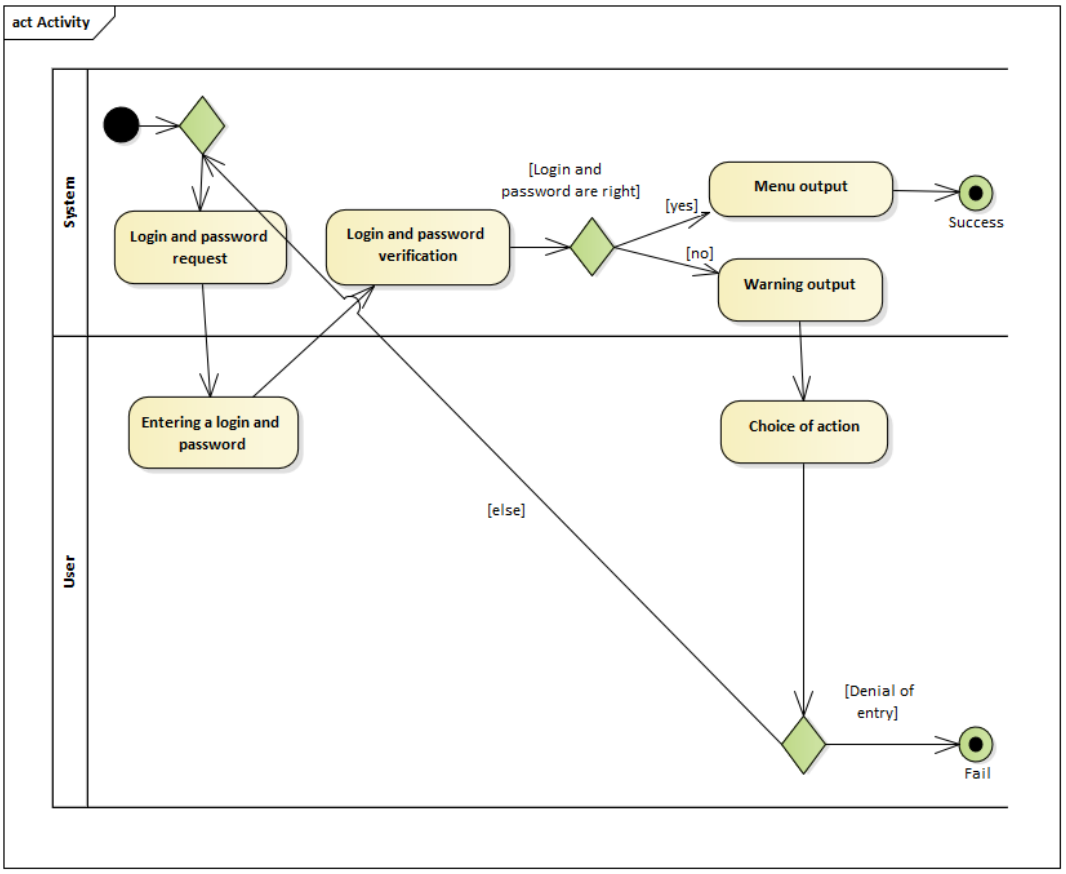

Figure 4.1: Logging in

4.3 Domain model

The chapter describes the entities that are related to the domain being analyzed. The individual classes are described in detail so that it is clear what all objects and information must be stored in the system. 4.2

4.3.1 Doctor

A person, who works in the hospital as a doctor. 4.1

4.3.2 Client

A person, who comes to the hospital as a client(patient). 4.2

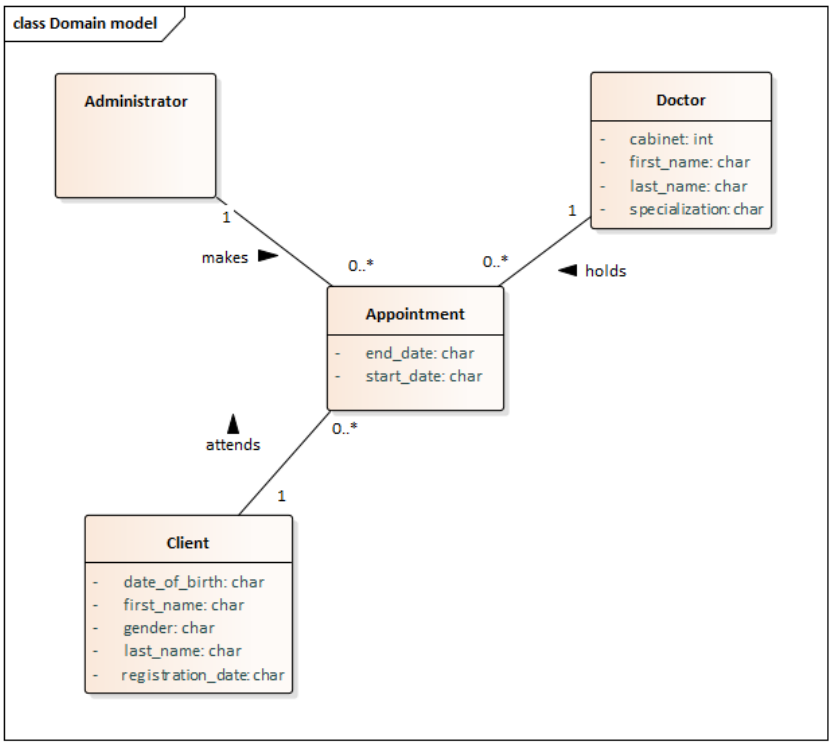

Figure 4.2: Domain model

Attribute name	Description
first_name	Name of the doctor.
last_name	Surname of the doctor.
cabinet	The number of cabinet, in which the doctor has an appointment with the patient.
specialization	Specialization of the doctor.

Table 4.1: Doctor: attributes

4.3.3 Appointment

The administrator has a possibility to make an appointment with the doctor. 4.3

Attribute name	Description
first_name	Name of the client.
last_name	Surname of the client.
date_of_birth	Date of birth of the client.
gender	Gender of the client.
registration_date	Registration date of the client.

Table 4.2: Client: attributes

Attribute name	Description
start_date	The start date of the appointment.
end_date	The end date of the appointment.

Table 4.3: Appointment: attributes

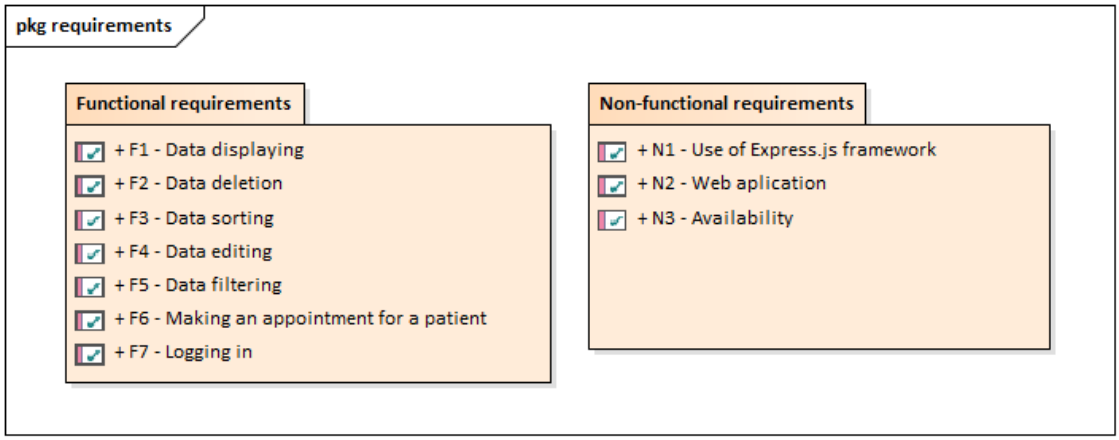

Figure 4.3: Model of requirements

4.4 Model of requirements

4.4.1 Functional requirements

During software development functional requirements define the functions that an entire application or just one of its components must perform. A function usually consists of three steps. They are data input, system behavior and

data output. It can calculate, perform business processes, manipulate data, establish user interaction, or perform other tasks. In other words, a functional requirement is what an application should or should not do after entering some data. Functional requirements are important because they show software developers how the system should behave. 4.4

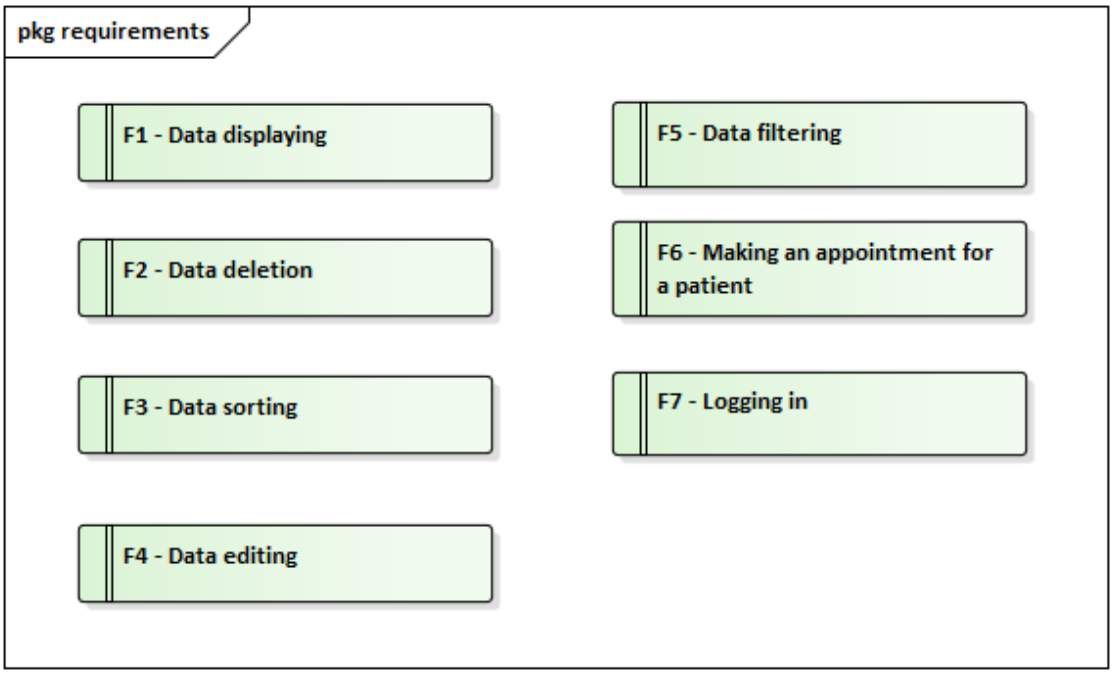

Figure 4.4: Model of requirements

4.4.1.1 F1 - Data displaying

The system will allow to view data of the patients and doctors, anamnesis of the patients and a calendar with appointments. The administrator has an access to all of these activities, the doctor does not have a possibility to view information about other doctors.

4.4.1.2 F2 - Data deletion

Administrator has an ability to delete data about patients and doctors, delete the appointments in case of necessity of its cancellation.

4.4.1.3 F3 - Data sorting

Data can be sorted by any of chosen attributes(name, date of birth, etc.).

4.4.1.4 F4 - Data editing

Administrator has an access to data editing. They can edit the patient's and doctor's information, information about appointments and anamnesis.

4.4.1.5 F5 - Data filtering

Data can be sorted by any of chosen attributes(name, date of birth, etc.).

4.4.1.6 F6 - Making an appointment for a patient

The administrator makes and appointemnt with the doctor, including it into the calendar of appointments.

4.4.1.7 F7 - Logging in

Administrator and doctors have a possibility to log in the system.

4.4.2 Non-functional requirements

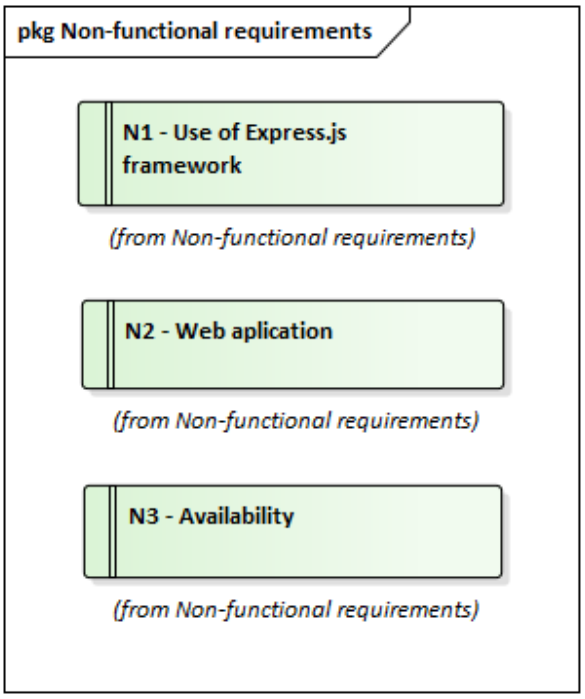

Figure 4.5: Model of requirements

4.4.2.1 N1 - Use of Express.js framework

The back-end of the web application is written in JavaScript of the Express.js framework.

4.4.3 N2 - Web aplication

The application is accessible via the web with an emphasis on responsiveness. The app displays in a user-friendly way on desktop, tablet and mobile phone.

4.4.3.1 N3 - Availability

The system is available 24/7.

4.4.4 User requirements

User requirements, also known as "Use cases", describe how the project will be used by end users.

4.4.4.1 Participants

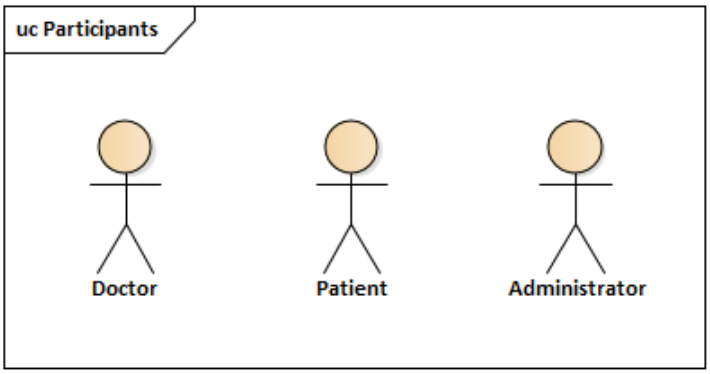

Figure 4.6: Participants

4.4.4.2 UC1 - Logging in

Administrator and doctors log in the system using login and password. On that stage of development, the logging in process for the patient has not been developed yet. The accounts for administrator and doctor were created.

4.4.4.3 UC2 - Availability of data about patients

Administrator and doctors can view the information about the patient including last name, first name, date of birth, male, registration date and optional comment. They can view both full information and selected information.

4.4.4.4 UC3 - Availability of data about doctors

Administrator can view information about the doctors including last name, first name, specialization and number of cabinet. They can view both full information and selected information.

4.4.4.5 UC4 - Entering new data or editing existing information about patients

In case of error or situation, when the data of the patient have to be changed, the system allows the registrant to edit old data or to add new data.

4.4.4.6 UC5 - Entering new data or editing existing information about doctors

In case of error or situation when, the data of the doctor have to be changed, the system allows the registrant to edit old data or to add new data.

4.4.4.7 UC6 - Deletion the patient's data

The registrant can delete the patient's data if the patient's cooperation with the hospital is terminated.

4.4.4.8 UC7 - Deletion the doctor's data

The registrant can delete the doctor's data if the doctor's cooperation with the hospital is terminated.

4.4.4.9 UC8 - Making an appointment with a doctor

The patient comes to the hospital reception and asks the administrator for making an appointment with the certain doctor. The administrator offers the patient free date and time. If the patient is satisfied with the time, the appointment is fixed in the system.

4.4.4.10 UC9 - Editing or deleting the appointments with the doctor

The patient or the doctor can cancel the appointment or change data. The patient can also change the doctor,they want to have the appointment with.

In that case the administrator has a possibility to edit data of the appointment or to delete the appointment from the calendar.

4.4.4.11 UC10 - Viewing the calendar with appointments with the doctor

Administrator and doctors have an access to calendar with appointments.

4.4.4.12 UC11 - Adding the anamnesis

Administrator and doctors have a possibility to add and edit anamneses of patients.

4.4.4.13 UC12 - Viewing the anamnesis

Administrator and doctors have a possibility to view anamneses of patients.

4.4.4.14 UC13 - Data sorting

Both administrator and doctor have a possibility to sort data by any of attributes.

4.4.4.15 UC14 - Data filter

Both administrator and doctor have a possibility to filter data by any of attributes.

4.5 Overview of the implementation of use case requirements

Source \ Target	Functional requirements::F1 - Data displaying	Functional requirements::F2 - Data deletion	Functional requirements::F3 - Data sorting	Functional requirements::F4 - Data editing	Functional requirements::F5 - Data filtering	Functional requirements::F6 - Making an appointment for a patient	Functional requirements::F7 - Logging in
Use cases::UC1 - Logging in							↑
Use cases::UC10 - Viewing the calendar with appointments with the doctor	↑						
Use cases::UC11 - Adding the anamnesis				↑			
Use cases::UC12 - Viewing the anamnesis	↑						
Use cases::UC13 - Data sorting			↑				
Use cases::UC14 - Data filter					↑		
Use cases::UC2 - Availability of data about patients	↑						
Use cases::UC3 - Availability of data about doctors	↑						
Use cases::UC4 - Entering new data or editing existing information about patients				↑			
Use cases::UC5 - Entering new data or editing existing information about doctors				↑			
Use cases::UC6 - Deletion the patient's data		↑					
Use cases::UC7 - Deletion the doctor's data		↑					
Use cases::UC8 - Making an appointment with a doctor						↑	
Use cases::UC9 - Editing or deleting the appointments with the doctor		↑		↑			

Figure 4.7: Requirements tracking matrix

Chapter 5

Design and implementation

5.1 Description of the application under development

In order to make the end user's experience with the program as convenient as possible, the UI[9] must be as user-friendly as possible.

The apilication is available on `http://78.111.88.101:3000/`.

When the user first opens the program, they will have to log in 5.1. Only the administrator and doctors can access the system at this implementation stage. One administrator account and one doctor account were created. The registered administrator has a login is "manager@clinic.com" and a password "clinicmanager". The registered doctor has a login is "doctor@clinic.com" and a password "clinicdoctor". If the data is incorrect, the fields light up in red 5.2.

Once you have logged into the manager's account, you will see a menu with three items: "Clients", "Doctors" and "Doctor's appointments". 5.3
By clicking on the "Clients" button, we see a list of clients containing their names, surnames, dates of birth, gender and dates of registration. 5.4 Data can be filtered and sorted by any of attributes. It is possible to add a new client, edit the data of an already added client, add an anamnesis of the client or view an existing one, or delete a client or the list of clients. 5.5
By clicking on the "Doctors" button, we see a list of doctors containing their names, surnames, specializations and numbers of cabinets.5.6 Data can be filtered and sorted by any of attributes. The doctors' data can also be edited or deleted.
By clicking on the "Doctor's appointments" button, we see a calendar with appointments. It is possible to edit already made appointments, delete them

[9] UI–User interface

or create new on free places of calendar 5.7. The calendar can be opened in different formats: day, week, month.

Once you have logged into the doctor's account, you will see a menu with two items: "Clients" and "Doctor's appointments". Doctors have an access to patients' data without a possibility of its editing. The can add and view anamnesis of the patient and view a calendar with appointments without an ability to edit it.

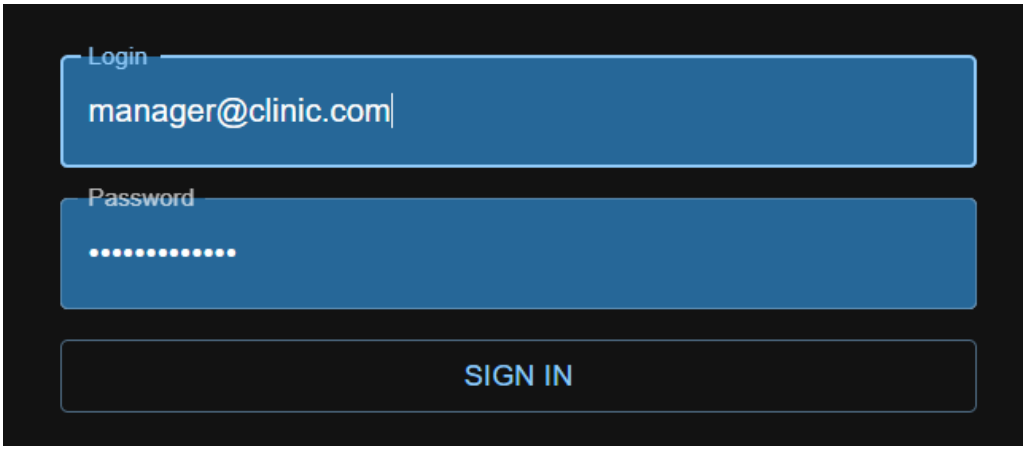

Figure 5.1: Logging in

Figure 5.2: Logging in error

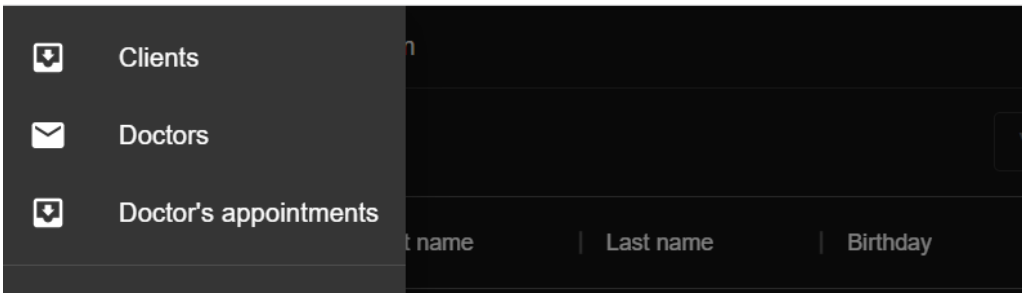

Figure 5.3: Menu

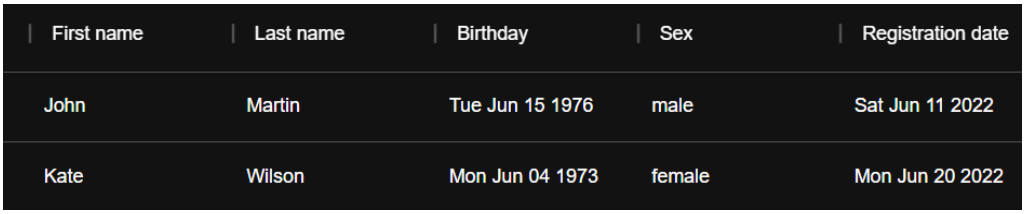

Figure 5.4: Clients

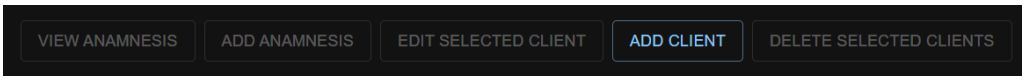

Figure 5.5: Functions

5.2 Architecture of the aplication

5.2.1 Backend

5.2.1.1 Node.js

The server was written using Node.js. It is an open-source and cross-platform JavaScript runtime environment, which is a popular tool for almost any kind of project including web applications. [11] Node.js contains a vast number of libraries.

5.2.1.2 Express

Express is one of the libraries, used during the backend implementation. Express is a flexible Node.js web application framework that provides features for web and mobile applications. [12] In the thesis it is used for handling requests and routing. Express provides one of the most simple yet powerful ways to create a web server. The middleware functions, used in the application are

Figure 5.6: Doctors

morgan and cookie-parser. Middleware templates are the building blocks of each Express application.

5.2.1.3 Morgan

Morgan is used for logging. It is an HTTP [10] request level Middleware, which is a great tool that logs the requests along with some other information depending upon its configuration and the preset used.

5.2.1.4 Cookie-parser

Cookie-parser is used for cookie handling. Cookies are simple, small files that are sent to client with a server request and stored on the client side.

5.2.1.5 Node-postgres

Pg is used for connecting to and querying the PostgreSQL database. Node-postgres consists of node.js modules in order to interface with PostgreSQL database.

5.2.1.6 Yarn

Yarn is used for installing packages and building the initial application template. It is fast, reliable and secure. Yarn caches every package it has downloaded, so it never needs to download the same package again. Besides, it maximizes resource utilization. Yarn is able to guarantee that any installation that works on one system will work exactly the same on another system due to concise lockfile format and a deterministic algorithm for install operations. Also, yarn uses checksums to verify the integrity of every installed package before its code is executed.[13]

[10] HTTP–Hypertext Transfer Protocol

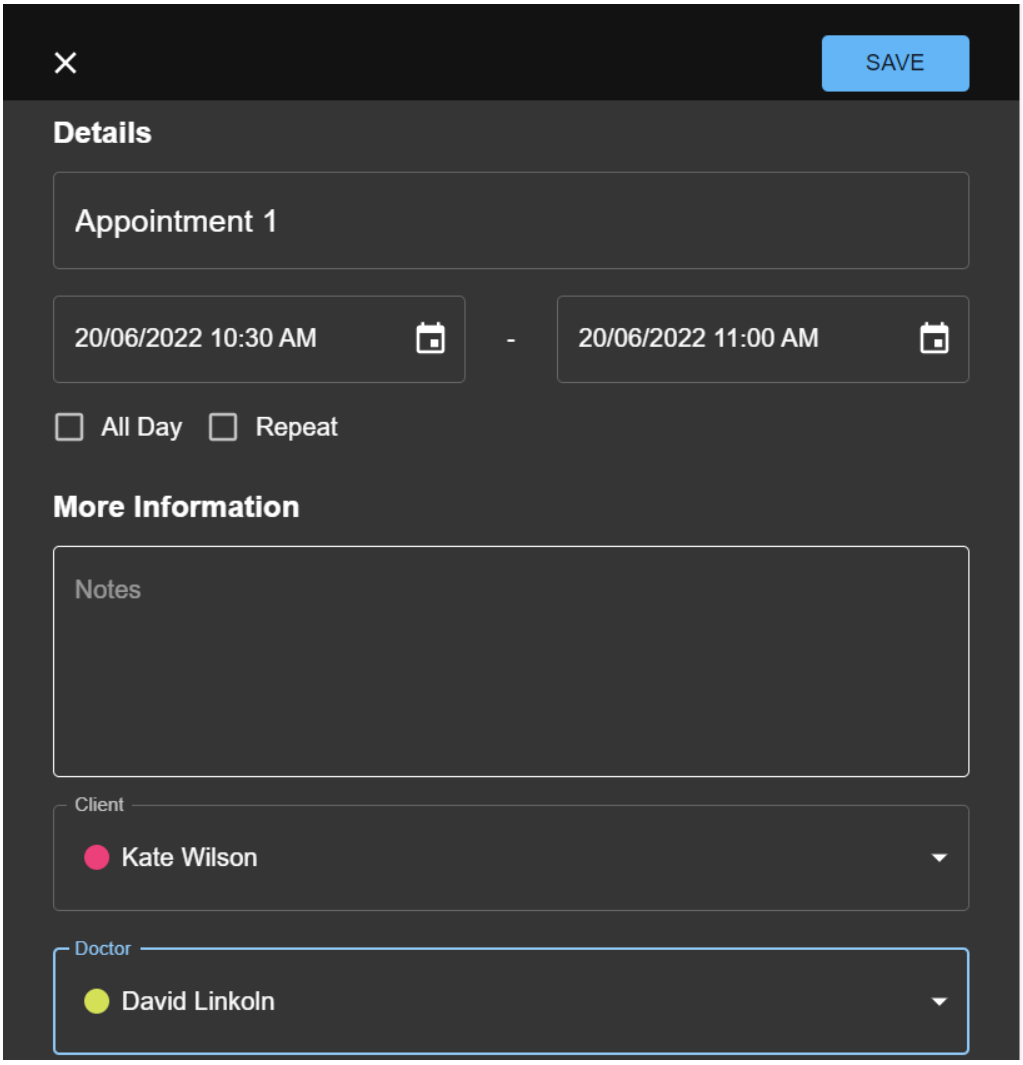

Figure 5.7: Appointments

5.2.2 Frontend

A JavaScript frontend framework is a collection of JavaScript code libraries, which offers reusable code components, a universal development environment, compilers, toolsets, code libraries, APIs, etc., to facilitate the app. [14]

5.2.2.1 React

React is taken as the basis of a project to implement a reactive application. It uses JSX and allows developers to write HTML snippets inside JavaScript files. Besides, React works cohesively with routing or API integrations. One of it's main advantages is the possibility to write components without classes.

5.2.2.2 Redux

Redux is used for storing/processing application stats. The Redux DevTools make it easy to trace why, where, when, how your application's state changed.

5.2.2.3 Axios

Axios is used for API queries. It is a Javascript library for making HTTP requests that works both in the browser and in the Node.js platform.

5.2.2.4 MUI

MUI [11] is used for UI creation. Its components work without any additional setup, and don't pollute the global scope.

5.2.2.5 Devexpress/dx

For creating calendars and timelines was used devexpress/dx-react-scheduler.

5.2.2.6 ESLint

ESLint was used to maintain a consistent code style. It is a code analysis tool for identifying problematic patterns found in JavaScript code.

5.2.3 Version control

Git was used for version control in both parts of the application in connection with GitHub.

[11] MUI–Material user interface

Chapter 6

Financial plan

6.1 The business case concept

Medical records, such as doctors' notes, are specific textual data. Because they are rich in complex terms, they require the use of a complex information storage structure that to facilitate the processing of data that includes information about patients, their diagnoses, prescriptions and recommendations. The economic justification of the thesis will include the assessment of material costs associated with the maintenance of used equipment, determination of the amount of depreciation deductions of used of fixed assets used, the assessment of the full cost value. There will also be some mathematical conclusions of economic feasibility of the thesis.

6.2 Drawing up a timetable of work

In order to calculate costs during the design phase, it is necessary to determine the duration of each activity. The duration of the work will be measured in man-days.

The designer's time according to Table 6.1 is 105 days.

6.3 Estimating the value of wages and social contributions of the HIS

Based on the data on the complexity of the work performed and the rate of executors, it is necessary to determine the costs of salaries of executors and deductions for insurance premiums for compulsory social, pension and medical insurance.

Name of work	**Duration of work (days)**
Problem statement	7
Subject area analysis	18
Exploring development tools	25
System designing	20
Formalisation of the explanatory memorandum	25
Finally	105

Table 6.1: A detailed timetable for carrying out the work

The cost of the basic wages of executors is determined by formula:

$$P = \sum_{i=1}^{k} T_i * C_i$$

,

- P - costs of executors' basic salaries(CZK [12]);
- k - number of executors;
- T(i) - time spent by the i-th executor(days);
- C(i) - rate of the i-th executor(CZK/day).

Let us calculate the daily wage rate for the project participant. To do this, we divide the monthly salary by the number of working days in month(22 days). For a student as a monthly salary is accepted 17600 CZK.

$$P_{day} = \frac{17600}{22} = 800$$

Data on expenses for basic wages are presented in the Table 6.2.
Let us determine the deductions for insurance premiums for compulsory social,pension and health insurance with basic and additional wages performers' fees according to the formula:

$$P_{insurance} = P * \frac{H_{social}}{100}$$

,

[12]CZK–Czech koruna

- P(insurance) -social contributions are needed from wages(CZK);
- P - costs of executors' basic salaries(CZK);
- H(social) - standard for deductions for insurance premiums for mandatory social, pension and medical insurance (take equal to 30%)(CZK/day)6.3.

Executor	**Daily rate(CZK / day)**	**Number of days**	**Expenses for the basic salary(CZK)**
Designer	800	105	84000

Table 6.2: Expenses for basic wages for project executors

Executor	**Expenses for the basic salary(CZK)**	**Social contributions needs(CZK)**
Designer	84000	25200

Table 6.3: Deductions for social needs of project executors

6.4 Calculation of material costs

The project required the purchase of various raw materials . These costs are calculated according to the formula:

$$P_{materials} = \sum_{i=1}^{L} G_l * F_l * (1 + \frac{H_{transport}}{100})$$

,

- P(materials) - costs of raw materials(CZK);
- l - raw material or material type index;
- G(l) - the rate of consumption of the l-th material per unit of output (unit);
- F(l) - unit purchase price of the l-th material (CZK/unit);

- H(transport) - the rate of transportation and procurement costs (take equal to 10%).

The results of the calculations are presented in Table 6.4.

Product	**Material from**	**Type**	**Norm expenditure per item (units)**	**Price per unit (CZK)**	**Amount per item (CZK)**
Ink	Paint	Coloured	1	699	699
Office paper	Paper	A4	1	380	380

Table 6.4: Calculation of raw material costs

$$P_{materials} = (699 + 380) * (1 + \frac{10}{100}) = 1186.9$$

6.5 Estimating the costs associated with the maintenance and operation of the used equipment

The maintenance and operating costs of the equipment are based on per hour of equipment operation, taking into account the cost and capacity of the equipment according to the formula:

$$P_{equipment} = \sum_{i=0}^{m} G_l^{mh} * t_l^{mh}$$

,

- P(equipment) - maintenance and operating costs of equipment(CZK);
- G(i)(mh) - estimated cost of one machine-hour of equipment operation at i-th technological operation (CZK/mh);
- t(i)(mh) - the number of machine-hours required to perform the i-th technological operation (mh).

A laptop and a printer have been used for this work. It is necessary to calculate electricity costs and take into account the costs of technological maintenance and repairs and access to the internet. The calculation of the costs of electricity used in the design of the information system is presented in Table 6.5

Device	**Electricity tariff (CZK / kWh)**	**Power consumption (kWh)**	**Cost per machine hour (CZK)**	**Number of machine hours**	**Amount (CZK)**
Laptop MSI	5.9123	0.18	0.23	280	64.4
Printer HP	5.9123	0.015	1.28	2	2.56

Table 6.5: Calculation of energy costs

Finally we get 66.96 CZK from energy costs. For internet access, the plan used is a 300 CZK monthly plan. Then the cost of the Internet for the period of implementation of the thesis will be calculated by formula:

$$P_{internet} = K_{months} * T * \frac{K_{internet}}{K_{days}}$$

,

- P(internet) - internet costs(CZK);
- K(months) - number of months in the period;
- K(internet) - number of days of internet use;
- K(days) - number of days in the period.

$$P_{internet} = 3 * 300 * \frac{76}{92} = 743.48$$

The total costs associated with the maintenance and operation of the equipment used, as well as the costs of the Internet:

$$P_{equipment} = 66.96 + 743.48 = 810.44$$

6.6 Determining the amount of depreciation deductions used fixed assets

Amortization is paying off an amount owed over time by making planned, incremental payments of principal and interest. [15] The list of the basic tools used to fulfil the tasks set in the thesis is given in Table 6.6.

Name of equipment	**Quantity(units)**	**Initial cost (CZK)**
Laptop MSI	1	68500
Printer HP	1	2400

Table 6.6: The main tools used in carrying out the tasks of the thesis

Finally we get 68500 + 2400 = 70900 CZK.
The depreciation charge for the year for the i-th fixed asset is determined according to the formula:

$$A_i = F_i * \frac{H_{ai}}{100}$$

,

- A(i) - depreciation charge for the year on the i-th capital asset(CZK);
- F - historical cost of the i-th fixed asset(CZK);
- H(ai) - is the annual depreciation rate of the i-th fixed asset (%), defined as the inverse of the useful life.

Electronic computing equipment is classified in the second depreciation group with a useful life of two to three years. Let us take the useful life of the laptop and printer T to be 3 years. Then the annual norm of amortisation of the laptop is:

$$H_a = 100/T = 33.33$$

Let us calculate the depreciation charge for the laptop for the year:

$$A_{laptop} = 68500 * 0.33 = 22605$$

Let us calculate the depreciation charge for the printer for the year:

$$A_{printer} = 2400 * 0.33 = 792$$

Let us determine the amount of depreciation charges for fixed assets, used in the process of the thesis according to the formula:

$$A_{i_thesis} = A_i * \frac{T_{i_thesis}}{12}$$

,

- A(i_thesis) - the depreciation charge for the i-th capital asset, used by the student in the work on the thesis(CZK);
- A(i) - depreciation charge for the year on the i-th capital asset(CZK);
- T(i_thesis) - the time during which the student uses the i-th fixed asset(months).

$$A_{i_thesis} = 22605 * \frac{3}{12} = 5651.25$$

$$A_{i_thesis} = 792 * \frac{3}{12} = 198$$

The results of the calculations are presented in Table 6.7.

Name of equipment	**Quantity (units)**	**Initial cost (CZK)**	**Time of use (months)**	**Depreciation charges (CZK)**
Laptop MSI	1	68500	3	5651.25
Printer HP	1	2400	3	198

Table 6.7: The main tools used in the execution of the thesis

Thus, the amount of depreciation deductions for fixed assets used is 5849,25 CZK.

6.7 Estimating overhead costs

The overhead cost is 40% of the monthly salary of the performers and are calculated as:

$$P_{overhead} = P * \frac{H_{overhead}}{100}$$

,

- P(overhead) - overhead costs(CZK);
- P - basic salary(CZK);
- H(overhead) - percentage of overhead(%).

The overhead costs amounted to:

$$P_{overhead} = 84000 * \frac{40}{100} = 33600$$

6.8 Calculation of the economic effect of using the IS

The introduction of an information system into the production process leads to conditional savings in staff time and conditional savings in wages. This is the economic effect of the data collection and processing system. Let us consider the benefit of reducing the number of actions on medical records, which is saved by eliminating the need for nursing staff to search for and issue paper records and the ability to review a patient's personal data and medical history at any time. In order to calculate these cost savings, a value for nurses' wages is needed. Therefore, in order to obtain the necessary values, primary the data on each worker, including their qualifications, are required.

The number of card statements is 1.6 times higher than the number of visits (e.g. because some of them are made by telephone contacts between the doctor and the patient). With an average workload of 15 patients a day, 5 days a week, for 48 weeks, there are 5,760 discharges per doctor each year, which takes approximately 384 hours of work time, or 1800000 CZK annually. The electronic medical records system makes it possible to minimise time of patients staying in hospitals. According to various estimates this reduction hospitalization reduces the time a patient spends in hospitals by an estimated 10-30%. The introduction of information technology into the administrative services of medical institutions are able to save 63% of the average cost of registering payment documents. The introduction of information technology in hospital administrative services saves 63% of the average cost of registration of payment documents. A more complete registration of all procedures carried out enables them to be entered into invoices, which increases the amount by 2%. Billing errors are reduced by 78%. [16]

Overall, financial benefits have been calculated for the entire health system, that can be derived from the introduction of health information technologies. Cost accounting for the implementation and support of information technology is a necessary step in assessing economic efficiency in the design by comparing

the benefits obtained with the costs incurred. The cost structure for the implementation and maintenance of information systems is considered in Table 6.8.

Expenditures	**Share in total costs(%)**
SW [13]	25
Administration	21
Support	16
Development	6
Communications	4
Human factor	21
Downtime	7

Table 6.8: The cost structure for the implementation and maintenance of information systems

On average, the time of admission per patient is 30 minutes, an appointment with one doctor is on average 10 minutes. After the introduction of electronic recording, the time spent on record keeping per patient, will be reduced to 3 minutes, i.e. if we assume that on average there are 15 patients per day per doctor, then the average time for record keeping will be reduced by 45 minutes a day.The saving of working time for receiving patients by one doctor per week will be 225 minutes.

Since there are 15 doctors on the medical staff, we calculate the time savings are calculated for all doctors.

225 * 15 = 3375 minutes - time savings for the entire medical personnel per working week.
45 * 20 = 900 minutes - the time planned for the reception before the implementation of the HIS.
900 - 335 = 565 minutes - daily working time of reception after implementation of HIS.

If the user, when saving i-type of activity using program saves T(i), hours, then productivity increase P(i) (in %) is determined by the formula:

$$P_i = 100 * \frac{\delta T_j}{F_j - \delta T_j}$$

F(j) - the time that the user planned to perform work of type j before the implementation of the program (hours).

$$\frac{335}{900} - (335 * 100) = 59.299$$

- increase in labor productivity from saving appointment time. Now let's calculate the effect of the introduction of HIS for record keeping in business processes.

Type of work	**Before automation, Fj**	**Saving time, DT**	**Raise performance labor P(i) (in %)**
Information entry	20	15	100
Carrying out calculations	5	4	400
Preparation and printing reports	30	15	100
Data analysis and sampling	44	10	300

Table 6.9: Works before and after workplace automation

Savings associated with increased user productivity is defined by the formula:

$$\delta P = Z * \sum_i \frac{P_i}{100}$$

, Z - average annual salary of staff.

Let us calculate the cost of maintaining staff, based on the condition that the salary one employee of the medical staff is 25000 CZK.

$$Z = 1 * 25000 * (1 + \frac{34\%}{100}) = 33500 CZK$$

For simplicity, overhead and other costs prior to development and implementation programs will be considered as unchanged, i.e. implementation of the program cause ink savings in printer cartridges, paper consumption, etc.

Even with a rough calculation, the cost-effectiveness of the of the planned

implementation of the information system is significant. Based on the results of the cost-effectiveness calculation of the design and of the future implementation of the medical information system can be determined, that it is profitable. Although the benefit is indirect, in terms of time saved, it is usually more noticeable in the medium and long term, usually more visible in the medium and long term. The implementation of HIS can lead to adjustments in the business process itself, because tasks and business processes carried out faster. Workers can process large amounts of information in their working time information, which can be used either to reduce staff costs or to boost business growth at a constant rate, regardless of the number of staff involved.

Let's calculate the savings from increased labour productivity. We will use the data in Table 6.9 as input data.

6.9 Estimation of the full cost

To estimate the total cost, we sum up the costs for all items considered in the Table 6.10.

Name of item	**Amount, CZK**	**Share of expenditure(in %)**
Labour expenses	84000	55.76
Expenditure on raw materials	1186.9	0.788
Social security contributions	25200	16.72
Expenses for maintenance and operating of equipment	810.44	0.54
Depreciation charge	5849.25	3.88
Overhead costs	33600	22.3
Finally	150646.59	100

Table 6.10: The total cost of the system to be designed

Savings related to increased staff productivity:

$$P = 33500 * 9 = 301500CZK$$

The result is the following expected cost-effectiveness:

$$E = 301500 - 150646.59 * 0.15 = 278903.012$$

6.10 Conclusions on financial efficiency

In this section, the main economic costs of designing an information system of a medical organization were considered. The calculated indicators of economic efficiency allow us to conclude that the cost of designing this information system is 150646.59 CZK. Economic efficiency from the use of the information system associated with an increase in staff productivity is 278903.012 CZK. Based on the assessment of economic efficiency, it can be concluded, that the development and implementation of the proposed software product is economically justified and expedient.

Conclusion

The aim of the thesis was to design an automated information system for medical organization. The first thing that was done was the analysis of the subject area, through which the processes that take place in healthcare institutions were studied and understood. In the process, the user requirements were collected and analysed. Based on these, the functional requirements for the application to be developed were compiled. In addition, a requirements tracking matrix was developed to help in the design and development process to track the compliance of the software components to the expectations of the end users. Basic information about the processing of personal data, the purposes of the processing and possible threats to its leakage was discussed. In addition, the legislation on personal sensitive data processing in Russia and the Czech Republic was analysed. Besides, the last section of financial analysis proved, that the proposed SW product is economically justified and expedient.

Practical part of the thesis was implemented in JavaScript, with the help of its vast variety of libraries and frameworks, which were rather understandable for me as for person, who implemented in this language for the first time. Accounts have been developed for an administrator and a doctor. Administrator has the possibility to edit and add clients' and doctors' data, make the appointments and add them to the calendar. The doctors have an access only to viewing the patients' information, adding and viewing their anamneses and to viewing the calendar with appointments.

I would like to continue developing this app, because at the moment it is just a prototype. In the future, I would like to add more functionality, particularly patient accounts, which will allow to do many things without a necessity to go to the reception of the hospital. For instance, making an appointnent with the doctor. I come from a small city of Vladikavkaz in the south of Russia, where the quality of medical information systems is low. Therefore, I would like to significantly increase the efficiency of the city hospitals by developing

and implementing my own medical information system.

Appendix A

Acronyms

HIS Hospital information system

IS Information system

BPMN Business process modeling notation

UML Unified Modeling Language

IoT Internet of Things

PHI Protected health information

CZK Czech koruna

SW Software

UI User interface

NNP Net national product

EU European Union

EC European Commission

MUI Material user interface

mh machine hours

Appendix B

Contents of enclosed CD

- `readme.txt` ..... the file with CD contents description
- `src` ..... the directory of source codes
  - `wbdcm` ..... implementation sources
  - `thesis` ..... the directory of LaTeX source codes of the thesis
- `text` ..... the thesis text directory
  - `Thesis_Elisavet_Nafanailidou.pdf` ... thethesis text in PDF format

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