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SERVICE-ORIENTED ARCHITECTURE OF ARTIFICIAL INTELLIGENCE SYSTEM IN HEALTHCARE

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ABSTRACT

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Service-Oriented Architecture of Artificial Intelligence System in Healthcare
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This master thesis is dedicated to service-oriented architecture of artificial intelligence system in healthcare. Artificial intelligence, being a promising concept itself, gets especially topical in such a subtle domain as healthcare. Artificial intelligence systems open enormous opportunities that may totally change the face of modern healthcare. However, implementation of these systems is also inevitably associated with certain difficulties. The goal of the thesis was to develop a service-oriented architecture of artificial intelligence system for a healthcare organization, in order to provide theoretically sound basis for implementation projects in healthcare organizations. To achieve this goal, analysis of sources on related topics, systematization of collected information and architecture modeling were carried out. The work was mainly conducted from the point of view of enterprise architecture and did not deepen into artificial intelligence theory and technologies or social impacts of artificial intelligence. As a result of the work, a systematic idea of healthcare artificial intelligence systems in the international arena was formed, and frameworks and models that could be useful in implementing these systems were presented. The work done showed the challenges associated with artificial intelligence in healthcare, and also suggested possible solutions for them. The results of the thesis may give organizations a starting point to harness the power of artificial intelligence with the maximal benefit.

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Zilia Bikkulova,
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LIST OF SYMBOLS AND ABBREVIATIONS

AGI	Artificial General Intelligence
AI	Artificial Intelligence
BPC	Business Planning And Consolidation
BPM	Business Process Management
BI	Business Intelligence
CRM	Customer Relationship Management
CT	Computed Tomography
EA	Enterprise Architecture
EAI	Enterprise Application Integration
EAM	Enterprise Asset Management
ECG	Electrocardiography
EIS	Enterprise Information System
FPGA	Field-Programmable Gate Array
GP	General Practitioner
GPU	Graphic Processing Unit
HR	Human Resource
HRM	Human Resource Management
IoT	Internet of Things
IS	Information System
IT	Information Technology
MRI	Magnetic Resonance Imaging
NHS	National Health Service
SOA	Service-Oriented Architecture
UML	Unified Modeling Language
BPMN	Business Process Model and Notation

1 INTRODUCTION

1.1 Background

The term "artificial intelligence" (AI) is now very common. But it is often used by the mass audience without a clear understanding of what kind of concept lies behind it. For example, the audience is often skeptical of AI due to the merger of this concept with artificial general intelligence (AGI) (or so-called “strong” AI), which occurs in the mass consciousness. It is necessary to understand that AGI is “the holy Grail” of AI science, a hypothetical, science fiction-like concept meaning machine that can experience consciousness. But this does not depreciate the "weak AI" already existing and working in many areas and everything that has been achieved with its help. It is also necessary to realize that the “weak” AI helps a human, and does not try to imitate all the capabilities of human mind.

It is customary to talk about the enormous opportunities that AI opens up for a variety of industries: AI makes trading decisions, manages weapons and human resources, writes music, and makes diagnoses. But it is not so obvious what is behind each implementation of the AI system, what efforts and resources had to be spent to fit this system into the existing technical, organizational and social context, and what difficulties companies face, mastering technologies that are new for them and for humanity as a whole. Therefore, it is important to develop models and frameworks that will help companies implement AI technologies with maximum benefit and minimum cost.

Before talking about AI, its concept should be defined in the context of this work. Different dictionaries and studies give different definitions of artificial intelligence (AI). AI may be considered a special capability of computers, or a branch of science about this capability.

The Oxford Dictionary provides the definition of AI, where it is described as the theory and development of computer systems that are capable to perform tasks usually requiring intelligence of a human (for instance, visual perception, decision-making, translation from one language to another, speech recognition) [1]. According to Merriam-Webster, AI may be defined as: 1) a branch of computer science that deals with simulating intelligent behavior in computers; 2) the ability of a machine to imitate intelligent human behavior [2]. The Encyclopedia Britannica defines AI as the capability of a computer or a computer-controlled robot to perform tasks usually associated with intelligent beings [3]. In Wikipedia, AI is intelligence that is demonstrated by machines, in contradistinction to the natural intelligence demonstrated by humans and other animals [4]. For the context of current research, the second definition of AI given by Merriam-Webster seems to be the most correct.

1.2 Goals and delimitations

The goal of the thesis is to develop a service-oriented architecture of artificial intelligence system for a healthcare organization. The goal is reached by performing following tasks:

1. To get and present an idea of AI in healthcare, its current state in Finland and in the entire world, by explaining the AI background, by making an overview on existing AI healthcare projects, by mapping and classifying them, and analyzing challenges these and another AI systems may face.

2. To prepare a foundation for the practical part of the thesis by building framework for service-oriented architecture (SOA) in healthcare: by describing necessary terms, principles and approaches, and by making an overview of the use of SOA in healthcare and related challenges.

3. To perform the practical part of the thesis, id est to define the place of AI in the improvement of business processes, to formulate the task for building of a SOA, to describe business model of a medical organization, and to build a SOA.

Delimitations of the research conducted in the thesis are the following:

1. The subject of the thesis is “weak”, not “strong” AI. The AI system is positioned as an assistant for a human, not as a system that is supposed to replace a human entirely.

2. The work is conducted based on best practices of medical organizations. Its results still

may need customization for a certain case.

3. The work is conducted from the point of view of enterprise architecture (EA), information system (IS) architecture and business process management (BPM) and is not focused on the technical realization of the AI technology, nor on the social consequences of implementation of an AI solution.

1.3 Structure of the thesis

Section 2 of the thesis is an overview of the use of AI in healthcare. It consists of giving background on the topic and spotlighting its general relevance; describing noticeable healthcare AI systems over the world and in Finland particularly; mapping and classifying healthcare AI systems; and finally, describing challenges for AI in healthcare and possible solutions for them.

Section 3 is intended to build a framework for SOA in healthcare. In this section, main terms, principles and approaches of SOA are formulated; overview on the use of SOA in healthcare is given; challenges of SOA in healthcare are described.

Section 4 is dedicated to development of SOA for an AI system in healthcare. First, an application of a process innovation framework with regard to the opportunities of AI systems is described. Second, the task for creating a business model canvas and building a SOA of AI system in a healthcare organization is formulated. Then, business model canvas of a medical organization using an AI system is developed. Finally, the SOA of AI system in healthcare is built.

Section 5 is the discussion part of the thesis. It is divided into chapters accordingly to the contents of the thesis and consists of summarizing the work conducted in each section of the thesis and highlighting the gained results and their meaning.

Section 6 is the conclusions of the thesis. It summarizes the results of the thesis and mention opportunities for application of them and for the further research.

2 OVERVIEW OF THE USE OF ARTIFICIAL INTELLIGENCE IN HEALTHCARE

2.1 Artificial intelligence background

Even if AI may seem to be a very young phenomenon, the development of AI actually started in the middle of the twentieth century. The term “artificial intelligence” was officially used for the first time by an American computer scientist John McCarthy (1927-2011) at the Dartmouth Conference in 1956. He explained AI as a science and technology for creating intelligent computer programs; and, despite the differences in the interpretation of the term, the final judgment made by the participants in the meeting was as follows: "any aspect of human rational activity can be accurately described in such a way that the machine can imitate it" [5].

The first full-grown demonstration of intelligence by the machine is the concept of a robot by the British cybernetician William Gray Walter (1910-1977). In 1948–1949 he built mechanical "turtles". These robots rode to the light source and, resting on obstacles, handed over and went around them [5]. The robots were able to make the conclusion about the impossibility of travel and make the decision on maneuvering around. They were created exclusively from analog components [5].

In 1954, IBM demonstrated an unfinished automatic translator from Russian to English, which operated with 6 rules and possessed a vocabulary of 250 words from organic chemistry [5]. The demonstration made a splash in media, and that motivated further funding for AI research. According to estimates, out of 4,000 full-time translators from different languages who were members of the government Joint Publication Research Service, only 300 people were busy a month [5]. Improving the quality of recognition and automatic translation would bring large savings by reducing the staff [5].

In 1965, a project intending to create a new generation automatic sorting machine was launched, leaded by the Japanese Ministry of Post and Telecommunications. A year later, in Toshiba, a prototype of a mechanism for recognizing hand-written print numbers was ready; and in 1967, Toshiba introduced a sorter with optical character recognition (OCR) technology [5]. The machine scanned the envelope with a Visicon digital camera and sent the resulting impression to the recognition unit, where all unnecessary information was discarded, except for the numbers grouped in the index [5]. After recognizing handwritten numbers, the letter went into the respective sorting tray [5].

AI made itself really known in 1997: on May 11, in New York, a computer won for the first time in history during a chess match held in accordance with all “human” rules [5]. It was a match between the IBM Deep Blue chess computer and the reigning world chess champion Garry Kasparov [5]. A year earlier the machine lost to the human player.

AI has risen again in the 2010s and penetrated customers’ devices and applications: at that time, the power of computers and mobile devices has got already enough to afford the use of AI. Due to global digitalization, large databases necessary for AI analysis and training were created, and instead of outdated neural network learning algorithms, much more efficient new algorithms were developed [5].

The appearance of AI on the trading floors created a powerful momentum to e-commerce – the recommending AI on Amazon provides 35% of total sales, evaluating the items viewed and selecting the products that the customer will most likely buy [5]. AI is already used in many creative mobile applications, in all recommendation systems, in voice recognition systems, in most monitoring systems, smart houses, household appliances, robots of all possible types, and so on [5]. Modern research in the field of AI includes the following directions:

1. Knowledge representation and development of a knowledge-based system. This direction is responsible for the creation of expert systems, providing some structured knowledge in terms of knowledge engineering, the essence of which is to formalize the acquired knowledge [6].

2. AI systems software. A considerable number of programming languages have been developed in which the first place is not computational procedures, but logical and symbolic ones. The most famous of them are Lisp and Prolog. Lisp is the most important language in

the environment of symbolic information processing. A large number of programs in the field of working with the natural language have been written in Lisp, which makes this language fundamental for use in the field of AI. In turn, the Prolog language is responsible for logic. Mathematical logic is a formalization of human thinking, so its use in AI is inevitable [6].

3. Development of natural language interfaces and machine translation. The most challenging task in machine translation is to teach the machine to understand the meaning of the text similarly to a human: not just to replace the words of one language with the equivalent of another language, but to analyze the meaning conveyed by these words. However, recently there has been progress in this area. Now the most promising representative of the area is voice assistants who analyze human speech and perform appropriate actions (Siri, Google Assistant) [6].

4. Intelligent robots. The relevant problems in the area of intelligent robots are the problems of machine vision and adequate storage, as well as the processing of three-dimensional visual information. But work is ongoing and the first serious steps are already being taken. For example, in the field of machine vision, it was possible to replace the old “blind” robots, programmed to take part and perform an operation in a certain place and at a certain time, with new robots equipped with video cameras and new software that allows them to identify and search details [6].

5. Learning and self-education. The results of research in this area are systems that can accumulate knowledge and make decisions based on accumulated experience. Such systems are trained on some examples, after which the process of self-learning is launched [6].

6. Pattern recognition. The pattern recognition procedure is conducted based on a certain set of features pertaining to the object. This direction is developing together with the previous one: recognition becomes more correct due to clarifying the features and learning from errors [6].

7. New computer architectures. It has been understood that the traditional computer archi-

tecture will not allow solving the problems faced by AI. In this regard, efforts are directed to the development of completely new hardware architectures. There are already special machines tuned for the Lisp and Prolog languages [6].

8. Games and machine art. In games, AI analyzes the actions of the player and responds to them using its built-in logic. There is also such a phenomenon as machine creativity, which consists, for example, in creating music and writing poems [6].

2.2 Relevance of artificial intelligence in healthcare

Today, AI is believed to be the most relevant area in IT research and the leading driver of so-called Industry 4.0 – breakthrough growth in industry. Healthcare is one of the fields that can allow reaching a truly effective level of AI development based on neural networks and machine learning. It is assumed that the use of AI may largely improve the diagnosis accuracy, lighten the life for patients who suffer from different diseases, speed up developing and releasing medicines, et cetera. [7]

AI may be particularly useful in healthcare due to its ability to process big amounts of data and make comparison and analysis of them [8]. A human is capable to identify patterns in data as well, but it may be a tiresome process to which a machine is more suitable, especially when there are many variables or possible scenarios. In difficult conditions, for example, overwork and shortage of time, it gets even easier for doctors to miss alarm signs that are crucial to make a correct diagnosis. Hence, people who work in healthcare should get any help that can be provided. AI can be this help, detecting signals that may otherwise be missed by doctors [9]. Smart assistants can give advice to doctors, as well as show tendency to diseases, or disclose diseases early, in the stages when they are still invisible to the human eye [8].

2.3 Overview of existing artificial intelligence systems

The fact confirming the relevance of AI in healthcare is interest of important IT market figures, such as Google and IBM, in the area. They are offering solutions of AI in healthcare.

IBM Watson, a computer system for answering questions, offers healthcare applications. IBM Watson supports decision making for medical workers using generation of hypotheses, natural language abilities and evidence-based training [10]. For example, IBM developers, together with the American Heart Association, decided to expand the capabilities of Watson, offering capabilities of the system in cardiology. According to the authors of the project, the system will analyze a huge amount of medical data related to a particular patient. These data include ultrasound images, x-rays, and all other graphical data that can help clarify a person’s diagnosis. At the very beginning, Watson's capabilities will be used to look for signs of aortic heart valve stenosis. The problem is that it is not so easy to detect valve stenosis, despite the fact that it is a very common heart defect in adults (70–85% of cases among all defects). Watson will try to determine what it “sees” on the medical images: stenosis, tumor, infection or just an anatomical anomaly, and then give the appropriate assessment to the attending physician in order to speed up and enhance the quality of physician’s work [7].

A. V. Gusev, Ph.D., deputy development director in the company K-MIS, considers that the IBM Watson project currently can be regarded as a kind of testing ground where advanced IT technologies can be run, in order to identify and discuss emerging difficulties and inspire researchers to new products. And then already tested prototypes should be converted to serial production, achieving higher price-quality indicators and usability in real conditions [7].

DeepMind Health, which is recently joining with Google Health, aims to address healthcare challenges related to the development of AI research and mobile tools and to create products enhancing patient outcomes and supporting service groups [9]. DeepMind Health system, according to its developers, is capable of processing hundreds of thousands of medical records in a few minutes and extracting the necessary information from them. DeepMind is collaborating with the Murfields Eye Hospital (UK) to improve the quality of treatment. Using a million anonymized eye images obtained with a tomograph, researchers try to create algorithms based on machine learning technologies that would help detect the early signs of eye diseases. Another company, Verily, that is also a part of Google, is engaged in the same. The specialists of this company use AI and Google search engine algorithms in order to analyze what makes a person healthy [7].

There is also an FDNA (Boston, USA), a startup creating a suite of applications Face2Gene that use face analysis, AI and genome understanding. It strives to enhance diagnosing and healing rare diseases. With the Face2Gene Research application, using de-identified patients' data, doctors are able to share their results and to test and analyze cohorts of patients together with clinicians all over the world [12].

There are some important Russian projects that should be named in the overview. First one is Third Opinion, a company aiming to empower healthcare with AI. Among solved tasks, the company mention, for example, following: detecting pathological cells in the blood and bone marrow analyses and detecting nosologies in "fundus" images [13].

Second one is Botkin.AI – a platform using AI for the medical information analysis. It includes mathematical models for image analysis, tools for visualization of pathology analysis results, et cetera. The platform provides customizable interaction between AI and radiologists [14].

A direct user of AI healthcare application may be not only a medical worker, but also a patient. Nowadays, there is such a tendency as telemedicine applications for patients. Their algorithms are different: some of them, such as fitness trackers, gather data through wearable sensors; others are more like inquirers gathering data via questioning. Some AI systems are able to use oral communication and others use texts. After receiving the data, the applications provide recommendations on what a patient should do, or send the necessary information to the doctor. An example of application of this kind can be Ada [8]. Ada is a healthcare company that was established in 2011, in Germany, by a team of doctors, scientists and pioneers of the industry. It proposes a health platform based on AI. The Ada application was launched worldwide in 2016, and since that time it has become the number 1 healthcare application in 140 countries. It works in the following way: Ada offers simple and relevant questions to a user in a personalized interactive chat, and then compares their answers to similar cases, in order to aid users in finding possible explanations for their symptoms. The Ada application has a complex knowledge base that encompasses thousands of conditions and symptoms. After conducting the health assessment of the user, Ada gives a recommendation on what the user can do next (for instance, to see a doctor or pharmacist, or to request emergency care). So far, Ada conducted 15 million user health assessments [15].

2.4 World map of artificial intelligence systems in healthcare

In this research, mapping of top AI healthcare startups has been conducted twice – in 2018 and 2020. Both maps will be presented in order to make the comparison and trace the tendencies. On the maps the italic numbers show the quantities of top-80 AI startups from each country.

The world map 2018 of AI healthcare startups is presented in the Fig. 1. The map is made on the base of the "Top-80 AI startups in Healthcare" for 2018. This top is created according to startup funding [16].

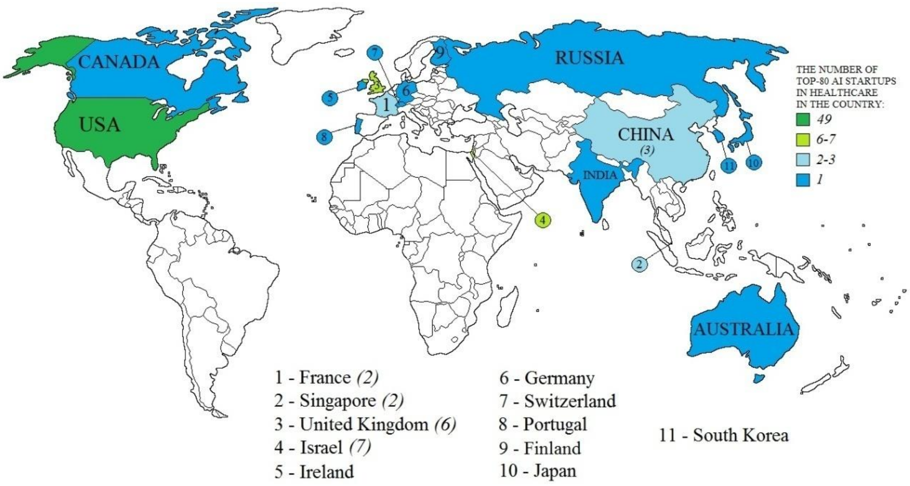

Fig. 1. AI healthcare startups – world map 2018 [17]

As seen from Fig. 1, 4 clusters of countries were extracted. The 1st cluster (presented in the green color) was characterized as "countries with the highest quantity of top AI healthcare startups". This cluster comprises 1 country – the United States of America (49 startups).

The 2nd cluster (presented in the light-green color) was characterized as "countries with high quantity of top AI healthcare startups” and it comprises the following 2 countries: Israel (7 startups), the United Kingdom (6 startups).

The 3rd cluster (presented in the light-blue color) was characterized as “countries with medium quantity of top AI healthcare startups”. This cluster comprises the following 3 countries: China (3 startups), France (2 startups), Singapore (2 startups).

The 4th cluster (presented in the blue color) was characterized as “countries with 1 top AI healthcare startup” and it comprises 11 countries: Australia, Canada, Finland, Germany, India, Ireland, Japan, Portugal, Russia, South Korea and Switzerland.

Countries that are not marked with any color have no startup in the considered top.

Thus, in 2018 the United States of America, Israel and the United Kingdom were the leaders of the use of AI in healthcare, judging by the quantity of top startups in them [17].

The world map 2020 of AI healthcare startups is presented in the Fig. 2. The map is made on the base of the “Top-80 AI startups in Healthcare” for 2020. This top is created according to startup funding [16].

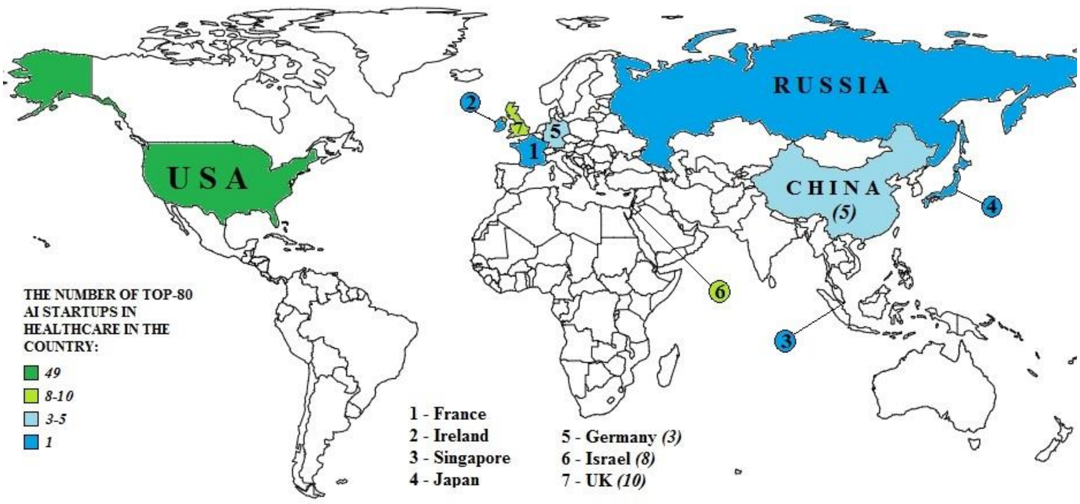

Fig. 2. AI healthcare startups – world map 2020

On this map presented in Fig. 2, 4 clusters of countries will be considered. The 1st cluster (green) is characterized as “countries with the highest quantity of top AI healthcare startups”. This cluster comprises 1 country – the USA (49 startups) – same as in previous map.

The 2nd cluster (light-green) is characterized as “countries with high quantity of top AI healthcare startups” and it comprises 2 countries: Israel (8 startups) and the UK (10 startups).

The 3rd cluster (light-blue) is characterized as “countries with medium quantity of top AI healthcare startups”. The cluster comprises 2 countries: China (5 startups) and Germany (3 startups).

The 4th cluster (blue) is characterized as “countries with 1 top AI healthcare startup” and it comprises 5 countries: France, Ireland, Japan, Russia and Singapore.

Countries not marked with any color have no startup in the considered top.

It can be concluded that the USA, Israel and the UK have kept their leadership, and Israel and the UK even reinforced their positions since the quantity of top startups in these countries has grown.

From the research, these three countries can be considered world leaders in the field of AI healthcare startups. Nevertheless, it is a rather conventional conclusion. Significance of countries from other clusters cannot be ignored: they are represented in the top, while many countries do not have startups in the top at all. Also, the top-80, that was the basis for the research, is composed only according to startup funding, without taking into account another factors. The research most likely reflected only those AI healthcare startups that are supported financially, and it is not possible to trace the number of ideas that faded away with no support. Plus, there is a country's background factor: it is appropriate to estimate the advancement of AI in healthcare in a country only taking into account the overall development of the country, its economic situation and so on [17].

Currently the first startup in the top is the UK startup Babylon Health. Babylon Health provides medical services either via its website or through mobile applications, which are funded differently through post-paid payments, a subscription-based model, centrally funded initiatives such as the National Health Service (NHS), or as a part of health insurance packages [18].

2.5 Artificial intelligence systems in healthcare of Finland

Finland launched its AI Programme in May 2017, when Mika Lintilä, the Minister of Economic Affairs, declared that Finland strives to become a global leader in applying AI and new ways of working [19]. Over the past two years, AI has become one of the most discussed subjects in Finland [19]. The following directions of the use of AI and robotics in healthcare of Finland can be extracted:

1. Taking care of people at home. According to Finnish regulations, people should be taken care of at home as long time as possible. AI assistants can be used to help people (for example, aging people) live at home, in familiar surroundings, independently and in good conditions, aiding them to take care of hygiene and diets [20].

2. Pharmaceuticals. Taking medication is a process in which mistakes can lead to serious consequences, and at the same time these mistakes are very easy to make. For example, only 23% of people with serious illnesses (like leukemia) take the right medication [20]. Sometimes people take excessive medication, not sufficient medication, or use drugs that interact with each other in unwanted ways. Automated treatment (AI reminders and AI moderators) may be a solution of the problem [20].

3. Hospital setting. Another specific area of improvement is the use of robotics in a hospital setting. Robotics can assist logistics, care and laboratory work. A research in Finland showed that 60-80% of nurses spend their working time on solving logistical issues [20]. This amount of time can be reduced due to the use of logistics robotics, including software robotics or drug delivery robots, and will also make the hospital safer and more efficient [20].

4. Rehabilitation. In Finland, every year 14,000 people get brain injuries [20]. Robotics and AI can be the help for rehabilitation of these people. AI-powered rehabilitation does not mean that human physiotherapists cannot be present and support the goals of patients. Instead, the therapist will work together with rehabilitation robots. AI can assist in wellness training and help people who cope with loneliness or other mental health problems. Robots are unable to replace humans totally, but they are able to expand the services of a nurse [20].

Further examples of the use of AI by healthcare companies in Finland will be mentioned. These companies are listed in the Final report of Finland's AI Programme 2019.

1. Neuro Event Labs (Tampere). There are 65 million patients with epilepsy who are affected by the problem of insufficient diagnosis [19]. Neuro Event Labs strives to find more effective ways of monitoring the patients' seizures. The first prototype of a remote monitoring device has been tested in 2016. That device can be set at home or in a hospital setting in the same room where a patient is. With the use of machine vision, the device monitors the patient and takes into account their movements and symptoms indicating the onset of a seizure. The system detects even small changes that were previously impossible to notice, such as breathing or movements of the patient. Since 2017, the system is used in several Finnish hospitals. It is also operated in other countries, like Belgium, Denmark, the UK and others [19].

2. Avaintec (Helsinki). In 2016, Avaintec established its own AI unit, DataChief, offering a tool for data analysis, as well as AI and machine learning solutions for healthcare organizations and social security. Avaintec has developed their algorithms in collaboration with Lappeenranta. They can be used to implement various data analyzes and AI solutions. Avaintec is creating different solutions based on AI, such as: a component helping analyze the log data recorded on the browsing of patient data; a component aiming to predict the worsening of the health status of aged people in home care; an application intended to improve the healthcare efficiency and reduce unnecessary hospital trips [19].

A number of Finnish organizations conduct research in the field of artificial intelligence in healthcare. These are some of them, mentioned in the Final report on AI in healthcare in Finland made by the University of Jyväskylä:

1. The Finnish Center for Artificial Intelligence (FCAI). FCAI is a competence center established by Aalto University, the University of Helsinki and VTT. An example of healthcare-related research can be the research program Agile Probabilistic AI led by Professor Aki Vehtari from Aalto University. The program develops interactive and AI-assisted processes and builds new AI models using probability programming. For instance, the program provides versatile tools for healthcare-related data analysis. These tools will be used to develop AI applications for both public and private healthcare needs [21].

2. The Helsinki Institute for Information Technology (HIIT). HIIT is a joint IT research institute of Aalto University and the University of Helsinki. The research institute conducts both fundamental and applied research. Currently, the key areas of research are AI, data analysis, computational health science and information security [21].

3. The University of Eastern Finland. This university studies the use of AI in medicine and healthcare biology, as well as neural networks, machine learning, speech recognition and data mining. Among their projects related to healthcare, there is PharmAI – AI for drug development, led by university researcher Jussi Paananen. AI automates the laborious early stages of drug development. For example, the goal is to screen drug targets from databases and locate relevant information from a variety of open and closed data sources. The research team is developing an AI-based system that other researchers can use online to search for new drug targets and markers without in-depth knowledge of data science [21].

4. The University of Jyväskylä. An example of healthcare-related research can be the research of social and health care service processes. The group, led by Docent Toni Ruohonen, develops and applies methods of process mining, event-based simulation and predictive analytics to the study of social and health care activities. Customer flow, service path and treatment process descriptions obtained from log files, registry data and databases provide information on the use and needs of customer services, controllability in different service entities, cause and effect relationships between different service entities and transac-

tions, and problems. Customer flow and service process descriptions generated using process mining can be translated into discrete simulation models using conversion algorithms [21].

5. Lappeenranta-Lahti University of Technology (LUT). An example of research can be machine vision and pattern recognition research. The group is led by Professor Lasse Lensu. The research areas of the group are visual inspection, computational vision, medical imaging and image processing, color vision and biomolecular vision. The goal of the group is to produce applications, especially using digital image processing and image analysis. Applications include body detection and identification, industrial machine vision, processing and analysis of retinal images of the eye, spectral imaging and analysis and modeling of photoactive biomolecules [21].

6. The University of Oulu. This university has been researching and teaching AI since the 1980s. As a result of basic research, significant progress has been made, for example, image and video processing (texture analysis, 3D vision) and emotional intelligence (micro-expressions, health recognition from video). The Research Unit for Medical Imaging, Physics and Technology (MIPT) develops and applies AI methods for the automatic analysis of radiological images (X-rays, magnetic images, et cetera), diagnostics and prediction of disease progression. Professor Simo Saarakkala's group is studying the application of AI methods related to the diagnosis and prognosis of osteoarthritis. In addition, the unit has embarked on a major research project to develop and apply AI methods to study the relationship between lower back pain and magnetic resonance imaging, improve mammography diagnostics, and reconstruct medical tomography images. Professor Miika Nieminen is the responsible director of the project. The strategic long-term goal of MIPT is to integrate AI-based diagnostics into hospital imaging processes [21].

7. University of Tampere. An example of the research group related to AI in healthcare may be ICory, a group led by postdoctoral researcher Jonna Koivisto. The goal of the Icory project consortium is to build a patient-oriented, next-generation solution for orthopedic and pediatric surgical treatment that utilizes digital communication, gaming, AI and robotics [21].

8. University of Turku. The group of Digital Health Technology Lab develops problem-based solutions mainly for the needs of healthcare clinical nursing in collaboration with other academic groups, research institutes and industry. The focus of the research is on wearable devices, the data they collect, the analysis of biosignals, their integration with other data, and the exploitation of the results as part of decision-making related to the care needs of the customer and the health care professional. One important part is the development of applications based on AI, which are moving in an increasingly personal and preventive direction in healthcare; for example, the detection of atrial fibrillation at home using a smartphone application for collecting biosignals and AI for data analysis [21].

2.6 Classification of artificial intelligence systems in healthcare

Some criteria offered by the authors of current research that can be used for classification of AI tools in healthcare are presented in Table 1.

Table 1. Classification of AI systems in healthcare [17].

Criteria	Classes	Examples
By purpose	For diagnostics assistance	IBM Watson
	For healthcare enterprises management	Qventus
	For training planning / healthy lifestyle	Gymfitty
By data collection means	Collecting data by sensors	Cardiio
	Collecting data by inquiring	Ada
By types of users	For doctors	DeepMind Health
	For patients	Get In Shape
By types of processed data	Processing expressions in natural language	Your.MD
	Processing images	Face2Gene
	Processing numeric data	Gymfitty

Some of the projects mentioned in Table 1 will be described below. Qventus was founded in 2012 in the USA. It set the goal of optimizing the solutions in hospitals in real time to improve the quality of services and reduce costs. The mission of the project is to simplify the work of the healthcare system so that staff can better concentrate on helping patients.

Qventus is an AI-based platform that solves operational tasks in different departments of the hospital. Qventus also integrates healthcare systems [17].

Gymfitty can be noted among the fitness applications. It is performing the functions of a personal trainer. Gymfitty adapts the user's trainings according to his or her performance. Based on a number of factors (user's goals, his or her level of physical fitness, heart rate, feedback, data from past trainings), the application creates personalized instructions for training [17].

Cardiio is a project from the USA, founded in 2012. This project is developing intelligent algorithms for smartphones and wearable devices intended to monitor health conditions. Cardio is not a tool for diagnosing, preventing, or treating any condition and cannot replace professional healthcare. It is positioned as an assistant in everyday life [17].

2.7 Challenges of artificial intelligence systems in healthcare

Apart from technical challenges, there is also a set of specific social and ethical difficulties that we may encounter when using AI in healthcare. Since the introduction of AI into healthcare involves interaction of AI with a wide audience of people, there may be some bias from users towards AI systems: they may suspect AI to be dangerous. Moreover, the final decisions on implementation of the technology are often made by non-IT people having only a vague idea of AI. The solution to these problems will be raising awareness, refuting common misconceptions about AI; and, in relation to governments, it is relevant to be capable to clearly and convincingly express ideas so that governments understand importance of the implementation and possible profits from it [22].

Another obstacle for AI in healthcare may be the information security and privacy issue. Data used for teaching AI should be prevented from being passed on to third parties. There should be reliable protection against cyberattacks. In healthcare data protection needs special attention, because in this field a cyber attack can literally lead to death (for instance, remote hacking of a pacemaker or deliberate re-teaching of a diagnostic system and recommendations for offering a deadly medicine or procedure). Also, a number of related questions arise: what protection is actually reliable, who assesses reliability and who will be in charge in case of an incident [22].

Moreover, AI systems inevitably impact the work and life of medical employees. Regarding this aspect, two paths of positioning AI in healthcare can be formulated [17]:

1. AI is an assistant for healthcare employees and patients. This path involves following the idea of a human doctor as an a mandatory, indispensable object, since medicine is a science primarily about a human being; and a human being can be properly analyzed only by another human being – not by an artificial system that is unable to take into account all significant subtle details. Thus, the AI is an assistant, and the doctor is responsible for interpreting the outcomes of its work and for their application [17].

2. AI replaces doctors once it becomes advanced enough for this. On this path, we need to investigate to what point the doctor can be really replaced by AI. We will have to seriously question whether we can trust AI, and we will have to provide very high reliability of the AI system. So far, the second path looks rather like a utopia [17].

Implementation of AI may lead to job loss. For instance, in 2017, due to the beginning of the work of Watson Explorer, the remote interface of the IBM Watson cognitive system, Fukoku Mutual Life Insurance (Japan) had to dismiss 34 employees [22].

In any case, issues of AI in healthcare: technical problems, issues in matters of confidentiality and security, laws and responsibilities, as well as underwater rocks of ethical and psychological nature – need to be further worked at. If we answer the challenges, AI will become a useful instrument that can help to save lives and bring noticeable improvements into our everyday reality [22].

Table 2 shows brief description of challenges for embedding and using AI in healthcare that have been detected in the framework of the research, and possible solutions for them.

Table 2. Challenges of AI systems in healthcare [17, 22, 23, 24, 25].

Challenge	**Possible solution**
Technical challenges	
Providing appropriate flexibility and performance	Using architectures based on GPUs, FPGAs and special-purpose AI chips
Providing appropriate data latency and data bandwidth	Faster networks
Necessity for data to cross boundaries of the servers or boundaries between the servers and storage	Providing data locality, or enhancing integration between GPUs and storage, or providing composability of AI servers
Social challenges	
Mistrust from company governments (when it comes to embedding) and from users (when it comes to usage)	Increasing awareness about AI and its relevance, in a clear and convincing manner
Privacy and information safety	Clear assigning of responsibilities and taking protection measures that are proven to be reliable
Affect on humans in the industry and job loss	Correct way of positioning AI in healthcare. Training medical employees to work with AI

Current research is focused more on the organizational aspect of AI system in healthcare. Basically, the main technical challenge is the fact AI systems often work based on architectures that completely differ from traditional ones. Therefore, it is important to choose the proper AI architecture that would satisfy requests of the company [25].

It makes relevant elaboration of SOA for AI system, which will be the subject of further chapters. Next, main theoretical concepts laying the further research foundation will be explained.

3 FRAMEWORK FOR SERVICE-ORIENTED ARCHITECTURE IN HEALTHCARE

3.1 Main terms of service-oriented architecture

The first basic term to be considered is the term of architecture. According to GOST R ISO / IEC 18384-1-2017 Information Technology, architecture is the basic concepts or properties of a system in an environment embodied in its elements, relationships and the specific principles of its design and development [26].

The Open Group Architecture Forum (TOGAF) has the following definitions of architecture: 1) a formal description or detailed plan of the system at the component level to guide the process of its creation; 2) the structure of the components, their interconnections, the principles and directions of development that determine their development and evolution [27].

Architecture is necessary for the following tasks: 1) designing and modeling at different levels of abstraction; 2) separating instructions from implementation; 3) building flexible systems; 4) ensuring addressing business; 5) analysis of the volume of changes in requirements; 6) ensuring principles are followed [27].

According to GOST R ISO / IEC 18384-1-2017 Information Technology, service-oriented architecture (SOA) is an architectural style in which business systems and IT systems are designed in terms of the services available through the interface and the results of these services [26]. In IBM SOA foundation SOA is defined as follows: "SOA is an architectural style for creating an enterprise IT architecture, using service-oriented principles to achieve a close connection between the business and its supporting information systems" [27].

IBM SOA foundation offers an SOA reference model, as shown in Fig. 3, which presents the main capabilities required to support a SOA. Since this model itself is based on service orientation, it gives an opportunity to incrementally implement SOA as new business requirements emerge, starting with small projects and expanding integration [27].

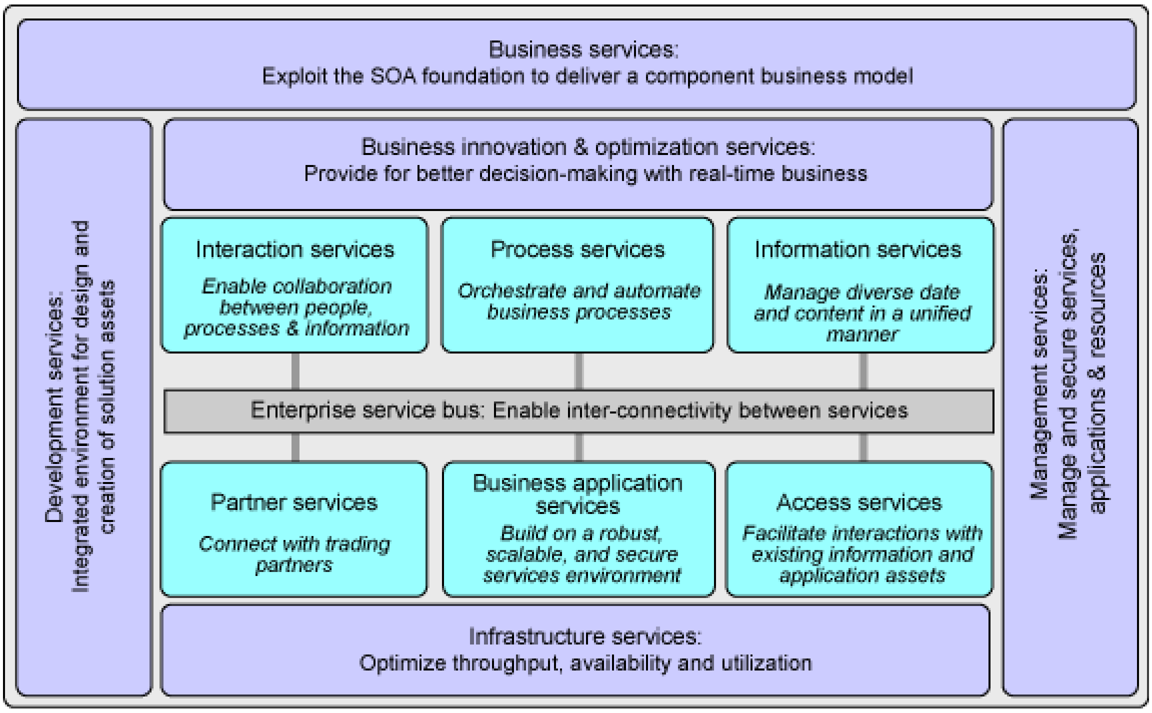

Fig. 3. SOA foundation reference model [27].

SOA has the following features: 1) it improves the relation between the business and the EA; 2) it allows creating complex applications from sets of integrated services; 3) with SOA, flexibility of business processes is provided; 4) in an evolutionary way, SOA introduces new opportunities, new ways for cooperation, new supporting infrastructures and new types of software applications into the industry [27].

One of the main terms of SOA is a service. A service is a logical representation of a set of actions that generate specified results; the service is autonomous, may consist of other services, while consumers of this service are not required to know its internal structure [26]. There is also a definition by IBM: "A service is a visible resource that performs a repetitive task and is described by an external instruction" [27]. The key ideas behind the concept of a service are:

1. Business orientation: services are oriented toward business needs and not toward IT capabilities. Service analysis and design techniques support the orientation of services toward business [27].

2. Instructions: services are self-contained and are described in terms of interfaces, operations, semantics, dynamic characteristics, policies and properties of the service [27].

3. Reuse: reuse of services is provided by their modular planning [27].

4. Agreements: service agreements are concluded between entities referred to as providers and users. These agreements are based on service instructions and do not affect the implementation of the services themselves [27].

5. Location and visibility: throughout their life cycle, services are hosted and made visible through service metadata, registries, and storage [27].

6. Aggregation: on loosely coupled services, unifying business processes and complex applications for one or several enterprises are built [27].

Another key concept of SOA is interfaces. They are meant for presenting the capabilities of a particular service to users and for organization of interaction between various types of services. In the service interface, parameters for accessing it are defined and the result is described, id est the interface should determine the essence of the service, and not the technology for its implementation [28].

3.2 Principles of service-oriented architecture

Essence of SOA, as of a style, can be formulated in the following general principles:

1. Building the information system (IS) not as a monolithic system, but as a block system, in which it is possible to assemble the required complex IT solution from blocks (services) [29].

2. The blocks are connected with the use of business process management (BPM) systems that control service calls and workflow [29]. BPM is engaged in the full life cycle of business processes in order to increase their efficiency, flexibility and manageability. BPM conducts modeling, simulation, optimization, placement, execution, management and mon-

itoring of business processes, after which it produces the results necessary for improving models and again begins a cycle of improvements [27].

3. A set of already existing services can be used to automate new business processes; hence processes automated with the use of SOA can be easily configured or rebuilt according to specific needs of the company or in response to changes in environment [29].

4. The concepts of "service" and "process" are interdependent, and they can be used at different levels of generalization. For example, a small process can be organized as a separate service, if it can be typified. At the same time, the process can be divided into separate services that interact with each other within the process [29].

5. Standard service blocks are created for subsequent reuse in different processes, and the more services are available, the faster and easier it will be to introduce new automated processes and optimize existing ones [29].

3.3 Approaches of service-oriented architecture

1. OASIS SOA Reference Model (SOA-RM). This model provides a common basis (concepts and terms) for service-oriented modeling and identifies meta-model aspects of services [30]. OASIS has adopted the Reference Model for SOA. The model aims to introduce a clear technical SOA terminology for developers and architects. The OASIS technical committee that worked on the model defines SOA-RM as an abstract base for understanding core objects and the relationships between them in a service-oriented environment and for developing consistent standards and specifications that support such an environment [31]. The model unifies SOA concepts and can be used by architects to develop SOA or in SOA training. The committee also notes that SOA-RM is not directly related to any standards, technologies or other details of specific implementations [31]. The goal of the model is to provide general semantics that remove all ambiguities in various SOA implementations. However, according to ZapThink analysts, SOA-RM will not be suitable for development. The reference model from OASIS, according to ZapThink, will help architects coordinate individual SOA projects in an organization or plan to create a unified corporate architecture, but the abstractness of its concepts prevents the use of SOA-RM in

specific implementations of SOA [31].

2. OASIS Reference Architecture Foundation for SOA (SOA-RAF). It is an abstract, basic reference architecture focused on business through a service view [30]. SOA-RAF is meant to describe the foundation on which a specific SOA may be constructed. It comes from the concepts and interconnections defined in SOA-RM, as well as from work carried out in other organizations. SOA-RAF concentrates on the approach to integration of business with the IT necessary to support it. SOA-RAF includes 3 main views: “The Participating in a SOA ecosystem” focusing on how participants are part of a SOA ecosystem; “The Realization of a SOA ecosystem” addressing the requirements for building a SOA-based system in a SOA ecosystem; and “The Ownership in a SOA ecosystem” concentrating on what is meant by ownership of a SOA-based system [32].

3. The Open Group SOA Reference Architecture (SOA-RA). SOA-RA provides recommendations and architecture, design and implementation options for creating architectures of service-oriented solutions, including cloud computing architectures. The purpose of the SOA-RA is to give a prototype for making and evaluating architecture, and also to provide information, templates and building blocks for integrating the basic elements of a SOA into an EA or a solution [33].

4. The Open Group SOA Ontology. This standard defines the concept, terms and semantics of SOA from both business and technical points of view [30]. It is intended to ensure communication between business and technical people; to improve understanding of SOA concepts; to provide means to clearly and unequivocally state issues and opportunities [34]. The SOA Ontology can be used by business people to enhance their understanding of SOA concepts and the use of these concepts; by architects and architecture methodologists; by software and system designers for structure and terminology guidance [34].

5. Service-oriented Modeling Framework (SOMF). This methodology has a specialized, technology-independent notation helping to model, analyze and identify services. It proposes a formal method for identifying services at various levels of abstraction [30]. SOMF is used by architects, analysts, developers and managers to address EA, SOA, application

architecture and organizational cloud computing tasks. SOMF fosters a holistic picture of corporate software objects that are considered service-oriented assets, id est services [35].

3.4 Overview on the use of service-oriented architecture in healthcare

There are a few publications related to SOA in healthcare. Among them there is “ICT for the elderly: service-oriented architecture of a system for remote monitoring of the health status of patients with diabetes” by Zaikina N. V. et alia. In this article, the authors develop a system for remote monitoring of a patient’s health status based on a service-oriented event-driven architecture. Together with a detailed description of the system architecture and its advantages, the article gives an overview of the remote medical care market, its barriers and development potential [36].

SOA is used in the article by Kopanitsa G. D. and Silich V. A. “Development of a system for collecting and analyzing medical statistics based on the medical data transfer standard ISO 13606”. This article investigates the possibility of combining medical institutions into a single information space. The authors use the standard ISO 13606 and a SOA to implement a system for collecting and analyzing medical data to ensure the rapid collection and analysis of medical statistics by regional health authorities. The authors show effectiveness of this solution to improve the efficiency of the health care system across the region of Russia [37].

T. Yang et alia in their article “A Scalable Healthcare Information System Based on a Service-oriented Architecture” describe the healthcare IS used in National Taiwan University Hospital (NTUH) and propose a SOA-based healthcare IS according to the HL7 service standard. The focus of the offered architecture is system scalability, both from hardware and software points of view [38].

F. Kart et alia describe an e-healthcare system in their paper “Building a Distributed E-Healthcare System Using SOA”. This system uses a SOA as a tool to design, implement and manage health services and can be easily extended to other medical professionals, including technicians who conduct and report analyzes requested by doctors. Moreover, the system can be associated with other applications providing information on drugs and dosages and warn about the interaction between drugs. Also, the system can be associated with drug delivery devices that give prompts and control proper and timely taking of medication [39].

The article “The Integrated Informational Environment of the social domain” by Shifrin M. A. highlights the fundamental principles of building a unified information environment for the social sphere. To ensure sustainable evolutionary development of this information environment, the author proposes to rely on modern principles of building complex information and computing systems, such as the process approach, SOA and resource sharing. The author emphasizes that it is important to combine a centralized approach to building infrastructure components with a competitive approach when solving specific problems [40].

Huang H.K. in the paper “Expansion of picture archiving and communication system – PACS by SOA technology” describes expansion of the archiving and image transfer system, PACS (Picture Archiving Communication System), which is widely used in healthcare facilities. The author proposes to supplement the system structure with new functions that are based on a SOA. The constructed system is intended for use in distributed medical image processing systems and is aimed at fast and high-quality diagnosis [41].

The described papers concern SOA in healthcare without focusing on AI. The topic of SOA of AI system in healthcare is currently not covered in literature significantly, as far as it can be judged from the conducted overview.

3.5 Challenges of service-oriented architecture in healthcare

The use of IT in general in the field of healthcare faces the same challenges as the use of IT in any other field, but there are certain features that make IT in healthcare unique. Among them can be named: the uniqueness of data and business processes, difficult regulation and a wide variety of stakeholders (clinics, patients, suppliers, et cetera) [42]. Current requests of the healthcare field concerning IT in general include:

1. Creating a permanent patient history. This way a record about patient’s health can be shared between several healthcare specialists and systems [42].

2. Ensuring identity and security management [42]. The security question that is important in any domain gets especially crucial in healthcare because healthcare involves big amounts of sensitive data.

3. Evolving to new medical unions and responding the rapid change in regulatory requirements [42].

4. Ensuring the collaboration of completely different systems [42].

5. Maintaining investments in legacy systems [42].

SOA can provide flexibility, adaptability, legacy leverage and cost-effectiveness for medical systems [42]. However, there are a few points that can be considered challenging for the implementation and the use of SOA in healthcare:

1. The required relationship between business goals and the value of SOA is not always clear to those who adopt SOA – they are required to have both business and IT skills in order to understand this relationship [42].

2. SOA cannot be "bought off the shelf" – it is an architectural style, not a ready solution. There may be variety of architectures that can be built in the SOA style. It means that many actions have to be taken and many decisions have to be made by the adopter: elaborating certain elements of the certain architecture and their interactions; building system qualities into the architecture; design and implementation of the services; decisions on technologies and tradeoffs. All these actions and decisions are associated with risks [42].

3. It is not always feasible to integrate all legacy systems into the SOA environment. Technical feasibility and cost-benefit should be analyzed beforehand for each system [42].

4. SOA supposes not only a shift in technology; it also supposes changes in the model of organizational governance. It is important to decide which life-cycle model should be used for services and to define requiring governance mechanisms [42].

5. It is always difficult to design a “good” service – service provider must define what is the right granularity and quality of services, and also predict potential consumers and usage patterns [42].

4 DEVELOPMENT OF SERVICE-ORIENTED ARCHITECTURE FOR ARTIFICIAL INTELLIGENCE SYSTEM IN HEALTHCARE

4.1 The place of artificial intelligence in the improvement of business processes

Management of enterprise business processes involves continuous improvement of these processes. In order to make the improvement successful, it is important to conduct systemic, all-around analysis of the processes and reveal their disadvantages and potential for enhancement in all aspects. Such analysis can be made with the use of "7Rs" framework, that was developed by The 24/7 Innovation Group [43]. "7Rs" framework offers 7 categories of questions (7 heuristics) and possible questions within them. These questions can be applied to the "as-is" business process model, and, by answering them, it is possible to get a list of necessary points to improve in the model. Then, according to this list, the "to-be" model can be built. The advantages of the "7Rs" framework are the following:

1. Universalism. Heuristics and the questions described in the framework are generalized. The framework is universal and suitable for various business processes at enterprises in different industries.

2. Versatility. The framework provides directions (heuristics) in which improvements can be made. This provides a starting point for reflection in various aspects of the business process, so that the analysis is more multifaceted.

3. Localization. Within the heuristics, the framework provides the most common questions from companies' practice that can be asked about the processes to identify potential improvements. These questions are easy to understand and are aimed at concrete, local enhancement, indicating a specific process characteristic or aspect. The authors of the framework indicated the applicability for each question, that is, they described in which specific cases the question should be asked for a particular activity within the business process.

The "7Rs" framework is showed in Table 3. It should be mentioned that, obviously, not all heuristics and questions of the framework can be applied for each model. The framework has to be customized (id est, depending on the certain case, heuristics and questions can be removed and/or added).

Table 3. The "7Rs" process innovation framework [43].

Heuristic (the "R") / Question	**Applicability**
# 1 RETHINK	applicable always
# 2 RECONFIGURE	
How to liquidate the activity?	when the activity is unnecessary and brings low value
How to combine the common activities?	1) when common activities are performed in several places or performed inconsistently; 2) when there can be cost savings depending on the production scale
How to reduce reconciliation by giving priority to quality?	1) when it takes a lot of time to approve documents and correct errors; 2) when accountability for errors is little
How can information exchange with customers and suppliers make the process better?	1) when it is hard to predict demand and there is uncertainty about it; 2) when inventory interruptions occur frequently; 3) when inventory is excessive
How to get rid of intermediaries and of work without added value?	when the intermediaries do not add any value, but simply retransmit goods and services
How to borrow and improve the best practices of other industries?	when searching new ideas (always)
# 3 RESEQUENCE	
How can efficiency be increased with the use of prediction?	1) when accurate information about demand is accessible at an early stage; 2) when forecast models have proven reliable; 3) when accuracy or inventory costs are less crucial than time compression; 4) when changes of the product or service are rather low
How can flexibility be enhanced due to postponement?	1) when there is a need for customized products/services; 2) when there are large inventory carrying costs; 3) when forecast models are not accurate
How can time be reduced due to parallelism?	1) when there are limited time dependencies between activities; 2) when time compression is crucial; 3) when rework is needed because errors are detected late

Table 3 (continuation). The “7Rs” process innovation framework [43].

Heuristic (the “R”) / Question	**Applicability**
# 3 RESEQUENCE	
How to minimize the quantity of interconnections and dependencies?	1) when there are “bottlenecks”; 2) when there are big queues; 3) when handoffs are frequent;
# 4 RELOCATE	
How can this activity be brought closer to the customer or supplier in order to increase its effectiveness?	1) when the distance from the customer or supplier has caused a delay, misunderstanding or mistake; 2) when customer convenience is crucial; 3) when customer volume is big, and delivery time or costs are high
How can this activity be brought closer to associated activities for better communication?	1) when high-level teamwork and cooperation are required to perform the activities; 2) when alterations and errors are difficult to track to their source
How can cycle time be reduced by lowering travel time and distance?	1) when travel is an important part of the process; 2) when goods are shipped several times (from the factory to the warehouse to the customer)
How to create geographically virtual organizations?	1) when resources are geographically distributed, but to achieve the result you do not need to be nearby; 2) when group software technologies can be used effectively; 3) when the cost of doing business may be lower in another geographic area
# 5 REDUCE	
How to decrease or increase frequency of this activity?	1) when activities have no added value but are necessary; 2) when variation in the process or product is low; 3) when there is high variability and low installation costs and time (for example, small batches)
How would getting more information improve effectiveness?	1) when greater accuracy is necessary; 2) when better segmentation would enhance marketing effectiveness
How would less information or fewer controls simplify and improve efficiency?	1) when most of the cost goes to data collection or monitoring; 2) when value obtained from information or controls is minimal; 3) when perfect accuracy is not required
How to use critical resources in a more effective way?	1) when critical resource utilization is low; 2) when critical resources do work without added value or unnecessary work

Table 3 (continuation). The "7Rs" process innovation framework [43].

Heuristic (the "R") / Question	**Applicability**
# 6 REASSIGN	
How can existing activities and decisions be moved to a different organization?	1) when a different organization possess skills or resources that your organization lacks; 2) when you wish different branding; 3) when changing the previous operating model/culture is too difficult
How can the activity be outsourced?	1) when you do not carry out this activity at the world-class level; 2) when this is neither core competency nor critical; 3) when another organization carries out this activity at the world-class level; 4) when your resources are limited and you wish to concentrate on your core business areas
How can this activity be performed by the customer?	1) when customers wish to be able to help themselves (self-care); 2) when there are some certain unprofitable customer segments; when costs should be reduced
How can the organization perform an activity that is already performed by the customer?	1) when the customer wishes to have better convenience and/or value; 2) when the organization wishes to become closer to the customer
How can tasks be compressed and integrated due to cross-training?	1) when multiple tasks are required to get the result; 2) when processes are not complicated enough to justify having a specialist; 3) when only 20% of cases or less need conducting special expertise
How can this activity be performed by suppliers or partners?	1) when the supplier/partner possesses skills, resources or economies of scale that your organization lacks; 2) when the activity is not crucial nor a core competency; 3) when the activity is in the business arena, which may change quickly in the future, and additional flexibility is required
# 7 RETOOL	
How to transform the process with technology?	when it is necessary to get more independent of the location, time, performer
How to automate the activity?	1) when the current process is paper or manual and cannot be eliminated; 2) when the activity suffers from errors, inconsistencies or coordination issues; 3) when large transaction volumes are required

Table 3 (continuation). The “7Rs” process innovation framework [43].

Heuristic (the “R”) / Question	Applicability
# 7 RETOOL	
How to leverage resources and competencies to get a competitive advantage?	1) when the organization possesses world-level competencies; 2) when the existing business does not seem to have potential of growth
How can the process be enhanced by up-skilling, down-skilling or multi-skilling?	1) when satisfaction of customers is low (up-skilling); 2) when technology can create knowledge workers (down-skilling); 3) when to achieve the result, several specialists are required (multi-skilling)

Next, the potential place of AI in process innovation is defined, based on the framework. The result is presented in Table 4. This table is general and it encompasses improvements that can be done with the of various AI systems with different functionalities.

Table 4. Possible use of the AI system in process innovation for a medical organization

Heuristic (the “R”) / Question	The proposed principle of improvement with AI	An example of activity being improved	Possible improvements in the activity	Related process / value metrics
# 1 RETHINK				
How to improve the business process?	Correcting the current business process model using “7Rs” question list with regard to the AI system	All business processes	Analysis of “as-is” business process model, revealing problems in the model with the use of “7Rs” framework and working on them	Number of bottlenecks, waste activities et cetera in the model / Time of the process; Overall added value of the process

Table 4 (continuation). Possible use of the AI system in process innovation for a medical organization

Heuristic (the "R") / Question	The proposed principle of improvement with AI	An example of activity being improved	Possible improvements in the activity	Related process / value metrics
# 2 RECONFIGURE				
How can data exchange with healthcare suppliers make the process better?	Sharing patient data between organizations	All business processes	Gathering data from all sources throughout the whole way of patient's interaction with healthcare organizations and/or devices, in order to learn from these data and improve the quality of services (although, sensitiveness of the data is to be taken into account)	Patient data completeness / Quality of healthcare services; Personalization of healthcare services
How to borrow and improve the best practices of other industries?	Learning from practice of the use of AI in another industries	All business processes	Analyzing opportunities and obstacles of AI systems in different domains, in order to apply the learnt knowledge in healthcare	Number of bottlenecks, waste activities et cetera in the model / Time of the process; Overall added value of the process

Table 4 (continuation). Possible use of the AI system in process innovation for a medical organization

Heuristic (the "R") / Question	The proposed principle of improvement with AI	An example of activity being improved	Possible improvements in the activity	Heuristic (the "R") / Question
# 3 RESEQUENCE				
How can efficiency be increased with the use of prediction?	Using the functions of the AI system for early diagnostics	Disease diagnostics	Identification of the diagnosis by indirect signs at early stages of the disease	Amount of data necessary for making the prediction / Time from the onset of the disease to the start of treatment of the disease
	Choosing better path of treatment with the use of AI	Disease treatment	The choice of treatment methods based on the individual characteristics of the body and the selection of drugs using digital twins	Amount of data necessary for making the prediction / Time to find the correct treatment for a patient
	Predicting availability of beds	Bed management in hospital setting	Predicting discharges => planning bed occupancy in more efficient way	Amount of data necessary for making the prediction / Time of waiting for a bed

Table 4 (continuation). Possible use of the AI system in process innovation for a medical organization

Heuristic (the "R") / Question	**The proposed principle of improvement with AI**	**An example of activity being improved**	**Possible improvements in the activity**	**Heuristic (the "R") / Question**
# 3 RESEQUENCE				
How can efficiency be increased with the use of prediction?	Predicting worsening of the health state with AI	Treatment at home care	Predicting worsening of the health status of aged people in home care [19]	Amount of data necessary for making the prediction / Time to take measures before worsening of the health state
# 5 REDUCE				
How to use critical resources (human resources) in a more effective way?	Providing AI assistance for doctors	Disease diagnostics	Preventing doctors from working with too big amounts of data, committing this task to the AI system => preventing overwhelming and subsequent diagnosis mistakes	Amount of data necessary for making a diagnosis / Time to make a diagnosis; Correctness of the diagnosis
# 6 REASSIGN				
How can this activity be performed by the customer?	Providing AI assistance for people at home care so that they could perform self-care	Treatment at home care	Providing AI assistance for people (for example, aging people) to live at home, in familiar surroundings, independently and in good conditions, aiding them to take care of hygiene and diets [20].	Amount of data necessary for personalized care / Time of patient's ability of staying home independently

Table 4 (continuation). Possible use of the AI system in process innovation for a medical organization

Heuristic (the "R") / Question	The proposed principle of improvement with AI	An example of activity being improved	Possible improvements in the activity	Heuristic (the "R") / Question
# 7 RETOOL				
How to automate the activity?	Solving logistical issues with the help of AI	Nurse care in hospital setting	Providing robotics assistance for logistics, care and laboratory work => nurses do not spend their working time on solving logistical issues; this will also make the hospital safer and more efficient [20]	Performance of robots / Percentage of time spent by human employees doing their direct job
	Searching new drug targets with the help of AI	Drug discovery in pharmacy	Automating the laborious early stages of drug development with the use of AI screening drug targets from databases and locating relevant information from a variety of open and closed data sources [21]	Amount of data necessary to teach the AI / Time to discover a new drug
	AI analysis of radiological images	Disease diagnostics	AI determines what it "sees" on the medical images and then gives the appropriate assessment to the attending physician in order to speed up and enhance the quality of physician's work [7]	Amount of data necessary to teach the AI / Time to make a diagnosis

Table 4 (continuation). Possible use of the AI system in process innovation for a medical organization

Heuristic (the "R") / Question	The proposed principle of improvement with AI	An example of activity being improved	Possible improvements in the activity	Heuristic (the "R") / Question
# 7 RETOOL				
How to automate the activity?	Taking medication automated with AI	Disease treatment	Preventing patients from taking excessive medication, not sufficient medication, or using drugs that interact with each other in unwanted ways, with the use of automated treatment (AI reminders and AI moderators) [20]	Amount of data necessary to teach the AI / Number of errors while taking medication
	Using rehabilitation robots	Nurse care in hospital setting	Providing robotics and AI help for rehabilitation of people with brain injuries: assisting in wellness training and helping to cope with loneliness or other mental health problems [20]	Amount of data necessary to teach the AI / Rehabilitation time

4.2 Formulation of the task for creating a business model canvas and building the service-oriented architecture

Before conducting the practical part (building a business model canvas and a SOA) in the framework of this thesis, it is necessary to formulate several points. First is which task the AI system that is described in the work is intended for and which delimitation it has. The task of the system is the following: identification of the diagnosis, including identification by indirect signs in the early stages of the disease. The delimitation of the system is that it is positioned as an assistant for a human, not as a system that is supposed to replace a human entirely.

Second is which kind of organization the practical part of the thesis is applicable for. The practical part is conducted based on best practices of medical organizations. Its results still may need customization for a certain case, but basically fit for any outpatient clinic with a wide profile.

Third is the viewpoint and the scope of the practical part. It is conducted from the point of view of EA, IS architecture and BPM. It is not focused neither on the technical realization of the AI technology, nor on the social consequences of implementation of AI solution.

4.3 Business model canvas of medical organization with the use of artificial intelligence system

A business model of an organization can be defined as a study of its potential in various aspects; the business model reflects the characteristics of the organization and its relationship with the external environment, which can be a source for creating uniqueness and competitiveness, but also shows the necessary resources and associated costs. In this thesis, the Osterwalder’s business model canvas is used, because of the following advantages:

1. Systemic view. Business model canvas fosters systemic thinking, id est it encourages thinking of an organization as of a system, considering connections and interdependencies between the elements. The aspects of business model are presented as segments of the canvas.

2. Intuitiveness. Understanding of business model canvas does not require any special knowledge; hence it can be read by people of any departments, as well as by external entities like sponsors. It provides a single conceptual base for all of them so that they could speak the same language.

3. Easiness to rework. Because of its simplicity, business model canvas is an agile tool, encouraging iterative process of reworking. Basically it can be used like a board for ideas that have to be tested and enhanced.

4. Visibility. When it comes to implementation of a new IT solution, it is important to

clearly see both profits and additional costs it brings. Business model canvas can help to provide visibility: it is possible to build “as-is” business model canvas and then create a similar canvas, but segment by segment applying the changes that come with the implementation, getting “to-be” model. Then the difference between the two models will be visible by aspects.

The Osterwalder’s canvas comprises segments that are logically connected to each other. They can be filled in this order:

1. Customer segments. Here, the target audience of the enterprise should be indentified: to whom will it mainly provide goods and/or services? To whom the value created by the enterprise is meant?

2. Value proposition. In this segment, it is needed to determine the enterprise’s proposals that make its goods and services attractive to customers and that distinguish these goods and services from those offered by other enterprises. It is necessary not to list the goods and services themselves in this segment, but to formulate their mission in relation to the customer: what value do they bring and what needs are they intended to satisfy?

3. Key activities. To deliver the mentioned value, the enterprise needs to perform certain activities. What activities are the core ones for delivering the value?

4. Key resources. Performing the key activities in the needed way (and hence bringing the value) requires assets, such as human resources, intellectual property and so on. In this segment these assets are determined, answering the question: what key resources are needed to perform the key activities so that they deliver the aimed value?

5. Key partnerships. It is necessary to identify organizations with which partnerships can potentially be implemented to better achieve goals; at the same time, it is important to question, by what can these organizations be motivated for partnership?

6. Channels. This segment defines in which ways awareness about the organization is

spread, through which means the connections with customers are set. Main questions asked while filling this segment are: what channels are the best to communicate with customers? Which expenses they require? How is it possible to integrate them into the established practices of the enterprise and the customers?

7. Customer relationships. This segment is to identify which sort of relationship the enterprise will have with each customer segment. The related questions are: how do we establish the relationships? How do we maintain them?

8. Cost structure. Here, the following questions are answered: what are the most significant costs in the business model and what are the most costly activities and resources? This segment can include fixed or variable costs.

9. Revenue streams. This segment is to define the income that is being generated in the business model, and also to enlighten related questions: for what value the customers wish to pay? In which ways do they wish to pay? What is the contribution of each revenue stream to the general stream?

The “as-is” model canvas for a clinic is showed in Fig. 4.

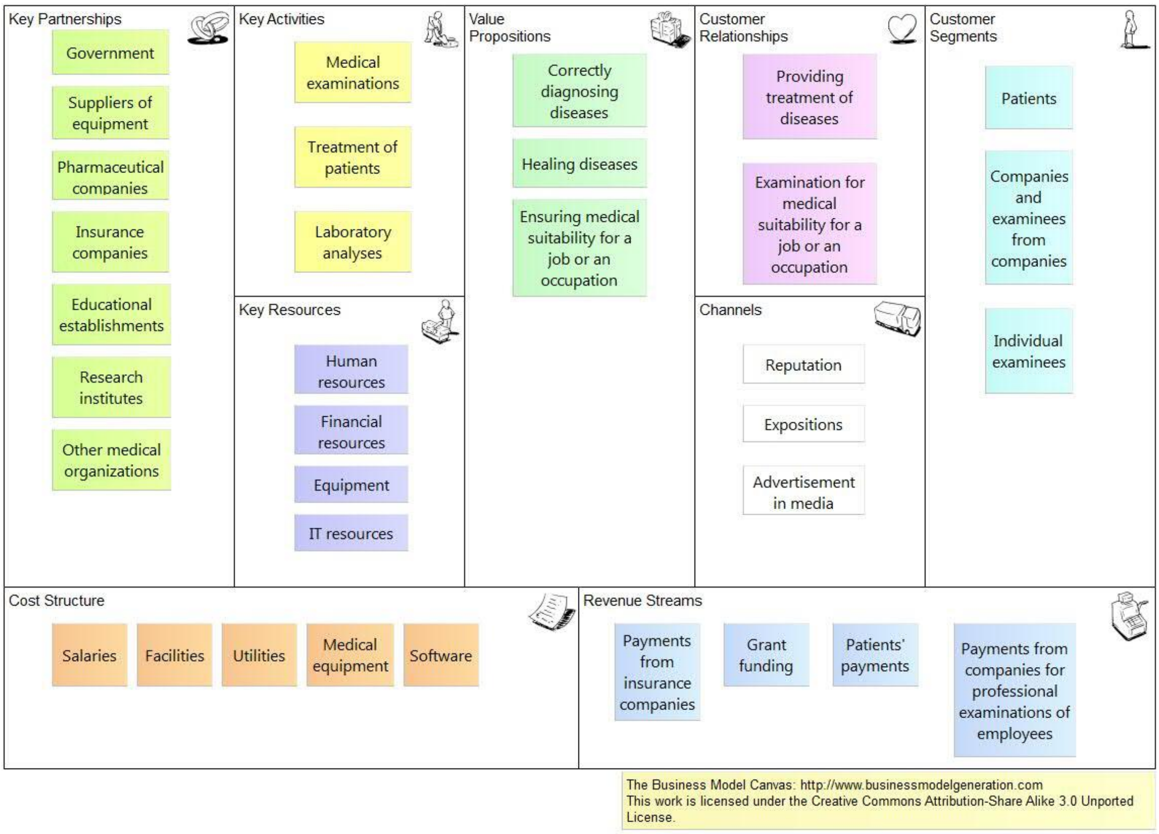

Fig. 4. “As-is” business model canvas of a clinic

To build a “to-be” business model canvas of an enterprise after the introduction of AI technology in it, it is necessary to answer questions on each of the segments regarding the changes that have occurred. These questions can be formulated as follows:

1. Customer segments. What additional consumer segments may appear after the introduction of technology?

2. Value proposition. What additional value propositions may appear after the introduction of technology? How can the already existing value propositions be reformulated and refined?

3. Key activities. What key activities may be added after the introduction of technology? How can the implementation of pre-existing key activities change?

4. Key resources. What additional resources may be required when using the new technology? What resources are provided by the new technology? What resources can be reduced due to the new technology?

5. Key partnerships. What new partners of the enterprise can appear after the introduction of technology? How can the technology create additional motivation for partnerships?

6. Key channels. What new communication channels may be required after the introduction of technology? What additional channels of communication with customers can be created using new technology? How can the communication channels that existed before the introduction of the technology be modified?

7. Customer relationships. What new customer relationships can be established? How can the relationships existing before the introduction of technology change?

8. Cost structure. What costs can be reduced after the introduction of technology? What costs will appear with the introduction?

9. Revenue streams. What additional revenue streams may appear? How can the technology change the contribution of pre-existing streams to the total stream?

The “to-be” model canvas for a clinic after the implementation of an AI diagnostics system is showed in Fig. 4.

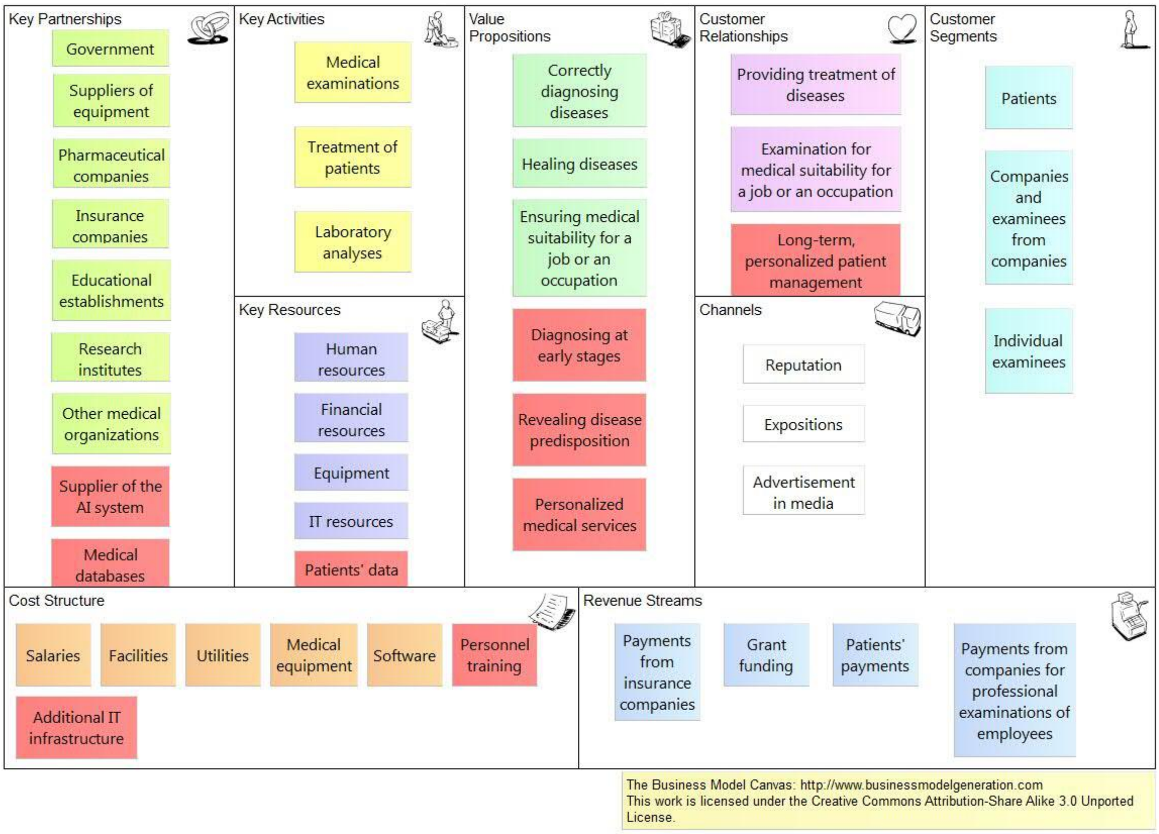

Fig. 5. "To-be" business model canvas of a clinic

Next, the main changes coming with the introduction of an AI diagnostics system will be described by canvas segments. The nuances of these changes will be different depending on specificity of a certain medical organization and a certain AI system.

1. Changes in customer segments and relationships. The main consumer segments will not change, but due to the capabilities of the AI system and the associated augmentation of the value proposition, the patient audience can be expanded by adding patients who want to know their predisposition to diseases and / or identify diseases in the early stages, in order to take preventative measures. As a result, relationships with patients will become more long-term. They will also be of a more individual nature (since AI systems allow personalizing medical services).

2. Changes in value proposition. The introduction of the AI system can help improve the diagnosis process and increase its accuracy, and, as a result, make the treatment process more effective. The accuracy in making decisions about the medical suitability of exami-

nees for certain types of activities may also increase. Additional value propositions that appear with the implementation of the AI system are: diagnostics in the early stages of the development of the disease, identification of a predisposition to diseases, personalized medical services.

3. Changes in key activities. The key activities of the organization will remain the same, but their quality can be improved by assistance of the AI system in making diagnostic decisions.

4. Changes in key resources. The AI system can be considered a new key IT resource of the organization. At the same time, such a resource as patients' data becomes a key resource, since data is the basis for the operation of the AI system.

5. Changes in key partnerships. In connection with the implementation of the AI system, the relationship of the medical organization with other medical organizations should become closer. It can be assumed that a single information space will be created for the exchange of experience between specialists of different organizations. Also, communication with medical databases should be organized, the data from which will be used by the AI system. It should also be noted that the use of the AI system by a medical organization can serve as an additional motivation for cooperation with this organization, since the AI technology arouses interest.

6. Changes in key channels. The communication channels remain the same, but it is likely that the company may receive more media coverage due to the popularity and relevance of the technology introduced. The introduced technology can also improve the company's reputation in the eyes of specialists and a wide audience.

8. Changes in cost structure. The AI system will require the cost of acquiring the necessary IT infrastructure (to provide the necessary computing power, storage capacity, et cetera). Also, staff should be trained to work with the implemented system, which will also require additional expenses. On the other hand, some expenses can be reduced by making more accurate diagnoses and, consequently, avoiding unnecessary medical decisions.

9. Changes in revenue streams. With the help of the AI system, it becomes possible to implement social programs financed from state and private grants.

4.4 Service-oriented architecture with the use of artificial intelligence system service

4.4.1 The ArchiMate language

In this thesis, the SOA will be built with the use of the ArchiMate language. ArchiMate is a modeling language by The Open Group that allows describing, analyzing and visualizing architectures and has a service-oriented sight [44]. The advantages of ArchiMate, that were the reason for choosing it for the thesis, are the following:

1. The thesis considers not a specific organization, but a general case. The use of such notations as UML and BPMN is appropriate in narrow areas when deepening in the details of processes, while the use of ArchiMate is suitable for the vast majority of practical cases, due to the simplicity and conciseness of the language [44].

2. ArchiMate is a single language that connects various areas of the organization: business processes, information flows, technical infrastructure [44]. Due to this, various stakeholders can be involved in the development of architecture and have access to all requirements [44].

The framework of ArchiMate is a matrix of 3 rows (layers) and 3 columns (aspects) [44]. Higher layers use services that are provided by lower layers [44]. The layers can be defined as the following:

1. Business layer (shown in yellow on ArchiMate views). This layer interacts with external customers and proposes them services. Services are implemented through business processes that are performed by business actors and roles [44]. The example blocks on this layer: Business actor, Business process, Business role, Business service, Contract, Representation.

2. Application layer (shown in blue on ArchiMate views). This layer comprises software

applications necessary to support the business components [44]. The example blocks on this layer: Application component, Application interface, Application process, Data object.

3. Technology layer (shown in green on ArchiMate views). This layer supports the application layer with hardware and infrastructure necessary for running the applications [44]. The example blocks on this layer: Node, Device, System software.

Aspects of ArchiMate are formulated with regard to relationships between actors and objects and to actions that are conducted. Aspects can be defined as the following:

1. Active structure. This aspect reflects entities conducting actions (demonstrating behavior) [44]. Examples of such entities can be Application Component (Application layer), Business Actor (Business layer), Device (Technology layer).

2. Behavior. This aspect reflects actions (processes, functions) performed by actors (id est, it reflects behavior demonstrated by active structure) [44]. Example of behavioral entities can be: Application Event (Application layer), Business Process (Business layer), Technology interaction (Technology layer).

3. Passive structure. This aspect reflects objects, upon which some actions are done [44]. Examples of such objects can be Artifact (Technology layer), Data Object (Application layer), Representation (Business layer).

4.4.2 Business process landscape

The landscape of business processes is the initial step for building SOA. It is intended to reflect business processes at the highest level. Fig. 6 shows business process landscape for the medical organization. The processes are grouped by type.

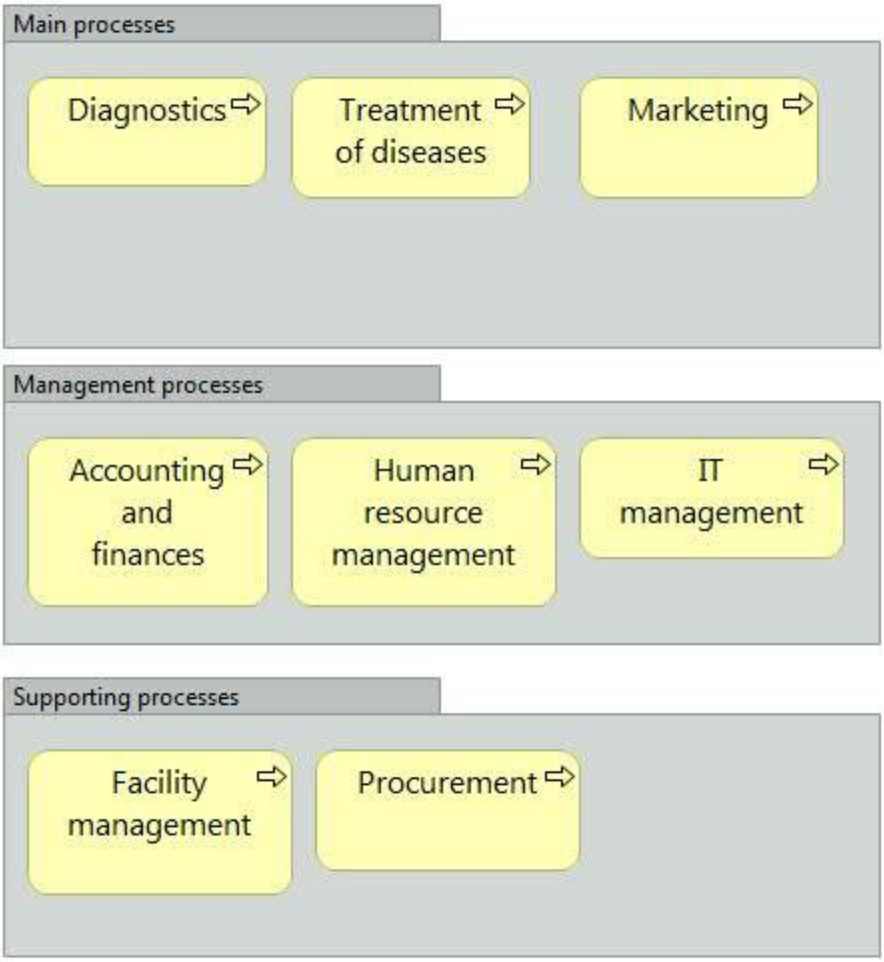

Fig. 6 Business process landscape

1. Main processes (can be also called key or core processes) – those processes that concern providing customer service and that create customer value. They are the base for the revenue in the organization and the purpose of existence of the organization [45].

2. Management processes – those processes that are related to management tasks. Generally, these tasks are concerned with planning and decision making, organizing, leading and controlling.

3. Support processes – those processes that ensure working of the main processes and running of the operations in the organization [45]. Support processes provide business resources in the required quality and quantity, ensuring the quality of the supply of resources or support services [45].

The used business process block (the example is showed in Fig. 7) in the ArchiMate language represents an internal, not externally visible behavior unit (or a set of units) designed for realization of services [46]. It is a behavioral element in the business layer.

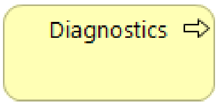

Fig. 7. Example business process block

4.4.3 Architecture of the enterprise information system

Next, architecture of an enterprise information system (EIS) in a medical organization based on the Enterprise Resource Planning (ERP) system is presented. The ERP can be understood as a strategy used by companies for management and integration of important elements of their business [47]. The ERP system is a software package implementing this strategy.

The architecture of EIS reflecting used ERP modules and external modules showed in Fig. 8. In this model of architecture, medical AI system is presented as a component of the ERP system. Other considered modules of the ERP system and external modules are described below.

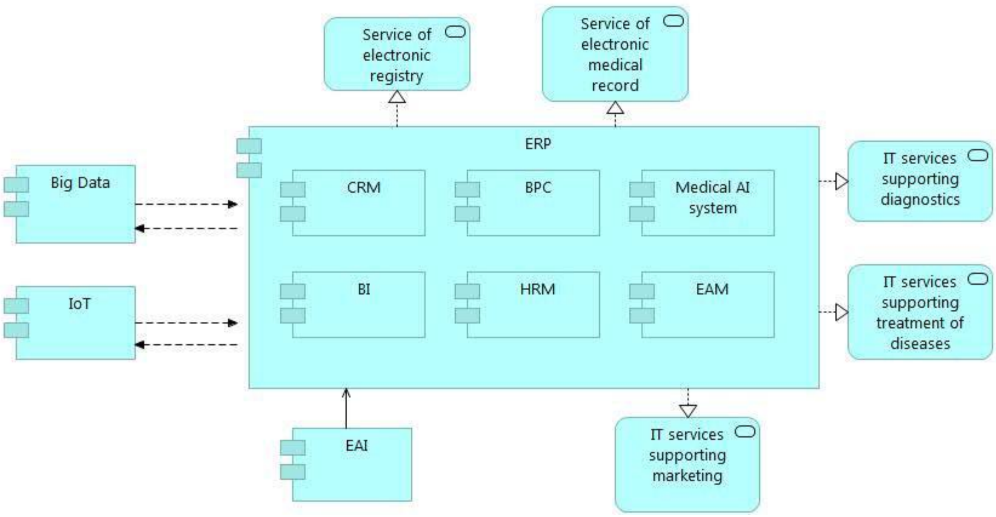

Fig. 8. Enterprise information system

Customer Relationship Management (CRM) is a module meant for managing the interaction of the organization with its current and potential customers [48]. Due to analysis of customer history data, the CRM module enables improving business relations with customers, which leads to sales growth stimulation [48].

Business Planning and Consolidation (BPC) is a module meant to support all operational and financial operations in the organization [49]. It provides automation and optimization of business forecasting, planning, and consolidation in the organization [49].

The Business Intelligence (BI) module is intended to provide better understanding of a business in its business context, providing a historical, current and predictive view of business operations [50]. BI often seeks to support enhancing business decision making [50].

The Human Resource Management (HRM) module is meant for automated complex personnel management [51]. HRM systems consist of a wide range of business processes and analytical capabilities, allowing full maintenance of the "history" of employees, from employment and salary calculation to planning and career development [51].

The Enterprise Asset Management (EAM) module allows managing the full life cycle of corporate assets: buildings and structures, industrial equipment, fleet, engineering infrastructure elements, IT equipment, business applications, software licenses and others [52]. EAM systems support solving the strategic tasks of the organization: improving the capital productivity and personnel, optimizing operating costs with a minimum of risks and required productivity, increasing reliability, rational use of technical resources, et cetera [52].

Enterprise Application Integration (EAI) is an integration program structure that combines various kinds of applications developed independently of each other, so that they work as a whole, transparent to the user [53]. These applications can use different technologies and remain independently manageable [53].

The external Big Data module is an application component comprising all functionality related to big data. In the model showed in Fig. 8, big data refers to complex and large medical data sets, including data from diagnostics practice that will be used to teach the medical AI system.

The external Internet of Things (IoT) module is an application component comprising all functionality related to IoT. In the model showed in Fig. 8, IoT refers to the system of interrelated medical devices that may be used to collect data about patient's health state.

The details on the structure of the AI system and its alignment with the diagnostics process will be showed in the subchapter 4.4.10. In the model showed in Fig. 8, the following ArchiMate blocks and arrows have been used:

1. Application component (the example is showed in Fig. 9). This block represents an encapsulation of application functionality [46]. It comprises its behavior and data, provides services and makes them accessible via interfaces [46].

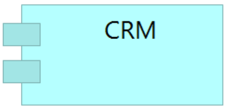

Fig. 9. Example application component block

2. Application service (the example is showed in Fig. 10). This block represents explicitly defined application behavior [46]. An application service provides the component functionality to the environment of the component [46]. This functionality is available through one or more application interfaces [46]. An application service is a behavioral element at the application layer.

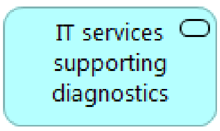

Fig. 10. Example application service block

3. Serving relationship (the example is showed in Fig. 11). This arrow represents providing the functionality of one element to another element and describes how interfaces or services offered by a behavioral or active structure element are serving objects in their envi-

ronment [46].

Fig. 11. The serving relationship arrow

7. Realization relationship (the example is showed in Fig. 12). This arrow represents how logical objects (for instance, services), are implemented through more specific objects [46].

Fig. 12. The realization relationship arrow

7. Flow relationship (the example is showed in Fig. 13). This relationship means that there is information flow between the services – analysis results, and the related value [46].

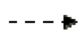

Fig. 13. The flow relationship arrow

4.4.4 General view of the service-oriented architecture

The view of the SOA containing the main processes of a medical organization is showed in Fig. 14. This view presents elements of the SOA in a generalized way.

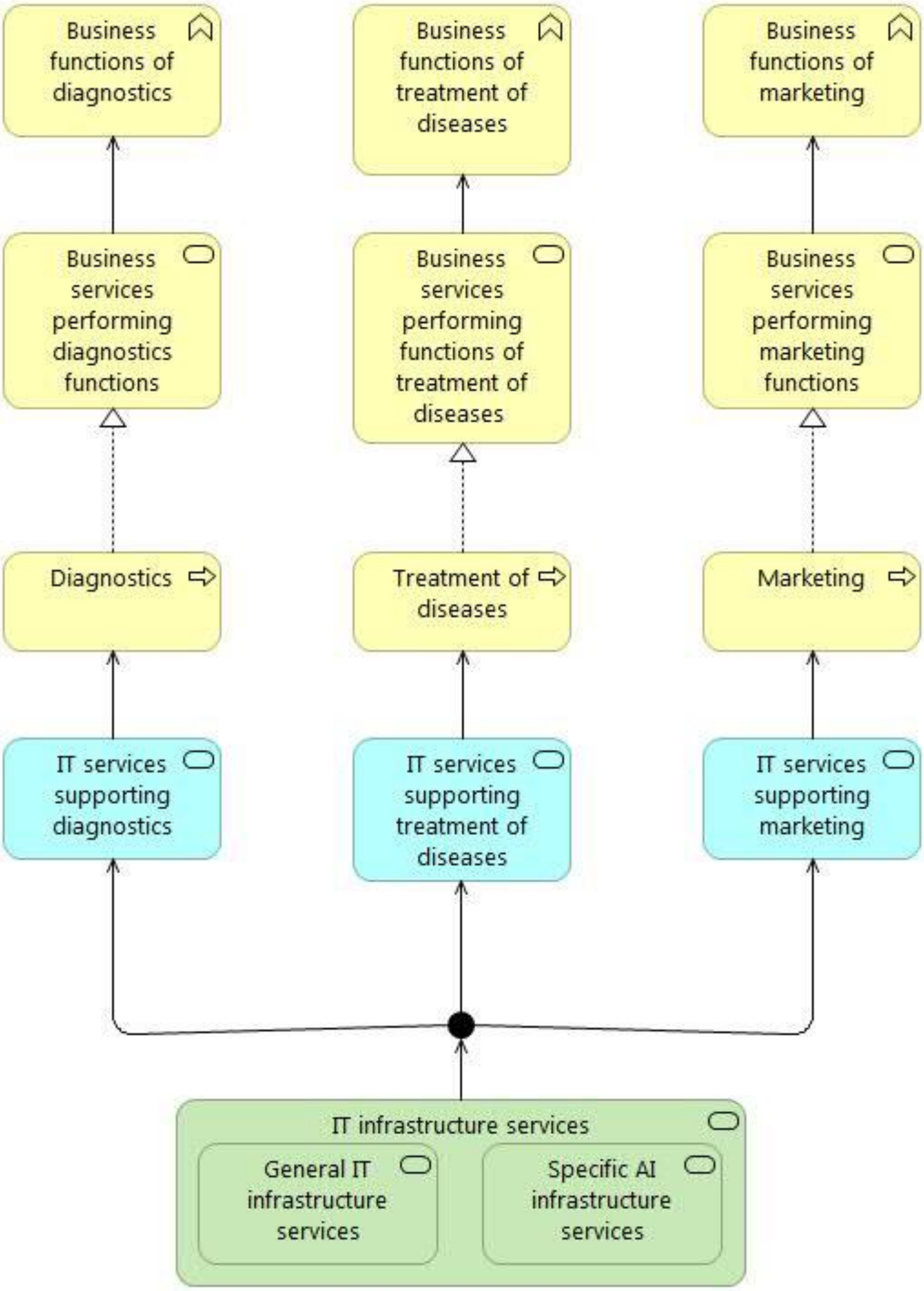

Fig. 14. General view of the SOA

In Fig. 14, the business layer is presented in a more detailed way. The following blocks and connections of ArchiMate have been used:

1. Business service (the example is showed in Fig. 15). This block represents an exter-

nally visible functionality that makes sense for the environment and is realized by a business process [46]. It is a behavioral element in the business layer.

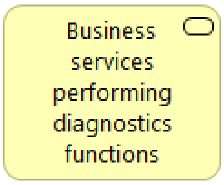

Fig. 15. Example business service block

2. Business function (the example is showed in Fig. 16). This block reflects the internal behavior that is needed to produce a set of services (or it can be understood as a valuable function for a customer that is served by services) [46]. While business processes describe the flow of actions, business functions group actions by skills, knowledge and resources each action requires [46]. A business function is a behavioral element in the business layer.

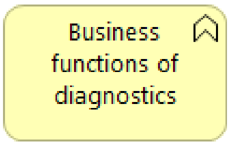

Fig. 16. Example business function block

5. Technology service (the example is showed in Fig. 17). This block represents explicitly defined technology behavior [46]. A technology service provides the node functionality to the environment of the node [46]. This functionality is available through one or more technology interfaces [46]. A technology service is a behavioral element in the technology layer.

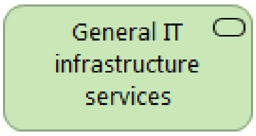

Fig. 17. Example technology service block

4.4.5 Detailing the diagnostics process

In Fig. 18, the detail view of SOA for diagnostics process is presented. The business layer is showed in a more detailed way.

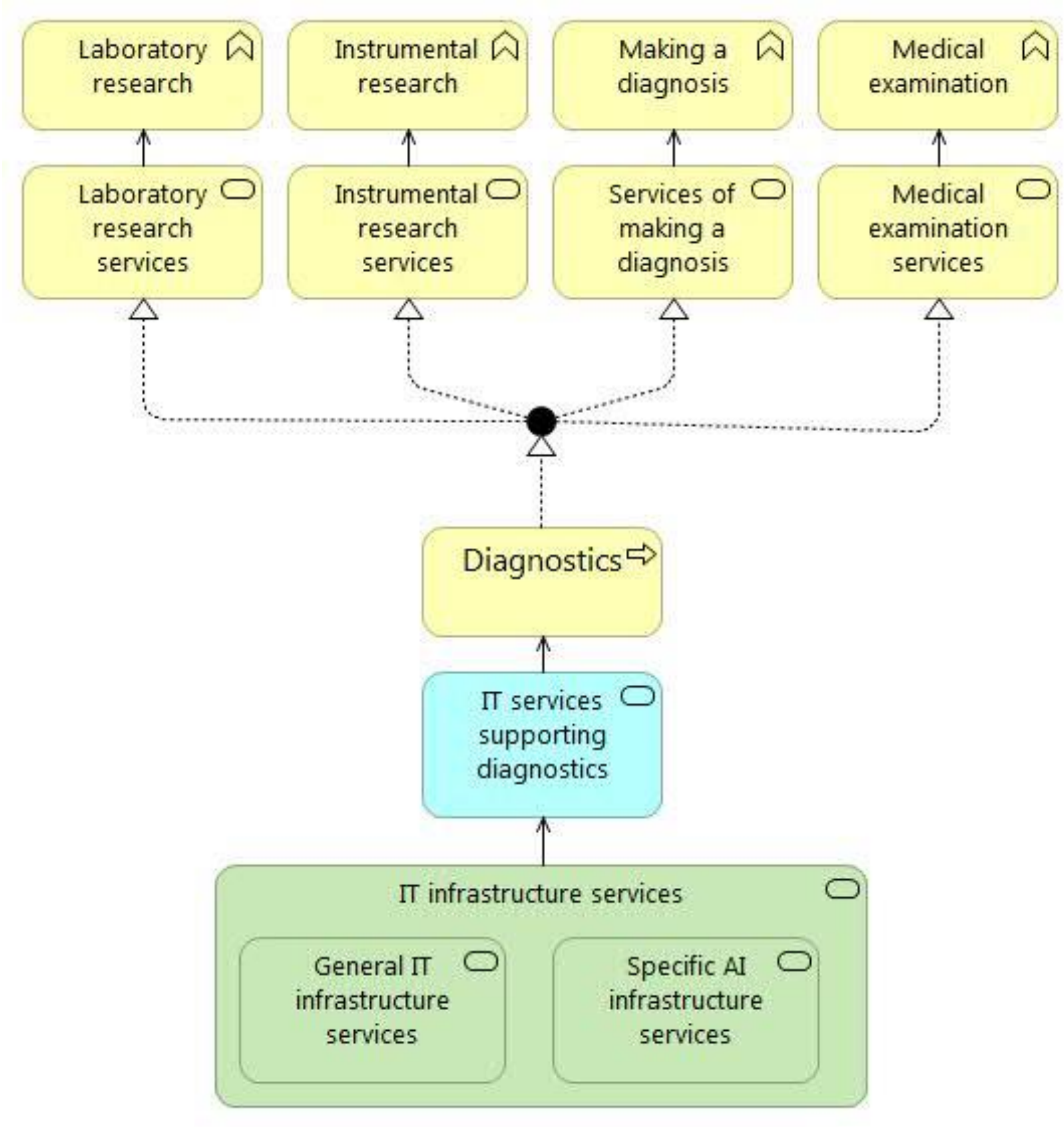

Fig. 18. Detailed view of the diagnostics process

Other layers, as much as it is necessary for the scope of the thesis, will be detailed further. Business functions of diagnostics were defined as the following:

1. The laboratory research function is a function of conducting laboratory tests on samples

of biological materials (like blood) in order to define their relevant physical and/or chemical characteristics and then to compare the characteristics to medical norms. It helps providing data that are processed further by a doctor and/or an AI system for further diagnostics.

2. The instrumental research function is a function of conducting medical examination with the use of technical instruments and electronic devices, such as MRI and ECG. This function produces graphical and text data (like electrocardiograms and pictures of organs) that are processed further by a doctor and/or an AI system in order to make a diagnosis.

3. The function of making a diagnosis is a function of analyzing gathered data and making a conclusion about what the disease or the problem is. The outcome of this function is the stated diagnosis and respective recommendations.

4. The function of medical examination is a function of conducting examinations for medical suitability of employees, individuals seeking a driver license and so on. The outcome of this function is the stated conclusion on medical suitability/non-suitability and respective recommendations.

4.4.6 Detailing laboratory research services

The detailed view of the laboratory research services block is presented in Fig. 19. The laboratory research services are the material sampling service and the results managing service.

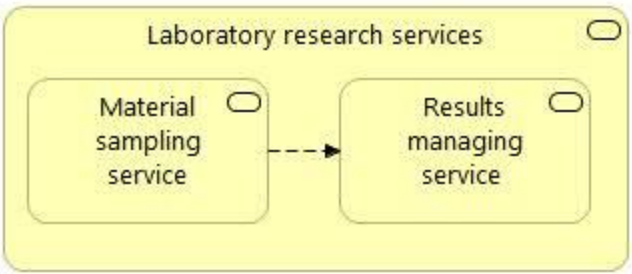

Fig. 19. Detailed view of the laboratory research services block

1. The material sampling service provides gathering biological material from the patient

for further processing. After gathering the samples, the inner subprocess of analysis starts.

2. The results managing service is storing medical research results of the patients and delivering the results to them. The delivery of the results can be conducted via e-mail or be printed and provided with the stamp of the organization (upon request). Also, if necessary, the results can be passed to other medical specialists.

4.4.7 Detailing instrumental research services

The detailed view of the instrumental research services block is presented in Fig. 20. The instrumental research services may be divided by type of the research: roentgenology service, MRI service and so on. Fig. 20 shows draft list of the services; the clinic may not have some of them or have other ones. Information flows go to the results managing service (see the subchapter 4.4.6).

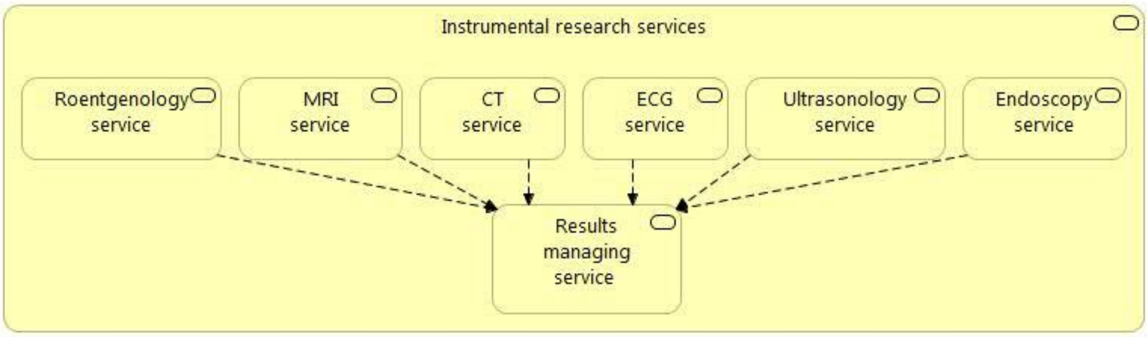

Fig. 20. Detailed view of the instrumental research services block

4.4.8 Detailing services of making a diagnosis

The detailed view of the instrumental research services block is presented in Fig. 21. These services are the following: the GP service, the services of specialized doctors, the results managing service, the diagnosis conclusion service. These services exchange patient data and/or information, which are showed as the flow relationship.

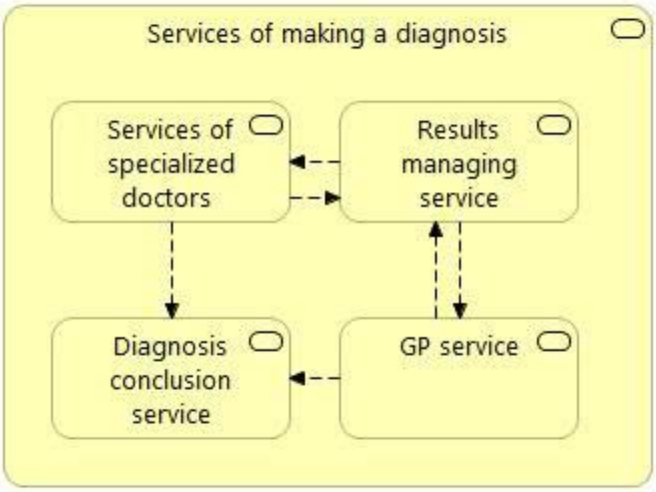

Fig. 21. Detailed view of the block of services of making a diagnosis

1. General practitioner (GP) service. Within this service, a general practitioner carries out a medical survey, examination of the patient and analysis of the available results of laboratory and instrumental research. The respective notes are made in patient's electronic medical record. If necessary, the patient can be forwarded to specialized doctors and additional laboratory and instrumental research.

2. Services of specialized doctors. Within this service, specialized doctors (such as cardiologists, pulmonologists, otolaryngologists et cetera) carry out a medical survey, examination of the patient and analysis of the available results of laboratory and instrumental research. The respective notes are made in patient's electronic medical record. If necessary, the patient may be forwarded from one specialized doctor to another and to additional laboratory and instrumental research.

3. Diagnosis conclusion service. This service is intended to inform the patient about the stated diagnosis and give all the related recommendations. A document about the diagnosis and prescriptions is given to the patient, and the respective notes are made in patient's electronic medical record. If necessary, the patient may be referred for a second appointment with the same or another specialist, or a decision about his hospitalization may be made.

4. Results managing service (see the subchapter 4.4.6). From this service, the GP and specialized doctors get relevant patient data and information to perform their services.

4.4.9 Detailing medical examination services

In Fig. 22 the detailed view of the medical examination services block is presented. This block comprises the services of making a diagnosis (see the subchapter 4.4.8) and suitability conclusion service getting data and information flow from them. The suitability conclusion service is intended to inform the examined person and their organization about the suitability conclusion made based on the stated diagnosis, and to give all the related recommendations. A document about the suitability is provided.

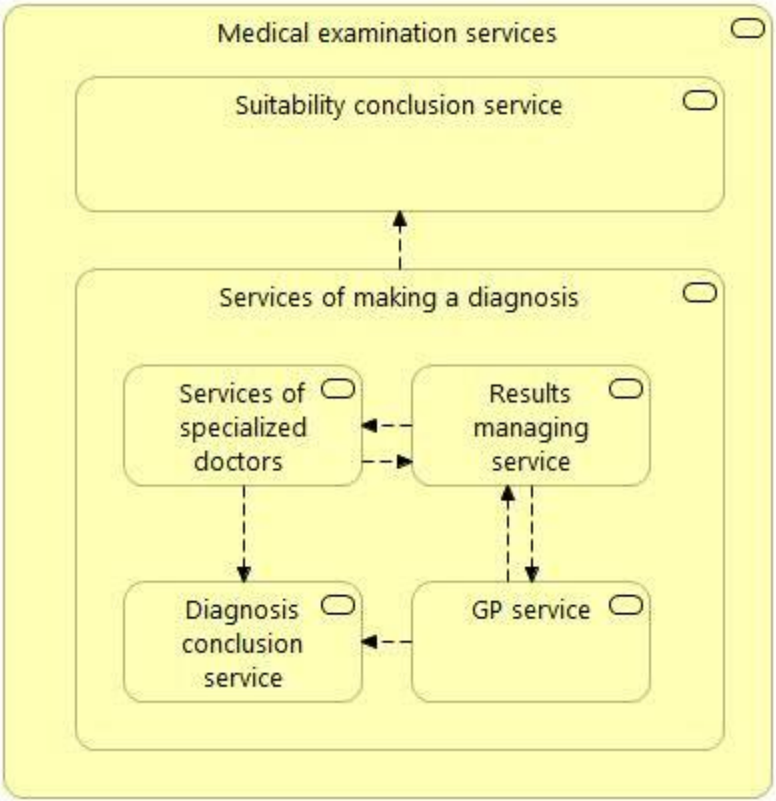

Fig. 22. Detailed view of medical examination services

4.4.10 Alignment of the diagnostics process

Alignment of a business process is representation of this process in a detailed way augmented with application and technology layers. The alignment of the diagnostics process is showed in Fig. 23.

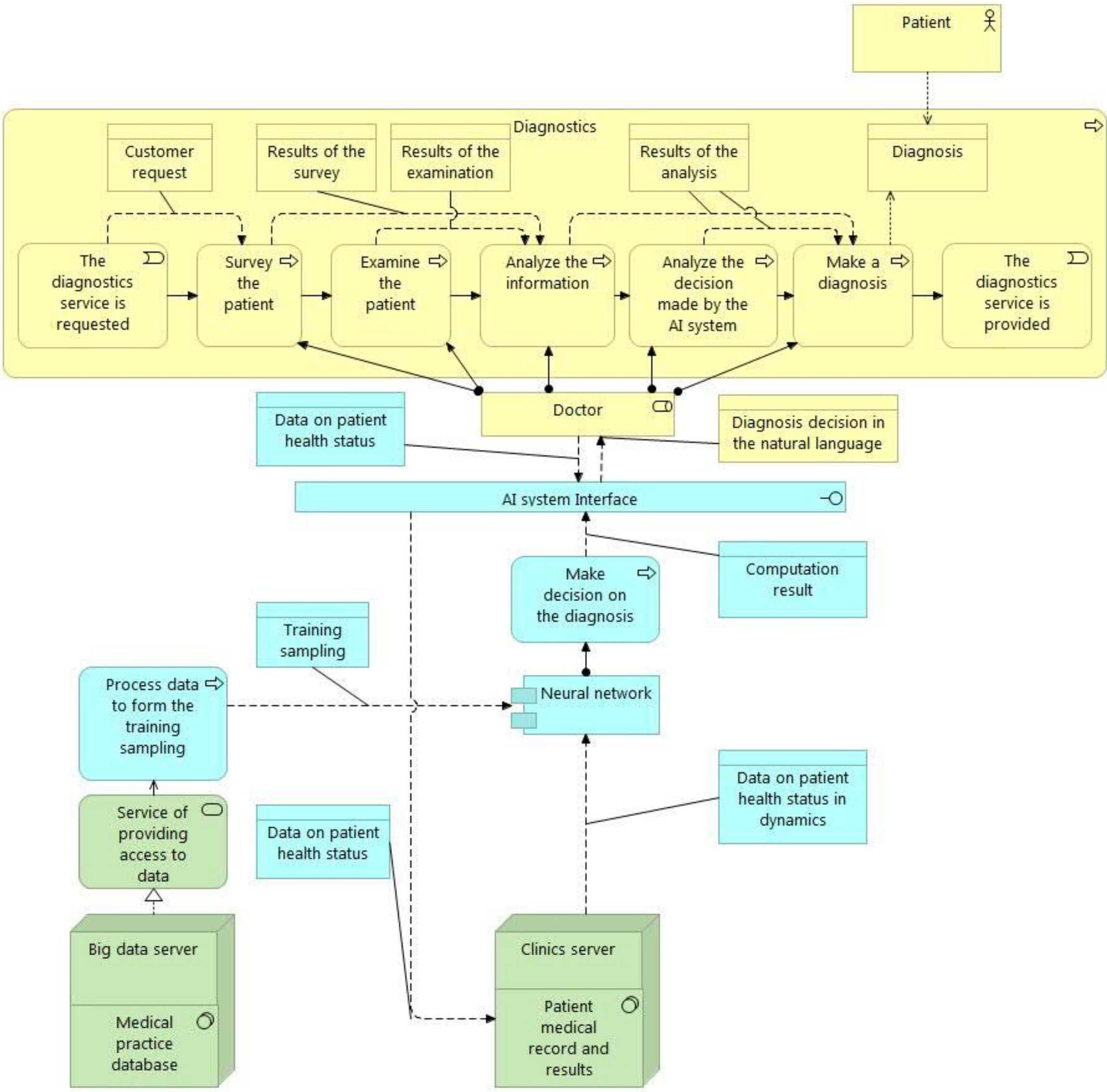

Fig. 23. Diagnostics process alignment

1. Business event (the example is showed in Fig. 24). This block represents something that happens and impact business behavior [46]. Events can come from environment (for instance, from a customer) or have an internal origin (for instance, from another business processes) [46]. A business event may trigger a business process or be triggered by it [46].

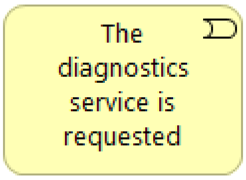

Fig. 24. Example business event block

2. Business object (the example is showed in Fig. 25). This block represents a unit of information that is significant for the business [46]. A business object simulates the type of object several instances of which may exist in the organization [46].

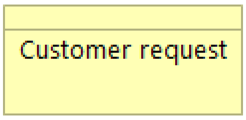

Fig. 25. Example business object block

3. Business role (the example is showed in Fig. 26). This block represents a named specific behavior of a business entity that takes part in a given context [46]. A business actor performs a behavior of this role, and the role may be fulfilled by multiple business actors [46]. In the model showed in Fig. 23, it is reasonable to present "doctor" as business role, because this term may mean the GP, as well as any specialized doctor who is participating in the diagnostics process.

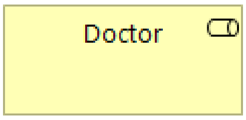

Fig. 26. Example business role block

4. Business actor (the example is showed in Fig. 27). This block represents an entity that performs behavior in the organization [46]. This entity may be external or internal. A business actor can perform multiples business roles, and a business role can be performed by multiple business actors [46].

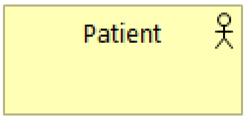

Fig. 27. Example business actor block

5. Triggering relationship (the example is showed in Fig. 28). This arrow represents cause-effect relationships between behavioral blocks – in this case, between business processes and events [46].

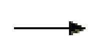

Fig. 28. The triggering relationship arrow

6. Access relationship (the example is showed in Fig. 29). This arrow represents that a process perform some action upon a passive element – in this case, creates a new business object [46].

Fig. 29. The access relationship arrow

7. Assignment relationship (the example is showed in Fig. 30). This arrow links active elements (such as business roles or application components) with units of behavior they perform [46].

Fig. 30. The assignment relationship arrow

8. Application process (the example is showed in Fig. 31). This block represents a sequence of application behavior that gains a certain result [46]. An application process describes internal behavior of an application component, which is necessary to implement a set of services [46].

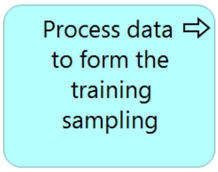

Fig. 31. Example application process block

9. Data object (the example is showed in Fig. 32). This block represents data that is structured to be processed by a machine [46]. A data object is a separate piece of information clearly relevant not just to the application layer, but also to the business [46]. A data object

simulates the type of object several instances of which may exist in applications [46].

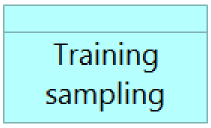

Fig. 32. Example data object block

10. Application interface (the example is showed in Fig. 33). This block represents an access point where application services are provided to a user, another application component, or node [46]. The application interface determines how the functionality of an element can be accessed by other elements [46].

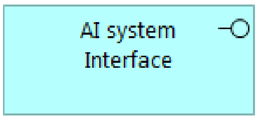

Fig. 33. Example application interface block

11. System software (the example is showed in Fig. 34). This block represents software providing or contributing an environment for storage, execution, and use of software or data unfolded therein [46].

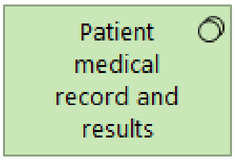

Fig. 34. Example system software block

12. Node (the example is showed in Fig. 35). This block represents a computing or physical resource that hosts other computing or physical resources, or manipulates them, or interacts with them [46]. Nodes execute, store and process technological objects (like artifacts) [46].

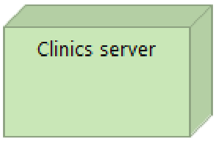

Fig. 35. Example node block

5 DISCUSSION

5.1 Overview of the use of artificial intelligence in healthcare

In the section “Overview of the use of artificial intelligence in healthcare” background on the thesis topic was given and general relevance of the topic was enlightened. It was done by describing milestones in the history of AI and directions of the AI research; by describing noticeable healthcare AI systems over the world and in Finland particularly; by mapping and classifying healthcare AI systems; and eventually, by describing challenges for AI in healthcare and possible solutions for them.

The use of AI in healthcare in Finland and around the world has been investigated by examining electronic resources such as articles, company official websites and official reports. Information has been collected on the various uses of AI in healthcare, AI systems offered by the market, and existing startups in AI in healthcare. Criteria were created for the classification of AI systems in healthcare, and then the considered AI systems were classified according to those criteria.

Startups were investigated, classified by country of origin and put on a world map. Afterwards the countries were divided into clusters, according to the quantity of startups in them, and leading countries were indentified. Startup investigation was conducted in 2018 and in 2020, and then the results for both years were compared.

Challenges for the implementation of AI systems in healthcare and possible solutions for them were described based on generalized experience of companies and opinions of researchers. The challenges were classified by its nature: to technical and social ones.

As a result, this section created a nowadays picture of AI in healthcare, outlined its capabilities and challenges and proved the significance of the thesis subject. The formed idea of the state of AI in the world and related opportunities allows better understanding of the subsequent sections of the master thesis.

5.2 Framework for service-oriented architecture in healthcare

Section “Framework for service-oriented architecture in healthcare” was intended to build a framework for SOA in healthcare by describing main terms, principles and approaches of SOA; by giving overview on the use of SOA in healthcare; and by describing challenges of SOA in healthcare.

At first, several definitions of architecture from various sources were given, and then the tasks for which the architecture as a whole is intended were described. Next, the definitions of SOA were given, its reference model from IBM was presented, and the main features of SOA were listed. Then, the main definitions related to SOA and the key ideas behind them were given. The principles of SOA and approaches to modeling SOA were formulated.

Overview on the use of SOA in healthcare was made by investigating papers on the topic. The content of 6 papers on this topic was described. All the papers examined during the overview were dedicated to SOA in healthcare, but none of them had a focus on the use of AI. Based on the overview, it was concluded that SOA of AI system in healthcare is not significantly covered in scientific papers.

Then, challenges of SOA in healthcare were presented. Unique features of IT in healthcare were described; special requests of the field regarding IT were listed; finally, points that can be challenging for the use of SOA in healthcare were formulated.

Thus, this section described the terminology used in the master thesis, clarified concepts behind the terms and presented an image of the use of SOA in healthcare. The section was intended to create a ground for the subsequent practical part of the thesis.

5.3 Development of service-oriented architecture for artificial intelligence system in healthcare

In the section “Development of service-oriented architecture for artificial intelligence system in healthcare” opportunities that AI may provide for business process innovation are presented. Next, the task for creating a business model canvas and building the service-oriented architecture is formulated. A business model canvas of medical organization using AI system is developed. Finally, development of SOA with the use of AI system service is conducted.

The opportunities for business process innovation with the use of AI in healthcare were described according to the “7Rs” framework. The framework itself was given and then the place of various functions of AI systems was described following the provided process innovation structure.

While the work on opportunities of business innovation was done for multiple capabilities of AI systems that can be implemented in different kinds of medical organizations, the subsequent work in the thesis is dedicated to a narrow task. In the task formulation chapter, the task of the AI system and delimitation of the system are formulated, the considered kind of organization is described, and the viewpoint and the scope for the subsequent part of the thesis are defined.

The canvas of the business model was built according to the Osterwalder template, which is described and explained in the beginning of the section. First, an “as-is” canvas (for an organization before the introduction of the AI system) was built, based on the experience of medical organizations. Then, for each of the canvas segments, questions related to the implementation of the AI system were formulated. Based on the answers to these questions, a “to-be” canvas was constructed, reflecting the changes that occurred in the organization.

The developed business model canvas can be used in the implementation of AI systems in healthcare organizations. The developed model has limitations that are usually pertaining to the Osterwalder model. It does not replace the planning of the entire business model. The canvas can be considered an approximate outline of the business model, which should help to quickly draw up several options. In a real organization, the canvas needs to be constantly updated, and it is also necessary to outline the parameters of the business model by creating several canvases.

A SOA with the use of AI system service is built in several stages. First, the language used for modeling for SOA (ArchiMate) is described, to give understanding of the models; although, all the models are provided with explanations of the notation throughout the following subchapters. Then, business process landscape is built in order to reflect business processes of the organization at the highest level in a grouped form. Architecture of the EIS is developed, to describe in more details the application layer of the SOA. Description of the technology layer is outside of the scope of this work. Next, the general view of the SOA is showed, with subsequent detailing of the diagnostics process and its services. Finally, the alignment of the diagnostics process is built – id est, the three layers of the process are showed on one model.

6 CONCLUSIONS

As a result of mapping top AI healthcare startups in 2018 and 2020, the following world leaders in this field were indentified: the United States of America, Israel and the United Kingdom. This conclusion means that these countries currently have the best environment for development in the area of AI in healthcare.

Based on the overview of existing AI systems in healthcare, the following criteria were identified for their classification: by purpose; by data collection means; by types of users; by types of processed data. These criteria and distinguished classes can be used to further classify AI systems in healthcare.

The research conducted in the thesis showed that the most significant challenges of AI systems in healthcare have technical and social nature. The generalized solution for technical challenges can be formulated as choosing the appropriate AI architecture. The generalized solution for social challenges is increasing AI awareness among both specialists and mass audience and providing an appropriate level of overall safety and technical security of AI. These solutions can be a subject of further research.

Judging by papers overview, it can be concluded that SOA of AI system in healthcare is a topic poorly encompassed in research. The results obtained in this thesis can be a starting point for further research on the topic, as well as a starting point and a reference for works on implementation of SOAs of AI system in healthcare organizations.

The opportunities for business process innovation with the use of AI in healthcare, described in the thesis, can be used as a set of ideas for analyzing and enhancing the business processes in healthcare organizations.

As a result of the work, 2 business model canvases of a healthcare organization were developed: “as-is” – before the implementation of the AI system, and “to-be” – after the implementation. These canvases can be used as an approximate outline of the business models for healthcare organizations going to adopt AI systems.

The final outcome of the work is the developed SOA with the use of AI system service. The developed models may be used as reference models for building the SOA of AI system in healthcare organizations. However, the technology layer of the SOA is not elaborated in this work (because of being outside of the scope) and can be a subject of the further research.

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